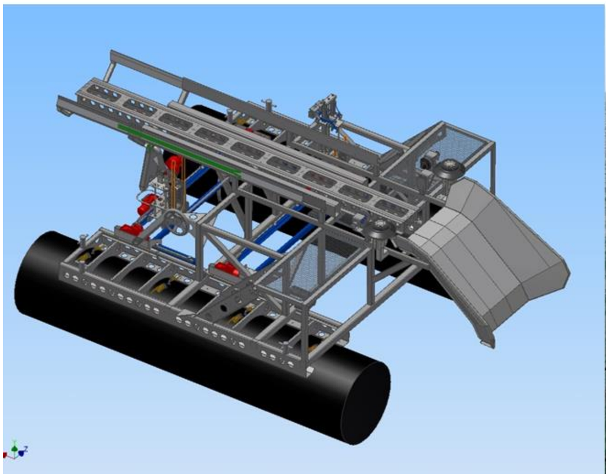
Eindrapportage Innovatief Oogsten van Mosselzaad

Technisch praktijkgericht onderzoek

HZ UNIVERSITY OF APPLIED SCIENCES
LECTORAAT DUURZAAM INNOVEREN EN ONDERNEMEN
SEPTEMBER 2013 - DECEMBER 2015



Europees Visserijfonds: Investering in duurzame visserij

Ministerie van Economische Zaken

Jansen Tholen B.V.

Provincie Zeeland

HZ UNIVERSITY OF APPLIED SCIENCES

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MANAGEMENTSAMENVATTING

Het lectoraat Duurzaam Innoveren en Ondernemen van HZ University of Applied Sciences, Jansen Tholen en Firma Gebr. Schot zijn een samenwerking aangegaan voor het innoveren van de mosselzaadinvanginstallatie, specifiek uitwerken van een nieuwe oogsttechniek van mosselzaad tot een prototype installatie. De samenwerking binnen dit project tussen het bedrijfsleven, docent-onderzoekers en studenten is tot stand gekomen door de HZ Smart Services Boulevard, de brug tussen beroepspraktijk en onderwijs van de HZ. De uitvoering van het project werd mede mogelijk gemaakt door het Europees Visserij Fonds (EVF) en het Ministerie van Economische Zaken ter investering in duurzame ontwikkeling van visserijgebieden. Dit project is ook mede mogelijk gemaakt door Provincie Zeeland, die de HZ Smart Services Boulevard ondersteunde.

In het tweejarig project “Innovatief Oogsten van Mosselzaad” mechaniseerden en automatiseerden docentonderzoekers met hulp van studenten Engineering de oogsttechniek voor de mosselzaadinvanginstallatie (MZI) in opdracht van Firma Gebroeders Schot, mosselvissers, en Jansen Tholen BV, producent van machines. Tevens werd gewerkt door een docent-onderzoeker en een student aan de communicatie rondom van de MZI. Ten slotte werd er vanuit de onderzoeksgroep Aquacultuur onderzoek gedaan naar in hoeverre aangroei voorkomen kan worden op de biodegradeerbare plastic MZI haken. Op basis van de testen aan boord met het prototype zullen firma Schot en Jansen Tholen de noodzakelijke aanpassingen doorvoeren. Bij afronding van het project zal de oogstinstallatie met alle bijbehorende publicaties, waaronder technische specificaties en handboeken, worden opgeleverd door Jansen Tholen.

Op de gevraagde aspecten van ontwikkelmogelijkheden van het oogstvlot zijn ontwerpen gemaakt en prototypes gebouwd. Ook het prototype van de jetpomp is gerealiseerd. Alle prototypes zijn getest en er zijn verbetervoorstellen doorgevoerd. Daarnaast is een inventarisatie gemaakt van cruciale onderdelen van het hele oogst systeem en is er parametertabel opgesteld waarop een ontwerper aangeraden dimensies van een jetpomp kan aflezen. De inzichten van de berekeningen en metingen worden gebruikt om de pomp verder te optimaliseren. Ten slotte zijn er detailtekeningen t.b.v. productie zijn gerealiseerd van een ontwerp dat substraatlijn verzamelt op een rol.

Er is onderzoek gedaan naar de aangroei van organismen aan de biobased haken en is een project gestart m.b.t. communicatie. Deze twee projecten lopen nog en worden in januari 2016 opgeleverd. De resultaten van dit project ‘Innovatief Oogsten van mosselzaad’ borduren voort op de resultaten van het project 1. ‘Ontwikkeling gautomatiseerd MZI-systeem’. De rapportage van dit eerdere project is hier te vinden.

INHOUDSOPGAVE

1. INLEIDING

HZ University of Applied Sciences, Jansen Tholen en Firma Gebr. Schot zijn een samenwerking aangegaan voor het innoveren van de mosselzaadinvanginstallatie in twee projecten: 'Ontwikkeling gaautomatiseerd MZI systeem' en 'Innovatief Oogsten van mosselzaad'. De samenwerking binnen dit project 'Innovatief Oogsten van Mosselzaad' tussen het bedrijfsleven, docent-onderzoekers en studenten is tot stand gekomen door de HZ Smart Services Boulevard. De uitvoering van het project werd mede mogelijk gemaakt door het Europees Visserij Fonds (EVF) en het Ministerie van Economische Zaken ter investering in duurzame ontwikkeling van visserijgebieden. Dit project is ook mede mogelijk gemaakt door Provincie Zeeland, die de HZ Smart Services Boulevard ondersteunde.

HZ doet praktijkgericht onderzoek op basis van vraagstukken uit de praktijk. In dit project werkten docentonderzoekers, studenten en Jansen Tholen/Gebr. Schot samen in het projectteam. De docentonderzoekers in dit project waren verantwoordelijk voor de kwaliteit van de eindproducten die opgeleverd zijn aan Jansen Tholen. De studenten waren verantwoordelijk voor hun eigen leerresultaten. Jansen Tholen is verantwoordelijk voor het implementeren van het eindproduct in de eigen organisatie en zorgde voor informatie en contactpersonen vanuit de eigen organisatie. Tevens was er een coördinator onderzoek betrokken bij het project om de kwaliteit te waarborgen.

In het tweejarig project "Innovatief Oogsten van Mosselzaad" mechaniseerden en automatiseerden docentonderzoekers met hulp van studenten Engineering de oogsttechniek voor de mosselzaadinvanginstallatie (MZI) in opdracht van Firma Gebroeders Schot, mosselvissers, en Jansen Tholen BV, producent van machines. Tevens werd gewerkt door een docent-onderzoeker en een student aan de communicatie rondom van de MZI. Ten slotte werd er vanuit de onderzoeksgroep Aquacultuur onderzoek gedaan naar in hoeverre aangroei voorkomen kan worden op de biodegradeerbare plastic MZI haken. Op basis van de testen aan boord met het prototype zullen firma Schot en Jansen Tholen de noodzakelijke aanpassingen doorvoeren. Bij afronding van het project zal de oogstinstallatie met alle bijbehorende publicaties, waaronder technische specificaties en handboeken, worden opgeleverd door Jansen Tholen.

Op de gevraagde aspecten van ontwikkelmogelijkheden van het oogstvlot zijn ontwerpen gemaakt en prototypes gebouwd. Ook het prototype van de jetpomp is gerealiseerd. Alle prototypes zijn getest en er zijn verbetervoorstellen doorgevoerd. Daarnaast is een inventarisatie gemaakt van cruciale onderdelen van het hele oogst systeem en is er parametertabel opgesteld waarop een ontwerper aangeraden dimensies van een jetpomp kan aflezen. De inzichten van de berekeningen en metingen worden gebruikt om de pomp verder te optimaliseren. Ten slotte zijn er detailtekeningen t.b.v. productie zijn gerealiseerd van een ontwerp dat substraatlijn verzamelt op een rol.

Tevens wordt er momenteel een communicatieplan opgesteld en zijn onderzoekers vanuit de Delta Academy bezig met een onderzoeksproject m.b.t. de aangroei van organismen aan biobased haken en de effecten daarvan. Deze projecten zijn nog niet afgerond.

Wij bedanken het Europees Visserij Fonds (EVF), het Ministerie van Economische Zaken en de Provincie Zeeland voor het mede mogelijk maken van dit succesvolle innovatieproject, waarin onderwijs, onderzoek, en het bedrijfsleven op een unieke manier samen zijn gekomen en samen tot concrete innovatie zijn gekomen.

2. DOELSTELLING

Jansen Tholen B.V. werkt aan veel verschillende innovatieve projecten. Een voorbeeld hiervan is het innovatieve MZI Systeem. Dit systeem zorgt voor verbeterde werkomstandigheden ten opzichte van de oude inzaai systemen. Daarnaast werkt de MZI op een manier die vriendelijker is voor het milieu. Het systeem van Jansen Tholen verbetert de MZI niet alleen op het gebied van efficiëntie, maar ook qua ergonomie, veiligheid en energieverbruik. Jansen Tholen en Firma gebr. Schot willen de hoeveelheid arbeid verminderen, de zwaarte van het werk verlichten en het verlies van mosselzaad verminderen. Daardoor kan deze vorm van teelt concurrerender worden en beter aan scherpere normen voldoen. Als het systeem met succes werkt, willen zij een business model ontwikkelen voor de MZI. Jansen Tholen levert met deze vernieuwing een belangrijke bijdrage aan de verduurzaming en daarmee de toekomst van deze voor de Zeeuwse economie zeer belangrijke sector.

Firma Schot zal in samenwerking met Jansen Tholen het idee aangaande een nieuwe oogsttechniek van mosselzaad uitwerken tot een prototype installatie. Firma Schot is verantwoordelijk voor het projectidee en stelt de criteria vast waaraan de oogstinstallatie zal moeten voldoen. Jansen Tholen zal de installatie ontwerpen en uitwerken. Vervolgens zal Jansen Tholen een prototype bouwen dat wordt getest aan boord van de TH 4 van de firma Schot. Op basis van de testen aan boord met het prototype zullen firma Schot en Jansen Tholen de noodzakelijke aanpassingen doorvoeren. Bij afronding van het project zal de oogstinstallatie met alle bijbehorende publicaties, waaronder technische specificaties en handboeken, worden opgeleverd door Jansen Tholen.

Gedurende het project zal de HZ University een bijdrage leveren middels het leveren van expertise en monitoring, alsmede het doen van onderzoek, zowel op technisch als economisch gebied. Onderzoeksresultaten zullen worden opgeleverd middels diverse rapportages. Door een nauwe samenwerking met kennis instituten, zoals de HZ University of Applied Sciences, zal er een duidelijke vermeerdering in kennis ontstaan. De hierdoor opgebouwde expertise zal wereldwijd toepasbaar zijn, waardoor economische, maar ook milieutechnische voordelen internationaal geëxporteerd kunnen worden. Op basis van de nieuw ontwikkelde kennis zal het onderwijs verbeterd en geactualiseerd worden

HZ, Jansen Tholen en Firma Gebr. Schot werken gezamenlijk aan innovatie in dit unieke samenwerkingsproject, dat waarde oplevert voor zowel de bedrijven, de hogeschool als de regio. Het project levert de bedrijven nieuwe kennis op die zij kunnen omzetten tot innovatie in hun bedrijf. De studenten van de HZ maken kennis met echte vraagstukken uit de praktijk en de HZ bouwt als kennisinstituut kennis op voor haar body of knowledge die terugvloeit in het onderwijs. Tevens is de Zeeuwse economie gebaat bij innovatie in het bedrijfsleven, omdat dit leidt tot hoogwaardige werkgelegenheid.

Voor het gehele project is de volgende doelstelling benoemd:
"Het doel van het project is de doorontwikkeling van een geautomatiseerd oogstsysteem op de mosselzaad invanginstallatie (MZI), waarbij de verwijdering van het mosselzaad van het substraat efficiënter, sneller en minder arbeidsintensief kan worden uitgevoerd en het valverlies en beschadiging van mosselzaad kan worden beperkt tot een minimum, waardoor het rendement van MZI's kan worden verhoogd en zo de transitie, binnen de gestelde termijn dan wel sneller, te voltooien".

De specifieke doel- en vraagstellingen zijn in de deelprojecten gedefinieerd en verder uitgewerkt. Alle resultaten van de deelprojecten zijn opgenomen in de bijlages. De rapportages borduren voort op de resultaten van het project 'Ontwikkeling gautomatiseerd MZI-systeem'.

3. OPDRACHTBESCHRIJVING

De opdracht die HZ, Jansen Tholen en Firma Schot samen uitvoerden in dit project, borduren voort op de resultaten van het project 1. ‘Ontwikkeling gautomatiseerd MZI-systeem’.

Project 2. Innovatief Oogsten van mosselzaad
Najaarsemester 2014-2015:

Ontwikkel de jetpomp richting productie en verken ontwikkelmogelijkheden van het automatiseren en robuust maken van het oogstvlot.

1. Test het verschaalde prototype van mosselzaad-oogst-opzuig-jetpomp in zo realistisch mogelijke condities. Probeer zoveel mogelijk het gedrag vast te leggen in meetgegevens (druk, debiet, stroomsnelheid, pompvermogen). Verwoord je ervaring in onderbouwde verbeteraanwijzingen.
2. Verken de mogelijkheden om de oogst-installatie naast de “mooi weer automatisering” ook bestand te maken tegen probleemsituaties.
    a. Wat kan een vision-systeem bijdragen aan het voorkomen dat bij het oogsten de machine op een haak vastloopt,
    b. Wat kan een vision systeem bijdragen aan het regelen van het verwijderen van het mosselzaad van de substraat,
    c. Voorkom dat er problemen opdoen (of behandel problemen als ze opdoen) bij het verzamelen van de substraat in een bigbag,
    d. Controle en beheersing van hele oogstsysteem.

Voorjaarsemester 2014-2015:

Vertaal de kennis van de jetpomp naar ontwerpvoorschriften voor een pomp op een andere boot. Ontwerp t/m produtietekeningen het systeem dat de substraatlijn verzamelt.

3. Voer simulaties uit van de stroming in de jetpomp. Combineer deze met de metingen aan het model en aan het prototype. Vertaal de conclusies naar ontwerpvoorschriften voor een pomp op een andere boot.
4. Maak een pas op de plaats tbv de conceptkeuze om de substraatlijn bij het oogsten te verzamelen. Maak een nieuwe conceptkeus. Werk deze keus uit tot een ontwerp dat gereed is voor productie. Maak ook de productietekeningen.

Najaarssemester 2015:

1. Communicatieplan ontwikkelen en gedeeltelijke uitvoering hiervan.
2. Onderzoek vanuit onderzoeksgroep Aquacultuur de aangroei van organismen aan biobased haken in het zoute water en effecten daarvan.

De HZ heeft in oktober 2013 offerte uitgebracht aan Jansen Tholen voor het realiseren van deze doelen. In vervolggesprekken zijn de specifieke doelen op hoofdlijnen bepaald en in periodiek overleg werden de doelstellingen aangescherpt en werd voortschrijdend inzicht meegenomen in de vraagstellingen.

5. SAMENVATTING VAN RESULTATEN

De resultaten van dit project borduren voort op de resultaten van het project 1. ‘Ontwikkeling gautomatiseerd MZI-systeem’. Inhoudelijk sluiten de projecten nauw op elkaar aan. Dat is de reden waarom de bijlagen starten bij bijlage 5. Bijlage 1 t/m 4 horen ontbreken hier, omdat deze horen bij project 1. ‘Ontwikkeling gautomatiseerd MZI-systeem’. Deze rapportage is hier terug te vinden.

Resultaten project ‘Innovatief Oogsten van Mosselzaad’

Najaarsemester 2014-2015:

1. Prototype is gerealiseerd:
   a. De ervaring van de tests met het model prototype zijn gebruikt om een 1 op 1 ontwerp te maken.
   b. De pomp is uitgedetailleerd met het oog op de productiemogelijkheden van het bedrijf.
   c. De tekeningen zijn gemaakt.
   d. Het prototype is gebouwd.
   e. Tests zijn uitgevoerd en hadden succes. Met de pomp die aan boord is, wordt ruimschoots de aanzuigsnelheid gehaald, zodat de mossels die al losgekomen zijn van het substraat niet meer terug vallen, maar netjes geoogst worden. Door een aantal goede ontwerpkeuzes is het gelukt om de kostprijs laag te houden. Het doel was om onder de aanschafprijs te komen van een andere pomp die overigens niet de goede specificaties heeft om ingebouwd te worden. Dat doel is net niet gehaald, maar was ook wel heel ambitieus. De eerstvolgende pomp die in de richting komt (maar ook nog niet goed genoeg) is 70% duurder. De enige gevonden pomp die gebruikt zou kunnen worden is een factor 5 duurder.

Zie voor het volledige onderzoeksrapport: **Bijlage 5.** (voorlopig) rapport Jetpompontwerp.

2. Op de gevraagde aspecten van ontwikkelmogelijkheden van het oogstvlot zijn ontwerpen gemaakt en prototypes gebouwd; details zijn in het verslag terug te vinden. Het doel van deze studie is, om de mogelijkheden te verkennen om de zaai- en oogstautomaten autonomer te laten functioneren. Daardoor zijn minder mensen nodig tijdens de werkzaamheden en kan de kwaliteit en de snelheid verder omhoog. Het is gebleken uit de studies dat ook die aspecten die normaliter door een mens worden gecontroleerd (omdat ze moeilijk anders dan visueel gemeten/geschat kunnen worden), ook via een beeldherkenningssysteem gemeten kunnen worden. Zodoende hoeft dit werk niet meer met voortdurende concentratie gedaan te worden, kan er makkelijker geoptimaliseerd worden en zal de resulterende kwaliteit constanter zijn.
   a. Visionsysteem prototype is gebouwd om ophanghaken te herkennen en daar een signalering op te geven. Een programma is ingesteld om in een foto de haak te kunnen herkennen. Ook op foto’s waar de haak op een achtergrond van substraatlijn is weergegeven kan het systeem met grote betrouwbaarheid de haak aanwijzen.
   Zie voor het volledige onderzoeksrapport: **Bijlage 6.** Rapport van ophanghaak herkenning.
   b. Visionsysteem prototype is gebouwd om mossels te herkennen en het aantal weer te geven. Een programma is ingesteld om in een foto het aantal mossels te tellen. Ook op foto’s waar de mossels in verschillende grootte en oriëntatie en op een achtergrond van substraatlijn zijn weergegeven kan het systeem met grote betrouwbaarheid het

aantal weergeven.
Zie voor het volledige onderzoeksrapport: **Bijlage 7.** Rapport van mosselherkenning.

c. Een ontwerp is gemaakt en een prototype is gebouwd van een systeem dat de substraatlijn na het ontmosselen geleidt en in een bigbag verzamelt. Daarbij is rekening gehouden met het verwisselen en opslaan van de bigbags als ze vol zijn.
Zie voor het volledige onderzoeksrapport: **Bijlage 8.** Rapport van mechanisatie van substraat in bigbag.
d. Een inventarisatie is gemaakt van cruciale onderdelen van het hele oogst systeem. Per onderdeel zijn grootheden vastgesteld die met sensoren gemeten kunnen worden. In een overzicht is weergegeven hoe een automaat zou moeten reageren om bij te sturen of anders ingrijpen om problemen te voorkomen. Van een beperkt deel van het systeem is een prototype gemaakt als toets voor de realiseerbaarheid.
Zie voor het volledige onderzoeksrapport: **Bijlage 9.** Rapport van oogstvlot supervision.

Voorjaarsemester 2014-2015:

3. Een parametertabel is opgesteld waarop een ontwerper aangeraden dimensies van een jetpomp kan aflezen. De inzichten van de berekeningen en metingen worden gebruikt om de pomp verder te optimaliseren. Ook kan nu vanuit deze kennis het ontwerp van de pomp aangepast worden voor de situatie op een ander schip. Dit is een voorwaarde om het oogstvlot te kunnen verkopen/verhuren aan een andere mosselteler.
   a. De gegevens van de testen met de prototypes zijn geanalyseerd.
   b. Zowel door studenten als door docentonderzoekers zijn flow-calculaties uitgevoerd om de testgegevens beter te kunnen extrapoleren.
   c. De resultaten zijn vertaald en in een tabel gezet die gebruikt kan worden om een pomp te maken die op een andere boot ook functioneert. Er is ook aangegeven waar de geadviseerde waardes meer en waar ze minder betrouwbaar zijn vanuit het perspectief van de tests.

   Zie voor de volledige onderzoeksrapporten: **Bijlage 10A**: Rapport van ontwerp van parameter tabel; en **Bijlage 10B**: controle berekeningen Comsol en conclusies

4. Detailtekeningen t.b.v. productie zijn gerealiseerd van een ontwerp dat substraatlijn verzamelt op een rol. Zoals gebruikelijk is een aantal alternatieve concepten opgesteld en uitgewerkt. Daarvan zijn specificaties en voor- en nadelen geschat. Op basis daarvan zijn ontwerpkeuzes gemaakt, die vervolgens tot in productietekeningen zijn uitgewerkt. Een verrassende wending in dit deelproject was, dat het makkelijker blijkt te zijn om de substraat te verzamelen op een rol dan in een bigbag. Verder zijn er slimme keuzes gemaakt om snel te kunnen opstarten en van rol te wisselen.
   a. Een aantal concepten zijn op cruciale aspecten geverifieerd.
   b. Conceptkeus is opnieuw genomen.
   c. Details zijn berekend en vastgesteld.
   d. Productietekeningen zijn gemaakt.

Zie voor het volledige onderzoeksrapport: **Bijlage 11.** Rapport van substraatrol ontwerp.

Najaarssemester 2015:

1. Communicatieplan: Jansen Tholen B.V. communiceert met verschillende doelgroepen. Het is belangrijk om voor ieder verschillende doelgroep een andere aanpak en andere boodschap van

communiceren te nemen. De doelstelling is dat in december 2016 50 procent van de huidige klanten bekend zijn met de Mossel Zaad Invanginstallatie.

Zie voor de voorlopige resultaten op het gebied van communicatie **Bijlage 12.** Communicatieplan en materiaal.

2. Aquacultuur: De studenten onderzoeken onder leiding van twee docentonderzoekers in hoeverre aangroei voorkomen kan worden op de biodegradeerbare plastic MZI haken en of er een onderling verschil zit in mate van aangroei tussen verschillende (biodegradeerbare) plastics. De tussenmeting daarvan vindt begin december plaats. Daarnaast kijken ze naar de mate van schuiven van de MZI haken op de lijnen bij verschillende stroomsnelheden en richtingen. Dit project wordt eind januari afgerond en opgeleverd aan Jansen Tholen.

Omdat er nog geen metingen uitgevoerd konden worden, kunnen er nog geen voorlopige resultaten gepresenteerd worden. Deze worden op een later moment aan Jansen Tholen gepresenteerd.

6. INDIRECTE EFFECTEN

Naast de directe resultaten die ontstaan zijn uit de verschillende deelprojecten, zijn er ook indirecte resultaten geboekt met dit project.

In een aantal deelprojecten is naast de interactie met Jansen Tholen, ook samenwerking met andere bedrijven opgezet:

1. Sharkskin: Er is samenwerking gezocht met Sharkskin voor de biobased haken. Op dit moment levert Sharkskin Jansen Tholen het product dat gebruikt wordt op de biobased haken.
2. Krohne: wil samen met de HZ en eventueel andere partijen specifieke sensoren ontwikkelen om bijvoorbeeld specificaties aan mossels non-destructief te meten.

Indirecte effecten met betrekking tot studenten:
Studenten bleven na dit project bij Jansen Tholen werken of stagelopen. Ook hebben sommige studenten een eigen bedrijf opgericht en verlenen vanuit hun bedrijf diensten aan Jansen Tholen.

Indirecte effecten in de regio:
In de regionale media is veel aandacht besteed aan dit project. Er zijn artikelen verschenen in de PZC, de Bode en de Faam. Ook is er een groter artikel geplaatst in 'de Ondernemer'. Ook is het project te zien geweest in een uitzending van 'Ondernemend Nederland' op RTL 7.

Figuur 1. Artikel PZC – februari 2015

Mosselzaad wordt straks automatisch geoogst

door **Frank Balkenende**

VLISSINGEN – Dit voorjaar wordt hij getest in de Oosterschelde en de Waddenzee: een geautomatiseerde mosselbroedzaai- en oogstinstallatie (mzi). Voordelen: minder verlies aan mosselbroed en medewerkers met minder rugpijn.

Studenten engineering van de HZ werken in een tweejarig project aan de verbetering van de huidige mzi. Dat doen ze in opdracht van en samen met Firma Gebroeders Schot (mosselvissers uit Zierikzee) en machinefabriek Jansen ... n BV. Mosselzaadvanginstal- ... zijn een milieuvriendelijker ... atief voor de traditionele zaadvisserij per schip die vergaand aan banden is gelegd. In een notendop zijn mzi's drijvende tonnen met touwen die zes meter diep in het water hangen. Zwevend mosselzaad kan zich daaraan hechten. Kwekers kunnen ook broed op de touwen aanbrengen. Dat wordt er in het najaar afgehaald en gedeponeerd op kweekpercelen waar het uitgroeit tot consumptiemosselen.
De mzi's zijn arbeidsintensief en doen een aanslag op het lichaam, omdat personeel langdurig buiten boord moet hangen. Ook gaat veel mosselzaad tijdens de 'oogst' verloren. Dat kan beter, dachten mosselkweekbedrijf Schot en machineproducent Jansen. Ze zochten samenwerking met de Academie voor Technologie en Innovatie, zeg maar de engineers van de HZ in Vlissingen. Samen met de bedrijven ontwikkelden ze een geautomatiseeerde mosselzaai- en oogstinstallatie. Schot en Jansen hebben patent aangevraagd op de zaaimachine, die ze op de markt willen brengen. Daarom mag HZ-docent en projectleider Willem Haak niet alle details prijsgeven: „In feite zijn het twee drijvende platforms van zo'n vier bij vijf meter. De zaaimachine zet in het voorjaar zelf de substraatlijnen uit. De oogstmachine heeft roterende flappen waarmee automatisch kan worden geoogst. Doordat er beeldherkenning is ingebouwd, scant de machine zelf hoeveel mosselen er op de touwen zitten en welke kracht nodig is om ze eraf te halen."
Het prototype wordt dit voorjaar beproefd in de Oosterschelde en de Waddenzee. De techniek zorgt voor een duurzamere mosselkweek. Dat is ook de reden dat het Europees Visserij Fonds (EVF), Provincie Zeeland en het Ministerie van Economische Zaken met zo'n 10.000 euro het tweejarige project financieel ondersteunen

> **De oogstmachine heeft roterende flappen waarmee automatisch kan worden geoogst.**
> Willem Haak, projectleider HZ

Figuur 2. Artikel De Ondernemer – maart 2015

de Ondernemer · Voor ondernemend & werkend Zeeland

Waardeontwikkeling met 'Value Management'

Ageeth van Maldegem, docent commerciële economie.

Ondernemen is snel reageren op de marktontwikkelingen, kansen pakken en investeren als dat nodig is. Té snel reageren kan uiteindelijk veel minder 'waarde' opleveren dan vooraf werd verwacht. Stel je wil een productielijn en sales divisie opzetten voor een product met een korte levenscyclus en hoge omzet. Klinkt goed, maar het biedt geen garantie op een rooskleurige opbrengst onder de streep.

Tekst **Annet van de Ree**

Met Value Management wordt een dergelijke beslissingssituatie op strategisch niveau uitgewerkt en de werkelijke waarde van een investering op lange termijn in beeld gebracht. Hiermee ben je als ondernemer beter in staat om een toekomstbestendige organisatie op te bouwen. Ageeth van Maldegem, docent commerciële economie en coördinator van de projectvakken bij HZ Academie voor Economie en Management, introduceerde hiervoor een 'Value management' module, waarmee niet alleen de toekomstige waarde van een project of organisatie boven tafel komt, maar ook de randvoorwaarden voor de invulling hiervan.

"Value Management is een methodologie, gericht op het identificeren van de waarde van een project en het managen van die waarde", legt Van Maldegem uit. "Dat klinkt theoretisch, maar het gaat om het maken van keuzes op strategisch niveau. Bij een ontwikkeltraject horen een aantal kritische succesfactoren, gelinked aan doelstelling en realisatie. Voorbeelden zijn bepaalde partners of leveranciers, licentie-ontwikkeling, een sales organisatie. Onze studenten hanteren voor het berekenen en inzichtelijk maken van de bijdrage van deze factoren een internationaal erkende rekentool. In 2015 zijn de eerste projecten door HZ studenten uitgevoerd bij Maatschappelijk Werk Walcheren, de dertien Zeeuwse gemeenten en aquacultuur bedrijf Smit&Smit. Voor komend jaar hebben zich al tien opdrachtgevers aangemeld, vooral starters, die voor een aantal belangrijke beslissingen staan."

Van Maldegem promoveert momenteel aan Cranfield University (UK) op het onderwerp 'Customer's Hidden Needs'. Samen met Value Management, Sociale Innovatie en Service Design, de onderzoeksthema's voor studenten en docentenonderzoekers, draagt dit actief bij aan innovatie voor bedrijven en instellingen in regio.

Jansen Tholen BV is een bedrijf dat zich profileert als leverancier van geïntegreerde oplossingen in het modificeren en onderhouden van machines, productielijnen en industriële installaties. Door een goede afstemming is het mogelijk om tijd- en materiaal verlies tot een minimum te beperken. Het project 'Value Management' past dan ook perfect in de denkwijze van het bedrijf.

Tekst **Annet van de Ree** Foto **Dirk-Jan Gjeltema**

Van offerte tot en met onderhoudsservice

Voor directeur Siem Jansen en het team van Jansen Tholen BV is innoveren en meedenken met specifieke vragen van klanten dagelijks werk. Het bedrijf startte in 1985 op initiatief van Siem Jansen en al snel volgde zijn twee broers hem in de zaak. Siem is manager van de mechanische afdeling en is één van de drie directeuren. Beide broers sturen de elektrotechniek aan en zorgen onder meer voor de administratieve kant. Siem Jansen werkte in de afgelopen jaren met enige regelmaat met studenten van de Academies van Hogeschool Zeeland. Het project 'value management' trok zijn aandacht voor een project in de automatisering van een MZI (Mosselzaad Invanginstallatie). Dit project wordt, ondersteund met Europese subsidie uit het Europees Visserij Fonds (EFV), voor fa. Gebr. A.J. Schot met de Tholen 4 ontwikkeld.

Het project

Het project 'Ontwikkeling geautomatiseerd MZI systeem' is een initiatief van Firma Gebr. A.J. Schot TH 4 en Jansen Tholen BV en wordt mede mogelijk gemaakt door het Europees Visserij Fonds (EVF) en het Ministerie van Economische Zaken ter investering in duurzame ontwikkeling van visserijgebieden.

Eigen onderhoudsservice

"In het kader van het value management project wordt er in nauw overleg met de studenten van de HZ Academie voor Economie en Management verder gebouwd aan de ontwikkeling van de MZI. Het is boeiend om met deze studenten te werken. Je wordt zelf in de loop der jaren toch wat bedrijfsblind en een frisse blik op het proces en de kritische vragen brengen hiaten aan het licht," legt Jansen uit. Het hele project is nog volop in uitvoering, maar helder is dat wij de onderhoudsservice beter zelf kunnen uitvoeren. Dit wilden we in een eerder scenario gaan uitbesteden. De rekenmodules die in value management worden gehanteerd, maakten duidelijk dat we dit beter in eigen hand kunnen houden. De redenen hiervoor zijn onder meer dat de markt voor de MIZ's beperkt is en wij als bedrijf nog in de productontwikkelingsfase zitten. Via een eigen onderhoudsservicedienst kunnen we veel leren uit de praktijk en het product doorontwikkelen. Die kennis zetten we om in het optimaliseren van het product, om de innovatieve kennis vervolgens aan mosselvissers te leveren."

De Ondernemer Zeeland 24 | 25

Directeur Siem Jansen is erg enthousiast over de samenwerking met HZ-studenten en -onderzoekers.

> Het is boeiend om met deze studenten te werken. Je wordt zelf in de loop der jaren toch wat bedrijfsblind en een frisse blik op het proces en de kritische vragen brengen hiaten aan het licht.

Oorspronkelijke scenario

"In het oorspronkelijke scenario zouden we ook met verkopers gaan werken met het oog op export. We kijken nu naar mogelijke samenwerking zowel in Nederland als in het buitenland. Over de grens zijn de vissystemen vaak net even anders. Verkoop naar het buitenland zit er voorlopig niet in."

De hele cyclus

Binnen het bedrijf is value management bij de betrokken medewerkers tot nu toe met enthousiasme ontvangen, zegt Jansen. "Ik verwacht wel dat we in de toekomst meer gaan werken met de methodiek, vooral voor grote projecten. Het pakt de hele cyclus van een project mee, van offerte tot aan onderhoudsservice. Dat past erg goed in onze denkwijze over kwaliteit en onnodig afstemmingsverlies. We zijn tevreden met de support van HZ en de bijdrage van de studenten. Het blijkt voor beide partijen interessant. De uitwerking via value management bevestigt al dan niet onze inschattingen en welke kant we dan op moeten. Het is een continu proces dat je in samenwerking met je klant moet uitvoeren. Ik zou het andere bedrijven aanraden om ermee aan de slag te gaan. Het is voor ons een prima managementtool en voor bepaalde bedrijven biedt het zeker meerwaarde in de uitvoering van grote projecten."

Het MZI-project is overigens nog niet afgerond. "Er zal nog regelmatig contact zijn met docentonderzoeker Armand van Oostrom en de studenten. Voor ons heeft het traject tot nu toe meer 'value' opgeleverd," benadrukt Jansen tot slot.

Daarnaast heeft de HZ op haar website een aantal keer aandacht besteed aan dit project, zoals bijvoorbeeld dit artikel: http://m.hz.nl/nieuws/hz-studenten-engineering-automatiseren-mosselzaadinvanginstallatie

Ten slotte werd Jansen Tholen met de Mossel Zaad Invanginstallatie overtuigend verkozen tot winnaar van de publieksprijs van de Emergo Innovatieprijs 2015 met 41 procent van de online publieksstemmen.

Figuur 3. MZI publieksprijs Emergo Innovatieprijs 2015

7. CONCLUSIE

Er is de afgelopen periode hard gewerkt aan de overkoepelende doelstelling van het project: *"Het doel van het project is de doorontwikkeling van een geautomatiseerd oogstsysteem op de mosselzaad invanginstallatie (MZI), waarbij de verwijdering van het mosselzaad van het substraat efficiënter, sneller en minder arbeidsintensief kan worden uitgevoerd en het valverlies en beschadiging van mosselzaad kan worden beperkt tot een minimum, waardoor het rendement van MZI's kan worden verhoogd en zo de transitie, binnen de gestelde termijn dan wel sneller, te voltooien".*
Er zijn deelprojecten opgestart met onderzoekers en studenten vanuit meerdere opleidingen om deze doelstelling te behalen.

In de deelprojecten zijn specifieke doelstellingen opgesteld. Deze doelstellingen zijn grotendeels behaald. Er is een proefmodel gemaakt van het oogstvlot en er is mee getest. Onderdelen van het oogstvlot zijn ook gebouwd en getest. De resultaten van de tests zijn zo succesvol geweest, dat de ontwikkelplannen gecontinueerd worden en er meer partijen bij betrokken zijn.

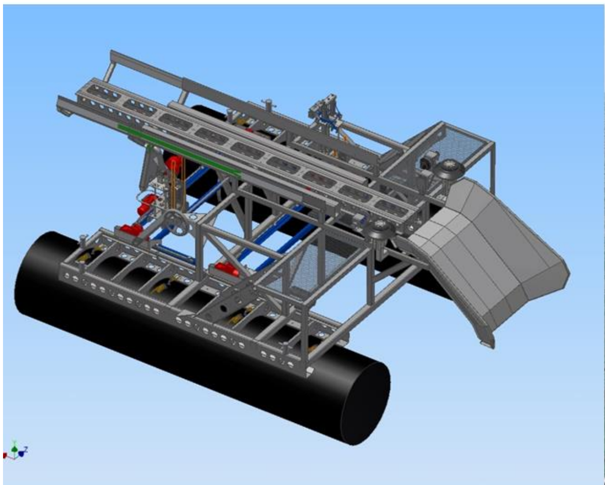
Er zijn echter nog genoeg uitdagingen waar vervolgonderzoek op ingezet kan worden. Tevens kan doorgegaan worden met de aanbevelingen uit de verschillende deelprojecten. HZ University of Applied Sciences draagt vanuit structurele samenwerking graag bij aan vervolgonderzoek in dit project.

De conclusies van alle deelprojecten en gedetailleerde beschrijvingen van de resultaten zijn te vinden in de onderzoeksrapporten in de bijlages.

BIJLAGES

5. *(Voorlopig)* rapport Jetpompontwerp
6. Rapport van ophanghaak herkenning.
7. Rapport van mosselherkenning.
8. Rapport van mechanisatie van substraat in bigbag.
9. Rapport van oogstvlot supervision.
10. A & B: Rapporten van ontwerp van parameter tabel en FEM-controle berekeningen
11. Rapport van substraatrol ontwerp
12. Communicatieplan en materiaal (voorlopig)

BIJLAGE 5



Europees Visserijfonds:
Investering in duurzame visserij

Ministerie van Economische Zaken

Jansen Tholen B.V.

Provincie Zeeland

HZ UNIVERSITY OF APPLIED SCIENCES

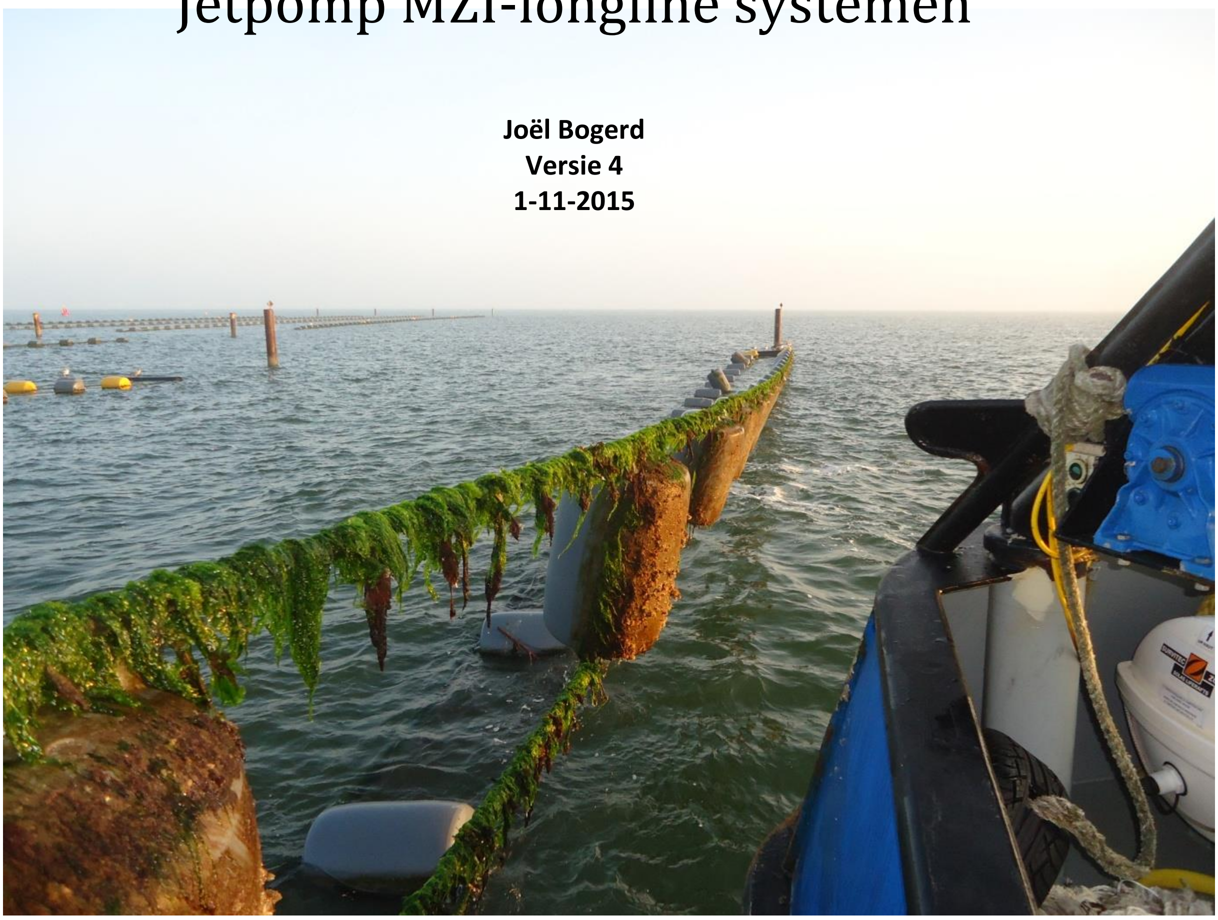
Eindrapport

Jetpomp MZI-longline systemen

Joël Bogerd

Versie 4

1-11-2015



Titelblad

Onderdeel:	Eindrapport
Auteur:	J. Bogerd
Versie:	4
Plaats uitgave:	Tholen
Jaar uitgave:	2015
Onderwijs instelling:	HZ University of applied science
Stagedocent:	Ir. J.C.W. Haak MTD
Stagebegeleider:	ing. J. Goudswaard
In opdracht van:	Jansen Tholen B.V.
Classificatie:	Intern , vertrouwelijk

Management samenvatting

De regelgeving binnen de mosselsector is gewijzigd van bodemvisserij tot het gebruik van MZI-Longline systemen. Binnen dit nieuwe systeem zal er tijdens het oogsten van het mosselzaad gebruik gemaakt worden van een jetpomp. Deze jetpomp wordt aangedreven door een vloeistofpomp en zal een zuigend effect creëren. Waarmee mosselzaad vanuit de zee getransporteerd wordt tot in het laadruim van de mosselkotter.

Hierbij is het noodzakelijk om het valverlies en mosselbreuk tijdens het oogsten te beperken en de ergonomische werkomstandigheden zullen daarbij verbetert moeten worden.

De bijbehorende vraagstelling is een ontwerp van een jetpomp die ingezet kan worden binnen het MZI-systeem. Toon hierbij de werking van het ontwerp van de jetpomp aan door middel van een literatuuronderzoek. Voer het literatuuronderzoek uit aan de hand van vooronderzoek, berekeningen, simulaties en praktijktesten. Hierin moet duidelijk worden welke parameters invloed hebben op het resultaat van de jetpomp.

Daarbij zal stapsgewijs via de methodiek van Eggert gewerkt worden om van verschillende concepten een werkend prototype te produceren, die daadwerkelijk ingezet kan worden tijdens het oogsten van het mosselzaad.

Al snel wordt duidelijk dat de theoretische onderbouwing van de werking van de jetpomp bijna onmogelijk is. Bekende formules kunnen een globale benadering geven over de werking van een Venturi-systeem (zuigend effect door het creëren van een onderdruk), maar wanneer de factoren binnen een ontwerp van een jetpomp meegenomen worden in deze berekening komen we uit op een dood spoor. Hierbij kunnen kleine aanpassingen binnen een ontwerp, zoals een diameter vergroting/verkleinen of een hoek verandering theoretisch niet in kaart gebracht worden.

Daardoor is er gekozen om een CFD-software pakket, wat speciaal opgezet is om vloeistofberekeningen te maken, te gebruiken voor het verdere onderzoek binnen dit project. Hierbij is gestart met het onderzoek naar de verschillende parameters die van invloed zijn op de werking van de jetpomp. Aan de hand van opgestelde eisen betreft minimale diameter leidingwerk wat nodig is om mosselzaad te transporteren is er gestart met het ontwerpen van een prototype.

Dit prototype is tot stand gekomen uit de bevindingen van dit software programma, maar of dit programma daadwerkelijk dicht bij de werkelijkheid komt kan alleen getest worden met een praktijktest van het prototype.

Voorwoord

Tegenwoordig is het vinden van een stage die aansluit bij de opleiding niet zo gemakkelijk meer. Voorafgaand aan mijn afstudeerperiode heb ik gesolliciteerd bij een aantal verschillende bedrijven, maar Jansen Tholen BV was de enige die een compleet onderzoek met een bijhorend ontwerp proces kon aanbeiden. Het feit dat het mogelijk is om een prototype te bouwen en dan ook te testen is een belangrijke doorslag geweest in de keuze voor het bedrijf.

Daarvoor wil ik graag Jansen Tholen BV bedanken in het algemeen voor de enthousiaste en de snelle respons voor het aanbeiden van de stage opdracht. Daarbij zijn een aantal personen die dicht bij het project betrokken zijn en dus persoonlijk wil bedanken. Ten eerste wil ik Jansper Goudswaard bedanken voor de begeleiding en voor de informatie die nodig was om het project uit te voeren. Verder zou ik graag Willem Haak willen bedanken voor de procesbegeleiding en zijn rol als afstudeerbegeleider. Bij het produceren van het prototype wil ik graag Peter Bijl bedanken voor de praktijk kennis om het ontwerp productie klaar te maken.

Verder wil ik Krohne Nederland BV. bedankten voor de informatie betreft nauwkeurige vloeistofmetingen, en voor de elektomagnetische flowmeter die speciaal voor de testen is ingezet om meer grip te krijgen op de werking van de jetpomp.

Als laatst wil ik het overige personeel bedankten voor het realiseren en de hulp bij het testen van het prototype.

Gebruikte afkortingen/verwijzingen

In het rapport wordt gebruik gemaakt van bepaalde afkortingen of verwijzingen die nu worden toegelicht, hierbij is er een onderverdeling binnen de mosselsector, toegepaste theorie en software betekenissen.

Mosselsector

Afkorting	Beschrijving
Venturi-effect	*Een vernauwing in diameter geeft een vloeistofversnelling, wat resulteert in een onderdruk*
Jetpomp	*Ander woord voor Aspirator*
Aspirator	*Een apparaat waar vloeistof gebruikt wordt om een ander medium op te zuigen, gebruikt van het Venturi-effect*
substraatlijn	*Een lijn in de vorm van touw of netten die ingezet worden binnen de mosselvangst*
mosselzaad	*Mossel larve die uitgegroeid zijn tot 1 a 2 cm*
MZI	*Mosselzaadinvanginstallaties, het winnen van mosselzaad d.m.v. hangcultuur*
Mosselkotter	*Boot ontworpen speciaal voor het zaaien en oogsten van mosselen*

Toegepaste theorie

Afkorting	Beschrijving
Bernoulli	*Een natuurkundige wetmatigheid die het stromingsgedrag van vloeistoffen en gassen beschrijft*
Navier-Stokes	*Een differentiaalvergelijking waarin de verandering in impuls altijd in evenwicht is met de druk*
Reynolds getal	*Een dimensie loos getal dat bepaalt of een stroming laminair of turbulent is, maar ook om de similariteit tussen stromingen te onderzoeken (schaalwetten)*
Darcy-Weisbach	*Een empirische vergelijking die het verband weergeeft tussen enerzijds het verlies in piëzometrische hoogte en anderzijds de gemiddelde snelheid van een fluïdum*

Software toepassingen

Afkorting	Beschrijving
CFD	*Computational Fluid Dynamics, dynamische flow simulatie software*
Boundry conditions	*Randvoorwaarden, denken aan input- en output gegevens*
Planes	*Doorsnede ontwerp, in de richting x,y en z*
Velocity Magnitude	*Vloeistof snelheid*
Static pressure	*Statische druk*

Inhoud

1 Introductie

Voor het behalen van een Bachelor programma is een periode nodig om dat de student kan laten zien dat hij kan functioneren binnen professionele werkomgeving. Het educatieve programma of Engineering vereist dat elke student deze periode uitvoert binnen een uitdagende en professionele omgeving, om de juiste professionele- en onderzoek competenties, zoals beschreven staat voor de graad van Bachelor of Engineering (B Eng) te krijgen. Om deze reden is besloten om deze periode uit te voeren bij Jansen Tholen BV.

Om een goed beeld te creëren gaan we eerst bekijken wie de opdrachtgever is en wat het bedrijf inhoud.

- **Bedrijfsnaam:** Jansen Tholen B.V.
- **Bedrijfsgroep:** Jansen Tholen Group
- **Vestigingsplaats:** Tholen, Nederland

Jansen Tholen B.V. is een onderneming opgericht in 1985 door drie gebroeders Jansen. Vanaf 1995 draagt de onderneming de huidige naam "Jansen Tholen B.V.". Vandaag de dag is de onderneming uitgegroeid tot een bedrijf dat uniek is in de diversiteit van de activiteiten. Hierbij kan het gaan om ontwerp, bouw, installatie, reparatie of onderhoud van machines in het algemeen.

Verder biedt de onderneming ook draai- en freeswerk, opspuitwerk, elektrotechniek of super finishing van walsrollen aan. Met deze vele mogelijkheden kan Jansen Tholen B.V. gezien worden als een totaalpartner die een geïntegreerde oplossing kan bieden, waarmee een mogelijk afstemmingsverlies kan worden voorkomen.

Verdere toelichting betreft de opzet binnen de Jansen Tholen Group, zie Bijlage 1: *Missie statement Jansen technology Group.*

De aanleiding voor het onderzoek is omdat de regelgeving voor het vangen van mosselzaad steeds strenger wordt. Met name het verkrijgen van mosselzaad vanaf de natuurlijke zaadbanken zal in de toekomst verder beperkt worden. Het ingevangen mosselzaad wordt uitgezet op kweekpercelen en groeit daar uit tot volwassen consumptiemossel.

Omdat bodemvisserij steeds meer beperkt wordt, is een nieuw systeem bedacht om mosselzaad te verkrijgen. In het zeewater worden rondzwevende mossellarven ingevangen in netten en touwen. Hoe dit handig, goed en goedkoop uitgevoerd kan worden, is momenteel volop in ontwikkeling. Voorlopig is deze nieuwe manier van zaadvangen duurder dan het verkrijgen van zaad op natuurlijke mosselbanken.

Jansen Tholen is een machinefabriek met ervaring in het ontwerpen en bouwen van teeltmachines. Oostinga is een mosselvisser en is bij Jansen Tholen gekomen met een ontwikkelvraag. Tot nu toe is de machine voor het plaatsen van de MosselZaad-Invangsystemen (MZI's) ontwikkeld en wordt momenteel gebouwd. De oogstmachine is in het komende semester in ontwikkeling: concepten zijn gekozen en de engineering is in volle gang.

Als reactie op de aanleiding voor het onderzoek is de aanvraag gekomen vanuit mosselkweker gebr. A.J. Schot voor een nieuw ontwerp van een oogstmachine voor het oogsten van het mosselzaad.

Samen met het MosselZaad-Invangsystemen (MZI's) zal dit een compleet systeem aanbieden. Voor zowel het invangen en het oogsten van het mosselzaad.

De doelsituatie met dit complete systeem is om te kunnen voldoen aan de strengere regelgeving. En daarbij de manier van zaadvangen aanpassen zodat het handig, goed en goedkoop uitgevoerd kan worden. Waarbij het verwijderen van het mosselzaad van het substraat efficiënter, sneller en minder arbeidsintensief wordt uitgevoerd en het valverlies en beschadigingen van mosselzaad wordt beperkt tot een minimum.

2 Probleem definiëring

Binnen de omschrijving van de probleem definiëring zal er gekeken worden naar de behoefte van de klant. Dit levert een pakket met eisen op waaraan het project moet voldoen (zie bijlage 2 PVE). Met deze informatie zal er een duidelijke opdracht omschrijving geformuleerd worden wat leiding zal zijn binnen de uitvoering van het onderzoek.

2.1 Probleem overzicht

Gericht aan de nieuwe wet- en regelgeving zijn er nieuwe methodes ontwikkeld ter ondersteuning van het oogsten van het mosselzaad, maar de praktijk wijst uit dat het oogsten van mosselzaad met behulp van de reeks bestaande apparatuur veel tijd kost en lijdt tot veel valverlies en beschadiging van het mosselzaad. Hierbij is door Jansen Tholen B.V. een nieuwe techniek ontwikkeld voor het losmaken van de substraatlijn van de hoofdlijn. Daarbij zal er een jetpomp ontwikkeld worden om de substraatlijn aan boord van de TH4 te krijgen, deze jetpomp moet er voor zorgen dat het valverlies en beschadigingen van het mosselzaad beperkt wordt en de ergonomische omstandigheden voor het personeel toe zal nemen.

2.2 Doelstellingen

Er waren twee doelstellingen binnen dit project, een doel *in* het project en een doelstelling *van* het project.

Doel in het project

Het doel in het project is het ontwerpen van een jetpomp die goedkoper is dan jetpompen van concurrenten, de kostprijs van de jetpomp mag daarom niet boven de 2500,- euro komen. Waarbij de concurrent een jetpomp kan leveren voor rond de 5000,- euro.

Doel van het project

Het doel van het project is om met de jetpomp het valverlies en mosselbreuk tijdens het oogsten te beperken en de ergonomische werkomstandigheden te verbeteren.

2.3 Opdrachtformulering

Afgeleid van de doelstelling van het project, wordt er een hoofdvraag met een bijhorend product geformuleerd. Daarna zal er door middel van deelvragen een beter inzicht gecreëerd worden voor het te kunnen beantwoorden van de hoofdvraag.

De precieze opdracht

Ontwerp een jetpomp die ingezet kan worden binnen het MZI-systeem. Toon de werking van het ontwerp aan door middel van een literatuuronderzoek. Voer het literatuuronderzoek uit aan de hand van vooronderzoek, berekeningen, simulaties en praktijktesten. Hierin moet duidelijk worden welke parameters invloed hebben op het resultaat van de jetpomp.

2.4 Hoofdvraag

Kan door middel van simulaties, berekeningen en praktijk testen een ontwerp van een jetpomp ontwikkeld worden waarin duidelijk wordt welke parameters van invloed zijn op de werking van de jetpomp, en die voldoet aan de gestelde eisen binnen het oogsten van mosselzaad?

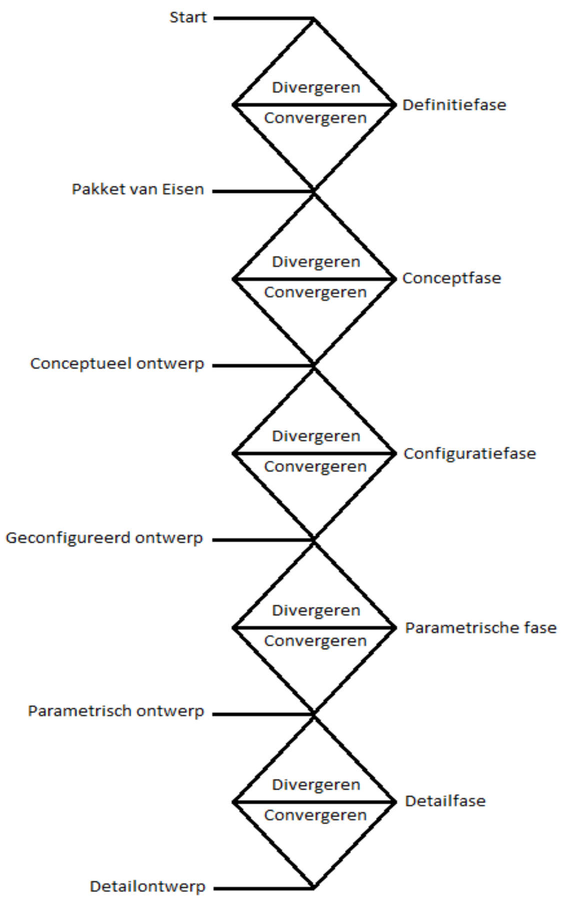
2.5 Methodiek

Om de doelstellingen binnen het onderzoek te behalen en daarmee de hoofdvraag te kunnen beantwoorden, wordt er volgens een methodiek gewerkt wat zal helpen binnen het genereren van een juiste aanpak.

Deze fasen zijn onderdeel van de ontwerpmethode van Eggert die wordt gebruikt als basislijn bij dit project.

Deze ontwerpmethode bestaat uit vijf verschillende ontwerpfasen, elk met een eigen uitgang. De afbeelding hiernaast geeft een globale indruk van de ontwerp fasen met een indicatie van de output per fase. Elke fase bestaat uit een divergerende en convergerende werking. Hiermee wordt bedoeld dat binnen elke fasen verschillende ideeën worden opgevat (Divergeren) om uiteindelijk te kiezen voor de beste oplossing/ ontwerp (Convergeren).

Voor deze methode is gekozen uit de ervaringen die opgedaan zijn binnen de opleiding. Verder sluit deze methodiek aan bij het onderzoek naar de werking van de jetpomp, en de hierbij horende verschillende ontwerpkeuzes.



Figuur 1 Eggert Methodiek

1. **Definitie fase**
   Tijdens de definitiefase zal zoveel mogelijk informatie over het ontwerp worden verzameld, dit in de vorm van voorgaande onderzoeken, bestaande literatuur en overige technische specificaties.

2. **Conceptuele fase**
   In deze fase zullen verschillende alternatieve oplossingen worden bedacht. Deze oplossingen worden samengebundeld tot een concept waar vervolgens een testmodel van gemaakt zal worden. Verschillende concepten zullen in deze fase al beperkt worden door het pakket van eisen.

3. **Configuratie fase**
   In de configuratie fase zal er vervolgens gekeken worden naar hoe alle meetapparatuur op het testmodel gevestigd kan worden. Hier is ook duidelijk welke meetinstrumenten er gebruikt zullen worden. Voor het echte ontwerp word er in deze fase gekeken naar hoe de leidingen en motoren op de jetpomp aangesloten worden.

4. **Parametrisch ontwerp**
   In het parametrische ontwerp word de geometrie, afmetingen en materialen bepaald die gebruikt gaan worden. Aan het eind van deze fase zal er een compleet test model of eindproduct zijn gemaakt dat gemakkelijk aan de testopstelling geplaatst kan worden.

5. **Detail ontwerp**
   Het detail ontwerp bestaat uit het uiteindelijke ontwerp. Na ieder parametrisch ontwerp vind een test plaats waaruit data komt en vervolgens een iteratieslag plaatsvind. Hierna word een nieuw ontwerp gemaakt totdat er voldoende informatie beschikbaar is om het uiteindelijke detailontwerp te maken.

2.6 Deelvragen

Om de doelstellingen binnen het onderzoek te behalen en daarmee de hoofdvraag te beantwoorden. Zijn er meerdere deelvragen opgesteld die per verschillende fasen uitgewerkt zullen worden.

Nr.	Deelvraag	Ontwerpfase (Eggert)
D1.	Wat zijn de eisen en wensen van de opdrachtgever?	*Definiëringfase*
D2.	Wat zijn de eisen en wensen van de gebruiker?	*Definiëringfase*
D3.	Welke huidige jetpomp systemen bestaan er?	*Definiëringfase*
D4.	Welke huidige jetpomp systemen zijn toepasbaar binnen de mosselsector?	*Definiëringfase*
D5.	Welke parameters zijn van toepassing binnen het gebruik van een jetpomp?	*Definiëringfase*
D6.	Kan met een CFD simulatie de werkelijkheid nagebootst worden, en hoe is dit controleerbaar?	*Definiëringfase*
D7.	Welke van de concepten is het beste, en wat zijn de bijhorende parameters?	*Conceptfase*
D8.	Hoe zien mogelijke configuraties van het concept eruit?	*Configuratiefase*
D9.	Welk van de configuraties is het beste en hoe ziet deze eruit?	*Configuratiefase*
D10.	Hoe zien mogelijke parametrische varianten van het geconfigureerd ontwerp eruit?	*Parametrische ontwerp*
D11.	Welk van de parametrische varianten is het beste en hoe ziet deze eruit?	*Parametrische ontwerp*
D12.	Hoe zien mogelijke detailvarianten van het parametrische ontwerp eruit, en hoe kan deze getest worden op bruikbaarheid (aan boord van de TH4)?	*Detail ontwerp*
D13.	Hoe verhoudt het gedetailleerde ontwerp zich in vergelijking met de verwachte performance?	*Detail ontwerp*

Tabel 1 Deelvragen gedefinieerd per methodiek fase

2.7 Theoretisch kader

Om de deelvragen te kunnen beantwoorden, wordt er in het vooronderzoek en tijdens de verdere periode gebruik gemaakt van een theoretisch kader. Hierdoor worden de resultaten gewaarborgd en zal toegepaste informatie als bewijslast dienen voor het generen van geloofwaardige resultaten.

1. Stromingsleer

Het te ontwerpen systeem zal onderworpen worden aan vloeistof stromingen. In het ontwerp moet hier rekening mee gehouden worden. Hiervoor is diepere kennis nodig van deze vloeistofstromingen en dan de nadruk op turbulente stromingen. De bijhorende berekeningen zullen uitgewerkt worden en de Navier-Stokes en de Wet van Bernoulli zullen hierin een belangrijke rol spelen. Het boek van dhr. N.H.Dekkers, & dhr.J.M.H Wijnen (Eenvoudige stromingsleer voor het HBO) (Wijnen, 2007)

2. Sterkteleer

De vloeistof zal d.m.v. een nozzle aan een versnelling onderheven worden, dit levert een kracht op het materiaal en zal meegenomen moeten worden in het ontwerp. Hiervoor is kennis van statica, sterkteleer en dynamica voor nodig. Hierbij zullen de boeken van dhr. R.C. Hibbeler (*Statica, Sterkteleer en Dynamica*) een mogelijk hulpmiddel kunnen zijn. (Hibbeler, Statica, 2010) (Hibbeler, Sterkteleer, 2007) (Hibbeler, Dynamica, 2010)

3. Materiaalkunde

De keuze van de materialen zullen al tijdens het ontwerpen worden vastgesteld. Materialenkennis is hier een vereiste. Een juiste onderbouwing kan uit het boek van dhr. M. Kooijman (*Materiaalkunde voor Technici*) gehaald worden. (Kooijman, 2009)

4. Aandrijftechniek

Een vloeistofpomp zorgt voor de aanvoer van energie dat in de jetpomp omgezet wordt in zuigkracht. Hiervoor is kennis over verschillende aandrijftechnieken nodig. Het boek van dhr. Jac. Stolk (*Machineonderdelen*)zal een mogelijk hulpmiddel zijn. (Stolk, 2009)

5. Gebruikersinterfaces

Een machinaal aangedreven systeem zal moeten worden bediend door een gebruiker. Om in kaart te brengen hoe een gebruiker het apparaat wil kunnen bedienen is kennis nodig over gebruikersinterfaces. Het boek van dhr. J.M. Dirken (*Productergonomie*) zal een mogelijk hulpmiddel kunnen zijn. (Dirken, 2005)

6. Productietechnieken

Het te ontwerpen systeem zal uiteindelijk geproduceerd moeten worden. Omdat er tijdens het ontwerpen al rekening moet worden gehouden met de uiteindelijke productie is er kennis nodig van productietechnieken. Hierbij zal het boek van dhr. H.J.J. Kals (*Industriële productie*) (Kals, 2007) een mogelijk hulpmiddel kunnen zijn.

7. Projectmanagement

Omdat dit volledige project zal moeten worden gemanaged, is er kennis nodig van projectmanagement. Hierbij zal het boek van dhr. R.J. Eggert (*Technisch ontwerpen*) (Eggert R. , 2007) en het boek van mw. N. Van Glabbeek (*Succesvol studeren, communiceren en onderzoeken*) (Glabbeek, 2009) een mogelijk hulpmiddel kunnen zijn.

8. Kwaliteitsbeheersing

De documentatie gericht aan de HZ zal moeten voldoen aan de gestelde norm die geld binnen de afstudeerstage. De voortgang binnen het project zal in documenten worden vastgelegd. Hiervoor zijn 2 handleidingen beschikbaar gesteld waaraan de documenten moeten voldoen:

Studentenhandleiding Afstuderen (Sciences, 2013) en Studentenhandleiding Afstuderen DEEL2 S2-2013/2014 (Verhage, 2013).

Bijhorend worden competenties opgesteld die binnen het persoonlijk ontwikkelingsplan moet worden uitgewerkt. Hierbij zal het boek van R. Grit, R, Guit, N. van der Sijde (Competentiemanagement, persoonlijk ontwikkelingsplan) een hulpmiddel zijn. (Grit, Guit, & Sijde, 2007)

9. Ontwerpmethodiek

Gedurende dit project zal worden gewerkt volgens de ontwerpmethodiek van Eggert. Om dit zo effectief mogelijk te doen is kennis nodig over deze methodiek. De kennis zal voornamelijk afkomstig zijn uit ervaring. Een mogelijk hulpmiddel bij het navolgen van de methodiek is het boek van dhr. R.J. Eggert (*Technisch ontwerpen*). (Eggert R. , 2007)

10. OntwerpTechnieken

Voor het construeren van de verschillende concepten, wordt er gebruikt gemaakt van het standaarddesign programma Inventor dat aanwezig is binnen Jansen Tholen B.V. Een bijhorende informatie boek van dhr. R. Boeklagen (Inventor 11, Computer Ondersteund Ontwerpen) zal geraadpleegd worden. (Boeklagen, 2006)

Tijdens het uitvoeren van de Autodesk CFD simulaties wordt de officiële website geraadpleegd. Op deze site worden de verschillende handelingen toegelicht, en er bestaat ook een forum waarin verschillende ontwerpers hun bevindingen kunnen delen. (bv, 2014)

11. Vooronderzoek

Naast het gebruik van het theoretisch kader, zal de behaalde kennis vanuit het vooronderzoek ook toegepast worden binnen de afstudeerstage(zie tabel 4). Hierbij wordt er genoodzaakt om de gebruikte kennis eerst te onderwerpen aan geloofwaardigheid, voordat de aannames verwerkt worden in het afstudeerproject.

Nr.	Vakgebied	Literatuur/bron	Auteur
V1.	Vooronderzoek	Onderzoek rapportage	J. van Bale & R. Melis
V2.	Vooronderzoek	Database praktijk testen Jetpomp	J. van Bale & R. Melis
V3.	Vooronderzoek	Project Plan	J. van Bale & R. Melis
V4.	Vooronderzoek	Analyse verslag	J. van Bale & R. Melis
V5.	Concepten/berekeningen	Simulaties (CFD)	Ir. J.C.W. Haak MTD
V6.	Probleemanalyse	Innovatief oogsten van mosselzaad	E. van der Tuin
V7.	Klant-eisen	Innovatief oogsten van mosselzaad	E. van der Tuin

Tabel 2 Kennis vanuit het vooronderzoek

3 Definitie fase

Tijdens de definitiefase zal zoveel mogelijk informatie over het ontwerp worden verzameld, dit in de vorm van voorgaande onderzoeken, bestaande literatuur en overige technische specificaties. Met deze informatie zal antwoord gezocht worden geformuleerde deelvragen.

Nr.	Deelvraag
D1.	Wat zijn de eisen en wensen van de opdrachtgever?
D2.	Wat zijn de eisen en wensen van de gebruiker?
D3.	Welke huidige jetpomp systemen bestaan er?
D4.	Welke huidige jetpomp systemen zijn toepasbaar binnen de mosselsector?
D5.	Welke parameters zijn van toepassing binnen het gebruik van een jetpomp?
D6.	Kan met een CFD simulatie de werkelijkheid nagebootst worden, en hoe is dit controleerbaar?

Tabel 3 Definitie fase

Aangezien dat de wetregelgeving voor het verkrijgen van mosselzaad van de natuurlijke zaadbanken verandert is, zal de huidige manier van oogsten niet voldoen aan de nieuwe wetregelgeving. Bijkomend is de huidige manier van oogsten zeer arbeidsintensief en ergonomisch niet verantwoord (zie figuur 2 huidige manier van oogsten).

Figuur 2 Huidige manier van oogsten

Om hier een juiste oplossing voor te vinden wordt er eerst bekeken wat de exacte eisen zijn vanuit de wensen van de klant gebr. Schot:

3.1.1 Gebruiksomgeving

In de huidige situatie wordt er veel arbeid verricht tijdens het oogsten van het mosselzaad. De bedoeling is om het proces te automatiseren, bijkomende eisen zijn:

- Beperken arbeidsintensief
- Beperken handmatige handelingen
- De ergonomische omstandigheden moeten verbetert worden.
- De efficiëntie zal verhoogt moeten worden
- Beperken brandstofverbruik

3.1.2 Performance

Het huidige systeem voldoet niet aan de productie eisen, het nieuwe systeem zal hierin moeten uitblinken. Daarbij zullen volgende performance handelingen verbetert moeten worden:

- Het valverlies van het mosselzaad zal beperkt moeten worden.
- De beschadigingen aan het mosselzaad zal beperkt moeten worden.
- De proces snelheid zal omhoog moeten.
- De economische haalbaarheid zal geoptimaliseerd moeten worden
- Het systeem mag geen storingen vertonen tijdens het oogsten van het mosselzaad

3.1.3 Geometrische beperkingen

Het systeem is beperkt tot de geometrie aan boord van de TH4, hierbij lettend op afmetingen maar ook naar mogelijk energie levering in de vorm van pompvermogens elektrisch, hydraulisch:

- Het geautomatiseerde oogstsysteem moet toepasbaar zijn, aan boord van de TH4.
- Het geautomatiseerde oogstsysteem moet compact zijn, om voldoende ruimte beschikbaar te houden aan boord van de TH4.
- Het systeem moet aangedreven worden met bestaande vermogens aanwezig bij de TH4

3.1.4 Onderhoud

Het systeem zal zo efficiënt mogelijk moeten functioneren, daarbij:

- Onderhoud aan het systeem moet zo veel mogelijk beperkt blijven
- Na het oogst seizoen moet het systeem makkelijk te reinigen zijn

3.1.5 Veiligheid

Om de ergonomische omstandigheden te verbeteren zal de veiligheid van het systeem moeten voldoen aan:

- Het systeem moet bestand zijn tegen de weeromstandigheden, hierbij denkend aan:
  - Wind, Golfslag, Turbulentie in het water
- Er mag geen risico met betrekking tot het gebruik van elektrische machines in een water omgeving zijn.

Een totaal overzicht van het pakket van eisen is als bijlage toegevoegd: *zie Bijlage 2: Programma van Eisen*

3.2 Werking jetpomp

Vanuit de opgestelde eisen is er bepaald dat het geautomatiseerde oogstsysteem zal bestaan uit een jetpomp, die het substraatlijn met het mosselzaad zal opzuigen en transporteren richting het ruim van de mosselkotter.

De definitie van een jetpomp is het volgende: het onder hoge snelheid toevoegen van een 2e gas of vloeistof in een systeem. Door het toevoegen onder hoge snelheid zal er een impuls ontstaan waardoor de twee gassen/vloeistoffen met elkaar zullen mengen en zal er eenmaal samengevoegd een hogere snelheid ontstaan dan dat er eerst aanwezig was. (Debiet verhoging in een systeem). (Jetpump definition, sd)

3.2.1 Behoud van Energie, wet van Bernoulli

De wet van Bernoulli is een natuurkundige wet die het energieniveau van vloeistoffen en gassen beschrijft. Dit energieniveau word berekend aan de hand van de druk, snelheid en hoogte van de vloeistof/gas op een bepaald punt. Als het energieniveau van verschillende punten met elkaar word vergeleken zullen deze dus gelijk moeten zijn, aangezien energie nooit verloren gaat in een ideale situatie. (Wet van Bernoulli, 2014)

De wet van Bernoulli is als volgt:

$$\frac{1}{2}\rho v^2 + \rho g h + p = constant$$

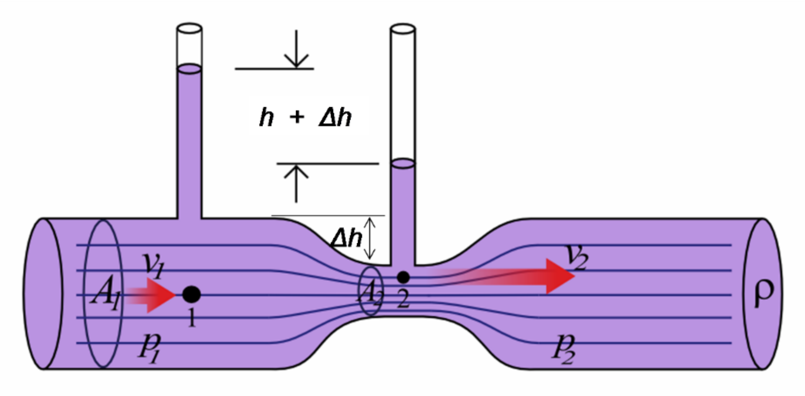
Hierin is:
v de snelheid (m/s)
g de valversnelling (m/s^2)
h het hoogteverschil (m)
g de druk (Pa)
ρ de (massa)dichtheid (kg/m^3)

"Wanneer de snelheid van een vloeistof versnelt, neemt de druk af"

De afname van druk maakt het mogelijk om een vacuüm te genereren. Deze eigenschap kan in de vorm van een jetpomp worden toegepast om mosselzaad op te zuigen en te transporteren over een bepaalde lengte. Deze eigenschap zal ik stapsgewijs toelichten om de werking binnen de jetpomp duidelijk te maken.

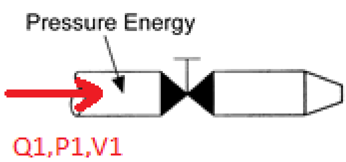
3.3 Venturi effect, vacuüm

Het Venturi effect is een effect dat optreed als afgeleide van de wet van Bernoulli. Als de snelheid van de stroom in een systeem toeneemt zal er een drukverschil ontstaan, aangezien de energie niet verloren kan gaan. Hoe meer de snelheid toeneemt des te hoger dit drukverschil zal zijn. Bij een bepaalde snelheidsverhoging zal de druk zoveel afnemen dat er onderdruk zal ontstaan, wat zorgt voor een zuigende werking. (Venturi-effect, sd)



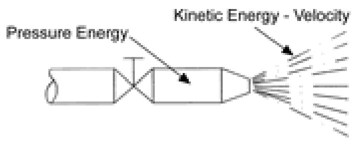
3.3.1 Vacuüm effect

Een vloeistofpomp geeft de aanvoer van een debiet (Q1), dit met een bepaalde vloeistofsnelheid (V1). Dat resulteert in een druk (P1).



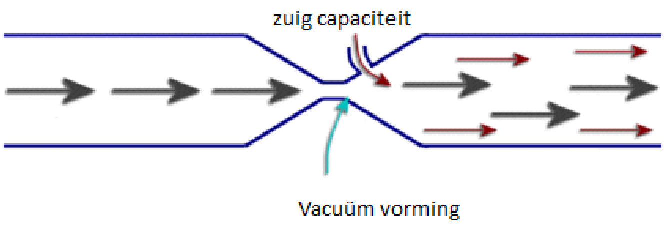
Figuur 3 Static pressure

De aanvoer van de vloeistof heeft een hoge druk (P1), maar door een grote doorstoomoppervlakte een lage vloeistofsnelheid (V1). Wanneer we een vernauwing in de vorm van een nozzle toepassen neemt de vloeistofsnelheid toe maar zal de druk afnemen.



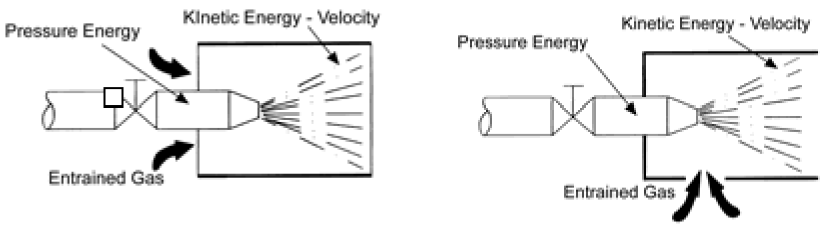
Figuur 4 Pressure energy omzet naar Kinetic energy

Deze daling in druk creëert een vacuüm direct na de nozzle.



Figuur 5 Vacuüm vorming

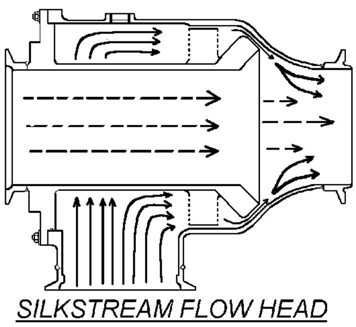
Dit vacuüm is in staat om een ander medium op te zuigen. In ons geval is dit zeewater met het mosselzaad plus substraattouw. Maar om dit effect te kunnen gebruiken zal er door middel van insluiting een behuizing geplaatst worden rond dit vacuüm.



Figuur 6 vrijheid in insluiten vacuüm

3.4 Bestaand systeem

De Silkstream jetpomp is een ontwerp wat specifiek voor het transporteren van zalmen is bedoeld. Hierdoor is de transportleiding door de jetpomp horizontaal gehouden en tevens een grote diameter zodat de zalmen onbeschadigd getransporteerd zullen worden.



Figuur 7: Silkstream

Dit systeem heeft zijn eigen in de praktijk al bewezen en zal dus als studiemodel dienen voor het ontwerp van een nieuwe jetpomp die toepasbaar is binnen de mosselsector. (Silkstream, sd)

Voor meerde bestaande systemen zie -*Bijlage 3: Jetpomp toepassingen*

4 Concept fase

De conceptfase heeft als functie om te onderzoeken welke parameters invloed hebben op de totale werking van de jetpomp. Het analytisch aantonen van deze parameters en daarmee de werking van de jetpomp is door de complexiteit van de berekeningen bijna onmogelijk. Zeker wanneer er onderzocht moet worden welke parameters van invloed zijn en wat de meest efficiënte afstelling is van de jetpomp. Daarom zal er gebruik gemaakt worden van een simulatie pakket wat speciaal gericht is op vloeistofberekeningen.

Dit simulatiepakket is een onderdeel van Autodesk en met deze simulaties kan de werking van de jetpomp worden toegelicht (visueel beeld). Het voordeel van dit programma is dat er makkelijk wijzigen aan het ontwerp gemaakt kunnen worden zonder hierbij nieuwe berekeningen te formuleren. Om het aantal onbekende te beperken zal de input gegevens als vaste waarde dienen binnen deze simulaties. *zie bijlage 4: Pomp gegevens*

onderdeel	waarde	eenheid
Diameter leiding	DN200	$[mm]$
Debiet	800	$[m^3/h]$
Druk	1.7	$[bar]$

Tabel 4 Vaste input gegevens

Met de resultaten van de verschillende simulaties zal een antwoord geformuleerd worden op de onderstaande deelvraag.:

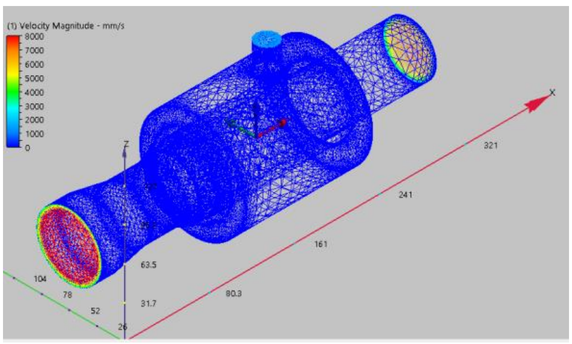
Nr.	Deelvraag	Ontwerpfase (Eggert)
D7.	Welke van de concepten is het beste, en wat zijn de bijhorende parameters?	*Conceptfase*

Tabel 5 Concept fase

Binnen de CFD software wordt een 3D design omgezet naar een simulatie, hierbij worden de *Boundry conditions* en materiaalkeuze *solid en fluid* toegekend. Onderstaande functies zullen de nauwkeurigheid en weergave van de resultaten vastleggen.

Mesh number of element

Binnen de solver van het simulatie programma wordt het ontwerp verdeeld in elementen. Deze elementen bepalen de nauwkeurigheid van de te verwerken berekeningen. En speelt daarom een belangrijke factor binnen de nauwkeurigheid van de verschillende simulaties.

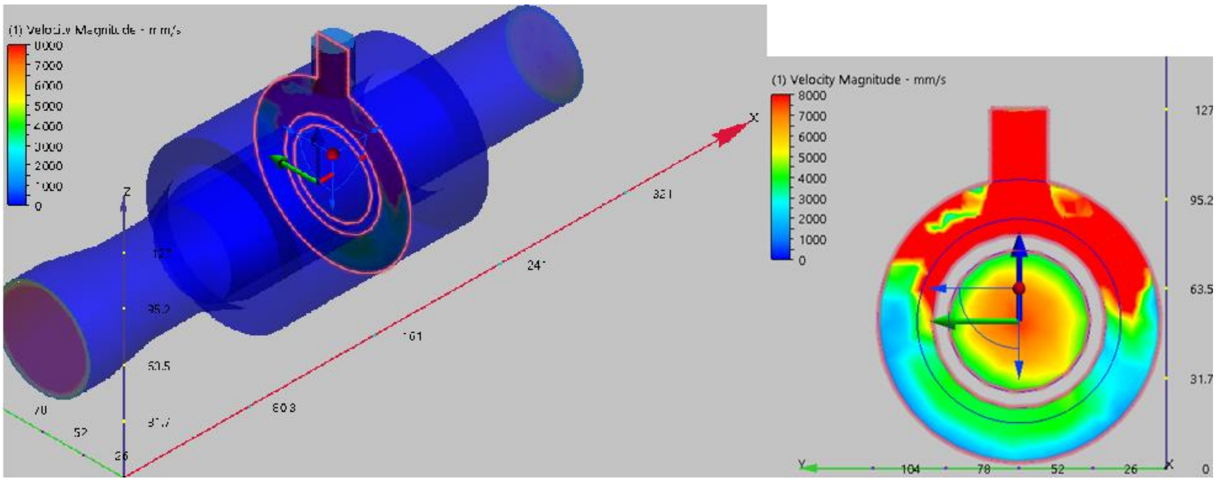


Figuur 7 "Global" results

Dus hoe meer (en dus kleiner) de elementen, hoe nauwkeuriger het eindresultaat. Het nadeel hiervan is dat de benodigde calculatie tijd toeneemt wanneer de elementen toenemen.

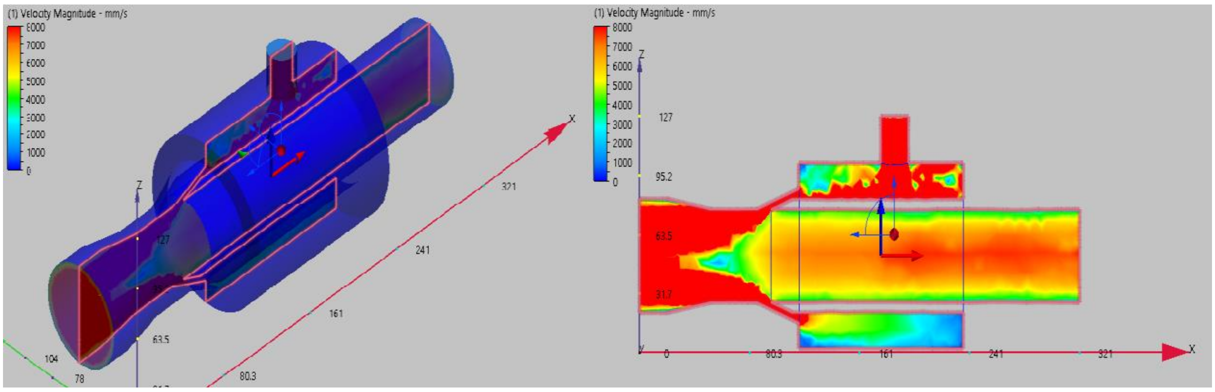
Planes

Wanneer de simulatie uitgevoerd is en de bijhorende resultaten geopend worden, krijgen we te maken met een "Global" resultaten weergaven. Aangezien we met een gesloten jetpomp werken en dus benieuwd zijn naar het resultaat wat binnenin afspeelt, worden er "Planes" ingevoegd.



Figuur 8 Globel result plane

Deze "Planes" snijden het ontwerp op de gewenste manier door. En kan zo verschoven worden de juiste plek waar het resultaat bekeken zal worden. Dus in deze verschuiving is er vrijheid in alle richtingen (x,y,z).



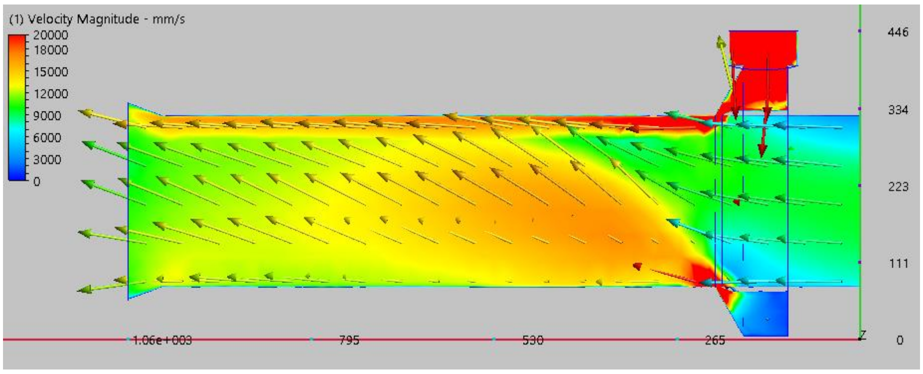
Figuur 9 Globol result plane 2

Legenda

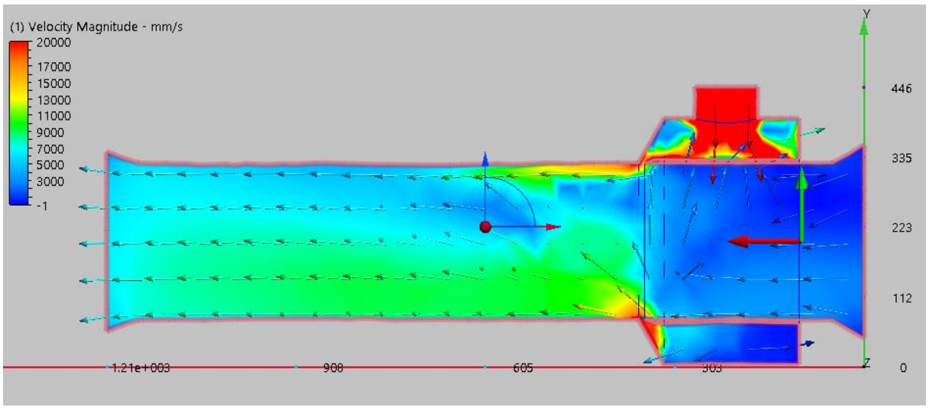
Binnen de werking van de jetpomp zijn we opzoek naar de *Velocity Magnitude* en *Static Pressure*.

4.1 Lengte inletkamer

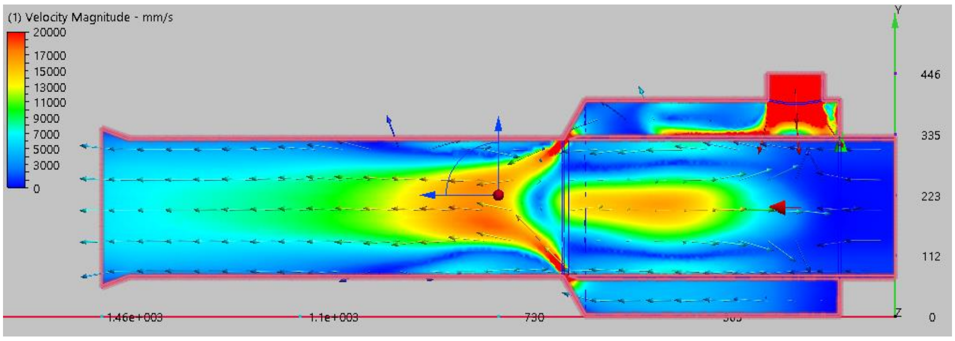
Om de werking van de nozzle te kunnen aantonen, is het belangrijk dat de vloeistof dat aangevoerd wordt door de vloeistof pomp zicht evenredig verdeeld over de nozzle. Hierbij zal er eerst onderzocht worden welk effect de inletkamer op deze verdeling van de vloeistof heeft. Om deze werking aan te tonen zal er gekeken worden naar de vloeistof snelheid.



Figuur 10 Inletkamer 100[mm] “velocity” [mm/s]



Figuur 11 Inletkamer 250[mm] “velocity” [mm/s]



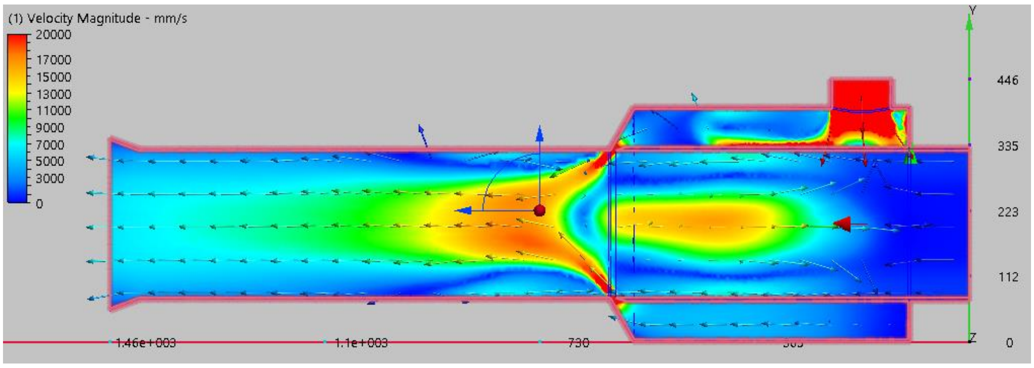
Figuur 12 Inletkamer 500[mm] “velocity” [mm/s]

resultaat

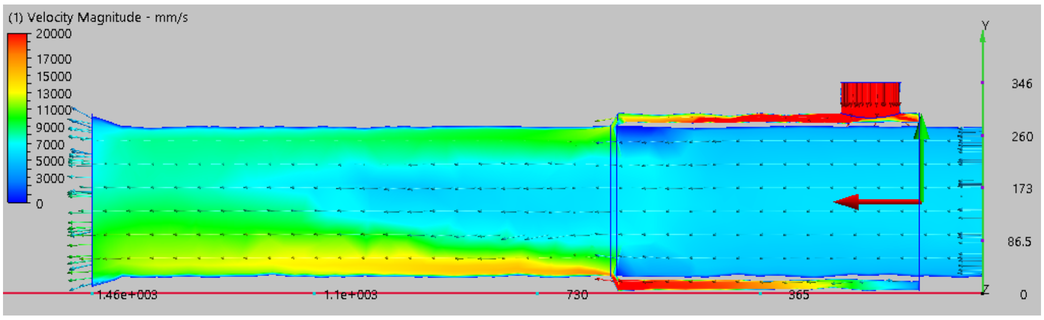
Wanneer de geometrie van de inletkamer op 500[mm] gezet wordt, wordt het zichtbaar dat de vloeistof zicht netjes verdeeld over de gehele nozzle. Dit is te verwijten naar in de inhoud wat voldoende plek moet bieden om de input stroom rond de zuigleiding te laten vormen. Neemt de lengte van de inletkamer toe tot 700[mm], het blijft het zelfde resultaat geven.

4.2 Hoogte inletkamer

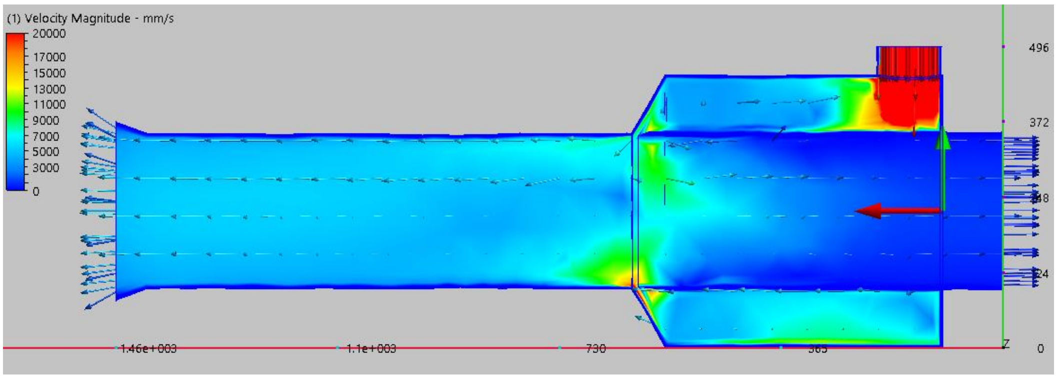
Om de werking van de nozzle te kunnen aantonen, is het belangrijk dat de vloeistof dat aangevoerd wordt door de vloeistof pomp zicht evenredig verdeeld over de nozzle. Hierbij is voorafgaand aan deze test gekeken naar de lengte van de inletkamer. Nu zal er onderzocht worden wat de hoogte van de inletkamer als effect heeft op de vloeistof verdeling rond de nozzle. Tevens bepaald de hoogte ook de lengte van de nozzle.



Figuur 13 Hoogte-Inletkamer 75[mm] "velocity" [mm/s]



Figuur 14 Hoogte-Inletkamer 25[mm] "velocity" [mm/s]



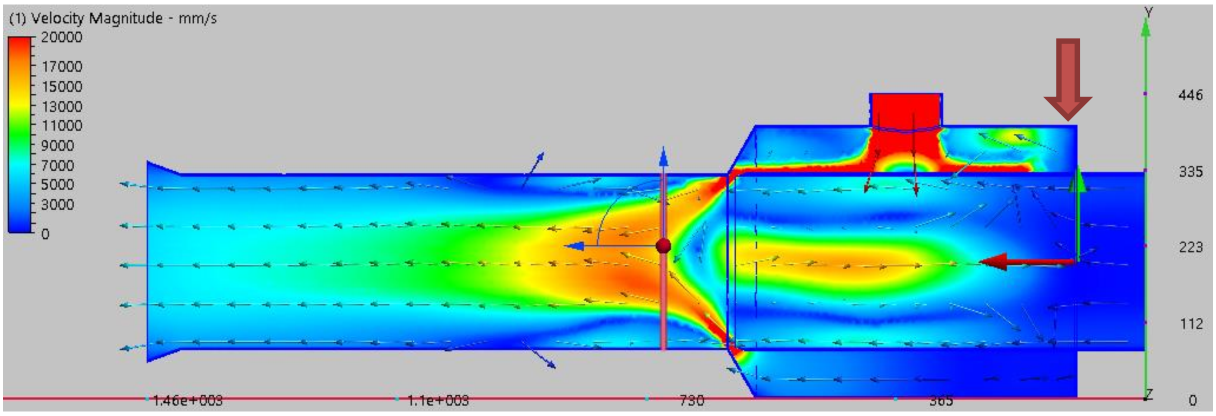
Figuur 15 Hoogte-Inletkamer 100[mm] "velocity" [mm/s]

Resultaat

Zoals verwacht zien we dat bij een hoogte van 25[mm] er een slechte verdeling is rond de nozzle. Maar verandert de hoogte naar 100[mm] of hoger, zien we dat er ook een slechte verdeling is rond de nozzle. Daarbij wordt er geen zuigend vermogen meer gecreëerd. Dit is te verwijten aan een te grote inhoud, de vloeistof draait rond in de inletkamer.

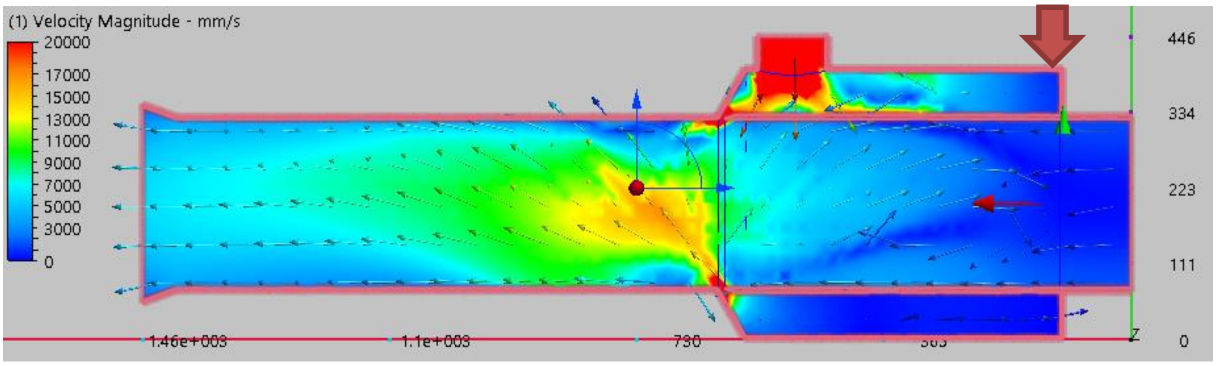
4.3 Plaatsing invoer

De invoerleiding die de vloeistof vanaf de pomp naar de jetpomp transporteert, zal bij logische nadenken zo ver mogelijk “rechts” (in onderstaande afbeelding, aangegeven door rode pijl) geplaats worden. Nu zal er een vergelijking opgesteld worden wanneer deze invoerleiding in het midden van de inletkamer geplaats worden (op 250[mm] van de rode pijl).



Figuur 16 Plaatsing invoer 250[mm] “velocity” [mm/s]

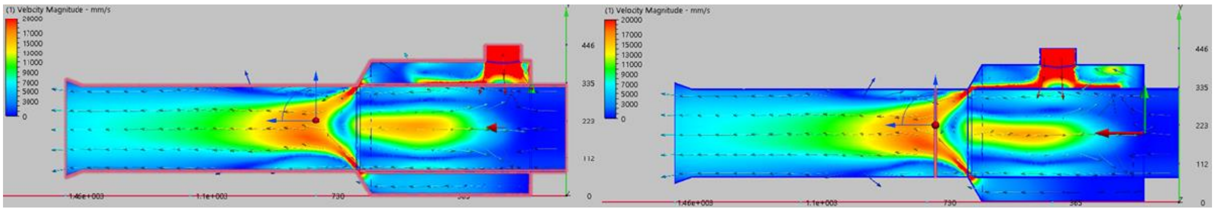
Wanneer de pomp invoer leiding op een afstand van 450[mm] van de rode pijl geplaats wordt. En dus naast de nozzle plaats vindt, zien we een terug komend patroon van ongelijke verdeling van de vloeistof.



Figuur 17 Plaatsing invoer 450[mm] “velocity” [mm/s]

Resultaat

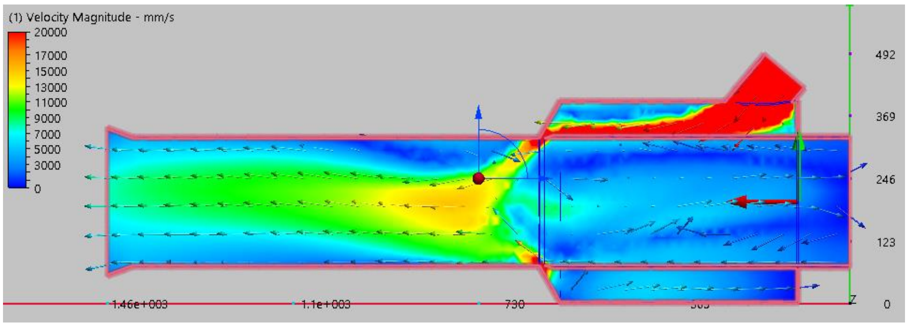
Wanneer de pomp invoer leiding geplaats wordt tussen het midden en zo ver mogelijk recht van de inletkamer, toont dit de nagenoeg het zelfde eindresultaat. Wanneer we de cijfers vergelijken zien we een verschil van 1.25%.



Wanneer de pomp invoer leiding voorbij het midden richting de nozzle geplaats wordt, zien we een ongelijk verdeelde vloeistof stroom, en dus niet bruikbaar binnen het ontwerp.

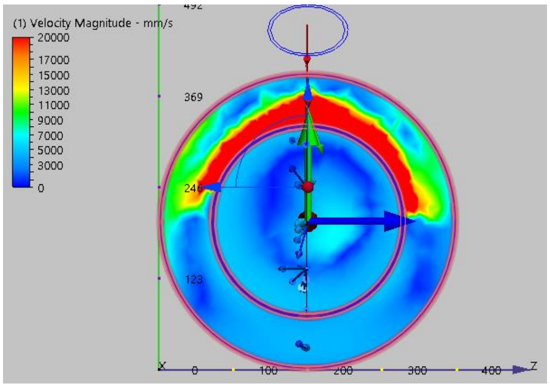
4.4 Hoek pomp invoer leiding

De effecten van de vloeistofstroom ingevoerd in de inletkamer onder een bepaalde hoek zal getest worden, deze test levert een resultaat dat de efficiëntie van de jetpomp verhoogt of juist verlaagt.

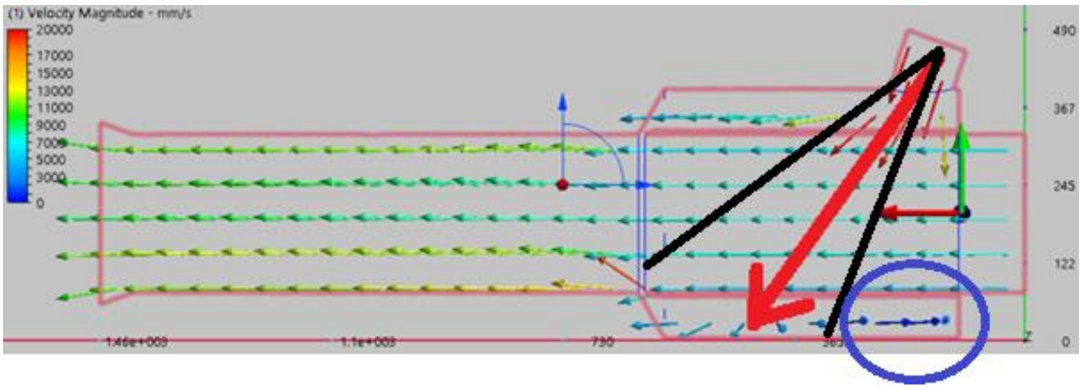


Figuur 18 Hoek invoer van 50graden

Zoals verwacht levert de hoek van 50 graden een ongelijk verdeelde vloeistofstroom door de nozzle. En dus niet bruikbaar voor het eind ontwerp. Dit is duidelijk terug te zien in onderstaande afbeelding.



Figuur 19 Doorsnede ter hoogte van Nozzle



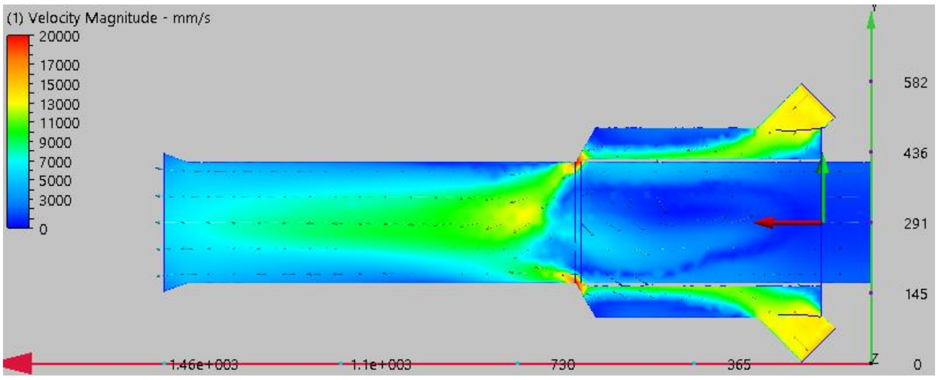
Figuur 20 Vloeistof richting X,Y richting

Resultaat

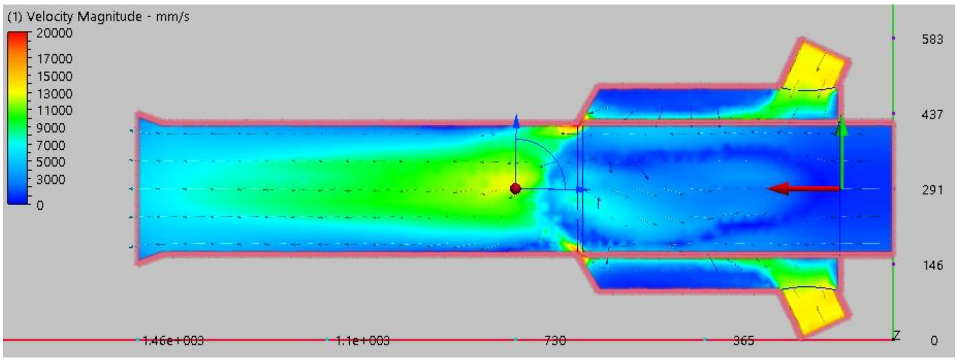
In bovenstaande figuur geeft de rode pijl de vloeistof richting aan, de vloeistof verspreid zich voornamelijk binnen het gedeelte dat is aangegeven door de zwarte lijnen. Daardoor zien we bij het resultaat dat er een ongelijke verdeling van de vloeistof plaats vindt. Hierbij is duidelijk zichtbaar dat de vloeistof de weg van de minste weerstand kiest.

4.5 Dubbele pomp invoer leiding

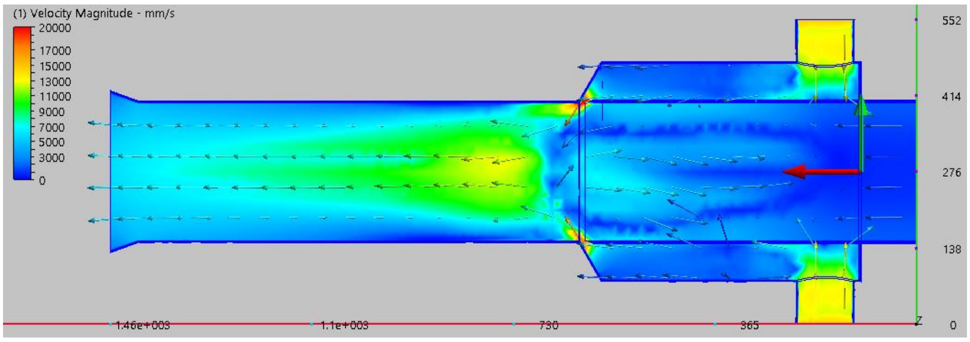
De verschillende simulaties met een invoer leiding geplaats onder een bepaalde hoek heeft op het ontwerp een negatief resultaat. Wanneer er twee invoer leidingen toegepast worden zal er naar verwachting een beter resultaat uit komen.



Figuur 21 Dubbele invoer onder een hoek van 45graden



Figuur 22 Dubbele invoer onder een hoek van 65graden



Figuur 23 Dubbele invoer onder een hoek van 90graden

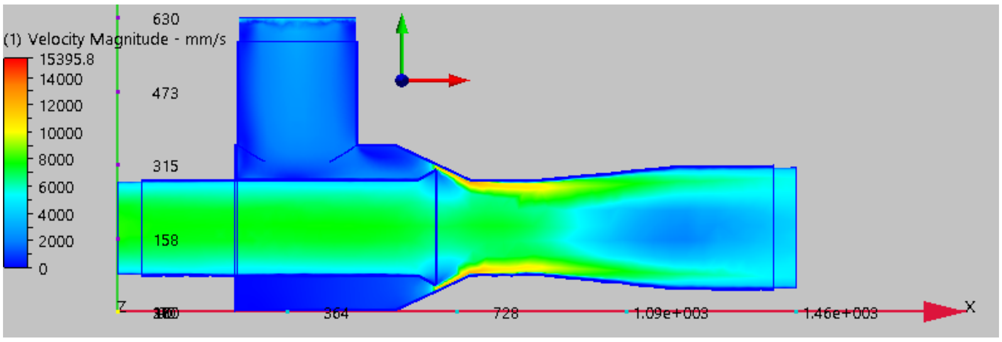
Resultaat

In vergelijking met een enkele invoer leiding onder een bepaalde hoek, zien we duidelijk dat bij het toepassen van twee invoerleidingen er een verdeelde stroming rond de nozzle vormt. De onderlinge resultaten komen overeen, dus de het bepalen van een ideale hoek heeft hier geen toegevoegde waarde. Deze toepassing kan dus worden toegepast wanneer er twee vloeistofpompen en dus twee invoer leidingen worden gebruikt voor de aansturing van de jetpomp.

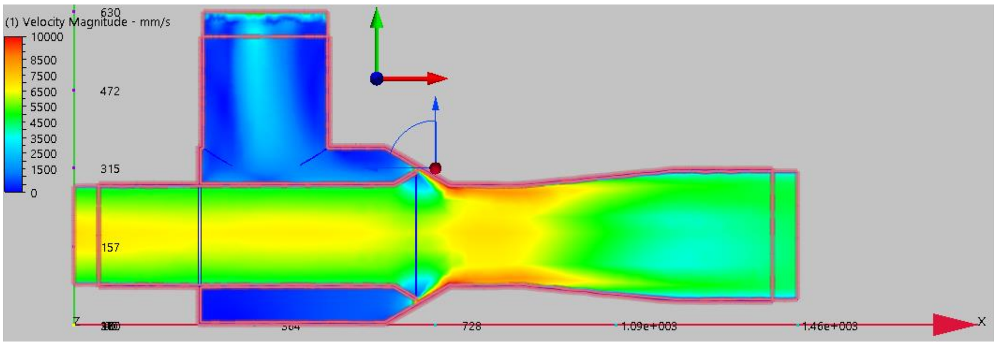
4.6 Inspuithoeken

Naar verwachting zal de hoek van de nozzle een belangrijke parameter zijn binnen het ontwerp van de jetpomp. Dus om dit goed te kunnen testen is er een nieuw ontwerp gemaakt waarin gefocust wordt op deze hoek. Tijdens het testen van deze hoek blijven overige afmetingen gelijk, denkend aan de doorstroomopening en de inhoud van de inletkamer.

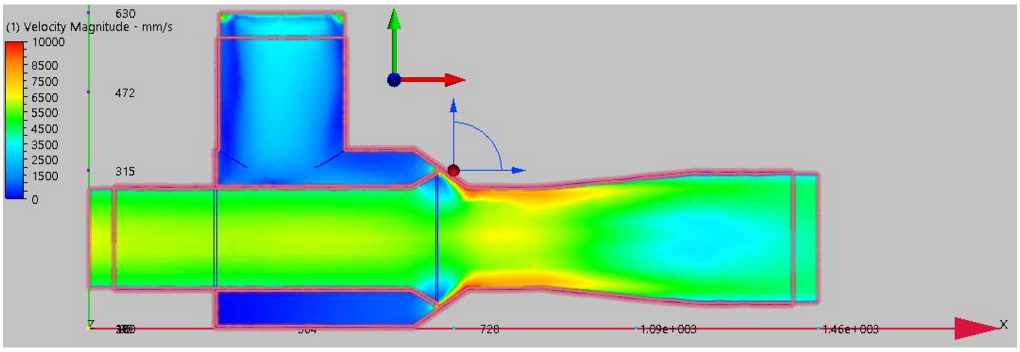
Daarbij is aan de zuigleiding een omhoog-staande rand toegevoegd die de nozzle vormt. Deze rand zorgt voor de vernauwing wat voor de vloeistofversnelling zorgt. Daarbij blijft er een stuk van de behuizing over die onder een hoek getest zal worden in onderstaande simulaties.



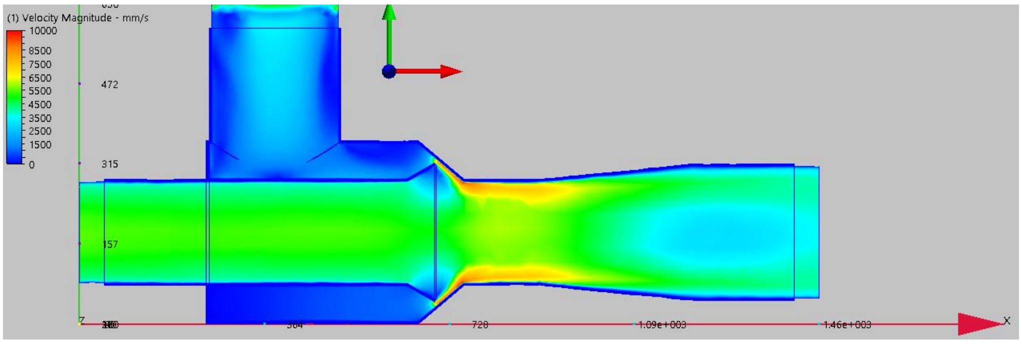
Figuur 24 Inspuithoek nozzle 25graden



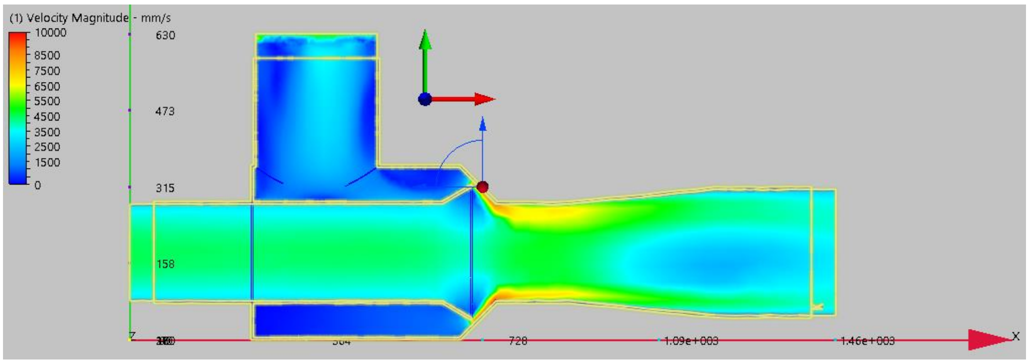
Figuur 25 Inspuithoek nozzle 30graden



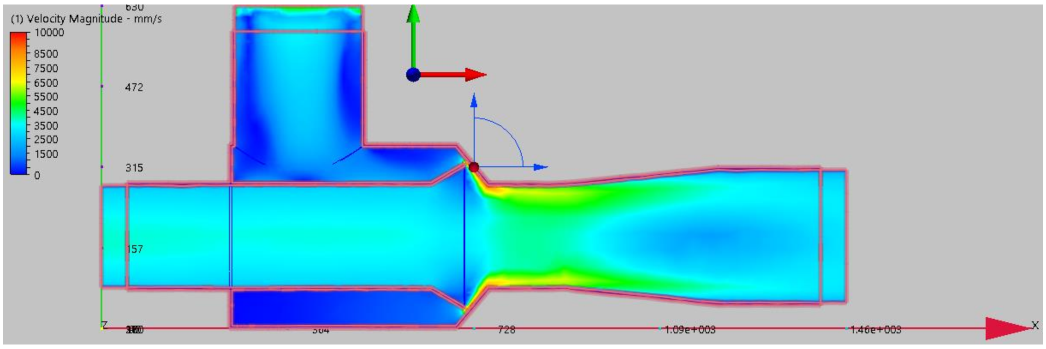
Figuur 26 Inspuithoek nozzle 35graden



Figuur 27 Inspuithoek nozzle 40graden



Figuur 28 Inspuithoek nozzle 45graden



Figuur 29 Inspuithoek nozzle 50graden

Resultaat

Binnen de verschillende simulaties is het effect op het zuigvermogen duidelijk zichtbaar. Hierbij blijkt dat de jetpomp het meest efficiënt is bij een hoek tussen de 30 en 40 graden. Vooral de simulatie bij een hoek van 30 graden heeft een mooi eind resultaat.

Daarbij is ook zichtbaar dat bij een scherpe hoek de vloeistof niet netjes afbuigt. Dus in het volgende ontwerp zal het toepassen van een radius in de behuizing een positief effect hebben.

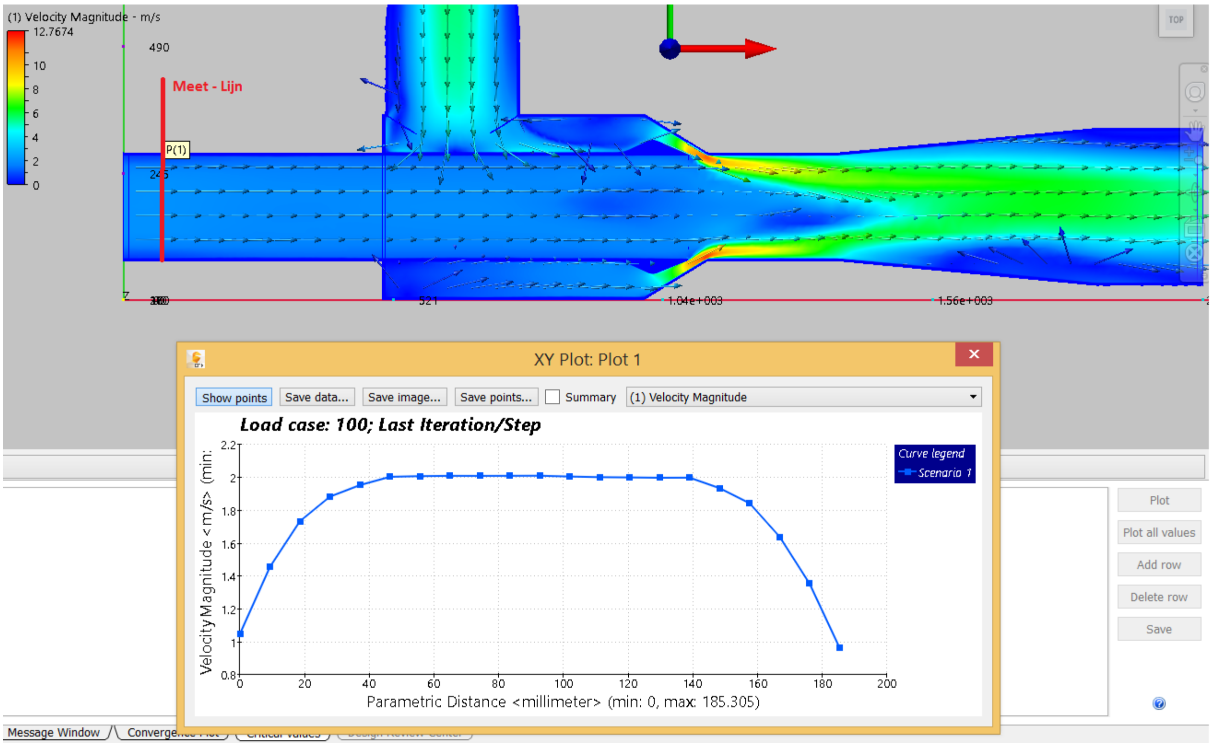
4.7 Eind concept

De behaalde kennis vanuit de conceptfasen zal samen gevoegd worden tot een eind ontwerp. Binnen dit eindontwerp zal er via kleine aanpassingen gekeken worden naar het effect wanneer de hoogte van de nozzle (zie rode lijn) en de radius van de behuizing (zie blauwe lijn) worden aangepast.

Daarbij zal de doorstroomopening vastgelegd worden op 15[mm]. Het ontwerp van de nozzle in convergent 10˚. De pompgegevens voor deze simulaties worden afgeleid van de vloeistofpomp die aanwezig is op de TH4, en bedragen 800[m3/h] bij 1.7[bar].

4.7.1 Simulatie 1

Tijdens deze simulatie wordt er geen radius ingevoegd. Verder zal de nozzle een convergente hoek hebben van 10◦ en een diameter van 260[mm].



Figuur 30 Simulatie 1, zonder radius

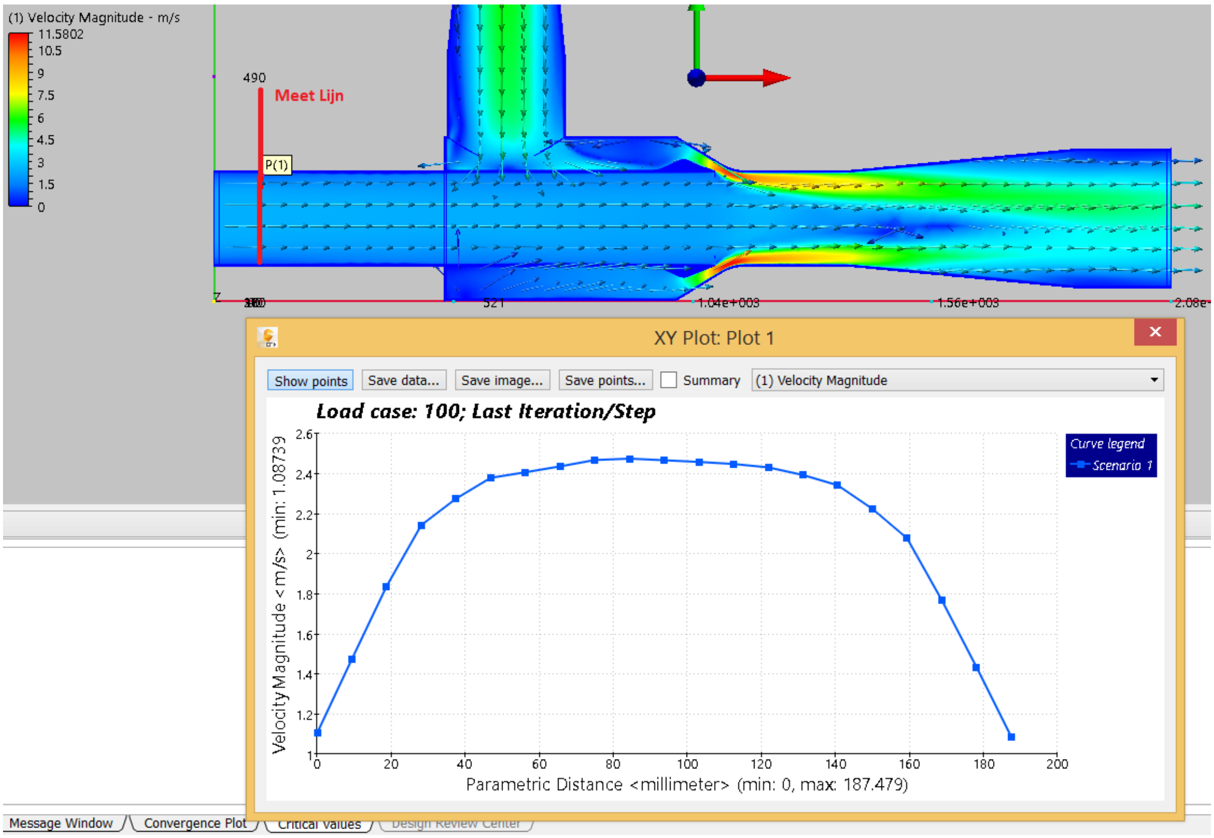
Resultaat

Bij het bepalen van het eindresultaat, is er in de zuigleiding een *plane* ingevoegd die de vloeistofsnelheid weergeeft (zie rode lijn: Meet lijn). Vanaf dit punt wordt de vloeistofsnelheid weergegeven in [m/s]. De vloeistofsnelheid in de zuigleiding bedraagt +- 2 [m/s].

4.7.2 Simulatie 2

Voor simulatie 1 in de configuratie fase is de ideale hoek vastgesteld op 31.5◦. Tijdens deze simulatie wordt er direct na de nozzel een radius van 100 ingevoegd. Na verwachting uit de conceptfase zal deze radius een positieve werking hebben op het eindresultaat.

Verder zal de nozzle een convergente hoek hebben van 10◦ en een diameter van 260[mm].



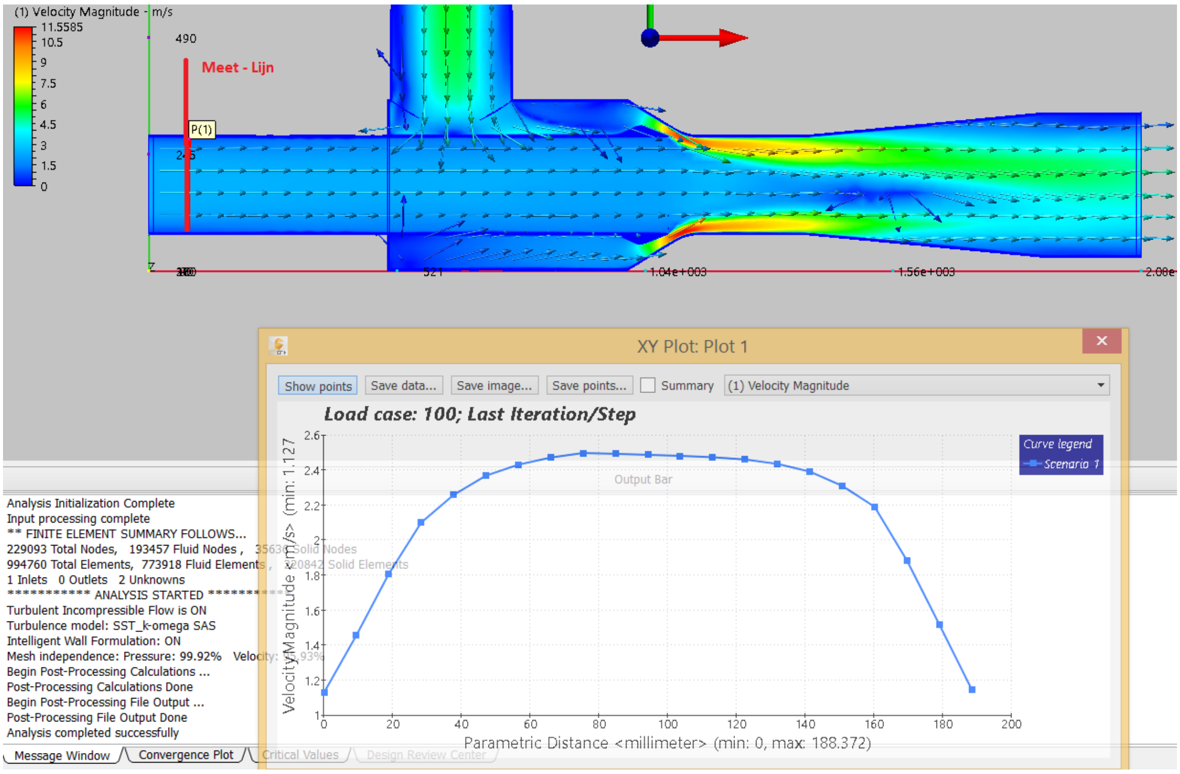
Figuur 31 Simulatie 2, radius 100

Resultaat

Bij het bepalen van het eindresultaat, is er in de zuigleiding een *plane* ingevoegd die de vloeistofsnelheid weergeeft (zie rode lijn: Meet lijn). Vanaf dit punt wordt de vloeistofsnelheid weergegeven in [m/s]. De vloeistofsnelheid in de zuigleiding bedraagt +- 2.4 [m/s].

4.7.3 Simulatie 3

Binnen simulatie 3 zal er getest worden of de hoogte van de nozzle invloed heeft op de werking van de jetpomp. In voorgaande twee simulaties is een diameter van 260[mm] toegepast. In deze simulatie wordt de diameter terug gebracht naar 225[mm]. Tevens blijft de radius op 100 staan.



Figuur 32 Simulatie 3

Resultaat

Gemiddelde vloeistofsnelheid in de zuigleiding bedraagt: 2.4 [m/s]

Conclusie

Het invoegen van een radius in de behuizing heeft een positief effect op het zuigvermogen. Het zuigvermogen neemt dan ook toe met 20%. Wanneer er dan ook naar de vloeistofstroom na de nozzle gekeken wordt zien we dat de vloeistof met hoge snelheid iets langer blijft bestaan. Dus er vindt minder wrijving plaats wanneer er een radius gebruikt wordt.

Daarbij is er getest of kleine aanpassingen aan de hoogte van de nozzle effect heeft op het zuigvermogen. Maar bij het resultaat wordt duidelijk dat het aanpassen van de hoogte geen effect heeft op de werking van de jetpomp.

5 Configuratie fase

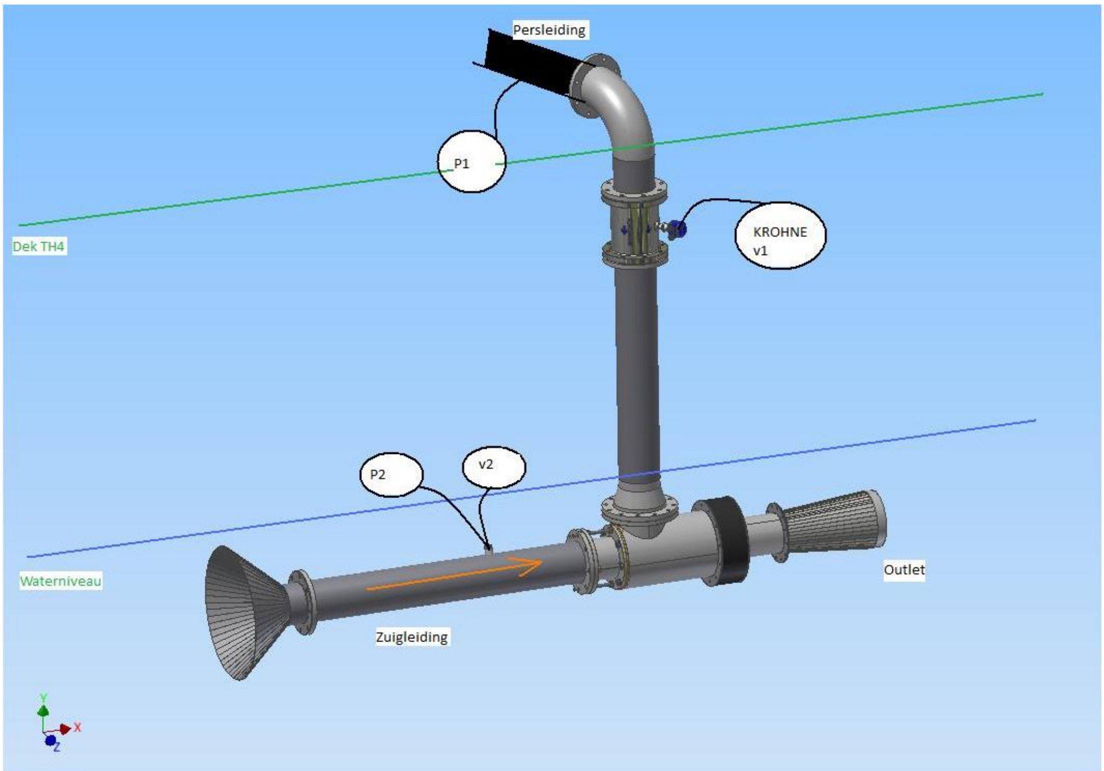
Binnen de configuratie fase zal er gekeken worden naar hoe alle meetapparatuur op het testmodel gevestigd kan worden. Hier is ook duidelijk welke meetinstrumenten er gebruikt zullen worden. Voor het echte ontwerp word er in deze fase gekeken naar hoe de leidingen en vloeistofpomp op de jetpomp aangesloten worden.

Hiermee zal een antwoord geformuleerd worden op de twee onderstaande vragen:

Nr.	Deelvraag	Ontwerpfase (Eggert)
D8.	Hoe zien mogelijke configuraties van het concept eruit?	*Configuratiefase*
D9.	Welk van de configuraties is het beste en hoe ziet deze eruit?	*Configuratiefase*

5.1 Opstelling 1

Voor de praktijk test wordt de jetpomp onder de waterlijn geplaats. Hierbij wordt extra leidingwerk toegepast om de jetpomp te koppelen aan de vloeistofpomp die aan boord van de TH4 staat. Daarbij worden de test waardes inzichtelijk gemaakt door middel van flow- en druk sensoren.

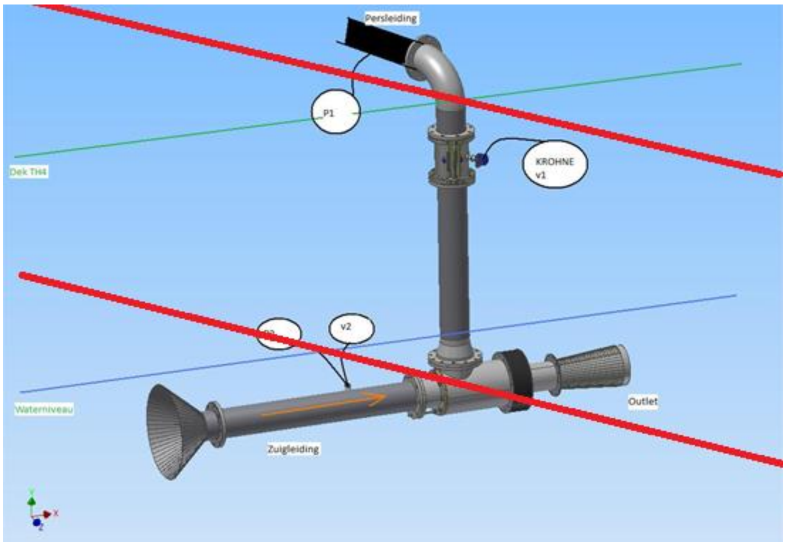


Figuur 33 Opstelling 1, praktijk test

5.2 Opstelling 2

De jetpomp wordt gekanteld zodat de outlet van de pomp boven de waterlijn komt te liggen en hierdoor geen tegendruk zal hebben van het te verplaatsen water.

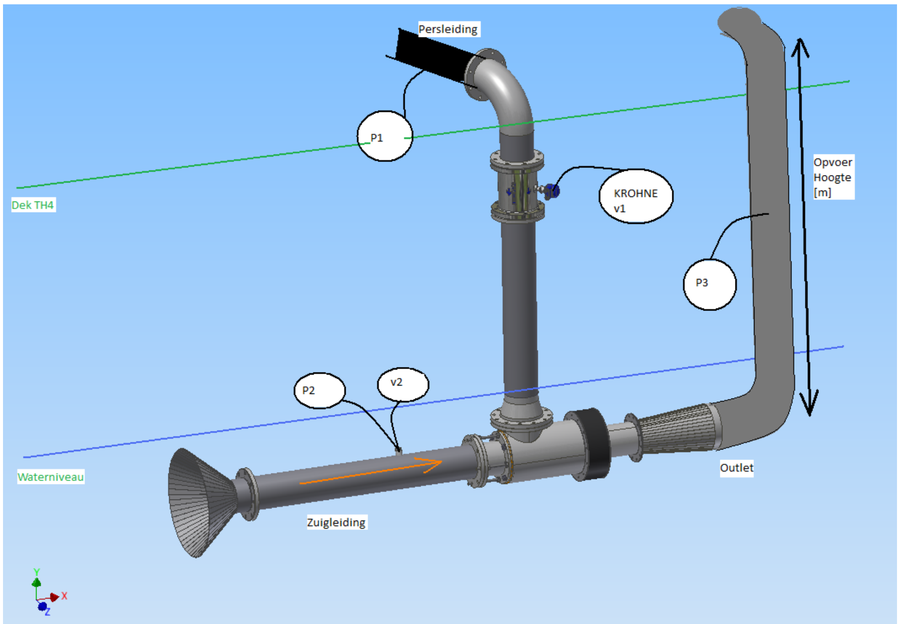
Die nieuwe lijnen zijn aangegeven in rood. Hierbij is de onderste lijn de lijn wat het waterniveau aangeeft. De bovenste lijn geeft het dek van de TH4 weer.



Figuur 34 Opstelling 2, praktijk test

5.3 Opstelling 3

Tijdens de praktijk test met testopstelling 2 zal er onderzocht worden wat het effect van de opvoerhoogte is op de werking van de jetpomp. Afwijkend van testopstelling 1 zien we een extra stuk leidingwerk wat gekoppeld wordt aan de outlet van de jetpomp. Dit leidingwerk heeft een lengte van 3[m] en zorgt ervoor dat de vloeistof getransporteerd wordt tot in het ruim van de mosselkotter.



Figuur 35 Opstelling 3, praktijk test

5.4 Toegevoegde apparatuur

5.4.1 Leidingwerk

Persleiding

Vanaf de vloeistofpomp loopt er leidingwerk met een diameter van DN200 door het ruim van de mosselkotter. Via een koppeling wordt op dit bestaand leidingwerk een flexibel persslang toegepast die rijkt tot de zijkant van de mosselkotter. Vanaf dit punt wordt een stuk leidingwerk aan van 3[m] richting de waterlijn geplaatst die voor een vaste verbinding zorgt met de jetpomp.

Zuigleiding

Aan het ontwerp van de jetpomp wordt de zuigleiding verlengt met een buis van 3[m]. Deze extra lengte is nodig om nauwkeurige meetwaardes te genereren.

5.4.2 Meet sensoren

Druk sensor P1

Om de geleverde druk vanaf de vloeistofpomp, en dus de druk over de jetpomp te meten wordt er een druk sensor in de persleiding geplaatst.

Flow sensor V1

Om te kijken welk debiet door de jetpomp stroomt is het belangrijk dat er een betrouwbare flow sensor geplaats wordt in de persleiding. Hierbij wordt gebruik gemaakt van een Elektromagnetische flowmeter van KROHNE.

Druk sensor P2

De jetpomp creëert een onderdruk waardoor een vloeistof wordt aangezogen in de zuigleiding. Om deze onderdruk te meten wordt er een drukmeter geplaatst in de zuigleiding.

Flow sensor V2

Om het debiet te bepalen in de zuigleiding is er gekozen om een paddleflow meter toe te passen. De vloeistof in de zuigleiding drijft een wieltje aan, wat omgezet wordt naar een debiet meting.

5.4.3 Totale meetwaardes

De totale meetwaardes worden weergegeven door 5 sensoren en worden in onderstaande tabel toegelicht:

Gevraagd	Eenheid
Persleiding	
Druk	[Bar]
Flowmeter KROHNE	[m/s]
Zuigleiding	
Onderdruk	[Bar]
Flowmeter Paddleflow	[m/s]
Outlet	
Druk	[Bar]

5.5 Plaatsing jetpomp

Uit voorgaande praktijktest bleek de jetpomp niet in staat te zijn om vanaf het dek van de TH4 voldoende zuigcapaciteit te behalen om te kunnen voldoen aan de gestelde eisen, het opzuigen van substraatlijn met mosselzaad.

Om deze reden is er getest met de jetpomp onder de waterlijn. I.p.v. het overwinnen van de opvoerhoogte met zuigcapaciteit, zal de jetpomp nu de hoogte moeten overwinnen met zijn opvoerhoogte.

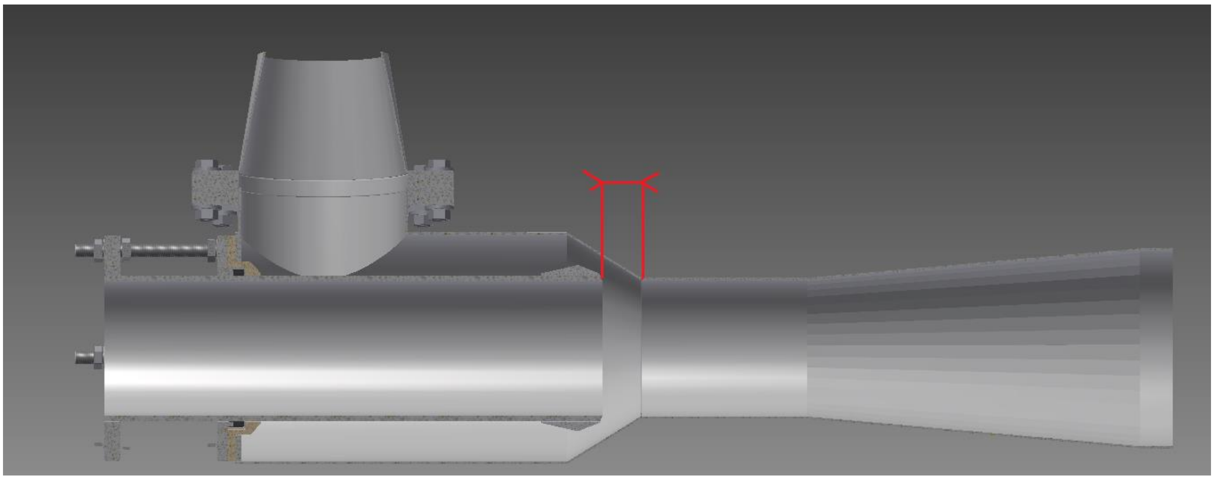
Figuur 36 Plaatsing jetpomp

Na de voorgaande praktijk test bleek de jetpomp in staat om deze hoogte te overwinnen en een zuigvermogen te genereren.

5.6 Instel variabelen

5.6.1 Doorstroomopening

Voorafgaand van elke test wordt een doorstroomopening bepaald. Dit is de enigste variabele die instelbaar zal zijn tijdens de test. Hierbij zal gestart worden met een opening van 30[mm] en vanaf dat punt zal in stappen de doorstroomopening verkleind worden (zie afstand aangegeven in rood).



Tijdens het testen zal aan de hand van de afstand, gemeten tussen de flenzen, de doorstroomopening bepaald worden. Om te beginnen zal de doorstroomopening eerst afgesloten worden, zodat bekend is welke doorstroomopening hoort bij een bepaalde afstand tussen de flenzen.

5.6.2 Motortoerental

De tweede variabele binnen de opstelling is het vermogen van de motor die de vloeistofpomp aandrijft. Om de jetpomp te testen op efficiëntie zal het toerental van de motor gelijk gehouden moeten worden.

De tweede variabele binnen de opstelling is het toerental van de motor die de vloeistofpomp aandrijft. Dit toerental is afleesbaar in de stuurhut en zal bij elke test op 1700[RPM] gehouden worden.

5.6.3 Vloeistofpomp toerental

De vloeistofpomp wordt aangedreven door een hydraulische installatie, het toerental van de motor is bekend. En de bijhorende toerental van de vloeistofpomp zal bepaald worden door een as-meting (onder de traanplaat beschermkap).

5.7 Lijst benodigdheden

Voor het monteren van de opstelling bevindt zich standaard gereedschap altijd in de werk bus van Jansen Tholen BV. De wat specifieke gereedschappen die nodig zijn tijdens de praktijk test staan hieronder genoteerd:

Part	Toepassing
Momentsleutel	Montage KROHNE 84[Nm]
Ratel	Flenzen + afstellen buis jetpomp
Slangenklem	Extra voor persleiding
Rolmaat	Afstellen nozzle opening
Temperatuur meter	Hydrauliek
Toerentalmeter	Vloeistofpomp as-snelheid

Figuur 37 Gereedschappen

Verder zal er een lijst opgesteld worden van de verschillende onderdelen die nodig zijn binnen de praktijk test.

5.7.1 Hardware

Sensoren

- Paddleflowmeter + fitting
- KROHNE elektromagnetische flowmeter + bescherm kappen
- Druk meters (2st)
- Onderdruk meter (1st)

Leidingwerk

- Buis zuigleiding
- Kegel voor aan de zuigopening
- Buis persleiding
- Bocht 90◦ voor aan de leiding van de TH4
- Flexibele persleiding (zwart)
- Bouten/moeren voor de flenzen

Jetpomp

- Binnenhuis
- Behuizing
- Stopbuspakking
- Bouten/moeren voor de flenzen

Overig

- Spanbanden
- Takels
- camera

5.8 Uitvoering handelingen

Er zal kort toegelicht worden wat de globale handelingen zijn binnen de praktijk test, denken aan de montage van de opstelling tot de uitvoering en vast legging van de meetresultaten binnen de praktijk test.

Montage

Voor de montage van de complete testopstelling zal er rekening gehouden worden met de gewichten van de losse onderdelen. Hiervoor zal minimaal 2man sterk voor nodig zijn om het leidingwerk en overige te transporteren naar de TH4.

Afstellen

De afstelling van de jetpomp gaat door middel van de afstand tussen de flenzen aan te passen. Hiervoor zal 1 persoon nodig zijn en deze zal moeten beschikken over een sleutel/ratel en een rolmaat.

Aflezen meet resultaten

Tijdens de uitvoering van de praktijk testen zal er 1 persoon verantwoordelijk zijn voor het vastleggen van de meetresultaten. Deze worden ingevuld bij de opgestelde format formulier per opstelling.

Tijd over/ wat te doen?

Wanneer er na de uitvoering van de praktijk test tijd over is, zal er getest worden met materialen in te voeren in de zuigleiding (Hierbij denkend aan substraatlijn of dik touw). De resultaten zullen door middel van foto’s en filmpjes als bewijslast dienen. Meetresultaten voor deze handelingen worden niet uitgevoerd.

6 Parametrische fase

In het parametrische ontwerp word de geometrie, afmetingen en materialen bepaald die gebruikt gaan worden. Aan het eind van deze fase zal er een compleet prototype zijn gemaakt dat gemakkelijk aan de testopstelling geplaatst kan worden. Zodat er een antwoord geformuleerd is voor onderstaande deelvragen:

Nr.	Deelvraag	Ontwerpfase (Eggert)
D10.	Hoe zien mogelijke parametrische varianten van het geconfigureerd ontwerp eruit?	*Parametrische fase*
D11.	Welk van de parametrische varianten is het beste en hoe ziet deze eruit?	*Parametrische fase*

Figuur 38 Deelvragen parametrische fase

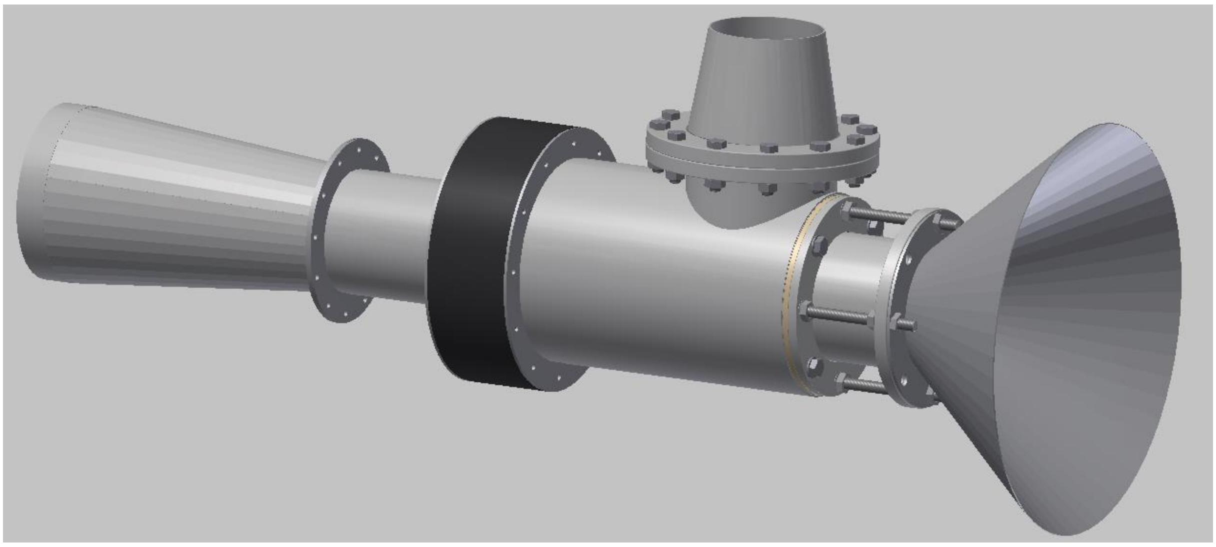
De vertaling van een ontwerp dat gebruikt wordt binnen de simulaties vertaald zich naar een eindontwerp dat gereed is voor productie. Daarbij moet ook rekening gehouden worden met monteren en demonteren van het systeem. En om de kostprijs te drukken zal er zoveel mogelijk van standaard afmetingen gebruik gemaakt worden (Buis diameter, Flenzen, enz.).

Hierbij wordt niet elk onderdeel toegelicht, maar alleen de onderdelen waarbij de eigenschappen van de afmetingen impact hebben op de werking van de jetpomp.

6.1 Prototype

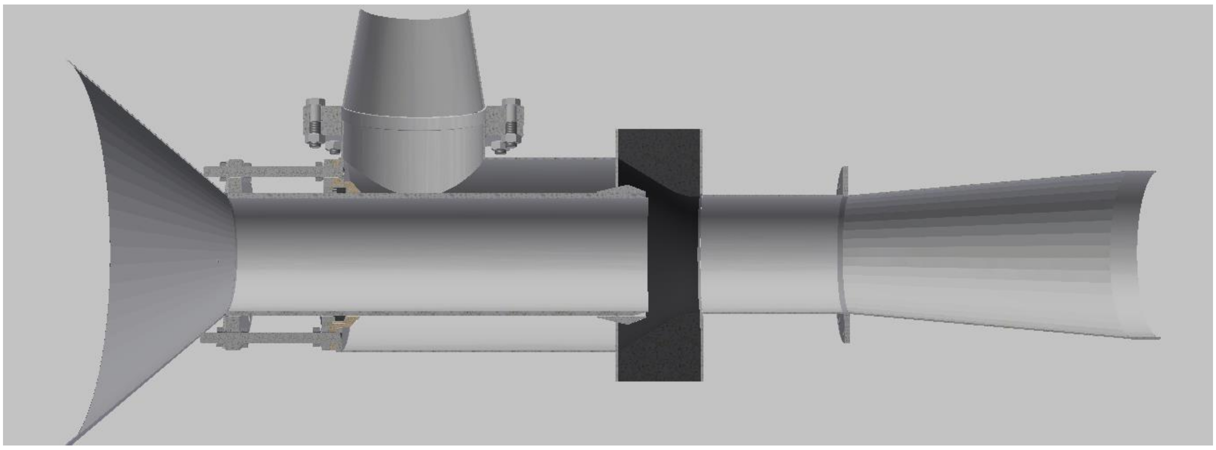
6.1.1 Samenstelling prototype

De samenstelling van het prototype is een combinatie van het ontwerp instelbaar te maken, maar hierin de maten zoveel mogelijk gelijk te houden aan de geteste simulaties. Daarbij komen we uit op onderstaande prototype.



Figuur 39 Prototype jetpomp

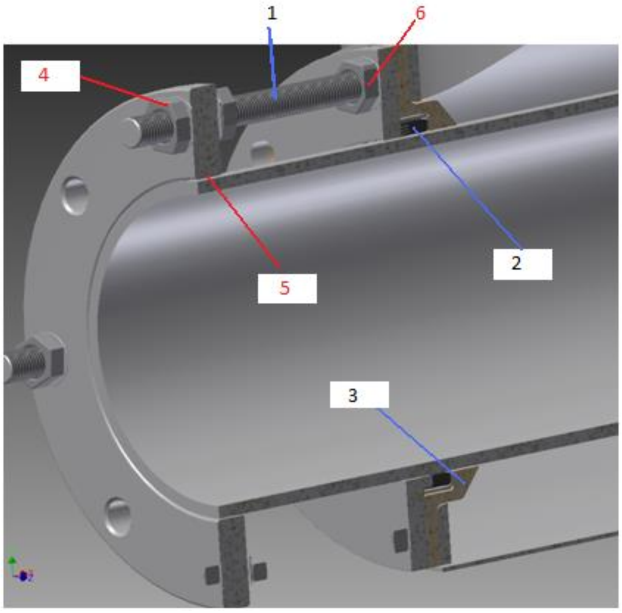
Bijhorend aan bovenstaand figuur hoort een doorsnede van het prototype om werking van de jetpomp duidelijk zichtbaar te maken.



Figuur 40 Doorsnede Prototype jetpomp

6.1.2 Instelbaar ontwerp

Nu de laatste simulaties uitgevoerd zijn, is de geometrie voor het prototype bekend. Hiervoor zal er een passend systeem bedacht worden waardoor de doorstroomopening aangepast kan worden, zonder de jetpomp compleet te demonteren.



Figuur 41 Verstellen doorstroomopening

1 Draadstangen

Het toepassen van de draadstangen hebben bij het parametrische ontwerp een aantal functies. De belangrijkste is het kunnen instellen van de doorstroomopening van de nozzle, wat gebeurt aan de hand van het aan/los draaien van de moeren (nr:4).

Los daarvan is het mogelijk om de flens die de pakking aandrukt strak tegen de behuizing aan te drukken (nr:6).

2 Stopbuspakking

De pakking die als afsluiting dient tussen de behuizing van de jetpomp en de zuigleiding (nr:2) wordt aangedrukt d.m.v. een flens. Aangezien de zuigleiding horizontaal moet kunnen schuiven en makkelijk gemonteerd moet worden, is er voor een stopbuspakking gekozen.

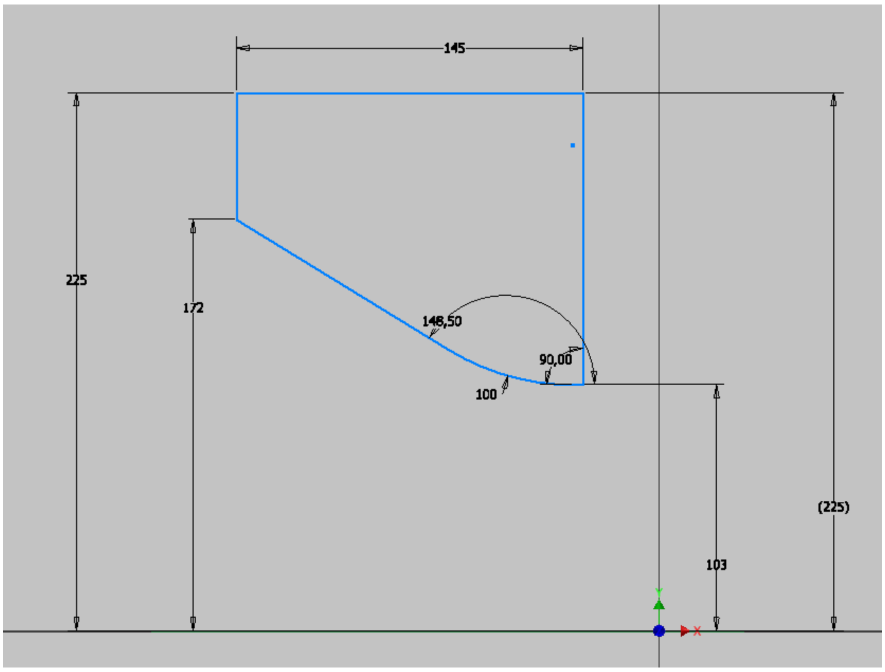
3 Kunststof flens

De kunststof flens creëert een kamer waarin de stopbuspakking een plekje kan krijgen. Om zeker te zijn dat de pakking niet lekt is het verstandig om minimaal twee ringen tegen elkaar te plaatsen.

Aangezien dat de jetpomp te maken krijgt met veel water is de keuze gevallen om drie ringen pakking materiaal toe te passen. Wat dit een lengte geeft wat een standaard flens niet kan overbruggen. Daarom is er gekozen voor een flens (nr:3) vervaardigd uit HDPE.

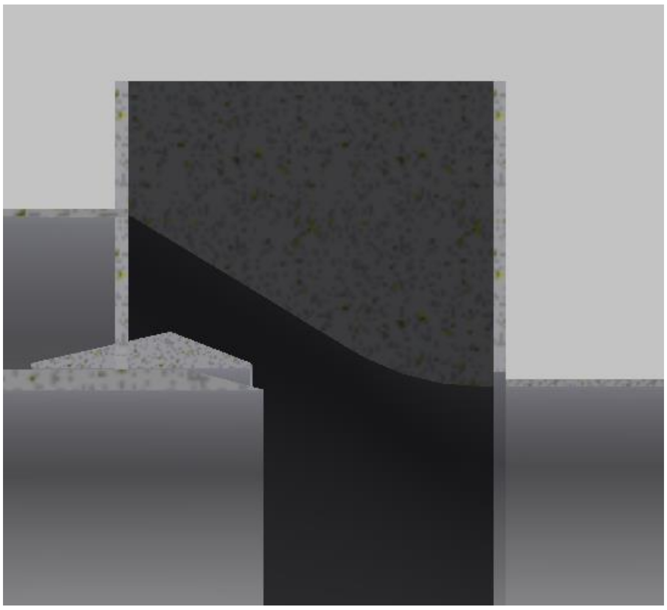
6.1.3 Nozzle ontwerp

Vanuit de simulaties is er een nozzle geconstrueerd met een hoek van 31.5 graden, hierbij wordt er tevens een radius van 100 toegevoegd om de vloeistofstroom beter te begeleiden.



Figuur 42 Afmetingen nozzle behuizing

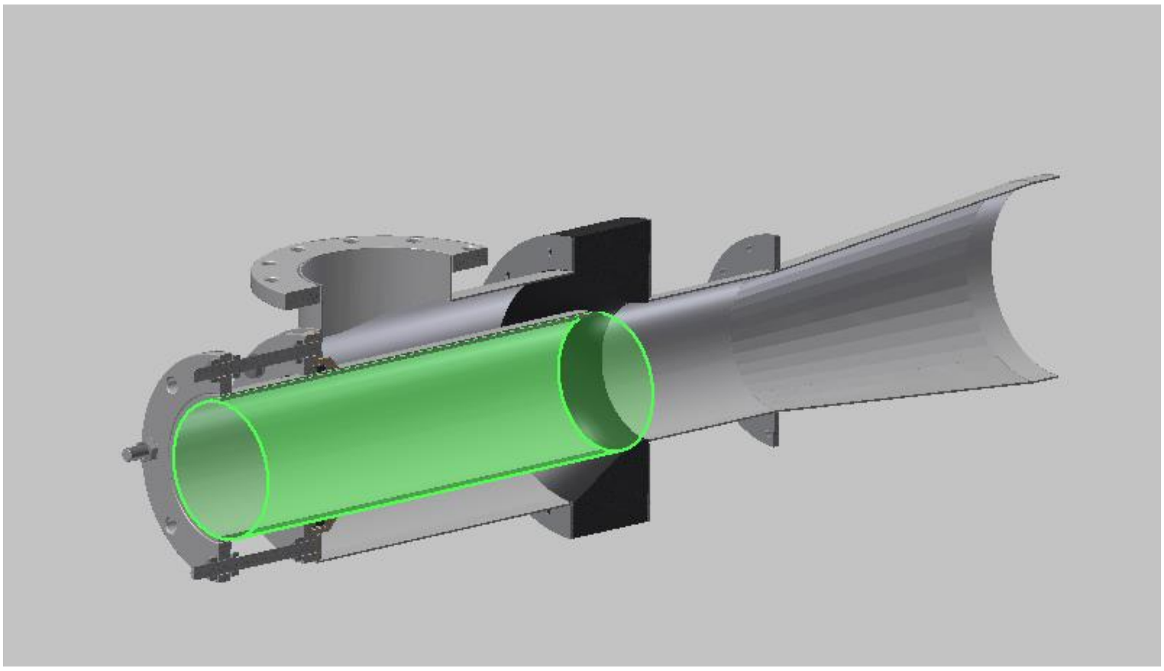
Om de breedte van 145[mm] te creëren en de bijhorende hoek met radius nauwkeurig in te voegen, wordt er gekozen om dit door verspanen te produceren. Hiervoor worden 3 HDPE platen van 50[mm] op elkaar geklemd, en vastgehouden door een boutverbinding.



Figuur 43 Nozzle, HDPE zwart platen

6.1.3 Zuigleiding

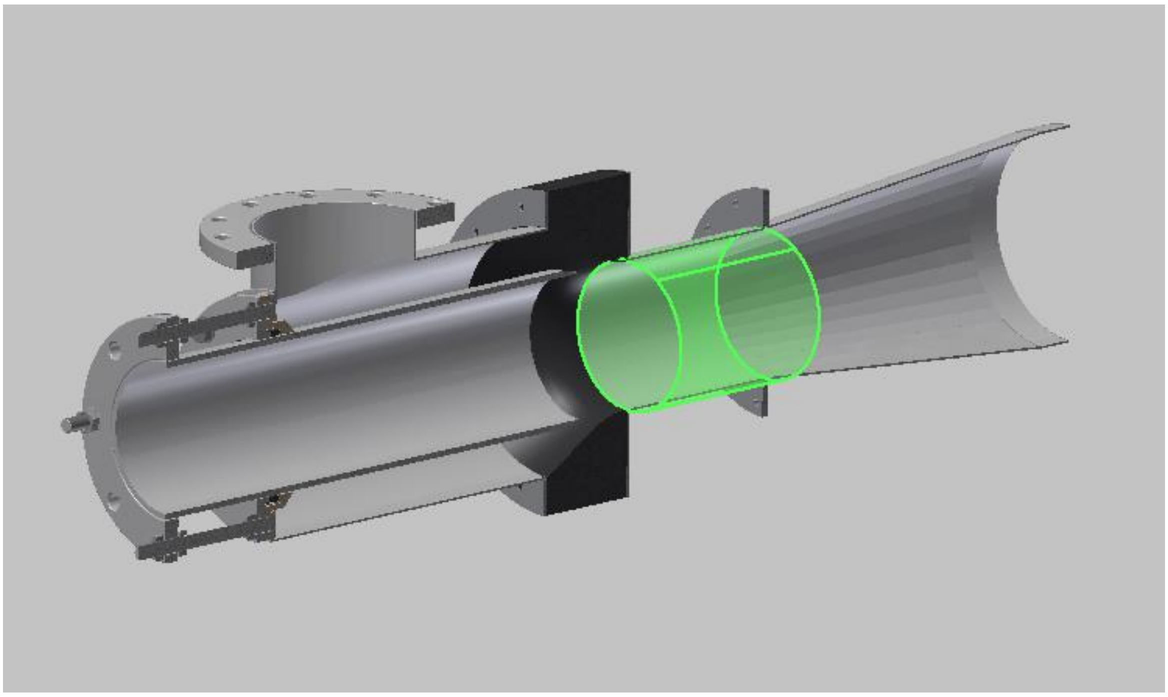
Voor de zuigleiding is gekozen om een RVS buis te kiezen met een materiaal dikte van 8.1[mm]. De bijhorende diameter is 200[mm] met een lengte van 750[mm].



Figuur 44 RVS zuigleiding

6.1.4 Throat

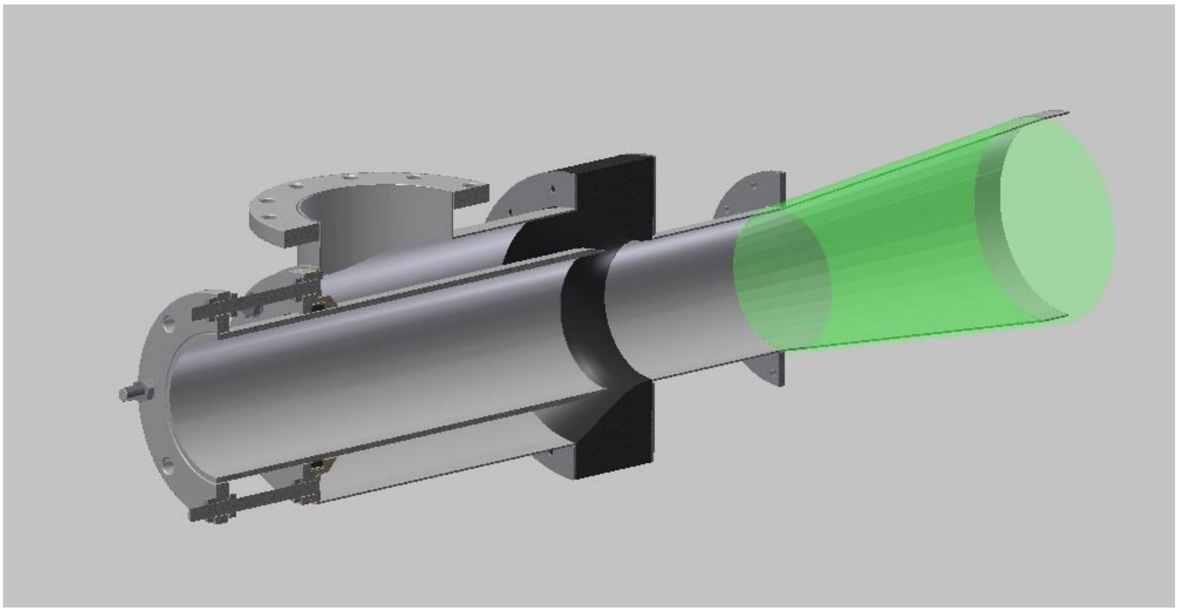
Voor de throat is gekozen om gebruik te maken van een wals techniek om van een RVS plaat met dikte 3[mm], tot een stuk buis te komen met een diameter van 203[mm] en een lengte van 260[mm].



Figuur 45 RVS Throat

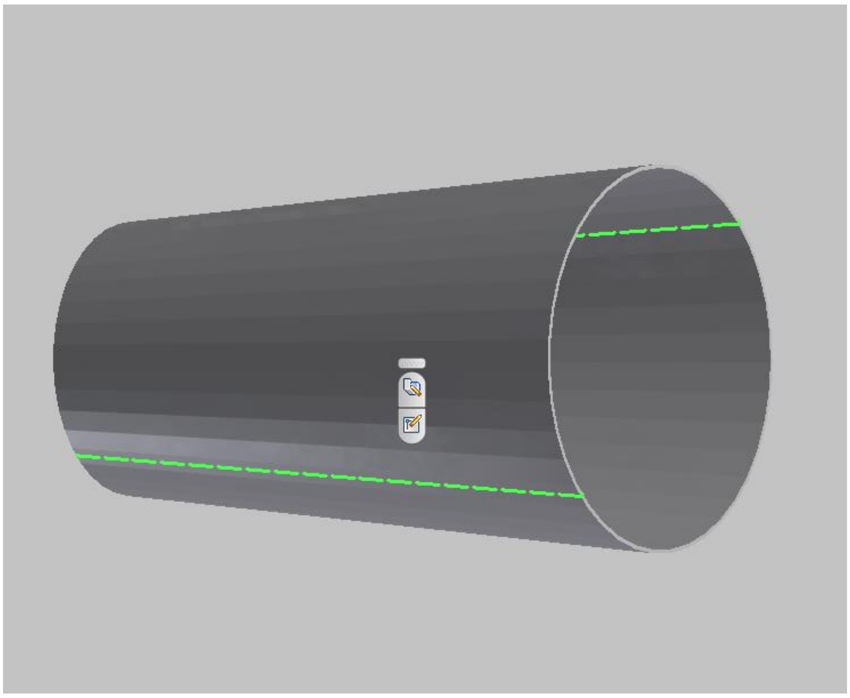
6.1.5 Diffusor

Voor de diffusor wordt een plaat rvs gebruikt om door middel van een kant methode tot onderstaand eindproduct te komen.



Figuur 46 RVS Diffusor

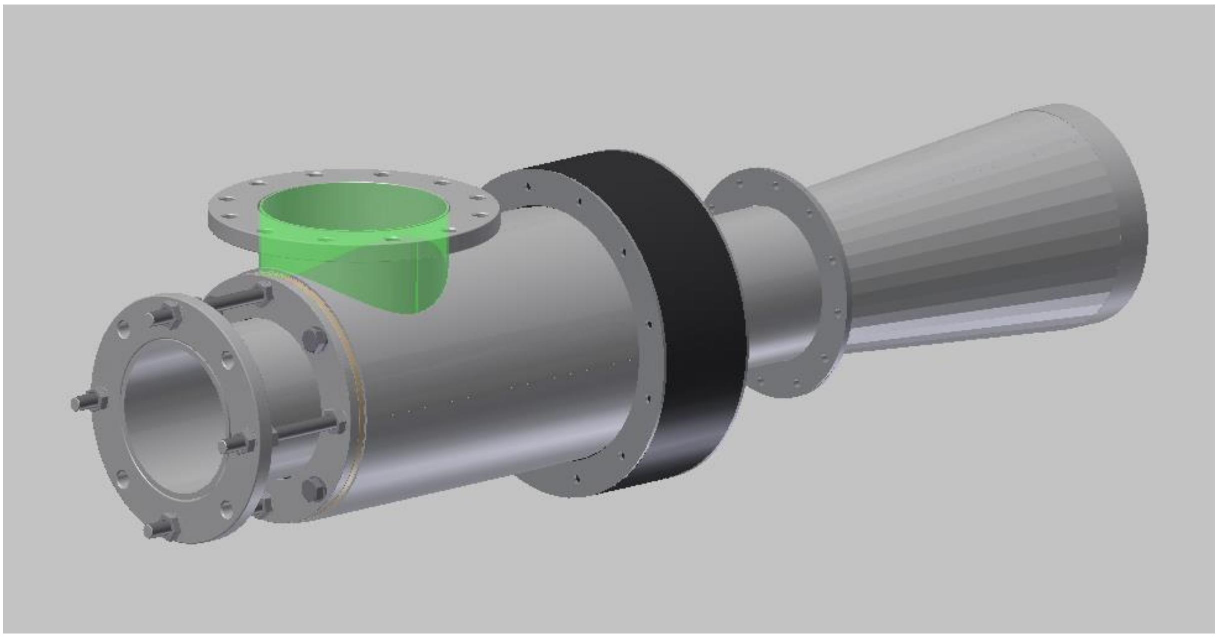
Een rvs plaat wordt op de juiste maat gelaserd. Dit vormt 2 stukken wat via kant werk voorzien wordt van de juiste diameter. Om vervolgens met 2 lassen tot een diffusor te komen (zie laslijnen aangegeven in groen). Totale lengte is 500[mm], met een kleine diameter van 203[mm] en een grote diameter van 295[mm],



Figuur 47 Laslijnen diffusor

6.1.6 Persleiding diameter

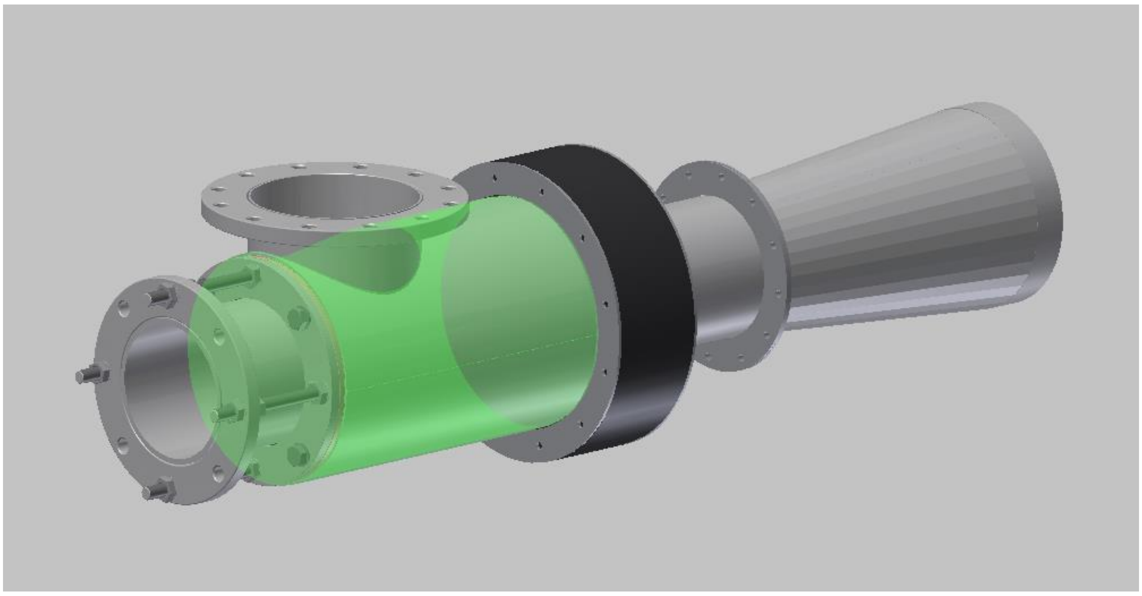
Voor de persleiding is gekozen om gebruik te maken van een wals techniek om van een RVS plaat met dikte 3[mm], tot een stuk buis te komen met een diameter van 250[mm] en een hoogte van 100[mm].



Figuur 48 RVS Persleiding diameter

6.1.7 Buitenmantel

Voor de buitenmantel is gekozen om gebruik te maken van een wals techniek om van een RVS plaat met dikte 3[mm], tot een stuk buis te komen met een diameter van 350[mm] en een lengte van 500[mm].



Figuur 49 RVS Buitenmantel

7 Detailontwerpfase

Het detail ontwerp bestaat uit het uiteindelijke ontwerp. Na ieder parametrisch ontwerp vind een test plaats waaruit data komt en vervolgens een iteratieslag plaatsvind. Hierna word een nieuw ontwerp gemaakt totdat er voldoende informatie beschikbaar is om het uiteindelijke detailontwerp te maken.

Aan de hand van de behaalde resultaten vanuit de praktijktesten, zal er een uitspraak gedaan worden naar de inzetbaarheid aan boord van de TH4. De conclusie zal een antwoord geven op onderstaande deelvragen.

Nr.	Deelvraag	Ontwerpfase (Eggert)
D12.	Hoe zien mogelijke detailvarianten van het parametrische ontwerp eruit, en hoe kan deze getest worden op bruikbaarheid (aan boord van de TH4)?	*Detailfase*
D13.	Hoe verhoudt het gedetailleerde ontwerp zich in vergelijking met de verwachte performance?	*Detailfase*

Daarbij kan na het beoordelen van deze praktijktesten een antwoord gegeven worden op de onderstaande doelstellingen binnen het project, en of het opgesteld budget haalbaar is voor een werkend prototype.

Doel in het project

Het doel in het project is het ontwerpen van een jetpomp die goedkoper is dan jetpompen van concurrenten, de kostprijs mag daarom niet boven de 2500,- euro komen.

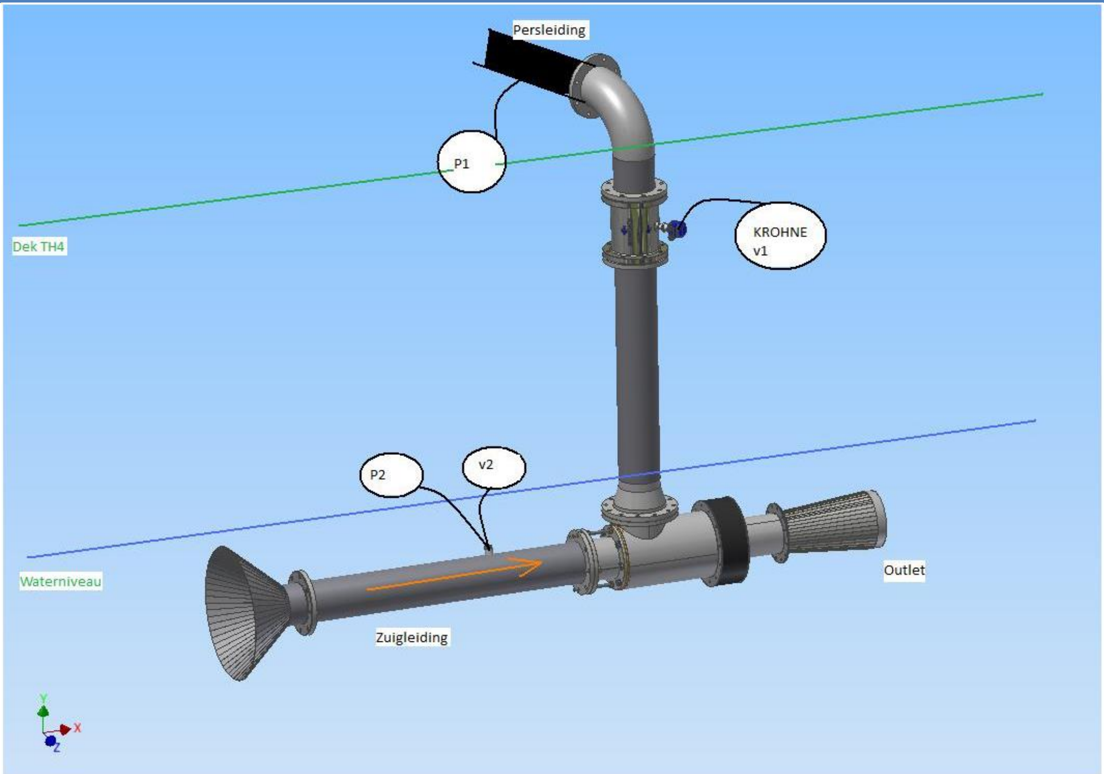
Doel van het project

Het doel van het project is om met de jetpomp het valverlies en mosselbreuk tijdens het oogsten te beperken en de ergonomische werkomstandigheden te verbeteren.

9.1 Testopstelling 1

Hierbij dienen onderstaande gegevens als input gegevens voor de testopstelling.

Input gegevens	Waarde	Eenheid
Toerental motor Caterpillar	1600	[RPM]
Toerental Vloeistofpomp KSB ETA 250-29	1390	[RPM]
Druk hydraulisch systeem	140	[Bar]
Persleiding		
P1	0.5	[Bar]
V1 KROHNE	530	$[m^3/h]$
Nozzle		
Doorstroom Opening	39	[mm]



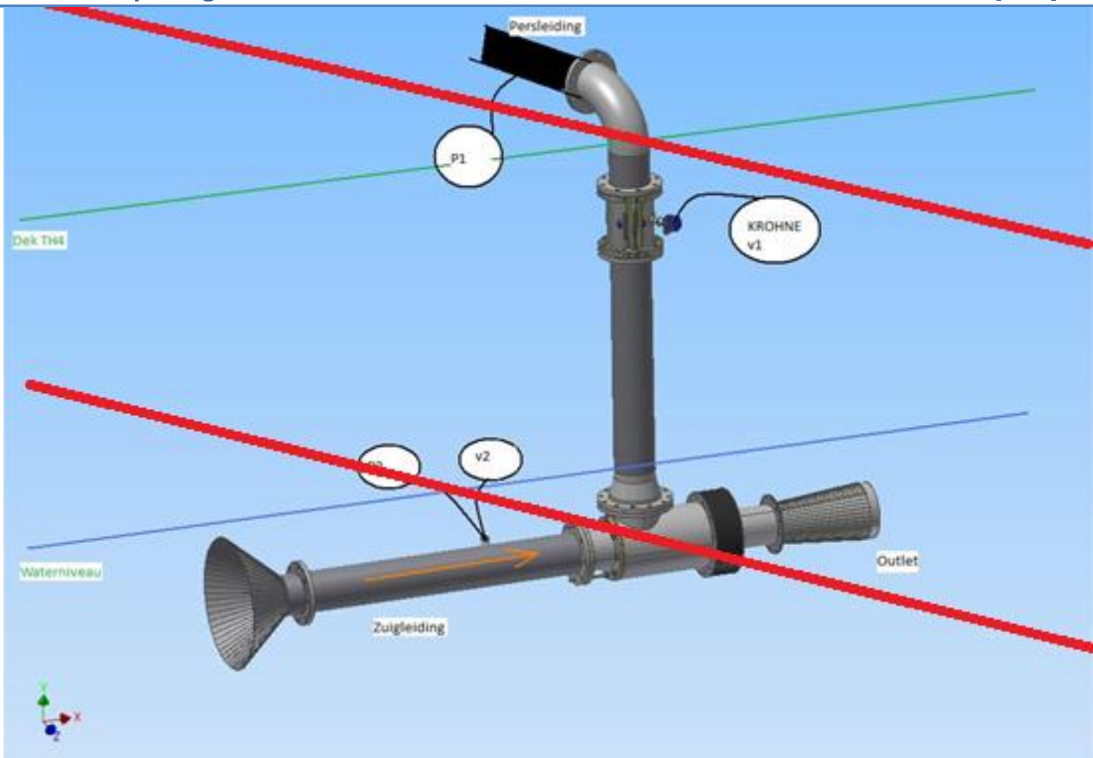
Resultaat	Waarde	Eenheid
Zuigeleiding		
P2	0.05 / 0.01	[Bar]
V2	450	$[m^3/h]$

Eindresultaat	Waarde	Eenheid
Input flow	530	$[m^3/h]$
Zuigleiding flow	450	$[m^3/h]$
Percentage zuigvermogen	85	[%]

9.2 Testopstelling 2

Hierbij dienen onderstaande gegevens als input gegevens voor de testopstelling.

Input gegevens	Waarde	Eenheid
Toerental motor Caterpillar	1600	[RPM]
Toerental Vloeistofpomp KSB ETA 250-29	1440	[RPM]
Druk hydraulisch systeem	110	[Bar]
Persleiding		
P1	1.7	[Bar]
V1 KROHNE	300	$[m^3/h]$
Nozzle		
Doorstroom Opening	34	[mm]



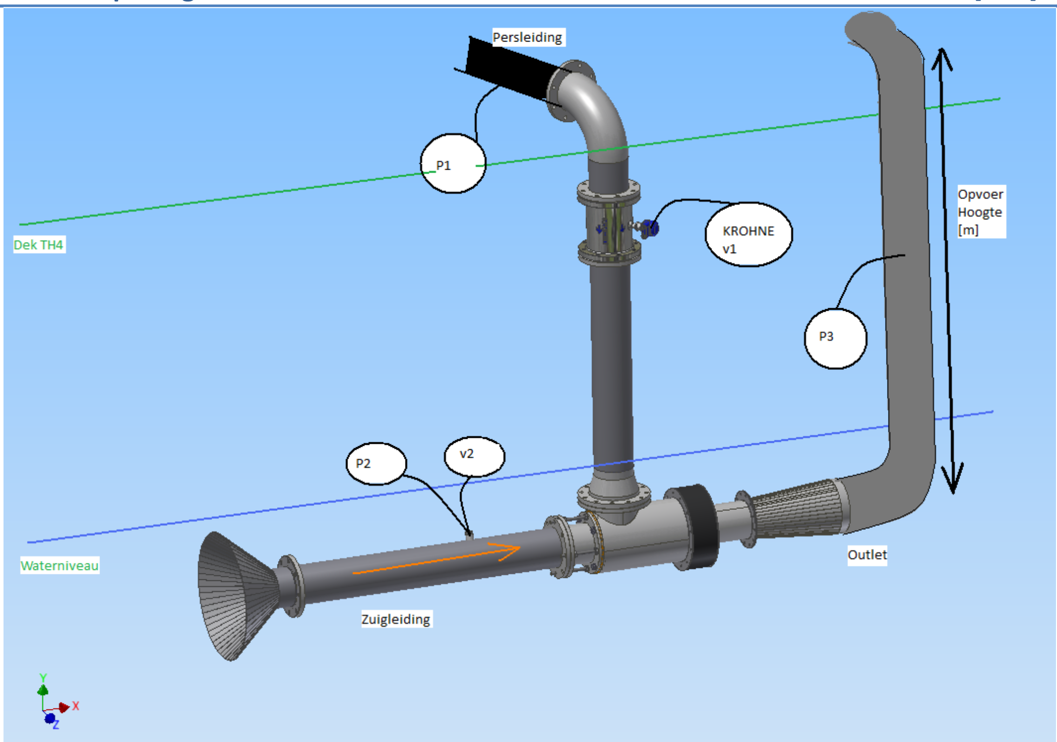
Resultaat	Waarde	Eenheid
Zuigeleiding		
P2	0	[Bar]
V2	345	$[m^3/h]$
Outlet		

Eindresultaat	Waarde	Eenheid
Input flow	300	$[m^3/h]$
Zuigleiding flow	345	$[m^3/h]$
Percentage zuigvermogen	115	[%]

9.3 Testopstelling 3

Hierbij dienen onderstaande gegevens als input gegevens voor de testopstelling.

Input gegevens	Waarde	Eenheid
Toerental motor Caterpillar	1600	[RPM]
Toerental Vloeistofpomp KSB ETA 250-29	1460	[RPM]
Druk hydraulisch systeem	135	[Bar]
Persleiding		
P1	1.9	[Bar]
V1 KROHNE	250	$[m^3/h]$
Nozzle		
Doorstroom Opening	19	[mm]



Resultaat	Waarde	Eenheid
Zuigeleiding		
P2	0	[Bar]
V2	170	$[m^3/h]$

Eindresultaat	Waarde	Eenheid
Input flow	250	$[m^3/h]$
Zuigleiding flow	170	$[m^3/h]$
Percentage zuigvermogen	68	[%]

9.4 Conclusie test resultaten

Testresultaat 1

Eindresultaat	Waarde	Eenheid
Input flow	530	$[m^3/h]$
Zuigleiding flow	450	$[m^3/h]$
Percentage zuigvermogen	85	[%]

Testresultaat 2

Eindresultaat	Waarde	Eenheid
Input flow	300	$[m^3/h]$
Zuigleiding flow	345	$[m^3/h]$
Percentage zuigvermogen	115	[%]

Testresultaat 3

Eindresultaat	Waarde	Eenheid
Input flow	250	$[m^3/h]$
Zuigleiding flow	170	$[m^3/h]$
Percentage zuigvermogen	68	[%]

Hierbij kan geconcludeerd worden dat de belangrijkste parameter binnen de werking van de jetpomp, de tegendruk is.

Tijdens opstelling 2 heeft de vloeistof na het uittreden van de jetpomp geen last van tegendruk. Dit in de vorm van tegendruk van het verplaatsen van water, of tegendruk om de opvoerhoogte te overwinnen. Daarom wordt er een percentage van 115% behaald in het zuigvermogen.

In opstelling 3, die toegepast zal worden aan boord van de TH4, zien we een afname van het percentage aan zuigvermogen. Daarbij is het noodzakelijk om de doorstroomopening bij elke testopstelling te wijzigen.

Hierin kan geconcludeerd worden dat meer tegendruk vraagt naar een grotere vloeistofsnelheid. Dat is duidelijk te zien dat voor de resultaten met meer tegendruk de doorstroomopening smaller gezet moet worden.

9.5 Conclusie opgestelde doelstellingen

Er waren twee doelstellingen binnen dit project, een doel *in* het project en een doelstelling *van* het project.

Doel in het project

Het doel in het project is het ontwerpen van een jetpomp die goedkoper is dan jetpompen van concurrenten, de kostprijs mag daarom niet boven de 2500,- euro komen.

Onderdeel	Tijd (uur)* uurloon (€)	Eenheid (€)
Kunststof plaat (HDPE Zwart)	-	150
RVS snijwerk	-	550.84
Verspanen	10 * 80	850
Buis RVS	-	200
Las werk (RVS)	10 * 70	700
Flenzen	-	349
Draadstangen	-	82
Bouten/moeren	-	17
Pakking materiaal	-	12
Assembly	1 * 70	70

Totaal kostprijsberekening prototype = € 2980,84

Discussie

Met de kostprijs voor het prototype van de jetpomp voldoet het project niet aan de maximale opgestelde kostprijs van € 2500,-. Dit is te verwijten aan de belangrijkste parameter binnen het ontwerp, het kunnen instellen van de doorstroomopening. Hierdoor is het ontwerp ingewikkelder geworden en uitgebreid met een extra flens waarbij verspanen nodig was, draadstangen, bouten en moeren.

De toegevoegde waarde bij het ontwerp is het kunnen aanpassen van de doorstroomopening. Dit kan op locatie en zelfs tijdens gebruik. Wat een groot voordeel heeft dat de jetpomp in verschillende omstandigheden inzetbaar is. Met als voorbeeld:

De nominale diameter van de substraatlijn met het mosselzaad is vastgesteld op 140[mm]. Wanneer er een reeks is waarbij de diameter toeneemt tot +-180[mm] vraagt dit om een andere instelling van de jetpomp om het extra gewicht in zuigvermogen te compenseren.

Daarom kan ik met trots zeggen dat het prototype daadwerkelijk ingezet wordt voor de mosseloogst en dan ook een vaste plek krijgt aan boord van de mosselkotter de TH4.

Doel van het project

Het doel van het project is om met de jetpomp het valverlies en mosselbreuk tijdens het oogsten te beperken en de ergonomische werkomstandigheden te verbeteren.

Conclusie

Met het gebruik van de jetpomp tijdens het oogsten is het doel van het project volbracht. De ergonomische werkomstandigheden zijn hierbij verbeterd. Wanneer het begin van een reeks substraatlijn in de zuigleiding geplaatst wordt, zal de complete lijn hierdoorheen gevoerd worden. Het telkens vasthaken van de lijn vervalt hierbij, zie figuur 2: Huidige manier van oogsten.

Eventuele valverlies, wanneer het mosselzaad los komt van de substraatlijn, bevindt zich nu in de zuigleiding. Hierdoor zal het losse mosselzaad meegezogen worden tot in het ruim. Daarbij zorgt het zuigvermogen voor voldoende stroming om de complete substraatlijn te transporteren.

Tijdens het oude systeem werd het mosselzaad gescheiden van het substraattouw d.m.v. rubberen flappen. Deze flappen scheiden het mosselzaad van de substraatlijn door een slaande beweging, wat veel beschadigingen en dus mosselbreuk oplevert. In het nieuwe systeem zal de vloeistofversnelling in de jetpomp ervoor zorgen dat het mosselzaad los komt van de substraatlijn. En dus mosselbreuk voorkomt.

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Bijlagen

Bijlage 1: Missie statement Jansen technologie group

Jansen Technology Groep: "Creëert oplossingen voor complexe technische uitdagingen "

Onze missie: Verbinden

"De Jansen Technology Groep verbindt diverse specialismes voor de industriële sector. Vanuit deze verbinding wil de Jansen Technology Groep een totaalpartner zijn die bijdraagt aan de inrichting en optimalisering van bedrijfsprocessen. Het leveren van een best mogelijke oplossing voor ieder technisch probleem is hierbij ons doel, klantgerichtheid en inzet van de juiste aanwezige specialismes zijn daarbij onze middelen."

Jansen Tholen B.V.: "Turnkey oplosser voor machines, productielijnen en industriële installaties"

"Jansen Tholen B.V. wil een bijdrage leveren aan duurzame en rendabele productieprocessen. Wij leveren turn-key oplossingen voor machines, productielijnen en industriële installaties, zowel nieuwbouw als modificatie. Onze expertise ligt op het gebied van engineering, maintenance en fabricage waarbij wij het belangrijk vinden om de voornaamste disciplines zelf in huis te hebben. Jansen Tholen B.V. wil door nauwe samenwerking met de klant maatwerk leveren die voorziet in specifieke wensen."

1. Wij zijn echte **probleemoplossers**, wij zoeken altijd naar de best mogelijke oplossing en stoppen niet voordat we deze gevonden hebben.
2. Hierin zijn we zeer **gedreven**
3. Een goede oplossing is een **duurzame** oplossing**.**
4. Wij zijn **trots** op onze resultaten en dragen dit actief uit
5. Wij zijn echte **teamspelers,** door een goede mix van medewerkers kunnen wij het beste resultaat halen.
6. In alles wat wij doen staat de **klant centraal** waarbij we zoeken naar de best mogelijke oplossing.

Multi-tech Tholen B.V.: "De specialist op het gebied van walsrollen."

"Multi-tech Tholen B.V. wil met name de kunststof- en grafische industrie voorzien van geoptimaliseerde walsrollen middels de inzet van vakspecifieke kennis waarmee de klant wordt voorzien van advies over de juiste behandelingsmethode. Multi-tech Tholen B.V. vindt het belangrijk om deze behandelingen zelf te kunnen uitvoeren, waarbij het superfinishen, reinigen en aanbrengen van structuur in de walsrollen in huis of op locatie kan plaatsvinden."

1. Wij zijn **specialisten** binnen ons vakgebied, wij bezitten kennis en kunde van rollen ten behoeve van onder andere de kunststof- en grafische industrie en zijn in staat deze direct toe te passen.
2. Wij streven er te allen tijden na om **kwaliteit** te leveren. Kwaliteit houdt voor ons in dat we de klant zijn verwachtingen hebben overtroffen.
3. Wij werken **klantgericht**. Ons advies biedt de best mogelijke oplossing voor de klant.

Plasticentrum: "De innovatieve kunststofleverancier"

"Het Plasticentrum bewerkt en levert diverse kunststoffen voor zowel de zakelijke als particuliere markt. De bijzondere kracht hierbij is de kennis van innovatie en duurzaamheid waardoor we de klant kan worden voorzien van een goed advies en producten ontwikkeld kunnen worden die direct aansluiten op de specifieke wensen."

1. Wij zijn echte **probleemoplossers**. De klant komt met een probleem of idee en wij stoppen niet voordat de perfecte oplossing is geboden.
2. Een goede oplossing is voor ons een **duurzame** oplossing.
3. **Samenwerking** staat bij ons voorop. Zowel de samenwerking tussen medewerkers, de interactie met de klant als de relatie met onze partners.
4. Wij zijn een **toegankelijke** organisatie, hebben oog en oor voor al u problemen en wensen op het gebied van kunststof.

Algemene beschrijving:

Jansen Technology Group is een drie-eenheid van disciplines binnen de industriële sector. Jansen Tholen B.V. is gespecialiseerd in het ontwerpen, bouwen, reviseren en modificeren van machines, productielijnen en industriële installaties. Multi-Tech Tholen B.V. bezit een specialisme op het gebied van walsrollen waardoor de rollen met behulp van unieke behandelmethodes geoptimaliseerd kunnen worden. Het Plasticentrum bewerkt en verhandelt kunststoffen, waarbij innovativiteit en duurzaamheid voorop staan.

Door deze unieke samenwerking kunnen diverse synergievoordelen behaald worden.

The Jansen technology Group is a three-unit of diverse disciplines within the industrial sector. Jansen Tholen B.V. has a specialization on engineering, fabricating, revising and modifying machinery, production lines and industrial equipment. Multi-tech Tholen B.V. is specialized in the field of rolls for the plastics- and graphical industry in which the rolls can be optimized by using unique treatment methods. The Plasticentrum treats and sells plastics, in which innovativity and sustainability are priorities.

By using this unique collaboration, synergies can be realized.

Bijlage 2 Programma van Eisen

1 Inleiding

Voor het kunnen uitwerken van het onderzoek naar de jetpomp zal er gekeken worden aan welke eisen het product moet voldoen. Dit is onder te verdelen in 'eisen van de klant' en 'eisen de projectverantwoordelijke'.

1.1 Opdrachtgever

De aanleiding voor het project is voortgekomen uit een vraag vanuit de firma gebr. A.J. Schot, die tijdens het oogsten van mosselzaad te kampen kregen met problemen.

- **Bedrijfsnaam:** gebr. A.J. Schot
- **Bedrijfsgroep:** Mosselkweker Shot
- **Vestigingsplaats:** Tholen, Nederland

De firma gebr. A.J. Shot is in het bezit van een vissersvloot, waarbij voor de boot TH4 een nieuw systeem opgezet moet worden voor het oogsten van mosselzaad door middel van MosselZaad-Invangsysteem (MZI).

1.2 Projectverantwoordelijke

Om een goed beeld te creëren gaan we eerst bekijken wie de opdrachtgever is en wat het bedrijf inhoud.

- **Bedrijfsnaam:** Jansen Tholen B.V.
- **Bedrijfsgroep:** Jansen Tholen Group
- **Vestigingsplaats:** Tholen, Nederland

Jansen Tholen B.V. is een onderneming opgericht in 1985 door drie gebroeders Jansen. Vanaf 1995 draagt de onderneming de huidige naam "Jansen Tholen B.V." Vandaag de dag is de onderneming uitgegroeid tot een bedrijf dat uniek is in de diversiteit van de activiteiten. Hierbij kan het gaan om ontwerp, bouw, installatie, reparatie of onderhoud van machines in het algemeen.

Verder biedt de onderneming ook draai- en freeswerk, opspuitwerk, elektrotechniek of superfinishing van walsrollen aan. Met deze vele mogelijkheden kan Jansen Tholen B.V. gezien worden als een totaalpartner die een geïntegreerde oplossing kan bieden, waarmee een mogelijk afstemmingsverlies kan worden voorkomen.

1.3 Aanleiding van het project

De regelgeving voor het vangen van mosselzaad wordt steeds strenger. Met name het verkrijgen van mosselzaad vanaf de natuurlijke zaadbanken zal in de toekomst verder beperkt worden. Het ingevangen mosselzaad wordt uitgezet op kweekpercelen en groeit daar uit tot volwassen consumptiemossel.

Omdat bodemvisserij steeds meer beperkt wordt, is een nieuw systeem bedacht om mosselzaad te verkrijgen. In het zeewater worden rondzwevende mossellarven ingevangen in netten en touwen. Hoe dit handig, goed en goedkoop uitgevoerd kan worden, is momenteel volop in ontwikkeling. Voorlopig is deze nieuwe manier van zaadvangen duurder dan het verkrijgen van zaad op natuurlijke mosselbanken.

Jansen Tholen is een machinefabriek met ervaring in het ontwerpen en bouwen van teeltmachines. Oostinga is een mosselvisser en is bij Jansen Tholen gekomen met een ontwikkelvraag. Tot nu toe is de machine voor het plaatsen van de MosselZaad-Invangsystemen (MZI's) ontwikkeld en wordt momenteel gebouwd. De oogstmachine is in het komende semester in ontwikkeling: concepten zijn gekozen en de engineering is in volle gang.

1.4 Doelsituatie

Binnen de aanvraag vanuit de mosselkweker gebr. A.J. Schot zal er een nieuw ontwerp van een oogstmachine voor het oogsten van de mosselzaad ontwikkeld worden. Samen met het MosselZaad-Invangsystemen (MZI's) zal dit een compleet systeem aanbieden. Voor zowel het invangen en het oogsten van het mosselzaad.

De doelsituatie met dit complete systeem is om te kunnen voldoen aan de strengere regelgeving. En daarbij de manier van zaadvangen aanpassen zodat het handig, goed en goedkoop uitgevoerd kan worden. Waarbij het verwijderen van het mosselzaad van het substraat efficiënter, sneller en minder arbeidsintensief wordt uitgevoerd en het valverlies en beschadigingen van mosselzaad wordt beperkt tot een minimum.

1.5 Probleemanalyse

Er zijn verschillende automatische installaties ontwikkeld ter ondersteuning van het oogsten van mosselzaad, maar de praktijk wijst uit dat het oogsten van mosselzaad met behulp van de reeks bestaande apparatuur veel tijd kost en lijdt tot veel valverlies en beschadiging van het mosselzaad. Hierbij is door Jansen Tholen B.V. een nieuwe techniek ontwikkeld voor het losmaken van de substraatlijn van de hoofdlijn. Daarbij zal er een jetpomp ontwikkeld worden om de substraatlijn aan boord van de TH4 te krijgen, deze jetpomp moet er voor zorgen dat het valverlies en beschadigingen van het mosselzaad beperkt wordt en de ergonomische omstandigheden voor het personeel toe zal nemen.

2. Eisen en wensen van de klant

De probleemstelling zal vertaald worden naar een nieuw systeem voor het oogsten van mosselzaad. Dit nieuwe systeem zal moeten voldoen aan de gestelde eisen.

Gebruiksomgeving

In de huidige situatie wordt er veel arbeid verricht tijdens het oogsten van het mosselzaad. De bedoeling is om het proces te automatiseren, bijkomende eisen zijn:

- Beperken arbeidsintensief
- Beperken handmatige handelingen
- De ergonomische omstandigheden moeten verbetert worden.
- De efficiëntie zal verhoogt moeten worden
- Beperken brandstofverbruik

Performance

Het huidige systeem voldoet niet aan de productie eisen, het nieuwe systeem zal hierin moeten uitblinken. Daarbij zullen volgende performance handelingen verbetert moeten worden:

- Het valverlies van het mosselzaad zal beperkt moeten worden.
- De beschadigingen aan het mosselzaad zal beperkt moeten worden.
- De proces snelheid zal omhoog moeten.
- De economische haalbaarheid zal geoptimaliseerd moeten worden
- Het systeem mag geen storingen vertonen tijdens het oogsten van het mosselzaad

Geometrische beperkingen

Het systeem is beperkt tot de geometrie aan boord van de TH4, hierbij lettend op afmetingen maar ook naar mogelijk energie levering in de vorm van pompvermogens elektrisch, hydraulisch:

- Het geautomatiseerde oogstsysteem moet toepasbaar zijn, aan boord van de TH4.
- Het geautomatiseerde oogstsysteem moet compact zijn, om voldoende ruimte beschikbaar te houden aan boord van de TH4.
- Het systeem moet aangedreven worden met bestaande vermogens aanwezig bij de TH4

Onderhoud

Het systeem zal zo efficiënt mogelijk moeten functioneren, daarbij:

- Onderhoud aan het systeem moet zo veel mogelijk beperkt blijven
- Na het oogst seizoen moet het systeem makkelijk te reinigen zijn

Veiligheid

Om de ergonomische omstandigheden te verbeteren zal de veiligheid van het systeem moeten voldoen aan:

- Het systeem moet bestand zijn tegen de weeromstandigheden, hierbij denkend aan:
  - Wind, Golfslag, Turbulentie in het water
- Er mag geen risico met betrekking tot het gebruik van elektrische machines in een water omgeving zijn.

3. Eisen en wensen van het bedrijf

Om de vraag van de klant tot werkelijk te kunnen uitvoeren, zal er een compleet oogstvlot ontworpen en geproduceerd worden. De bijhorende eisen die gelden voor het gebruik van een jetpomp binnen het oogstvlot zal worden toegelicht.

3.1 Prototype

Aan de hand van de vergaarde kennis binnen het literatuuronderzoek zal er een prototype worden ontwikkeld, die moet voldoen aan de volgende eisen:

Financieel

- Het budget voor het produceren van een prototype is vastgesteld op maximaal €2500,- voldoet de kostprijs van het prototype aan het gestelde budget.

Productie

- Het prototype van de jetpomp moet binnen Jansen Tholen B.V. geproduceerd worden, dus de benodigde productieprocessen moeten aanwezig zijn binnen Jansen Tholen B.V.

Prototype testen

- Tijdens het uitvoeren van de (praktijk) testen, zal de werkelijk zo nauwkeurig mogelijk worden nagebootst.
- Leg dit vast aan de hand van metingen en simulaties.

3.2 Eindontwerp

Om de vraag van de klant tot werkelijk te kunnen uitvoeren, zal de kennis behaald met het prototype verwerkt worden in het eindproduct. De bijhorende eisen aan het eind product zijn:

Pompkarakteristiek

Het bepalen van een juist pomptype hangt af van verschillende eisen binnen het systeem. Hierbij zal de pomp moeten voldoen aan de volgende criteria:

- De gekozen pomp moet een Laminaire stroming creëren.
- De gekozen pomp moet de hoogste efficiëntie aantonen.
- De gekozen pomp moet voldoen aan het gevraagde debiet dat nodig is voor de transport van het mosselzaad met de substraatlijn.
- De gekozen pomp moet voldoen aan het gevraagde opvoerhoogte, dat nodig is voor de transport van mosselzaad met substraatlijn vanaf het MZI-vlot tot aan boord van de TH4.
- De benodigde energie dat de pomp vraagt moet leverbaar zijn door de TH4.

Jetpomp

Het bepalen van de juiste jetpomp hangt af van verschillende eisen binnen het systeem. Hierbij zal de jetpomp moeten voldoen aan de volgende criteria:

- Voldoet de jetpomp aan de opgestelde diameter van minimaal 200[mm]
- Zorgt de inspuithoek (Nozzle) ervoor dat het water doordringt tot aan het substraattouw, en hierbij het mosselzaad scheidt van het substraattouw.
- Zorgt de inspuithoek met een juist debiet voor voldoende zuigkracht om het substraattouw met mosselzaad op te zuigen.

- Zorgt de inspuithoek met een juist debiet voor genoeg vermogen om het substraattouw met het mosselzaad te transporteren naar de TH4.
- Lage wrijving coëfficiënt van de jetpomp

Totaal systeem

Het bepalen van het totaal systeem heeft betrekking op

- Lage wrijving coëfficiënt van de transportslang
- Totale transport lengte jetpomp/slang minimaal houden
- Vermijden van het toepassen van appendages
- Benodigde energie zo veel mogelijk beperken
- Het losgekomen mosselzaad wordt ook opgezogen door middel van de jetpomp

Productie

De productie van het systeem moet voldoen aan de volgende eisen:

- Het eindontwerp van de jetpomp moet binnen Jansen Tholen B.V. geproduceerd worden.
- Het eindontwerp moet 'makkelijk' te produceren zijn, hierbij rekening houden dat er in de toekomst meerdere aantallen geproduceerd zullen worden.

Financieel

Het ontwerp van de jetpomp moet interessant zijn voor de consument en daarom:

- Kostprijs jetpomp moet lager zijn dan bestaande systemen
- Kostprijs jetpomp-installatie moet lager zijn dan bestaande systemen

Geometrische beperkingen

De jetpomp zal plaats moeten krijgen binnen het oogstvlot, bijkomende aandachtspunten zijn:

- De jetpomp moet gekoppeld worden aan de overige systemen binnen het oogstvlot
- De jetpomp moet geplaatst worden op het oogstvlot

De transportleiding met de jetpomp zal binnen het oogstvlot plaats moeten krijgen

Bijlage 3: Jetpomp toepassingen

1 Bestaande technieken

Het Venturi principe wordt in heel veel toepassingen gebruikt maar de werking komt altijd op hetzelfde neer. In het algemeen zijn er twee verschillende types die het Venturi principe toepassen:

Ejector: Een ejector gebruikt een gas als aandrijving. Ook zijn ze meestal te herkennen aan de divergerende-convergerende nozzle. Het convergeren is meestal benodigd doordat gassen een snelheid hoger dan het geluid kunnen behalen.

Eductor: Een eductor gebruik een vloeistof als aandrijving. Ze zijn meestal te herkennen aan de divergerende nozzle. Convergeren is hierbij niet benodigd doordat snelheden bij vloeistoffen meestal niet hoog oplopen.

Hieronder een paar voorbeelden van ontwerpen waarin het Venturi principe wordt toegepast.

1.1 Airbrush

Door middel van lucht in te spuiten onder hoge snelheid zal er onderdruk ontstaan in het gedeelte waar de verf in zit. Door deze onderdruk zal de verf opgezogen worden en gemengd worden met de lucht, waardoor een gelijke verdeling van de verflaag aangebracht kan worden. [figuur 1]

Figuur 50: Airbrush (ejector)

1.2 Aspirator

Door middel van de versmalling die aangebracht is neemt de stroomsnelheid toe en zal er onderdruk ontstaan. Aspirators worden bijvoorbeeld in ziekenhuizen gebruikt om overige stoffen bij een operatie weg te zuigen. Een voorbeeld hiervan is te zien in figuur 2. Waar de buis erg is verdund vind de aanzuiging plaats en aan de zijkant word lucht toegevoerd. Door de grote versmalling kan heel precies worden gezogen waardoor er maar weinig toevoer plaats hoeft te vinden. Een snelheidsverhoging geeft echter een drukverlaging.

Figuur 51: Aspirator (ejector)

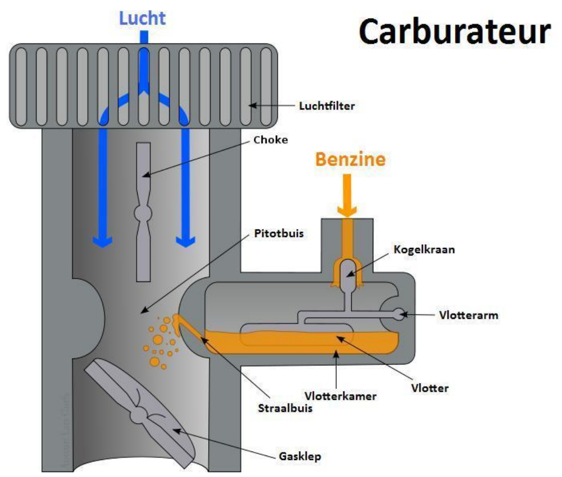
1.3 Bunsenbrander

dit is de brander die bijna iedereen kent uit de scheikunde lokalen, doormiddel van twee instelbare ringen kan zowel de gastoevoer als de luchttoevoer geregeld worden. [figuur 3]

Figuur 52: Bunsenbrander (ejector)

1.4 Carburateur

Dit is het deel van de verbrandingsmotor in een auto waar de lucht met benzine word gemengd. Het aanzuigen van de benzine gebeurd doormiddel van het Venturi principe. [figuur 4]



Figuur 53: Carburateur (ejector)

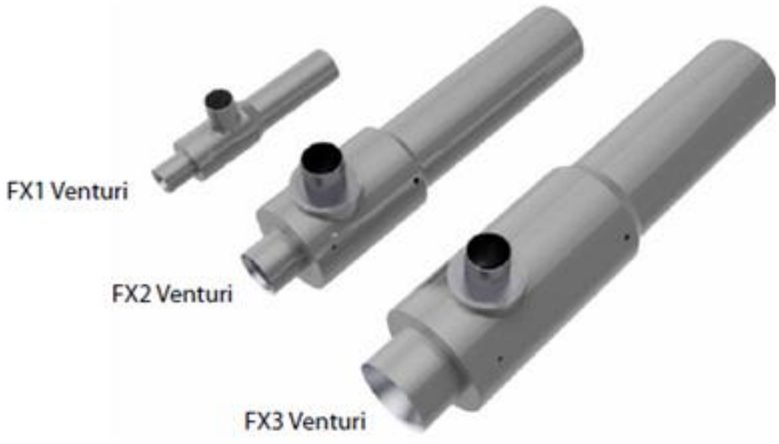
We kunnen verder op deze ontwerpen ingaan maar eigenlijk is maar een ding voor ons van belang. Alle verschillende ontwerpen maken namelijk gebruik van het Venturi principe. Bij bijna alle ontwerpen was de aanzuiging aan de zijkant in plaats van aan de ingang en bij veel ontwerpen was de buis niet geheel hol zodat de substraat lijn er niet doorheen kan. We zullen verder een paar ontwerpen bespreken waarbij de aanzuiging wel aan de goede kant zit en zullen verder op deze ontwerpen ingaan in het hoofdstuk Discussie.

2 Bestaande systemen

Om tot een nieuw design ontwerp te komen voor de jetpomp, die toegepast zal worden binnen het oogst-vlot, zal er eerst gekeken worden naar de huidige markt en wat deze hierin te beiden heeft.

2.1 CAC Venturi

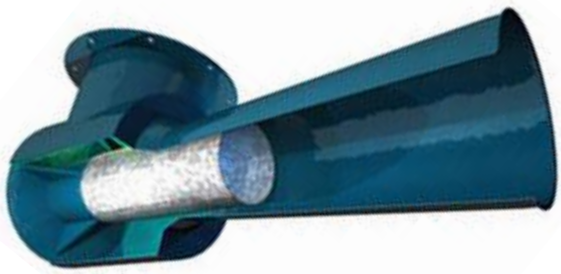
De FX serie wordt aangedreven door lucht en wordt ingezet bij het opzuigen van afval (denkend aan zaagsel of dergelijke). Om verstoppingen te voorkomen is hier ook voor een horizontale aanzuiging met de verticale persleiding. Het principe zal overeen komen met de jetpomp voor het mosselzaad maar door het gebruik van vloeistof krijgen we te maken met hogere drukken, wat weer invloed heeft op de materiaalsterkte. (ConverterAccessoryCorporation, sd)



Figuur 54 CAC Venturi, 3 verschillende afmetingen

2.2 Paramount

De Paramount jetpomp systeem wordt toegepast binnen een afzuigsysteem, en werkt dus met lucht. De manier van het plaatsen van de nozzle verschilt met andere systemen, en zal daarom ook meegenomen worden in de beslissen van de conceptenkeuzen. (Paramount, sd)



Figuur 55 Paramount Venturi system

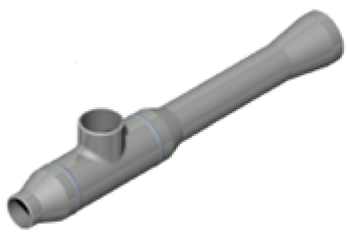
2.3 Transvac

Transvac is gespecialiseerd in industriële precessen, een onderdeel daarvan is nucleair mengen van verschillende stoffen. Hierbij hebben ze een jetpomp (figuur RVS Venturi) waarbij er 1 persleiding en 2 zuigleidingen aanwezig zijn. Hierbij is het mogelijk om 3 grondsoorten te mengen.

De volgende jetpomp is voorzien van een ceramische binnenlaag, deze laag is bestand tegen zuren. Het toepassen van een ander materiaal is van toepassing en zal meegenomen worden bij het eindconcept. Dit omdat het mogelijk is dat er cavitatie zal optreden rond de nozzle. Ook het transporteren van mosselzaad zal een impact hebben op het materiaal.

(TransvacSystems, 2014)

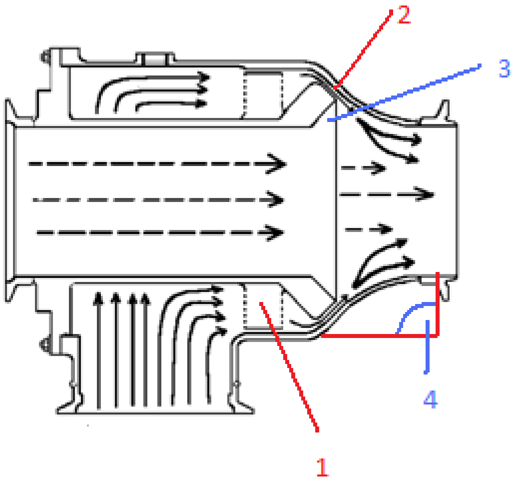
Figuur 56 RVS Ejector



Figuur 57 Ejector voorzien van Ceramische binnenlaag

2.4 ETI-Silkstream

De silkstream jetpomp word in de praktijk toegepast om zalmen schadeloos te verpompen. Een volwassen zalm weegt redelijk zwaar en de snelheid van het water zal dus zodanig hoog moeten zijn dat de zalmen opgevoerd kunnen worden.



Figuur 58 Silkstream Flow Head

De toepassing van de Silkstream komt grotendeels overeen met de toepassing binnen de mosselsector. Hierbij is er voor bepaalde eigenschappen gekozen:

Nr1: Aanvoer stroom voor de nozzle, laminari of turbulent.

Nr2: Nozzle hoek

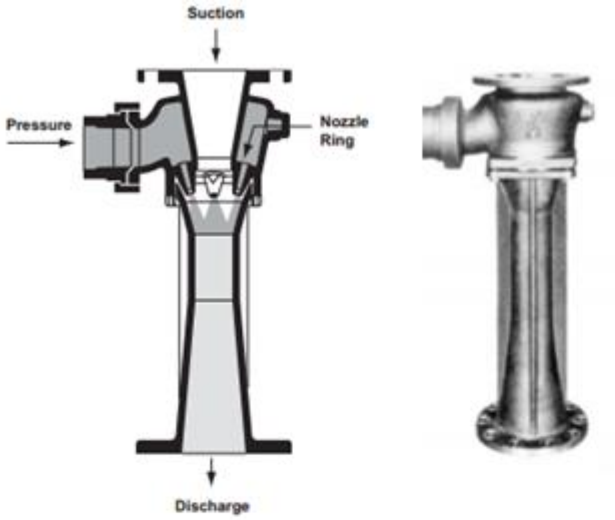
Nr3: Zuigleiding, vergroting van diameter voor de nozzle

Nr4: Radius ingevoegd na de nozzle

Figuur 59 Silkstream toegepast in werkveld

2.5 Schitte & Koerting

De jetpomp van schutte en koerting maakt gebruik van nozzles waar de versnelling van het water mee word gecreëerd. Zoals te zien is word er onder een redelijk scherpe hoek ingespoten, terwijl bij andere ontwerpen dit minder is. Ook is te zien dat vanuit verschillende kanten het water in word gespoten. Uit onze testen zal verder blijken wat voor effect dit op de stroming zal hebben.



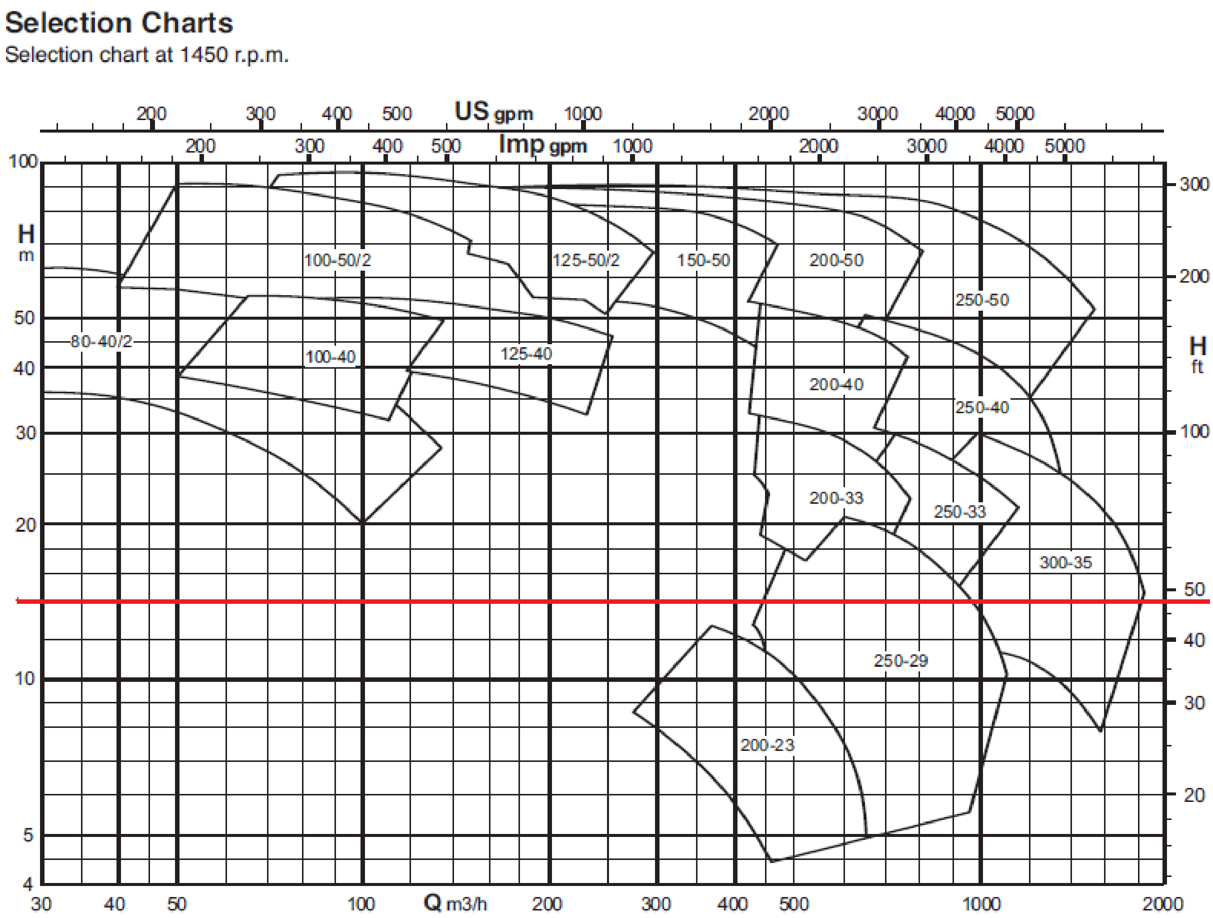
Figuur 60 Schitte & koerting

2.6 Aquakultur –Teich

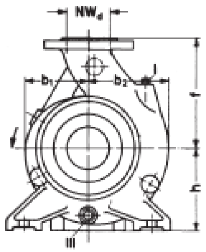
Een veel gebruikte vis pomp is de Aquakultur-Teich, deze werkt met 2 kamer die door middel van kleppen een zuigend effect creëren. Binnen het MZI project vervalt deze pomp omdat er met lange substraatlijnen gewerkt wordt.

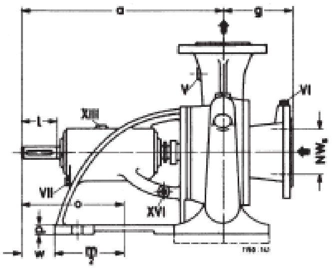
Figuur 61 Vispomp Aquakultur-Teich

Bijlage 4 Pomp gegevens

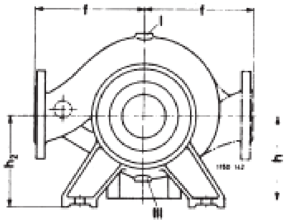


Tabel 6 Opvoerhoogte 250-29

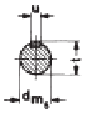




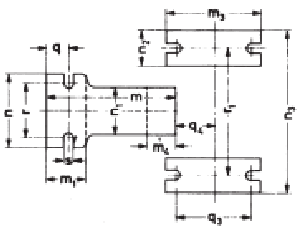
Pump foot for sizes 200-23 and 300-35

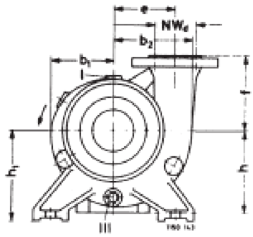


Cooling water inlet and outlet connections for stuffing-box design HW, and sealing liquid or leakage connections for design VSM are 3/8". Connection for other sealing liquid and flushing liquid VSH is 1/4" (see operating manual).



Shaft extension as per DIN 7160
key as per DIN 6885





Sizes 200-23, 250-29, 300-35
with tangential discharge branches

Connections provided for:

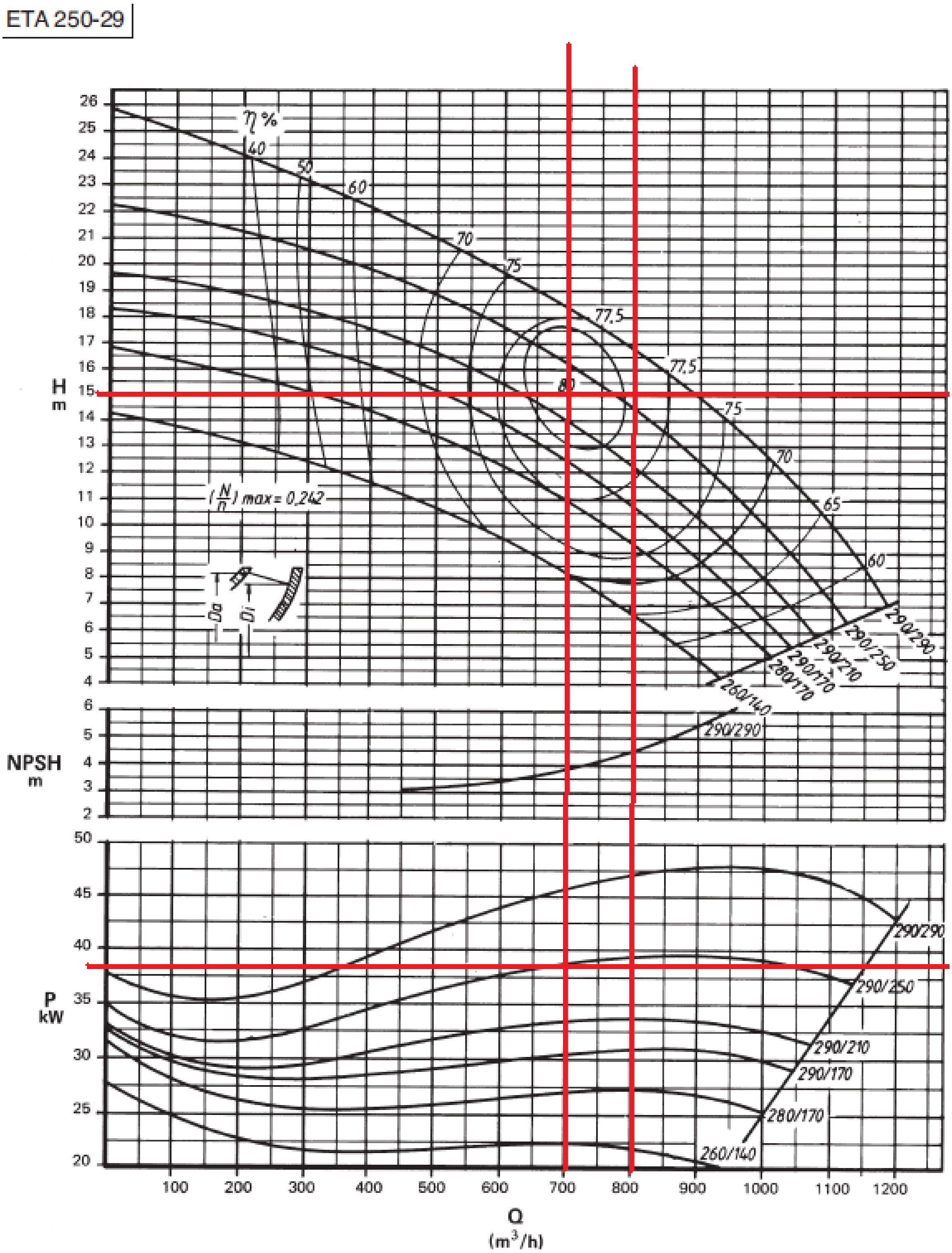
I	Priming funnel, venting	
	Size 100-40 to 125-50	1/2"
	Size 150-26 to 300-35	3/4"
III	Draining	
	Size 100-40 to 125-50	1/2"
	Size 150-26 to 300-35	3/4"
V	Pressure gauge	1/2"
VI	Vacuum gauge	1/2"
VII	Oil-drain plug	3/8"
XII	Oil-filling plug, dipstick	3/8"
XVI	Leakage drain bearing pedestal C	3/4"
	Leakage drain bearing pedestal D	1"

Size	Bearing Pedestal	Pump																								
		a	b_1	b_2	f	g	h	h_1	h_2	m	m_1	m_3	m_4	n	n_1	n_2	n^3	o	p	q	q_3	q_4	r	r_1	s	w
100-40	C	624	255	275	400	155	300	300		445	105	250	80	250	160	140	580	306	22	60	190	96	210	440	24	83
100-50	C	624	255	275	400	230	300	300		445	105	250	80	250	160	140	580	306	22	60	190	96	210	440	24	83
125-33	C	629	230	266	375	150	300	300		445	105	250	80	250	160	140	580	306	22	60	190	101	210	440	24	83
125-40	C	619	267	298	475	160	300	300	320	445	105	250	80	250	160	140	580	306	22	60	190	91	210	440	24	83
125-50	C	619	267	298	475	247	300	300	320	445	105	250	80	250	160	140	580	306	22	60	190	91	210	440	24	83
150-26	C	629	222	283	400	170	300	300		445	105	250	80	250	160	140	580	306	22	60	190	101	210	440	24	83
150-33	C	624	245	300	425	170	300	300		445	105	250	80	250	160	140	580	306	22	60	190	96	210	440	24	83
150-40	D	870	285	325	425	160	400	400		650	150	250	120	380	200	140	700	417	25	85	190	128	335	560	28	92
150-50	D	870	323	363	525	170	400	400		650	150	250	120	380	200	140	700	417	25	85	190	128	335	560	28	92
200-23	C	635	264	335	300	250	300	330		445	105	250	80	250	160	140	580	306	22	60	190	107	210	440	24	83
200-40	D	880	308	372	525	180	400	400		650	150	250	120	380	200	140	700	417	25	85	190	138	335	560	28	92
250-29	D	880	340	435	350	220	400	400		650	150	250	120	380	200	140	800	417	25	85	190	138	335	660	28	92

Tabel 7 Dimension Table 250-29

Size	Tangential discharge	Shaft extension				Suction Flange						Discharge Flange					
		dm [6]	l	u	t	Suction	Flange dia	Bolt Circle dia	Raised Face dia	Bolts Number	Bolts Hole dia	discharge	Flange dia	Bolt Circle dia	Raised Face dia	Bolts Number	Bolts Hole dia
100-40		42	105	12	45,1	125	250	210	188	8	18	100	220	180	158	8	18
100-50		42	105	12	45,1	125	250	210	188	8	18	100	220	180	158	8	18
125-33		42	105	12	45,1	150	285	240	212	8	23	125	250	210	188	8	18
125-40		42	105	12	45,1	150	285	240	212	8	23	125	250	210	188	8	18
125-50		42	105	12	45,1	150	285	240	212	8	23	125	250	210	188	8	18
150-26		42	105	12	45,1	200	340	295	268	8	23	150	285	240	212	8	23
150-33		42	105	12	45,1	200	340	295	268	8	23	150	285	240	212	8	23
150-40		50	135	14	53,5	200	340	295	268	8	23	150	285	240	212	8	23
150-50		50	135	14	53,5	200	340	295	268	8	23	150	285	240	212	8	23
200-23	244	42	105	12	45,1	200	340	295	268	8	23	200	340	295	268	8	23
200-40		50	135	14	53,5	250	395	350	320	12	23	200	340	295	268	8	23
250-29	292	50	135	14	53,5	250	395	350	320	12	23	250	395	350	320	12	23
250-33		50	135	14	53,5	300	445	400	370	12	23	250	395	350	320	12	23
250-40		50	135	14	53,5	300	445	400	370	12	23	250	395	350	320	12	23
250-50		50	135	14	53,5	300	445	400	370	12	23	250	395	350	320	12	23
300-35	352	50	135	14	53,5	300	445	400	370	12	23	300	445	400	370	12	23

Tabel 8 Suction, Discharge, 250-29



Tabel 9 Rendement η %

Deze pomp zal als basis dienen voor de start van verdere berekeningen, mocht er gaandeweg geconcludeerd worden dat de pomp niet voldoet aan de gevraagde waardes. Kan er altijd gekeken worden naar een andere pomp.

Bijlage 5: Vloeistofpompen

Centrifugaalpomp

De meest gebruikte vloeistofpompen zijn centrifugaalpompen, er wordt kort toegelicht wat hierbij de voor- en nadelen zijn van deze pompen.

Voordelen:

- Centrifugaalpompen zijn vaak klein van afmetingen vergeleken met andere principe pompen bij gelijke volumestroom en opvoerhoogte
- Minder bewegende delen dus meestal lagere onderhoudskosten
- Geschikt voor rechtstreekse aandrijving
- De inkoopprijs is lager in vergelijking met andere soorten pompen
- Ze leveren een gelijkmatige volumestroom
- In een aangepaste vorm geschikt voor sterk verontreinigde vloeistoffen

Nadelen:

- Centrifugaalpompen kunnen normaal gesproken geen lucht verpompen
- De volumestroom is afhankelijk van de benodigde opvoerhoogte
- Ze mogen niet draaien zonder toevoer van vloeistof

(Centrifugaalpomp principe, 2013)

Verdringerpomp

Over het algemeen zijn verdringerpompen kostelijker dan centrifugaalpompen, er wordt kort toegelicht wat hierbij de voor- en nadelen zijn van deze pompen.

http://www.sulteq.com/pomptechniek/roterende-verdringerpompen/

Voordelen:

- Geschikt voor viskeuze media
- Kleine types kunnen ook hoge drukken leveren
- De volumestroom varieert weinig bij wisselende drukverschillen
- De volumestroom kan eenvoudig geregeld worden door verandering van het toerental
- Veelal geschikt voor twee draairichtingen, waarbij ook de stroomrichting door de pomp verandert
- Zelf aanzuigend (ze kunnen lucht verwerken)

Nadelen:

- Systeem moet beveiligd worden tegen overdruk
- Veelal duurder dan centrifugaalpompen
- Sommige typen hebben 1 of meer lagers in de vloeistof, andere types meerdere as-afdichtingen

(Roterende verdringerpompen, 2013)

Hydraulische pomp

De hydrauliek heeft in vergelijking met andere kracht- en vermogenstransmissies speciale voordelen. Hydrauliek heeft bij de besturing en aandrijving van machines tot aanzienlijke prestatie- en efficiëntieverhogingen geleid.

Voordelen:

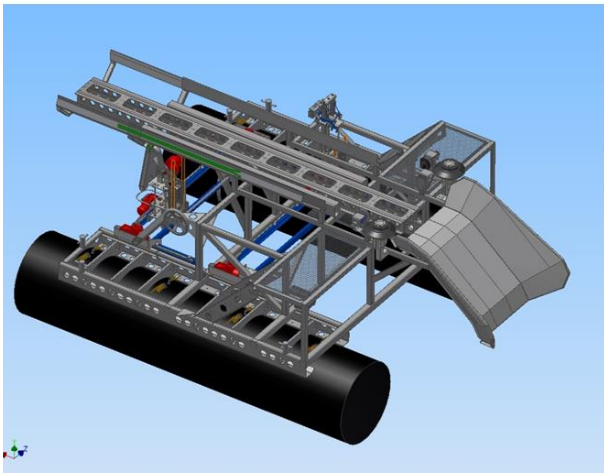
- Hoge krachtdichtheid, met beperkte benodigde ruimte
- Gemakkelijk omkeren van belastingen, daarbij is het mogelijk om te versnellen of vertragen
- Goede stuur- en regelbaarheid
- Eenvoudige transformatie van bewegingen
- Eenvoudige beveiliging tegen overbelasting
- Vrijheid in constructieve uitvoeringen
- Lange levensduur, vrij van onderhoud
- Standaardisatie is ver doorgevoerd (componenten uitwisselbaar)
- Eenvoudig te automatiseren

Nadelen:

- Afhankelijk van temperatuur, koelvoorzieningen kunnen noodzakelijk zijn.
- Lekkage van vloeistof, afdichtingproblemen kunnen in de hydrauliek tot lekverliezen leiden.
- Samendrukbaarheid van de hydraulische vloeistof (olie)
- Kosten, om lekkages te voorkomen worden hydraulische pompen met zeer geringe toleranties gefabriceerd. Dit voorhoogt de aanschaf kosten

(Hydrauliek, sd)

BIJLAGE 6



Europees Visserijfonds:
Investering in duurzame visserij

Ministerie van Economische Zaken

Jansen Tholen B.V.

Provincie Zeeland

HZ UNIVERSITY OF APPLIED SCIENCES

HOOK DETECTER

Jiejie BAO

Xiaojing YU

Boyang XIA

Xin XU

2015.1.8

Content

Introduction

Jansen Tholen B.V. has over 25 years unique in offering a variety of activities. Whether it comes to building, modification or maintenance of machines, production lines and industrial facilities, Jansen Tholen BV delivers a quality product and provides the custome with an integrated solution. This combination prevents unnecessary loss of coordination, where you reap the benefits as a customer.

Now they are facing a problem occurring in a mussel harvesting system: Hooks on the substrate wire have to been all removed before the wire goes into collecting machine. They need a system using some method to detect hooks that are not removed and send signal to the supervision system to call a halt.

Our team is here to offer a variety of possibilities to solve this issue using Eggert Methodology. This report aims to demonstrating the whole process of designing Computer Vision Software that detects hooks mainly and what decisions we make and what do we improve.

The methodology of Eggert is used in this assignment. There are 3 reasons to choose Eggert: 1.Eggert is the most similar design methodology for team members, every step and phase is well understood which will decrease the possibility of making mistakes or misunderstanding when designing. 2. As discussed at ADRM lesson, Eggert is more effective than DDM if it is a short-time engineering assignment, and this assignment exactly fits Eggert. 3. This assignment is more about designing program and testing it. Other methodologies may lean towards designing a real thing including materials and details. Eggert is feasible in designing both program and real thing.

Chapter 1: Formulation phase

1.1 Make Project Plan

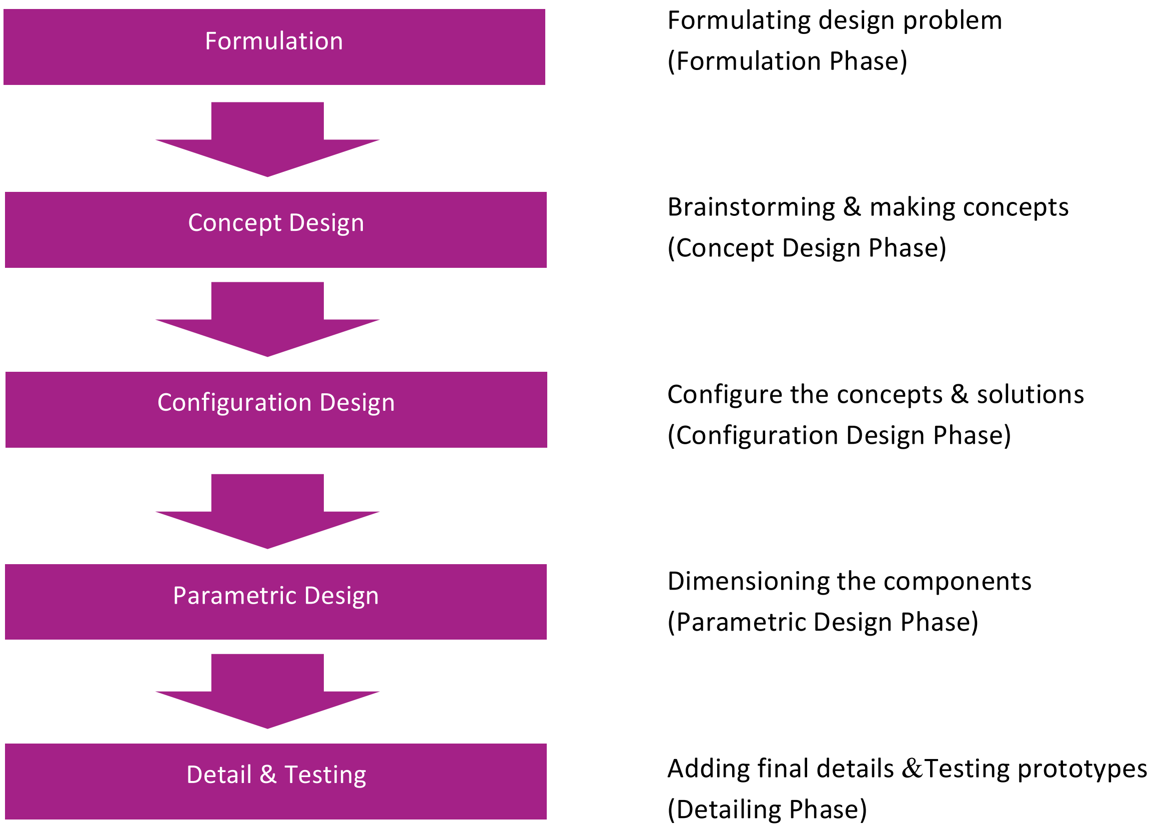


Figure 1.1

In this chapter, we have five phases: formulation phase, concept design phase, and configuration design phase, parametric design phase and detailing phase.

1.2 Define Engineering Design Specs

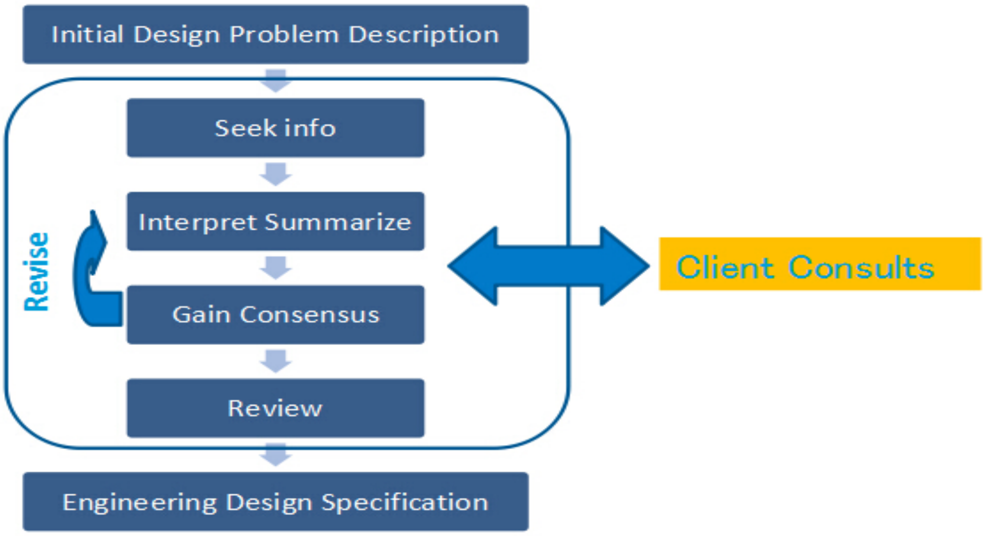


Figure 1.2

1.3 The requirements

1.3.1 Problem we meet:

- The hook has certain speed, so speed of recognition should at least satisfy the speed of hook.
- Lots of factors can influence the recognition results, so the precision is important.
- We may use software to control the device, so the parameter set is a problem.
- We should decide which signal outputs is better.

1.3.2 The requirements for solve the problems

REQUIREMENTS	
Speed of recognition	Time of recognition should be less than the min time between two hooks
Precision of recognition	Hooks can be recognized in the real environment without mistake
Parameter set	Parameter in software can be easily set and run smoothly
Signal output	Easily noticeable by staff around

Table 1.3

Chapter2 Concept phase

In this chapter, we make a function tree according to our client, and then, we have the brain storm and choose three concepts. After evaluating, we choose the best one.

2.1 Function tree

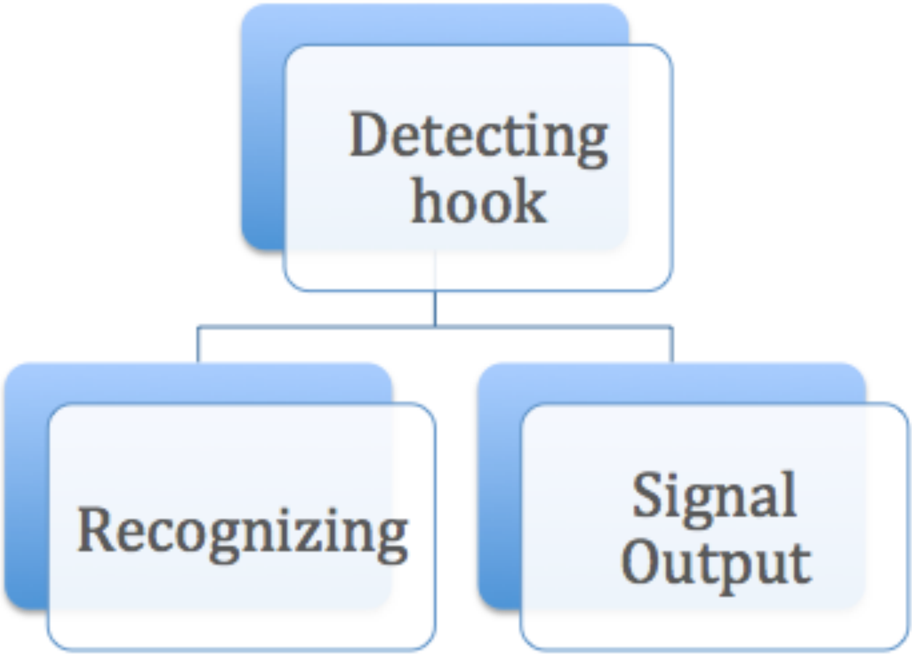


Figure 2.1

2.2 Formulate list of evaluation criteria

Before coming up with the concepts, we can make criteria according the EDS(Engineering Design Specification),and these specifications will be used in table.

Specification	Mark	Evaluate	Rate
Speed of recognition	5	Can be recognized within 0.5s	30%
	3	Can be recognized within 0.5s-1s	
	1	Can be recognized more than 1s	
Precision of recognition	5	Can recognize without any mistake	30%
	3	Need adjustment to keep precision	
	1	Cannot recognize smoothly	
Parameter set	5	Can be set easily and run perfectly	15%
	3	Can be set easily and run roughly	
	1	Need effort to set and run roughly	
Signal output	5	Noticeable and react immediately	25%
	3	Not noticeable but react immediately	
	1	Not noticeable and react not fast	

Figure 2.2

Table 2.2 is the standard of the evaluation in 2.5. The maximal mark is 5, and the minimal mark is 1. Different mark presents different certain meanings.

2.3 Concept choice

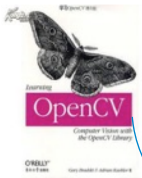
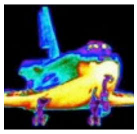
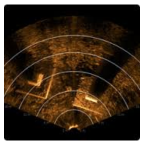
Recognizing	 ComputerVision	 Line sensor	 Limit switch	 X-ray	 Infrared-ray	 Ultrasound	 Nuclear magnetic resonance
Output signal(alarm)	 Speaker	 Buzzer	 Light				

Figure 2.3

(Solutions of X-ray, Infrared ray, Ultrasound, Nuclear magnetic resonance are not considered according to their costs and our limited knowledge.)

2.4 Make concept sketches

Concept 1:

Concept 1 = Computer vision software + light.
If there is any hook on the substrate wire, there will pass through an area where the camera takes picture. Then the picture will be sent to the computer and analyzed & compared. If the picture shows no hook, nothing happens. If the picture shows a hook, the sensor will output a high voltage signal (higher than a certain standard). Once the light receives the high voltage, It will operate immediately to warn people around. Also, the signal will be sent to the supervising system to decide to call a halt.

Concept 2:

Concept 2 = line sensor + buzzer.
If there is any hook on the substrate wire, there will pass through an area where the sensor launches infrared ray. If the line sensor detects no hook, nothing happens .If the line sensor detects a hook, the sensor will output a high voltage signal (higher than a certain standard). Once the buzzer receives the high voltage, it will operate immediately to warn people around. Also, the signal will be sent to the supervising system to decide to call a halt.

Concept 3:

Concept 3 = limit switch + speaker

If there is any hook on the substrate wire, it will touch the limit switch. The limit switch will represent a high voltage level which will enable the speaker operate to warn people immediately. Also, the signal will be sent to the supervising system to decide to call a

2.5 Evaluate concept choices

Criteria		Concept 1		Concept 2		Concept 3	
	Importance weight (%)	Rating	Weighted rating	Rating	Weighted rating	Rating	Weighted rating
Speed of recognition	30	4	1.2	5	1.5	5	1.5
Precision of recognition	30	5	1.5	3	0.9	3	0.9
Parameter set	15	3	0.45	5	0.75	5	0.75
Signal output	25	5	1.25	4	1	3	0.75
Total	100	NA	4.35	NA	4.15	NA	3.9
Result	Concept 1 is the best one						

Table 2.5

2.6 Evaluate the ultimate concept choices

Concept 1 has been chosen to be the best concept according to highest score in the weigh rated matrix.

Concept 1 gets higher score in requirement of precision of recognition than other two concepts although it is a little lower than other two in speed of recognition. But it is obvious that more emphasis should be put on precision of recognition rather than speed of recognition. As long as the system can recognize hook precisely, a more powerful CPU can be replaced in the computer to increase the speed of recognition.

Concept 1 also gets a relatively low score in parameter set because it needs a large amount of calculation to ensure precision in software. In the other hand, although no effort need to pay to use line sensor and limit switch, these two ways to recognize may have a possibility to make mistakes or miss hooks.

Signal output is another important requirement to determine the performance of how the system would warn people around. Concept 1 uses a light instead of a speaker and a buzzer in other two concepts. Light is better than other two ways in our opinion because people can see the light even they are in a noisy environment, and buzzer may not be effective considering the environment on a ship.

Chapter3: Configuration Phase

3.1 Alternative configurations and the corresponding analyzing

According to the concept phase, we choose the concept ComputerVision + Light as the final concept. After discussion we also assume three different possible ways of configuration to make our concept possible. Since only two main functions are selected, there is main configuration of choosing software and calculation in software (preliminary processing and main processing). But the basic processes of analyzing in software are the same.

Working Flow in software:

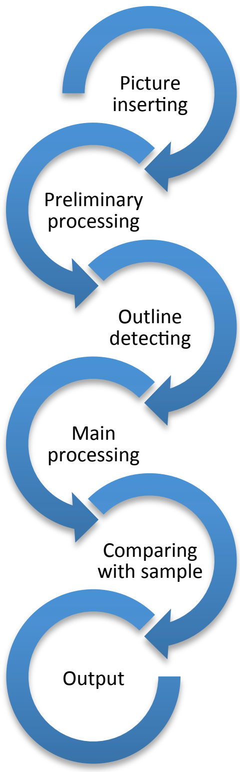


Figure 3.1

Configuration 1

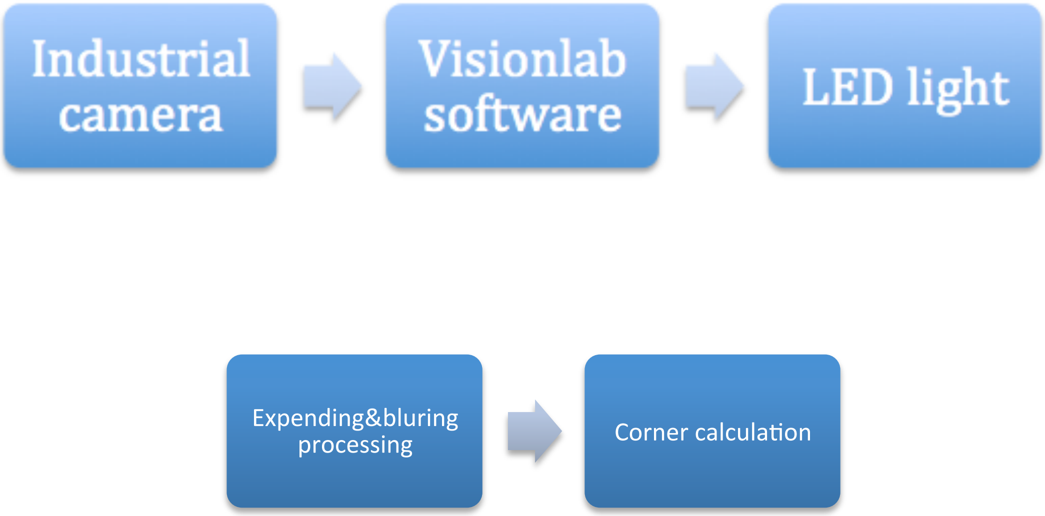


Figure 3.2

In configuration 1, the software VisionLab is used for recognizing.

There are two main steps for analyzing picture, expending&bluring is used to change the color of every point in the picture into the color of the center of every pixel. What is mentioned is to make the picture can be processed by later steps.

Corner calculation can be used to calculate the important and characteristic points in the picture

Configuration 2

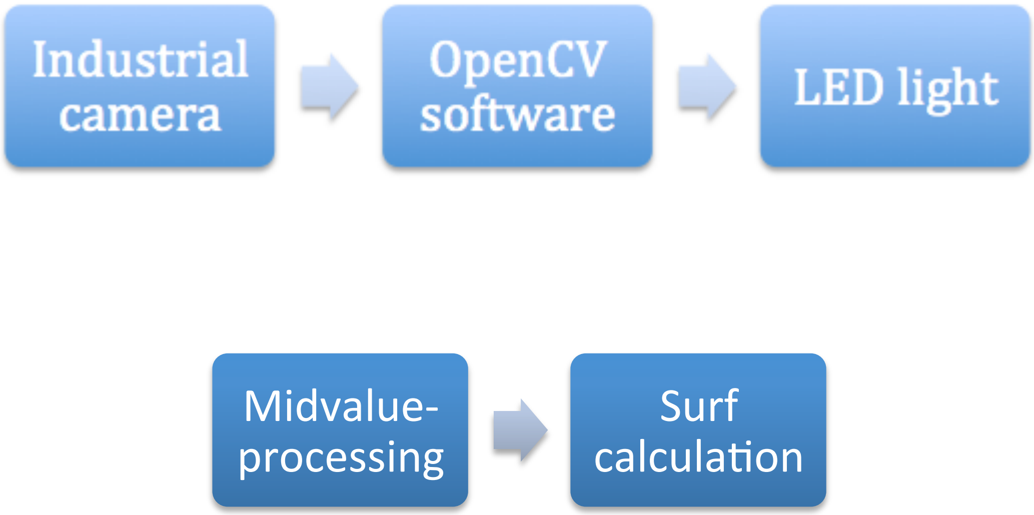


Figure 3.3

In configuration 2, the software OpenCV is used for recognizing.

There are two main steps for analyzing picture, midvalue-processing is used to change the color of every point in the picture into the average color of every pixel. What is mentioned is to make the picture can be processed by later steps.

Surf calculation can be used to calculate the important and characteristic points in the picture. It has a better ability to recognize but take a little more time than other ways.

Configuration 3

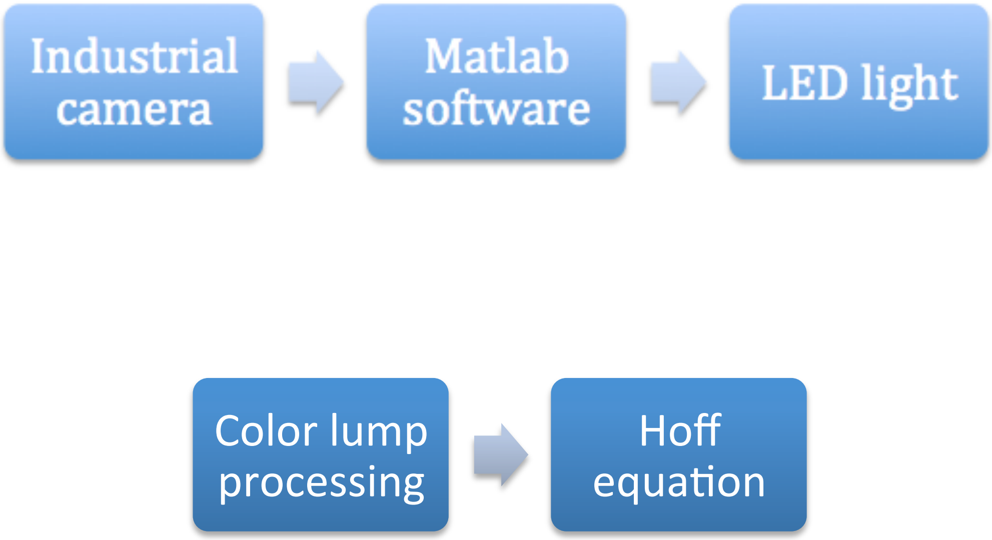


Figure 3.4

In configuration 3, the software Matlab is used for recognizing.

There are two main steps for analyzing picture, Color lump processing is used to change the color of every point in the picture into a color lump. What is mentioned is to make the picture can be processed by later steps.

Hoff equation can be used to calculate and find the straight line in the picture.

Configuration 4

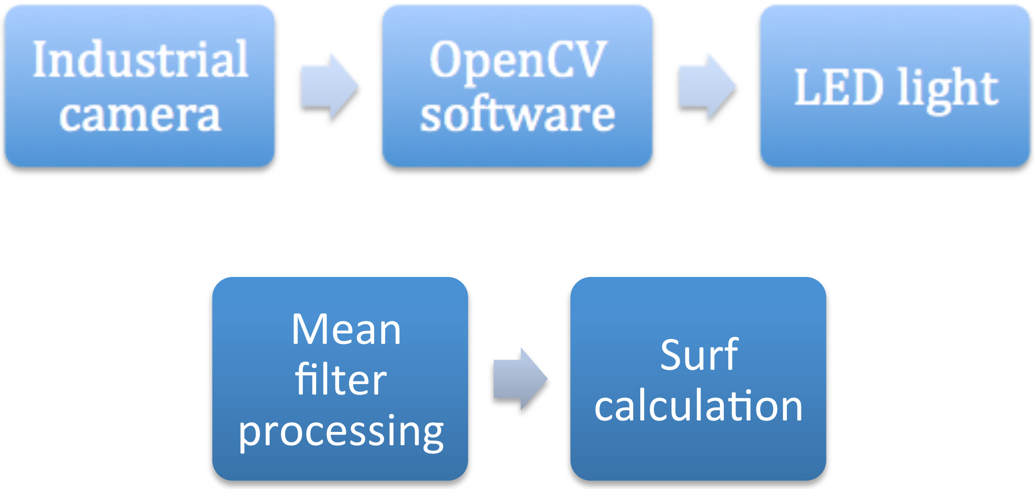


Figure3.5

In configuration 4, the software OpenCV is used for recognizing.

There are two main steps for analyzing picture, Mean-filter processing is used to decrease the influence of other unimportant points in the picture and blur it. What is mentioned is to make the picture can be processed by later steps.

Surf calculation can be used to calculate the important and characteristic points in the picture. It has a better ability to recognize but take a little more time than other ways.

Configuration 5

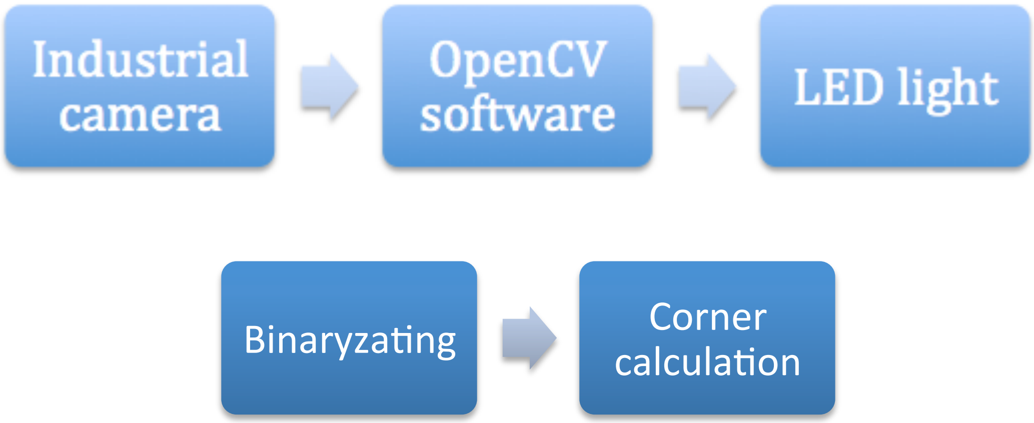


Figure 3.6

In configuration 5, the software OpenCV is used for recognizing.
There are two main steps for analyzing picture, Binartzating is used to make the picture only into color of black and white. What is mentioned is to make the picture can be processed by later steps. Corner calculation can be used to calculate the important and characteristic points in the picture

3.2 Evaluate configuration

According to the weighted rating matrix, **Configuration 2** is the best configuration according to its the highest score.
But **Configuration 4** and **Configuration 5** can be adopted in case Configuration 1 is not feasible in following phases.
Since high precision is demanded for the system, Midvalue-processing and Surf calculation are selected because they are more precise than other methods of analyzing.
On the other hand, about the selection of software: The advantage of matlab is easy to study, and it rough to program, the disadvantage is the low efficiency. Compared with Matlab, OpenCV only needs programmer's background of C/C++ programming, which is familiar for us and OpenCV is more precise and is used in engineering frequently. And visionlab is not as comprehensive as Matlab and OpenCV. Finally, Software OpenCV is selected.

Chapter 4: Parametric phase

4.1 List of parameter

Type	Name	Need further test or not
Hardware	Distance from camera to substrate	NO
	Maximum frequency of taking picture	NO
Input image	Size	NO
	Pixel	NO
	Degree of contrast	NO
	Aspect ratio	NO
	Degree of brightness	NO
Output image	Size	NO
	Pixel	NO
	Degree of contrast	NO
	Aspect ratio	NO
	Degree of brightness	NO
Sample image	Size	NO
	Pixel	NO
	Degree of contrast	NO
	Aspect ratio	NO
	Degree of brightness	NO
	Numbers of feature points	YES
Processing	Threshold of Binarization	YES
	Size of Kernel in Gaussinan	YES
	Threshold of SURF	YES
	Minimum number of points of matching	YES

Figure 4.1

The "NO" here just indicates that in this assignment those parameters marked "NO" don't need further test. But it may need further some test to show the feasibility of parameters in other assignments related to this.

Normally, it is mainly about the type of industrial camera used that influences the decision to do further test or not to determine parameters.

4.2 Parameter setting

- Distance from camera to substrate： 1m

The decision is made that the camera should be setup at a distance of 1m from the substrate wire. 1m is a good choice that the detecting system can not only obtain a good view of the substrate wire and hooks, but also have less influence to the machine.

- Maximum frequency of taking picture： 1 time every second

Considering the speed of the substrate wire may reach 1m/s and the distance between hooks are approximately 1m.

- Input image Size: larger than 2MB less than 5 MB
  Input image Pixel: 600*800
  Input image degree of contrast: 120:1
  Input image aspect ratio: 4:3
  Input image degree of brightness: 6 (from 0-10)

- Output image Size: larger than 2MB less than 5 MB
  Output image Pixel: 1200*800
  Output image degree of contrast: 1:1
  Output image aspect ratio: 8:3
  Output image degree of brightness: 6 (from 0-10)

- Sample image Size: larger than 2MB less than 5 MB
  Sample image Pixel: 600*800
  Sample image degree of contrast: 120:1
  Sample image aspect ratio: 4:3
  Sample image degree of brightness: 6 (from 0-10)
  Sample image numbers of feature points: ***to be tested***

- Threshold of Binarization: 65 (from 0 to 255) ***to be tested***

- Size of Kernel in Gaussinan: 3*3 ***to be tested***

- Threshold of SURF: 6000 ***to be tested***

- Minimum number of points of matching: 300 ***to be tested***

Parameters are going to be tested have a great impact on accuracy of detecting, it is necessary to do tests to determine which value exactly can detect precisely.

4.3 Arrays of pictures to test

Environment is complex, we cannot forecast that we can just meet the hook, besides some constant disturbance (wires and mussels), some unpredictable factors also can make some detecting jammings.

4.3.1 Increase difficulty of detecting hooks

- Only hook with white background color

Figure 4.2

- Hook with substrate wire with white background color

Figure 4.3

- Hook with substrate wire with background with disturbance

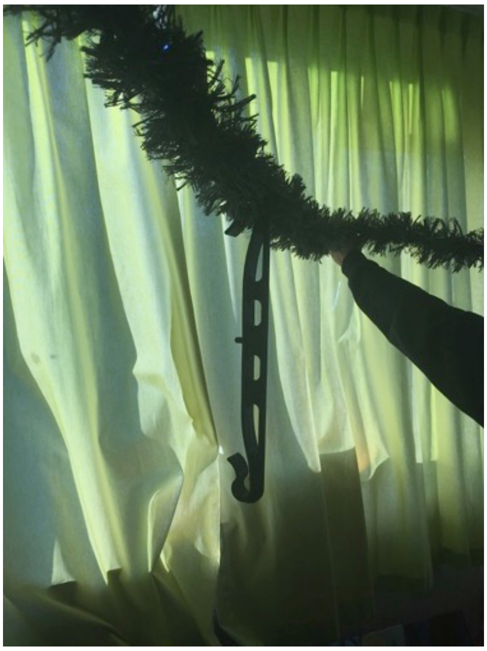


Figure 4.4

- Hook with substrate wire with more disturbance

Figure 4.5

4.3.2 Check if other subjects can be detected

- A pen with white background to check if the system can only hooks

Figure 4.6

- Substrate wire

Figure 4.7

Chapter 5: Detailing phase

5.1 Configuration Change

The following image is the result made by midvalue-preprocessing+SURF calculation(The program can be seen in appendices). As can be seen in the right part of the image, a large number of matching points are not located on the hook but somewhere in the background. So SIFT calculation is considered to replace SURF since SIFT is more precise than SURF.

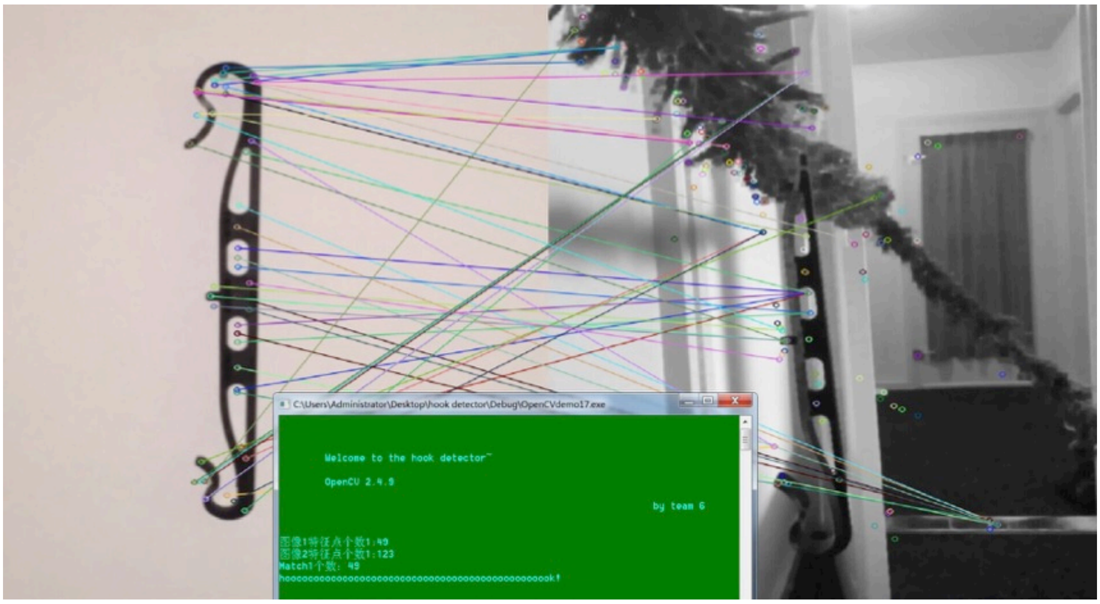


Figure 5.1

In addition, midvalue-processing is not as sufficient as expected. So open operation is considered to replace that since there is influence from special parts of substrate wire. RANSAC is another method to be used in the software which is expected to remove the matching points that far from satisfactory.

According to these changes, another test is set up and parameters will be configured according to the result.

5.2 Test result

1.Hook+Substrate						
Threshold value\open operation	3	4	5	7	8	9
200	11:16	08:17	07:13	02:10	04:11	01:12
300	10:15	03:15	08:14	03:10	02:11	03:12
500	10:13	06:13	10:18	04:10	03:10	01:12
800	13:16	08:16	10:18	04:10	02:10	01:12
1000	13:16	08:16	10:18	04:10	02:10	01:12
2.Pen						
Threshold value\open operation	3	4	5	7	8	9
200	13	17	11	13	13	12
300	13	17	11	13	13	12
500	13	17	11	13	13	12
800	13	17	11	13	13	12
1000	13	17	11	13	13	12
3.Hook+Substrate（light disturbance）						
Threshold value\open operation	3	4	5	7	8	9
200	04:12	07:16	14:19	05:09	09:14	09:13
300	08:15	14:16	05:13	06:08	09:14	13:17
500	14:21	12:20	21:25	13:15	09:14	13:17
800	14:21	16:21	21:25	12:15	09:14	13:17
1000	14:21	16:21	21:25	12:15	09:14	13:17
4.Substrate						
Threshold value\open operation	3	4	5	7	8	9
200	12	14	16	10	11	13
300	13	13	16	10	11	13
500	14	13	16	10	11	13
800	12	13	16	10	11	13
1000	12	13	16	10	11	13
5.Hook+Substrate（shadow disturbance）						
Threshold value\open operation	3	4	5	7	8	9
200	12:22	10:18	10:17	02:12	07:12	08:12
300	11:19	05:13	11:18	05:10	07:14	09:13
500	05:16	13:20	11:16	05:10	06:13	09:13
800	07:17	11:18	11:16	05:10	06:13	09:13
1000	07:17	11:18	11:16	05:10	06:13	09:13

6.Hook+Substrate（less disturbance）						
Threshold value\open operation	3	4	5	7	8	9
200	09:14	03:11	05:11	08:12	05:09	09:13
300	05:16	11:13	10:13	08:11	05:09	09:13
500	09:15	11:13	10:13	08:11	05:09	09:13
800	09:13	11:13	10:13	08:11	05:09	09:13
1000	09:13	11:13	10:13	08:11	05:09	09:13

Figure 5.2

(X: Y X is the number of matching points on hook; Y is the number of all matching points)

After analyzing the test data, parameters are defined: Value of threshold=300 Size of open operation=3.

But there is still disturbance from somewhere else on the picture, so Gaussian is decided to be used in the preprocessing step to reduce disturbance from the picture.
Size of Gaussian=3

5.3 Final result

At the end, the configuration in the configuration phase is almost completely changed. Now we are using open operation and Gaussian as preprocessing, SIFT and RANSAC as main processing method.

Over 90%

to detect any picture whether there is a hook in a background with limited disturbance

Final Working Flow:

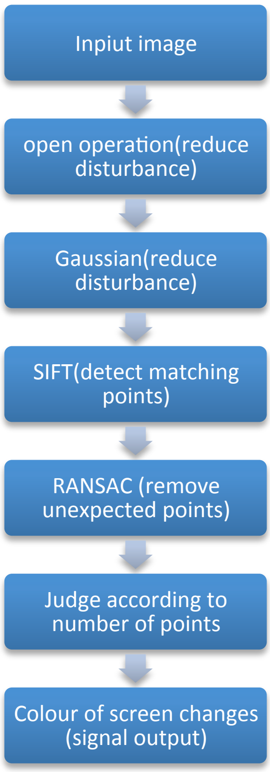


Figure 5.3

Final Test Result:

The background color of the program is blue originally, but it will turns into red if hook is detected. And number of match points is demonstrated. In the code, if the number is more than 15, that means there is a hook in the picture.

- **Hook only**

Figure 5.4

- **Hook+Substrate1**

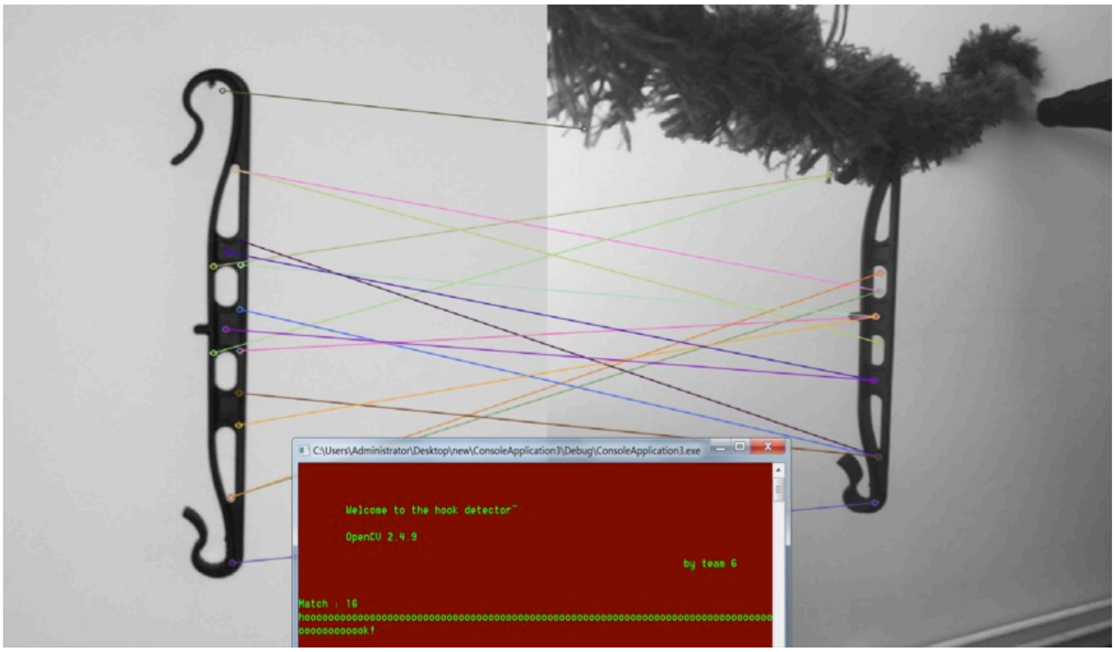


Figure 5.5

- **Hook+Substrare2**

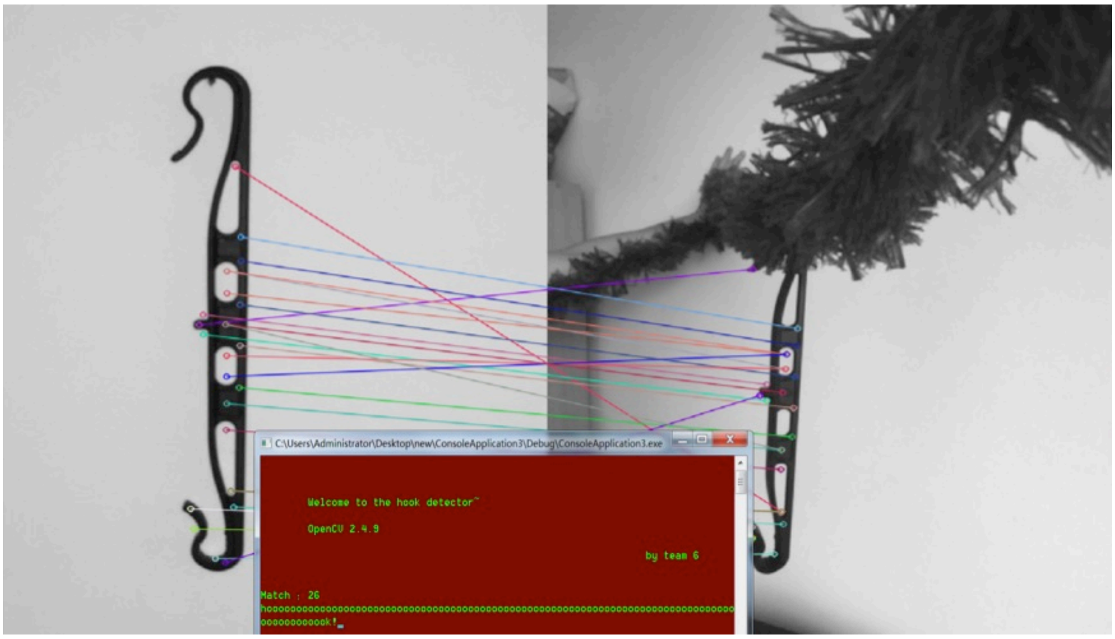


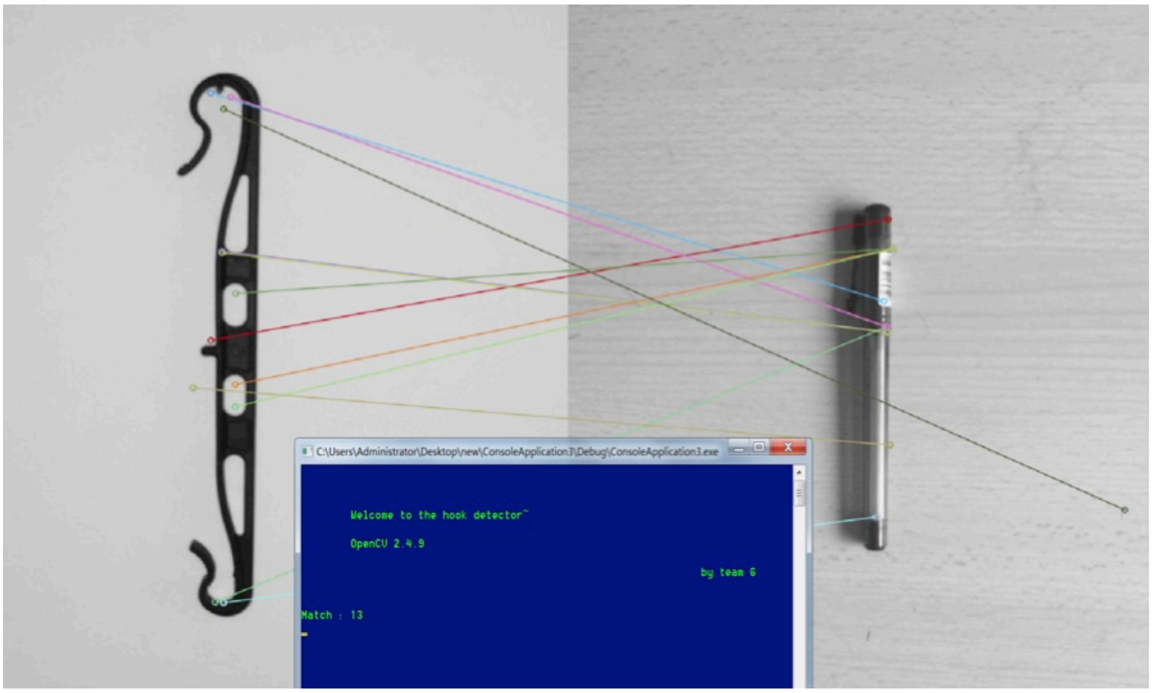
Figure 5.6

- **Hook+Substrate+Dimlight**

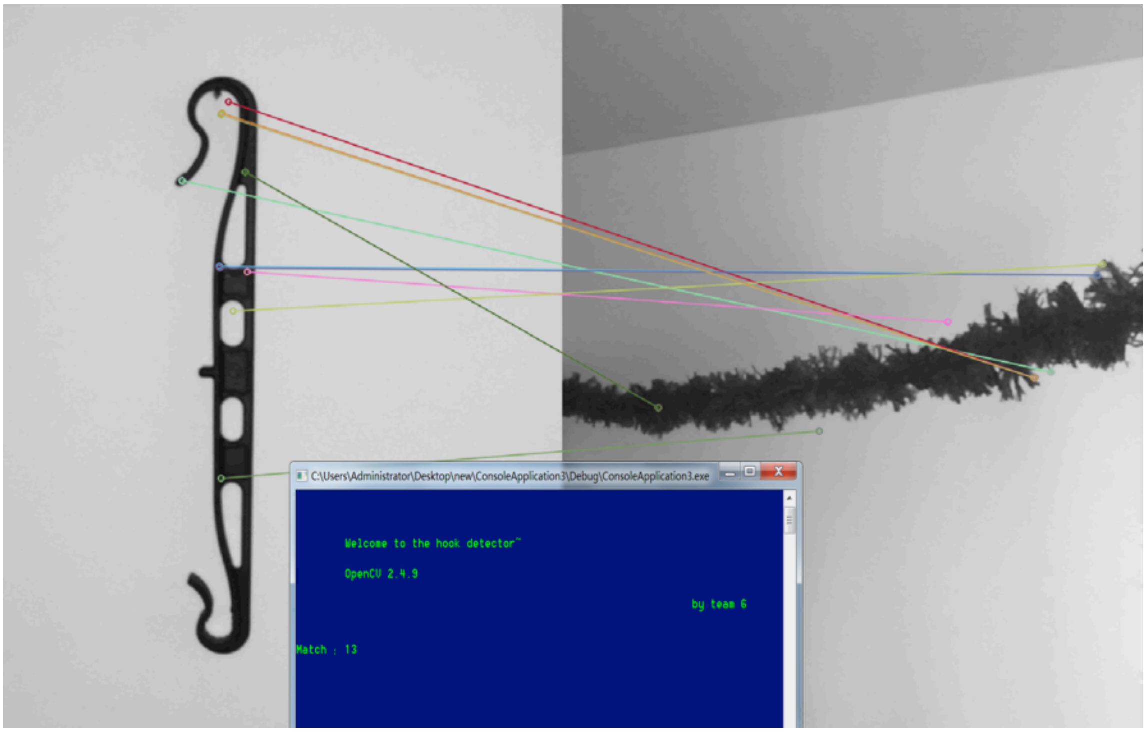
Figure 5.7

- **Hook+Substrate+Disturbance**

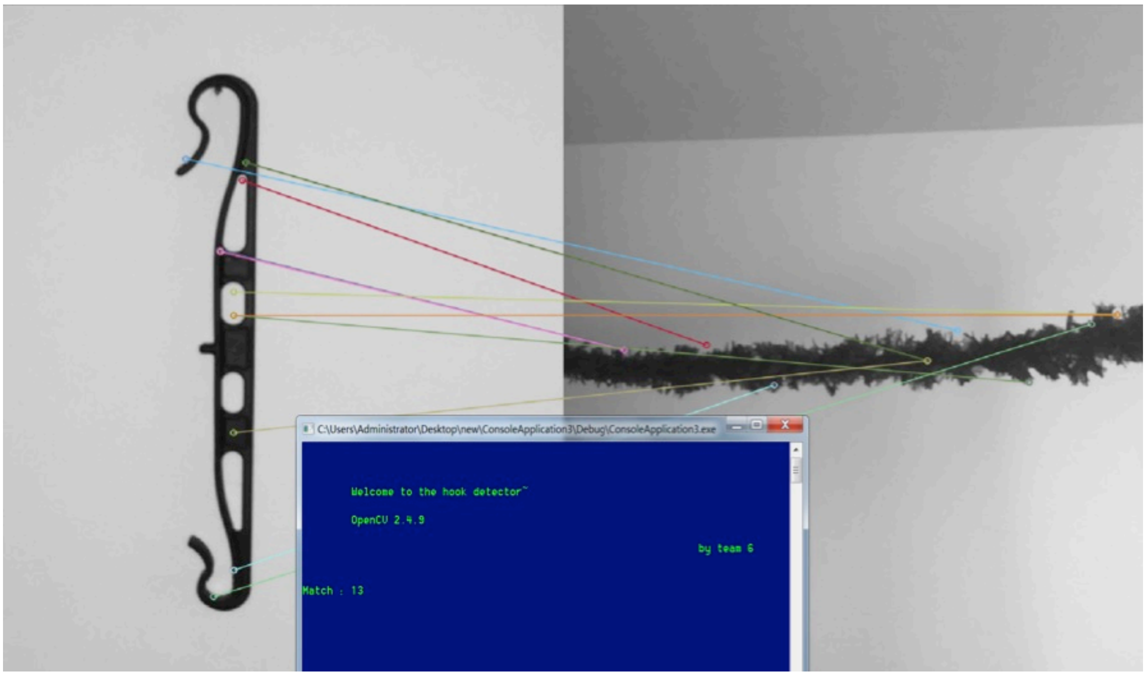
- **Pen**



- **Substrate1**



- **Substrate2**



Summary

How to detect hooks when harvest mussels. First of all, we listed the problems we met, then discussed the requirements needed. According to the requirements we draw the function, then came up with 3 concepts and selected the best concept, we also came up with 5 configurations for the best concept, then analyzed it so that got the best configuration.

Finally, we chose the image recognition to detect hooks. Pictures will be acquired by industrial camera, recognized and matched pictures by Open CV. It will shine the LED light to warn people notice it. To realize it, we set some parameters of Open CV, after that, we test lots of pictures which in some different situations. Finally got a good precision. Something need to be improved also be mentioned in the appendix.

Appendix 1

Program of Open CV:

```
#include "opencv2/core/core.hpp"
#include "opencv2/features2d/features2d.hpp"
#include "opencv2/highgui/highgui.hpp"
#include <opencv2/nonfree/nonfree.hpp>
#include<opencv2/legacy/legacy.hpp>
#include <iostream>


using namespace cv;
using namespace std;
static void ShowHelpText();
int main()
{

    //【0】change color of words
    system("color 1A");

    //【0】show help text screen
    ShowHelpText();
    Mat img_object = imread("1t.jpg", 0);
    Mat img_scene = imread("sample.jpg",0);
    Mat Gaussinan;
    Mat element = getStructuringElement(MORPH_RECT, Size(3,3));
    //open operation
    morphologyEx(img_object, img_object, MORPH_OPEN, element);
    morphologyEx(img_scene, img_scene, MORPH_OPEN, element);
    GaussianBlur(img_object, img_object, Size(3, 3), 0, 0);
    GaussianBlur(img_scene, img_scene, Size(3, 3), 0, 0);

    //step1:surf detection//////////////////////////////////////////////////////////////////
    int minHeassian =300;
    SiftFeatureDetector detector(minHeassian);

    std::vector<KeyPoint> m_LeftKey, m_RightKey;

    detector.detect(img_object, m_LeftKey);
    detector.detect(img_scene, m_RightKey);

    //step2:calculate the feature vector//////////////////////////////////////////////////////////////////
    SiftDescriptorExtractor extractor;
```

```
Mat descriptors_object, descriptors_scene;

extractor.compute(img_object, m_LeftKey, descriptors_object);
extractor.compute(img_scene, m_RightKey, descriptors_scene);

//step3:use flann to match the points//////////////////
FlannBasedMatcher matcher;
std::vector<DMatch> m_Matches;
matcher.match(descriptors_object, descriptors_scene, m_Matches);


// arrange space
int ptCount = (int)m_Matches.size();
Mat p1(ptCount, 2, CV_32F);
Mat p2(ptCount, 2, CV_32F);

// change Keypoint to Mat
Point2f pt;
for (int i = 0; i<ptCount; i++)
{
	pt = m_LeftKey[m_Matches[i].queryIdx].pt;
	p1.at<float>(i, 0) = pt.x;
	p1.at<float>(i, 1) = pt.y;

	pt = m_RightKey[m_Matches[i].trainIdx].pt;
	p2.at<float>(i, 0) = pt.x;
	p2.at<float>(i, 1) = pt.y;
}

// use RANSAC
 Mat m_Fundamental;
vector<uchar> m_RANSACStatus;
m_Fundamental = findFundamentalMat(p1, p2, m_RANSACStatus, FM_RANSAC);

// calculate unexpected points
int OutlinerCount = 0;
for (int i = 0; i<ptCount; i++)
{
	if (m_RANSACStatus[i] == 0) // 0 is unexpected point
	{
		OutlinerCount++;
	}
}
```

```
vector<Point2f> m_LeftInlier;
  vector<Point2f> m_RightInlier;
  vector<DMatch> m_InlierMatches;
int InlinerCount = ptCount - OutlinerCount;
m_InlierMatches.resize(InlinerCount);
m_LeftInlier.resize(InlinerCount);
m_RightInlier.resize(InlinerCount);
InlinerCount = 0;
for (int i = 0; i<ptCount; i++)
{
	if (m_RANSACStatus[i] != 0)
	{
		m_LeftInlier[InlinerCount].x = p1.at<float>(i, 0);
		m_LeftInlier[InlinerCount].y = p1.at<float>(i, 1);
		m_RightInlier[InlinerCount].x = p2.at<float>(i, 0);
		m_RightInlier[InlinerCount].y = p2.at<float>(i, 1);
		m_InlierMatches[InlinerCount].queryIdx = InlinerCount;
		m_InlierMatches[InlinerCount].trainIdx = InlinerCount;
		InlinerCount++;
	}
}


vector<KeyPoint> key1(InlinerCount);
vector<KeyPoint> key2(InlinerCount);
KeyPoint::convert(m_LeftInlier, key1);
KeyPoint::convert(m_RightInlier, key2);


Mat OutImage;
//show pictures and results
drawMatches(img_object, key1, img_scene, key2, m_InlierMatches, OutImage);
namedWindow("4", WINDOW_NORMAL);
imshow("4", OutImage);
cout << "Match ： " << m_InlierMatches.size() << endl;
if (m_InlierMatches.size()>15)
{

printf("hoooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo
oooooooooooooooooooooook!");
	system("color 4A");
}
waitKey(0);
```

```
    return 0;
}
static void ShowHelpText()
{
    //output test information
    printf(    "\n\n\n\tWelcome to the hook detector~\n\n");
    printf("\tOpenCV "CV_VERSION
        "\n\n\t\t\t\t\t\t\t\t by team 6 \n\n\n"    );
}
```

Appendix 2

Expected Problem

Problem	Description
The system can not detect hook precisely because the angle which the camera takes picture changes	The angle has to be in a certain range to keep most characteristic points in the picture. But if the angle changes too much, the picture will become less characteristic and hard to detect
The system will be not precise if something very similar to a hook (black and simple shape) appears in the picture	The detecting method is according to finding similar points between sample and picture taken by camera. So it will become not effective if a extremely similar subject appears in the picture
The system may not work if wrong format of pictures are input	600*800 pixel has been set in the program as the standard pixel and everything operates based on that. So only pictures of 600*800 is accepted
The system may not work if video is input instead of picture	The system still only supports image in regular format (.jpg .png .bmp). It will only take the first frame if a video is input
The system may not work if more than one hook in the picture	The system can detect only one hook if there are more than one hook in the picture, and all matching points focus on one hook

Recommended Hardware and Software

Part Name	Recommended Hardware/Software
Industry Camera	Basler acA800-560uc
PC	Intel Core I7 with 4GB RAM
Single-Chip Microcomputer	Siemens 80C51
Software Database	OpenCV 2.4.9
Operating Environment	Visual Studio 2013+Windows 7
Aspect of hook should be taken	

Instruction Brochure

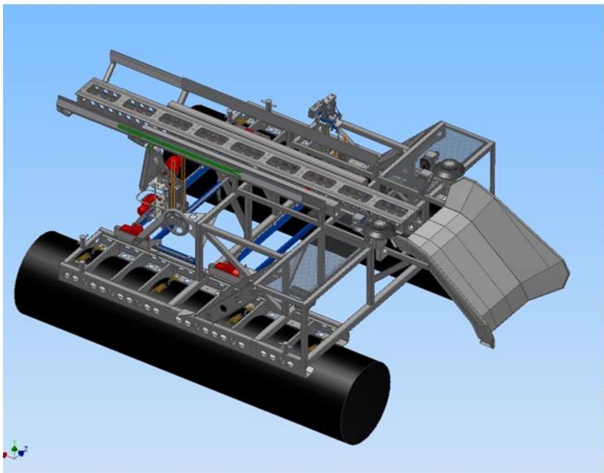
1. Install Windows 7 and VisualStudio 2013
2. Install OpenCV 2.4.9
3. Configure VisualStudio 2013 according to: https://www.youtube.com/watch?v=vwhTKsvHwfQ
4. Open “hookdetector.sin” and put picture to be detected in file “image”
5. Replace “sample.jpg” with the name of picture to be detected in the following code in program.

   “Mat img_scene = imread("sample.jpg",0);”

6. Operate the program by pressing F5 on keyboard, wait until the result appears:

If the color of the window turns from blue into red, it indicates there is a hook detected; If the color doesn’t change, it indicates that no hook detected.

BIJLAGE 7



Europees Visserijfonds:
Investering in duurzame visserij

Ministerie van Economische Zaken

Jansen Tholen B.V.

Provincie Zeeland

HZ UNIVERSITY OF APPLIED SCIENCES

Design of Mussel Detection system
------Project Report

Group 7

Date: 22.01. 2015
Version number: 2.0
Major: Mechatronics Engineering
Course number: CU158909

Members: Teng Yang
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Organization: HZ University of Applied Science & Jansen Tholen B.V.

Place: HZ University of Applied Science

CONTENTS

1. Introduction

Jansen Tholen B.V. designed a mussel harvesting system, which can realize the fully automated mussel harvesting. However, there remain problems during the design. So, Jansen Tholen B.V. has a cooperation project with HZ University of applied sciences. And group 7 receives an assignment to design a detection system that can count the remaining mussels on the substrate line.

2. Summery

2.1 Reason for the project

According to the information provided by Jansen Tholen B.V., the existing mussel removing system can remove the almost all of mussels. However, the percentage of damage is unsatisfied. Decreasing the speed of harvesting process can reduce the percentage of damage with the cost of lower efficiency. It means more mussels remain on substrate line and lower harvesting speed. Therefor, a detecting system should be developed to monitor the process of mussel harvesting and find the most efficient point (relatively less damage and remaining percentage).

2.2 Main question

Build a machine that can detect how many mussel remains during the process of harvesting?

Detailing description

Develop a detection system, which can detect the percentage of remaining mussel after the substrate wire goes through the harvesting machine. Process the test to make sure the ability of detection device to detect the mussels. In addition, the concept of how to transmit the detecting signal needs to be defined.

1. Build the prototype of mussel harvesting detecting device with fundamental function.
2. Test the prototype of mussel harvesting detection as realistic conditions possible. Record measurement data.

3. Background information

3.1 Host organization

Jansen Tholen B.V.
Jansen Tholen B.V. has a 25-year reputation in providing unique solutions to a broad industrial sector. Whether it concerns the construction, modification or maintenance of machinery, production lines and industrial installations, Jansen Tholen B.V. delivers quality products and integrated solutions to their customers.
The engineering-department of Jansen Tholen department provides in depth insight in the project by using a 3D-design, in which adjustment can be made in an early stage of the project. In our case, Jansen Tholen provides specifically designed devise to supervises the harvesting system, stores the empty substrate wire in a bag, removes hooks from the substrate wire, removes mussels from substrate wire.

Fig 3.1 Jansen Tholen B.V.

3.2 Mussel harvesting

The regulations for catching seed mussels are becoming stricter. In particular, the obtaining of seed mussels from the natural seed banks will be further restricted in the future. The seed mussels are planted in nurseries, where they then grow to fully-grown edible mussels.
Because bottom fishery is becoming more restricted, a new system has been devised to obtain seed mussels. In the seawater-floating mussel larvae are caught in nets and ropes. How this can be done in a convenient, cheap and cheaply executed way is currently under investigation. For now, this type of seed capturing is more expensive than obtaining the seeds on natural mussel beds.

3.3 Machine vision detection

Machine vision (MV) is the technology and methods used to provide imaging-based automatic inspection and analysis for such applications as automatic inspection, process control, and robot guidance in industry. The scope of MV is broad. MV is related to, though distinct from, computer vision.

Machine vision methods are defined as both the process of defining and creating an MV solution, and as the technical process that occurs during the operation of the solution. Here the latter is addressed. As of 2006, there was little standardization in the interfacing and configurations used in MV. This includes user interfaces, interfaces for the integration of multi-component systems and automated data interchange. Nonetheless, the first step in the MV sequence of operation is acquisition of an image, typically using cameras, lenses, and lighting that has been designed to provide the differentiation required by subsequent processing. MV software packages then employ various digital image-processing techniques to extract the required information, and often make decisions (such as pass/fail) based on the extracted information.

4. Formulation

4.1 Analysis of assignment

In project, the concept of how to detect percentage of remaining mussel should be developed. A certain detecting method should be proved that it could be able to get the accurate numbers of mussels that are still on substrate wire. To make sure Jansen Tholen B.V. can adjust the force of machine that used to harvest mussels, the numerical signal should be provided.

Products and sub-products
Detecting device of remaining mussel

- Exact definition of system boundaries
- A prototype of detecting device, which can realize the above-mentioned functions.
- Test and calculation results that can prove the function of device
- Other design dependency that contribute to the harvesting process

4.2 Project plan

As the analysis problem has been formulated, it is essential to understand the problem and plan its solution. After gathering related information, the project plan has been made to guide us.

4.3 EDS

Fundamentally, products are bought to satisfy needs and wants. The most important requirement of a product is that it should work. The information has been negotiated with client in detail.
The EDS requirements include 5 main categories: Design, Manufacturing/production, Transportation, Usage, Maintenance and Financial. After discussing with our client, the final requirements are listed in Appendix Table EDS.

4.4 Weight of requirements

Following table shows the weight of the requirements, which is the standard of judgment. The weight has been negotiated with client.

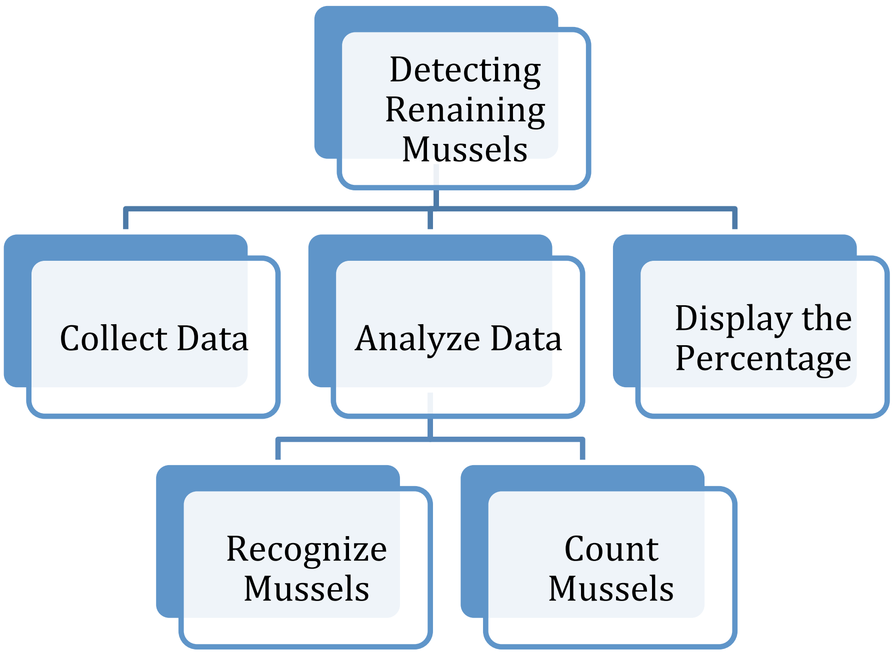
Table 4.4.1 weight of requirements

Requirements	Rating points（1～5）
1.Expected accuracy	5
2.Test difficulty	3
3.Good ability to work outside	1
4.Simple structure	1
5.Ease of UI	1

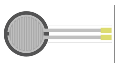
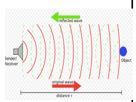
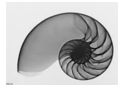
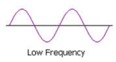
5. Concept Design

The basic functions are determined in concept phase. In addition several concepts will also be judged in this phase, according to weight matrix. After evaluation, best concept will be determined.

5.1 Function Tree



5.2 Morphological matrix

Functions	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5	Solution 6	Solution 7
Recognize mussels	 Infrared sensor	 Force sensor	 Camera	 Ultrasound device	 MRI	 X-ray	 low frequency electric field
Count Mussels	 PLC	 Computer	 Single chip				
Display the Percentage	 Lights	 LED screen	 Speaker				

Concept 1: Infrared radiation, PLC, Speaker
Concept 2: Force sensor, Computer, Lights
Concept 3: Camera, Computer, LED screen
Concept 4: ultrasound device, Single chip, Speaker
Concept 5: MRI, Computer, LED screen
Concept 6: X-ray, Computer, LED screen
Concept 7: Low frequency electric field, PLC, Lights

5.3 Concepts & Rough geometry layout sketches

Concept 1: Infrared sensor

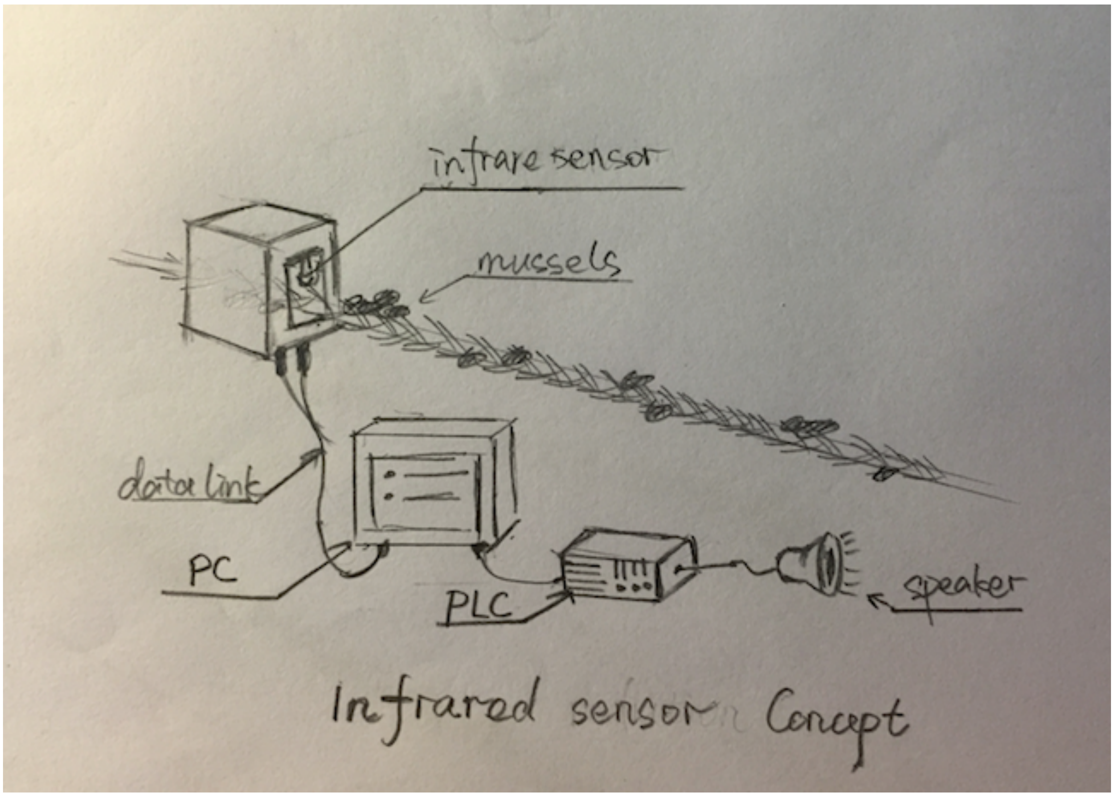


Fig 5.3.1

In the infrared sensor science, thermo-graphic cameras detect radiation in the infrared range. Since infrared radiation is mitted by all objects above absolute zero according to the black body radiation law, thermography makes is possible to see one's environment with or without visible illumination. Infrared imaging science is also possible to detect cool blooded animal like mussel. In mussel detection's situation, one or more thermo graphic cameras must be placed around the substrate line. Sensors can detect and thermo. After that, computer wills analysis the data and shows how many mussels are remained on the substrate line.

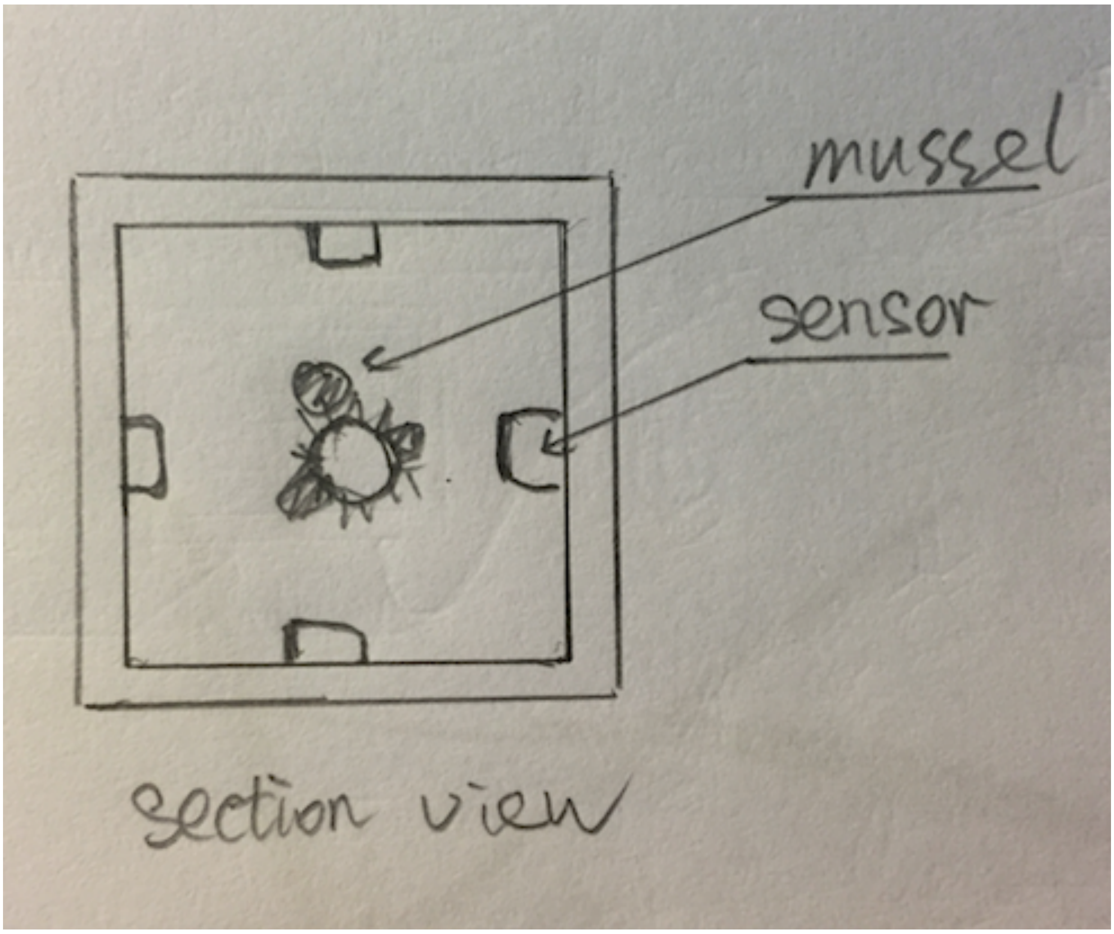


Fig 5.3.2

As shown on fig 5.3.1, the substrate line with remaining mussel will go through a detection device; several infrared sensors will be installed on it. When there is a mussel, the sensor will recognize it and count. Since the infrared radiations of mussels are very small, the amount of infrared sensors and the position of them will be the key of this concept. In the section view (Fig 5.3.2), four sensors will be installed, surrounding the substrate line, which make it easier to sense weak signal of infrared radiations.

Concept 2: Force sensor

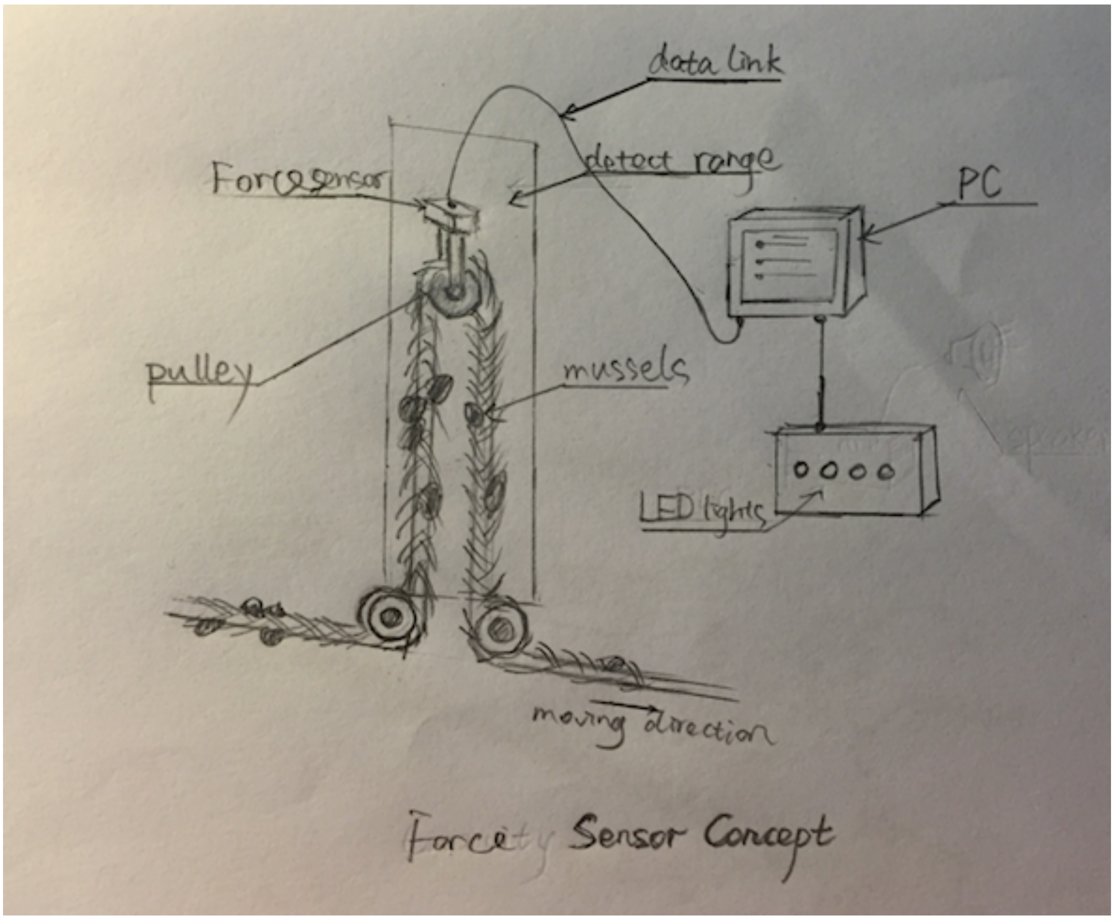


Fig 5.3.3

In the Concept 2, computer and lights are chosen to achieve the function of collecting data, analyzing data and display the final result. At first the average weight of a single mussel and an empty substrate line are required for further calculating. The first step of whole process is weighting the substrate line with remaining mussels. The signal from the gravity sensor will be the input of program in the computer. After that the program will do the calculation. First, it will get the difference between the input and the weight of an empty substrate line. This value is the total weight of remaining mussels. Then it is easy to get the amount of remaining mussels by subtracting the total weight with the average weight of a single mussel. Finally the program gives a signal to the lights and they will shows the percentage of remaining mussels is in which level according to the amount and the definition of percentage.

The problem of this concept is the tension of the substrate line. The tension will make the force sensor less accurate. So during the measurement the substrate line should stop to eliminate the tension. In addition, some useless stuff will also affect the detection result (like water and sea weed remain on the substrate line, because the weight of them are not constant).

Concept 3: Machine vision

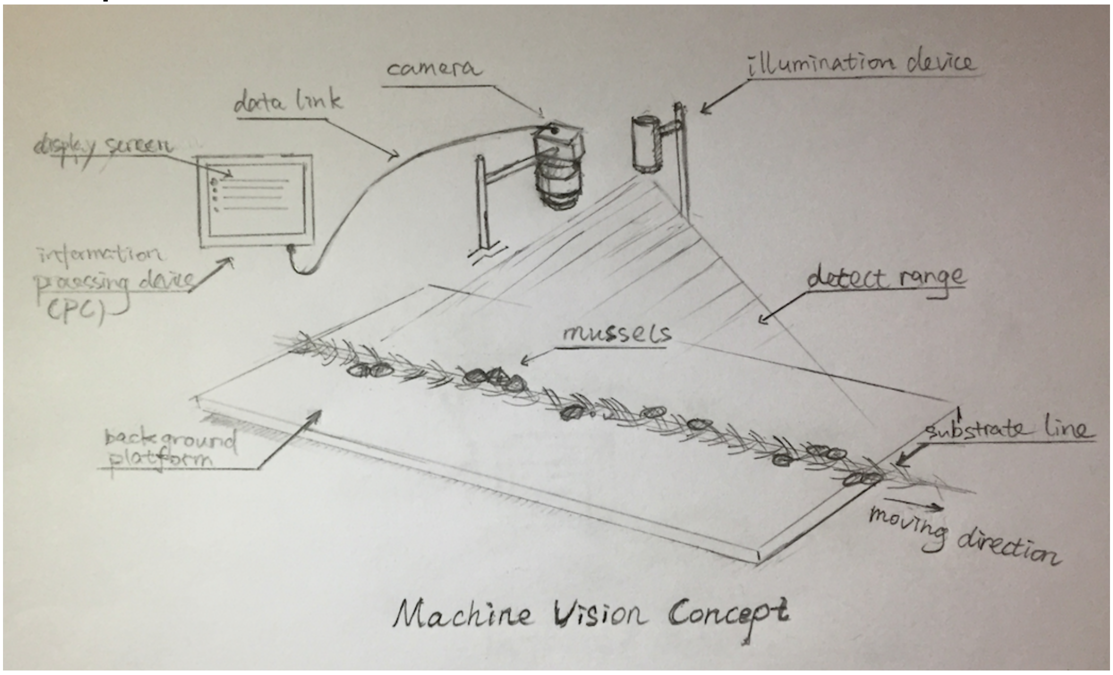


Fig 5.3.4

Machine vision concept (Fig 5.3.4) consists camera, computer and LED screen. First the visible camera will take pictures to collect the images of the substrate line every certain period for a certain distance. After that, all the images will be delivered to the computer. The software will transfer the images into data that can be recognized by computer. The background platform can make the information processing easier. If there are remaining mussels on the substrate wire, the computer will count the number of mussels. Finally, the number will be displayed on the LED screen as a percentage so that human beings can know how to adjust the machine.

For this concept, the main question is how to get the feasible picture that can be detected. So the problem is how to set the illumination device and camera, including the relative position of them and the strength of the lighting.

Concept 4: Ultrasound identification

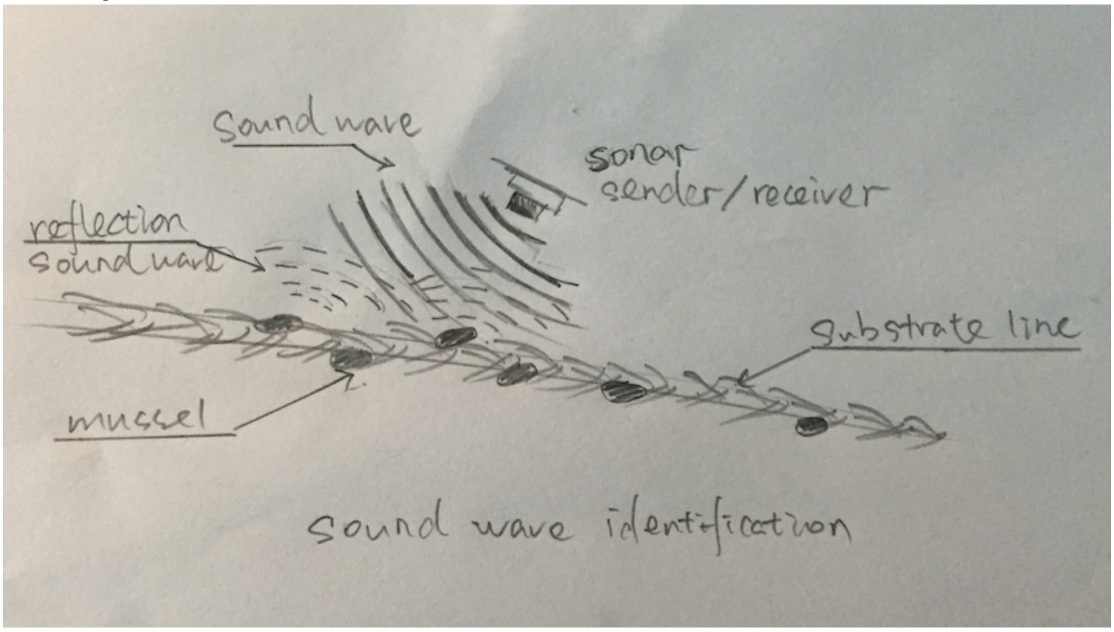


Fig 5.3.5

Ultrasound is an oscillating sound pressure wave with a frequency greater than the upper limit of the human hearing range. Ultrasound is used in many different fields. Ultrasonic devices are used to detect objects and measure distances. For example, Bats use a variety of ultrasonic ranging (echolocation) techniques to detect their prey. They can detect frequencies beyond 100 kHz, possibly up to 200 kHz. In the similar way, Acoustic microscopy is an ultrasound-based diagnostic imaging technique used to visualize features. In mussel detection's case, in the event of it is possible to clarify the 3D-model of mussel attached on the substrate line, later period programming can analysis the amount of mussel according to established 3D models.

Concept 5: MRI

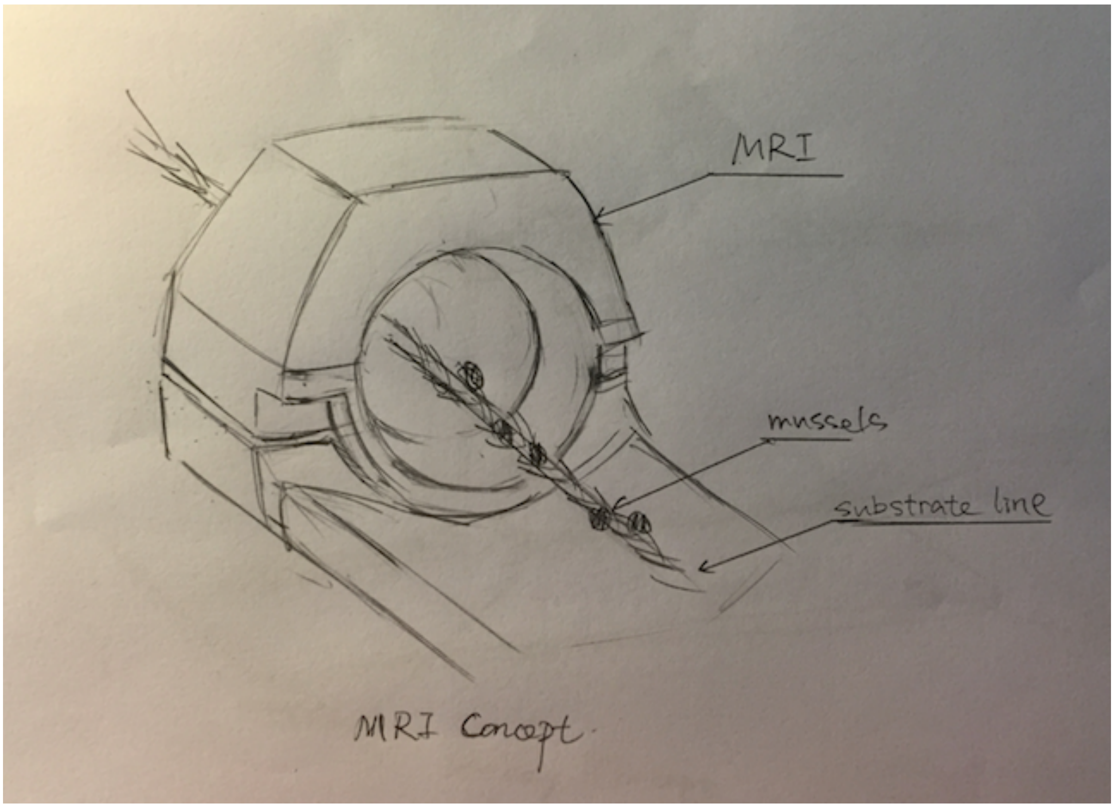


Fig 5.3.6

This concept is thought from the MRI technology in the medicine. MRI is called Magnetic Resonance Imaging. The core of this concept is the MRI system. It also consists other two elements, they are computer and LED screen. First the substrate line from the removing machine will go through the MRI machine. The gradient magnetic field in the MRI machine will detect the electromagnetic wave of different things and draw the image of the living objects according to the different attenuation of the energy in different conditions. The MRI can only detect the living things, so only the mussels' image will be drawn. The computer will count the number once the MRI machine detects the mussel every certain distance. At last, the percentage of the remaining mussels will be displayed on the LED screen.

This concept can have high accurate, about the expected costs will be very high. In addition, this high precision device could be hard to work perfectly on ship.

Concept 6: X-ray

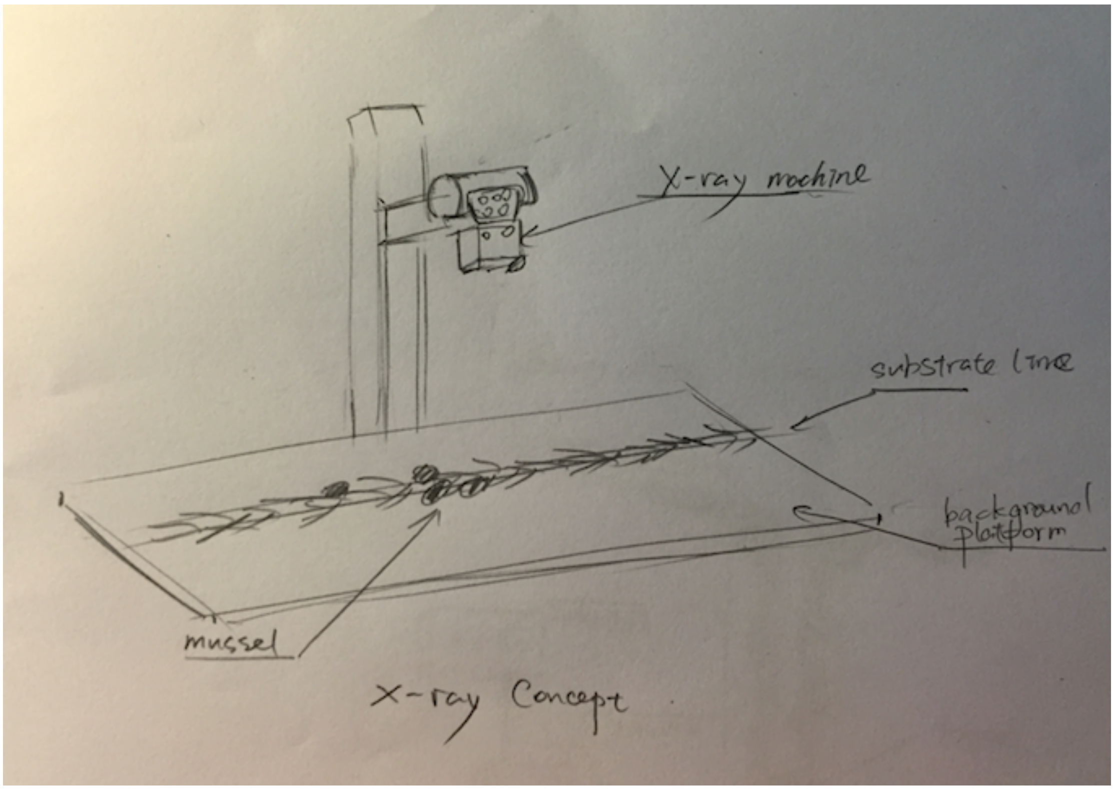


Fig 5.3.7

The x-ray concept includes the x-ray machine, computer and LED screen. First the x-ray machine will take picture for the substrate line. Then the computer receives the pictures and use software to recognize and count the mussels remains on the substrate line. Finally, the screen will display the result from the software. These are the basic principle of the x-ray concept.

The obvious advantage of this concept is that only the shell of mussel and the metal core of the substrate line will show in the picture. The plastic branches of substrate line and other things from the sea like sea-plant may no show clearly in the picture. So it can make the outline of mussels more clear and effectively reduce the disturbance. But the adaption for the working environment, the size and the power supply may be the problems of application.

Concept 7: Low frequency electric field

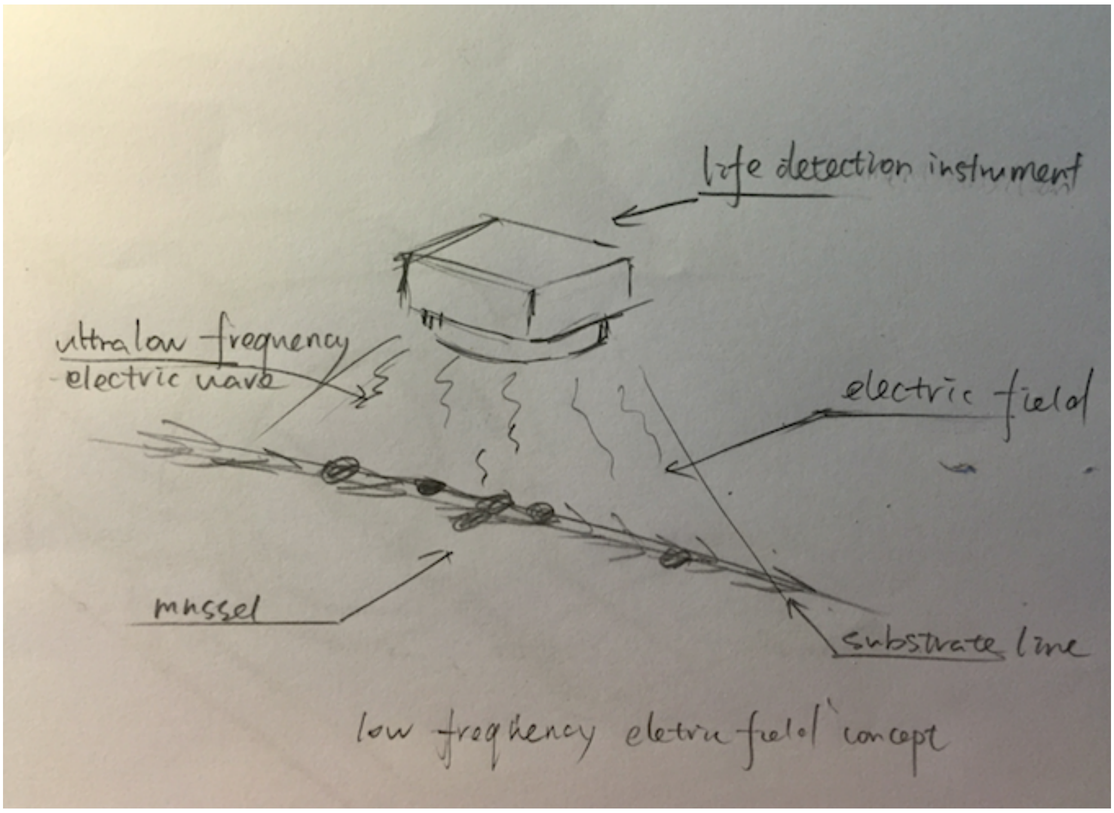


Fig 5.3.8

The research shows every living creation will deliver low frequency electric field itself. This is also the principle that how life detection instrument works in a earthquake. In this concept, a similar machine will be design. This machine can detect source of low frequency electric field and count each source.

The problem is electric field that mussel deliver is relatively weak. In addition, when many mussels remain, the electric field will overlap, which make it harder to detect the source. So the accuracy might not be high.

5.4 Evaluation

To evaluate the 3 concepts, the standards are necessary. Clients' opinions are considered to formulate the following judging standard. Table 5.4.1 Score Standards Of Concept Choice Evaluation shows how much it will get by its performance.

5.4.1 Score Standards Of Concept Choice Evaluation

Score standards of concept choice evaluation					
Requirements	**Score points**				
	1 point	**2 points**	**3 points**	**4 points**	**5 points**
1.Expected accuracy	±10%	±8%	±6%	±4%	±2%
2.Test difficulty	Need repeated field test		Need field test		Only need essential data
3.Good ability to work outside	Be able to work in normal weather	Be able to work when the temperature is over 35℃	Be able to work when the temperature is over 35℃and under 0℃	Be able to work with temperature over 35℃ and under 0℃ and wind	Be able to work with temperature over 35℃ and under 0℃, wind and wet
5.Simple structure	Assembling or disassembling time <=2.5 hours	Assembling or disassembling time <=2 hours	Assembling or disassembling time <=1.5 hours	Assembling or disassembling time <=1 hour	Assembling or disassembling time <= 45 minutes
6.Ease of UI	25 minutes to grasp the method of using	20 minutes to grasp the method of using	15 minutes to grasp the method of using	10 minutes to grasp the method of using	5 minutes to grasp the method of using

** MTBF means "Mean time between failures*

Based on *Table 5.4.1 Score Standards Of Concept Choice Evaluation,* three concepts are evaluated. After that, the final concept can be determined.

Table 5.4.2 Weighted Rating Table For Concept Choice Evaluation
** The scores of the concepts base on rough estimation about the performance.*

Weighted rating table for concept choice evaluation								
Requirements	**Weight**	**Concept 1**	**Concept 2**	**Concept 3**	**Concept 4**	**Concept 5**	**Concept 6**	**Concept 7**
	Points: 1~5	**Score: 0~5**						
1.Expected accuracy	5	2	1	4	3	4	2	3
2.Test difficulty	3	1	1	5	4	5	4	3
3.Good ability to work outside	1	2	5	3	3	3	2	4
4.Simple structure	1	5	3	3	4	2	3	3
5.Ease of UI	1	4	2	3	2	1	2	3
TOTAL SCORE:	**55**	**24**	**18**	**46**	**36**	**41**	**29**	**34**
PERCENTAGE SCORE:	**100%**	**57.6%**	**2%**	**83.6%**	**65.5%**	**74.5%**	**52.7%**	**61.9%**

In conclusion, the infrared sensor concept needs repeated field test to proof the design of detecting machine. However, for this student project, the equipment and test environment is not available. In addition, detection of weak infrared radiation is not very accurate. For the force sensor concept, the expected accuracy is relative low out of the other things (like water and sea weed) and tension on the substrate line. The other options have lower expected accuracy (not include MRI). If the cost is not a problem, MRI concept can also be another solution. According to the weight-rating table, the machine vision is selected as the final concept.

6.Configuration Design

6.1 lists of image processing in machine vision

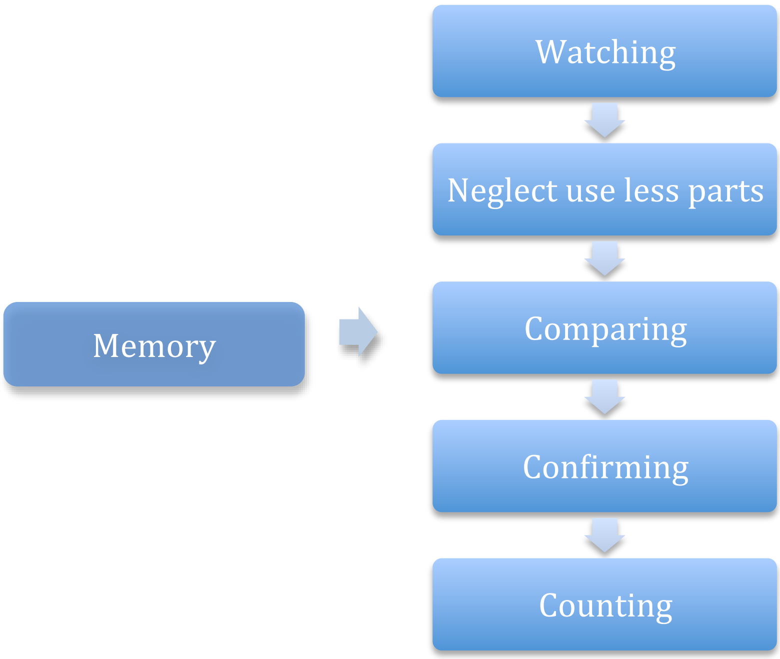
After research, several image processing method are listed in following table. These options have different function and the explanation of them will also be presented. In this project, several images processing method will be selected to realize the detecting function.⑤

Table 6.1 lists of image processing

Configuration lists of machine vision	
Processing	**Explanation**
Stitching/Registration	Combining of adjacent 2D or 3D images
Filtering	Consists of a set of operators that filter unnecessary parts of images
Gray scale processing	Convert the colorful image to gray image
Thresholding	Thresholding starts with setting or determining a gray value that will be useful for the following steps. The value is then used to separate portions of the image, and sometimes to transform each portion of the image simply black and white based on whether it is below or above that grayscale value
Pixel counting	Counts the number of light or dark
Segmentation	Partitioning a digital image into multiple segments to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze.
Edge detection②	Finding object edges
Blob matching	Inspecting an image for discrete blobs of connected pixels (e.g. a black hole in a grey object) as image landmarks. These blobs frequently represent optical targets for machining, robotic capture, or manufacturing failure
Neural net	Weighted and self-training multi-variable decision making
Feature matching④	Including template matching. Finding, matching, and/or counting specific patterns. This may include location of an object that may be rotated, partially hidden by another object, or varying in size
Color Analysis	Identify parts, products and items using color, assess quality from color, and isolate features using color

6.2 Human rules

The process machine works is similar to the process of human beings'. When human beings first see the substrate wire, the eyes first receive the image, and the brain will compare the image it received to the memory, and then confirm if there is any mussel remained. At last, it counts the number.



Human rules:

- Watching the image
- Neglect use less parts
- The shape of the mussel is roughly elliptical
- The color of the mussel is black which is darker than the substrate line
- The color drop sharply at the edge line of the mussel
- The size of the mussel is about from 1.5cm to 5cm
- There is some light reflection on the mussel
- There are some white spots on the mussel which will gradually become darker

- There are some gray areas which will fade away and mix with the black area
- The surface of the mussel is smooth
- Confirm the possible mussels with memory
- Count all the mussels

6.3 Preliminary configurations

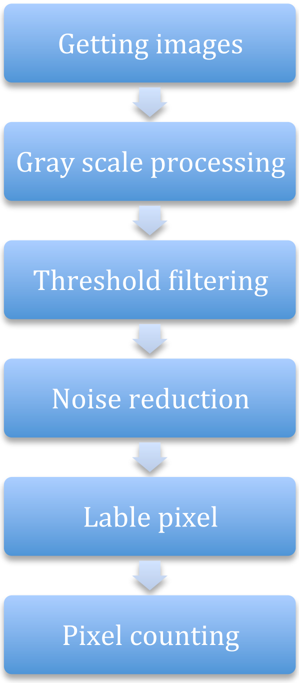
The preliminary configurations are based on the human's image treating processing. Some of human rules are selected and translate to computer language. There are two configurations listed below.

Configuration1

The core of Configuration1 is Pixel label. It mainly uses the color feature of mussel to reduce the background and other disturbance, then pick up the mussels and count them.①

Selected human rules:		**Computer language:**
Watching the image		Getting images
The color of the mussel is black which is darker than the substrate line		Gray scale processing
		Threshold filtering
Neglect use less parts		Noise reduction
The size of the mussel is about from 1.5cm to 5cm		Label pixel
Count all the mussels		Pixel counting

Working flow of Configuration 1:

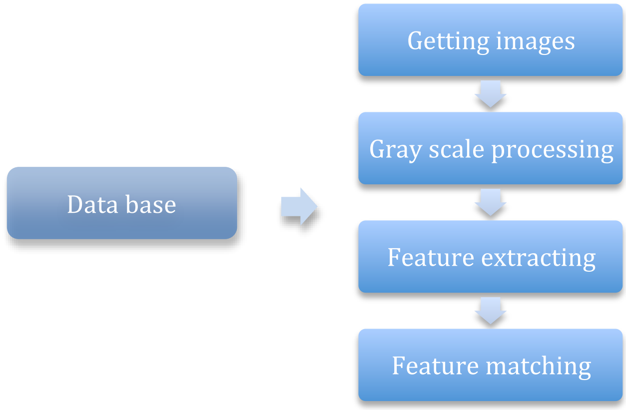


Configuration 2

The core of Configuration2 is feature matching. It can detect mussels by matching the feature of shape.

Selected human rules:		**Computer language:**
Watching the image		Getting images
The color of the mussel is black which is darker than the substrate line		Gray scale processing
The shape of the mussel is roughly elliptical		Feature extracting
The color drop sharply at the edge line of the mussel		
The surface of the mussel is smooth		
Confirm the possible mussels with memory		Feature matching

Working flow of Configuration 2:



6.4 Comparing and analyzing

Both of the Configuration1 and Configuration2 can detect the mussel in the picture. Figure 6.4.1 shows the defined feature of a mussel, Figure 6.4.2 shows the processing of feature matching when applying the function to an image and the result is clearly shows in the Figure 6.4.3 that only the most similar mussel can be detected.

The configuration 1 has been chosen for these two reasons:
1. Configuration 2 can only matching the most similar mussel on the background picture. If the substrate line is added into the picture, it will cause the loss of accuracy, since the situation of mussel stick with substrate line is too complex.

2. Configuration 1 can realize the function of counting more easily instead of configuration 2.

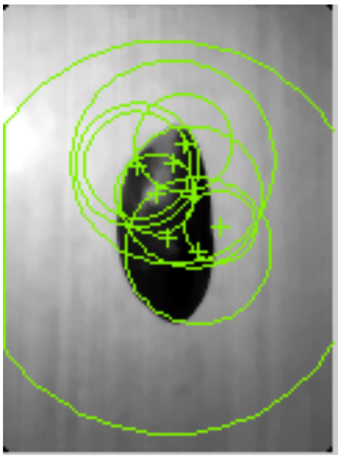


Figure 6.4.1

Figure 6.4.2

Figure 6.4.3

7.Parametric Design

In this phase, the setting of test and the process of programming will be presented. 7 situation are defined to complete the program.

7.1 Test definition

The test will be conducted to proof the feasibility of the detection system. The mussels, which should be detect are defined in following table according to the client’s requirements.

Table 7.1.1 rules of mussels

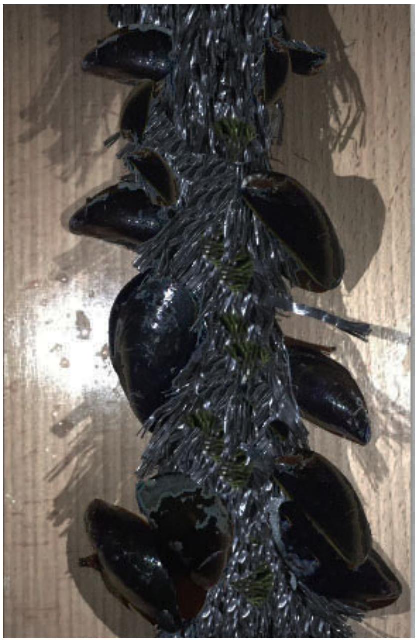
Rules of mussels	
Rough color	Black
Size	15 mm – 50 mm
Shape	Oval

Several test situations will be defined in following table.

Table 7.1.2 situation of tests

<table>
<tr><th colspan="3">Situation of tests</th></tr>
<tr><td>Situation 1</td><td>Separate mussels with same size on platform</td><td></td></tr>
<tr><td>Situation 2</td><td>Overlapped mussels with same size on platform</td><td></td></tr>
</table>

Situation 3	Separate mussels with same size on substrate line	
Situation 4	Separate mussels with different size on substrate line	
Situation 5	Overlapped mussels with same size on substrate line	
Situation 6	Overlapped mussels with different size on substrate line	

Situation 7	Overlapped mussels with different size on dirty substrate line (darker and with see-weed)	

7.2 Test process

7.2.1 Basic image processing

According the computer rules defined in configuration phase. Several matlab functions can be used to realize these computer rules.
The following sentences are essential and will be utilized in all the tests.⑥

- Read image

Function statement	Explanation
f=imread('figurename.jpg');	This statement can read the image 'figurename', and give this value to ' f ', in the following program the ' f ' will stand for the picture.

- Gray scale processing

Function statement	Explanation
F=rgb2gray(f);	This statement transfers the colorized picture in to gray one.
F0=imadjust(F,stretchlim(F),[0 1]); Ft=medfilt2(F0,[5 5]);	The gray picture can be adjusted into a clearer one with changing the parameters of these sentences.

- Thresholding

Function statement	Explanation
imhist(Ft)	With this sentence, the thresholding value can be known.
[M,N]=size(Ft); for x=1:M for y=1:N if Ft(x,y)<60 Ft(x,y)=0; else Ft(x,y)=255; end end end	Change the gray picture into white and black. In this sentence '60' stands for the thresholding value. '0' stands for totally black. '255' stands for totally white.

7.2.2 situation 1

The counting function should be realized in this test.
Through the above-mentioned image processing, matlab output the picture.
In this case, all the link area will be marked. Through counting the number of links, the number of mussel will be known.

- Label the links and counts

Function statement	Explanation
[L N]=bwlabel(F1,8)	Label the links
Sum = []; for i=1:N [r,c] = find(L==i); rc = [r c]; Num = length(rc); Sum([i])=Num; end	Sum[] is the an array defined to store the links information. [r,c]=find(L==i) function is used to label the links, 'r' stand for row label, 'c' stand for column label.

Figure 7.2.1 shows the picture after gray scale processing
Figure 7.2.2 shows the histogram, which is helpful to determine the thresholding value. The X-axis stands for the darkness. The Y-axis stands for the frequency. So from 0- 50 is the mussel, because the mussel is very dark. So, in this case thresholding around 50-100 is suitable. This value can be adjust according different situation.

Figure 7.2.1

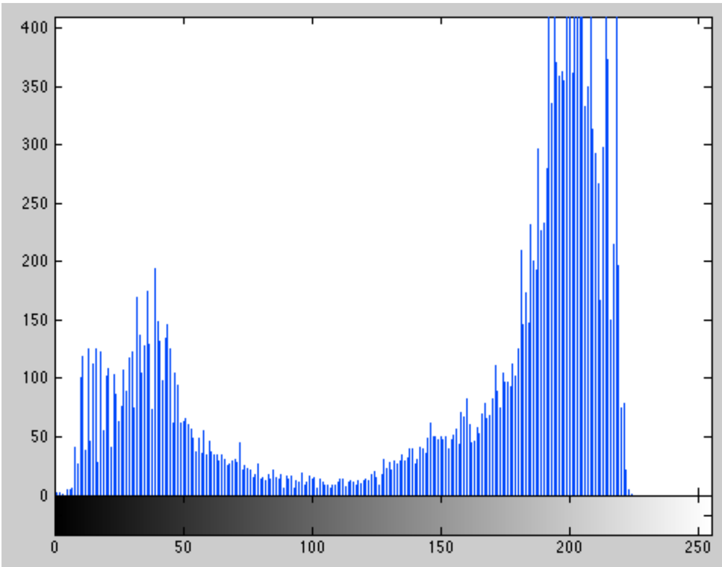


Figure 7.2.2

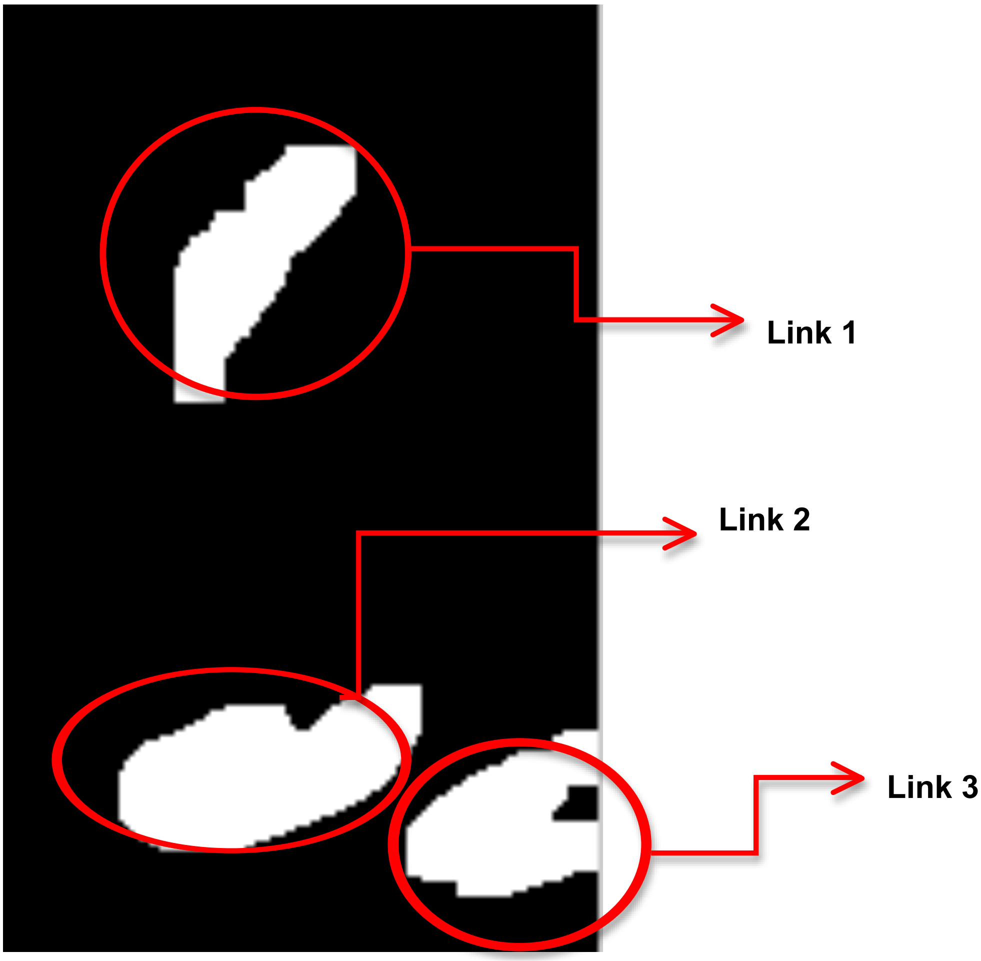


Figure 7.2.3

Figure 7.2.3 shows the picture after thresholding and the number on the picture is the label of several links. It can be easily figure out the number of mussel is 3.

7.2.3 situation 2

The labeling function is utilized in situation 1. The root of this function is counting the number of links. However, if the mussel overlapped, it will cause less accuracy, because the two overlapped mussels only have one links.
In this case, this problem should be solved. Figure 7.2.4 shows 3 mussels only have one link.

Figure 7.2.4

- Pixel counting

Function statement	Explanation
Num1 = sum(sum(L==1)); display(num1);	These sentences can give the pixel value of one link. According to these values, parameter of pixel counting can be adjusted easily.
if (Sum([i]))>7500 N=N+4; elseif (Sum([i]))> 6000 N=N+3; elseif(Sum([i])) > 4500 N =N + 2; elseif (Sum([i])) > 3000 N =N + 1; end end	The mussel counting process will go through this for loops. If the links area is larger than one normal mussel, for example, if the normal mussel's pixel value is around 1500 (know through Num1 = sum(sum(L==1));) and one link area is around 4000, then 'N' namely the number of links will add 1. So according to the 'for loop' the overlapped problem can be solved. Temporarily, the mussels should have similar size.

7.2.4 situation 3

In this situation, the background of detection is under substrate line. The challenge is the substrate line has close color with the mussels. After the image processing the noise will be very large. So, what should be done in this test is to adjust the parameters of thresholding, and add noise reduction processing. In addition, if the illuminations are set, the picture will be clearer and easier to detect. Figure 7.2.5 shows the result without noise reduction. Figure 7.2.6 shows the result of noise reduction

- Noise reduction

Function statement	Explanation
B=ones(10);	Change the value in ( ) , the remaining will be adjust. The larger the value is, the less remaining noise will be. However, if the number is too larger, the mussel will be also be deleted. So the value should be adjusted according the situation and environment.
F0=imclose(Ft,B);	This is close operation and will make the shape of mussels smoother.

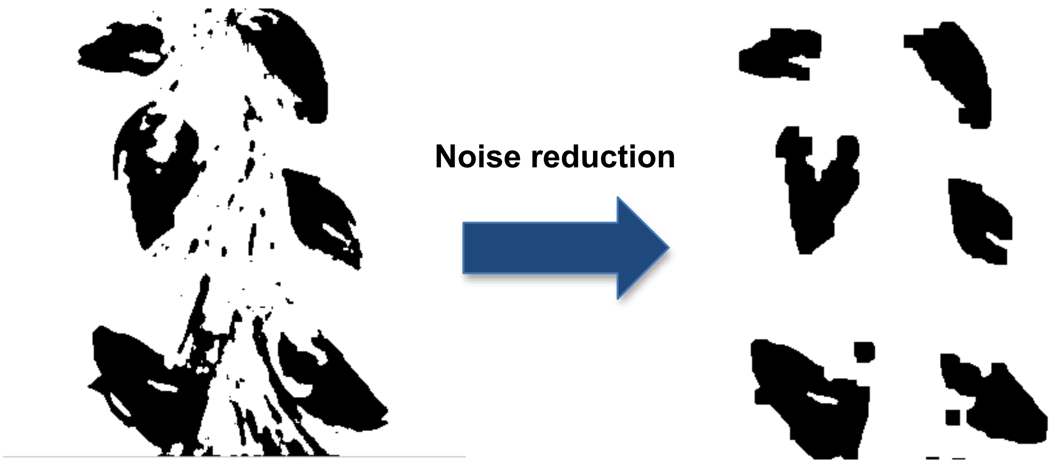


Fig 7.2.5

Fig 7.2.6

There is also noise spot remain on the picture, because the illumination is not totally enough. But pixel counting can also solve this problem. The smallest size of mussel that can be detected has been defined in parametric phase. So we assume the pixel value of the smallest mussel is 300. Then, add a 'for loop' to delete the noise.

Function statement	Explanation
for i=1:length(Sum) if (Sum([i]))<300 N=N -1; end end	If the pixel value of one link is smaller than 300，the link will be regarded as noise. When count the mussel this link will be deleted.

7.2.5 Situation 4

In this case, the mussel with different size will be added into detection. But they are also arranged separately. So in this test, there is not big problem and do not need to add new function.

Figure 7.2.7 shows the result of the image processing.

Figure 7.2.7

Notice that in the noise reduction, which mentioned in 7.2.4 situation 3, the parameter should be adjusted carefully; in case of the matlab system regard the small mussel as noise.

7.2.6 Situation 5

In this test, the mussels on the substrate line will be overlapped. The solution of 7.2.3 situation 2 can be utilized during test.

- Pixel counting

Function statement	Explanation
Num1 = sum(sum(L==1)); display(num1);	These sentences can give the pixel value of one link. According to these values, parameter of pixel counting can be adjusted easily.
for i=1:length(Sum) if (Sum([i]))> 27000 N=N+3; elseif (Sum([i]))> 19000 N=N+2; elseif (Sum([i]))> 10000 N=N+1; end end	The function is similar with 7.2.3 situation 2. What should be noticed is the pixel values of different picture are different. So, if the program needs to be used in real detection. The illumination and position of camera should be fixed. Or all the parameters get during test is useless

Figure 7.2.8 shows the result of image processing

Figure 7.2.8

7.2.7 Situation 6

In this test, the mussels on the substrate line will be overlapped and mussels with different size will be added. The solution of 7.2.3 situation 2 can be utilized during test. However, with the function of pixel counting, it will be hard to define the parameters, for example the two overlapped small mussels will be regarded as a big one. To realize this function, probability method will be used to estimate the number. Of cause this estimate method will reduce the accuracy. However, the result will be close to the real value. It will base on the adjustment of pixel parameters.

- Pixel counting

Function statement	Explanation
Num1 = sum(sum(L==1)); display(num1);	These sentences can give the pixel value of one link. According to these values, parameter of pixel counting can be adjusted easily.
for i=1:length(Sum) if (Sum([i]))> 21000 N=N+3; elseif (Sum([i]))< 12000 & (Sum([i]))>9500 N=N+2; elseif (Sum([i]))< 21000 & (Sum([i]))>15000 N=N+2; elseif (Sum([i]))<9500 & (Sum([i]))>8000 N=N+1; elseif (Sum([i]))< 15000 & (Sum([i]))>12000 N=N+1; elseif (Sum([i]))<4000 & (Sum([i]))>2000 N=N+1; end end	The mussels are divided into two kinds:big size and small size. Several situations are listed in these statements. (Sum([i]))> 21000: More than four big size mussel. (Sum([i]))< 12000 & (Sum([i]))>9500: One big mussel and two small mussels. (Sum([i]))< 21000 & (Sum([i]))>15000: Two big mussels and one small mussel. (Sum([i]))< 15000 & (Sum([i]))>12000: Two big mussels. (Sum([i]))<4000 & (Sum([i]))>2000 Two small mussels.

7.2.8 Situation 7

In this test, the substrate line will be very dirty, which mean the color of it will be darker. So it is harder to tell the mussel from the substrate line. To solve this question, some parameter about the thresholding and noise reduction needed to be adjusted:

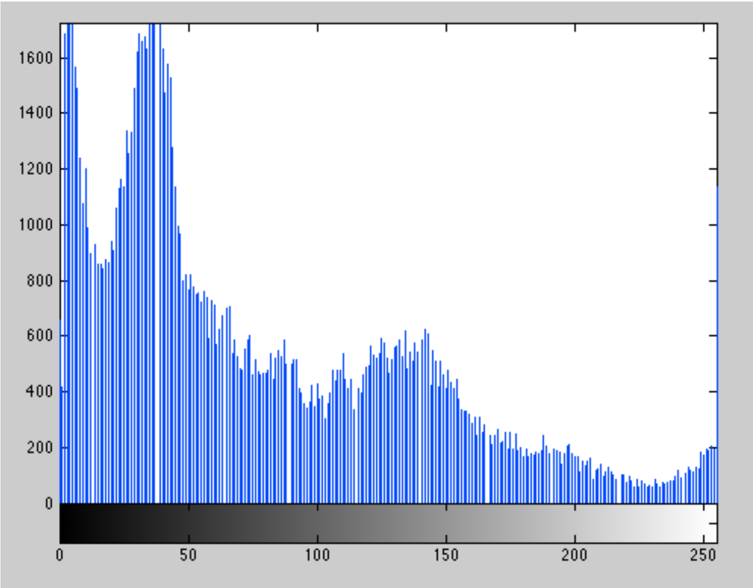


Fig 7.2.9

Function statement	Explanation

for x=1:M
    for y=1:N
        if Ft(x,y)<**30**
 	
            Ft(x,y)=0;
        else
            Ft(x,y)=255;
        end
    end
end
	In this situation, the threshold value has been adjusted from 50 to 30, according to the histogram on Fig 7.2.9. (From value 30 to 50 it is the parts of dark substrate).
	
	This value should be adjusted according to different environment.

8.Detailing

This phase will include some detailed information, for example accuracy, hard ware instrument, software instrument.

8.1 Batch test

After the tests in different situation, the structure of the program is decided. The next step is doing the batch test to ensure the accuracy of the program.

Batch test images		
 No.1	 No.2	 No.3
 No.4	 No.5	 No.6
 No.7	 No.8	 No.9


No.10


No.11

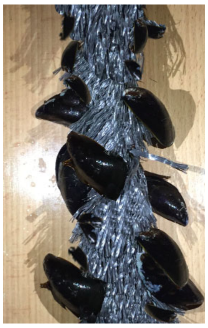

No.12


No.13


No.14


No.15


No.16


No.17


No.18


No.19


No.20


No.21

No.22	No.23	No.24
 No.25	 No.26	 No.27
 No.28	 No.29	 No.30

Test results			
No.	**Actual amount:**	**Detected amount:**	**Error:**
No. 1	9	10	+11%
No. 2	12	12	0
No. 3	11	11	0
No. 4	10	10	0
No. 5	12	12	0
No. 6	13	12	-7.7%
No. 7	13	12	-7.7%
No. 8	13	12	-7.7%
No. 9	15	14	-6.6%
No. 10	13	14	+7.7%
No. 11	18	17	-5.6%
No. 12	16	16	0
No. 13	16	15	-6.2%
No. 14	19	17	-8.9%
No. 15	16	15	-6.2%
No. 16	16	16	0
No. 17	18	16	-8.9%
No. 18	18	17	-5.6%
No. 19	17	16	-5.9%
No. 20	16	15	-6.2%
No. 21	17	17	0
No. 22	13	13	0
No. 23	12	13	+8.3%
No. 24	12	12	0%
No. 25	15	13	-13.3%
No. 26	15	13	-13.3%
No. 27	14	13	-7.1%
No. 28	13	13	0
No. 29	15	16	+6.7%
No. 30	11	12	0

Total amount:	**Undetected or over-detected amount:**	**Absolute error:**
428	**23**	**5.37%**

Analysis:

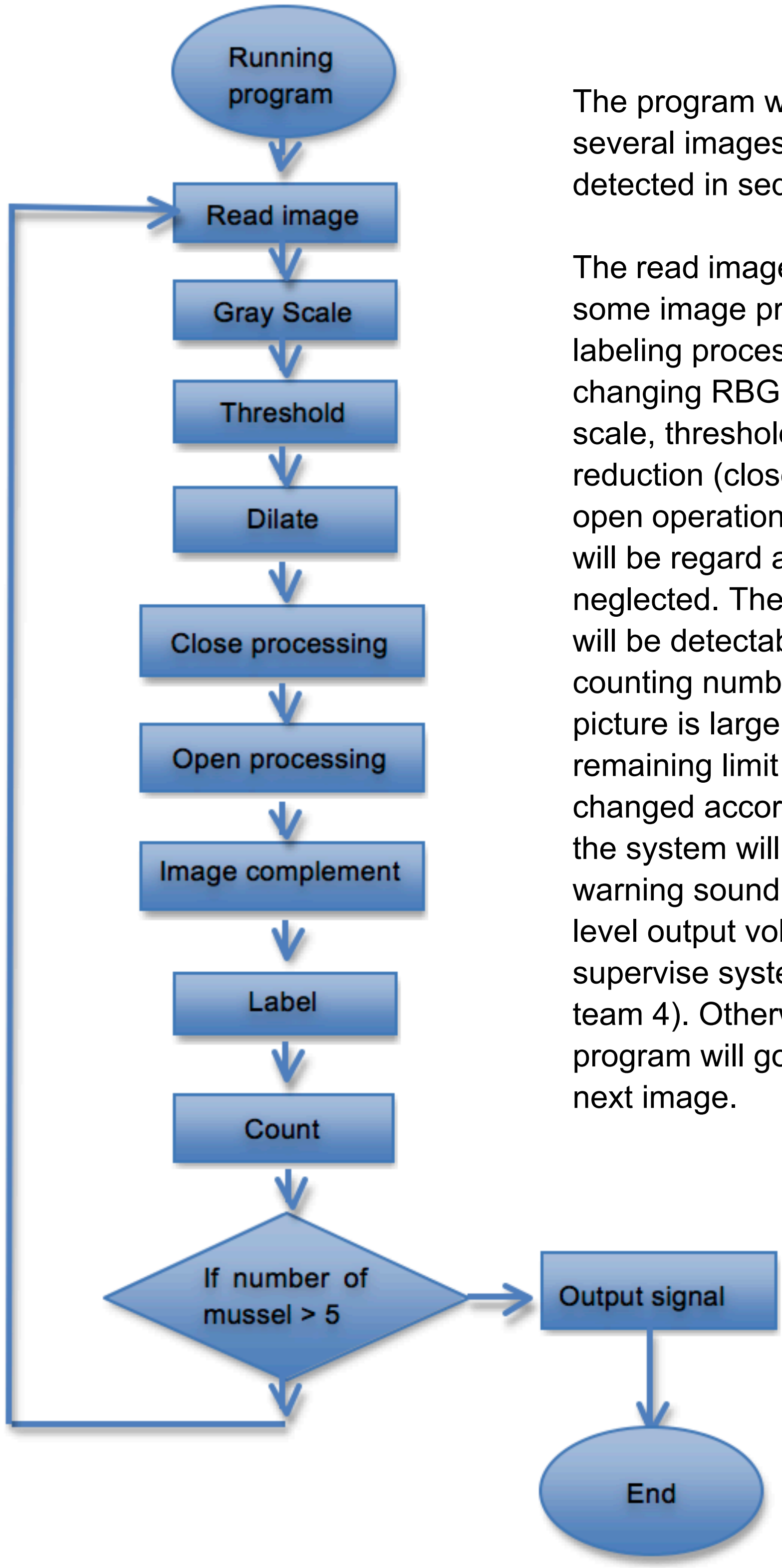
According to the test result, the accurate can reach to 5.8%. But the accurate is not very stable and in most case the count result is more than the real number. According to the observation, if the mussels have special size, like one mussel is especially large or between normal size and smallest size, the accuracy will be decrease.

Following table shows the cause of miscount:

Size	Cause
Especially big mussel	Mistake it as one normal size mussel sticking with one small size mussel, so count one mussel as two.
Two mussel with smallest size	Mistake it as one mussel normal size and smallest size, so count two mussel as one

Add these two conditions in two the program; the result is that the accuracy decrease. Because the condition is too complex, many unexpected problem will occur. For example mistake one normal size mussel sticking with one small size mussel as one especially big mussel.
The mentioned condition is low probable, to protect the accurate in most cases; these two conditions will be neglected, since the accuracy is qualifie

8.2 Working flow of program



The program will first read several images that need to be detected in sequence.

The read image will go through some image processing and labeling process, including changing RBG image to gray scale, thresholding, noise reduction (close operation and open operation). The substrate will be regard as noise and be neglected. Then the mussels will be detectable. If the counting number on one picture is larger than 5 (the remaining limit can be changed according to reality), the system will give the warning sound and a high level output voltage signal to supervise system (design by team 4). Otherwise, the program will go on to read the next image.

8.3 User instrument

8.3.1 Hardware instrument

The hardware of the system contains: Camera, lights, background board and the computer.

- Camera: During the test iphone6 is used as camera, the pixel is 800milion.

- Distance between camera and object: 50 cm

- Lights: During the test 2 flash lamps of iphone6 are used as lights, the luminance is 100 Lm. The lights can strengthen the contrast of mussels and substrate line.⑦

- Angle of lights: 60 degree

- Background board: Any white board can be use as the background of the image and it can reduce the disturbance of the environment. The board with matting surface may has a better effect.

- Computer: During the test OS X of mac is used as operating environment. The Matlab has both visions for both OS X and windows.

In reality, the use can use other equipment like camera or lights because the program has not any strict requirements for image source. The user can do some tests to change the parameters to get the best effect in real situation.

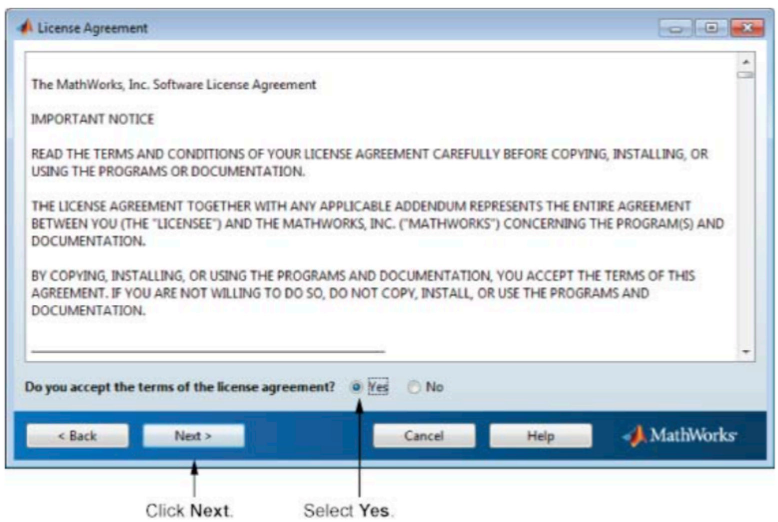
8.3.2 Software operation instrument

Install step:

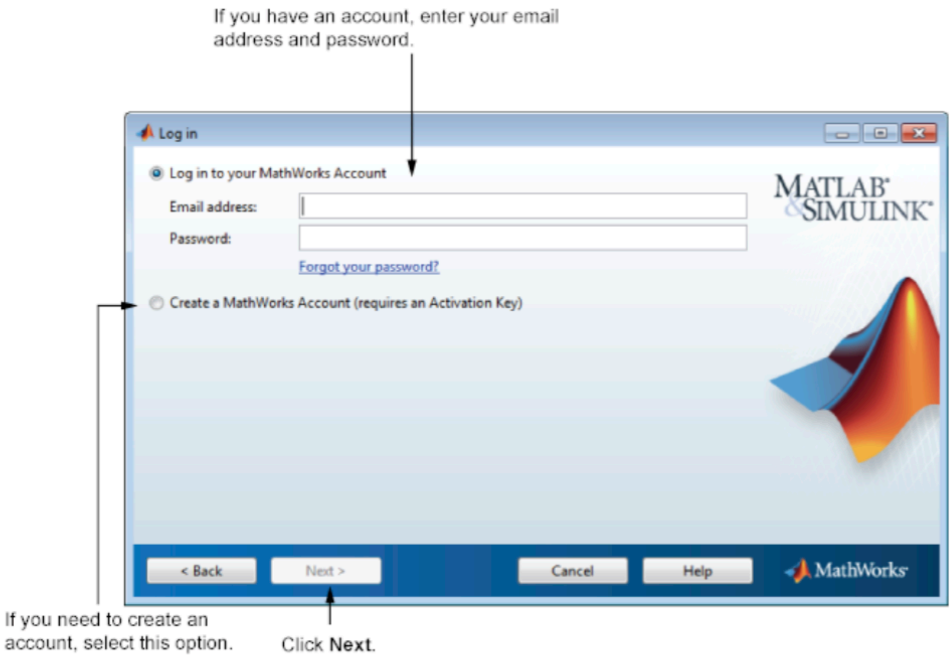
1. Download the software (10.62 GB)
2. Start the Installer

3. Install Using a MathWorks Account

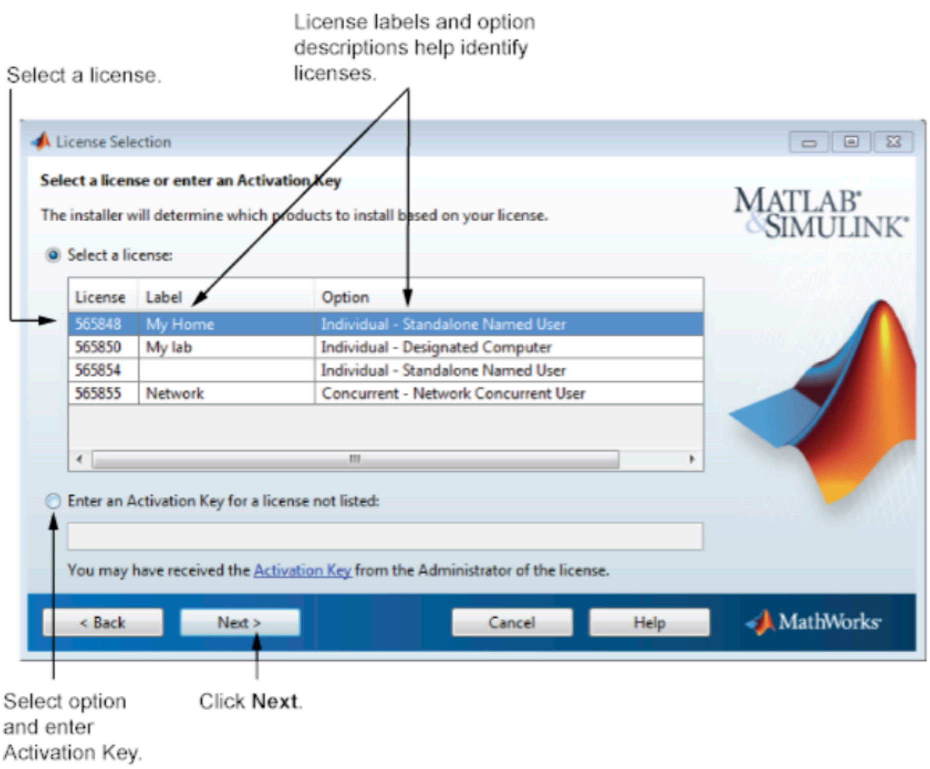
4. Review the Software License Agreement



5. Log In to Your MathWorks Account

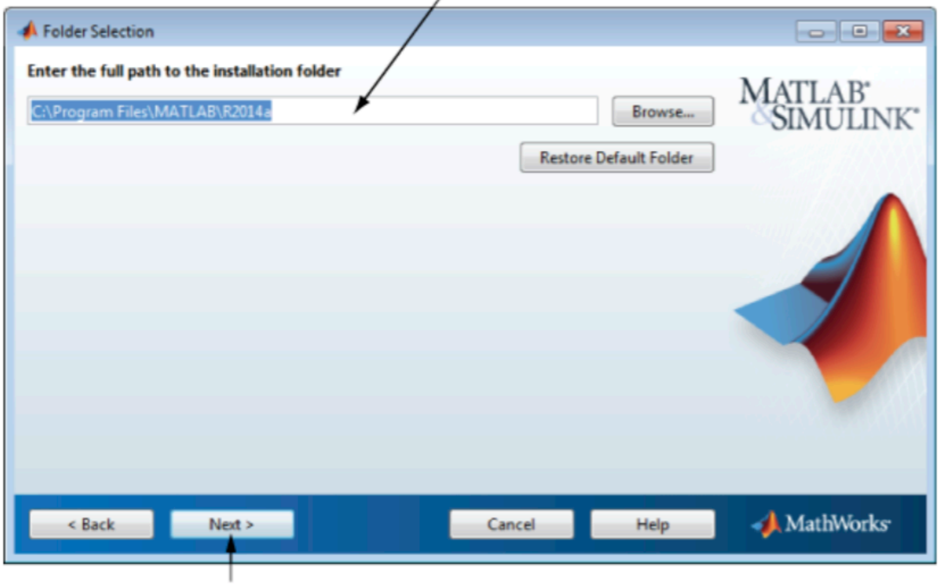


6. Select the License You Want to Install



7. Specify the Installation Folder

Specify name of installation folder.



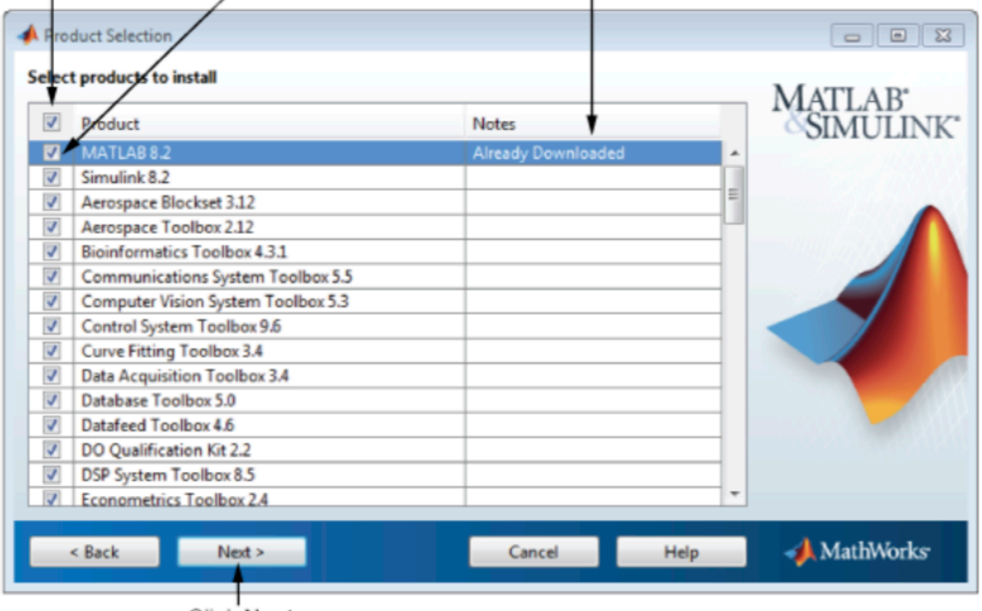
Click **Next**.

8. Specify Products to Install

Select or clear for all products.

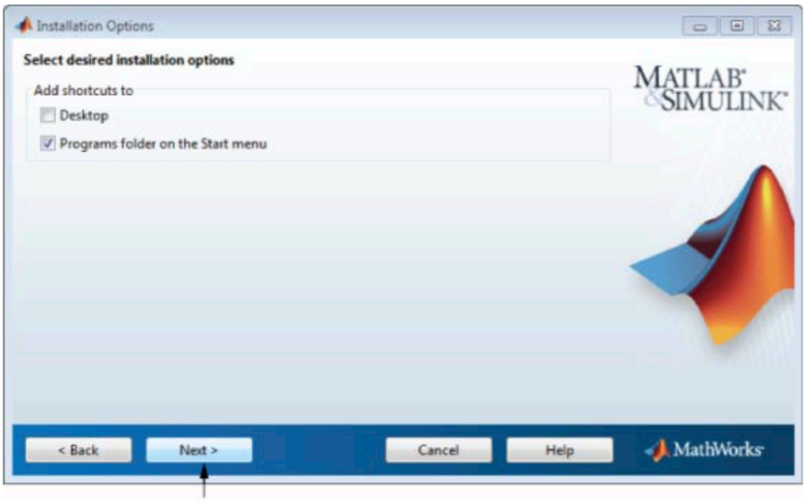
Select individual products.

The product exists in the download location or on a DVD; the installer does not download it.



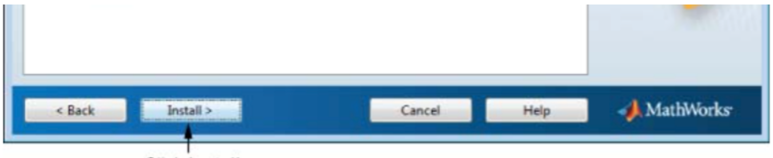
Click **Next**.

9. Specify Installation Options



Click Next

10. Confirm Your Choices



Click **Install**.

11. Complete the Installation

To activate your software, leave this selected.

Click **Next** to proceed to activation. If you cleared the check box, button label changes to **Finish**.

(All the test use Matlab 2014 OS X version, Matlab windows version has the same functions, please install follow the instrument)

Program operating steps:

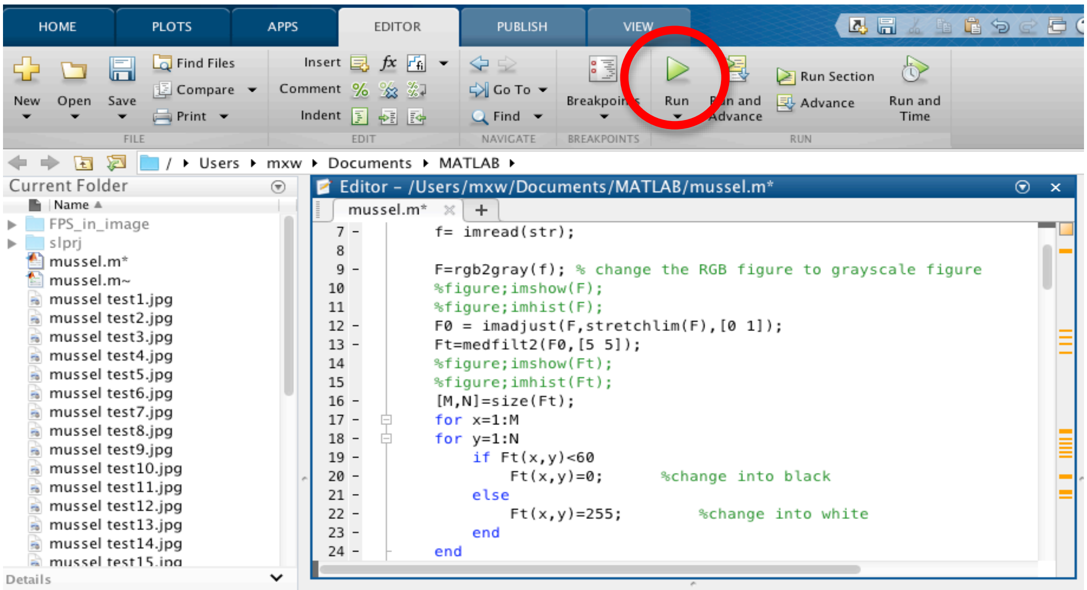
1. Put the images in the folder called MATLAB.

MATLAB

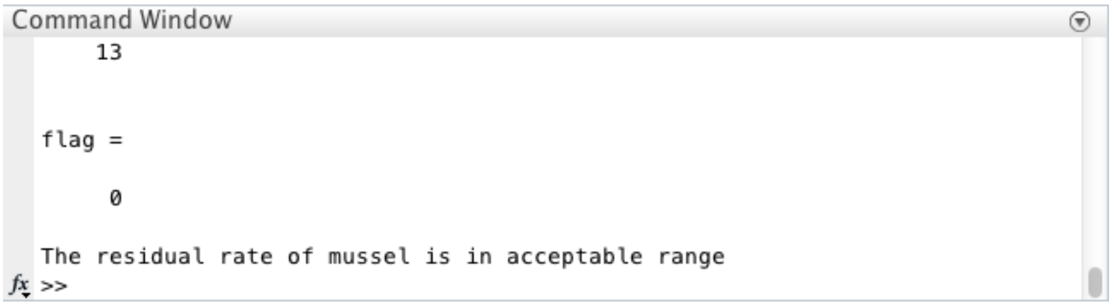
2. Double-click the “m.file”.

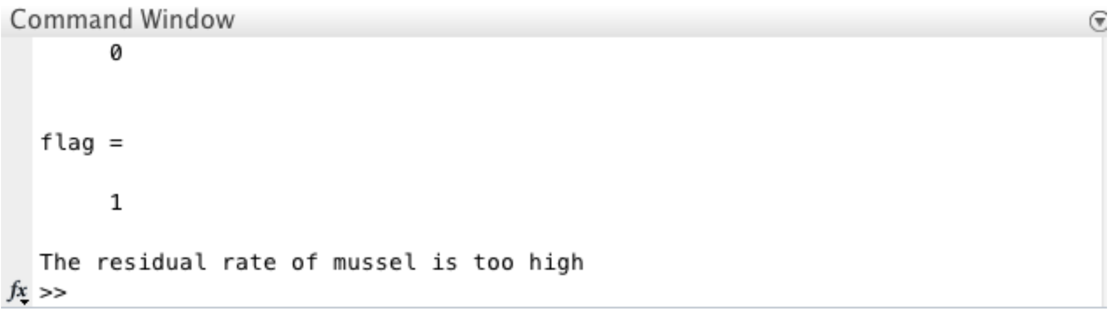
mussel.m

3. The program will show as the figure below and click the “Run” button (In the red circle on the figure) will start the program.



4. The warning text will show as figures below.





5. The results as amount of every image will show in the command window in sequence as the figure below. The user can change the parameters as “maximum remaining amount” to change the results of operation. Typing in “number” in command window can achieve the function of showing results

```
N =

    14


flag =

     0

The residual rate of mussel is in acceptable range
>> number

number =

  Columns 1 through 12

    10    12    11    10    12    12    12    12    14    14    17    16

  Columns 13 through 24

    15    17    15    16    16    17    16    15    17    13    13    11

  Columns 25 through 30

    15    15    16    13    15    14
```

6. Typing in ”number (d%)” can show the remaining amount of specific image.

```
>> number(5)

ans =

    12

>>
```

9.Appendix

Appendix 1: Completed program code

```
clear all;              %initialization
close all;
    number=[]    % array to store the counting result
    for i= 1:23

    str= strcat ('mussel test ', int2str(i) ,'.jpg') ; % for loop to read multiple figs
    f= imread(str);

    F=rgb2gray(f);                  % change the RGB figure to grayscale figure

    %figure;imshow(F); %the figures have been cancel to increase run speed
    %figure;imhist(F);        % if you need the figure,delete the'%'before them

    F0 = imadjust(F,stretchlim(F),[0 1]);
    Ft=medfilt2(F0,[5 5]);
    %figure;imshow(Ft);
    %figure;imhist(Ft);
    [M,N]=size(Ft);
    for x=1:M
    for y=1:N
        if Ft(x,y)<60
            Ft(x,y)=0;            %change into black
        else
            Ft(x,y)=255;          %change into white
        end
    end
    end

    %figure;imshow(Ft);

    B=ones(11);                  % reduce the noise

    F0=imclose(Ft,B);            % reduce the noise through close operation

    %figure;imshow(F0);

    F1=imadjust(F0,[0,1],[1,0],1);

    %figure;imshow(F1);
```

```
F1=imfill (F1, 'holes')            % fill the hole in link through open operation
  %figure;imshow(F1);

  [L N]=bwlabel(F1,8)               % label the links
  Sum = [];                         % array to store the links information

for i=1:N
[r,c] = find(L==i);                 %row label and column label
rc = [r c];
Num = length(rc);
Sum([i])=Num;
end

%num1 = sum(sum(L==1))        % these sentences used to show the pixel
                                 number
%num2 = sum(sum(L==2))        % of the links, used to adjust the parameters
%num3 = sum(sum(L==3))
%num4 = sum(sum(L==4))
%num5 = sum(sum(L==5))
%num6 = sum(sum(L==6))
%num7 = sum(sum(L==7))
%num8 = sum(sum(L==8))
%num9 = sum(sum(L==9))
%num10 = sum(sum(L==10))
%num11 = sum(sum(L==11))
%num12 = sum(sum(L==12))
%num13 = sum(sum(L==13))
%num14 = sum(sum(L==14))

%display(num1);
%display(num2);
%display(num3);
%display(num4);
%display(num5);
%display(num6);
%display(num7);
%display(num8);
%display(num9);
%display(num10);
%display(num11);
%display(num12);
%display(num13);
%display(num14);
```

```
    for i=1:length(Sum)                 % several condition of counting
     if (Sum([i]))> 11000
           N=N+3;

    elseif (Sum([i]))< 5800 & (Sum([i]))>5600
           N=N+2;
    elseif (Sum([i]))< 11000& (Sum([i]))>7500
           N=N+2;
    elseif (Sum([i]))<5600 & (Sum([i]))>3600
           N=N+1;
    elseif (Sum([i]))< 7500 & (Sum([i]))>5800
           N=N+1;
    elseif (Sum([i]))<1400 & (Sum([i]))>1000
           N=N+1;

           end
    end

     for i=1:length(Sum)           % neglect the too small mussel or noise
     if (Sum([i]))<300
    N=N -1;
     end
     end

    display(N);
    number=[number N];
    flag=0                        % give the low level output voltage
    if N>16                       % the condition to give high level output voltage
    flag=1                        % give the high level output voltage
    break;
    end
    N=0;                          % clear the count number
end

if(flag==1)      % give out warning tone when there is high level output voltage
sound(sin(2*pi*25*(1:4000)/100));
load handel
sound(y,Fs)
end

if(flag==0)     % give the statement when there is low level output voltage
disp('The residual rate of mussel is in acceptable range')
end;
```

Appendix 2: EDS

EDS of mussel detecting

Group 7

The EDS (Engineering Design Specifications) are the base of a project. 20 requirements are listed. The requirements include 6 main categories: Design, Manufacturing/production, Transportation, Usage, Maintenance and Financial. The requirements are listed in Table EDS below.

Table EDS

Main categories	Requirements	Details
Design	1. Show amount of remaining mussels	Accuracy: ±5%
	2. Covered area	Less than 1m*2m
	3. Adaption to normal power supplies	Can use a power supply of 400V at 50hz
	4. Detect mussels remain on the substrate line	
	5. Can be used in wet working environment	
	6. Maximum weight: 20kg	
	7. Fully automated	
Manufacturing /Production	8. Convenient for assembling during manufacturing	Maximum assembling time for one machine: 2 hours
	9. Safety	Make production safety regulations and operating rules
	10. Maximum production time for one single machine: 20 hours	Including the time to produce special components and to assemble them with standard blocks
Transportation	11. Can be transported by standard trucks	
Usage	12. Easy to understand the UI	The user can understand the UI in 5~10 minutes
Maintenance	13. Low maintenance frequency	No maintenance for 3000-hour working

	14.	Easy to change broken parts	Workers without mechanical skills can change the standard elements
	15.	Easy to find error points	Simple structure so that it is easy to disassemble
	16.	Easy to assemble and disassemble during maintenance	Maximum assembling time for one machine: 2 hours Disassembling time: 2 hours
Financial	17.	New components should cost a maximum of 30% of machine's price	
	18.	Low product price	With the overall performance, we may choose the cheapest one

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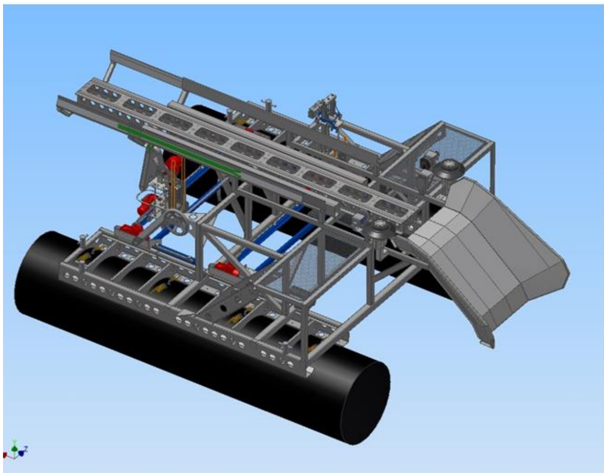


Europees Visserijfonds:
Investering in duurzame visserij

Ministerie van Economische Zaken

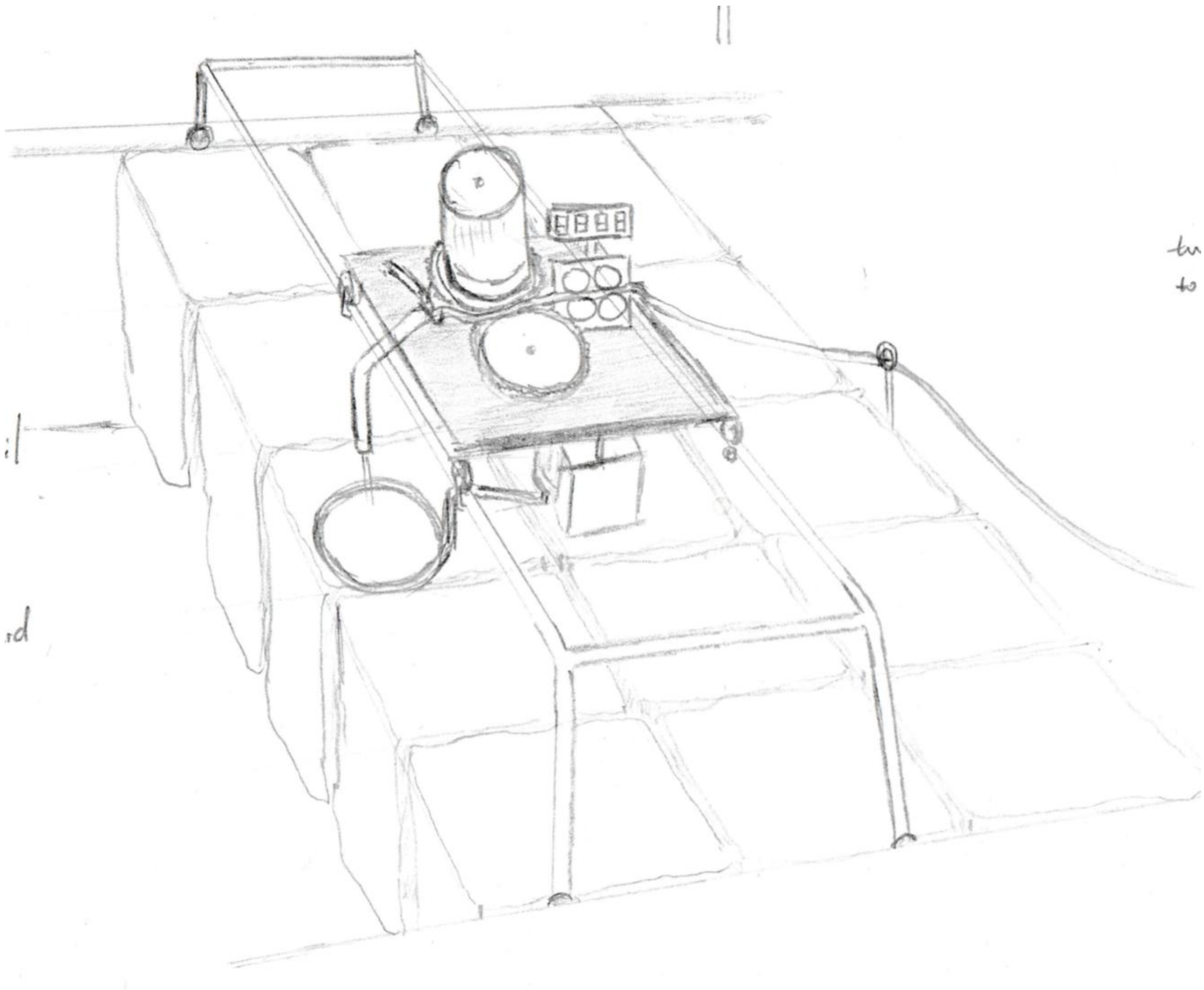
Jansen Tholen B.V.

Provincie Zeeland

HZ UNIVERSITY OF APPLIED SCIENCES

Final Report

Design of an automatic mussel rope collecting system



HZ University of Applied Sciences

Group 5

September 2014 – January 2015

Team members:
Fuliang MA
Qiuyi DING
Yingyuan QU
Shujing NIU

CONTENTS

SUMMARY

Commissioned by Jansen Tholen B.V., a new mussel collecting system is built to collect the mussels on the main ropes, which are in the sea. To meet customer's requirements, the system should be designed in four months. And in this report, the system designed is a part of the collecting system, which is used to collect the empty substrates into a big bag without human power.

1. Reason for report

1) The report is written to record the whole process of designing, which can be seen clearly on the basis of the Eggert methodology. The client can know clearly how the system is designed and how to use it.

2) All the technical principles applied in the designing process and their resources are explained in the report.

2. Problem statement

During the whole designing process, there are a lot of problems: How can more ropes be put into a big bag? How to guide the rope to the bag without human labour? What kind of power supply and motor types should be used? How to drive the rope? How to fill all the bags? How to press the rope? How to cut the rope?

3. Proposed concepts and motivated concept choice

Nine concepts of this automatic rope collecting system are proposed according to the customer's criteria. Weighted Rating Method is used to evaluate the most rational, feasible and efficient concept. The model is also made to improve the final design.

1 Formulation Phase

1.1 Project Plan

The first step of the formulation phase is to make a project plan, during which we can figure out what we are going to do and what is the deadlines of each phase. It is the necessary step to make all the tasks clear to all the members.

The very detailed Project Plan is shown in the **APPENDIX I: Project Plan**.

1.2 Engineering Design Specification (EDS)

There are 5 steps in the EDS categories: Design, manufacturing, transportation, usage, maintenance and financial. All the requirements of the above-mentioned categories are listed in the EDS chart, shown in the **APPENDIX II: EDS**.

2 Concept Phase

2.1 Function Tree

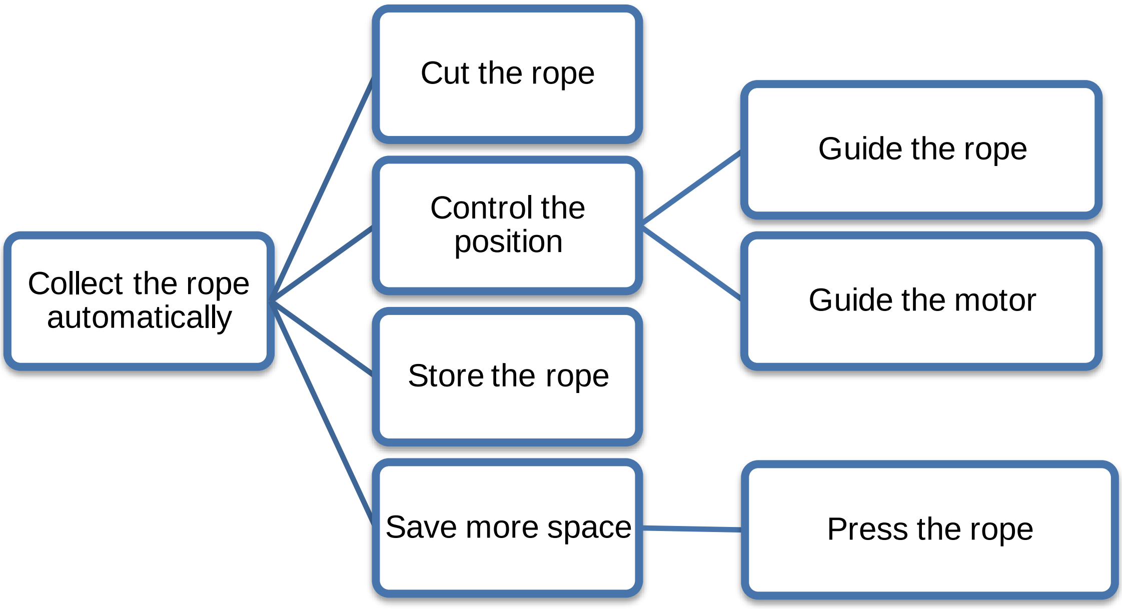


FIGURE 2.1 Function tree

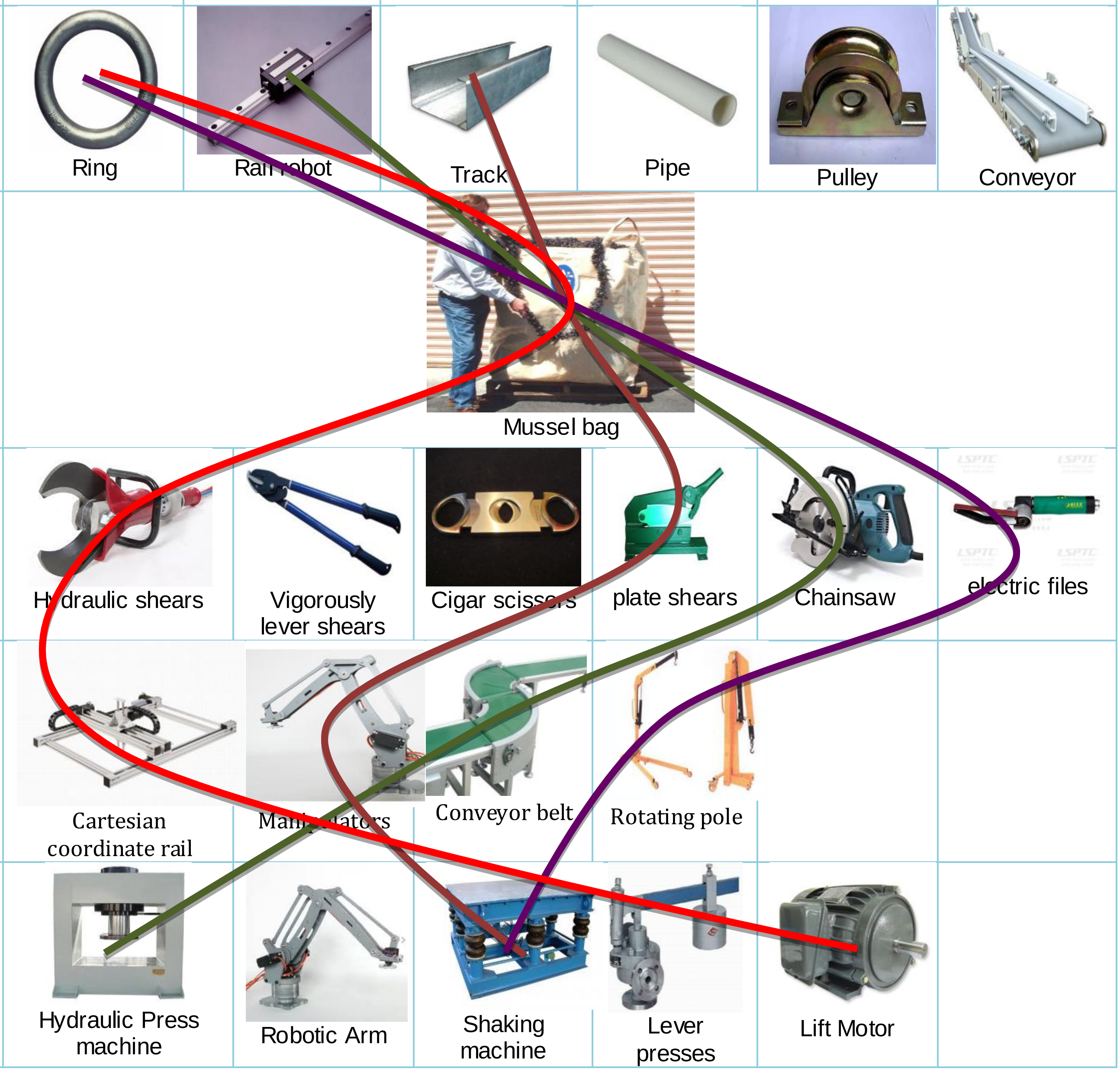
Function description

1. Cut the rope: The cutting machine will cut the rope when the bag is full.
2. Guide the rope: In the process, the rope will be guided from the former system of removing mussels to the bag.
3. Guide the motor: The motor will be moved to the top of each bag in order to put all the ropes into the bags.
4. Store the rope: All the rope will be stored in separate bags.
5. Save more space: There will be a method, which is pressing to make the bag have the biggest effective place to store more ropes.

2.2 Alternative Concepts

After searching on the Internet and discussing within the team, 9 feasible concepts are generated to achieve sub-functions, which is shown as Tab 2.1 below.

TABLE 2.1 Alternative Concept Part 1



Sub function	Alternative concepts 1	2	3	4	5	6
Guide the rope	Ring	Rail robot	Track	Pipe	Pulley	Conveyor
Store the rope			Mussel bag			
Cut the rope	Hydraulic shears	Vigorously lever shears	Cigar scissors	plate shears	Chainsaw	electric files
Guide the motor	Cartesian coordinate rail	Manipulators	Conveyor belt	Rotating pole		
Press the rope	Hydraulic Press machine	Robotic Arm	Shaking machine	Lever presses	Lift Motor	

Concept 1

Concept 2

Concept 3

Concept 4

TABLE 2.2 Alternative Concept Part 2

Sub function	Alternative concepts 1	2	3	4	5	6
Guide the rope	Ring	Rail robot	Track	Pipe	Pulley	Conveyor
Store the rope			Mussel bag			
Cut the rope	Hydraulic shears	Vigorously lever shears	Cigar scissors	plate shears	Chainsaw	electric files
Guide the motor	Cartesian coordinate rail	Manipulators	Conveyor belt	Rotating pole	Track	
Press the rope	Hydraulic Press machine	Robotic Arm	Shaking machine	Lever presses	Lift Motor	

Concept 5

Concept 6

Concept 7

Concept 8

Concept 9

2.3 Concept Description

After the choosing components for the concepts, 9 concepts have formed already. And how the concept works during the whole process and the feasibility explanation are described below. The advantages and disadvantages of a concept comparing with other concepts are also included in the **Appendix IV: Advantages and Disadvantages of concepts.**

2.3.1 Concept 1

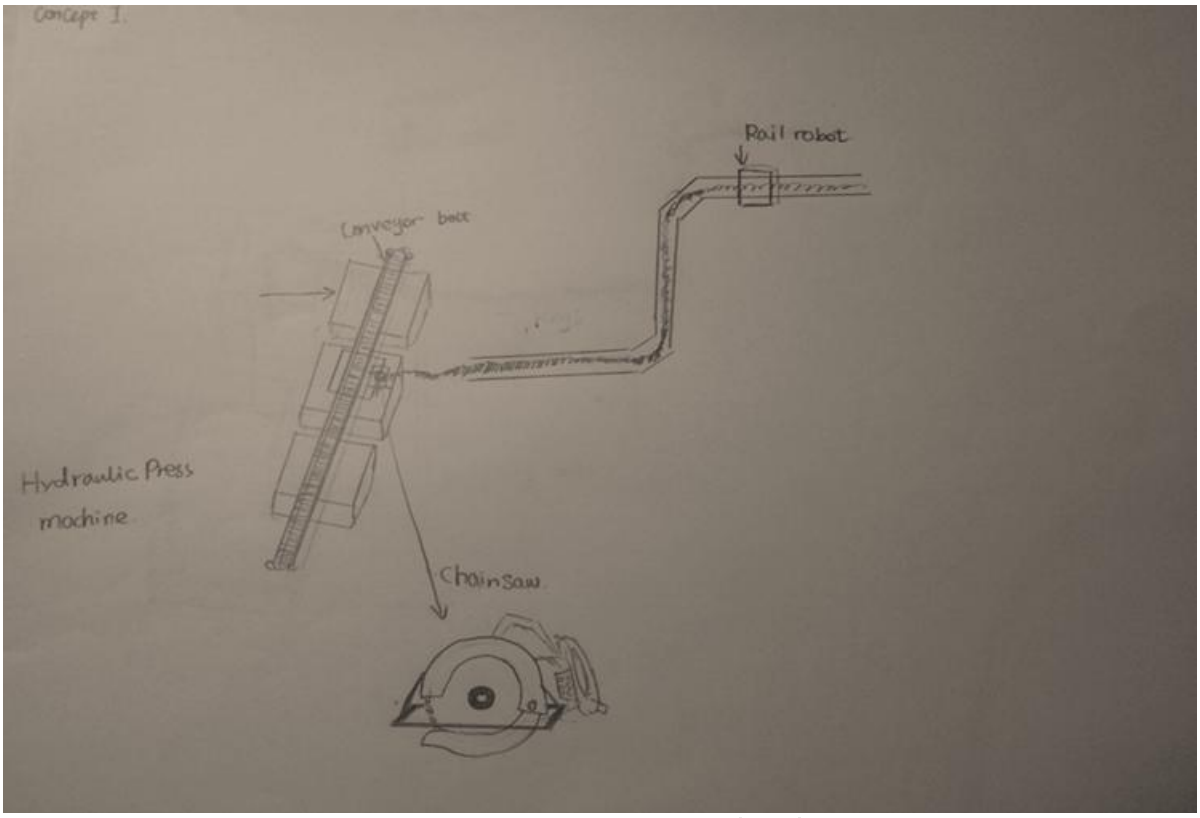


FIGURE 2.2 Concept1 Sketch

In the Fig 2.2 above, the rail robot will lead the rope directly to the top of the big bag. When the bag is full, the belt above the bag will move a certain distance in order to put the other ropes into the bag. On the other hand, the chainsaw will cut the rope once the bag is full. As the hydraulic pressing machine is powerful, it will be used to press the rope during the collecting process.

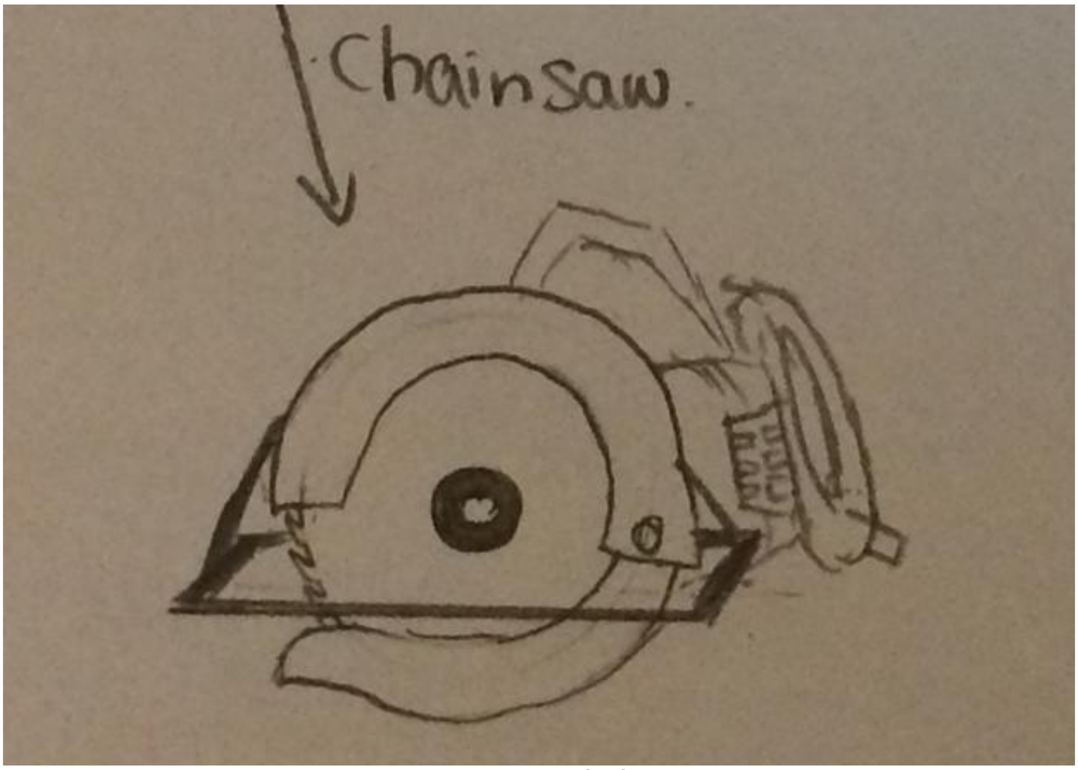


FIGURE 2.3 Chainsaw

This Fig 2.3 shows a normal chainsaw, which can fit the system properly. The system is good enough to cut the rope. As the cutting plate in the chainsaw can be replaced with many other kinds' plate, the chainsaw can cut many kinds of ropes.

2.3.2 Concept 2

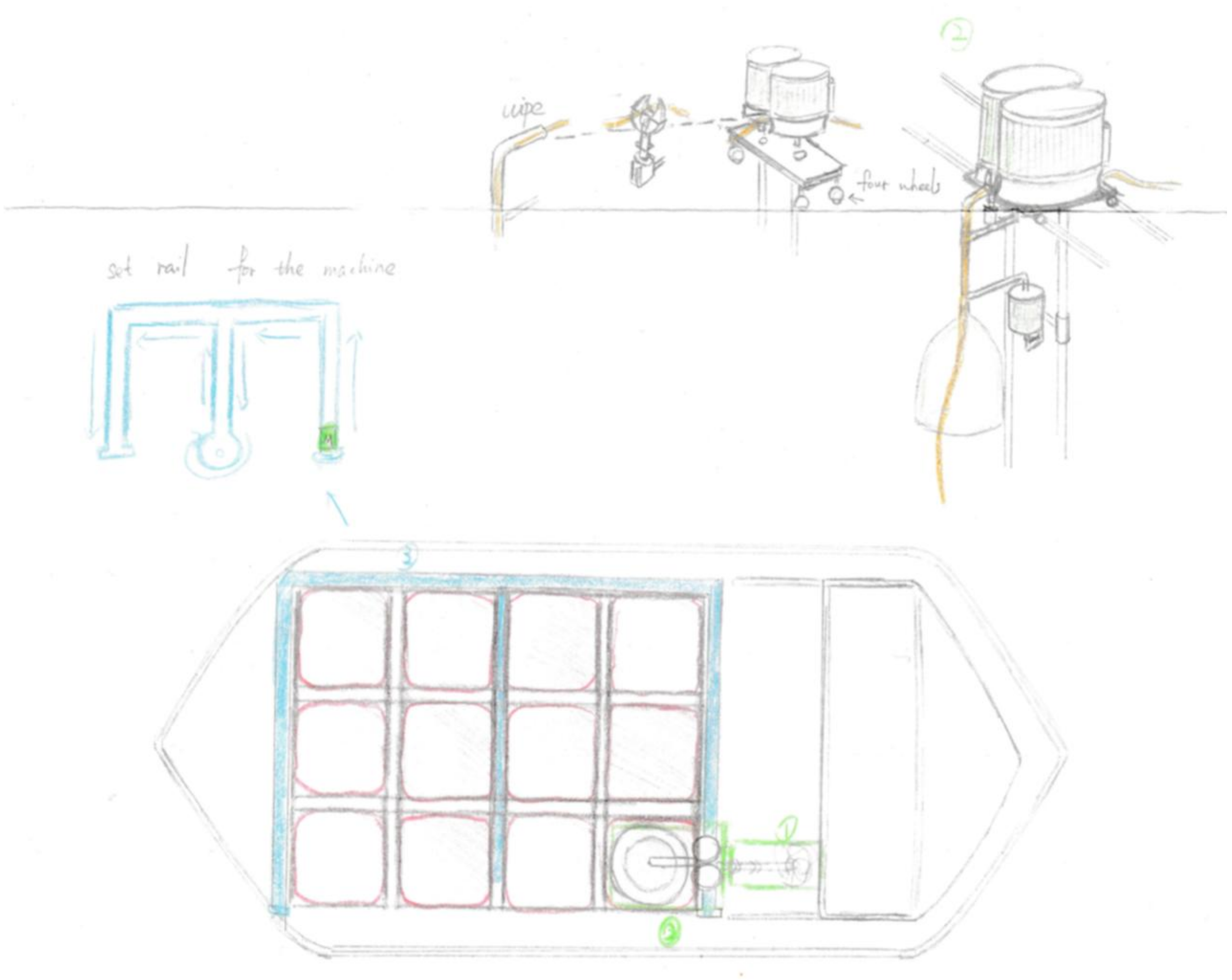


FIGURE 2.4 Concept 2 Sketch

This is the final concept that chosen from all the feasible concepts. It is a stable and automatic system. The position of the rope will be controlled by simple rings and pulled by the turning plate, which is driven by the motors above the plates. After pulled by the plate, a pipe will be used to lead the rope directly to the big bag. When the bag is almost full, the pressing machine driven by the motor will press the ropes to make space for more ropes. Once the bag is full, the hydraulic cutting machine placed between the pipe and the turning plate will cut the rope. Then the pulling and pressing system will stop and the whole system will be moved along the track to another empty bag. A model will also be made to show the working flows and functions.

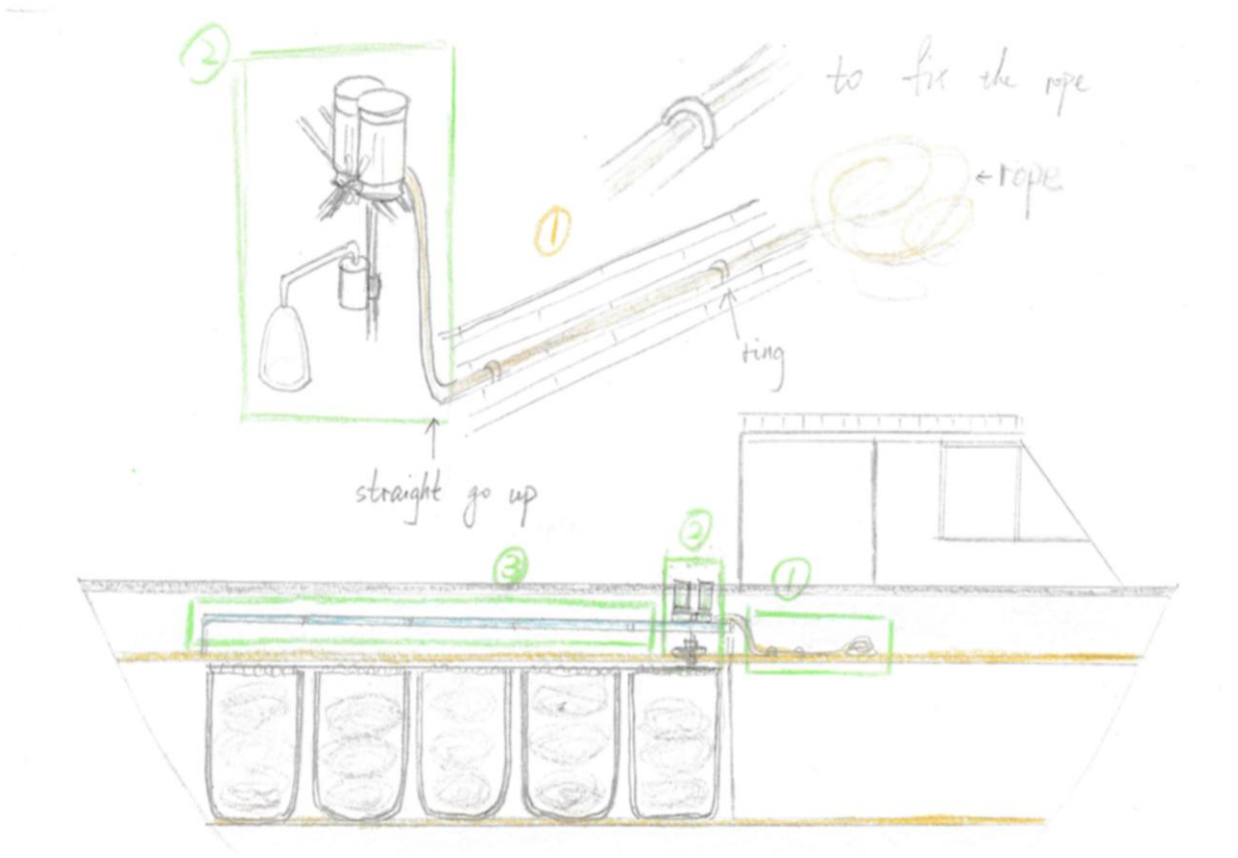


FIGURE 2.5 Concept 2 Sketch

From the above sketch, the whole structure of the collecting can be seen clearly. The size of the track is based on the numbers of bags. And the ropes will be put into each bag. The shape of the pressing part is like a funnel. This is designed to avoid the accumulation of the falling ropes, which means the pressing process and the rope collecting process work at the same time. The big funnel can contain the ropes and they will also fall down when the pressing part is lifted. This collecting system can almost fit all kinds of ships.

2.3.3 Concept 3

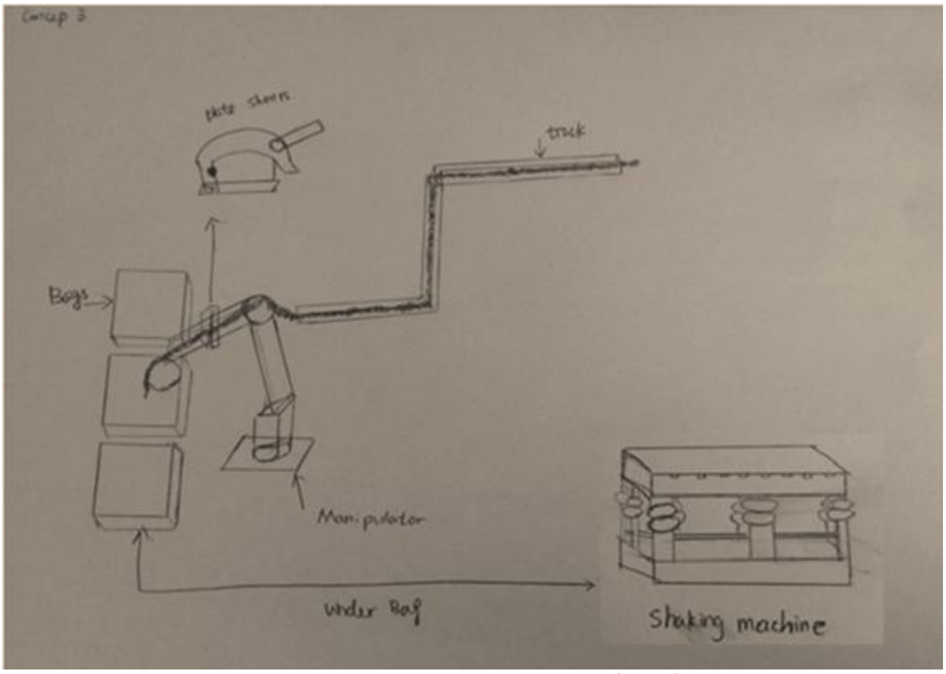


FIGURE 2.6 Concept 3 Sketch

In the Fig. 2.6, it is another system that uses the simple track to guide the rope to the manipulators, which is used to take the coming ropes to the top of each empty bag. When the bag is full, the plate shear will cut the rope at once and then rope will be moved and put into another bag. The shaking machine will shake the bag with ropes to save space for more ropes.

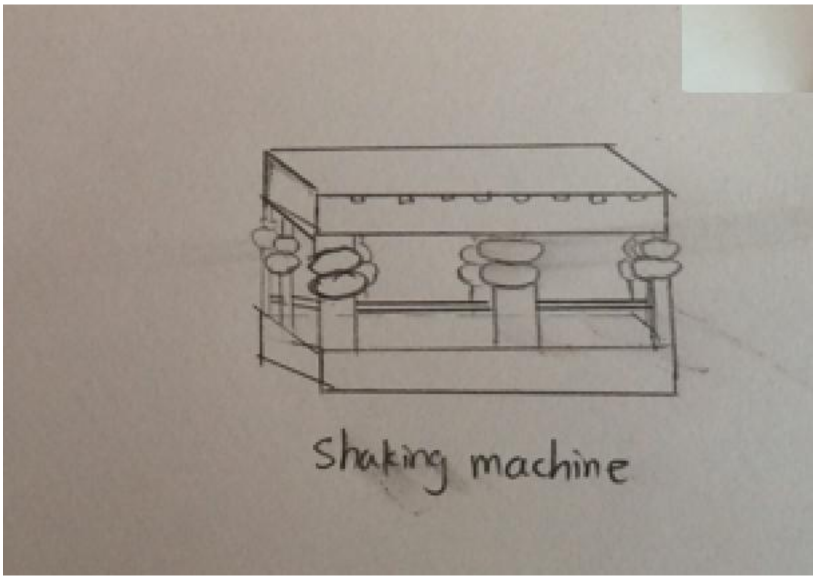


FIGURE 2.7 Shaking machine

The Fig 2.7 shows a typical shaking machine. The machine can shake in all directions with the bag, which means that the rope can spread more evenly in the bag. The machine is not only efficient but also stable.

2.3.4 Concept 4

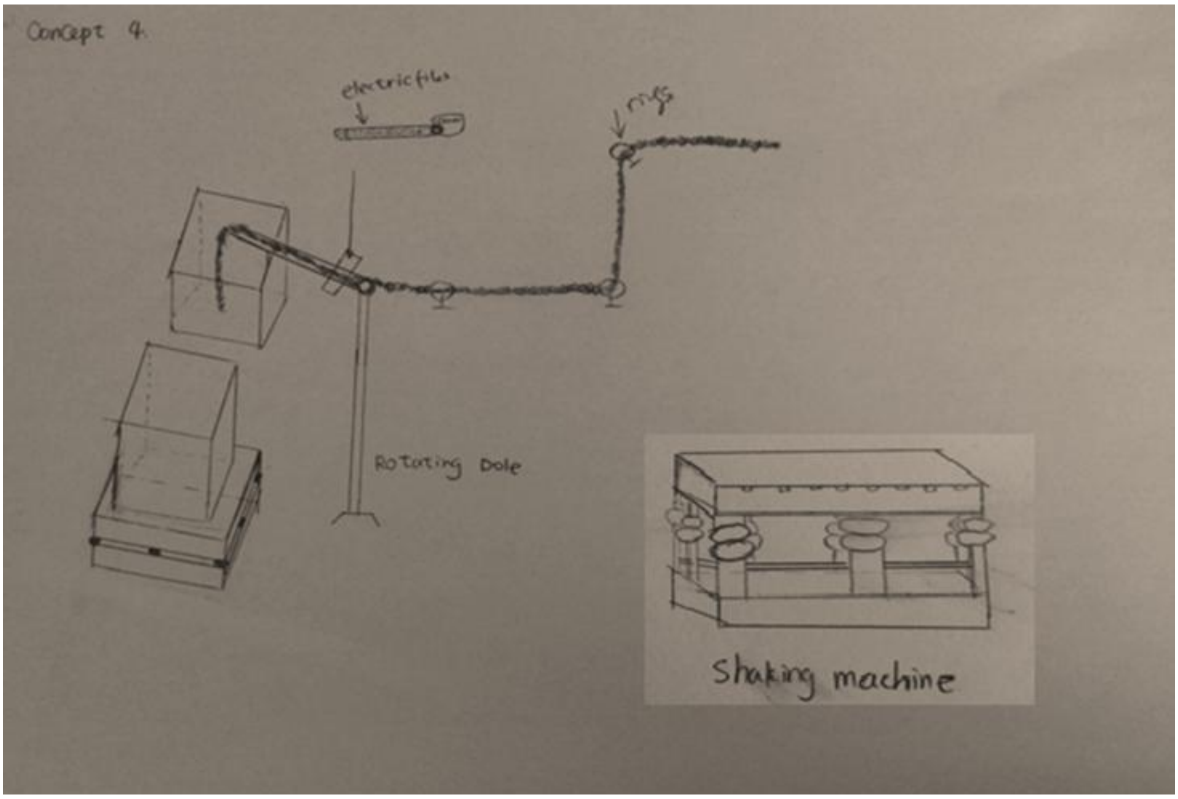


FIGURE 2.8 Concept 4 Sketch

In Fig 2.8, it is a completely new system using several elements different from other concepts. The important part in the system is a rotating pole and it can lead the ropes into each empty bags. Before this part, many rings are used to guide the position of the ropes. The electric files will cut the rope when the bag is full and then the rotating part will put the ropes into another bag. While the system is collecting the rope, a shaking machine is used to vibrate the bottom of the bag. The vibration can make more space in the bag and then more ropes can be put into the bag.

2.3.5 *Concept 5*

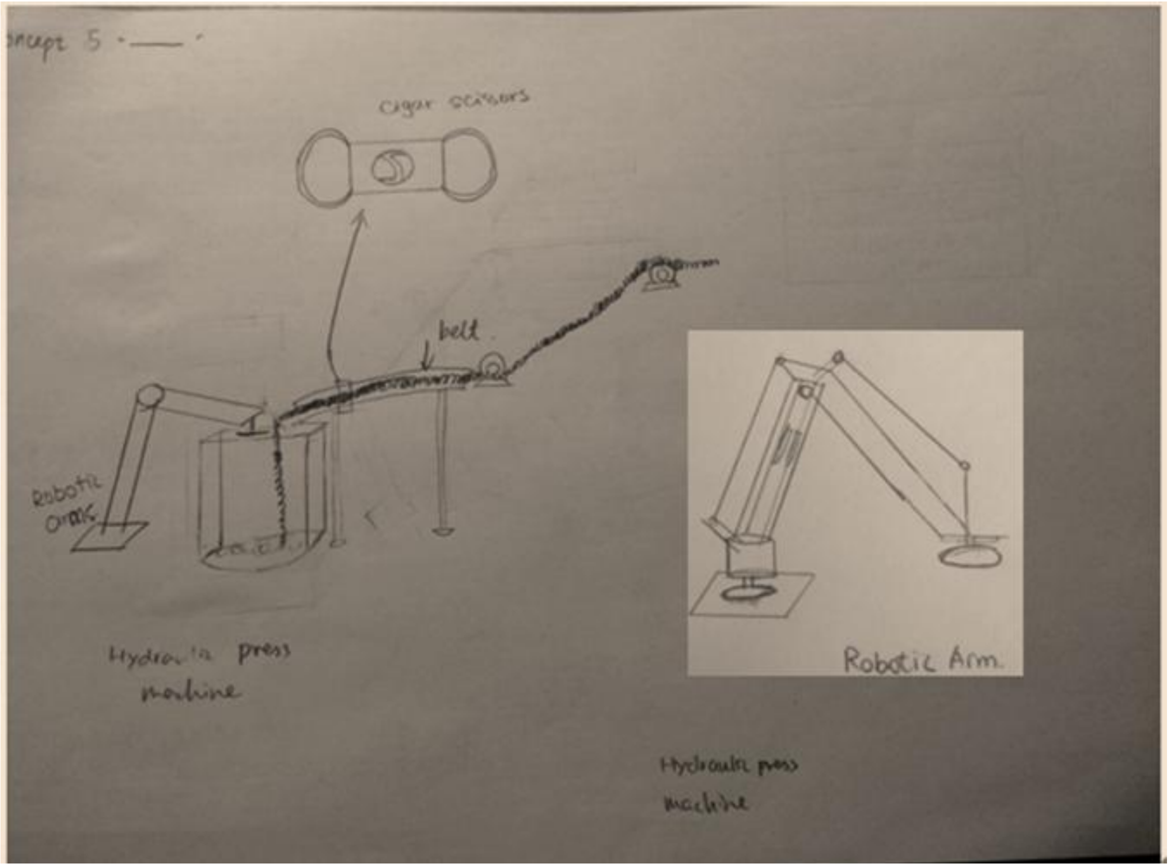


FIGURE 2.9 Concept 5 Sketch

As can be seen from the sketch above, the pulley controlled the rope (no mussel on it) position. Then the rope will be transported by the belt to the top of the big bag. The cigar scissor will cut the rope when the big bag is full. And during the rope collecting process, the robotic arm will press the rope in the bag to release more space for putting more ropes.

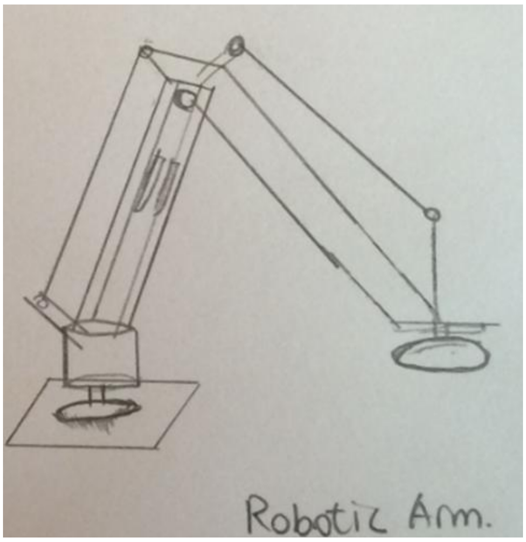


FIGURE 2.10 Robotic arm

The robotic arm shown above is used to provide forces to press the rope for making more spaces for the upcoming rope. Using robotic arm to do so optimizes the non-stop rope collecting without man power.

2.3.6 Concept 6

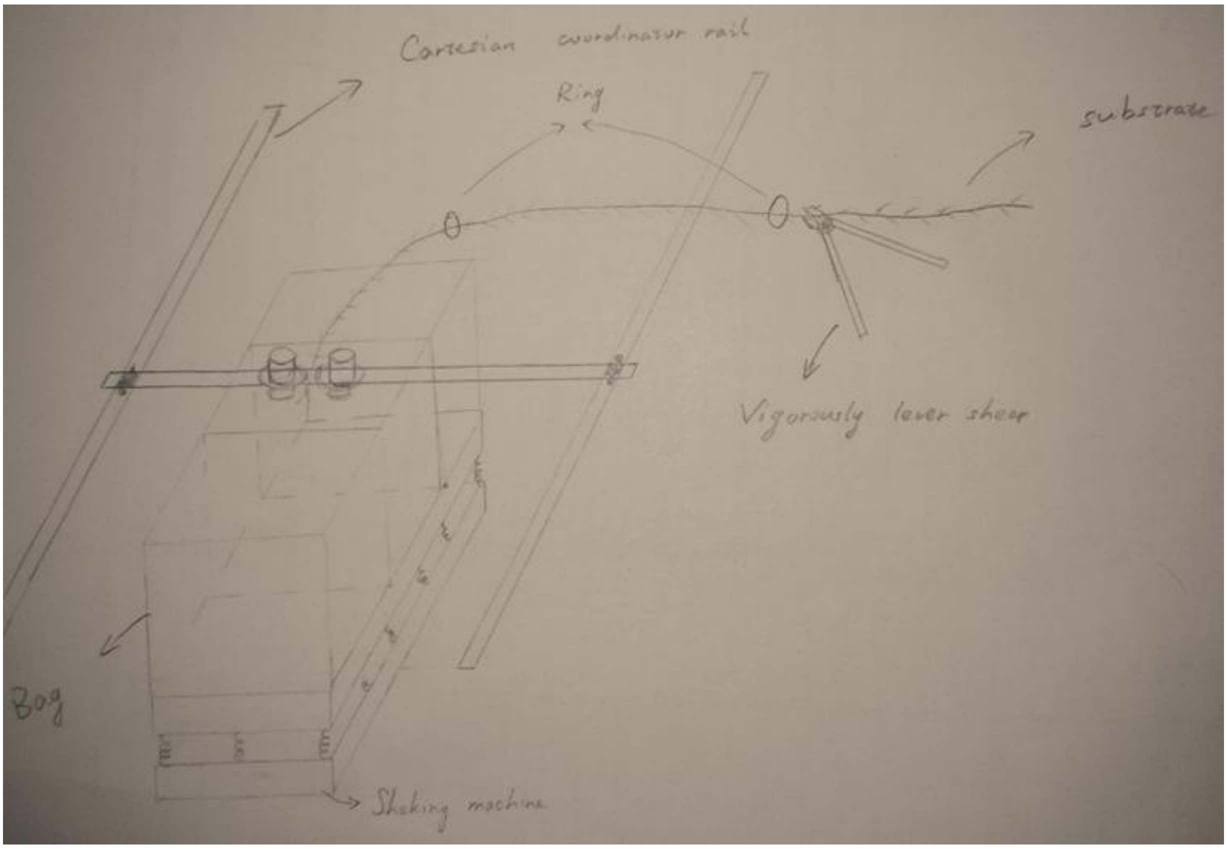


FIGURE 2.11 Concept 6 Sketch

In the sketch Fig.2.11, it is new efficient collecting system. The ring is still used to control the position of the rope and it has the high performance when working. The leading motor on the Cartesian coordinate rail will pull the rope and put the rope into the bags. The Cartesian coordinate rail will lead the motor to the middle top of the bag to ensure all the ropes will be put into the bags. The shaking machine will shake the bag during the process of collecting. Once the bag is full, the vigorously lever shears will cut the rope and the machine will stop unless another new rope has come.

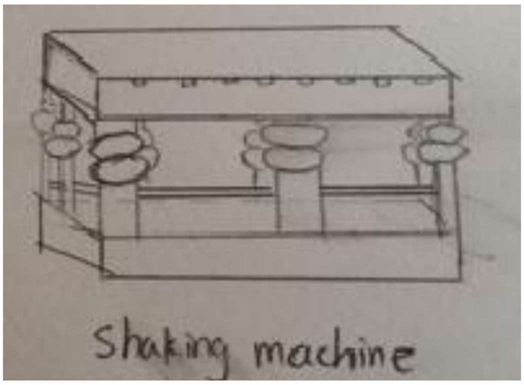


FIGURE 2.12 Shaking machine

The shaking machine is installed under the bag bottom to provide forces to shake the bag in order to make the rope arrange better. Then more space will be free for the upcoming rope, and the shaking machine is working under a certain frequency during the whole collecting process.

2.3.7 Concept 7

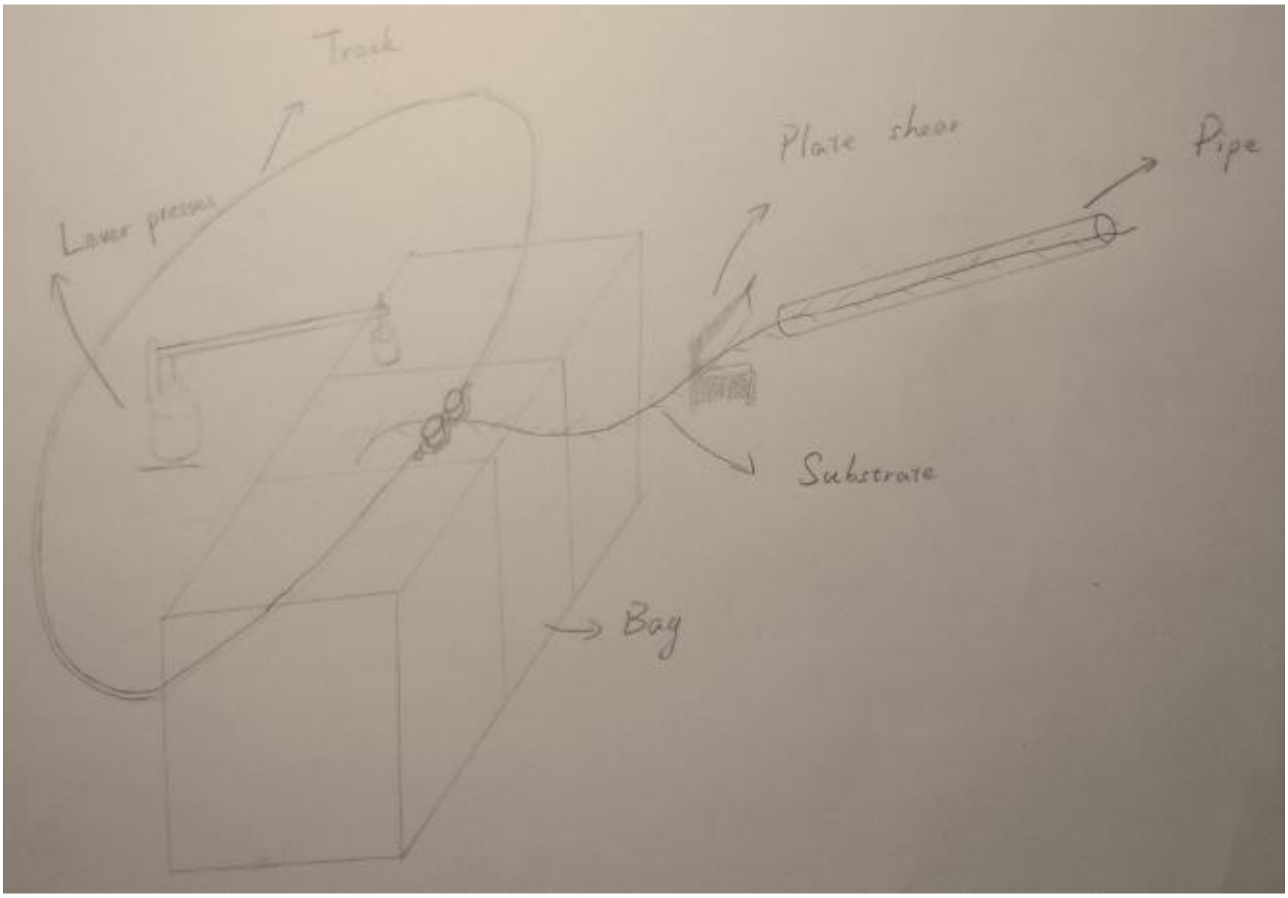


FIGURE 2.13 Concept 7 Sketch

From the above figure, a pipe can be seen that it leads the rope directly to the motor. The motor will be moved by using the track to each top of the empty bag. At the same time, the lever press will press the rope in the bag all the time until the bag is full. This method can save some spaces for more ropes. The plate shear will cut the rope once the bag is full and after that the collecting system will stop working unless another rope comes.

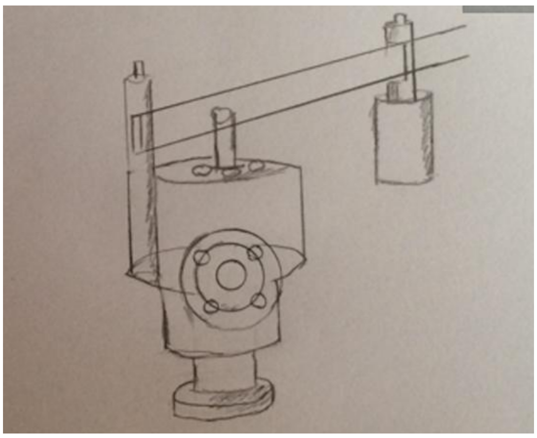


FIGURE 2.14 Plate shear

This is the sketch of the heater. The shape of the heater is like a pipe, which means that the water in the rope will be evaporated by the hot water in the pipe wall. Unlike other methods of removing the water, the rope will not be broken by the shape things during the process.

2.3.8 Concept 8

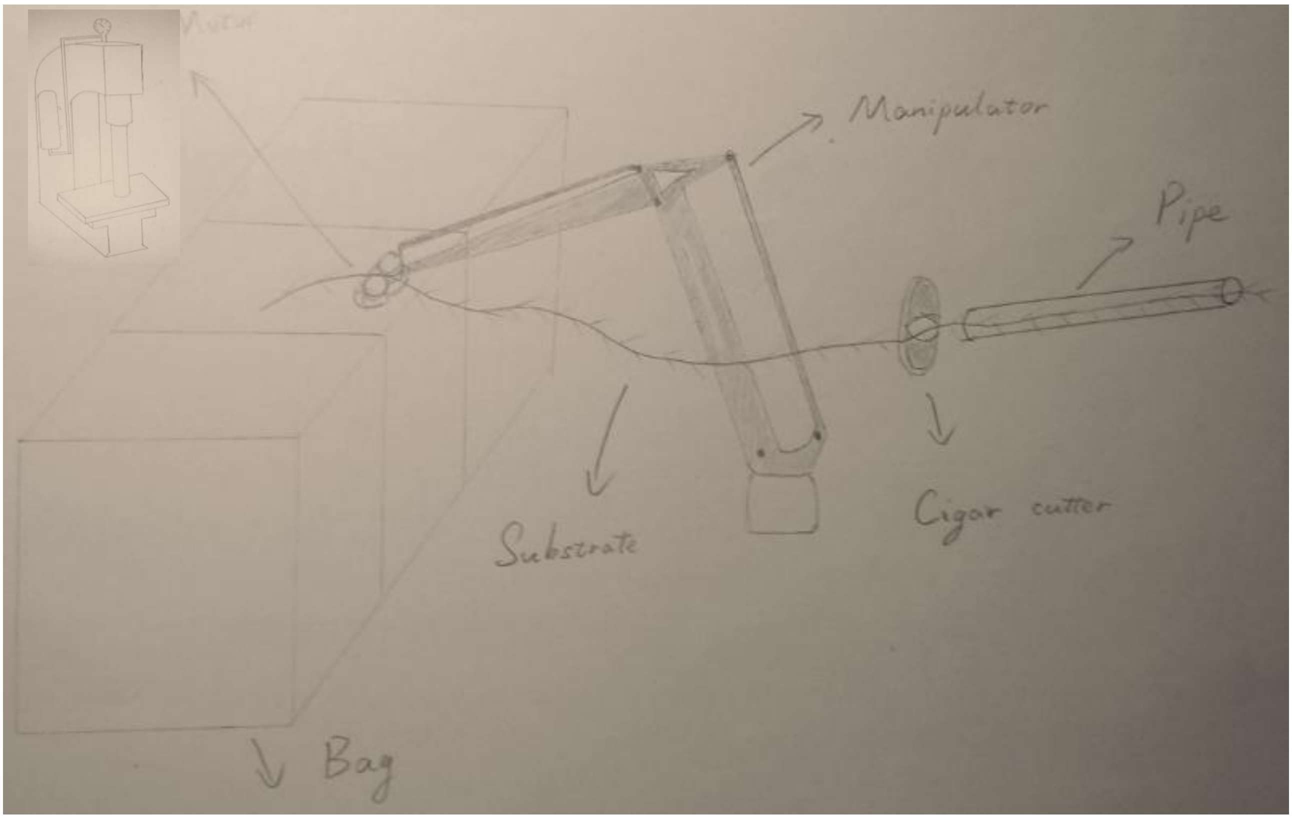


FIGURE 2.15 Concept 8 Sketch

In the Fig 2.15, a motor is used to pull the ropes. In the same time, the pipe will control the position of the rope. In this system, the advanced manipulator is used to move the motor, which means that the manipulator will lead the motor to the middle top of an empty bag when one bag is full. During the process of collecting, the hydraulic pressing machine will press the rope all the time. When the bag is full the cigar cutter will cut the rope and stop the collecting machine.

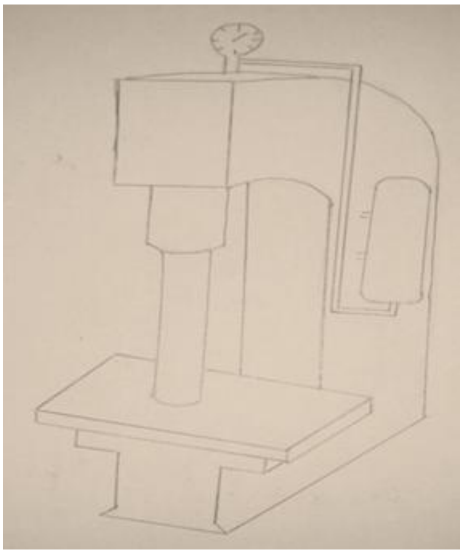


FIGURE 2.16 Hydraulic machine

In the Fig 2.16, it is a hydraulic machine which can compress the rope in the bag to make more space for another rope. The hydraulic machine is so powerful that the efficiency will be high.

2.3.9 Concept 9

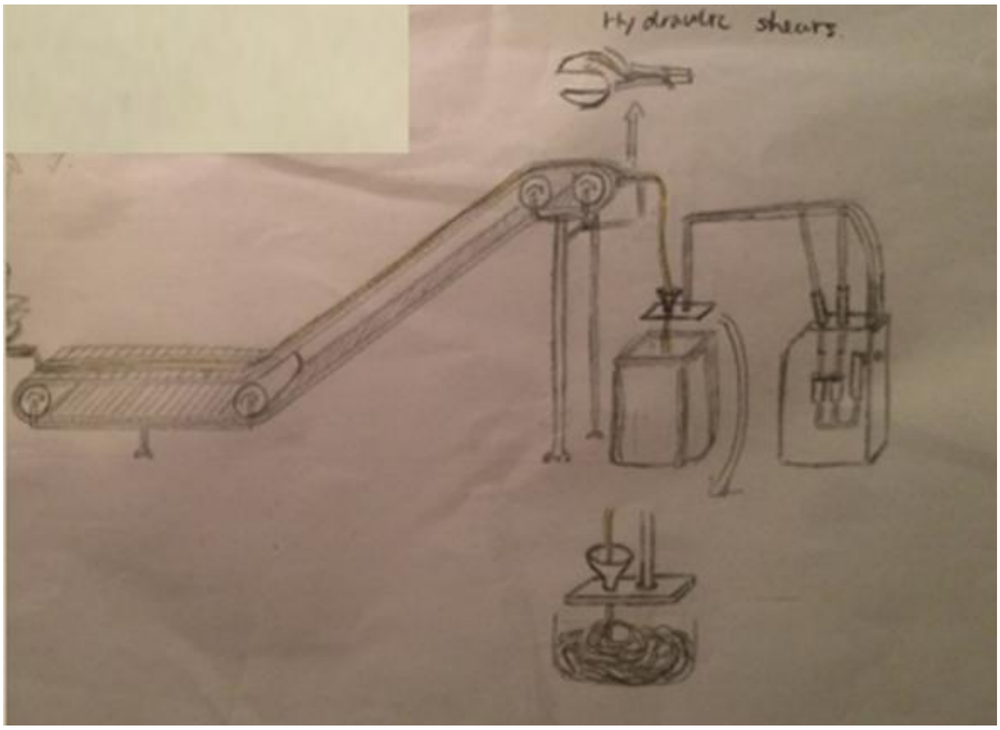


FIGURE 2.17 Concept 9 Sketch

This is a stable and automatic system to collect the mussel rope. The rope will be transported by the crawler belt directly to the connection part on the middle top of the big bag. In the meanwhile, the hydraulic pressing machine will press the rope all the time. The hydraulic cutter will cut the rope when the bag is full and the pressing machine will also stop. The pressing process will not influence the process of the falling rope because of the special funnel on the hydraulic arm.

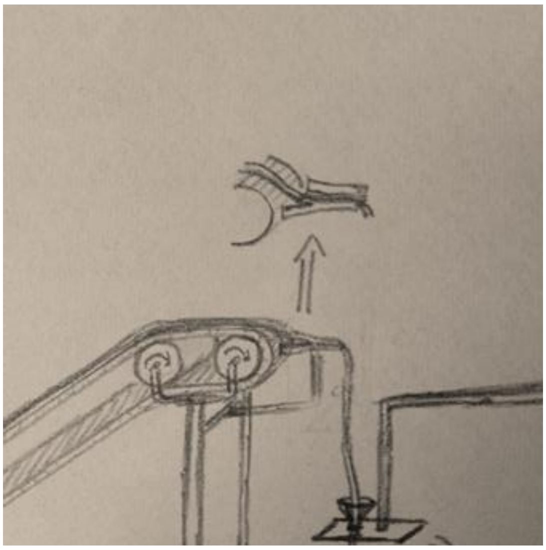


FIGURE 2.18 Connection part

As we can see, all the connection parts use the special design to guide the direction of the rope and avoid the bend of the rope. The width is almost the same as the diameter of the rope and the length of the rope is depended on the distance of the connection parts.

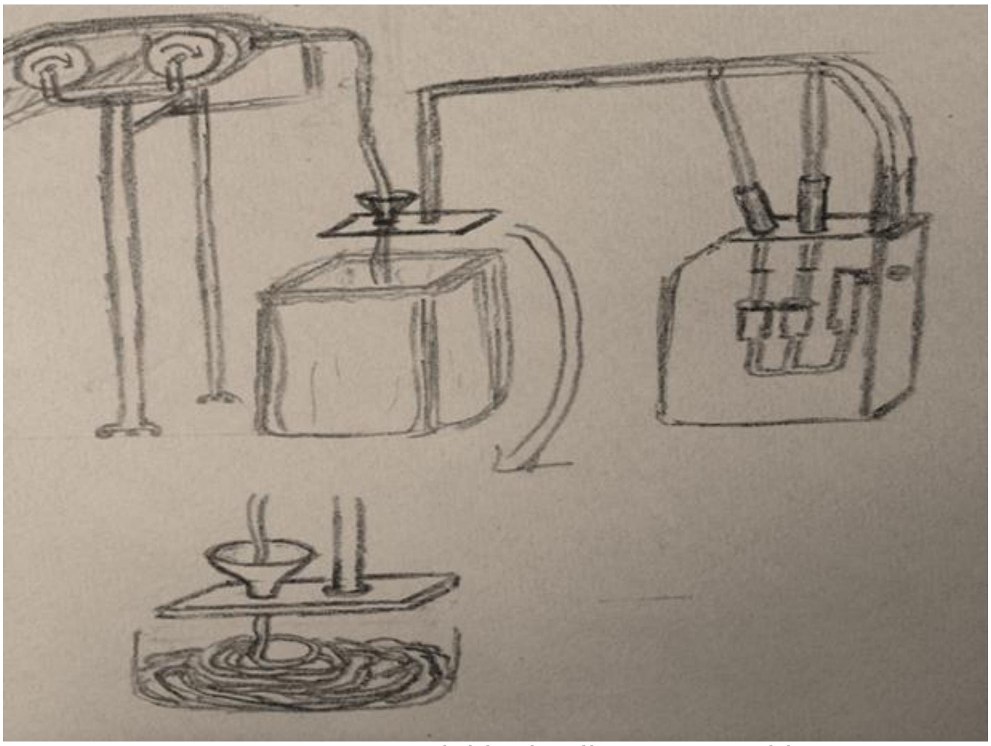


FIGURE 2.19 Special hydraulic press machine

In the Fig 2.19, we can see the last part of the rope collecting system. And this is the very important part during the process, because the special hydraulic press machine will make more space after pressing the ropes in the bags. Another smart design is the funnel on the pressing plate. The funnel will collect the falling rope while the plate is pressing the ropes in the bag. This design solve the problems that the hydraulic pressing plate and the crawler belt can work at the same time which means the falling rope will not influence the work of the pressing plate.

2.4 Evaluation of Concept Alternatives

Several most important and common properties of the rope collecting system are listed as criteria, and the important weight of each item is given by the client. Through evaluating those properties of each alternative in every concept, the best concept comes out with the highest score of overall.

The 9 concepts are evaluated in the following three tables. First three concepts are in the Tab 2.3, Concept 4, 5, 6 are in the Tab 2.4, and the Concept 7, 8, 9 are in the Tab 2.5.

TABLE 2.3 Weighted Rating Method Part 1

Criteria	Importance Weight	Concept Alternatives					
		Concept 1 (Green)		Concept 2 (Red)		Concept 3 (Brown)	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Light weight	1	2	2	4	4	2	2
Proper size	3	3	9	4	12	3	9
High efficiency	3	4	12	4	12	4	12
High automation	5	4	20	5	25	4	20
High safety	5	5	25	5	25	4	20
Easy to operate	4	4	16	5	20	3	12
Long life time	1	3	3	3	3	3	3
Long MTBF	1	3	3	3	3	3	3
Low producing cost	1	3	3	4	4	2	2
Total score		**NA**	**93**	**NA**	**108**	**NA**	**83**

REF: The importance weight ranges from 1 to 5. 1 is 'Unsatisfactory', 2 is 'Just tolerable', 3 is 'Adequate', 4 is 'Good', 5 is 'Very good'. And the details and process of evaluating are shown in APPENDIX III: Concept Score Standard.

TABLE 2.4 Weighted Rating Method Part 2

Criteria	Importance	Concept Alternatives

	Weight	Concept 4 (Purple)		Concept 5 (Orange)		Concept 6 (Blue)	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Light weight	1	4	4	2	3	2	2
Proper size	3	3	9	4	12	3	9
High efficiency	3	3	9	3	9	4	12
High automation	5	4	20	4	20	4	20
High safety	5	4	20	5	25	5	25
Easy to operate	4	4	16	3	12	4	16
Long life time	1	3	3	3	3	4	4
Long MTBF	1	3	3	2	2	4	4
Low producing cost	1	2	2	1	1	2	2
Total score		**NA**	**86**	**NA**	**87**	**NA**	**94**

REF: The importance weight ranges from 1 to 5. 1 is 'Unsatisfactory', 2 is 'Just tolerable', 3 is 'Adequate', 4 is 'Good', 5 is 'Very good'. And the details and process of evaluating are shown in APPENDIX III: Concept Score Standard.

TABLE 2.5 Weighted Rating Method Part 3

Criteria	Importance	Concept Alternatives

	Weight	Concept 7 (Navy)		Concept 8 (Black)		Concept 9 (Yellow)	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Light weight	1	1	1	4	4	4	**4**
Proper size	3	2	6	4	12	4	**12**
High efficiency	3	3	9	3	9	5	**15**
High automation	5	4	20	4	20	4	**20**
High safety	5	3	15	4	20	5	**25**
Easy to operate	4	4	16	3	12	4	**16**
Long life time	1	2	2	4	4	5	**5**
Long MTBF	1	2	2	4	4	3	**3**
Low producing cost	1	1	1	3	3	4	**4**
Total score		**NA**	**72**	**NA**	**88**	**NA**	**103**

REF: The importance weight ranges from 1 to 5. 1 is 'Unsatisfactory', 2 is 'Just tolerable', 3 is 'Adequate', 4 is 'Good', 5 is 'Very good'. And the details and process of evaluating are shown in APPENDIX III: Concept Score Standard.

The total scores of all nine concepts shows that the Concept 2 is the best of them, with the highest score of 108.

3 Configuration Phase

In the configuration phase, the alternatives are not that much as concept phase, for the parts of the system is limited.

After discussion of different places to set the special part, there are few principles to be followed:

1. Do not make the machine complicated.
2. Should consider the force distribution.
3. Should consider the most efficient erection sequence and working condition.

3.1 Configuration Scheme A

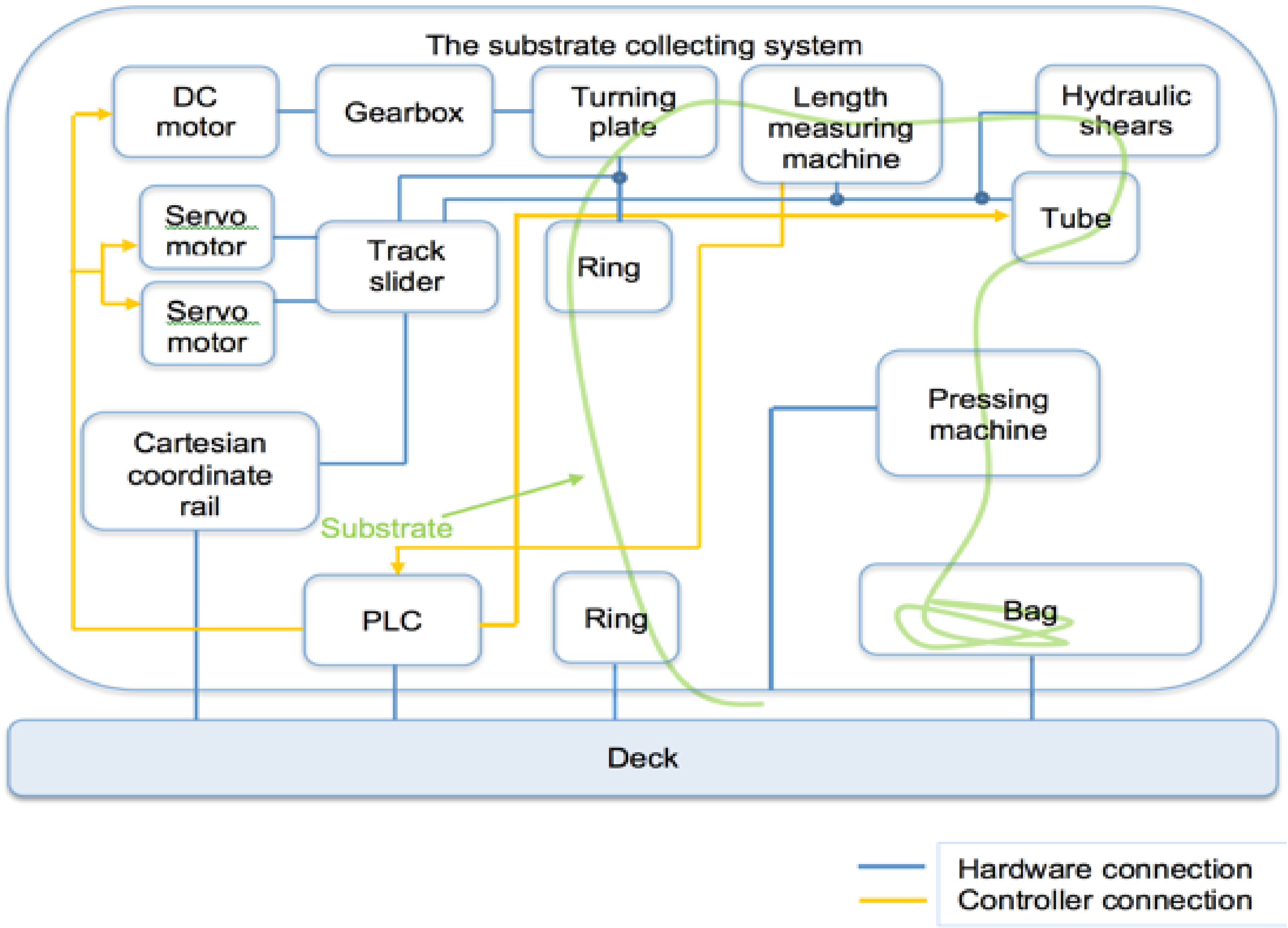


FIGURE 3.1 Configuration Scheme A

In this configuration, rings are used to guide the rope to the turning plate. The DC motor is connected to the turning plate through the gearbox. The turning plate pull the rope and the rope falls from the guiding tube into the bag. The hydraulic shears are between the length measuring machine and the tube. The length measuring machine tells the PLC the total length of substrate in the bag. The pressing machine is mounted on the deck and presses the rope when the bag is 66.5% full. When the bag is completely full, the hydraulic shears will cut the rope. Then the plc controls the servo motor on the Cartesian coordinate rail to change position and be above another bag. The system will repeat the steps above until all the ropes are collected in the bags.

Advantages：
1. The rope can easily be guided by less rings, cheap and sufficient.
2. Easy to install the hydraulic machine
3. Less load on the Cartesian coordinator rail.

Disadvantages:
1. Rope is cut near the turning plate, the rope is easy to slip from the motor.
2. Need to guide the substrate into the machine every time after the substrate is cut.
3. Pressing machine takes too much space.

3.2 Configuration Scheme B

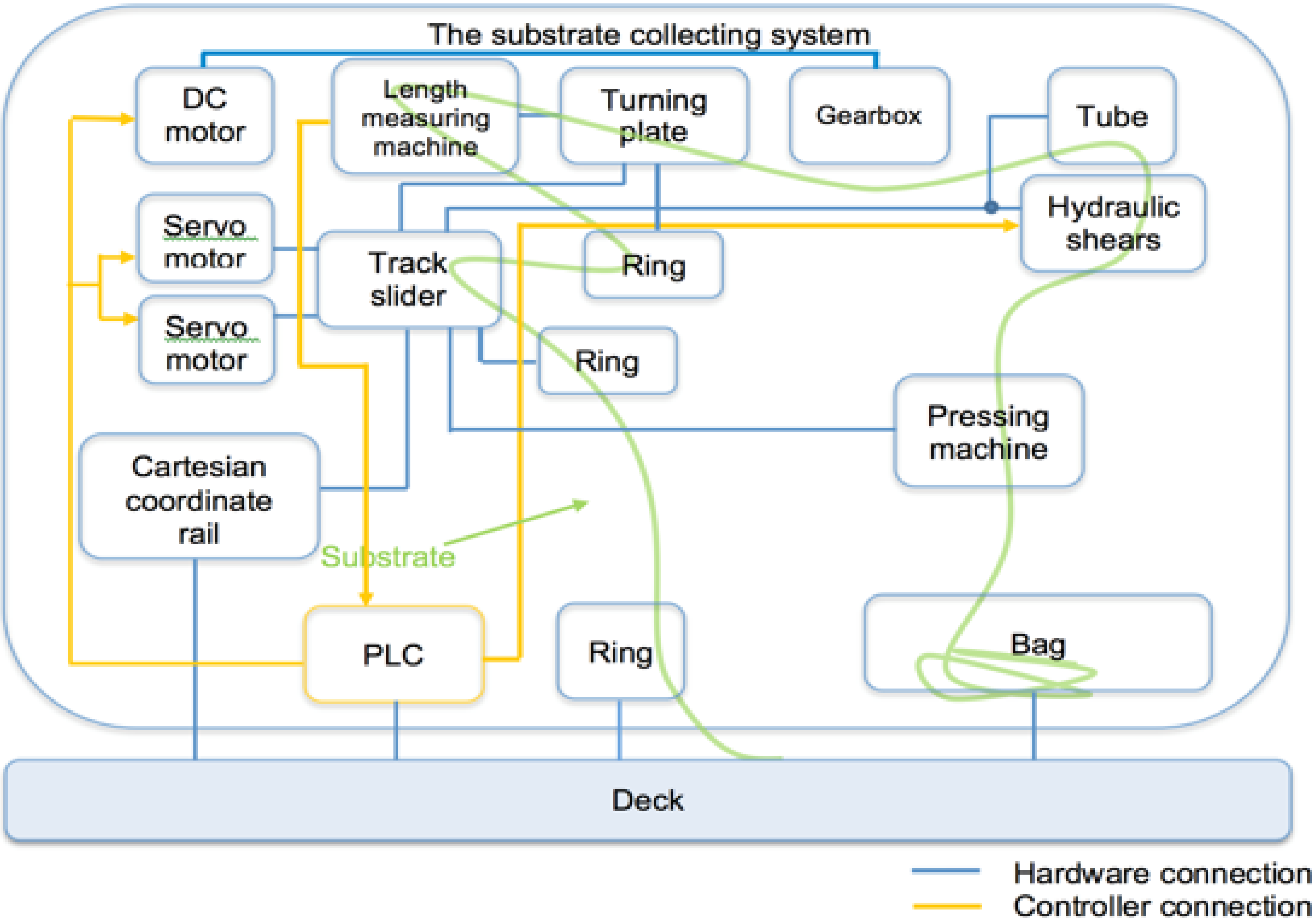


FIGURE 3.2 Configuration Scheme B

In this configuration, rings are used to guide the rope to the track slider then to the turning plate. The DC motor is connected to the turning plate through the gearbox. The turning plate pull the rope and the rope falls from the guiding tube into the bag. The length measuring machine tells the PLC the total length of substrate in the bag. The pressing machine presses the rope when the bag is 66.5% full. When the bag is completely full, the hydraulic shears will cut the rope. Then the plc controls the servo motor on the Cartesian coordinate rail to change position and be above another bag. The system will repeat the steps above until all the ropes are collected in the bags.

Advantages：
1. No need to guide the rope into the machine after the rope is cut
2. Save space on the deck
3. Well organized, easy to control the position of the substrates

Disadvantages:
1. The structure of cutting machine will be more complicated.
2. The load on the Cartesian coordinator rail is higher
3. Require more rings

3.3 Evaluation of Configuration Schemes

TABLE 3.1 Weighted Rating Configuration

Criteria	Importance Weight	Configuration Alternatives			
		Configuration A		Configuration B	
		Rating	Weighted Rating	Rating	Weighted Rating
Light weight	1	2	2	2	2
Proper size	3	4	12	4	12
High efficiency	3	4	12	4	12
High automation	5	5	25	4	20
High safety	5	5	25	5	25
Easy to operate	4	5	20	5	20
Long life time	1	3	3	3	3
Long MTBF	1	3	3	3	3
Low producing cost	1	4	4	4	4
Total score		NA	106	NA	101

3.4 Conclusion

Configuration A is better than B, especially because it's more efficient and space saving. In configuration A, the rope cutting process is before the pressing process, thus save more space and improve efficiency of cutting substrate. While the configuration B puts the shears after pressing machine will leads to more load on the frame of pressing machine. This problem is avoided in configuration A by moving the hydraulic shears before the pressing machine.

In configuration B, using the Cartesian coordinate rail to move the motor, the pressing machine and the hydraulic shears all together also fix the problem (difficult to coordinate the positions of each components) Configuration A works with more automation and accurate, for the given substrates are collected by two gears automatically, as well as the falling substrates are guided by a pipe which avoids the substrates fall out the bag. Based on above consideration, configuration A is the better configuration.

4 Parametric Phase

In parametric phase, all the main components will be specified, all the properties and parameters will be discussed and designed.

4.1 Link part

4.1.1 Rings

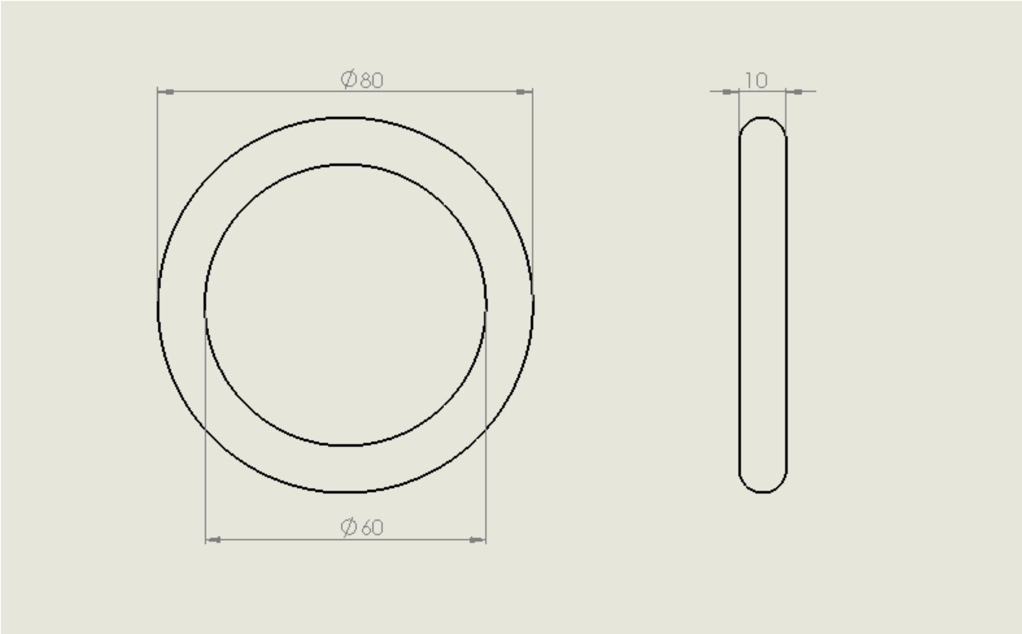


FIGURE 4.1 Ring

Consideration:

For the link part. After considering the price and working conditions. Rings are the best method to guide the rope to the motor. For rings are used to guide wet substrates, in order to keep them in usable condition. The materials should choose from waterproof material.

Material: 6061 aluminium alloy

6061 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S". This material is widely used in Marine fittings.

TABLE 4.1 Amount distribution in components

Component	Amount (wt.%)
Aluminium	Balance
Magnesium	0.8-1.2
Silicon	0.4 – 0.8
Iron	Max. 0.7
Copper	0.15-0.40

Zinc	Max. 0.25
Titanium	Max. 0.15
Manganese	Max. 0.15
Chromium	0.04-0.35
Others	0.05

TABLE 4.2 Physical Properties	
Density	2.7 g/cm3
Size	D1 80mm D2 60mm D3 10mm
Melting Point	Approx 580°C
Modulus of Elasticity	70-80 GPA
Poisson Ratio	0.3

Typical properties of aluminium alloy 6061 include:

– Medium to high strength
– Good toughness
– Excellent corrosion resistance to atmospheric conditions
– Good corrosion resistance to sea water
– Can be anodized
– Good weldability and brazability
– Good workability
– Widely available

4.1.2 Pipe

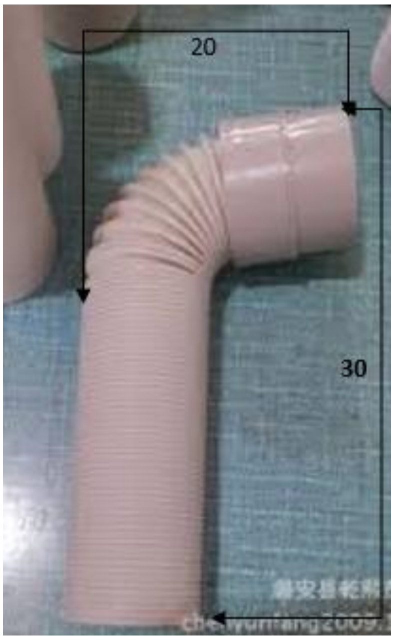


FIGURE 4.2 Tube

Material: Rigid PVC

PVC's relatively low cost, biological and chemical resistance and workability have resulted in it being used for a wide variety of applications. PVC has high hardness and mechanical properties. The mechanical properties enhance with the molecular weight increasing but decrease with the temperature increasing. The mechanical properties of rigid PVC (uPVC) are very good.

TABLE 4.3 Physical Properties

Material	Rigid PVC
Size	20*30*2.4
Tensile Strength at Yield	⩾40MPa
Softening temperature	⩾90℃
Size (mm)	200*300*2.4

4.1.3 Hydraulic shears

FIGURE 4.3 Hydraulic shears

Hydraulic shear is one of the excellent rescue tools, which uses the latest design and machining, heat treatment and surface treatment, and use of high-strength steel and high-strength aerospace aluminium alloy, high strength, high strength, small volume, light weight, excellent quality.

There are many kinds of hydraulic shears. Some of them are very big. What the system needs is small and light. After checking many shears, and combining with the whole system, then comes to a best type of hydraulic shears.

TABLE 4.4 Hydraulic shears

Details	
Article number	100.102.032
Basic specifications	
Model	HMC 8 U
Max. Working pressure	72 (bar/Mpa)
Performance	
Max. cutting force	78.5 KN
Width of jaw	40 mm
General specifications	

Required oil content (effective)	43 cc
Dimensions, weight and temperature	
Weight	3 kg
Temperature range	-20 + 55 °C -4 + 131 °F

TABLE 4.5 Size	
Length (mm)	420
Width (mm)	50

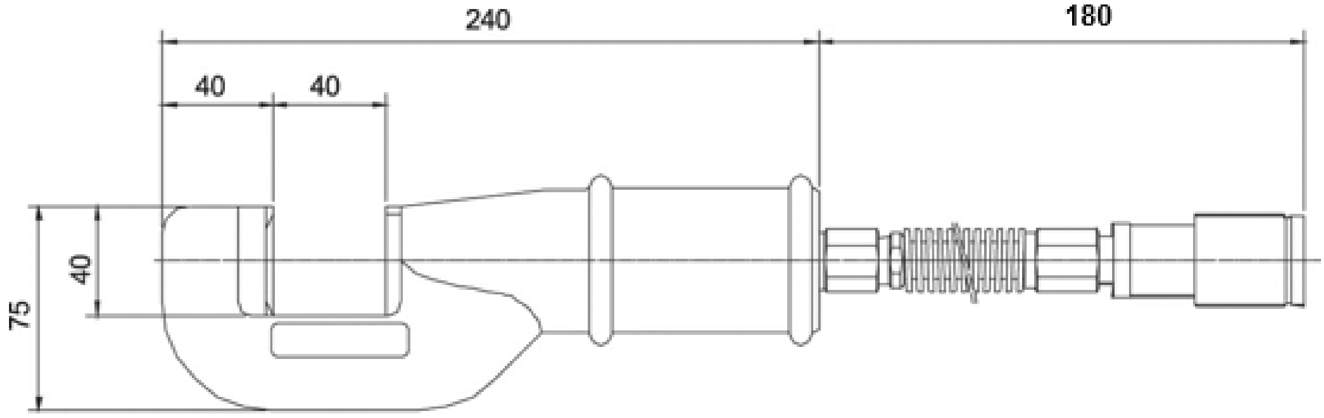


FIGURE 4.4 Hydraulic shears dimension

How to use?

When cutting steel, first close all the oil switch, flip the movable handle, the plunger pump to work, the hydraulic piston big push to promote the blade, cutting material up (do not continue the pressure, otherwise they will be damaged parts). After cutting the substrate, the segment can be automatically reset.

4.2 Rope driving device

4.2.1 The parametric of the driving part

The driving part is one of the most important parts in the collecting system and it is the only equipment that can drive the ropes. So it is really necessary to determine the specific parameter of the driving part. And the driving part consists of the two same turning plates, three same-size transmission gears and one driving motor.

Turning Plate

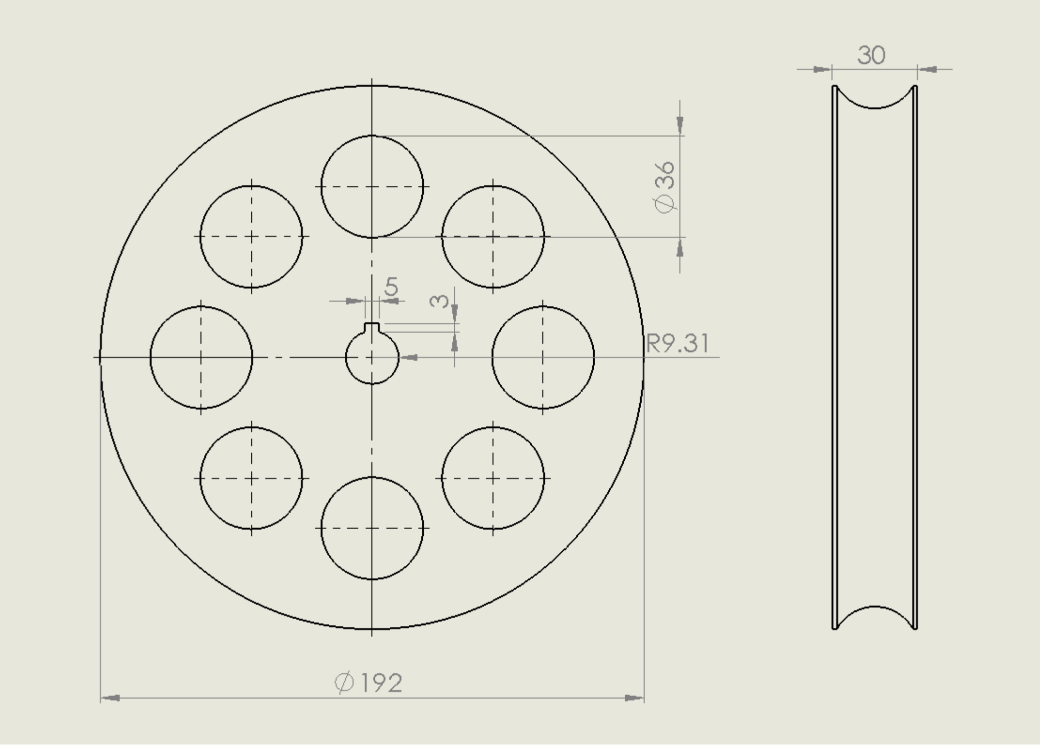


FIGURE 4.5 Turning plate

The system is used on the sea, so the equipment must be anti-corrosion. After the discussion in the group, the material of alloy is the best choice. The reason is that alloy has lightweight and good performance of strength, which is much better than the pure metal. And the alloy material can be used in the harsh environment for a long time. Another important thing is that the element in the alloy should be chosen. Different ratio of different element has different performances. The final choice is the Magnesium & Silicon alloy called brand 6061. It is 20% stronger than 5052 and almost the most anti-corrosion alloy in the alloy series which is more suitable for the weather on the sea. The margin of plate is a layer of rubber bands. The size of the plate is well calculated which is shown in the following table.

TABLE 4.6 Hydraulic shears

Model	5454	5052	6061
Price (EU/kg)	5	6	4
Strength extension (MPa)	>=215	>=170	>=310
Yield strength (Mpa)	>=85	>=65	>=276

Size (mm)	Φ190*20		
Material	Aluminum & magnesium alloy		Magnesium & Silicon alloy
Density (g/cm3)	2.73	2.72	2.82

The Gears

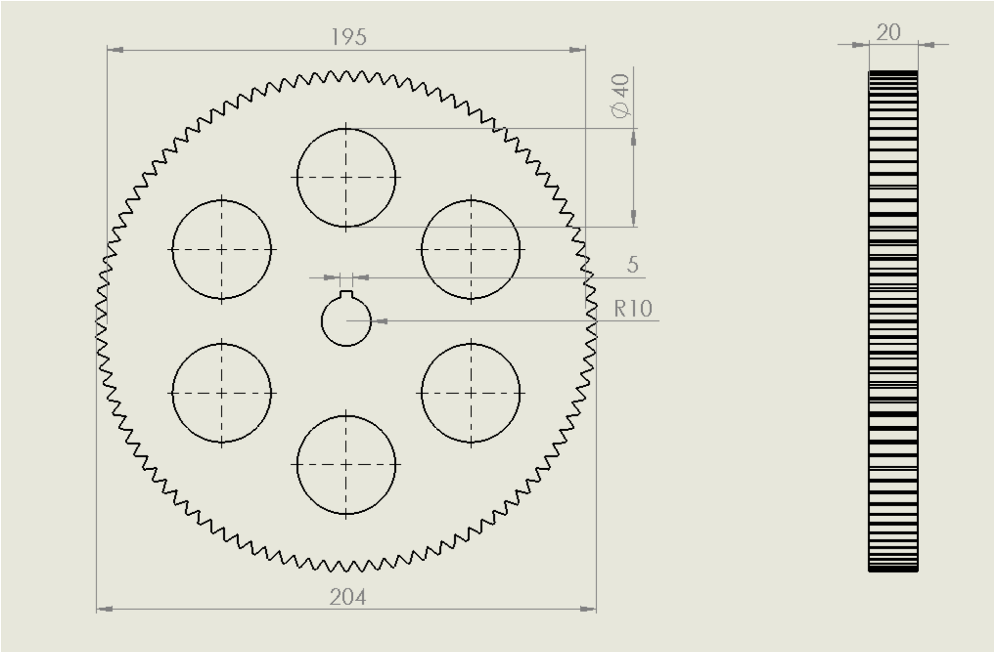


FIGURE 4.6 The gears

Because of the special size of the system, the parameter of the gears is well designed. The diameter of the gears is 200mm and the module of the gears is 2, which is the final data considered for a long time. At first the module is designed as 3 and the number of teeth will not be an integer and the number will be too less. If the module is designed as 1, the height of teeth will be too low. The reason that the module is chosen as 2 is that the more the teeth and less the module, the more stable the gears are. Another advantage is that the design will be compact and has low producing cost when the module is small. And the noise will be less if the module is less. All the parameters are shown in the following lines.

D: Reference circle diameter;
Z: Number of teeth;
m: Module;
Da: Tip diameter;
Df： Root Circle；
Ha*: Tooth Addendum coefficient;
Ha: Tooth Addendum;
C*: Tip clearance coefficient;
Hf: Tooth duodenum;
H: Depth of tooth;
p: Pitch of tooth;
e: Space width;
a: Reference centre distance;
b: Width of tooth

$$D = \left(\frac{P}{\pi}\right) * Z = m * Z = 200\ (mm)$$

$$m = 2, \mathrm{Ha}^* = 1, \mathrm{C}^* = 0.25, Z = 100$$

$$Da = m(Z + 2\mathrm{Ha}^*) = 204\ (mm)$$

$$\mathrm{Df} = \mathrm{D}\text{-}2Hf = 195(\mathrm{mm})$$

$$Ha = Ha * m = 2\ (mm)$$

$$Hf = \mathrm{m}(\mathrm{Ha}^* + \mathrm{C}^*) = 2.5\ (\mathrm{mm})$$

$$H = Ha + Hf = 4.5\ (mm)$$

$$p = \pi m = 6.2832\ (mm)$$

$$e = \frac{\pi m}{2} = 3.1416\ (mm)$$

$$a = \frac{m(Z + Z)}{2} = 200\ (mm)$$

$$b = 20(mm)$$

The parametric of the suitable motor

FIGURE 4.7 Driving motor

The motor is the only thing that can drive the gears and plates. As calculated the rotating speed should be around 3000r/min and then can attend the normal collecting speed of 0.5m/s. As a result, the final choice of the motor is the model of Y90S-2, which is a two-pole motor. The rotating speed can meet the requirements of the collecting speed. And the weight and power is also good for the collecting system. The specific parameter is shown in the following table.

Vmax: The maximum collecting speed
ω: Angular velocity of the turning plate
r: The radius of turning plate

n: The rotating speed of the motor

$$Vmax = \omega * r = 0.5\, m/s$$

$$\omega = \frac{Vmax}{r} = \frac{0.5}{0.0965} = 5.1813\, rad/s$$

$$\omega = \frac{2\pi n}{60}$$

$$n = \frac{30\omega}{\pi} = 30 * \frac{5.1813}{\pi} = 49.46\, r/s = 2940\, r/min$$

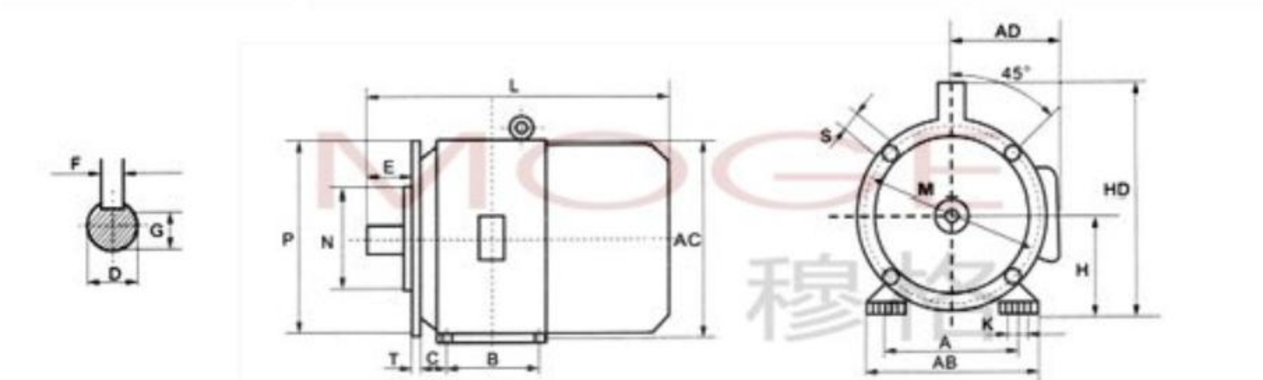


FIGURE 4.8 Driving motors specification

TABLE 4.7 Driving motor parameters								
Model	Poles	Rated Power (KW)	Rated Current (A)	Revolving Speed (r/min)	Power Factor	Efficiency	Weight (kg)	Size (mm)
Y90L-4	4	1.5	3.7	1400	0.79	79%	25	180*195*340
Y90S-4	4	1.1	2.7	1400	0.78	77%	24	180*195*315
Y90S-2	2	1.5	3.4	2840	0.85	78%	18	165*180*315
Y80M2-2	2	1.1	2.5	2830	0.86	77%	16	165*170*290

4.3 Track Slider System

4.3.1 Track Slider

The track slider is mounted on the Cartesian rail. The pressing machine is fixed below it and the turn-plates are installed on it. It is driven by the servomotor so it can move along the rail. The track slider is made of aluminium and the surface is hard anodize treated so it is corrosion resistant.

The slider has four wheels on the track so it can move smoothly, there are also two wheel below the track to help prevent it from moving up and down. It has a load capacity of about 160 kilograms which is enough for the devices fixed on it.

FIGURE 4.9 Track slider

TABLE 4.8 Track slider parameters	
Physical Properties	Amount
Material	Aluminium
Surface treatment	Hard anodize
Weight	5.5kg
Load capacity	160kg
Size (L*W*H)	70*50*15cm
Price	110 €

4.3.2 Motor: SSBSM80C-175CA Stainless Steel Brushless Servo Motors

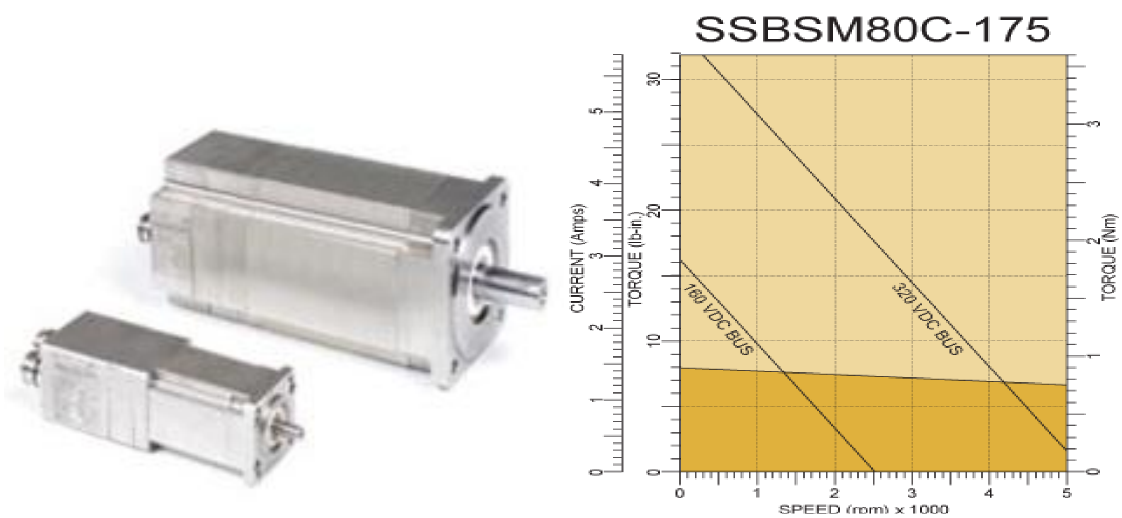


FIGURE 4.10 Servo motors

Baldor's totally stainless steel SSBSM series servo motors are designed to be applied in harsh, corrosive environments. These motors are designed to handle IP67 and withstand 100 bar (1500 psi) wash-down conditions. These stainless steel servo motors are offered in standard and low inertia designs for best machine inertial matching. Included in this quality design are environmental protected stator with premium moisture resistant wire and internal thermal over temperature protection.

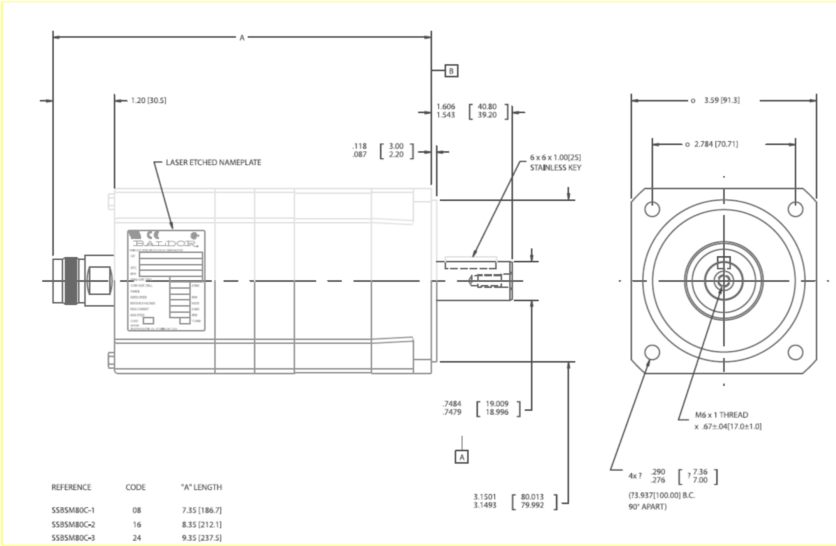


FIGURE 4.11 Servo motors

M=3.2+19+3+3.2+20=48.4kg
$J_L=m*r^2=48.4*4*4*0.01=7.7kg*cm^2$
$J_{m(min)}=J_L/R_i=7.7/5=1.54kg*cm^2$
$J_{m(max)}=J_L/R_i=7.7/3=2.57kg*cm^2$

M: mass of load
J_L: Inertia of load
$J_{m(min)}$: Minimum motor inertia
$J_{m(max)}$:Maximum motor inertia
R_i: Inertia ratio (range between 3-5 is ideal)

TABLE 4.9 Track slider parameters

Properties	Amount
Type	Servo motor
Motor inertia	$1.81kg*cm^2$
Continuous stall torque	0.9Nm
Continuous stall amps	1.5A
Peak current	4.1A
Poles	4
Max speed	7000rpm
Resistance	17.6Ω
Rated speed	4000rpm
Peak torque	2.7
Size(L*W*H)	7.35*9.1*9.1cm

4.4 PLC controller: SIMATIC S7-1200

4.4.1 Hardware for moving the frame and the machine on it: SIMATIC S7-1200 PLC

FIGURE 4.12 SIMATIC S7-1200

Overview

- Controller with integrated PROFINET IO controller interface for communication between SIMATIC controllers, HMI, programming device
- Data logging functionality for archiving of data at runtime from the user program
- Powerful, integrated technology functions such as counting, measuring, closed-loop control, and motion control
- Integrated digital and analog inputs/outputs
- Signal boards for direct use in a controller
- Signal modules for expansion of controllers by input/output channels
- The miniature controller that offers maximum automation at minimum cost.
- Extremely simple installation, programming and operation.
- Large-scale integration, space-saving, powerful.
- Suitable for small to medium-size automation engineering applications.
- Can be used both for simple controls and for complex automation tasks.

With exceptional real-time performance and powerful communication options

Technical specification

TABLE 4.10 SIMATIC S7-1200 Technical Specification
Compact CPU, DC/DC/DC
Integrated program/data memory 25 KB, load memory 1 MB
Boolean execution times 0.1 µs per operation
Power supply 24 V DC
6 digital inputs
4 digital outputs
2 analog inputs
Expandable by up to 3 communication modules and 1 signal board/communication board
Digital inputs can be used as HSC at 100 kHz
24 V DC digital outputs can be used as pulse outputs (PTO) or pulse width modulated outputs (PWM) at 100 kHz

4.4.2 Programming software: STEP 7 Basic V13

FIGURE 4.13 STEP7 Basic V13

SIMATIC STEP 7 Basic (TIA Portal) is a price-optimized subset of STEP 7 Professional controller software in the TIA Portal that can be used for engineering SIMATIC S7-1200 micro controllers and configuration of SIMATIC HMI Basic Panels, as WinCC Basic is part of the software package.

SIMATIC STEP 7 Basic offers the same benefits as STEP 7 Professional engineering software thanks to its integration into the TIA Portal engineering framework, e.g. direct online diagnostics, easy creation of technology objects and also the library concept for time-saving, efficient work and programming components reuse.

STEP 7 Basic (TIA Portal) supports the IEC programming languages LAD (Ladder Diagram) as well as FBD (Function Block Diagram) and SCL (structured text)

Hardware limit switches

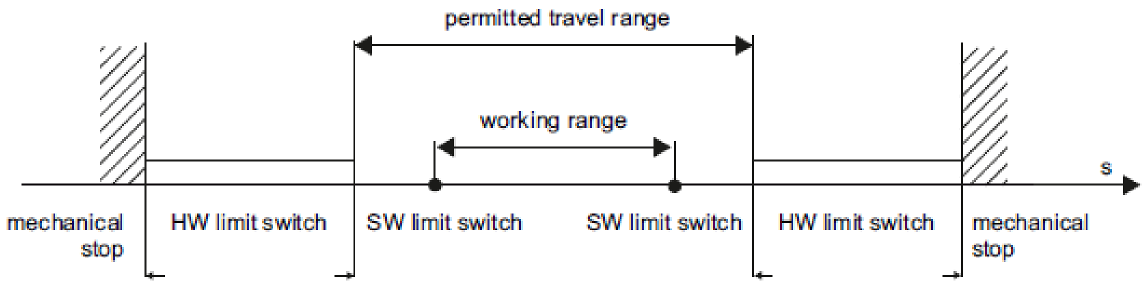


FIGURE 4.14 Hardware limit switches

Hardware limit switches are limit switches that limit the maximum "permitted traversing range" of the axis. Hardware limit switches are physical switching elements that must be connected to interrupt-capable inputs of the CPU.

Hardware connection

In the hardware connection graph shown below, two servo motors with power unit are connected to the Pulse Direction Outputs through a switch. The changeover between drives can be controlled, if required, by the user program via a digital output. If different axis configurations are required for the different drives, a changeover between these configurations is required for the Pulse Train Output.

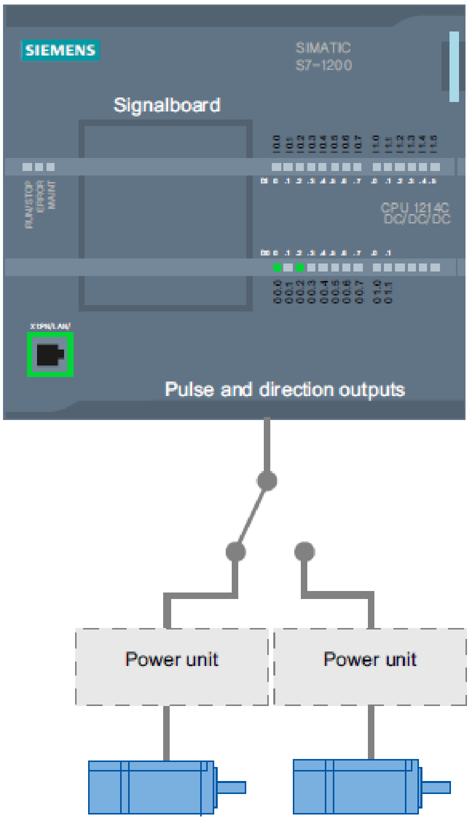


FIGURE 4.15 Hardware connection

4.4.3 The controlling of the position of the machine

The program scheme

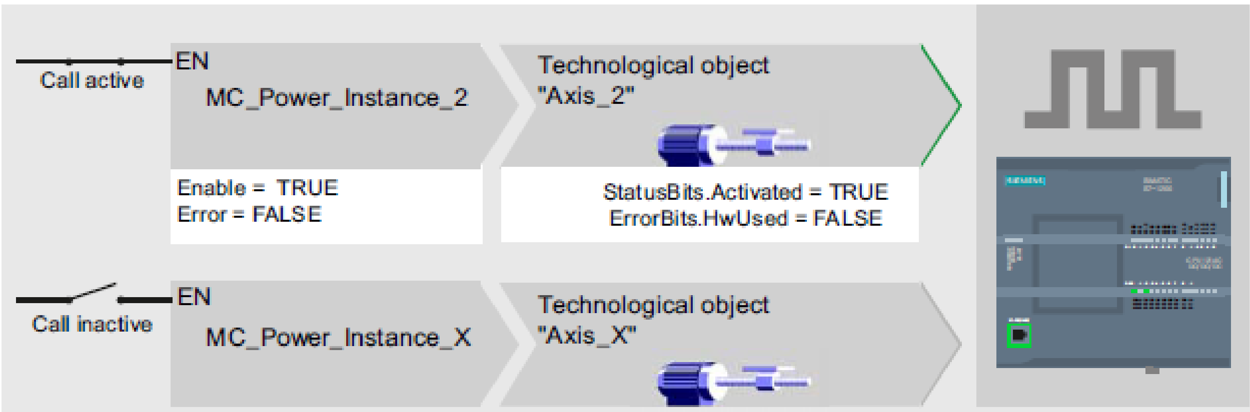


FIGURE 4.16 The program scheme

The graph described below shows how to switch between different servo motors and, thus, between different axis configurations. To use the same PTO (Pulse train output) with multiple axes without error indications, only the Motion Control instructions of the axis currently being used may be called.

Flow chart

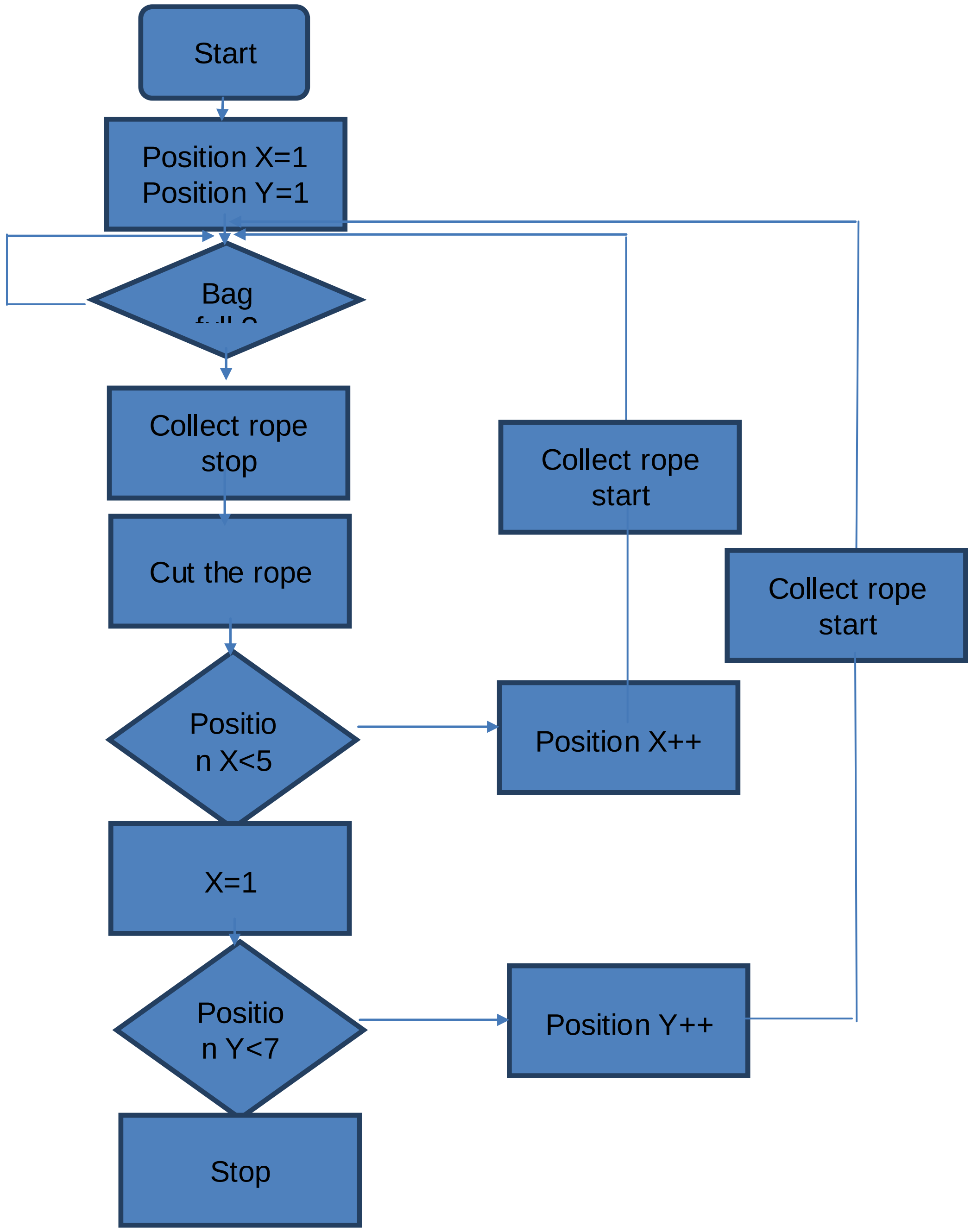


FIGURE 4.17 Flow chart

4.5 Pressing device

4.5.1 The general graph of pressing device

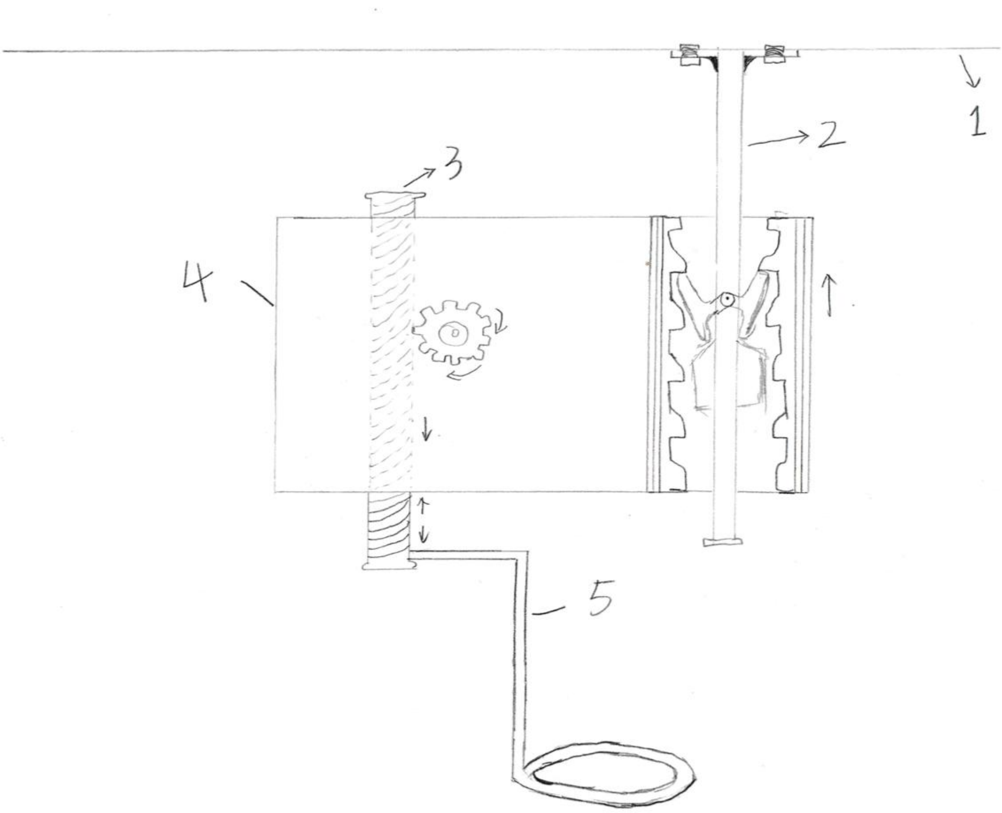


FIGURE 4.18 Pressing device

As shown in the figure, in general, the pressing device contains 4 parts (2, 3, 4, and 5). No.1 is the base surface of the whole system.

No.2 is the fixing bar with clamps and dampers to connect the motor and the base and to help the motor move vertically.

No.3 is the screw mandrel.

No.4 is a lifting motor, and No.5 is the pressing framework, which is fixed on the bottom of No.3.

Connection methods:
Between 1 and 2, we use screws and bolts to connect them, because by this way it is convenient to take the pressing device off the whole system to do the maintenance or change the components or it can be installed in another device.

Bar 2 and bar 3 go through the motor and they connect with the motor separately by gears and damper mechanisms.

The pressing framework 5 will be fixed on the bottom of bar 3 by welding.

Working process:

Step 1: Before start pressing

When the whole rope collecting system reaches the central position of the bag, the clamps on bar 2 will loosen to let the lifting motor go down to the bottom of bar 2 under the drive of the motor’s gravity.

At the meantime, the framework 5 will go down into the bag until the 50cm deep, waiting to start running bar 3 to press.

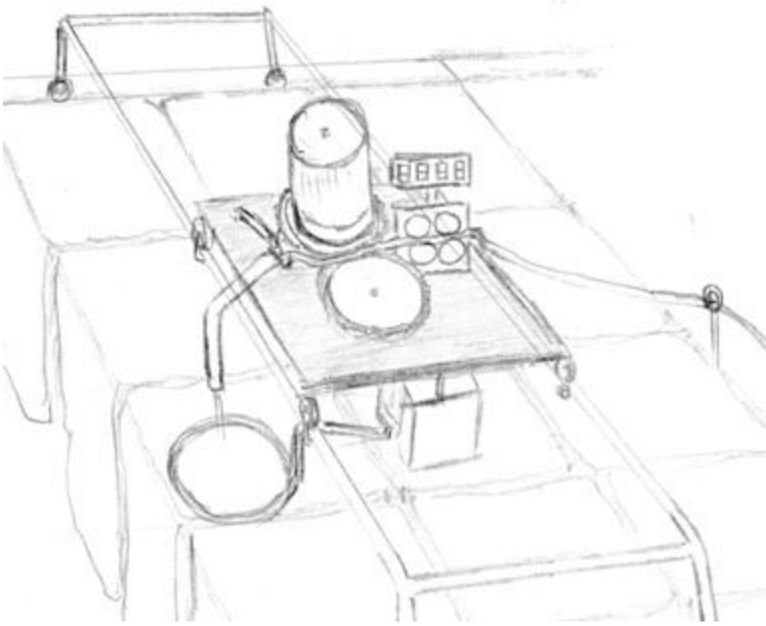


FIGURE 4.19 Before Pressing

Step 2: Start pressing (motor 4 not moving)
The pressing machine will start working when the rope reaches 1m height in the bag, so the machine will press the upper 50cm range out of 1.5m deep bag.

(For which we thought that there is no need to keep pressing during the whole process because the gravity of the ropes coming later will provide force to press the ropes coming former at the bottom).

The motor drives the bar 3 up and down repeatedly and meantime the framework 5 to press the ropes at a certain frequency and by doing the same movement. The framework will go up for 30cm, then go down for 30cm, repeatedly.

As shown in the figure, Fig 6.10 shows that the framework has moved to the bottom and started to move up and down for 30 cm, the height of framework is 50cm. During this step, the motor 4 is always keep fixed, the rope is keep coming, so the height of ropes will be higher and higher, but the framework keeps pressing at the same height.

So this step will help to collect as more as possible ropes at the same height until the counterforce the ropes provide to the framework is up to a certain force to lift the lifting motor.

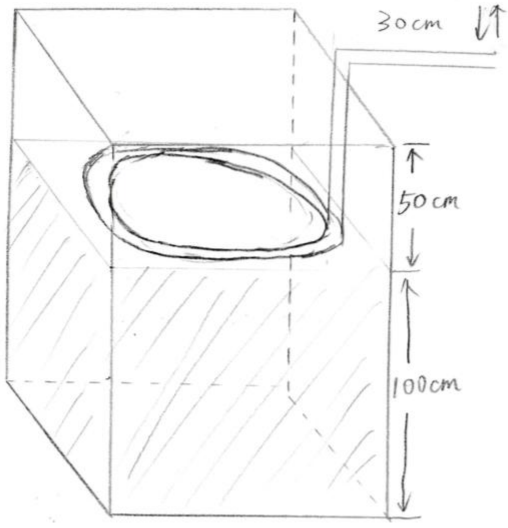


FIGURE 4.20 Framework moving pattern

Step 3: Lifting motor is pushed up by counterforce
When pressing, the ropes keep coming, so the framework will be lifted up when it cannot press down the ropes anymore. At this time, the framework and the bar 3 together with the motor will be lifted up to a higher working base.

To accomplish this requirement, we use the bar 2 together with the bars with gear on one-side to fix the height of the motor, just like the safety device in the elevator system, shown in Fig.3.

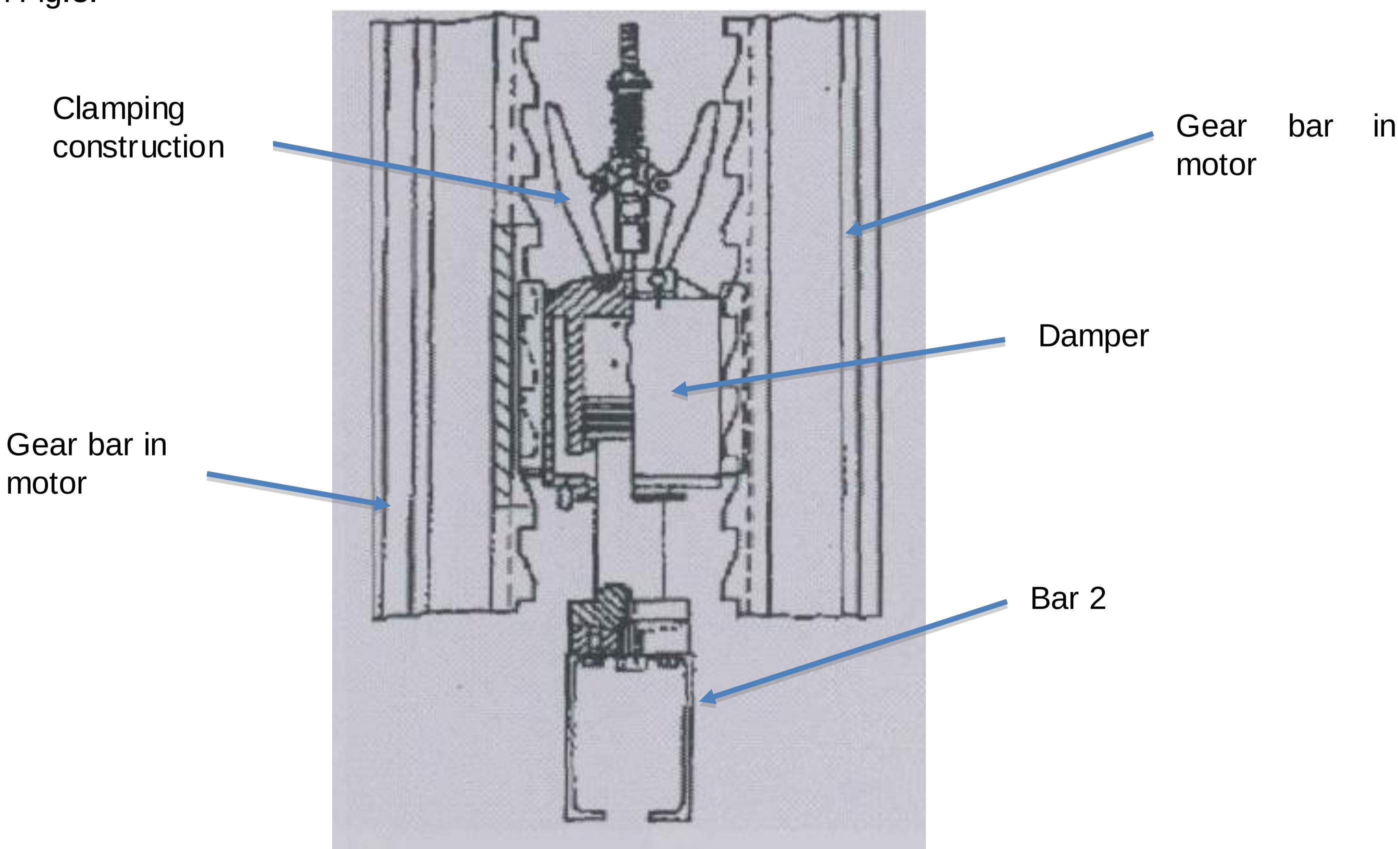


FIGURE 4.21 Motor moving device

As can be seen from the Fig 6.11, there are clamping construction and damper on bar 2, and the gear bar is a part of motor inside. When the motor has to be lifted up passively, since the bar 2 is fixed onto the system base, the gear bar will move up for several teethes (3cm every time) and the clamping construction will insert into teethes to support the motor.

The damper will decide the minimum force that allows the motor can be lifted up. When the motor is lifted up to the top of the gear bar, which means the bag is full, then the rope collecting motor will stop running, and the hydraulic shears will start to cut the rope. The damper can be a buffer when the motor should fall down again from the top to the bottom to start pressing the ropes all over again.

4.5.2 Possibilities discussion

Pressing method:

The existing rope collecting system is partly automatic. During the process the rope will be guided and pressed by a worker. Pressing the rope is to make more space for the up-coming rope so that one bag can contain ropes as much as possible. As the requirements of the client, our system needs to do so.

There are many ways to make more space in a bag, such as shaking the bag to make the rope lining more orderly, or press the rope. We asked a 6-meter long mussel rope from the client to do the experiment to figure out which way is more efficient. After comparison, we found out that, because the rope is soft and can be shaped easily by pressing.

Pressing the ropes comes out as the best way to save space in bags. To press the ropes, we can use mechanical and hydraulic press machine, but the hydraulic press machine is expensive and heavy, which is not suitable for our equipment.

So after the discussion in the group, we choose to use a rather easy equipment contains a motor and a pressing framework to simulate the foot step pressure comes from the worker.

Pressing framework:

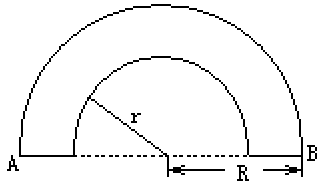
This pressing framework should be a special and unique design for our equipment. Its shape is discussed at first, the group members designed the contact surface as a circle instead of a plane. Because we did an experiment about how the ropes were ordered when they fell down naturally, we found that they usually ordered themselves as a circle with blank area in the middle, which means a plane has the same effect as a circle.

And if the framework is a plane, it will be so heavy that we have to cost more material and to use higher-power motor to drive the device. Since the existing pressing method is a worker step on the ropes to arrange them. So we calculate the pressure needed to press the ropes, shown in following:

Assume that:
A worker weighs G=70kg,
Then the force he provides is F=70kg*10N/kg=700N,
The area of his footprint is S=27cm*12cm*2=0.0648m^2,
Then the pressure P=F/S=700/0.0648=10802 N/m.

The diameter of the circle is 0.8m, because the width of the bag is 1m, we make a safe area of 10cm each side around the circle to make sure the equipment could enter the bag successfully.

To reduce the weight of the device, we set the cross-sectional shape as a ring, as shown in the figure, R=0.025m, r=0.02m.



And we choose 6061 Al-Mg-Si Alloy as material due to its light weight and nice anti-corrosion properties.

Pressing time:

The pressing machine will start to press the rope in the bag when the bag is almost 66.5% full (200m). The reason is that the pressing machine starts at this height is the height of the rail should be limited. If the rail that supports the small car is too high, the size will be much larger to ensure its stability.

Because most weight is concentrated on the small car. The only way to solve the problem is to widen the width of the rail and increase the weight of the rail to decrease the center of gravity of the whole system. And now the pressing range of the pressing machine is about 0.5m in the bag.

The plasticity of the rope is quite good, which means that it is not necessary to press the rope at the beginning and there is not much left space at first. When there is more rope, which means there is more wasted space that can be used, it is a more good chance to start the pressing work. The too early start will just increase the instability of system and decrease the span life of the pressing machine.

Pressing motor:

Since the pressing framework has been designed, we can calculate the force driving motor should provide to lifting and pressing the device.

The pressure P=10802 N/m

The area of the contacting surface between rope and circle is:

$S=2*\pi*0.4*0.05=0.12565m^2$

F=P*S=10802*0.12565=1357N

4.5.3 The properties of the pressing framework

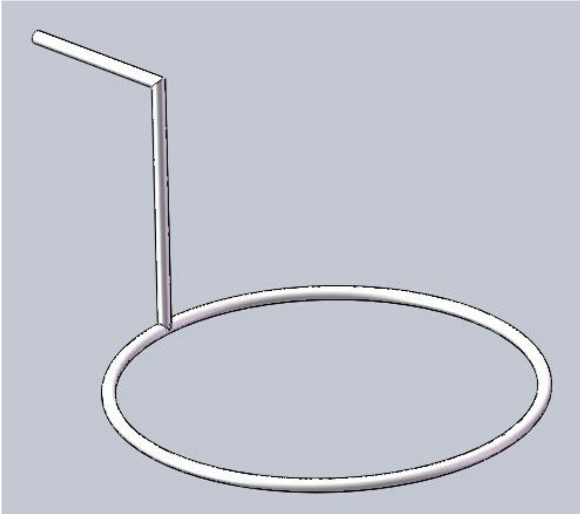


FIGURE 4.22 Pressing framework

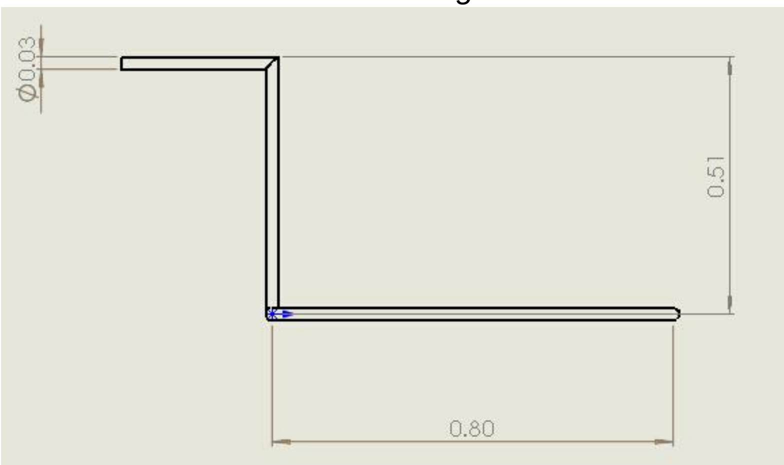


FIGURE 4.23 Lateral view

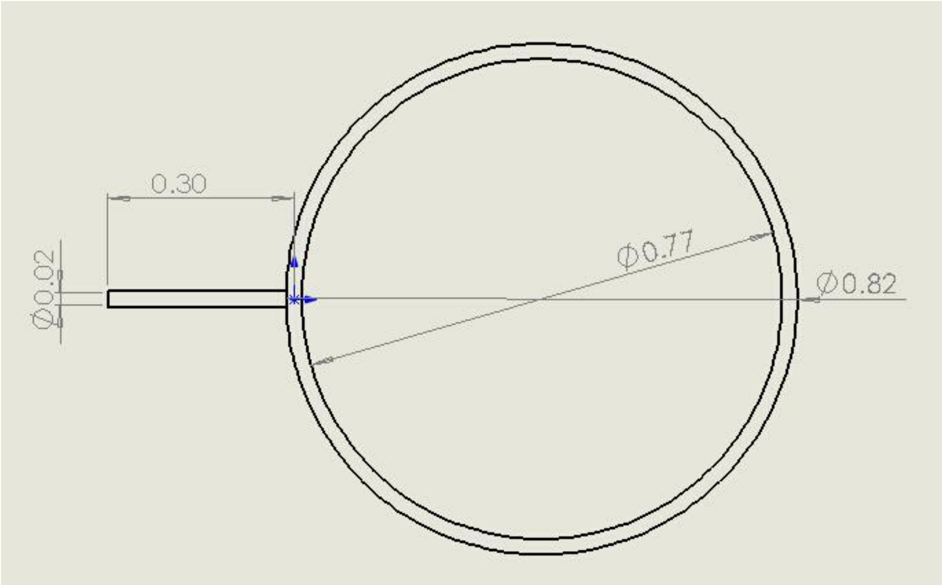


FIGURE 4.24 Vertical view

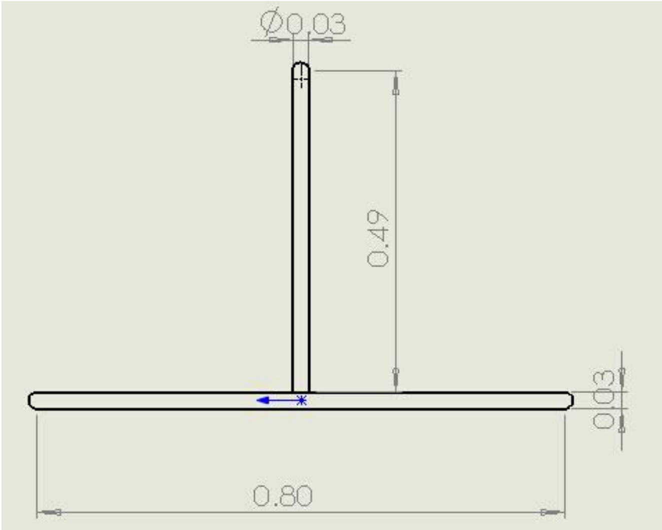


FIGURE 4.25 Side view

TABLE 4.11 Framework properties					
Shape	**Diameter**	**Cross-sectional shape**	**Cross-sectional Radius**	**Material**	**Weight**
Circle	0.8m	Ring	0.02-0.025m	6061 Al-Mg-Si Alloy	3.5kg

4.5.4 The properties of the press motor

We choose the AT Y-2T lifting motor as the press motor. Because its lifting load can be 250 kg, which is enough to lift the whole device and press the ropes.

TABLE4.12 Pressing motor properties								
Model	Ratio	Screw diameter (cm)	Screw Pitch (mm)	Revolving Speed (r/min)	Rated power (kw)	Lifting load (kg)	Downing load (kg)	Lifting speed (mm/min)
AT Y-2T	1/5 1/10 1/20	3	5	1800	0.8	250	500	1800

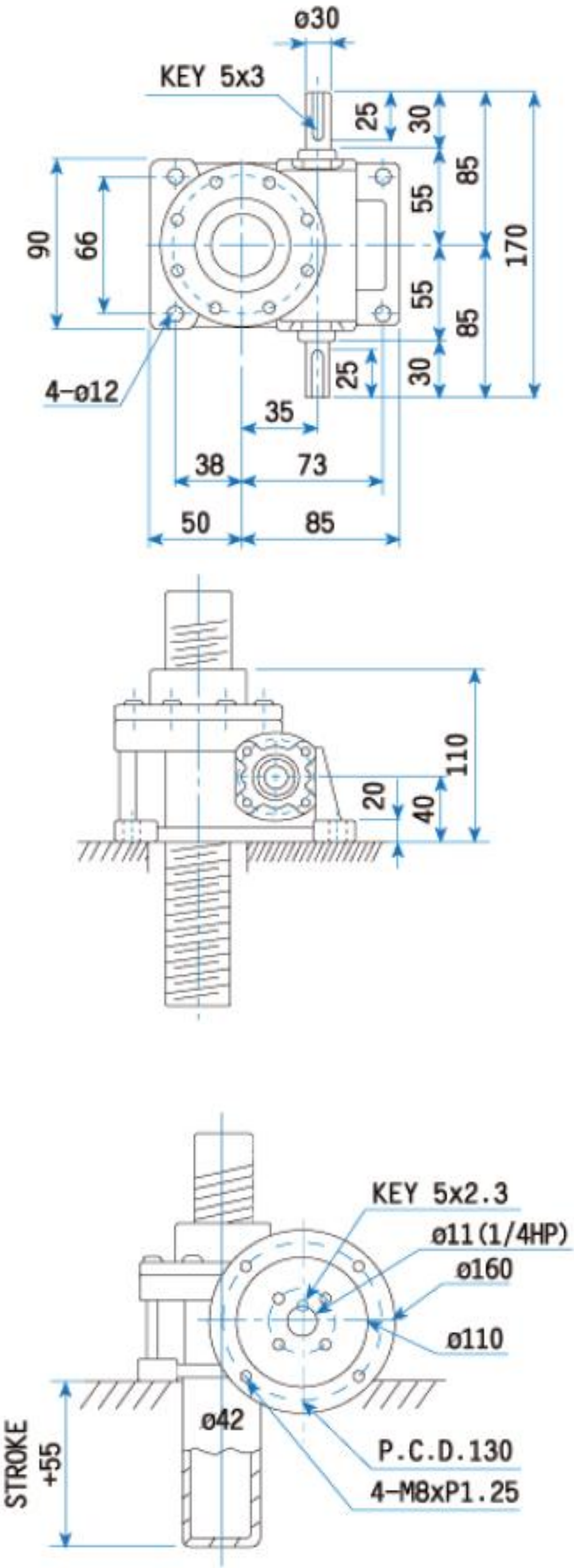


FIGURE 4.26 Lifting motor parameter

4.6 Substrate length-measuring device

The following picture is an equipment that can measure the length of the rope called the Length Rite 300. It is an accurate, portable, easy-to-maintain and lightweight wire length-measuring device. The device is used to ensure when the pressing machine can press the ropes in the bag and the user can see how long the bag can contain the ropes. The working flow is that the device will send a signal to let PLC controller to start the pressing machine when the bag is almost 66.5% full（200 meters）. With the help of PLC controller, the device can also measure both length count and the line speed of the collecting rope.

Substrate length-measuring device

FIGURE 4.27 Vertical view

Features

- Lightweight and Portable Design
- Highly accurate +/-0.2%
- Easy belt removal and installation
- Dedicated, easy to read, 6 digits
- Display for length count
- State of the Art, Remote Mountable electronic system allowing for two inputs and five outputs
- Maximum Speed: 600 feet per minute (200 meters per minute)
- Wire and Cable Size: 0.9mm – 24.7mm
- Measurement Accuracy: +/- 0.2%
- Weight: 2.3kg
- Dimensions: 108mm x 92mm x 228mm (L x W x H)
- Mount: Benchtop mounting holes
- Outputs: (PLC Controller Option) Counter & Line Speed
- Inputs: Remote Reset
- Measurement Units: Either Metric or Footage
- Belt: Polyurethane, steel reinforced, incompressible belt
- Reset: Push Button
- Count Display: 6 digits
- Mode Display (PLC): 2 characters by 20 characters
- Speed Display (PLC): 6 digits
- Calibration (PLC): Easily Programmable using Keypad
- Power: 115 VAC 50/60 Hz

4.7 Bills of Materials

TABLE 4.13 Bills of components

Component	Supplier	Size (mm)	Weight	Price
Ring	Dongguan Changany Yaodong Hardware accessories factory	Φ80	0.06kg*3	3€
Substrate length-measuring device	Taymer Company	108*92*228	2.3kg	100 €
Plate	Shenzhen Zhong Chuang Yu Steel Industry Co	Φ192*30	2.5kg*2	30€
Gear	Yong Kang gear factory	Φ200*20	4.1kg*2	20 €
Plate driving motor	MOGE	165*180*315	18kg	40 €
Pipe	Hebei Honglian	200*300*2.4	0.3kg	3€
Lifting motor	AT-reducers	140*300*90	15kg	50€
Pressing framework	Frameworks	1100*500*800	3.5kg	20€
Hydraulic cutting machine	Taizhou Defu machine company	320*50	3kg	100€
Servo motor	Baldor	7.35*9.1*9.1	4.9kg*4	120€
Track slider	Laing track slider	70*50*15	5.5kg	110€
PLC controller	Siemens	90*100*75	2.5kg	161€
Total			84.08kg	751€

5 Detailing Phase

5.1 The choice of motor and gears

The empty substrate is driven by the rotating plate in the system. And the rotating plate is followed by the driving motor. These are the final concepts that we choose in the collecting system. But there are four combinations among the plates, gears and motors. All the combinations can achieve the function of pulling the rope and they are all stable and feasible. The specific description of each combination is in the following context. Given the team member don't have much experience about the working condition and performance in the sea environment and the producing cost of the components, the choices are sent to the client to have a discussion. The conclusion is that the best combination is the one with one motor directly drive the plates and gears. The reason is that the bad environment on deck of the ship will damage or corrode the components in the system and the best choice is to use less possible parts, especially moving and electronic parts. In addition, all the electronic parts will be waterproof and most components will use the anti-corrosion material.

Description of each combination

1. The first one consists of two driving motors and two parts of turning plate. Each motor will drive the plate directly. In addition, the axle of the motor and the plate is the same one, so they are coaxial.

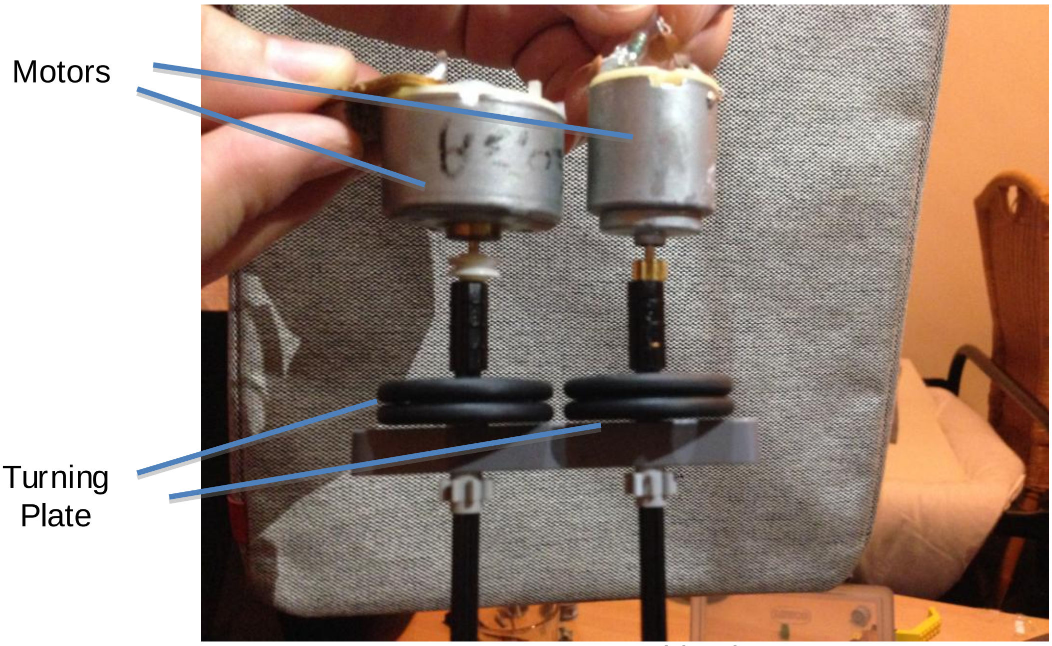


FIGURE 5.1 Combination 1

Advantage:
This combination is that there are no more gears and the motors rotate at the same time which means that the rotating speed of both motors are the same.

Disadvantage:
Though there are not many components in the combination, half of them are electronic parts. The price will be high and the working life will be lower than ones with less motors.

2. This is the combination with one motor and the motor doesn't drive the plates and gears directly. And there are four gears and two parts of plates in the system. The working flow is that the motor will directly drive a gear first, which is fixed on the axle of the motor, and then the other gears will be driven by the first one. The turning plates will also rotates with gears with the same angular velocity because the gears and plates are coaxial.

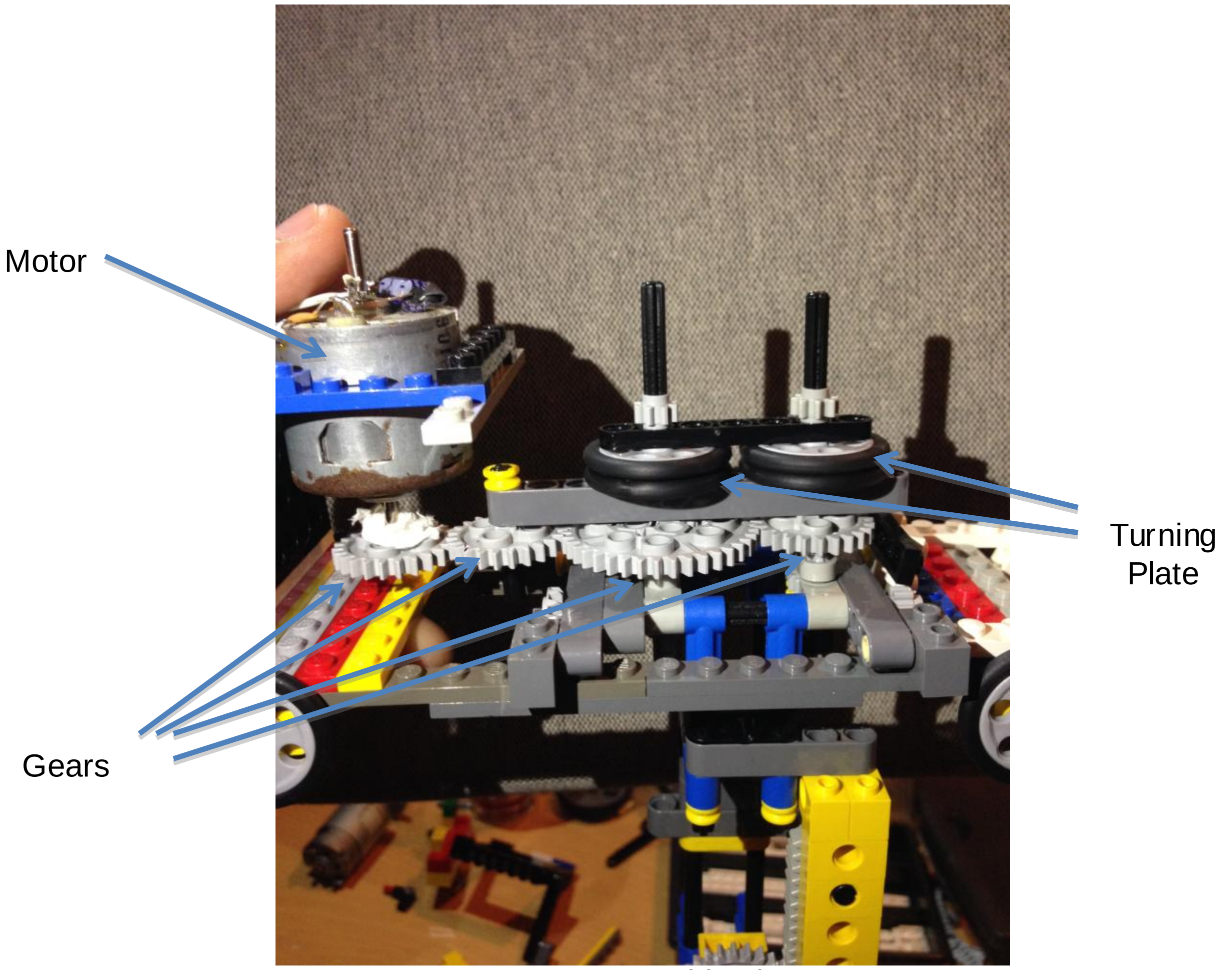


FIGURE 5.2 Combination 2

Advantage:
There is only one electronic part in the system and the two turning plates works with the same angular speed at the same time.

Disadvantage:
There are a lot of gears and the lifespan will be low and cost will be high. Given many gears, the motor should have much more power to attend the same speed.

3. This is the improved combination of the former one. The number of gears is decreased. The other parts are all the same as the other one. In this situation, the system will be more stable but the power of motor should still be a little bit higher than the combination that motor drives the plates and gears directly.

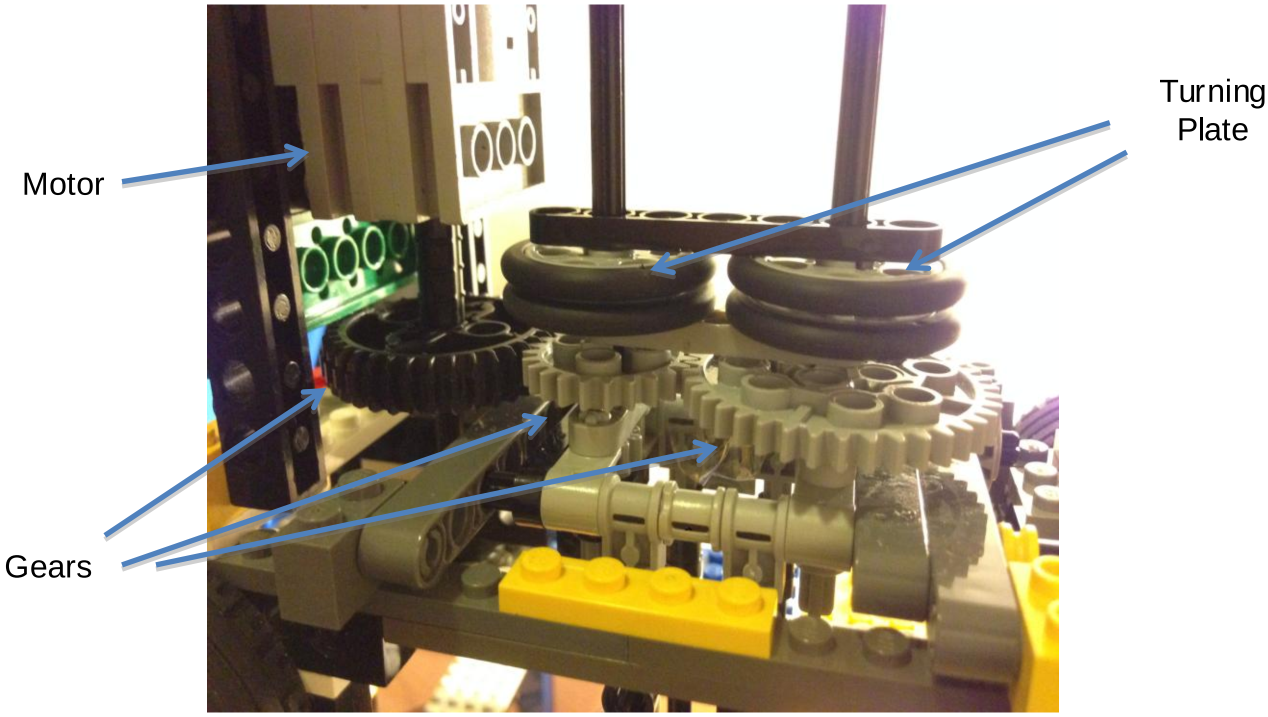


FIGURE 5.3 Combination 3

4. The last idea is to use the motor to drive the plates and gears directly. There is one motor in the system and it can drive the two plates at the same time. This is because the gear one under the plate one will drive the gear two when it is rotating. And then the gear two will drive the plate two simultaneously. This is the way that can use fewer motors and other components to achieve the function of pulling the rope.

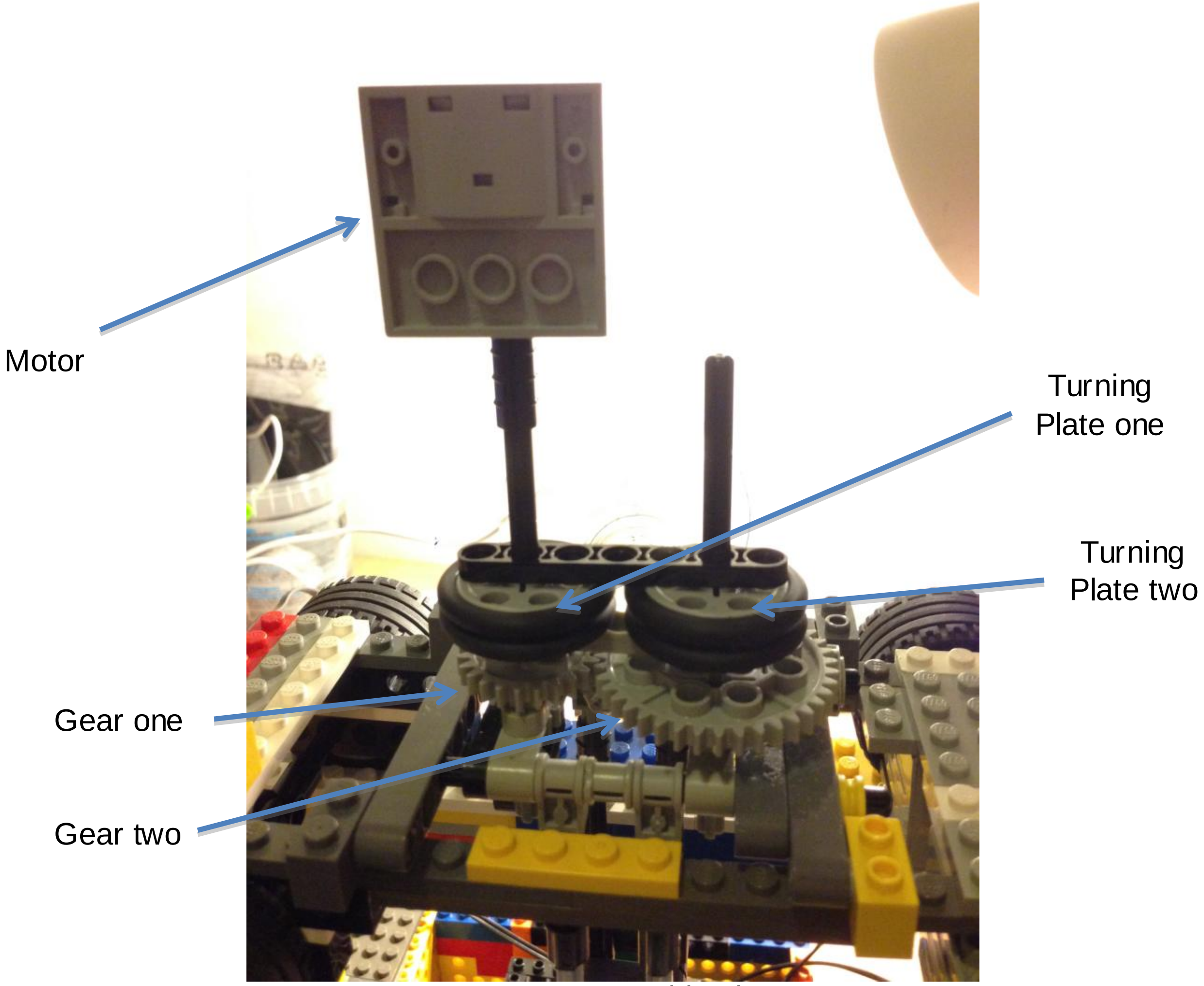


FIGURE 5.4 Combination 4

Advantage:
There is only one motor and it needs less power force of the motor to drive the system. The simultaneous working time of the gears and plates insure the stable output of the ropes.

Disadvantage:
The motor is fixed tightly on the axle with the gears and plates, because the center of gravity will be higher and intended to waggle.

5.2 The choice of the pipe (guide the rope)

In the collecting system, the guidance of the rope is always a very important part in the system. A lot of tests have been made to improve the collecting system, especially the guidance of rope. At first, there was no pipes or other equipment to guide the rope after pulled by the driving motor. But after the test of the model, some problems happened. The rope will come out without order, which means that the rope cannot falls into the bags successfully if the collecting speed is fast.

And after communicating with the client, the team members have known that the wind on the sea is also big that may cause the condition that substrate may be blown to each direction, which will make troubles when the system is collecting. As a result, the equipment of guiding the rope to the big bag is really necessary for the collecting system. Finally, a light plastic pipe is used to guide the substrate. The following description is the designing and improving process.

Description of the design

At the first time the model is made, the problems that the rope will come out from the pulling motor without order and it can't fall into the bag successfully are found. And then we use the Lego components to make a simple structure to limit the position of the rope. And the equipment has some effect. The disadvantage is that the rope sometimes will get stuck because the equipment is not smooth enough and the structure is too complex and not very stable.

Pipe
Edition
one

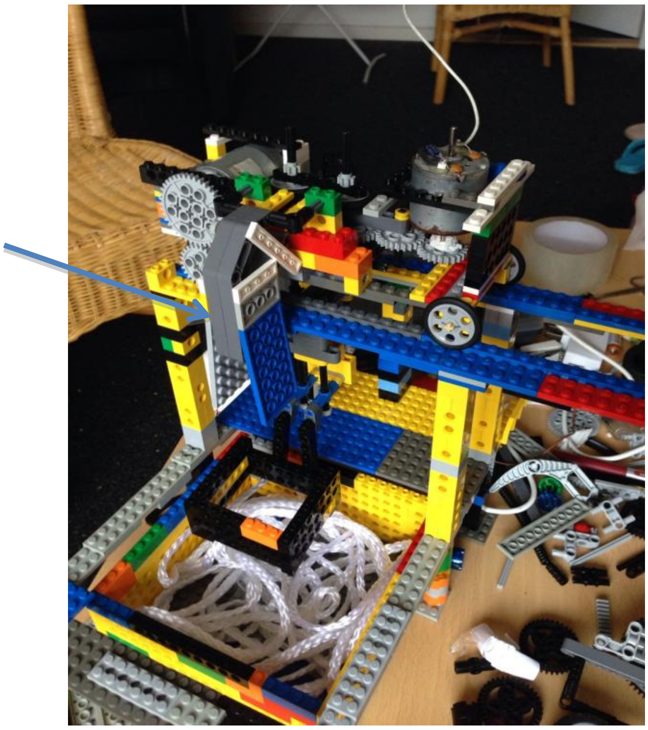


FIGURE 5.5 Pipe edition 1

Because of the limitation of the Lego components, the better one can't be made by them. As a result, the plastic bottle is used to improve the design. Through making the model, the importance of the pipe is realized. And the second pipe edition is still not very good because the pipe just guides the rope with short distance and the rope will fall out of the bag in the experiment when the collecting speed is fast.

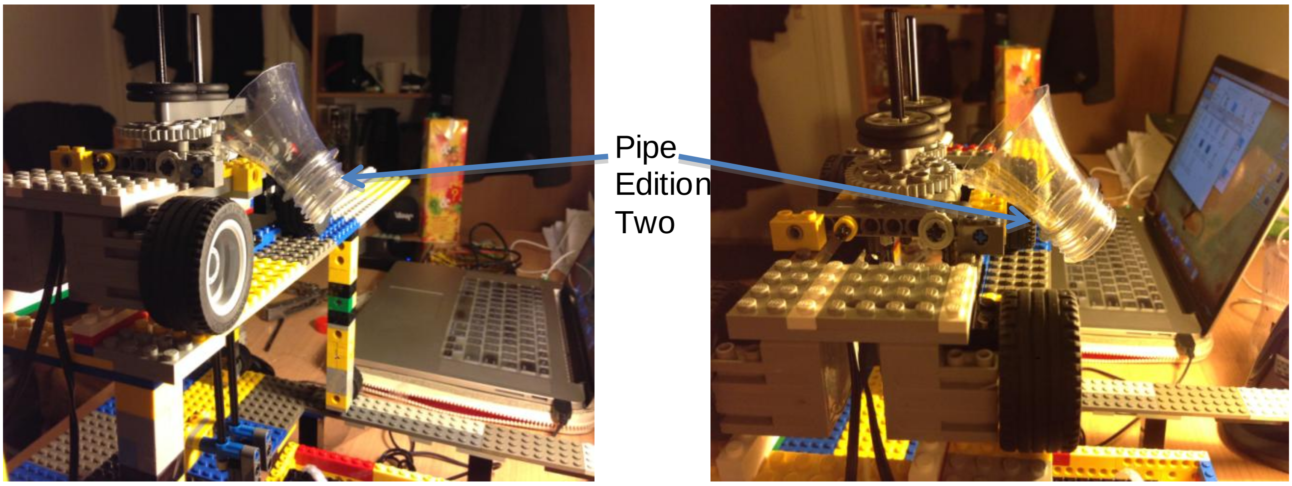


FIGURE 5.6 Pipe edition 2

3. This is the improved pipe with longer length. In this stage, each kind of speed from slow to fast is tested and also with the influence of wind by using the model. The problem of falling without order still exists. The following picture shows the shape and structure of the pipe. The left one is the pipe edition three. The pipe on the right is the edition four one. The difference between them is the gap at the end of the pipe. The edition four one has the gap to prevent the rope falling out of the bag. But the bad situation still exists after many experiments.

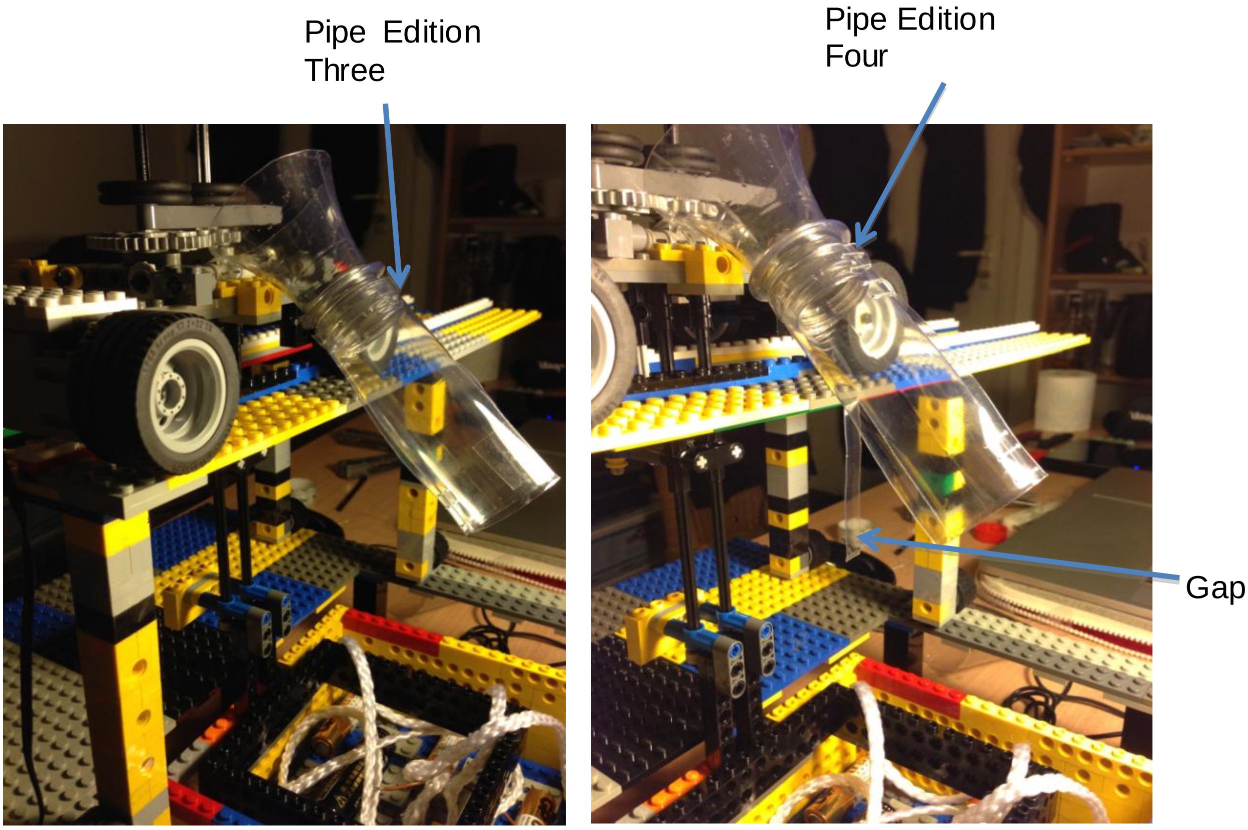
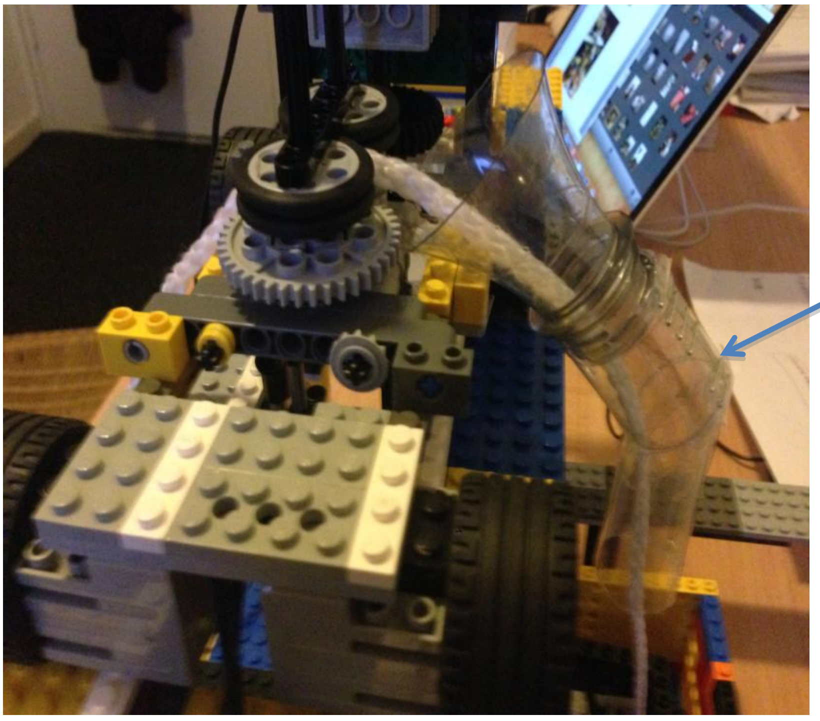


FIGURE 5.7 Pipe edition 3, 4

4. In the following picture is the final design with a curving pipe. In this final edition, the problem will not happen and the rope will fall into the bag through the pipe smoothly and won't be influenced by the harsh wind. The collecting speed won't influence the process of collecting also.



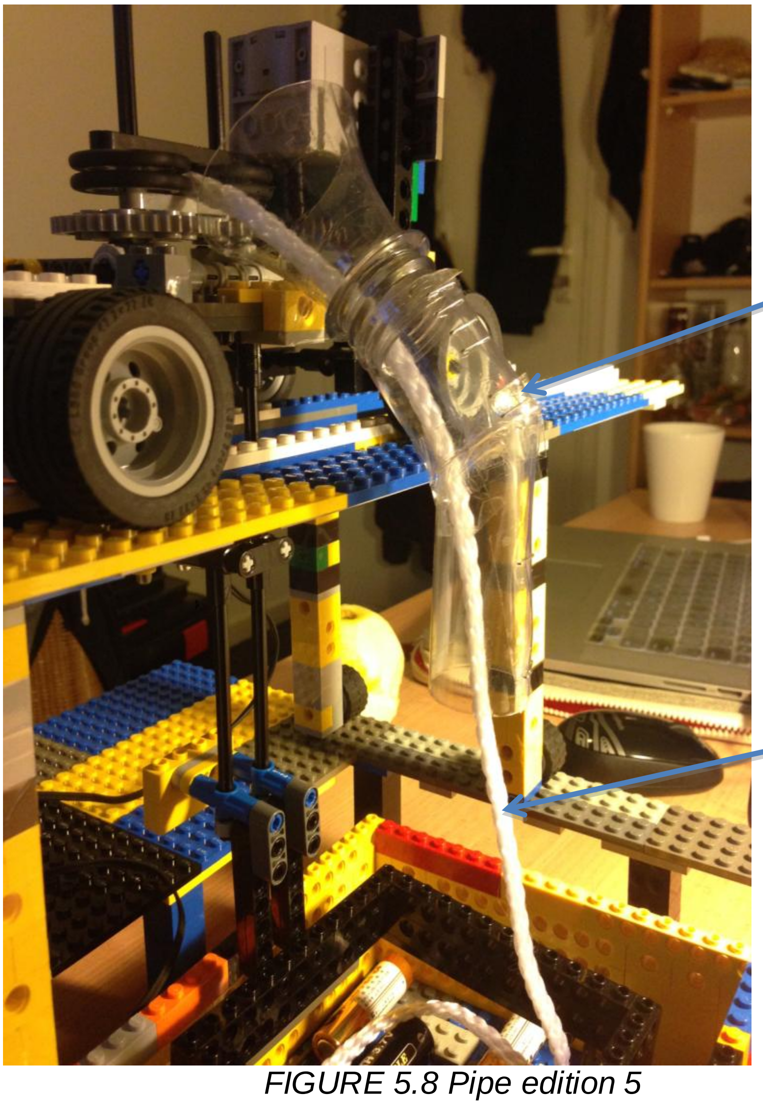


FIGURE 5.8 Pipe edition 5

5.3 The choice of the equipment to transport the substrate

At the beginning of the concept we choose the belt to transport the substrate from the output of the last mussel collecting system to the big bags as the final choice in the collecting system, which can be seen in the following picture. But after the discussion with the client, they thought the concept was not good enough because it is too complex and expensive.

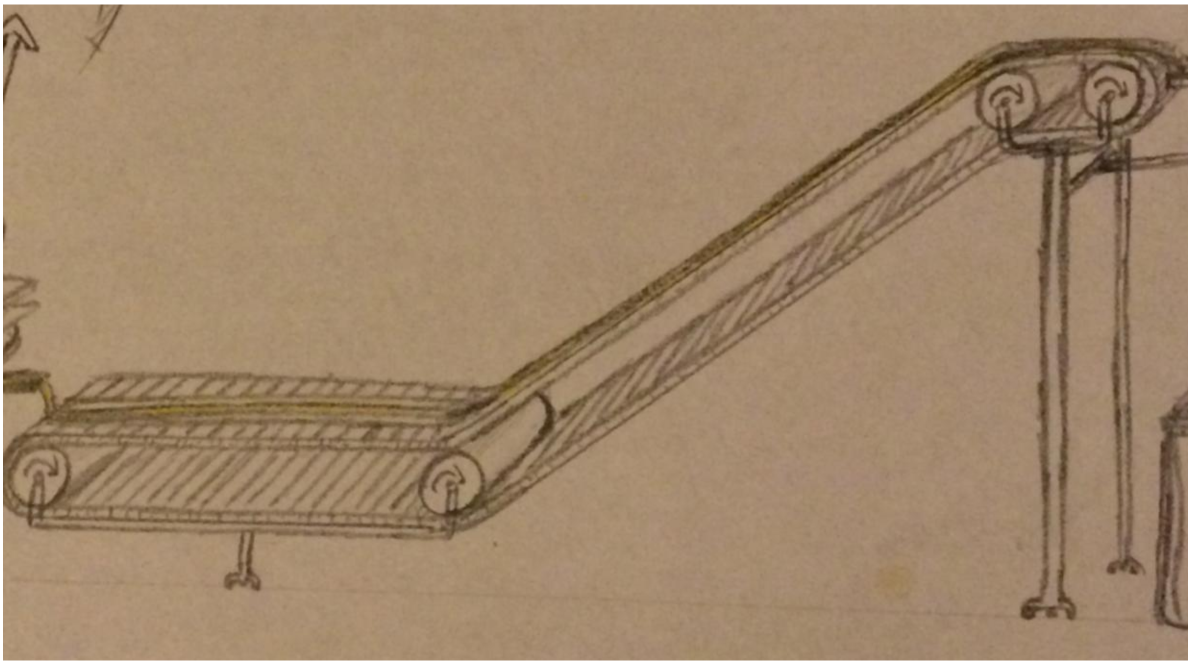


FIGURE 5.9 Belt transportation

The following design of transporting the substrate meets the client's requirements finally. Because the client recommend the ideas and they want the simple one with high performance. As a result the design with rings to control the position of the substrate and motors to pull the substrate can replace the design with belt. And the new design is much simpler and cheaper.

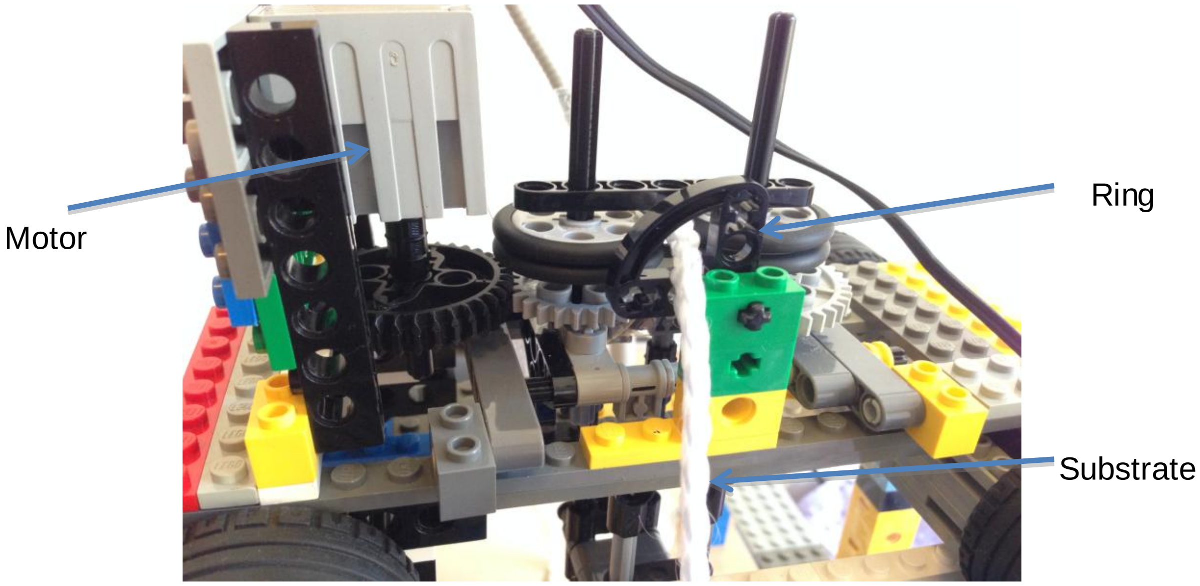


FIGURE 5.10 Motor pulling

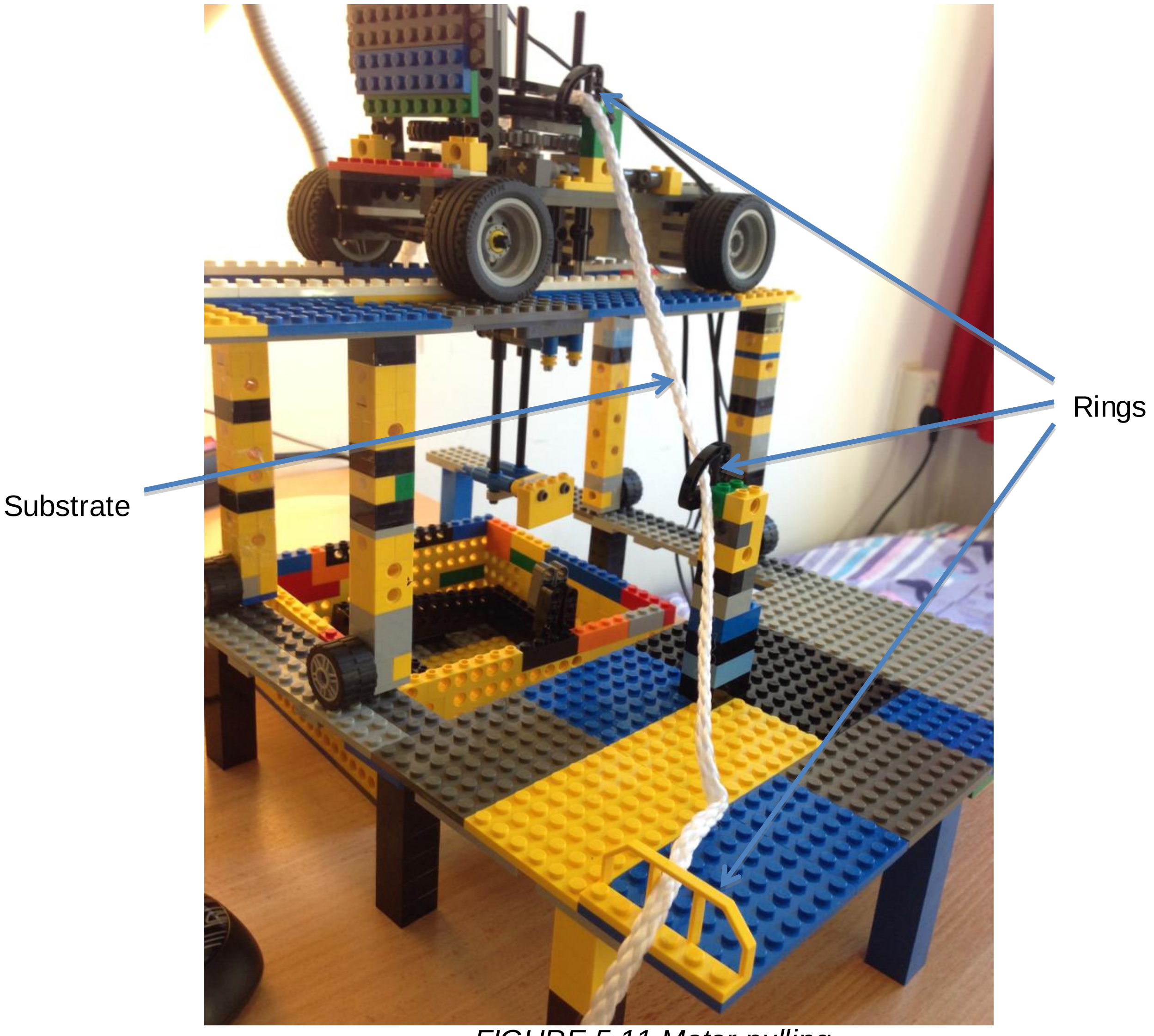


FIGURE 5.11 Motor pulling

5.4 The improvement of the moving system

The collecting system consists of the moving system, pressing system, pulling system and guiding system. The small car will transport the pulling part and the pressing part from one full bag to another empty bag. After making the model, the problem happens. It is that the small car will waggle when the pressing machine is working. Because the wheels of the car are not locked and the car is just put on the track and move forward by following the track.

In order to solve the problem, the group members find the solution to improve the stability of the small car when it is moving. At the axle of the wheel, there is a calliper that locks the wheel with the track under the car. The calliper will move by following the car. In this situation, the stability of the car will be improved a lot because the calliper on the wheel fits closely to the bottom of the track

The following pictures show the improvement of the model. The first one is the original one and the second one is the improved one with callipers.

FIGURE 5.12 Moving system edition 1

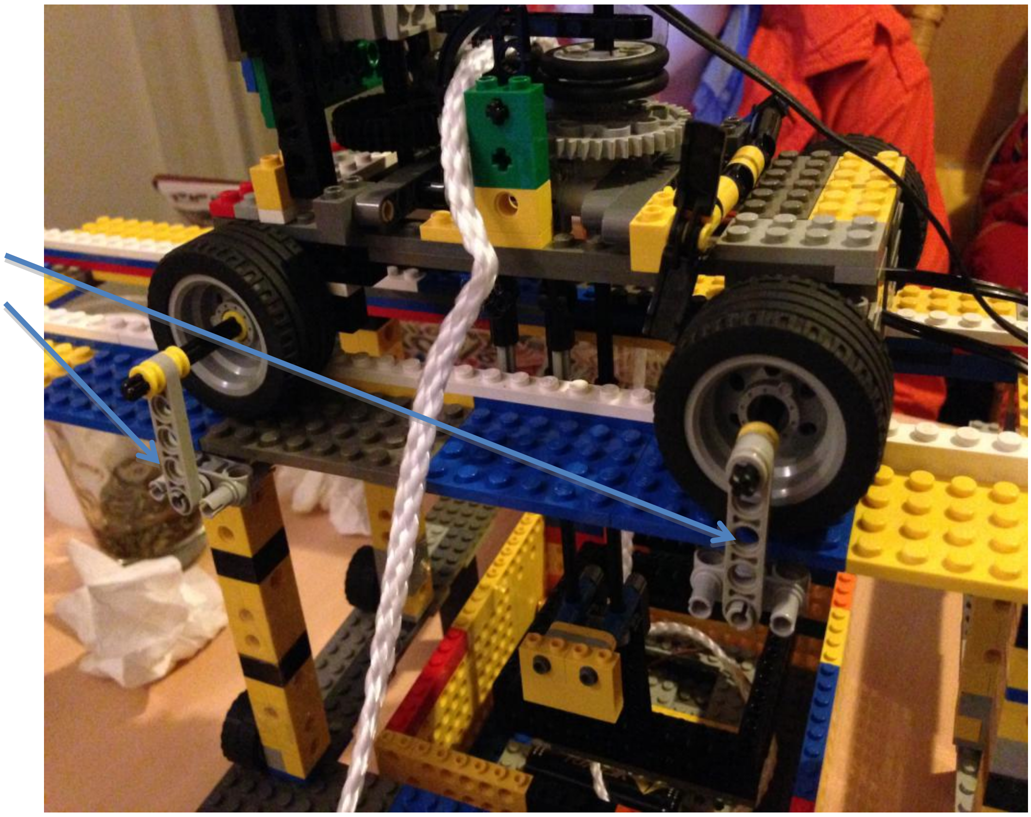


FIGURE 5.13 Moving system edition 2

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APPENDIX I / Project Plan

Chapter 1: Background

1) Problem statement:

Jansen Tholen B.V. is a machine factory with experience in designing and building cultivation machinery. Oostinga is a seed mussel grower and has contacted Jansen Tholen with a design question. So far, the sowing section of the machine has been developed and is currently being built. The harvester will be developed in the upcoming semester: concepts have been chosen and the engineering is in full swing. This is where the design assignment can be found.
The regulations for catching seed mussels are becoming stricter. In particular, the obtaining of seed mussels from the natural seed banks will be further restricted in the future. The seed mussels are planted in nurseries, where they then grow to fully-grown edible mussels. A new system has been devised to plant seed mussels at present. Another corresponding mussel collecting system will be designed in the near future. An electricity driven collecting system that arranges the empty mussel rope in a container is an important part of the system and it is the main research question of the research proposal.

2) Research question

What is the solution of collecting all the empty substrates rope into a big-bag automatically?

3) Objective

It is important to gain enough relative information for the project. The solutions of the research questions can be found by many kinds of research methods (Delft Design Method). At last, the best solution for the main question will be figured out after analysing and comparing all the feasible answers.

Chapter 2: Problem indication & Objectives

- Problem indication
  - Situation at the moment
    Problems:
    - What kind of energy can be used to drive the engine?
    - How to cut the substrate while the bag is full?
    - How to ensure the bag is full?
    - How to fill all the bags?
    - How to press the ropes?
  - Judgement

  - Project group goals:
    1. Design a device that can :
       - Gather the substrate into a big-bag;
       - Press the ropes in the bag to save more space;
       - Cut the substrate safely when the big-bag is full;
    2. Meet the requirements:
       - Meet the customer’s requirements;
       - Meet the requirements of engineering and technology, and the product can be produced and used with large number.

- Objectives of the client

  The client wants a system that can be sufficient enough to reduce the loss of mussel and the cost. As a result, this final design can be more competitive and better in order to meet stricter standards and competition. If the product is successful and has a good performance, the product will be sold to other fishermen.

Chapter 3: Assignment formulation

During the whole designing process, tests and experiments will be done to record and analyse to make improvements:

1. Design a measuring and controlling system to store the empty substrate in a bag, which can work well in a sea condition?

2. Explore the possible solutions to solve all the problems:

1) Discover all possible problems

In order to solve the problems efficiently and successfully, it is necessary to discover all possible problems in advance. The Internet research, desk research and field research are inevitable to be conducted. Through these researches the existed problems will be found and the system can be improved. Finally the other possible problems can be predicted after group discussion and client meeting. For example, the rope may broke, which is the biggest problem during the collecting process.

2) Detect each problem situation

The possible problems have been found. The next step is to discover that under what situation the problem may happen. And this is the necessary preparation for working out the corresponding solutions. The most important is to find a proper way to detect the problems.

3) Decide on solving action

The solution is based on the problem situation and many methods can be used to solve the same problem. The group discussion and client meeting is necessary to find many methods to the problem. Among these solutions, some of them are budget-friendly; some of them are more efficient, but the most suitable solution will be chosen based on the requirements given by the client.

4) Design solving action

After choosing the best solution, the details should be considered. And all the solutions should be feasible and effective. The Eggert Design Method will be used to design solving action.

5) Final products (Product Proposal to the client)

a) Report: Use the method of Eggert to design a device and record the process in the order of the EDM phases in the report. And every detail information of the device is included in the report.
b) Presentation: Choose the most important parts from the report to introduce the designed device to clients to prove why the system meets the entire requirements.

c) Collecting system: Use the method of Eggert to design the collecting system. The model will be made to test the system.

Chapter 4: Project activities (Eggert)

Phase 1: Formulation phase

TABLE I.1 Planning for Formulation Phase	
Duration	**How to do**
17 Days	1. Understand the subject. 2. Specify the requirements. 3. Make sure the budget and deadline are clear. 4. Distribute the tasks to the members.

- Make Project Plan
- Define Engineering Design Specification

Phase 2: Concept phase

TABLE I.2 Planning for Concept Phase	
Duration	**How to do**
11 Days	1. Through brainstorm, discussion, and consults with clients, the general concept of the product has to be formed. 2. At least 3 concepts. 3. Evaluate them and choose the best one.

- Brainstorm (individual + group)
- Formulate List of evaluation criteria
- Concept choice (min. 3)
- Evaluate concept choice
- Make concept sketches
- Present intermediate products
- Determine best concept
- Evaluate ultimate concept choices

Phase 3: Configuration phase

TABLE I.3 Planning for Configuration Phase	
Duration	**How to do**
10 Days	1. Put more specific information into the concept 2. Modify the concept according to the realistic condition

- Generate alternative configurations or lay-outs
- Analyse configuration
- Evaluate configuration

Phase 4: Parametric phase

TABLE I.4 Planning for Parametric Phase

Duration	How to do
9 Days	1. Specify the parametric properties according to the requirements

- Determine concept geometry
- Determine concept dimensions
- Choose materials
- Define required production processes

Phase 5: Detailed phase

TABLE I.5 Planning for Detailed Phase	
Duration	**How to do**
8 Days	1. Choose the colour of the device 2. Choose the material

Chapter 5: Intermediate products and final Products

1. Sub-product → Main Product

a) Detecting system
b) Cutting system
c) Placing system → Substrate collecting system
d) Power system
e) Pathway system
f) Warning system

2. Eggert Phases → Final products

- Final Report
- Final Presentation
- Final model of substrate collecting system (almost can be put on the table to prove that the system can work automatically and meet some basic principles)

Chapter 6: Quality control

a) Design Methodology

The whole design will be carried out by the existing design methodology called Delft Method. As a result, all the possible results will be achieved and supported by the established project management.

b) Source

All the group members will visit the company on September the 29th to know the situation, problems and the requirements of the clients. And the group members will visit the company and harvester at least once. As a result, the risk of a piece of misses is reduced.

c) Experience

Group members have the experience of designing products for several times. Students are familiar with designing methods and have solved some problems before. William is Battle-hardened filled with working experience and the capability of solving the designing problems. All the students had been trained how to do a project in the last three years.

d) Project Skills

The basic skills: Communication skills, Cartography skills, skills of making reports and testing skills.

e) Safety

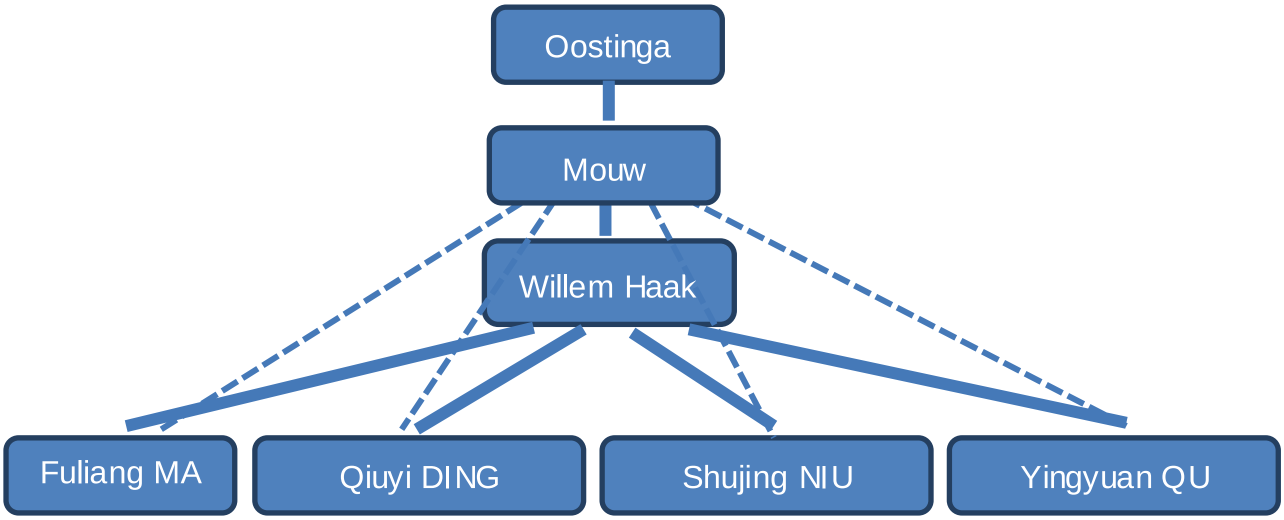
The system is operating on the sea. So the waterproof is quite important for the electrical machine and the power source. And the system must be anticorrosive and durable.

f) Setting requirements

The system should work in a setting condition. So the requirements are needed. The group members will communicate with clients to make consensus.

Chapter 7: Describing project group

- Team Member
  a) Fuliang Ma: Team Leader
  b) Qiuyi Ding: Team Member
  c) Yingyuan Qu: Team Member
  d) Shujing Niu: Team Member
- Company
  a) Company name: Jansen Tholen B.V.
  b) Address: Slabbecoornweg 51, 4691 RZ Tholen
- Communication
  a) Email: Rudypony@gmail.com
  b) Client: Mouw

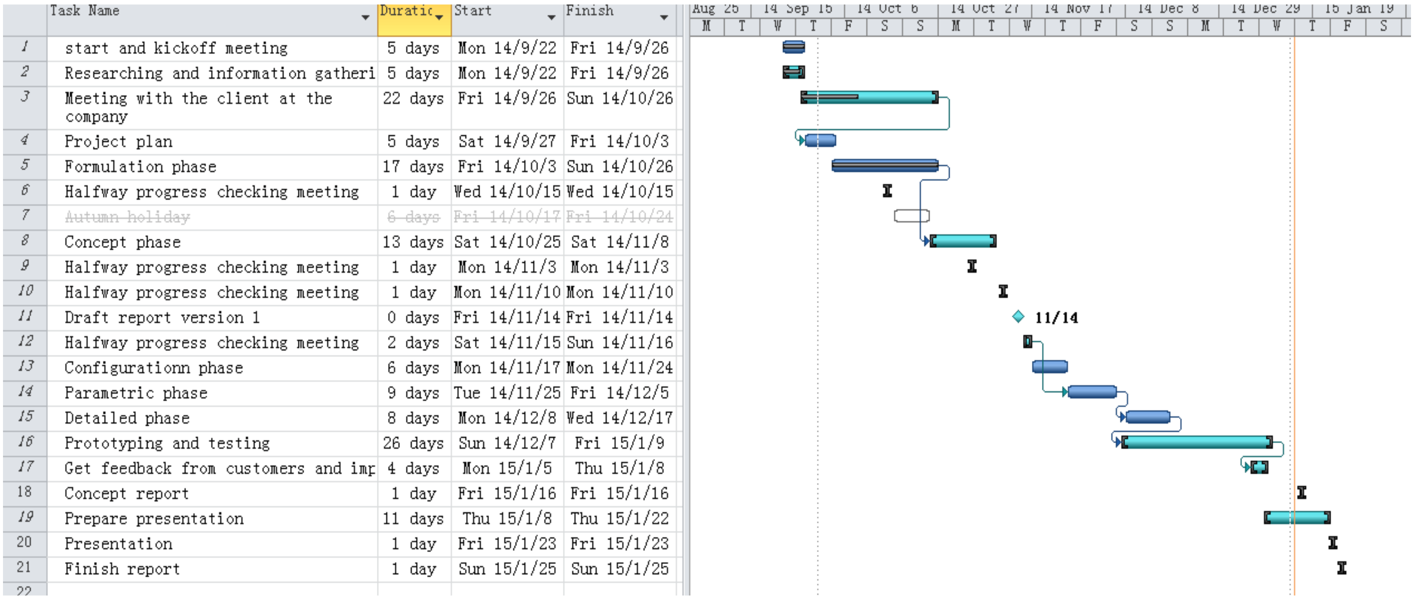


Chapter 8: Budget

Company Leader: preparation, feedback. 20 hours
Company Manager: preparation, feedback. 20 hours
Counselor at HZ: 80 hours (divided on projects and groups)
Group student: testing and designing expense reimbursement
Students Mechatronics: travelling expenses of five students (HZ)
Testing and production of models: € 500, -

Chapter 9: Time table (planning)

Timetable:



	Task Name	Duration	Start	Finish
1	start and kickoff meeting	5 days	Mon 14/9/22	Fri 14/9/26
2	Researching and information gatheri	5 days	Mon 14/9/22	Fri 14/9/26
3	Meeting with the client at the company	22 days	Fri 14/9/26	Sun 14/10/26
4	Project plan	5 days	Sat 14/9/27	Fri 14/10/3
5	Formulation phase	17 days	Fri 14/10/3	Sun 14/10/26
6	Halfway progress checking meeting	1 day	Wed 14/10/15	Wed 14/10/15
7	~~Autumn holiday~~	~~6 days~~	~~Fri 14/10/17~~	~~Fri 14/10/24~~
8	Concept phase	13 days	Sat 14/10/25	Sat 14/11/8
9	Halfway progress checking meeting	1 day	Mon 14/11/3	Mon 14/11/3
10	Halfway progress checking meeting	1 day	Mon 14/11/10	Mon 14/11/10
11	Draft report version 1	0 days	Fri 14/11/14	Fri 14/11/14
12	Halfway progress checking meeting	2 days	Sat 14/11/15	Sun 14/11/16
13	Configurationn phase	6 days	Mon 14/11/17	Mon 14/11/24
14	Parametric phase	9 days	Tue 14/11/25	Fri 14/12/5
15	Detailed phase	8 days	Mon 14/12/8	Wed 14/12/17
16	Prototyping and testing	26 days	Sun 14/12/7	Fri 15/1/9
17	Get feedback from customers and imp	4 days	Mon 15/1/5	Thu 15/1/8
18	Concept report	1 day	Fri 15/1/16	Fri 15/1/16
19	Prepare presentation	11 days	Thu 15/1/8	Thu 15/1/22
20	Presentation	1 day	Fri 15/1/23	Fri 15/1/23
21	Finish report	1 day	Sun 15/1/25	Sun 15/1/25
22				

FIGURE I.1. Time Table

APPENDIX II / EDS

TABLE II.1 EDS Requirements		
EDS category	**Requirements**	**Details**
Design	The device should be light in weight.	Less than 200kg
	The main part of the device should be in standard size.	Between2*4*3m and 4*8*4m
	The device should collect the rope to the bag automatically without any manpower.	It should use motors to give power, and the engine should have at least 500w to ensure the machine can work as required speed.
	The device should be safety.	The device should be fixed on the deck securely
	The electric part of the machine should be waterproof.	The electric part can work properly in the sea environment.
Transportation	The device should be carried easily and fit many ships.	Can be carried by people or one forklift or crane and used on other ships.
Usage	The device should have a long lifetime	At least five years.
	The device should operate at a fast speed.	Speed depends on difficulty of removing the mussel. Minimum speed 0.3m/s.
Maintenance	The device should run unstopped for a long time	The MTBF (mean time between failure) have to be at least 2400 hours
Financial	Total cost of the device should be reasonable.	Maximum 2000 Euro

APPENDIX III / Concept Score Standard

TABLE III.1					
Score	**1**	**2**	**3**	**4**	**5**
Light weight	200	190	130	140	150
Proper size	4*8*4	4*6*4	2*4*3	3*4*3	3*5*3
High efficiency	Collecting speed 0.2m/s	Collecting speed 0.4m/s	Collecting speed 0.6m/s	Collecting speed 0.8m/s	Collecting speed 1m/s
High Automation	Need people to operate all the time	Need people to operate during the working process	Need people to operate at first	Need people to watch the system	The working process needs no body
High safety	Can't work properly in the sea situation	Can work properly in few sea situations	Can work properly in some sea situations	Can work properly in most sea situations	Can work well in all the sea situations
Easy to operate	Need human power to do all the process	Need human power to cut, put and press the rope	Need human power to cut and put the rope	Need human power to put the rope	Only need to press the start button
Long life time	4 years	5 years	6 years	7 years	8 years
Long MTBF	70 days	100 days	120 days	150 days	180 days
Low producing cost	€ 3000, --	€ 2500, --	€ 2000, --	€ 1500, --	€ 1000, --

APPENDIX IV / Advantages and Disadvantages of Concepts

Concept 1. Rail robot + Mussel bag + Chainsaw + Conveyor belt +Hydraulic press machine.

Advantages:
(1) Rail robot is an efficient design for transmitting the mussel substrates.
(2) Conveyor belt can guide the rope to bag directly. This concept can reach the basic functions that the system required.

Disadvantage:
(1) Hydraulic press machine and conveyor belt is too expensive and heavy.

Concept 2. Ring + Mussel bag + Hydraulic shears + Cartesian coordinate rail + Lift Motor

Advantages:
(1) This system is really stable and fits almost all kinds' ships, which means the design can be used for other ships to collect ropes.
(2) The system can put substrates into all the bags with high automation.
(3) The pressing machine is very safe and connected to the moving car.
(4) The pressing part and the collecting part can work at the same time.
(5) The system is very simple and cheap.

Disadvantage:
(1) The track may be very big, which is based on the number of the bags.

Concept 3. Track + Mussel bag + Cigar scissors + Manipulators + Shaking machine

Advantages:
(1) Track can guide the substrate to the required position,
(2) Shaking machine can make substrates closer packed efficient.
(3) Manipulators are smart enough to control the position to fall the substrates.

Disadvantages:
(1) Manipulators need more controllers to control it.
(2) Cigar scissor can't be electrical and needs more manpower to work.

Concept 4. Ring + Mussel bag + Electric files + Conveyor belt + Shaking machine

Advantages:
(1) Ring is the cheap and efficient method to guide the substrates.
(2) Shaking machine can make substrates closer packed efficient. Electric files can work smartly to cut the substrates.

Disadvantages:

(1) Shacking machine is hard to remove to other positions when one bag is full.

Concept 5. Pulley + Mussel bag + Cigar scissors + Conveyor belt + Robotic Arm

Advantages：
(1) Pulley is simple and cheap to be used as transmit substrates.
(2) Conveyor belt can guide the rope to bag directly and it is stable.

Disadvantages：
(1) Robotic arm is expensive.
(2) Cigar scissor can't be automatic.
(3) Shacking machine is hard to remove to other positions when one bag is full.

Concept 6. Ring + Mussel bag + Vigorous lever shears + Cartesian coordinate rail + Shaking machine

Advantages:
(1) Cartesian coordinate rail is easy to transfer the collecting gears from bag to bag and it is efficient.
(2) Ring is the cheap and efficient method to guide the substrates.

Disadvantages：
(1) Vigorous lever shears can't be electrical and Shacking machine is hard to remove to other positions when one bag is full.

Concept 7. Pipe + Mussel bag + plate shears + Track + Lever presses

Advantages：
(1) Pipe is also an efficient method to transmit the substrates.
(2) Track can guide the substrate to the required position.

Disadvantages：
(1) Lever presses e is hard to remove to other positions when one bag is full.

Concept 8. Pipe + Mussel bag + Cigar scissors + Manipulators + Hydraulic Press machine

Advantages：
(1) Pipe is also an efficient method to transmit the substrates.
(2) Manipulators are smart enough to control the position to fall the substrates.

Disadvantages：
(1) Cigar scissor can't be electrical.
(2) Hydraulic press machine is too expensive and heavy.

Concept 9. Conveyor + Mussel bag + Hydraulic shears + Cartesian coordinate rail + Hydraulic Press machine

Advantages：
(1) Hydraulic shears is strong enough to cut the mussel substrates.
(2) Cartesian coordinate rail is easy to transfer the collecting gears from bag to bag.
(3) Hydraulic shears can cut the substrate efficiently and smartly.

Disadvantages：
(1) Conveyor may be complicated and expensive for the simple function.
(2) Hydraulic pressing machine is too expensive and heavy.

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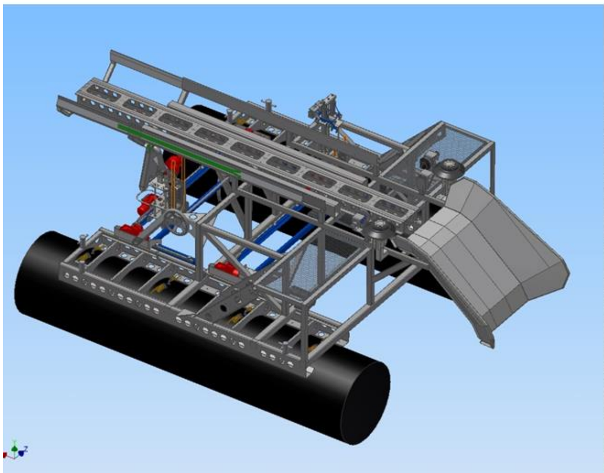


Europees Visserijfonds:
Investering in duurzame visserij

Ministerie van Economische Zaken

Jansen Tholen B.V.

Provincie Zeeland

HZ UNIVERSITY OF APPLIED SCIENCES

Final Report

Mechatronics project

Version 2.0

Group number: 4

Group members: Huang Yizhou 69438
Zhai Rongpeng 69462
Lu Yan 69442
Koen de Knegt 60813

Code of course: CU08061

Tutor: J.C.W Haak

Client: Jansen Tholen B.V.
Edward Mouw

Date: 2015/1/4

Content

Part Ⅰ Project Description

1. Project details

Project objective:	Make a design of a system supervises the (parts of the harvesting system).
Project supplier:	Edward Mouw Jansen Tholen B.V.
Project coach:	J.C.W Haak
Project leader:	Huang Yizhou
Project members:	Zhai Rongpeng Lu Yan Koen de Knegt

Project background:

Why the problem occurs?

In order to improve the quality and efficiency on mussel harvesting and reduce the cost of labor, Jansen Tholen B.V. needs the harvesting system that is efficient, safe and automatic. In addition, the system needs to detect errors and make response by itself.

What is the situation now?

Right now, the most popular harvesting system is half automatic and half human machine with substrate wires and hocks. This kind of system easily causes errors, for example, hocks don't be removed and mussels remain on the wires will both break down the machine. When the machine fails, fishermen must find out and repair by themselves.

If fishermen continue to use this kind of old system, they will not only be wasting time and money, due to the increasing of labor price and reducing of workload. Also, there will have a great danger if errors cannot be detected and warned by the system itself.

What are the goals?

A new design of system which can detect, control, warn and supervise the whole mussel system needs to be developed to effectively prevent the lost of money and time.

2. Research question

Main research question:

How to make a design of a computer system based on Multisim 11.0 which can supervise the (parts of the) mussel harvesting system by acting in signaling, slowing down or stopping when an error occurs?

3. Full vision of background

What is mussel?

Mussel is a kind of shellfish which is rich in nutritional value, people picked up the shells to get food in the ancient centuries. Nowadays, people farm mussels to get food. They put the mussel's seeds in the substrate wire (a kind of cable), and the wire will be floating on the sea by buoys. People plant the seeds in the June, and harvest in the second year in January. That's the time to use the harvesting system we designed.

What is the whole process of mussel farming and harvesting? [3.4.5]

The steps of process are mainly divided into these five parts.

First of all, distribute the seeds of mussel evenly onto the rope with mussel seeders. After about 6 to 9 months, the rope is pulled up to harvest mussels by using a peg rope tractor type hauler. Next, there are three ways (manual socking, Spanish socking method and automated socking method) to remove the mussels from the rope to a declumper out feed conveyor. Then, rope washer and rope reconditioning equipment are used to clean the rope off mussels to make sure they can be used a second time. Finally, collect all the mussels into barrels and clean them with brush cleaners and mussel graders.

What kind of system is now being used around the world? [6]

According to the research, we know that New Zealand (later show NZ) is using continuous mussel farming systems and in the Netherlands (later show NL), we use continuous mussel rope system. The benefit of NZ system is that it works half-automatic with low errors, but it cost a lot to buy, repair and maintain the whole system. The rope system in NL is an old-way system, which depends more on humans. People need to dress in heavy waterproof clothes and solve problems when the machinery has an error. Due to the high labor price, fishermen eagerly have a kind of harvesting system which can operate and detect errors automatically.

3 4 5 6 See Bibliography, all the information has been collected and changed into own words.

Part Ⅱ Formulation Phase

1. Requirement lists

Requirements of the client:

1. A waterproof working environment that can put the controller of the detecting system.
2. Basic operating knowledge of the global detecting system.

Requirements of the detecting system:

1. When the substrate wire is too heavy to rise by the hook, the system needs to control the hook removing motor to slow down.
2. If one of the three subsystems (hook removing system, mussel removing system, rope collecting system) doesn't work, three groups of these parts will send a stop signal to the main system, detect it and stop working.
3. If the hook isn't removed, the group who design the hook removing part will send an error signal to the global detecting system which will react by stopping the whole system.
4. When the mussels on the rope are stuck in the machine, the mussel removing system will ask for stopping that the global supervising system must response to the rope removing motor.
5. Slow down the motor if there are still some mussels on the rope which receives as a signal from the mussel removing system.
6. Detect whether there is a knot in the rope jamming the system, if true, stop the harvesting machine.
7. When the rope collecting system supervises the substrate is stuck in the bagging mechanism, the global system need to stop working.
8. The crew in the ship will detect the environment and weather, if the environment and weather is terrible to work, a stop signal by pressing a stop button to control the whole harvesting system.
9. When the temperature sensor supervises the motor is too hot, the detecting system need to stop the motor and the whole system.
10. If the detecting system finds a mechanical failure, stop the global system and alarming.
11. The global detecting system need to cut the power when the current is short.

Requirement of three subsystems:

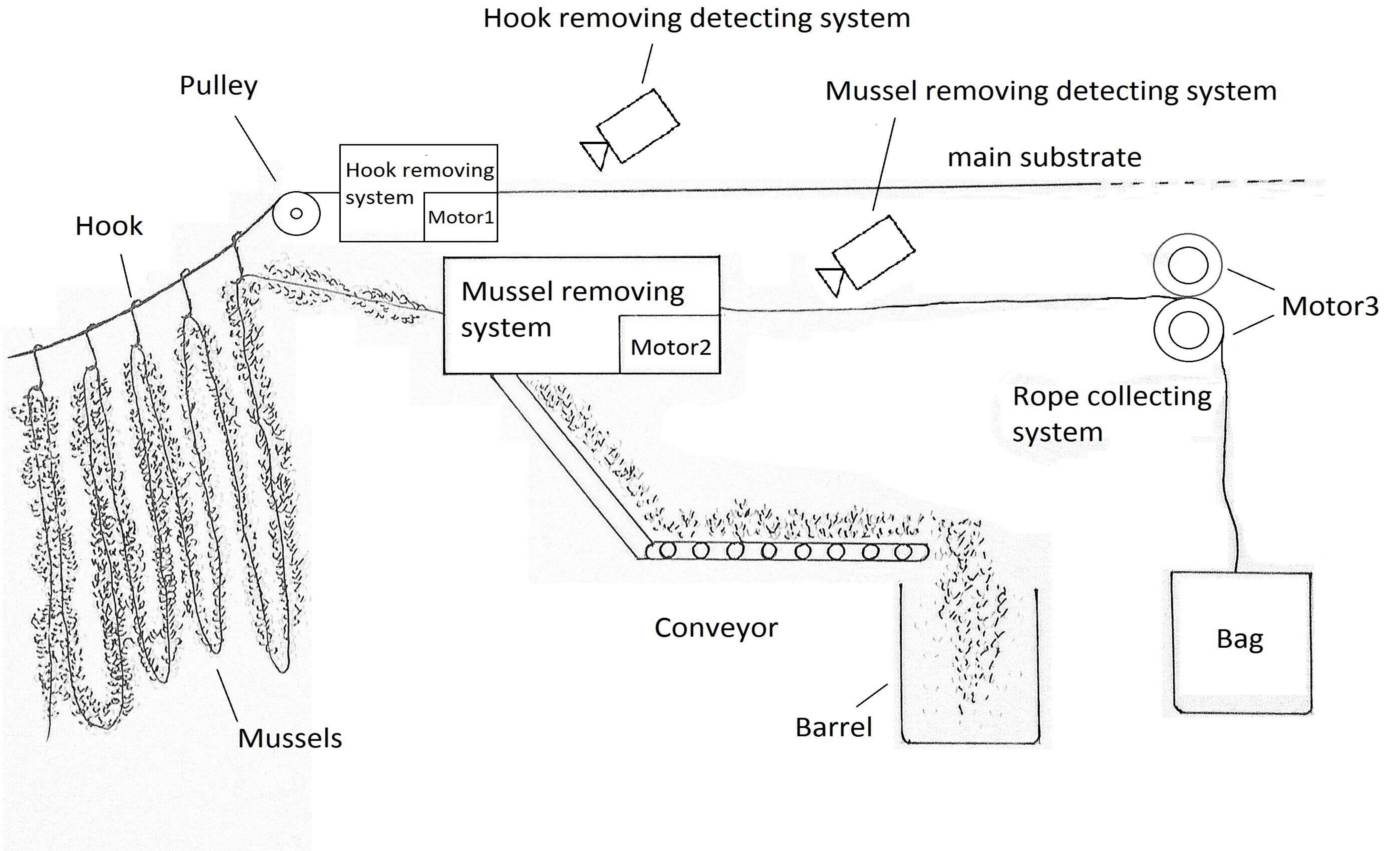
(The hook removing system, the mussel removing system, the rope collecting system)

1. Use the same standard and variables that show in the main supervising system:
    a) Send the output as a digital signal of the error, true for 1 and false for 0. Get the input digital signal in the same standard.
    b) The variables need to define a specific name that can show clearly in the code design part.
    c) Use the same motor and rope through the whole harvesting system.
2. Detect all the error that the global detecting system defined.

2. Errors list and sketch

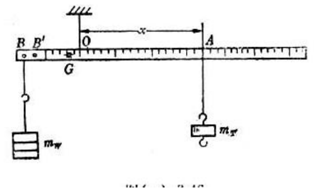
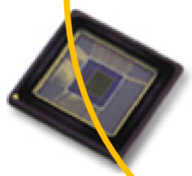
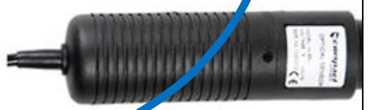
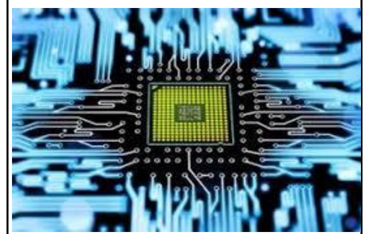
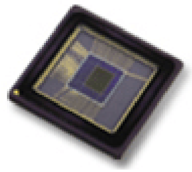
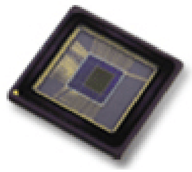
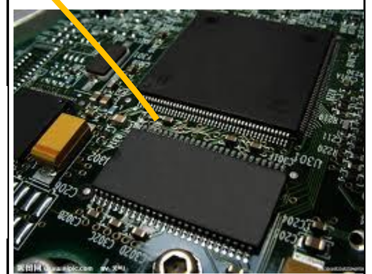
We discuss and find out 11 errors may occur when the system is operating, following chart is their description, how we detect these errors and the action we will take when errors occur.

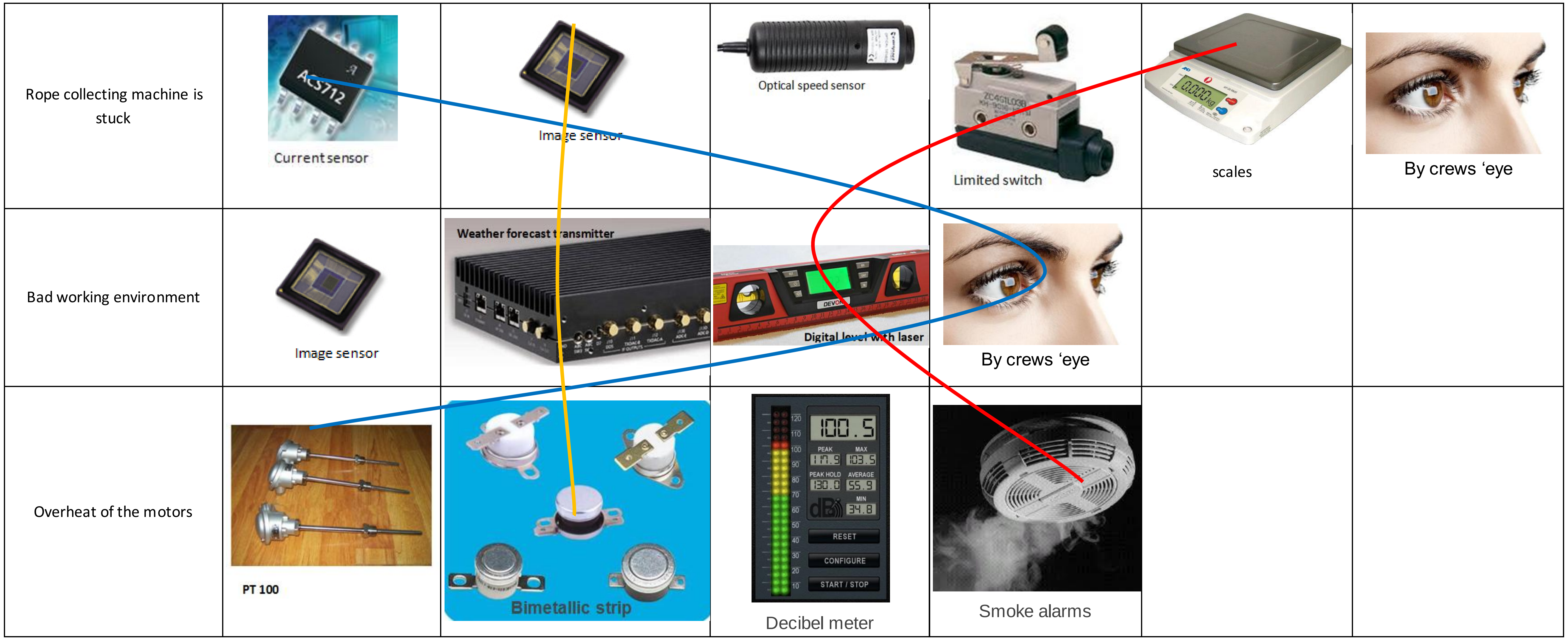
Error	Description	Detector	Action
substrate is overload	If the substrate is too heavy, it will be easily broken when it is hoisted quickly on the deck.	force sensor, Spring dynamometer	Slow down the lift motor, yellow LED
Hook removing arm is jammed	Seaweed or other things make the hook removing arm stuck.	Optical speed sensor, current measurement	Stop the whole system, alarming, red LED
The hook isn't removed	The hook removing arm fails to get the hook.		Stop the whole system, alarming, red LED
The hook removing detecting system isn't working	The hook removing detecting system isn't working		Stop the whole system, alarming, red LED
The mussel removing detecting system isn't working	The mussel removing detecting system isn't working		Stop the whole system, alarming, red LED
substrate is broken	1. Erosion of the ocean 2. It is cut off in the mussel removing machine. 3. High traction make it broken	current measurement of the rollers' motor, force sensor, Optical speed sensor	Stop the whole system, alarming, red LED
Flaps are stuck	A mess of Mussels and seaweed on the rope makes flaps of mussel removing machine hard to twist.	current measurement, image sensor, laser gun	Stop the whole system, alarming, red LED
Mussels remain on the substrate	Less than 100% mussels are removed		Slow down, alarming, yellow LED
Rope collecting machine is stuck	1. A knot on the substrate will jam the roller. 2. Remaining(seaweed) on the substrate will jam the roller	current measurement, Optical speed sensor, limited switch	Stop the whole system, alarming, red LED
Bad working environment	Bad weather, like storm and heavy rain.	crew's input, weather forecast transmitter, balance sensor	Stop the whole system, alarming, red LED
Overheat of the motors	Temperature of the motors are too hot	PT100,bimetallic thermometer	Stop the whole system, alarming, red LED


Hook removing detecting system
Pulley
Mussel removing detecting system
main substrate
Hook removing system
Motor1
Hook
Mussel removing system
Motor2
Motor3
Rope collecting system
Conveyor
Bag
Barrel
Mussels

3. Morphologic view

The Morphologic view shows the different ideas and alternatives we thought might work when different kinds of errors occur. Then based on these ideas, we choose three kinds of concepts.

Error	Alternatives					
Substrate is overload	 Current sensor	 Force sensor	 Spring dynamometer	 Optical speed sensor	 Limited switch	 steelyard
Hook removing arm is jammed	 Current sensor	 Image sensor	 Optical speed sensor	 Limited switch	 intelligent control chip	
Substrate is broken	 Current sensor	 Force sensor	 Optical speed sensor	 Image sensor	 Decibelmeter	
Flaps are stuck	 Current sensor	 Image sensor	 Optical speed sensor	 Chip in Separator system	 Decibelmeter	



Concept A

Concept B

Concept C

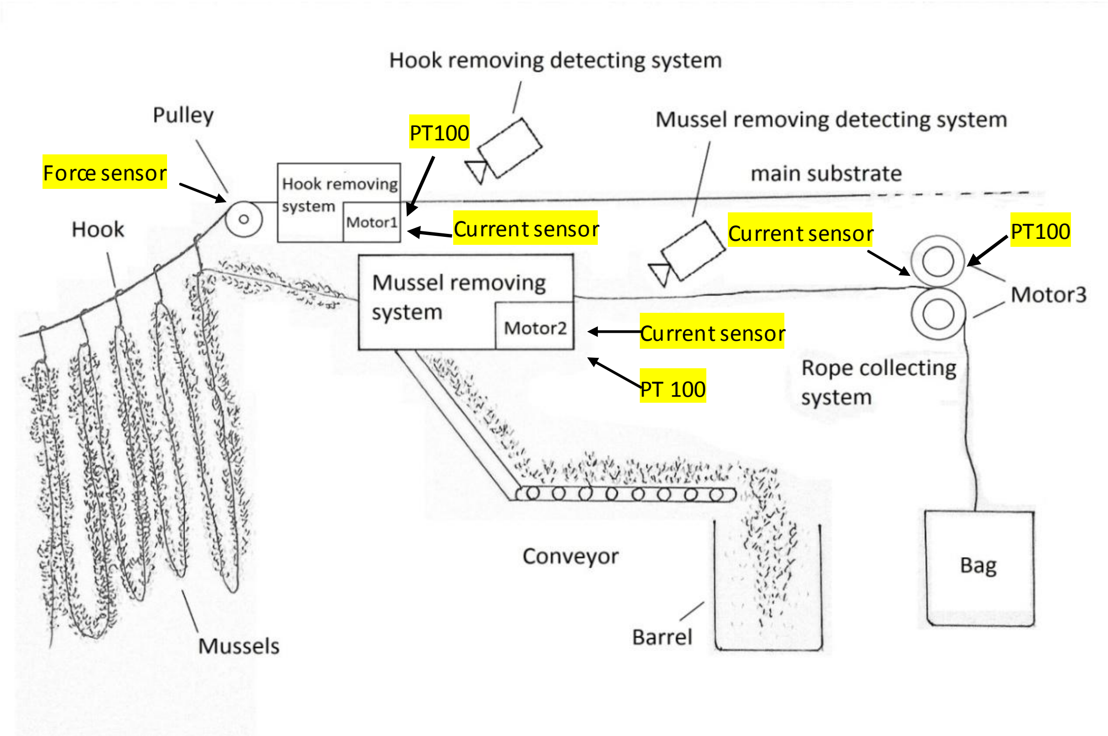
Part Ⅲ Concept Design

1. Description and analysis of three concepts

Concept A:

Core methods: Efficient, low cost, easy to build and make, reliable, can work properly on the ocean (reduce the affection of water)

Construction:



Description:

Using force sensor to detect whether the substrate line is too heavy or not according to the change of force.

Using optical speed sensor to detect whether the hook removing arm is jammed or not. We can know the speed of motor which activate the arm, if the speed becomes zero for few seconds (longer than the time used to take hooks off), it means it is jammed. It's more safe rather than use a current sensor here to avoid short circuit.

Using current sensor to detect the current flows through the motor, if the current suddenly becomes too low, it means the rope is broken, because the motor is now working in the no-load situation. If the current suddenly arises very high, it means there must has something jam in the motor which make it works under a blocked situation.

Using a stop button which gives the crew a chance to stop the whole system by human reduces many errors which cannot detect accurately by machines or sensors, like weather. If a storm comes, the crew can just stop the whole system by themselves.

Use PT100 to detect whether the motor is too hot or not. The temperature sensor will directly give an electrical signal to our processor.

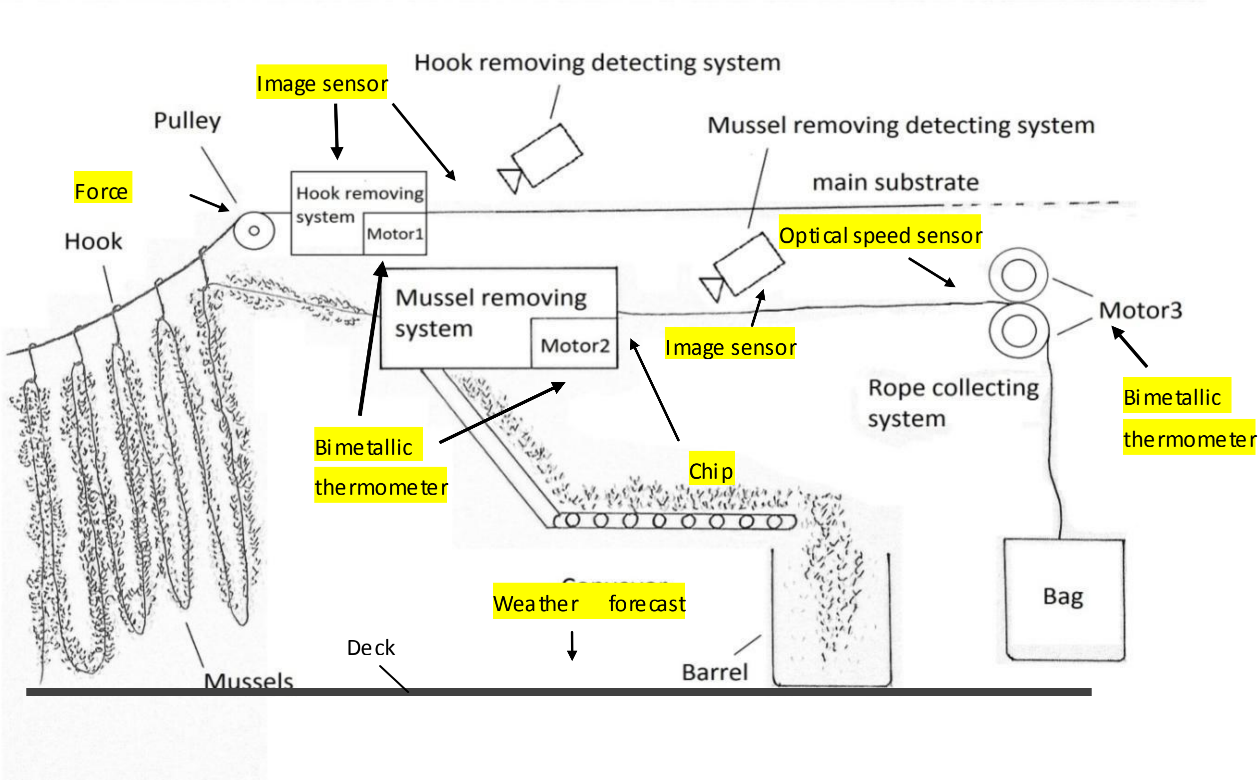
Analysis chart:

Error	Solution	Advantages	Disadvantages
Substrate is overload	Force sensor	1. Easy to measure 2. Low cost 3. Durable 4. Accuracy	1. Needs a water-proof cover
Hook removing arm is jammed	Optical speed sensor	1. Accuracy 2. Easy to use 3. Reliable	1. Not very durable 2. Delicate
Substrate is broken	current measurement device	1. Easy to measure 2. Low cost 3. Can work properly in various working situation	1. Not very accuracy
Flaps are stuck	current measurement device	1. Easy to measure 2. Low cost 3. Can work properly in various working situation	1. Not very accuracy
Rope collecting machine is stuck	current measurement device	1. Easy to measure 2. Low cost 3. Can work properly in various working situation	1. Not very accuracy
Bad working environment	crew operation	1. Can work properly in various working situation 2. Low cost 3. Safety	1. Needs human labor
Overheat of the motors	PT100	1. Accuracy 2. High efficiency	1. High cost 2. Delicate

Concept B:

Core methods: Efficient, accuracy, hard to build and analysis, reliable.

Construction:



Description:

An infrared sensor is an electronic device could sense some aspect of its surroundings. A sudden change in one area of the field of view, especially one that moves, will change the way electricity goes from the piezoelectric materials through the rest of the circuit. Infrared transducer here is used to detect whether the rope is broken.

Force sensor is to detect whether the substrate line is too heavy, sending the signal to the process. The system would go slow down if the substrate line is too heavy to lift, avoiding it broken.

Image sensors are installed in mussel removing system, bagging system and rope collecting system, respectively, which converts an optical image into an electronic signal to detect whether the rope is stuck in the system.

Bimetallic thermometer consists of two strips of different metals which expand at different rates. It converts a temperature change into mechanical displacement which is to detect the temperature of the motor to prevent short circuit or working too long time.

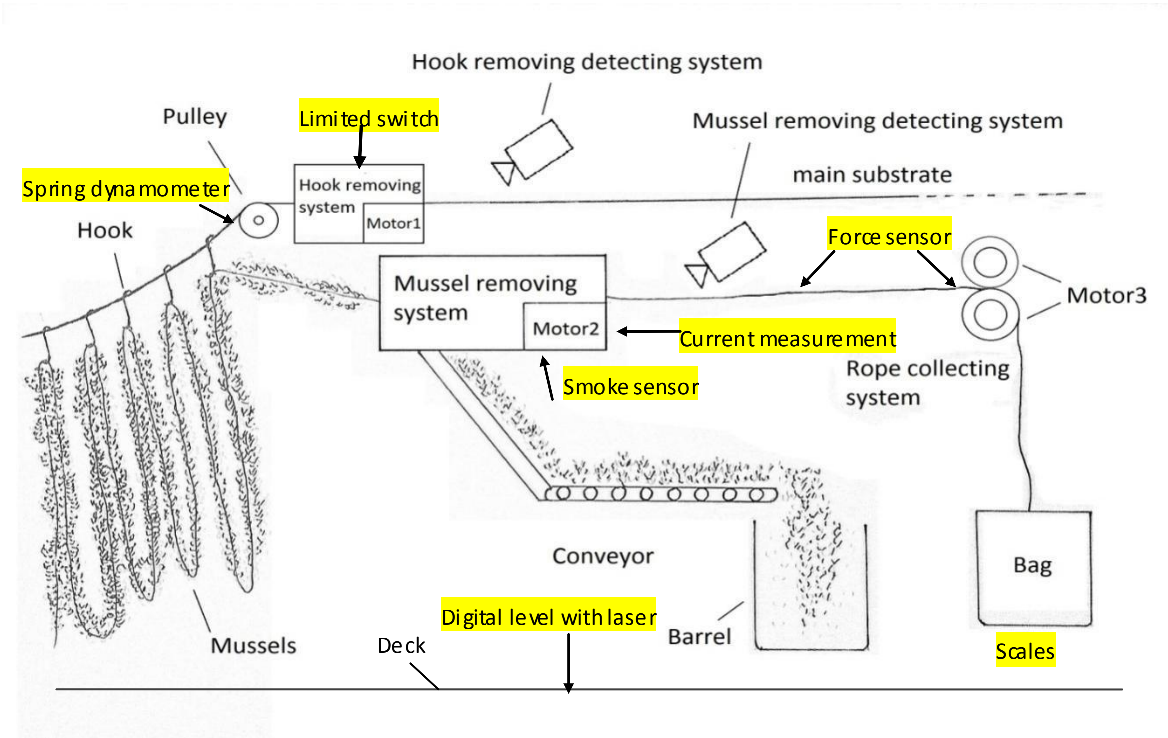
Analysis chart:

Error	Solution	Advantage	Disadvantage
Substrate is overload	force sensor	1. High accuracy 2. Small size and light weight	1. Low sensitive
Hook removing arm is jammed	image sensor	1. High accuracy	1. Expensive 2. High demand on the equipment 3. Need time to analyze the image.
Substrate is broken	Optical speed sensor	1. Stable 2. High sensitive 3. Doesn't need to touch the object when detecting.	1. Could be easily interfered by other heat resource. 2. Expensive.
Flaps are stuck	Chip in Separator system	1. Stable 2. have long lifetime	1. Expensive 2. High demand on the equipment
Rope collecting machine is stuck	image sensor	1. High accuracy	1. Expensive 2. High demand on the equipment 3. Need time to analyze the image.
Bad working environment	weather forecast transmitter	1. Save human labor	1. Low accuracy
Overheat of the motors	bimetallic thermometer	1. Not expensive 2. Small and light	1. Short life 2. Could not work under high voltage. 3. Low accuracy

Concept C:

Core methods: Efficient, accuracy, sensitive for the measurement and can work properly on the ocean (reduce the affection of water)

Construction:



Description:

Using a force sensor to supervise the force though the substrate timely that can make sure if the substrate is broken or not.

Limited switch can detect the motivation of the removing arm in the Hook removing system, for each turn it need to touch the switch to show it is working. If the cycle is stopped, that shows the arm is stopped.

The spring dynamometer can show the force by it length, if it is too heavy the length will be bigger and it will be reacted on the Sliding rheostat.

Current measurement device is a speed measure tool which can show the motivation of the motor 2. If the flaps are stuck, the motor will show a high current.

The scales is to detect if there is a knot or seaweed on the substrate which is stuck in the bagging machine by checking the weight of the substrate, It means this situation when the weight stop increasing.

Smoke alarm is a easy way to measure the temperature of the motor 2, if the motor is too hot, the smoker will alarm.

Using the Digital level with laser can show the level of the ship, if the ship is bumped by the wave and wind out of a limited field, the balance ball will go the edge of the board. If the ship is stable, the ball will show in the middle.

Analysis chart:

Error	Solution	Advantages	Disadvantages
Substrate is overload	Spring dynamometer	1. Low cost 2. Easy to use 3. Waterproof	1. Not very accuracy 2. Not very durable
Hook removing arm is jammed	Limited switch	1. Low cost 2. Easy to use 3. Reliable	1. Not very durable 2. Not very accuracy by missing errors
Substrate is broken	Force sensor	1. Easy to measure 2. Low cost 3. Durable	1. Not very accuracy
Flaps are stuck	current measurement device	1. Easy to measure 2. Low cost 3. Can work properly in various working situation	1. Not very accuracy
Rope collecting machine is stuck	scales	1. Easy to measure 2. Low cost	1. Not very accuracy
Bad working environment	Digital level with laser	1. Promptly 2. Low cost 3. Safety	1. Not very accuracy 2. High cost
Overheat of the motors	Smoke alarms	1. Durable 2. Accuracy	1. High cost 2. Not very sensitive 3. Later to reflect

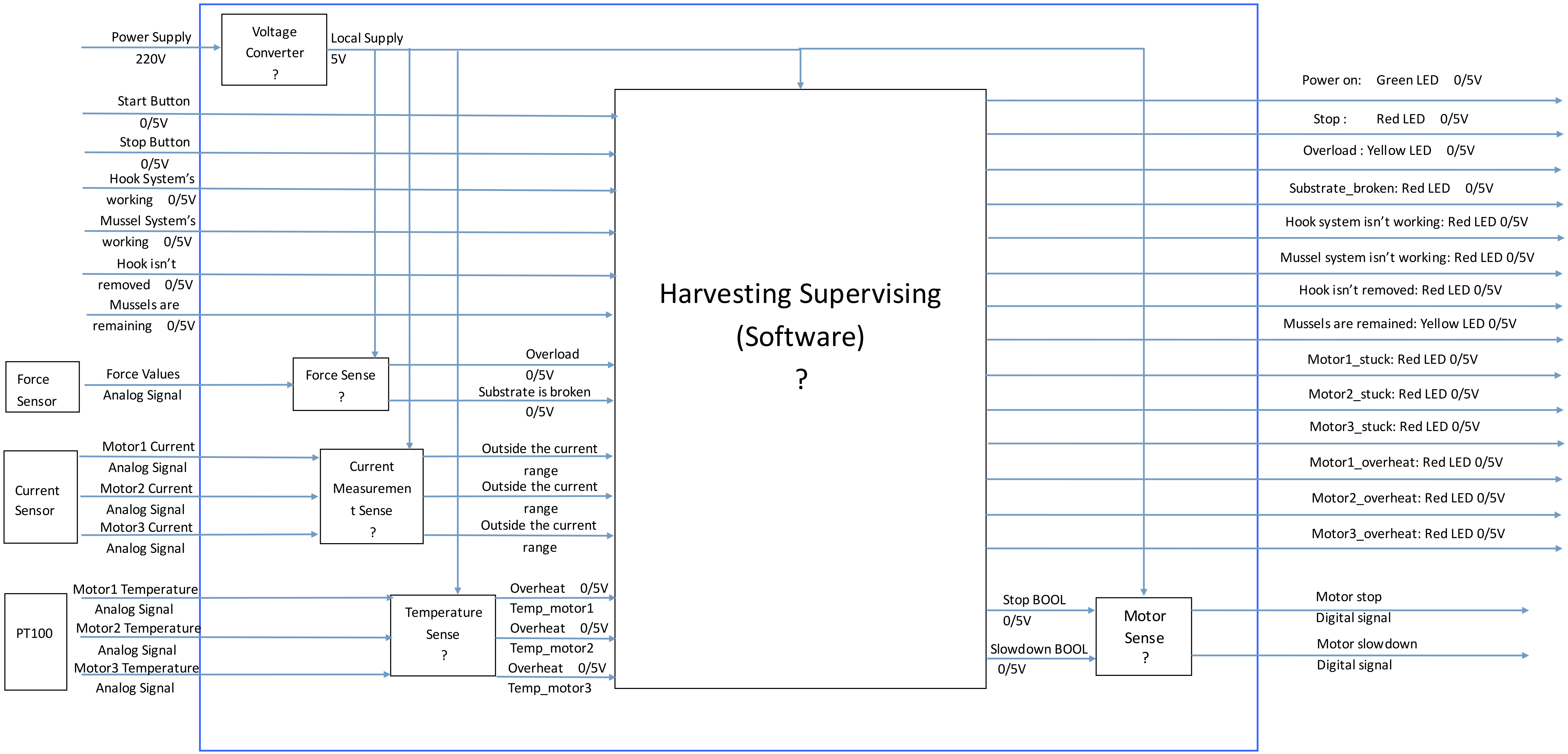
2. Concept comparing

Comparing form							
Criteria	**Importance weight**	**Concept Alternatives**					
		Concept A		**Concept B**		**Concept C**	
		Rating	**Weighted rating**	**Rating**	**Weighted rating**	**Rating**	**Weighted rating**
High efficiency	20%	4	0.8	5	1	3	0.6
Accuracy & Reliable	20%	4	0.8	5	1	4	0.8
Low cost	10%	5	0.5	1	0.1	3	0.3
Durable	10%	4	0.4	4	0.4	3	0.3
Work properly on the ocean	10%	4	0.4	3	0.3	2	0.2
Safety	20%	5	1	4	0.8	3	0.6
Size & Weight	10%	4	0.4	4	0.4	4	0.4
Total	100%		**4.3**		**4**		**3.2**

According to the comparison, we choose concept A as the concept for our project.

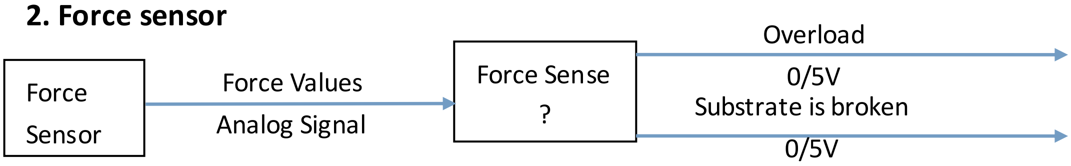
Part Ⅳ Configuration Phase

1. Internal overview



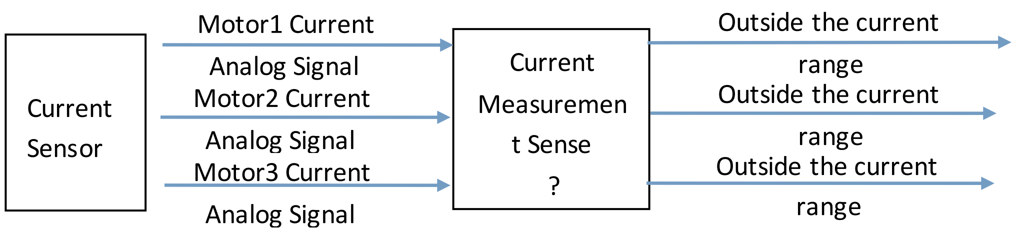
Motor Sense is just for showing motors' actions for different warnings by the simulation! For the real design, the input of the Motor Sense was from the warnings output signal(the output is just the LED shows)

2. Force sensor



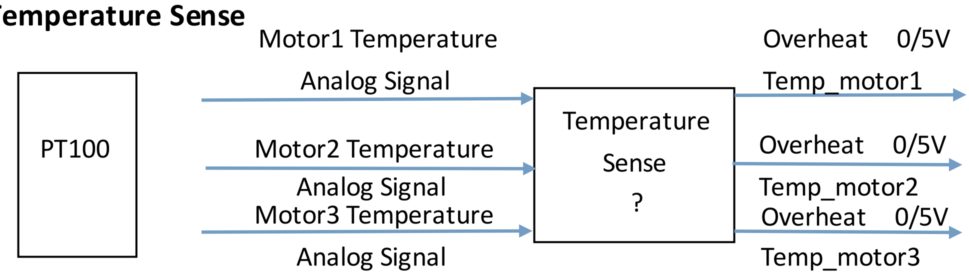
With the input from Force Sensor, it is an analog voltage signal. First we will use the ADC converter to change them into digital signal. By the chip and computer we can find that the values are written as digits, we need to define a range of normal situation. If it is higher than the maximum, the output overload will be "1" for 5V shows that the "overload" warning is true, otherwise, it will be "0" for 0V shows the "overload warning" is false. If it is lower than the minimum, the same to the "substrate is broken" warning, "1" for 5V shows it is true, or "0" for 0V shows it is false.

3. Current Measurement Sense

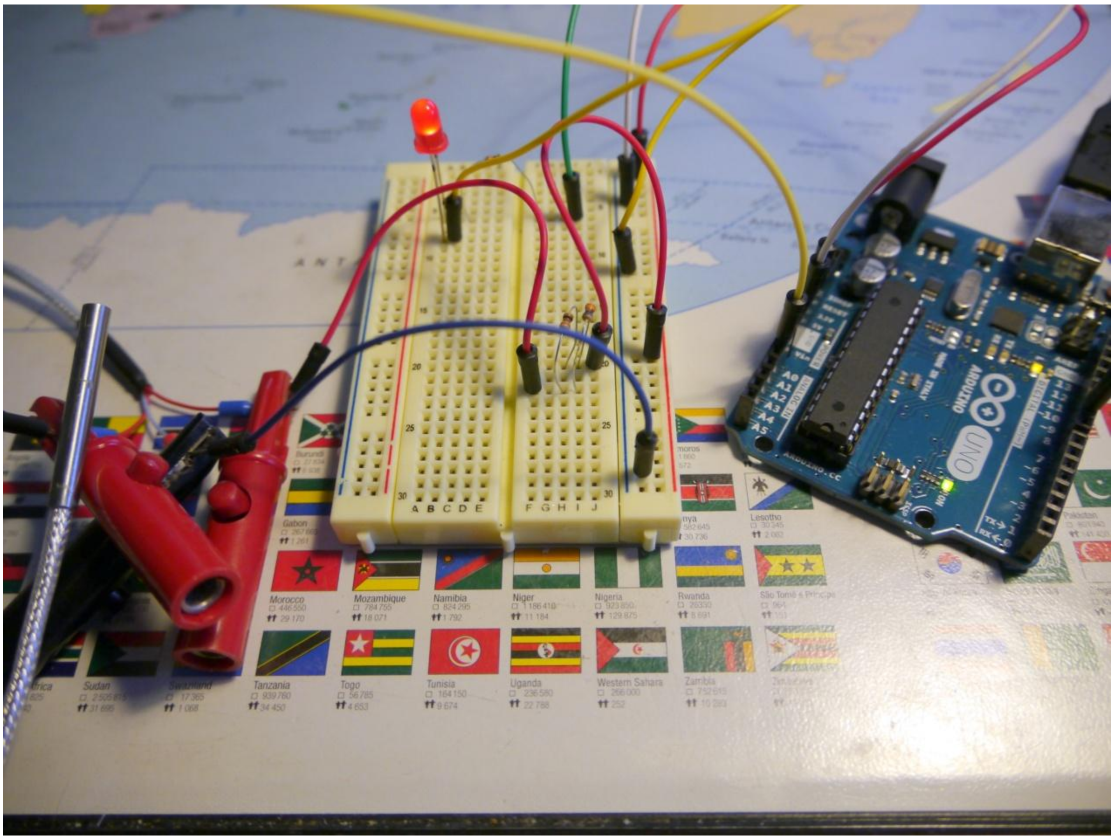


We will use the current sensor for each motor to detect their diversification of current. It has the same principle like the force sense. Convert the analog signal to digital signal. Defined a limited area, if the motor1 is stuck, the "Current_motor1" warning will be true for 5V, or it will be false for 0V. It is the same for motor 2 and 3.

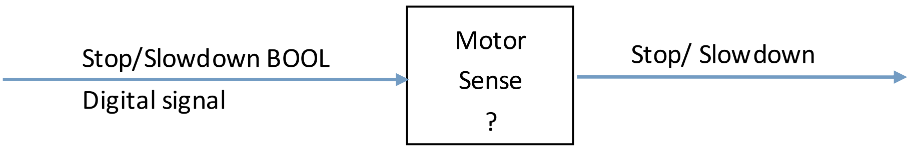
4.Temperature Sense



PT100 is a sensitive sensor we chose to supervise the temperature in motors. We will show how to build a real circuit and program design by Arduino. First we connected it into a ADC converter, and fired the voltage values into the chips, you can see the result on the computer.(It can also be used for the force sensor and current sensor), we also made a temperature range, if it is overheat, the output will be true for the warning as 5V, and for the reverse situation it will be false as 0V. Each motor is the same.

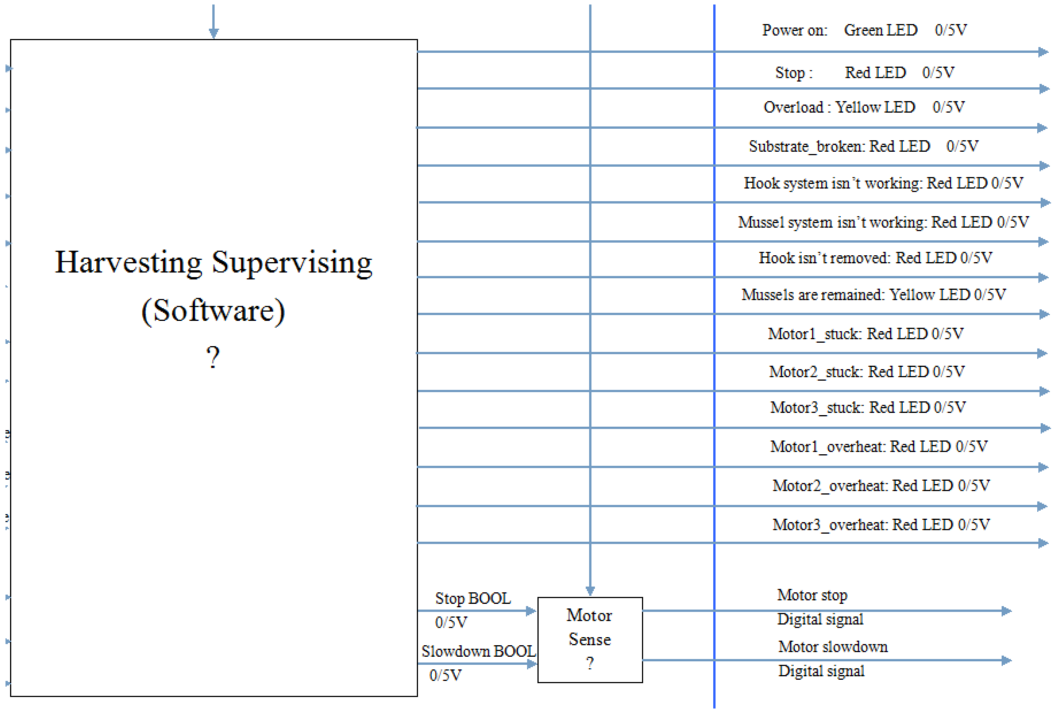


5. Motor Sense



In the internal overview, we just want to use the Multisim to show the motor's action for every warning. You can see the Motor action LED to show the solution of the motor when errors take place. So you can find the Stop BOOL and Slowdown BOOL output from the Software plate.

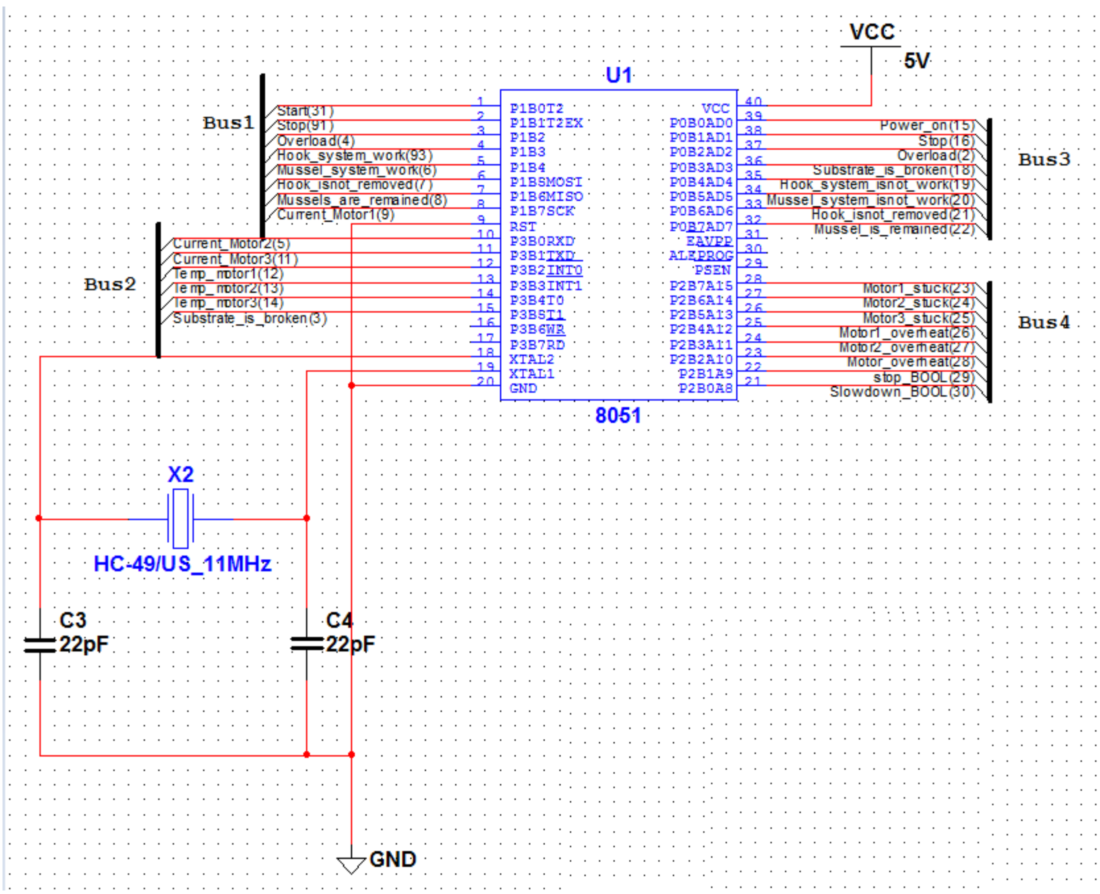
For the real design, this sense is run after each warning LED, so the input of Stop/Slowdown BOOL is the other 14 outputs from the Software plate, the Red LED means the motor need to stop, Yellow LED means it need to Slowdown, Green LED means it can run normally.



6. Harvesting Supervising

We chose the Multisim to simulate all the errors and solutions.

M8051 is the final micro-controller we used, and we use the Bus in the simulation, but you needn't use it for real setting up. The user just need to connect the related line to the right Pin.(We have named all lines):

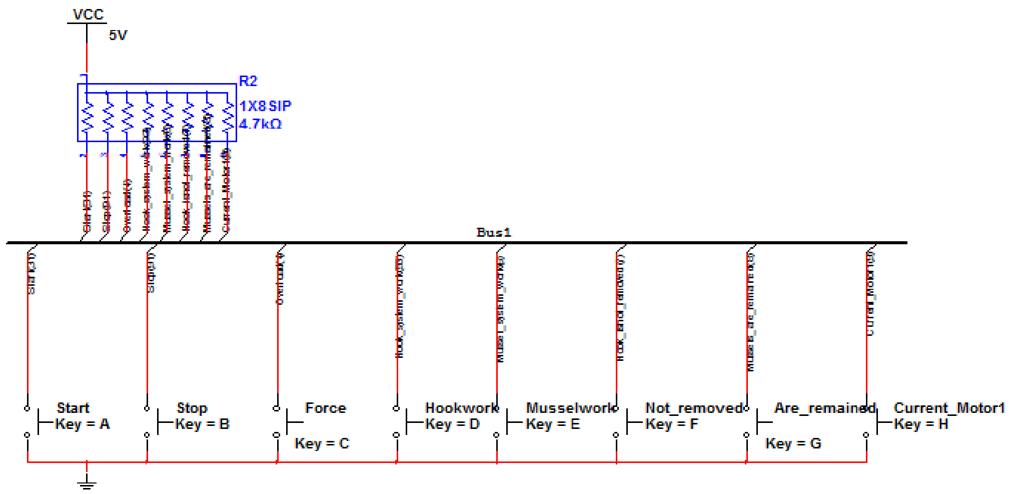


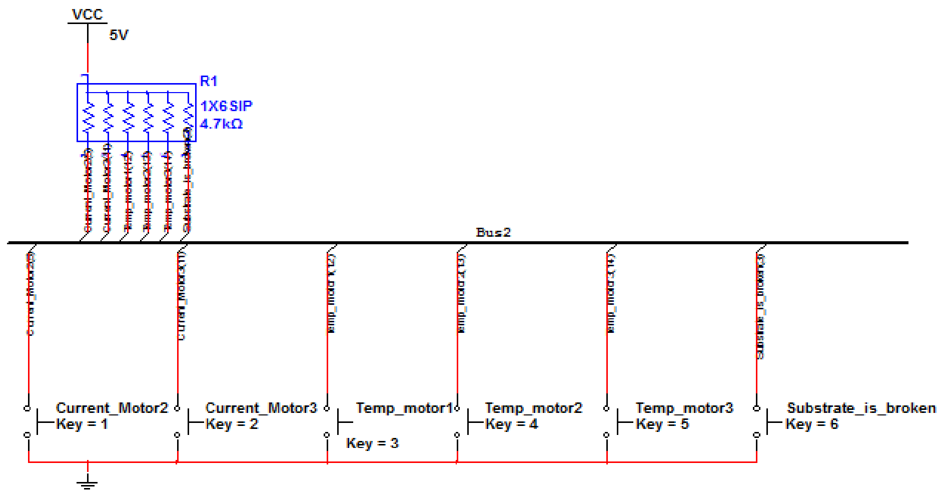
Bus1 and Bus2 connect with the input keys.

Bus3 and Bus3 connect with the output LED.

The input on the left:

We use pressing keys to simulate the error signal is true. 14 inputs are show as following picture:

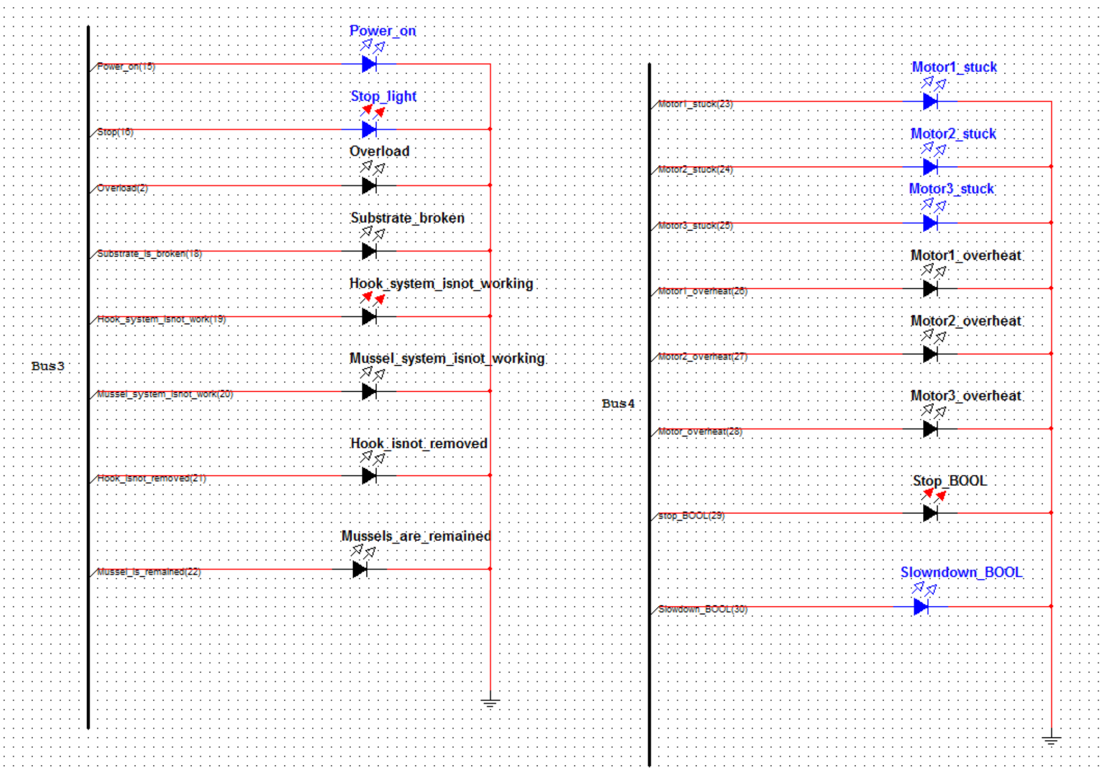




The Bus1 and Bus2 connect with the M8051 as the input signals.

The output on the right:

Each LED will show an error or a mode of the harvesting system:



The Bus3 and Bus4 connect with the M8051 as the output signals.

7. How to use our Multisim 11

We have put all the instructions besides switches, if you press down

Start	means this is the start button, the system starts to work
Stop	means this is the stop button, the system stops
Force	means force sensor detects the substrate is overload
Hookwork	means the hook-removing system is working properly
Musslework	means the mussle-detecting system is working properly
Not_removed	means there are hooks not been removed
Are_remained	means there are mussels still remained
Current_Motor1	means the current sensor detects current passes through motor1 is higher than standard value, something is stuck
Current_Motor2	means the current sensor detects current passes through motor2 is higher than standard value, something is stuck
Current_Motor3	means the current sensor detects current passes through motor3 is higher than standard value, something is stuck
Temp_Motor1	means PT100 detects the motor1's temperature is higher than safe temperature
Temp_Motor2	means PT100 detects the motor2's temperature is higher than safe

	temperature
Temp_Motor3	means PT100 detects the moto3's temperature is higher than safe temperature
Substrate_is_broken	means current sensor detects the current passes motor3 is lower than standard, then substrate line is broken

Then, you will see different reactions with led lights, showing warnings.

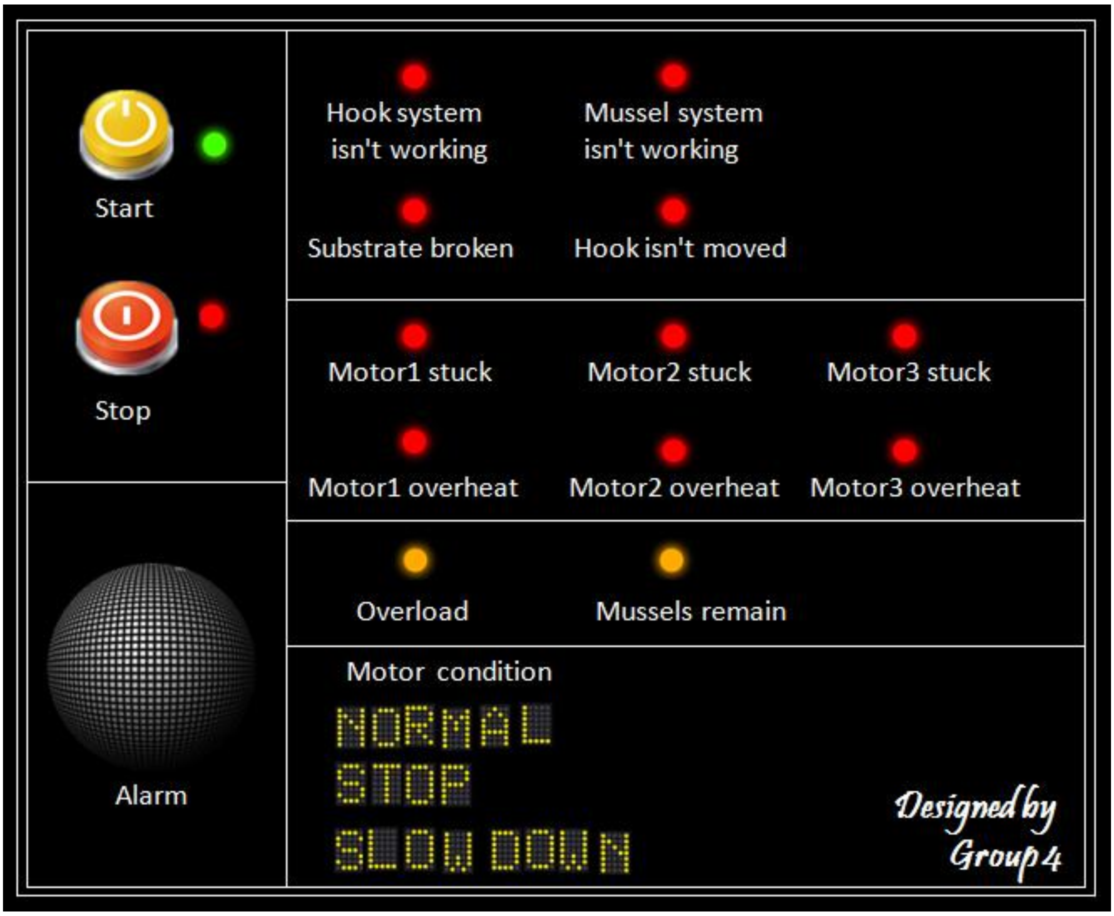
The C-code in M8051:

```
#include <8051.h>
void main()
{
    int a,n,m;
    P0=0x00;
    P2=0x00;
    while(1)
    {
      if((P1&0x01)==0)                    //Start button
    {
        P0=0x01;
        P2=0x00;
        a=1;
      }
      if((P1&0x02)==0)                    //Stop button
      {
        P0=0x02;
        a=0;
      }
      if(a==1)                            //System start working
      {
        if((P1&0x04)==0)                  //Overload, yellow LED
        {
            P0=0x05;
            P2=0x01;
          }
          if((P1&0x08)==0)                // Hook system isn't working, red LED, stop
        {
            P0=0x12;
            P2=0x02;
            a=0;
          }
          if((P1&0x10)==0)                // Mussel system isn't working: Red LED,stop
```

```
{
     P0=0x22;
     P2=0x02;
     a=0;
  }
  if((P1&0x20)==0)                    // Hook isn't removed: Red LED,stop
{
     P0=0x42;
     P2=0x02;
     a=0;
  }
  if((P1&0x40)==0)                    // Mussels are remained: Yellow LED
{
     P0=0x81;
     P2=0x01;
  }
  if((P1&0x80)==0)                   // Motor1_stuck: Red LED, stop
{
     P0=0x02;
     P2=0x82;
     a=0;
  }
  if((P3&0x01)==0)                   // Motor2_stuck: Red LED, stop
{
     P0=0x02;
     P2=0x42;
     a=0;
  }
  if((P3&0x02)==0)                    // Motor3_stuck: Red LED, stop
{
     P0=0x02;
     P2=0x22;
     a=0;
  }
  if((P3&0x04)==0)                 // Motor1_overheat: Red LED
{
     P0=0x02;
     P2=0x12;
     a=0;
  }
  if((P3&0x08)==0)                  // Motor2_overheat: Red LED, stop
{
     P0=0x02;
     P2=0x0A;
```

```
                a=0;
            }
            if((P3&0x10)==0)                    // Motor3_overheat: Red LED, stop
           {
                P0=0x02;
                P2=0x06;
                a=0;
            }
            if((P3&0x20)==0)                  // Substrate_broken: Red LED, stop
           {
                P0=0x0A;
                P2=0x02;
                a=0;
            }
        }
      }
}
```

8. Front Panel



9. Signal getting from sensor

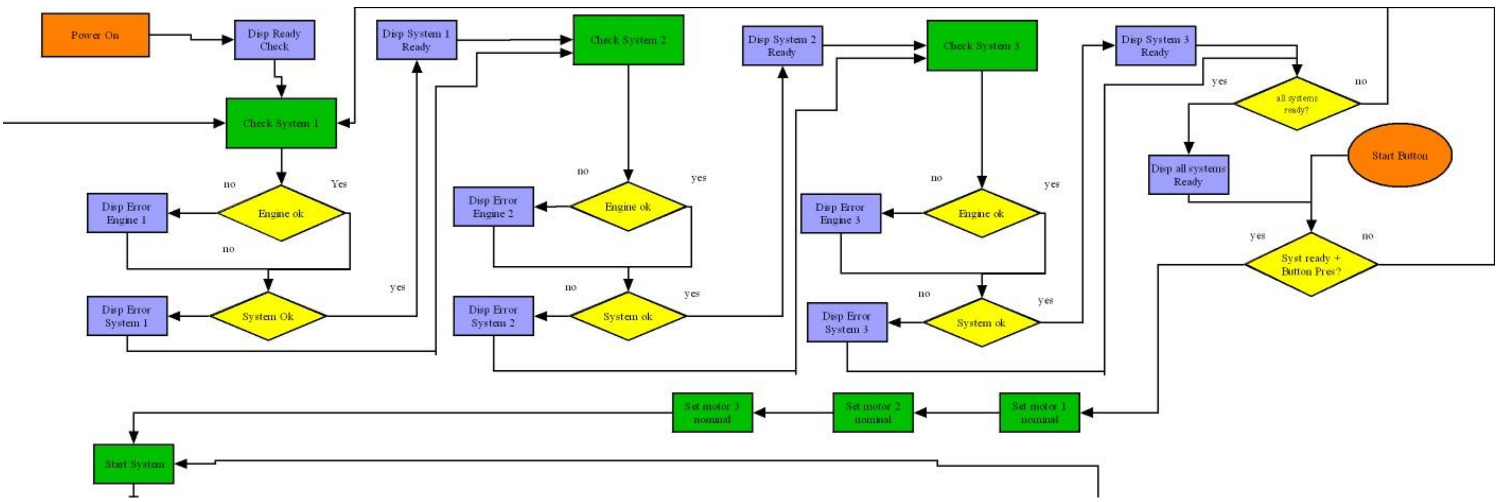
To make sure our Multisim design can work in real life, we decide to make a hardware design of PT100, a kind of temperature sensor, to ensure we can get outside real life input signal rather than just a switch instead . As our materials is limited, we don't have 8051 microcontroller, so we decide to use a LED light as our output, if the LED is on, means there will be a output signal which can send a '1' to our 8051 microcontroller and instead of the function of switch we design in Multisim. Then the theory will connect to reality.

Digital system Design

With all the necessary hardware parts designed the next part is making all these sensors and actuators work together. However because we don't know the final details of essential hardware like the micro controller, engines, power supplies, and signals we can only design the functions of the system over time.

The digital system consists of two main loops, a 'stand by loop' and a 'harvesting loop'. This setup allows for an activated and controlling system that can be turned on and off without turning the power off and on.

The stand by loop



(for the full system see appendix)

When the power is turned on, the system starts its 'ready check', this consists of checking each system for errors and relaying this data back to the crew via the control panel. For each sub-system the system checks if the engines are ready and if the sub-system itself has any errors. As this system is incapable of solving internal hardware errors itself, it displays all results to the crew so they can solve the error if one comes up.

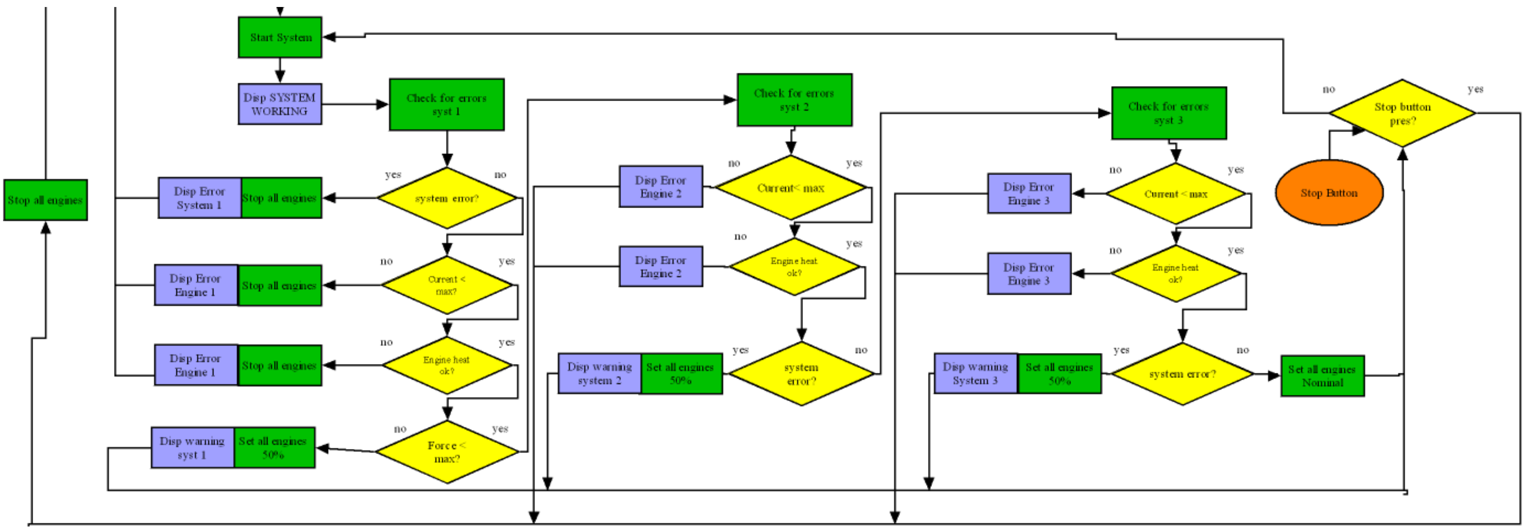
If all the sub-systems are checked and no errors were detected the loop opens up the 'start button', when this is pressed and all the sub-systems are ready to go, all engines are set to their nominal value (depending on the specifics of the hardware and preference of the crew) and are activated, continuing in the 'harvesting loop'.

Before we go into the details of the harvesting loop, there are some recommendations when implementing this draft into a coded system.

When reading sensory data, it is important to make use of a so called 'running average array', this is a piece of code that takes x measurements from a sensor and takes the average of that number, always replacing the oldest measurement in the array with a recent one. This eliminates a lot of noise from the sensors and makes the system overall more precise. This is because electronics work in the magnitude of milliseconds, and one false measurement over the course of a millisecond could led the system to believe there is an error, while it was just one false reading.

It is also recommended to use a variable to store and activate the results of the ready check, this allows the system to keep track of the sub- system status and make use of this information once it has passed by the sub-system specific check. If this is not implemented it might create unsafe situations as the system only knows there was a light lit on the control panel, but it has no variable to check.

The harvesting loop



(for the full system see appendix)

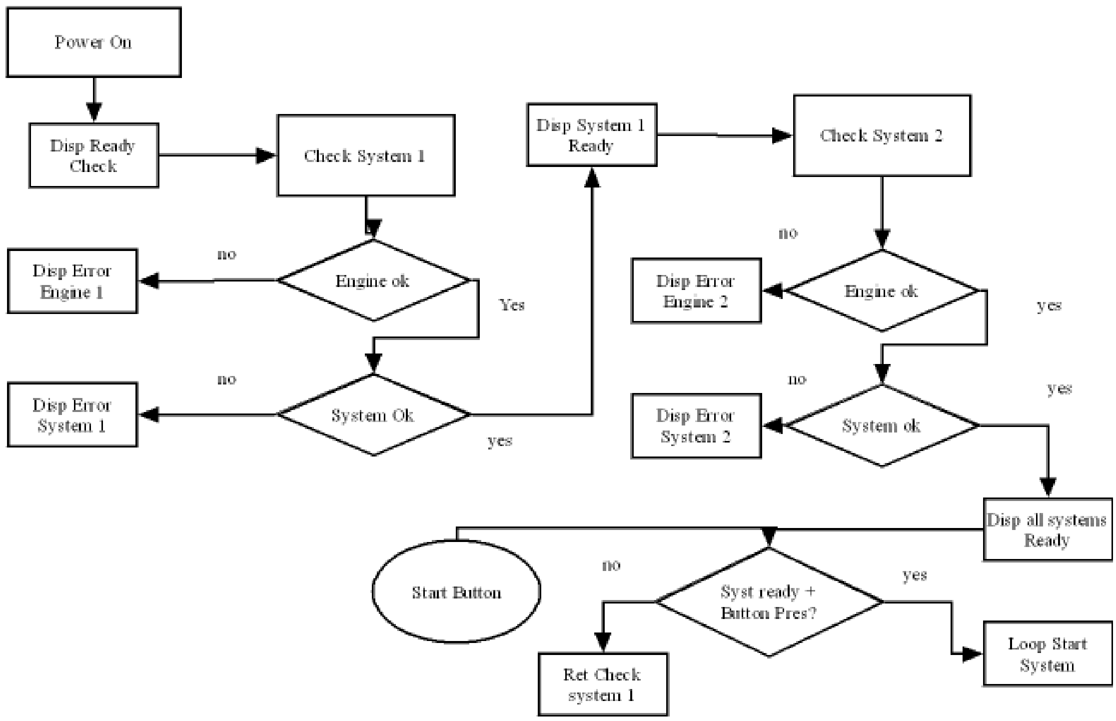
When the system is ready and the crew maneuvered the machine in position, the harvesting can begin. When the start button is pushed the system start of with its nominal values, as described at the stand by loop.

When the machine is operational the system start checking for error, it does this per system based of the error we defined early in the designing process.

In the ideal situation the system runs through all the sub-systems to find no errors, it then sets the engines to nominal value again (in case the previous loop slowed down) and check if the stop button is pressed, if not it starts over again at sub-system one. However more interesting is the situation when an error occurs; we defined two types of errors, critical errors and non-critical errors. No matter what sub-system suffers a critical error, the result is immediate shutdown of all engines and a return to the stand by loop. This will avoid further damage to the system and or crew, and gives the crew time and information to find and solve the error. Because of the impact of a critical error the system always checks for critical errors first, and then checks for non-critical errors. If the system suffers from a non-critical error, the harvesting can continue but at a slower pace so the system suffers no further damage or a critical error. To this end the immediate action the system takes when it finds a non-critical error is to slow down the engines to 50% of nominal value (placeholder number). If this action is taken it forces the system to start its error check from the beginning of the loop to compensate for any follow up errors that might occur.

Recommendations for turning this draft into code.
Just like the previous loop using a running average array helps stabilizing the system immensely, more important however is tuning the code to the microprocessor used. As a digital system can take only one action at a time, the speed of the processor is instrumental in determining how many actions can be taken 'simultaneously'. This is a serious concern which we cannot address at this point because of the limited information, however because all the engines pull on the same substrate wire, making them turn on and or off at the same time will make the difference between finding an error immediately after switching on, or having a smooth harvest. This problem becomes even more appearing if the different engines have to run at different speeds to achieve smooth operation.

10. Backup configuration



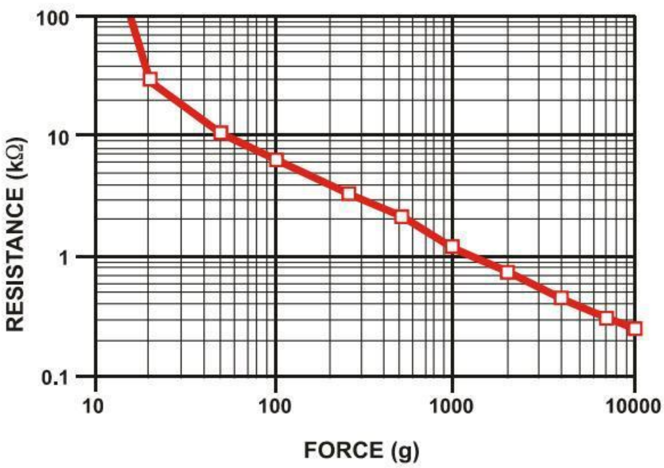
Part Ⅴ Parametric Phase

1. Sensor Data Sheets

Input	Process of sensor	Output
Voltage: 5V Current:1A	→ Force sensor →	Voltage: 15V Current doesn't has much change. Output→1

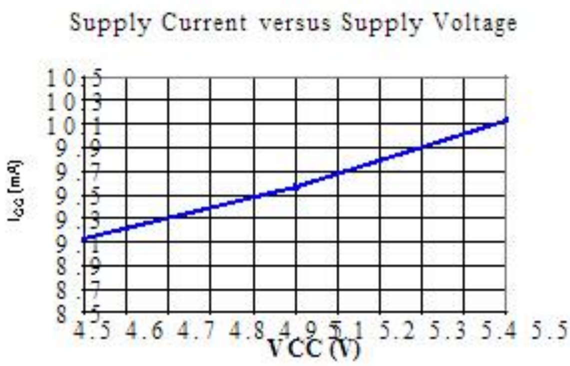
Force sensor

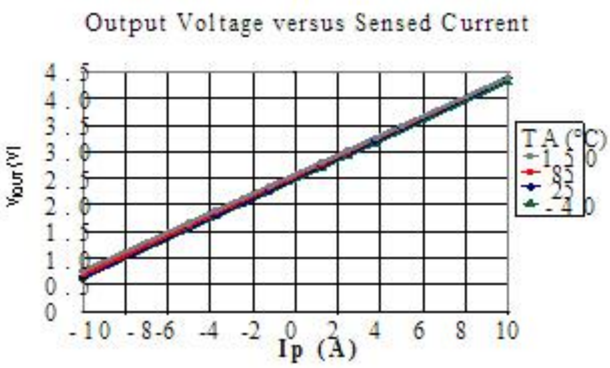
If the force changes, the resistance value will change. And then by a corresponding change in resistance of the measuring circuit is converted to an electrical signal (voltage or current), thereby completing the external force is converted into an electric signal process.

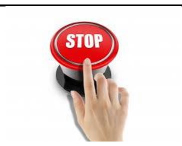
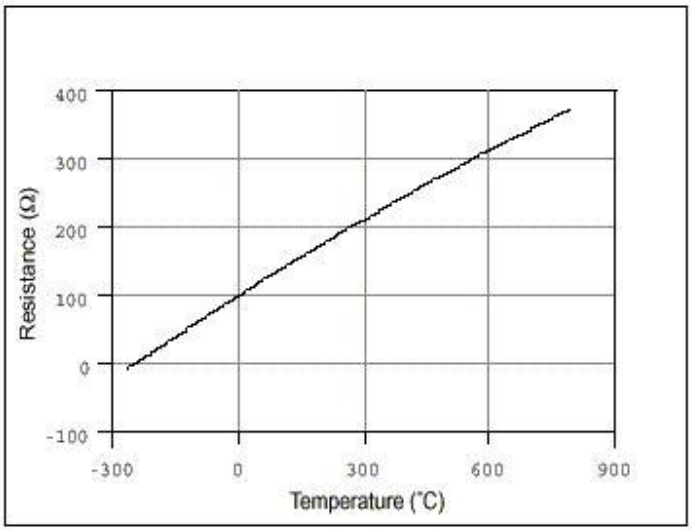


Force (lb)	Force (N)	FSR Resistance	(FSR + R) ohm	Current thru FSR+R	Voltage across R
None	None	Infinite	Infinite!	0 mA	0V
0.04 lb	0.2 N	30 Kohm	40 Kohm	0.13 mA	1.3 V
0.22 lb	1 N	6 Kohm	16 Kohm	0.31 mA	3.1 V
2.2 lb	10 N	1 Kohm	11 Kohm	0.45 mA	4.5 V
22 lb	100 N	250 ohm	10.25 Kohm	0.49 mA	4.9 V

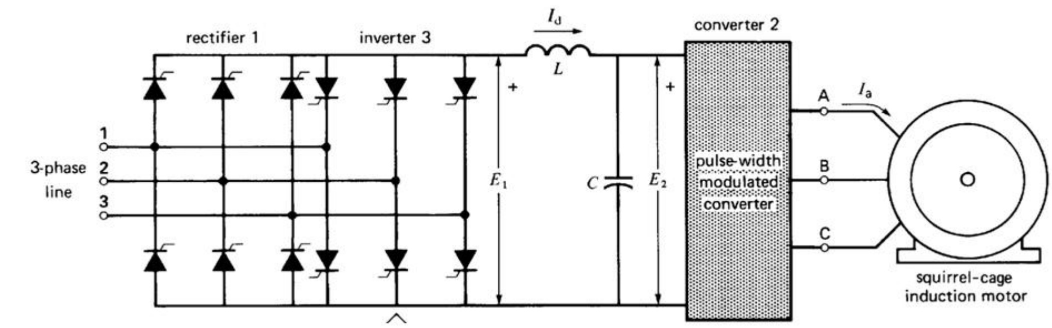
<table>
<tr>
<td>Voltage: 7-15vdc
Current: 120mA
Speed: 6,000 rpm</td>
<td>
optical speed sensor
The optical speed sensor detects the rpm of the motor. The principle is when the motor is rotating, the grating makes the laser becomes intermitted light, then the reflection of the lights through the circuit’s amplifier becomes square wave, then we can get the speed of the motor. We pick the electrical signal of the speed, when the speed is 0, it means the motor is stuck.</td>
<td>Voltage: Analogue 0-4v dc
Current: 120mA
Speed <=1000rpm
Output→1</td>
</tr>
<tr>
<td>Voltage: 4.5 V ~ 5.5 V
Current:9.3mA</td>
<td>

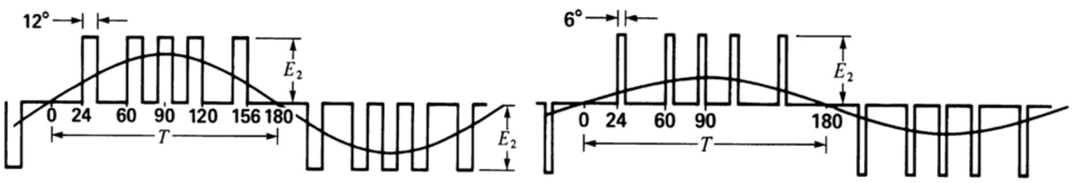
Current sensor
Through the current sensor, we can detect the current flows through the motor. When the motor is running properly, the current will varies in a standard range. If the current suddenly becomes very high, it means something is stuck in the motor. If the current suddenly becomes very low, it means the substrate is broken.



</td>
<td>Voltage: 4.5 V ~ 5.5 VV
Current : 66---185 mA
Output→1</td>
</tr>
</table>

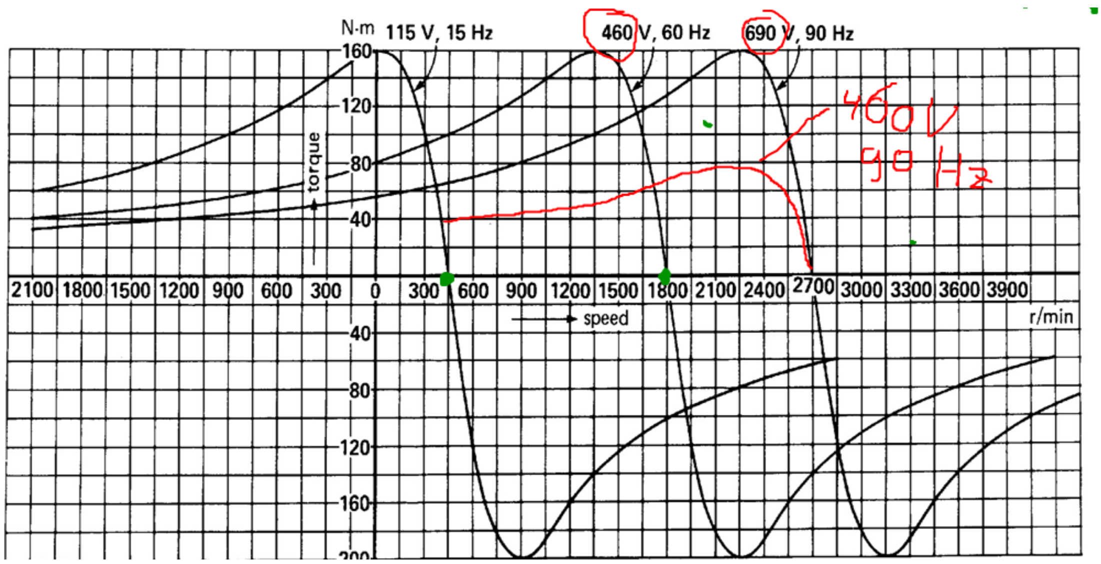
<table>
<tr>
<td>Crews press the stop button when bad environment or the work condition is coming.</td>
<td>
crew's input</td>
<td>Output→1</td>
</tr>
<tr>
<td>Voltage: 18V—32Vdc
Current: 250mA</td>
<td>
PT100
When the PT100 is at 0℃, its resistance is at 100 ohms. And its resistance grows at a constant speed approximately as the temperature rises. But the relationship between them is not a simple direct ratio , but more should be close to a parabola.
</td>
<td>Voltage: 0—10 V
Current : 4—20mA
Output→1</td>
</tr>
</table>

2. Motor Control [2]





We learned from our EI course from HZ, we can control our induction motor by frequency converter or PWM converter. The theory is to change the frequency or bandwidth of the input voltage, and through control the voltage to control the speed of the rotating speed.



From this picture we can see that when we increase the frequency, the frequency goes from 60HZ to 90HZ, the speed increases from 1800 n/min to 2700 n/min, vice versa.
We can use this method to control the speed of motor.

For our design, all three motors in the system are controlled together, means they will speed up, slow down or stop together. This will avoid errors if two motors are in different speed, the substrate between them will become too loose or too tight.

2 .Ir. L.J.M. Janssen. (2015). Electronic control of AC Motors CH. 23 PPT of EI course in HZ University of Applied Sciences

Part Ⅵ Testing Phase

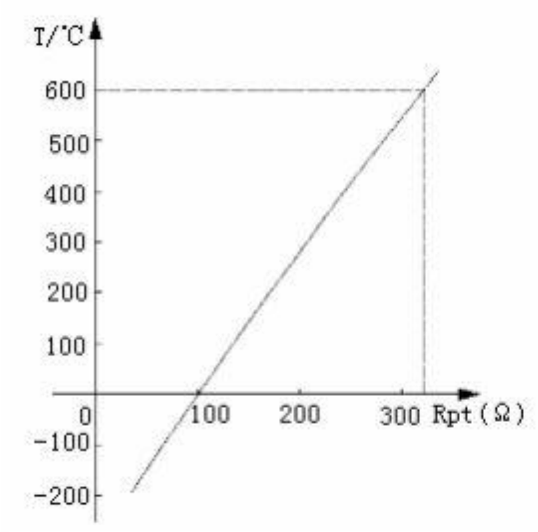
We choose PT100 as our testing sensor to show that we can get a signal from the sensor and through our software programming, we can get a output signal which can be used to make a reaction.

1. Research about PT100

Characteristics of Pt100

Platinum resistance, a very fine platinum wire, is made around a mica stent. Its diameter is from Φ0.03mm to Φ0.07 mm. Because the physical and chemical properties of platinum resistance, even at a high temperature, are very stable in oxidizing media, it has high accuracy, good stability and reliable performance characteristics. Therefore platinum resistance range from -200 to 650 ℃ are widely used, for instance PT100, PT500, Pt1000, etc. The relationship of resistance - temperature has a very good linearity. The relationship curve of resistance - temperature at -200 ~ 650 ℃is already very close to a straight line.

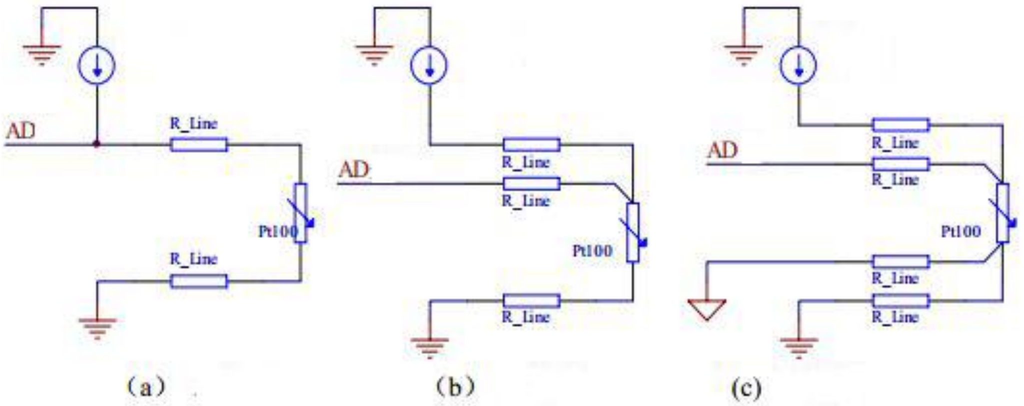
Pt100 temperature measurement principle



There are two ways to measure the temperature by PT100:

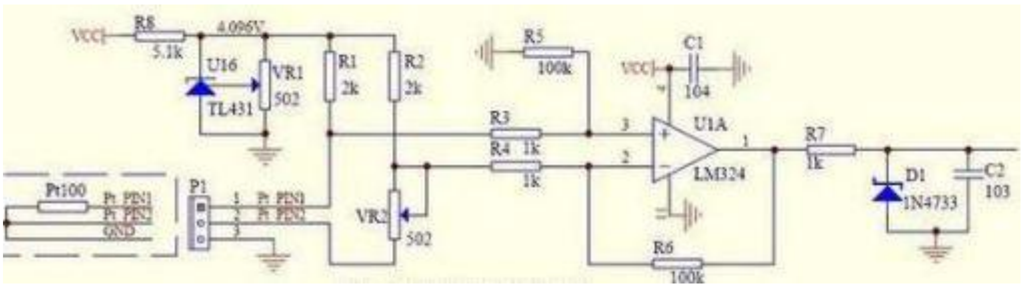
1. Design a constant-current source through Pt100, and detect changes in voltage through PT100 then convert it to the temperature.

In general, there are three connections, are two-wire connection, three-wire connection and four-wire connection:

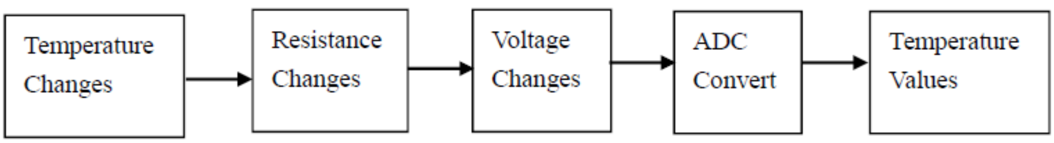


a. Two-wire connection: Figure (a) shows, this connection does not consider the resistance wire Pt100 cable, the positive output end A / D sampling ends together with a current source, because of this connection without considering temperature cable resistance, so it is only suitable for temperature measurement of short distance occasions.
b. Three-wire connection: Figure (b) shows, this connection add an A / D sampling compensation line. Three-wire connection eliminates measurement errors caused by connecting wire resistance, this connection suitable for temperature measurement of medium distance occasions.
c. Four-wire connection: Figure (c) shows, this connection is not only increasing the A / D sampling compensation line, also added an A / D line on the ground of compensation, such reductions may be taking a step forward small measurement error, can be used for temperature measurement of long distance occasions. If you only consider the accuracy, four-wire connection works best.

2. The use of the Wheatstone bridge [3], four resistors bridge three is constant, the other with Pt100 RTD. Pt100 resistance value changes when the test ends to generate a potential difference, which convert the electrical potential difference to temperature.



The only difference between the two programs is that the different circuits to get a signal, they have the same principle:

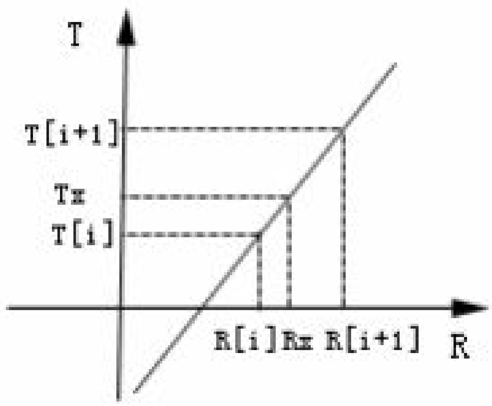


Non-linearity correction by interpolation algorithm for Pt100

First, establish a resistance - temperature indexing table (you can ask the vendor) on the chip ROM area.

	0℃	-10℃	-15℃	-20℃	-30℃	-40℃	-50℃	-60℃	-70℃	-80℃	-85℃	-90℃	-95℃	-100℃
-100℃	60.26	56.19	54.15	52.11	48	43.88	39.72	35.54	31.34	27.1	24.97	22.83	20.68	18.52
0℃	100	96.09	94.12	92.16	88.22	84.27	80.31	76.33	72.33	68.33	66.31	64.3	62.28	60.26
	0℃	10℃	15℃	20℃	30℃	40℃	50℃	60℃	70℃	80℃	85℃	90℃	95℃	100℃
0℃	100	103.9	105.85	107.79	111.67	115.54	119.4	123.24	127.08	130.9	132.8	134.71	136.61	138.51
100℃	138.51	142.29	144.18	146.07	149.83	153.58	157.33	161.05	164.77	168.48	170.33	172.17	174.02	175.86
200℃	175.86	179.53	181.36	183.19	186.84	190.47	194.1	197.71	201.31	204.9	206.7	208.48	210.27	212.05
300℃	212.05	215.61	217.38	219.15	222.68	226.21	229.72	233.21	236.7	240.18	241.91	243.64	245.37	247.09
400℃	247.09	250.53	252.25	253.96	257.38	260.78	264.18	267.56	270.93	274.29	275.97	277.64	279.31	280.98
500℃	280.98	284.3	285.96	287.62	290.92	294.21	297.49	300.75	304.01	307.25	308.87	310.49	312.1	313.71
600℃	313.71	316.92	318.52	320.12	323.3	326.48	329.64	332.79	335.93	339.06	340.62	342.18	343.73	345.28
700℃	345.28	348.38	349.92	351.46	354.53	357.59	360.64	363.67	366.7	369.71	371.21	372.71	374.21	375.7
800℃	375.7	378.68	380.17	381.65	384.6	387.55	390.48							

In the range of -200 ~ 650 ℃ calibrated Pt100 resistance value every 5 ℃ , as a total of 171 index points, respectively denoted by R [i], the corresponding temperature recorded as T [i], I get from 0 to 170.



Compared if R[i] <Rx<R [i+1]，then calculate the Tx.

$$Tx=T[i]+\frac{Rx-R[i]}{R[i+1]-R[i]}(T[i+1]-T[i])$$

Because T[i+1]- T[i]=5
So,

$$Tx=T[i]+5\cdot\frac{Rx-R[i]}{R[i+1]-R[i]}$$

2. Test of working principle

To test the working principle of the system we set up a test with a PT100 sensor and an arduino Uno microcontroller. The aim of this test was to show and test if a sensor could be read and an appropriate control signal could be send. As output of this test we used an LED controlled trough a PWM signal. This is the same signal that would be send to an engine H-bridge and thus serves well to show and test the working of the system.

For this test we used:

- an Arduino Uno microcontroller
- a 3 wire PT100 temperature sensor
- a LED
- two 330Ω resistors
- one 10kΩ resistor
- electric jumper cables
- Arduino – USB connector
- a windows PC

The setup

The setup for this test is as follows, the PT100 is connected to Gnd and 5V over a voltage divider made with two parallel 330Ω resistors. The input signal is read over the analog input on the arduino, these inputs are equipped with a ADC that ranges 0-5V to 0-1024. The output signal comes from a digital output equipped with a DAC that ranges from 0 to 255, over this output a Pulse With Modulated signal is send to a LED, connected to Gnd and 5V over a 10kΩ resistor.

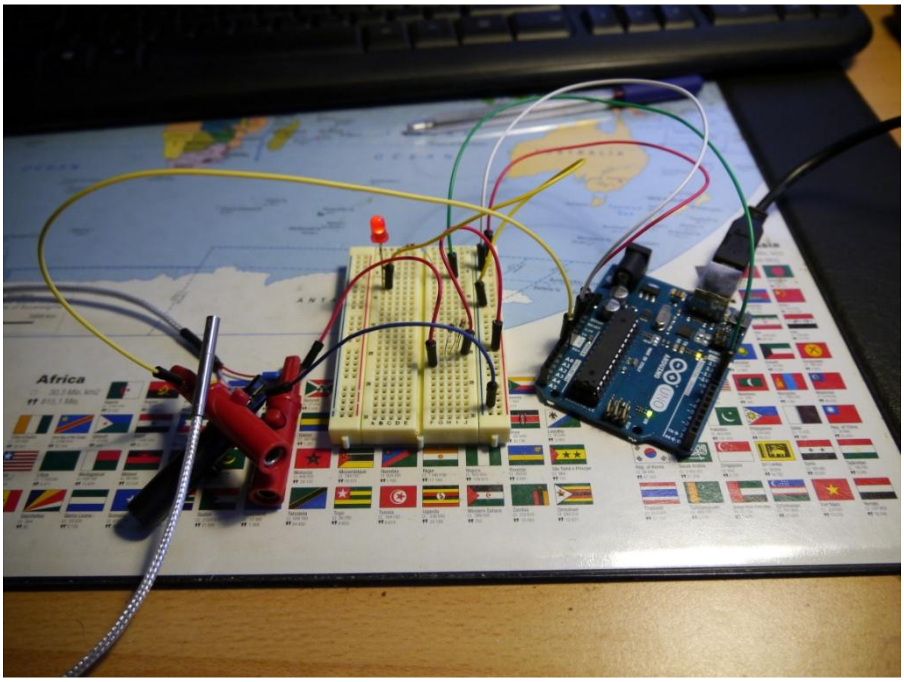


Fig6.3.1 Test device

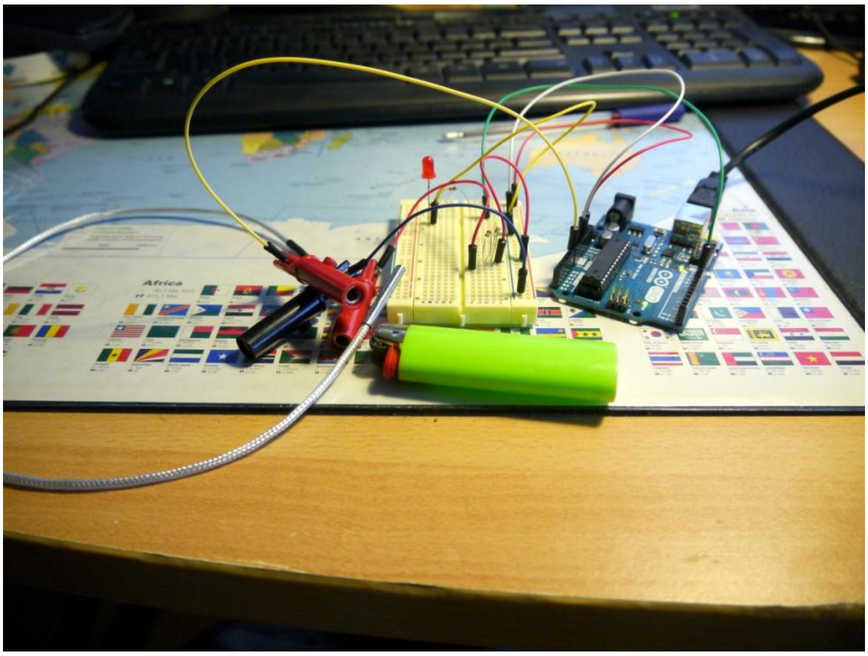


Fig6.3.1 Test device after heating

The code

The code was written in C++ and adapted to the arduino environment. It shows a clear example of the running average arrays that where mentioned for the digital system design.

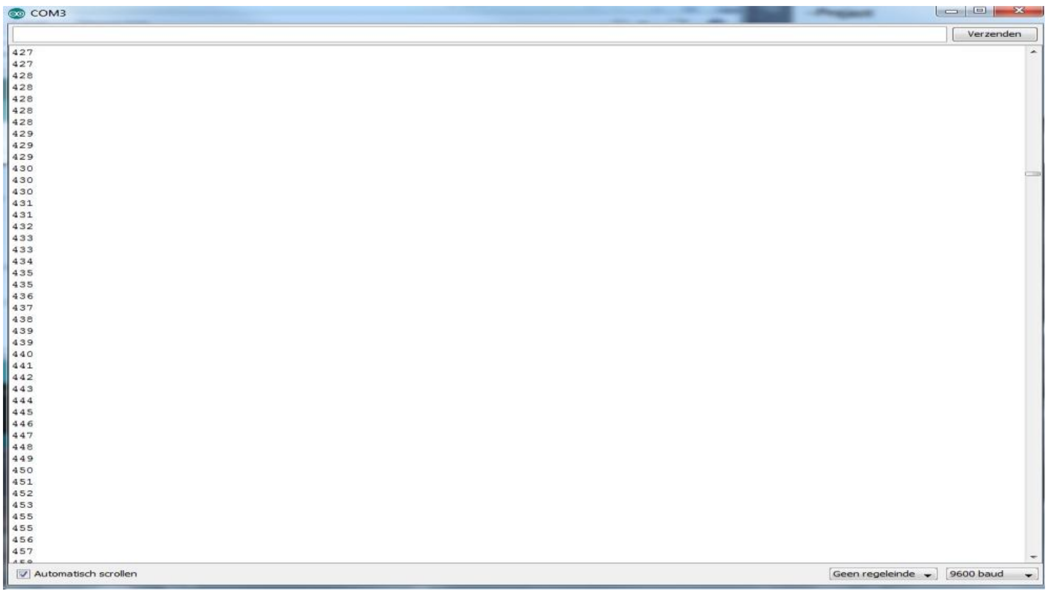
```
const int numReadings = 10;          //the size of the array
int readings[numReadings];           // the readings from the analog input
int readIndex = 0;                   // the index of the current reading
int total = 0;                       // the running total
int average = 0;                     // the average
int inputPin = A0;                   //declaration of I/O
int motorPin = 9;
void setup(){
   Serial.begin(9600);               //initiation of communication protocol to PC
   for (int thisReading = 0; thisReading < numReadings; thisReading++)
      readings[thisReading] = 0;
}


void loop(){
total= total - readings[readIndex];                    // subtract the last reading
readings[readIndex] = analogRead(inputPin);        // read from the sensor
```

```
total= total + readings[readIndex];          // add the reading to the total
readIndex = readIndex + 1;                   // advance to the next position in the array
if (readIndex >= numReadings)                // if we're at the end of the array...
readIndex = 0;                               // ...wrap around to the beginning
average = total / numReadings;               // calculate the average
Serial.println(average);                     //send measurement to PC
delay(100);                                  //delay for stability
   if(average > 450){                        //check for error
      analogWrite(motorPin, 0);              //take appropriate action
     }
   else{
      analogWrite(motorPin, 255);
   }
}
```

The results

This code reads the sensory input in a value that ranges from 0 to 1024, based on that data it compares it to the arbitrary number of 450 (about equal to 40-50 deg C, ideal for a test with a match and a surrounding temperature of ~20 deg C). If the input remain under 450, no error was detected and the LED remains lit. If the value goes over 450 however an error will be detected and the LED will turn off. For debugging reasons and insight into the test every average calculated will also be send back to the PC.

This code can be used for a multitude of sensors, however based on the sensor datasheet the physical setup might need to be changed or the comparing value needs to be adjusted to the new input.



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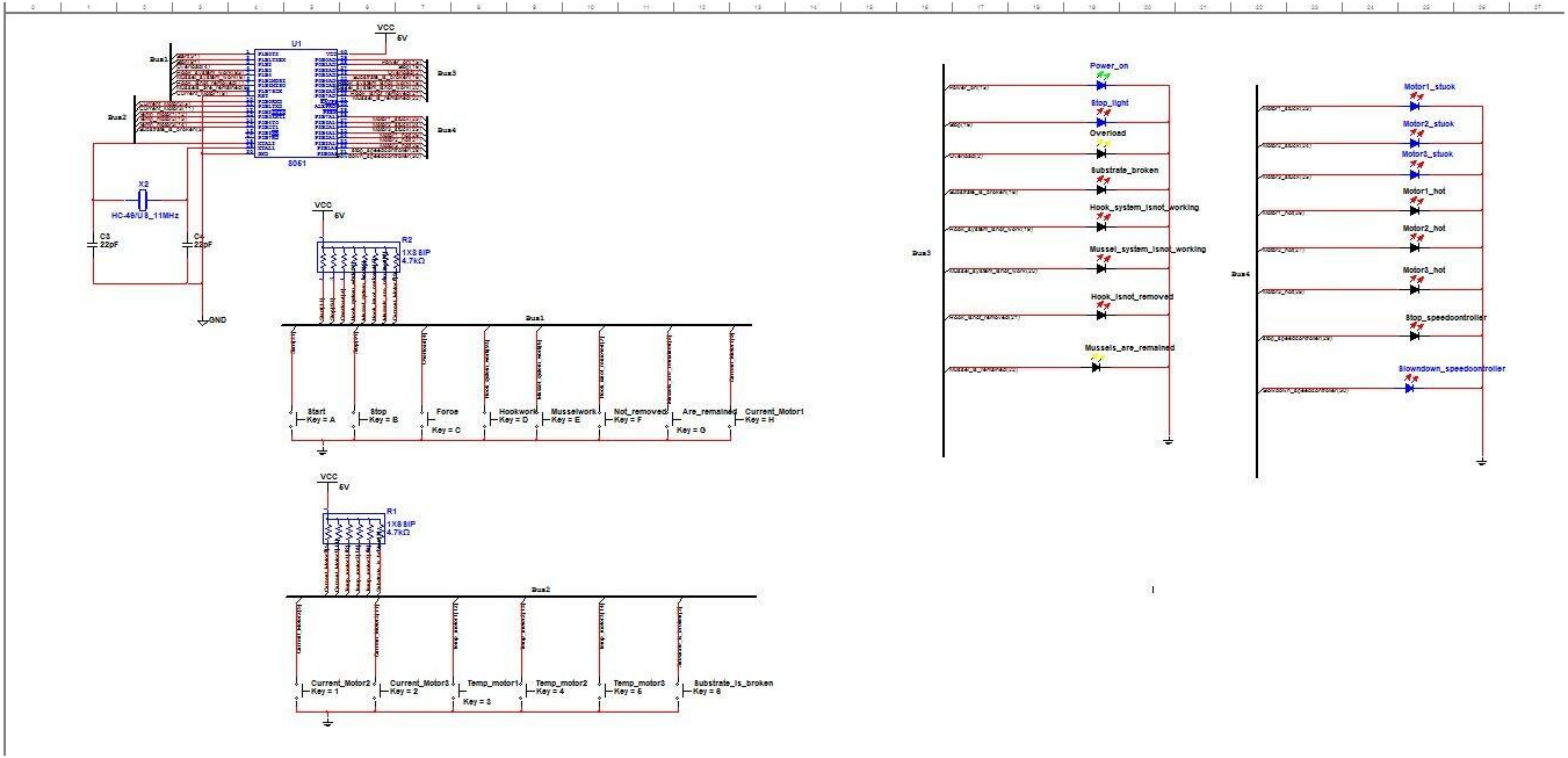
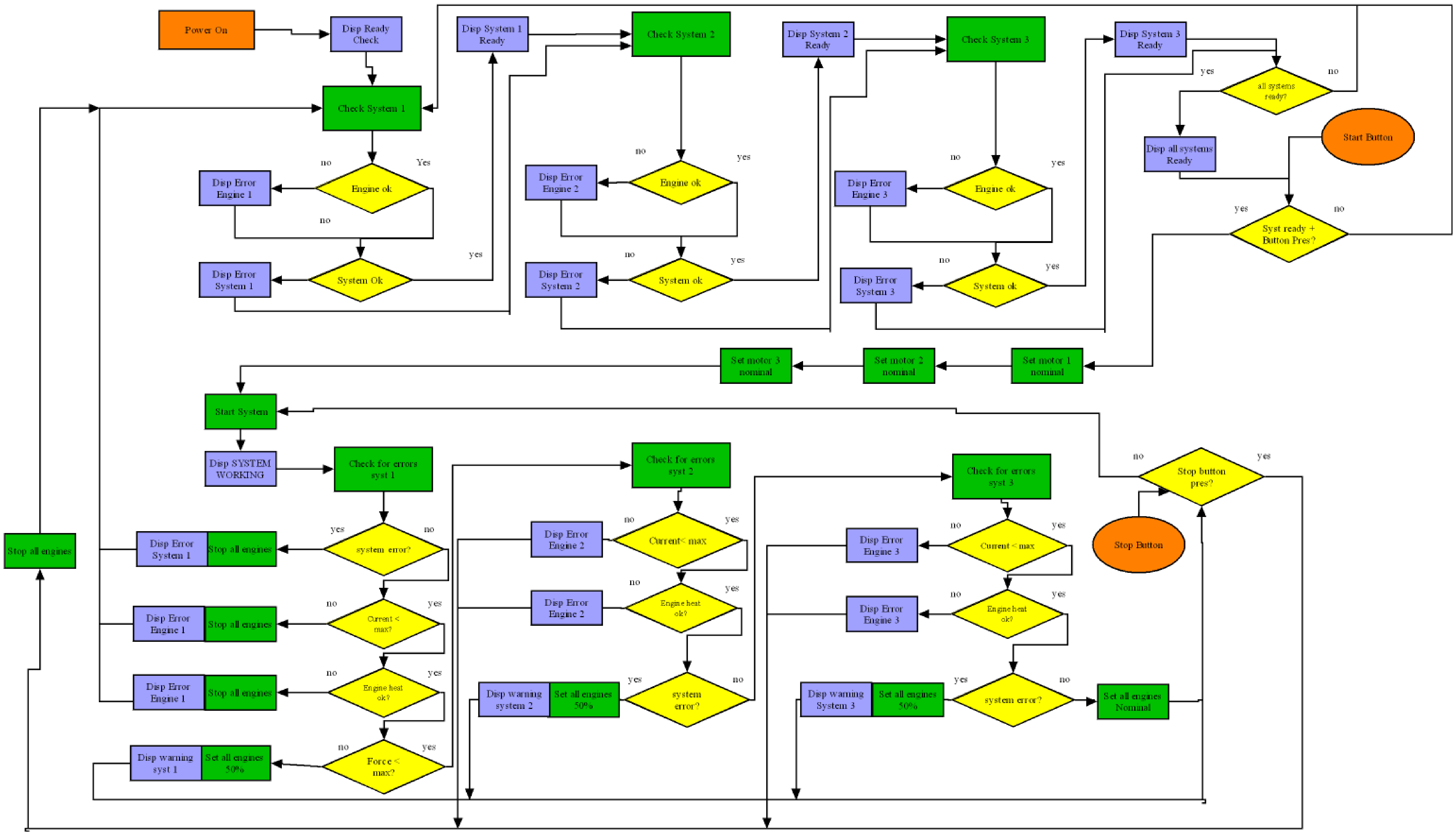
Appendix 1

Software system



Appendix 2

Hardware system



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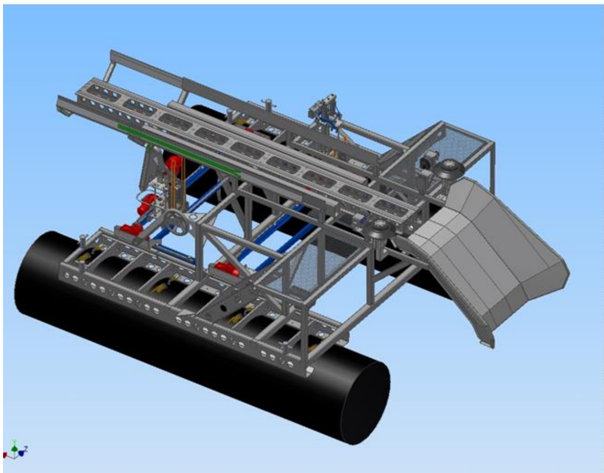


Europees Visserijfonds:
Investering in duurzame visserij

Ministerie van Economische Zaken

Jansen Tholen B.V.

Provincie Zeeland

HZ UNIVERSITY OF APPLIED SCIENCES

[2015]

PROJECT—JET PUMP

M. van Sighem, X. Wang, B. Li

Vlissingen, 5 June 2015

Title: Final report

Subtitle: Design of a jet pump

Authors: M. van Sighem, X. Wang, B. Li

Study program: Engineering - Minor R&D

School: HZ University of applied science

Teacher: J.C.W. Haak

Semester: 2 - 2014/2015

Vlissingen, June 2015

Table of content

1 Preface

1.1 Abstract

Jansen Tholen has already developed a jet pump for sucking the falling mussels when harvesting mussels. The purpose of this research is to find more jet pump's dimensions which can fit different ships and work most efficiently (suck most and fastest) for Jansen Tholen. The research mainly uses Solidworks Simulation to solve this problem. Relationship between the real test and the simulation has been made by comparing the difference and find rules between them applying company's 2nd test data. Finally the result is made from the addition of difference and simulation result. The best results are chosen and reorganized in to a new table, which offers the user best solution of parameters of the jet pump for different types of pump. That's the design product we deliver in the end.

1.2 Summary

This report is a document which shows the whole process of solving the problems from client Jansen Tholen from February 2015 to May 2015 this semester.

The client Jansen Tholen want to design a jet pump which can suck in both mussels and dropping mussels when harvest the mussel from sea. Now the company only has one simple model to do test on a ship. The problem is that the company needs different pumps to meet the requirements for different ships, and optimize the gap length, pipe angle or diameter of pipe to get the best efficiency.

There are 7 chapters in this report as well as bibliography and appendix. The first chapter Preface gives overview for the whole project. The next two chapters Introduction and Theoretical Framework state the problems of the project and analysis the theory structure to solve the project. Next the Method phase, the main thoughts and the productions in each phase are introduced in this chapter. As for the Results chapter, all the detailed products or documents are listed in this chapter according to the phases mentioned in Eggert method (Rudolph.J.Eggert, 2004). Later on in the Conclusion phase we write a conclusion for the whole project which gives the result, the problems and some reflection on the report. As for the Practice phase, we relate our results with the practice, analysis the real use of our project as well as the insufficient parts.

As for the method, the project uses EGGERT method to finish the task, and some phases have been slightly changed according to the assignment itself. There are 5 phases in the project: Formulation phase, concept phase, configuration phase, parametric phase and detailed design phase. Every phase has a set of products/documents/solutions that need to be delivered.

You can see everything mentioned above detailed in our report.

2 Introduction

2.1 Problem background

Jansen Tholen is now developing a new kind of jet pump model to harvest the mussels meanwhile sucking the dropping mussels into the ship. As is common knowledge, the mussel seeds grow on the ropes hanging in the sea. When the mussels are harvested from the sea, many mussels may drop from the rope (also referred as substrate) and sink to the sea. This would cause much loss. So the jet pump is designed to suck those dropping mussels as much as possible, and push the mussels back to the ship (J.C.W.Haak, 2014).

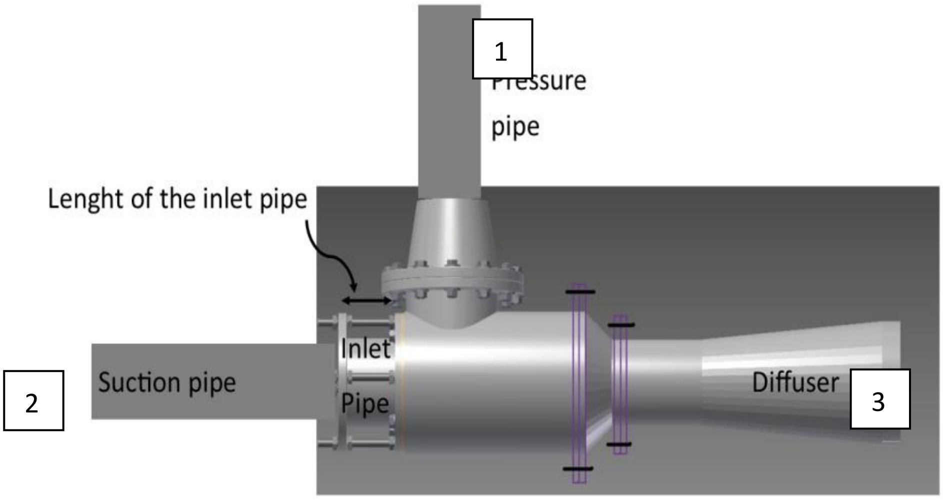


Figure 2.1 Jansen Tholen's initial jet pump model

Figure 2.1 shows the jet pump model the company has for now. The jet pump has three main parts. The first part on the top of the jet pump is the pressure pipe is connected with the pump on the ship, for pumping the water from the pump to jet pump; the second part on the left is the suction pipe, it is used for sucking in the ropes with mussels, when the mussels drops from the rope in the suction pipe, the pressure difference will force the mussels being sucked into the pipe; the third part on the right (the diffuser part) is for pushing the rope with mussels and dropping mussels out.

To judge whether a jet pump works efficiently or not depends on the sucking speed it has. If a jet pump suck faster, it will gain higher efficiency.

2.2 Problem statement

From now on Jansen Tholen has already designed a jet pump and done the first test on the ship, finding that placing the jet pump under the water is the most efficient situation. The problem is that this jet pump can only fit client's ship and the pump on it, which means that this product can't be widely used and has a great limitation on promotion in the market. Thus the client wants to design jet pumps with different parameters which can fit different kinds of pumps and ships and work with high efficiency as well. Parameters of a jet pump refers to the gap length(③,figure2.2), diameter of inlet pipe(⑤,figure2.2) , diameter of the pressure pipe(①,figure2.2) and discharge head(②,figure2.2) .

For the reason that from now on it is impossible to find these parameters by calculation directly, the objective of this project is to find the a way to get the best solutions of jet pump's parameters for different types of pumps, fit them well and work with the highest efficiency under the situation that placing the jet pump under the water. Finally organize all the best solutions in a table (Appendix G) for the clients.

Main question:
What are the best parameters of the jet pump that can fit different types of pumps as well as work with the highest efficiency?

Research questions:

- What are the crucial parameters for different pumps?
- What is the maximum pressure and speed can a pipe withstands?
- What is the maximum speed of water flow a pipe can withstand?
- How to judge the jet pump is sucking the water or not?
- What is the minimum speed in the outlet pipe which can push the mussels back to the ship successfully?
- How the nozzle shape(⑦,figure2.2) will influence the water flow in pipe?
- How the gap length(③,figure2.2) will influence the water flow in pipe?
- How the outlet pipe angle(④,figure2.2) will influence the water flow in pipe?
- What's the influence of different combination of parameters to the water flow?
- What's the difference between the flow simulation and the real test?
- If the gap length(③,figure2.2) is too small, will the water have bad effect back to the pump?

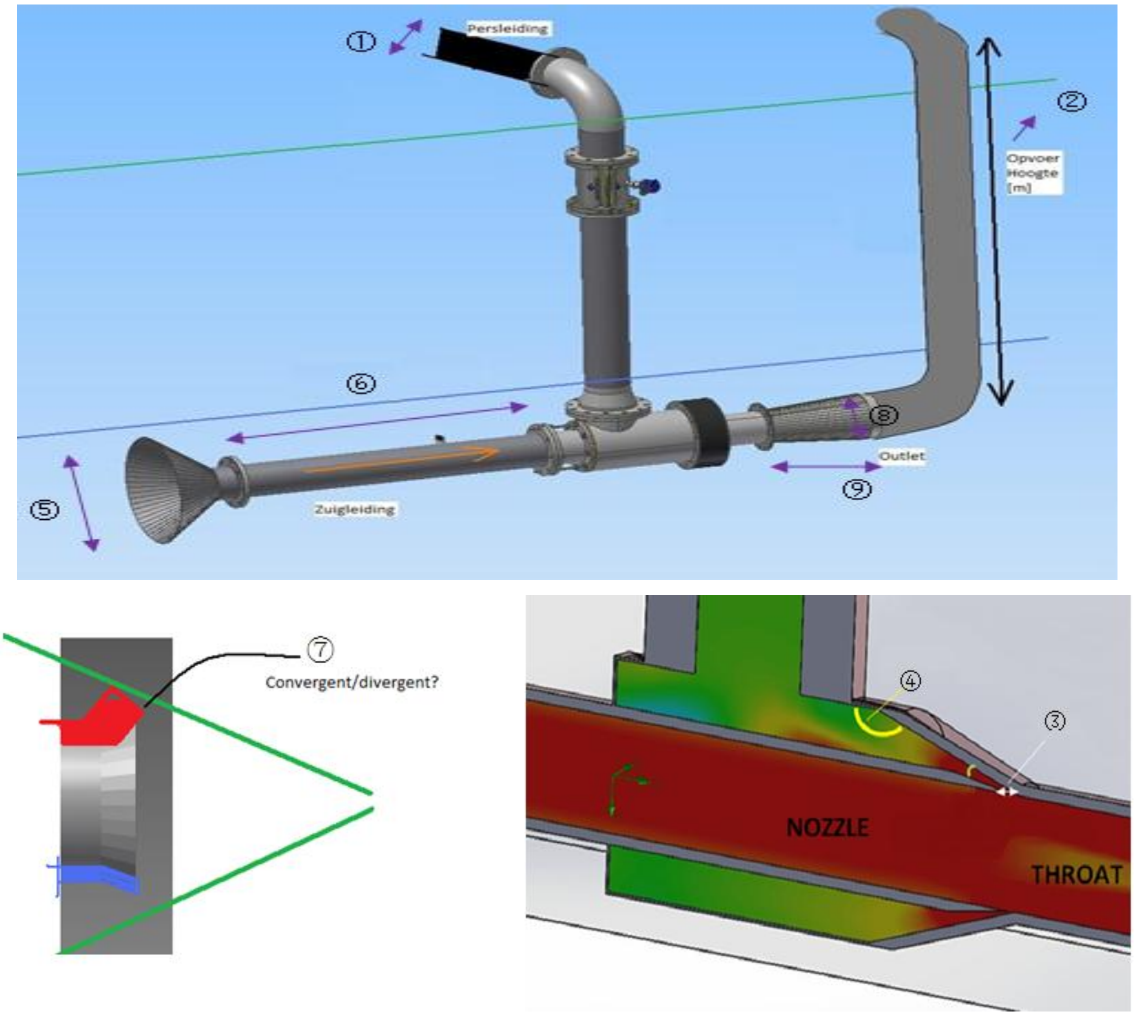

Persleiding
Opvoer
Hoogte
[m]
Zuigleiding
Outlet
Convergent/divergent?
NOZZLE
THROAT

Figure 2.2

3 Theoretical framework

After defining the problem and make the research questions for the whole project, we need to find ways to answer the research questions. For the research questions are build in professional field, their solutions need to be underpinned with existing knowledge which can be found in some reliable scientific literature, such as published books, research report on this field or formulas which can be used to do calculation. The literature we use will be stated later in the report.

For this project the most relevant knowledge is Hydrodynamics, which is the key concept of the problem statement. This is because the project is mainly about the parameters of the jet pump and their influence to water flow. In order to know how the water flow works and how it can be influenced, we found that it is mainly discussed in the subject of Hydrodynamics.

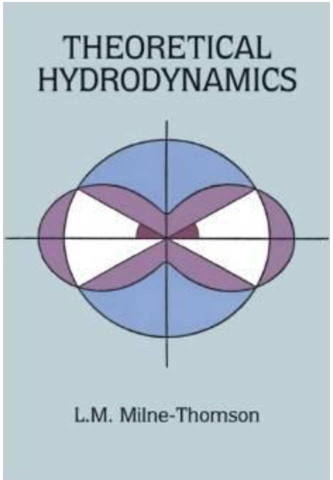


Figure.2.3 Theoretical Hydrodynamics

To get some preliminary understanding on Hydrodynamics, we choose a book called ‘Theoretical Hydrodynamics (Dover Books on Physics)(Figure 2.3) for learning. (L.M.Milne-Thomson, 1996)

In order to understand the project well, company’s 1st report (Bogerd, 2015)is the best choice. Because jet pump is a special designed product so it is important to analyze it to get an overview of it. For the client plan to do the 2nd test, the 2nd test report (Bogerd, Testplan praktijk test 2, 2015) which would be produced in March is also an important research source for our project. These sources are all reliable and scientific to our project.

For this project is aimed to provide a table of parameters of the jet pump a lot of calculation and simulation is indispensable. For the calculation we’ll look into the book ‘Theoretical Hydrodynamics (Dover Books on Physics)’ mentioned above as well as seek them on the internet. And for simulation, we’ll find suitable engineering software to do it through the internet.

The theoretical framework in detail including the analysis for the company’s 1st test, choice of engineering software, some answers to the research question which can be solved directly and the solving plan to the research questions are showed in **Chapter 5.1.1 Theoretical Framework.**

4 Method

To start a project, a suitable method is indispensable. For this project the Eggert design method is chosen, because compare to the Delft design method, this method is more suitable for the project and is more familiar to us. Eggert, in essence, will examine procedures and methods that can provide us with a framework for effective, logical decision making and a guideline for engineering design.
Each phase has his own important actions and milestones to achieve, which is lead by answering the research questions step by step.
There are 5 phases in all according to the Eggert design method (Figure 2.4), and each phase has his own important actions and milestones to achieve, which is lead by answering the research questions step by step. For the reason that this project is mainly aim to design a table of parameters for the each design phases in detail: jet pump, it is not a design project in the conventional sense. Structure in some phases will be adjusted a little. Underneath describes

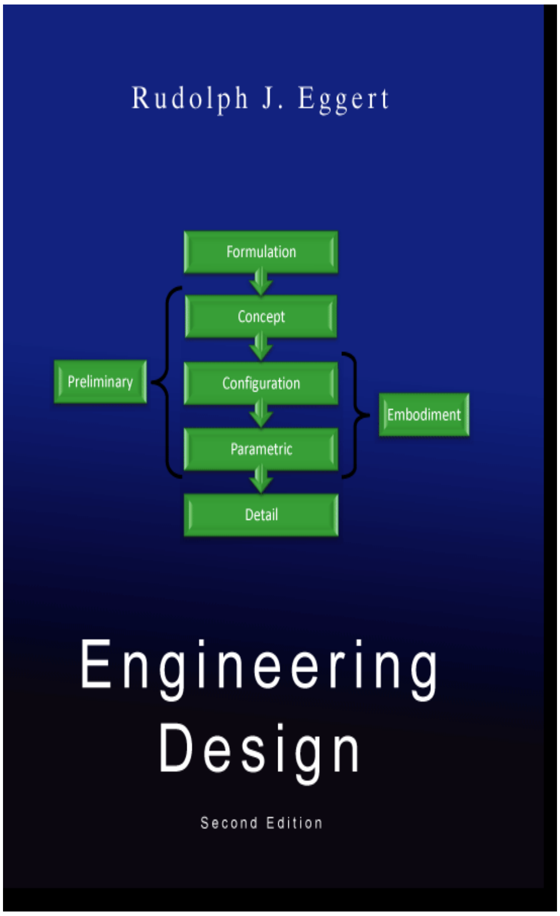


Figure 2.4 Eggert design method

Reason for the Choice of Eggert Method

We choose the Eggert methods for the following reasons:
First of all, the Eggert design method is the method we familiar with most. In all the past projects we all use Eggert method as our design method, so we know it well and can use it deftly. Secondly, comparing to the pressure cooker, the Eggert method is more suitable for our project. This is because although our project is not a normal real product design project, it still needs to design a lot of tables. While the pressure cooker method only includes 3 phase, the orientation phase, the execution phase and the finalization phase. It doesn't includes the process of making concept and designing. So the Eggert method method is more suitable for this project to the pressure cooker method. Last but not least, the delft method is similar to the Eggert design method, the difference is that it contains more

analysis. We don't choose delft design method is for the reason that we haven't known and used it before. It is not wise to choose it when we are not familiar with it, because if we choose the delft method we may make some mistakes and misunderstanding. In one word, Eggert design method is the best choice.

4.1 Formulation phase

Often the initial description of a design problem lacks the type of information necessary for a successful design and manufacturing process. As we become familiar with the problem, we probe deeper into various sources to obtain more details. So in this phase we need to seek information, interpret and gain consensus (Rudolph.J.Eggert, 2004). The theoretical framework for the project will be made, which includes analysis for the 1^{st} test, study for the previous documents, and find out the questions remain. These activities would help to answer some essential research questions in the project like what’s the maximum speed of water flow in a jet pump. Then find a suitable book for the basic theory study on jet pump. Finally made the list of requirements in order to maximize the client’s satisfaction through identifying what important parameters customer needs. This phase will lasts for a week from 22^{nd} to 28^{th} of February.

4.2 Concept phase

Concept design is a phase in the evolution of product when alternative design concepts are generated, evaluated, and selected for further development. A design concept is the abstract of a physical principle, material, and geometry (Rudolph.J.Eggert, 2004). In this phase a function tree for the jet pump will be made. This diagram would help us to identify whether functions are connected, and where the interface connections might be. After that a initial final table and one-variable study table will be design, which are the initial idea of what will be deliver in the end and the progress to understanding how the jet pump work and how each parameters will influence the water flow in the jet pump. This is also the first step and concept to find the answer for the research questions about the influences of one-variable. This phase will lasts for a week from 1st to 7th of March.

4.3 Configuration phase

Configuration phase is generally used for determining one or more feasible concepts for the parts that go into product (Rudolph.J.Eggert, 2004). For the reason that this project is not a normal product design but a best table of parameters, structure of this phase will be adjusted. We will optimize the final table and the one-variable table instead of choosing the best concept which is normally done in this phase. This is because the initial table is just a concept but not in detail. This project needs the accuracy, if the table we designed is not reasonable, it will influence the whole project and the following effort might be futile actions. Also during this phase the comparison table for the 2nd test would be design so as to find the difference between the real test and the flow simulation on computer. This phase will lasts for a week from 8th to 14th of March.

4.4 Parametric phase

What makes parametric design special and particularly challenging is that we will employ analytical and experimental methods to predict and evaluate the behavior of each of the design candidates to make these decisions (Rudolph.J.Eggert, 2004). For the specialization of our project, in this phase we will do a lot of calculation for the jet pump, as well as learning how to do the flow simulation in Solidworks. The calculation includes efficiency calculation, through flow surface calculation, minimum pumping back speed for mussel and boundary conditions for pressure used in flow simulation. These calculations would give a great help in completing the tables in next phase, which are the base of the next phase. This phase will lasts for 3 weeks from 15th of March to 4th of April.

4.5 Detail Designed phase

Detail design phase is used for completing the remaining decisions, resulting in comprehensive product specifications, drawings, manufacturing specifications, performance tests, and bills of materials (Rudolph.J.Eggert, 2004). During this phase the simulation for all the tables would be done by flow simulation and some calculation in Solidworks, including one-variable tables, comparison tables and the final table. After doing each table the analysis would be done, in order to research the influence of each important parameter on jet pump, the difference between the Solidworks Simulation and the influence of the combination of different parameters, which can answer part of the research question. After doing the final table, the best solutions would be chosen. That’s what we’ll deliver to the client in the end. This phase will last for 6 weeks from 4th of April to 23th of May.

5 Results

5.1 Formulation phase

5.1.1 Theoretical framework

5.1.1.1 Previous test analysis

Jansen Tholen had already done some tests on the initial jet pump. The test recorded data the pressure in pressure pipe, the negative pressure in suction pipe (Figure 5.1.1) and whether the jet pump sucks or not. The jet pump was put in 3 different working situations: placing the jet pump on ship (Table 5.1.1), on the quay (Table 5.1.2) and in the water (Table 5.1.3), changing the length of inlet pipe and gap (Figure 5.1.1). (Bogerd, Test resultaten jet pump, 2015) The results recorded in 1st report are showed below.

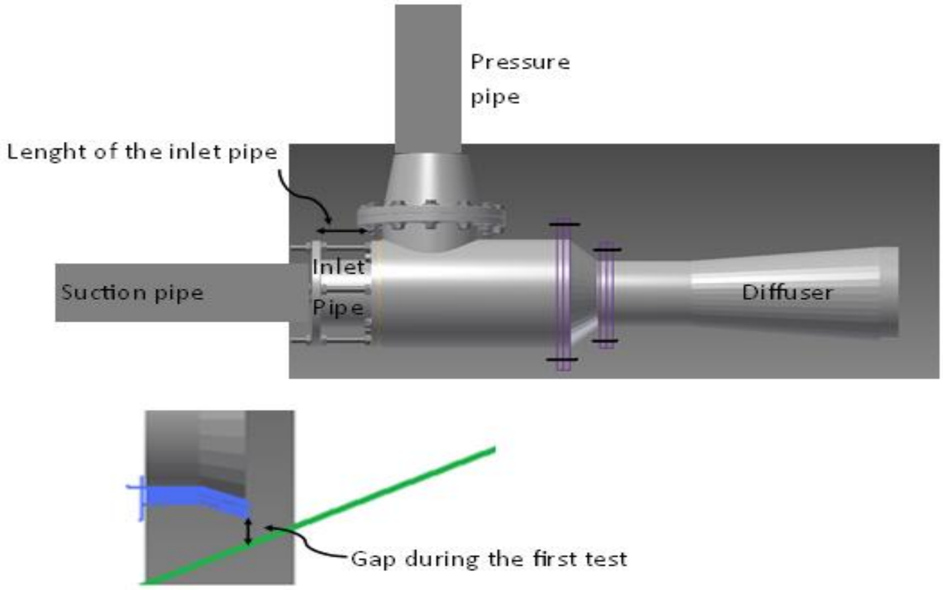
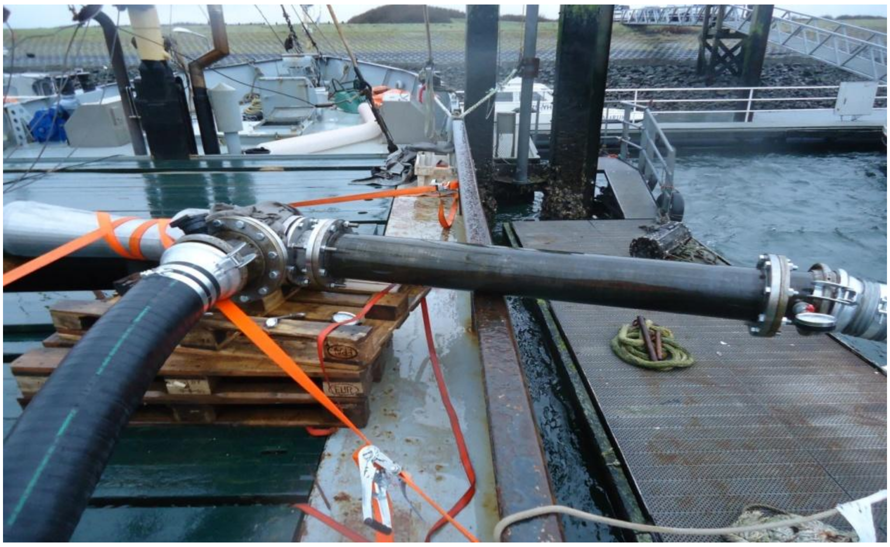


Figure 5.1.1 Initial jet pump



Test nr.:	Turning speed of the pump [RPM]	Length of the inlet [mm]	Gap [mm]	Pressure in pressure pipe [Bar]	Negative pressure in Suction pipe [bar]	Suction
1	1700	65	20	1	0.2	
2	1700	70	25	0.5	0	None
3	1700	60	15	1.2	0	None
4	1700	55	10	1.4	0	None
5	1700	50	5	1.8	0.1	
6	1700	100	55	0	0.05	
7	1700	47.5	2.5	2.2	0.2 / 0.3	Good suction

Table 5.1.1 - The jet pump is on the ship

Conclusions:

As we can see from the table, when the distance between the flanges is 47.5 [mm], the through-hole is 2.5 [mm]. Here we see that the pressure in pressure pipe sharp rise to 2.2 [bar]. The negative pressure in suction pipe is between 0.2 and 0.3 [bar].The jet pump works well and has a good suction.

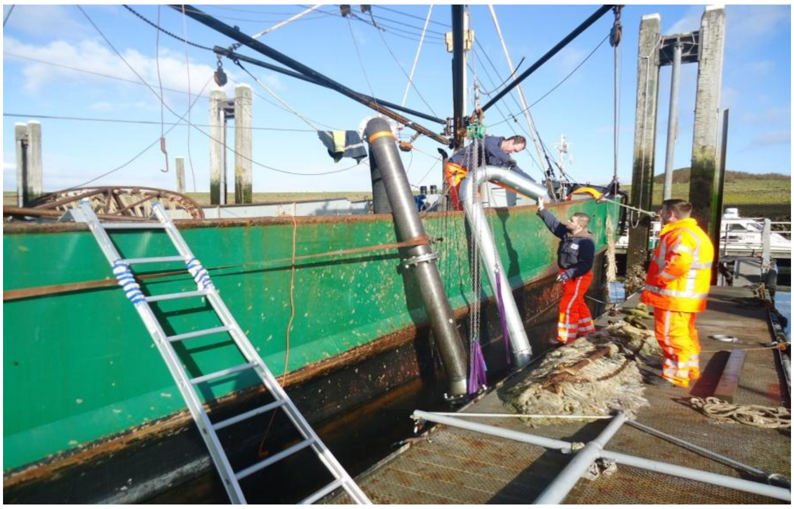
Test nr.:	Turning speed of the pump [RPM]	Length of the inlet [mm]	Gap [mm]	Pressure in pressure pipe [Bar]	Negative pressure in Suction pipe [bar]	Suction
1	1700	115	15	1	0	None
2	1700	105	5	1.9	-0.1	
3	1700	102	2	2.2	-0.15	Good suction

Table 5.1.2 - The jet pump is on the quay

Conclusions:

From the table we know, when the distance between the flanges is 102 [mm], the gap is 2 [mm], the pressure in pressure pipe is 2.2 [bar].It works well and have good suction.

But as the 1st saying, there is something wrong with the jet pump, so only three sets of data are available in this test.



Test nr.:	Turning speed of the pump [RPM]	Length of the inlet [mm]	Gap [mm]	Pressure in pressure pipe [Bar]	Negative pressure in Suction pipe [bar]	Suction
1	1700	80	4	2.2	-	Nearly none
2	1700	85	9	2	-	Good suction
3	1700	87	11	2.2	-	Good suction
4	1700	90	14	1.9	-	Good suction
5	1700	93	17	1.9	-	Good suction
6	1700	95	19	1.9	-	Good suction
7	1700	100	24	1	-	None

Table 5.1.3 - The Jet pump is in the water

Conclusions:

As we can see from the table, when the jet pump is put in the water, it works well in most tests.

The line in green means the jet pump works in best efficiency.

We guess that putting the jet pump in the water maybe the best choice than the other two conditions.

Changes in further test

After the 1st test, the company got conclusions from the results and found out disadvantages of the initial pump. They will change the jet pump as written in the 1st report:

1) In order to increase the suction, the angle of the pump will be change from +-42.5 degree (red line) to +-20 degree (blue line). (Figure 5.1.2)

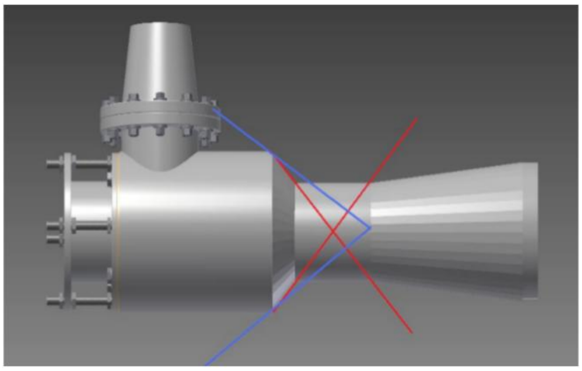


Figure 5.1.2 Further change on outside pipe angle

2) This part (Green line) will be made more fluent. (Figure 5.1.3)

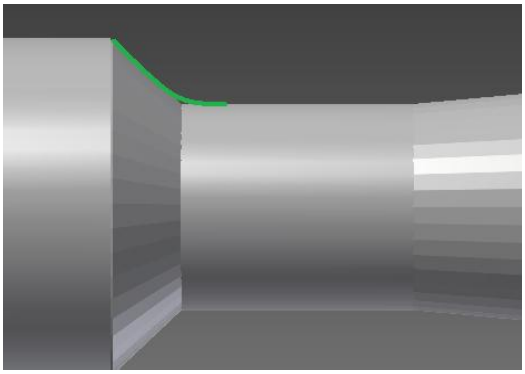


Figure 5.1.3 Further change on radian of outside pipe

3) Shape of the nozzle will be change (from blue part to red part).(Figure 5.1.4)

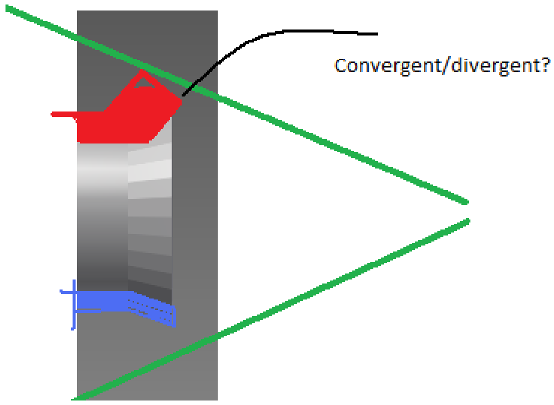


Figure 5.1.4 Further change on radian of outside pipe

Reflection on the 1st test

As mentioned in the problem statement, solutions need to be found to solve questions such as how the throw flow surface influence the water flow in pipe. We get from the 1st test that how the gap length influences the suction of the jet pump. The test results also show that working in the water is the best choice. Meanwhile the test results provide with reference value of pressure in the pressure pipe which have good suction ability.

But here are still some questions we didn't get any test evidence:

1) Whether the mussels and water can be sucked fluently from pipe to ship has not been test.
2) Whether the pressure for successful sucking will damage the mussel or not has not been tested.
3) Whether there would be any bad influence on the efficiency of pump when gap is too small has not been tested and researched.

5.1.1.2 Engineering Software

The 1st report gives us some guidance for the project, but we still need more tools and methods to solve every sub questions.

1) Solidworks.

   This is one of the main software we use during the project. And Solidworks flow simulation is the main package we use in Solidworks. Here's a brief introduction for Solidworks flow simulation from the Internet:

   Efficiently simulate fluid flow, heat transfer, and fluid forces critical to your design's success with SOLIDWORKS Flow Simulation. Driven by engineering goals, SOLIDWORKS Flow Simulation takes the complexity out of computational fluid dynamics (CFD) and enables Product Engineers to use CFD insights for making their technical decisions in a concurrent engineering approach. (Solidworks Simulation)

   So the flow simulation is used to simulate the fluid flow in jet pump and get theoretical values from the model. Further analysis and process are based on the data we get from simulation.

2) MathCAD.

MathCAD is useful engineering calculation software. Here is a brief introduction of MathCAD from official website:

MathCAD is math software that allows you to solve, analyze and share your most vital engineering calculations. Presented within an easy-to-use interface, its live mathematical notation, units intelligence, and powerful calculation capabilities allows engineers and design teams to capture and communicate their critical design and engineering knowledge (PTC Mathcad).

We choose MathCAD to do calculation such as prediction, fitted line calculation in the final phase. The software can show our calculation ideas clearly and reduce the mistakes as much as possible.

3) Physical theory on speed calculation and pressure calculation.

Not only is the engineering software vital for our project, but also the physical theory. There are many values need to be calculated out in the jet pump. For example, if we want to verify whether the speed is enough to pump the mussels back to the ship, what necessary is that we need to know the minimum speed at the bottom of discharge head. Knowledge about force analysis and speed calculation is essential to solve the problem.

5.1.1.3 Relevant theory about the project

- **What are the crucial parameters for different pumps?**

The most important parameter for a pump is its rotating speed, which unit is RPM (revolutions per minute), but this parameter cannot be used in flow simulation. Also the loss caused by the pressure pipe is unknown and changes in different situation. So the parameters volume and pressure at pressure pipe part (see the measure point in (Figure 5.1.5) of a jet pump is used to classify different pumps.

- **What is the maximum pressure a pipe can withstand?**

It depends on which standard is chosen. In the European standard describe the max pressure as PN-class. A pipe DN200 PN16 is a pipe with nominal diameter of 200 and pressure class till 16 bar. From the company's 2nd test we could see that the pressure measured in the pipe is no more than 2 bar under all situations (Bogerd, Testplan praktijk test 2, 2015), and the diameter of the pressure pipe in the 2nd test is about 8 inch. For 2 bar is far away from 16 bar, so it can be easy to know that normally the pipe of the jet pump can stand the pressure from the water flow under the condition of real test. Also when attending the 2nd test the staff said that if the pressure in the pressure pipe being so high, the pressure pipe has the probability to disjoint with the jet pump. In conclusion, the pressure in anywhere of the jet pump should not be over 2 bar for insurance purpose.

- **What is the maximum speed of water flow a pipe can withstand?**

Client has test that the maximum velocity in a pipe should be about 3m/s, which means the velocity of any point in the jet pump should not be over 3m/s.

- **How to judge the jet pump is suck or not?**
  As is mentioned in the project background, the jet pump's sucking is result from the difference of the pressure in inlet pipe and the environment pressure (Figure 5.1.5). When the pressure in the inlet pump is lower than the outside environment pressure, the jet pump can suck successfully. Later on the calculation for the environment pressure will be done by applying the knowledge about pressure.

- **What is the minimum speed in the outlet pipe which can push the mussels back to the ship successfully?**
  The minimum speed in the outlet pipe should be 1.5m/s that can successfully push the mussels back to the ship. This data is done by calculation, the progress in detail is described in Chapter 5.4.2.3 Minimum pumping back speed.

- **How the nozzle shape will influence the water flow in pipe?**
  To solve this problem needs a lot of simulation tests to find the common rule. So a set of one variable tables are the best choice. It will be design, complete and analyze later.

- **How the throw flow surface will influence the water flow in pipe?**
  To solve this problem needs a lot of simulation tests to find the common rule. So a set of one variable tables are the best choice. It will be design, complete and analyze later.

- **How the outlet pipe angle will influence the water flow in pipe?**
  To solve this problem needs a lot of simulation tests to find the common rule. So a set of one variable tables are the best choice. It will be design, complete and analyze later.

- **What's the influence of different combination of parameters to the water flow?**
  This question is similar to what company requires in the end. It will be solved by design a final table which would be deliver to the end in the end, then complete the table and analyze it in order to get a conclusion from it.

- **What's the difference between the flow simulation and the real test?**
  To compare the difference between the flow simulation and the real test, the plan is to design a comparison table and then apply the 2^{nd} test's data on the company's jet pump model in simulation and compare the results between them. Finally analyze the table and get the conclusion.

- **If the gap is too small, will the water have bad effect back to the pump?**
  The answer to this research question cannot be getting directly. So the solution for this question is to find how the velocity in the pressure pipe will change. If the velocity in the pressure decreases when the gap length is too small, it shows that the water will have a bad effect back to the pump. Because it is common knowledge that the velocity gets faster with the decrease of the gap length, if the velocity decrease , it means the water flow get stuck

and will probably back to the pump, which must influence the working efficiency of the pump.

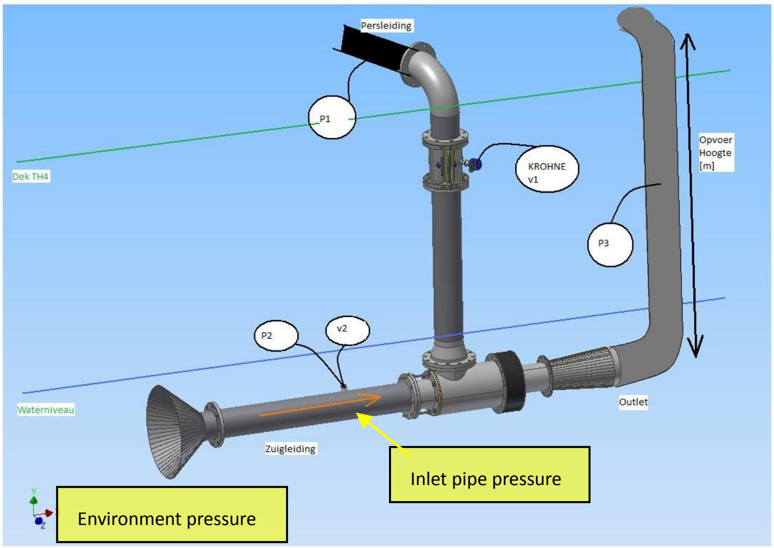


Figure 5.1.5.Parameters of the jet pump

5.1.2 List of requirements

To get a better result and make the jet pump work in a safe and efficient condition, the jet pumps as well as the jet pump need to meet some requirements.

1. As the recorded data and analysis in company 1st test (Chapter 5.1.2.1 Previous test analysis), we can see that it get a good efficiency when the jet pump working in the water, so jet pump should be put in the sea.
2. The function of the jet pump is sucking the mussels in. So the pressure in the pipe should be lower than the pressure in water, which can press the mussels in the pipe by pressure drop.
3. The jet pump should pump the mussels back to the ship rely on the water power and pressure, therefore the speed of water should be high enough to pump the mussels back, meanwhile the pressure in the pipe need to be higher than the atmospheric pressure. The calculation of water speed is showed in Chapter 5.4.2.3 Minimum pumping back speed.
4. The efficiency and safety are both important when the jet pump working, and of course the parameter design need to fit different ships.
5. The final result of the project is to deliver the design for different ships. Therefore the results need to be clear and well stated for the client.

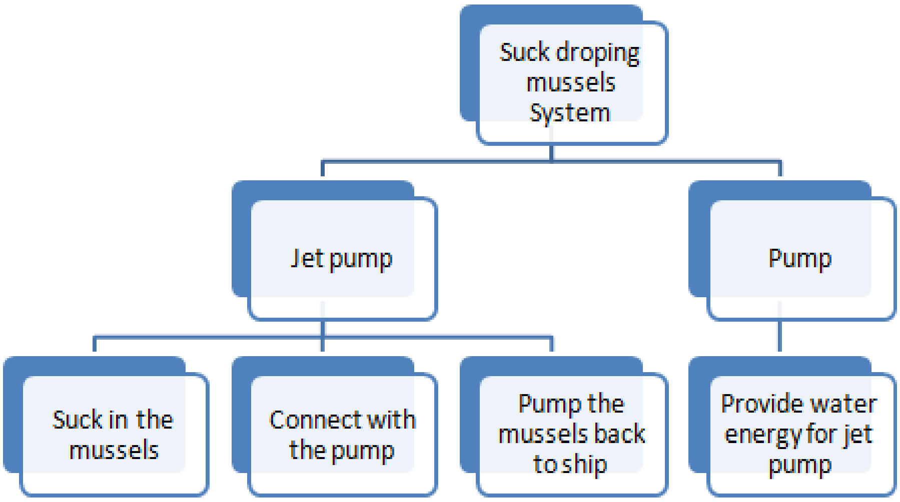
All the requirements mentioned above are stated clearly in the table below.

	List of requirements	Specific standard
Jet Pump	**Working environment**	
	1. The jet pump should be put in an efficient working environment.	The jet pump should put in the sea.
	Technology	
	1. The jet pump should suck in the falling mussels.	The pressure in inlet pipe should be smaller than environment water pressure.
	2. The speed of mussels at discharge head should be enough to pump back the ship.	The speed of mussels should be at least 1.5m/s
	3. Pressure of the outlet should be big enough to ensure most of the mussels can be suck up to the ship.	More than 1.013 bar.
	4. The jet pump needs to work in good efficiency	Compared with different conditions and choose the most efficiency ones
	5. The jet pump will not be damaged or disjointed under all working conditions.	The maximum pressure of every point in the pipe should not be over 2 bar.
	6. The jet pump should fit in different clients' pump	All the parameters of different pump such as diameter of pipe, pressure, flow rate are required to consider.
Results	**Production**	
	1. Our results should be easily understood by company and client.	State clearly by word or excel or other standard former to state clearly.
	2. The results need to be reliable.	The analysis and prediction need to based on theory and realistic.
	3. The results should be applicable.	The result table should be useful in further design and manufactory.
	4. The result should be visible not only words.	Use Solidworks to set up 3D model

5.1.3 Function tree

When developing a new product it is necessary to work on a higher abstract level to make the project more clear and exhaustive. To do this is we have to divide product in higher abstraction level: functions. All functions which must be fulfilled have to be listed in this product function tree.

For the final product we'll deliver is the table of parameters for the jet pump, the parameters we give must realize the functions below: sucking the mussel, connecting the pump and pulling the mussel up to the ship.



5.2 Concept phase

5.2.1 Initial final table

In this phase we design the initial final table which can deliver parameters of the jet pump for different common pump. But it's only a simple structure of what we want to deliver finally because we hadn't got all the information from company at that time. Therefore it's not the most suitable one.

The main idea of the initial final table is dividing the parameters to fixed values and changing values. Changing values means the results we can get from the simulation. The improved final table will be displayed in **5.3.1 Optimized final table**. Here is the initial final table (Table 5.2.1). The specific positions of the items are marked in Figure 5.2.1.

Green column: fixed value
White column: changing value

	Pump				Jet Pump							Ship
		①			②	③	⑤	④	⑥	⑦	⑧	⑨	
	Turning speed of pump [RPM]	Diameter of pipe [inch]	Volume [m3/h]	Speed [m/s]	Discharge Head [m]	Gap Length [mm]	Diameter of inlet pipe [mm]	Angle of outside pump	Length of inlet pipe [m]	Angle of nozzle [degree]	Diameter of diffuser [mm]	Length of diffuser [mm]	Height of ship's deck [m]
1													
2													
3													
4													
5													
6													

Table 5.2.1 Initial final table

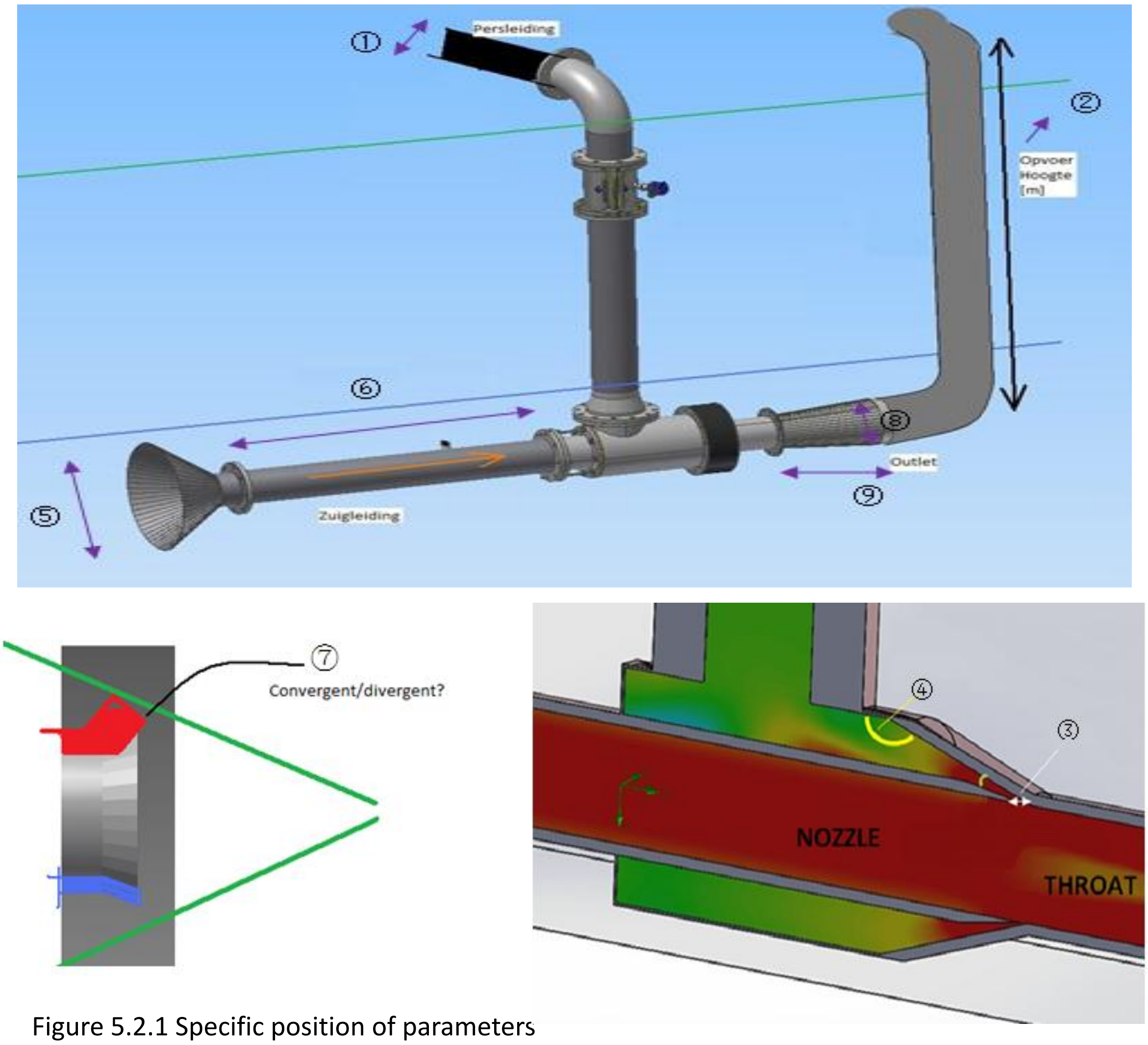


Figure 5.2.1 Specific position of parameters

5.2.2 Initial one variable analysis table

As stated in former report, studying the influence of one variable is part of our sub questions. So we design tables to do one variable study. That is to say, we keep only one variable in each test and keep other variables as invariants. We mainly focus on three variables: Gap length, nozzle shape and outside pipe angle. But In this phase, the one variable tables are all initial tables with some preliminary ideas which are not good enough. Later on the tables will be optimized and showed in the **5.3.2 Optimized one variable table.**

Due to these three one variable analysis tables are similar, only one table of nozzle shape is listed below. You can see the all the three in **Appendix A.**

Green column: fixed value
White column: changing value

Part 1: Influence of nozzle shape

To study the influence of nozzle shape, the idea is to set the nozzle shape as the only variable and other parameters to be the fixed inputs. We'll choose the values of one types of company's pump (e.g. the diameter of pipe is 4 inch) to be the fixed inputs for doing the SOLIDWORKS SIMULATION. Table 5.2.2 is the initial one variable table of nozzle shape, the position of parameters is marked in Figure 5.2.2.

	Pump				Jet Pump								Ship
		①			②	③	④	⑤	⑥	⑦	⑧	⑨	
	Turning speed of pump [RPM]	Diameter of pipe [inch]	Volume [m3/h]	Speed [m/s]	Discharge Head [m]	Gap Length [mm]	Angle of outside pump	Diameter of inlet pipe [mm]	Length of inlet pipe [m]	Angle of nozzle [degree]	Diameter of diffuser [mm]	Length of diffuser [mm]	Height of ship's deck [m]
1													
2													
3													
4													

Table 5.2.2 Initial one variable table nozzle shape

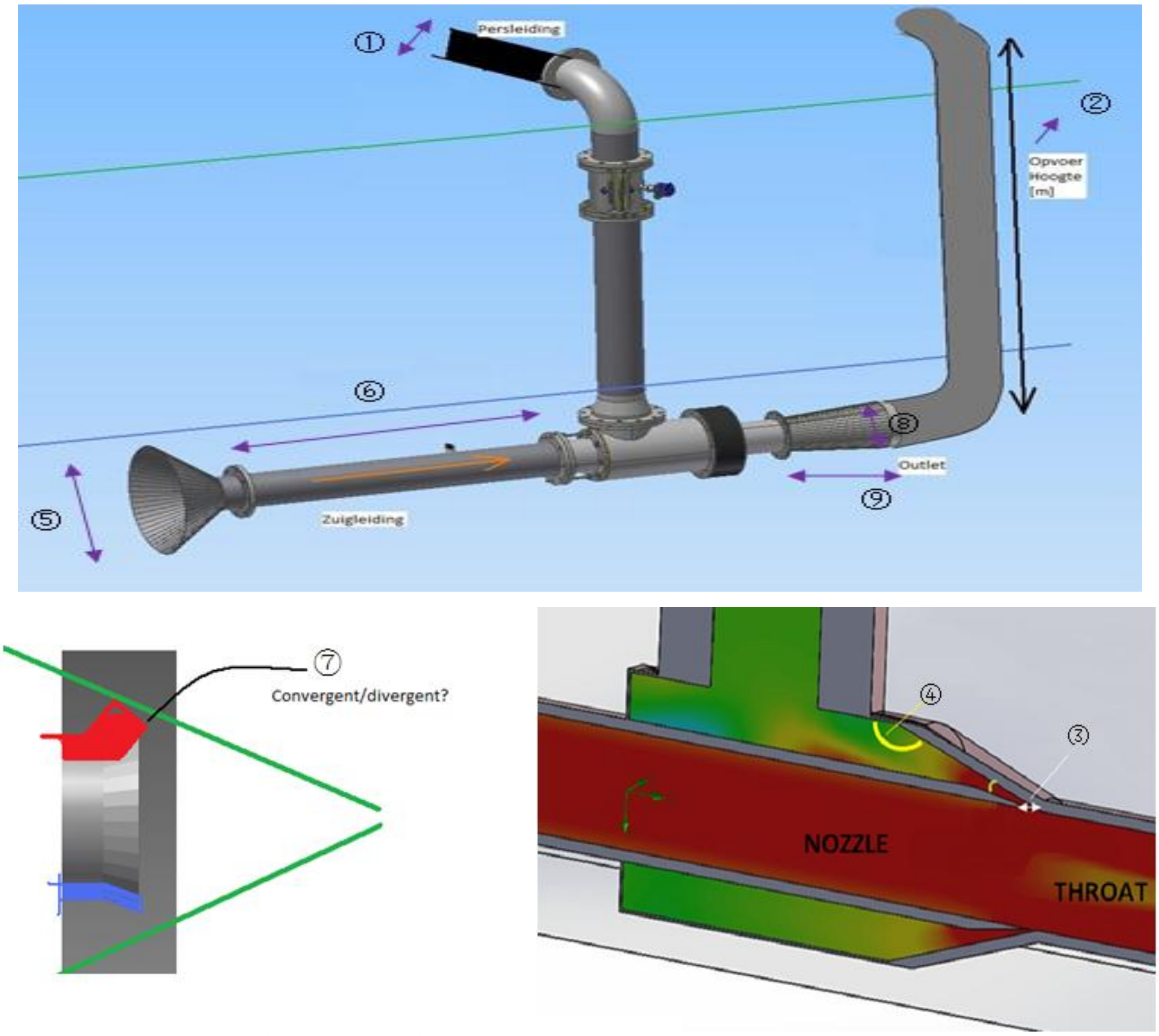


Figure 5.2.2 Specific position of parameters

Part 2: Influence of gap length

To study the influence of gap length, the idea is to set the gap length as the only variable and other parameters to be the fixed inputs. We'll choose the values of one types of company's pump (e.g. the diameter of pipe is 4 inch) to be the fixed inputs for doing the SOLIDWORKS SIMULATION. The specific table is in **Appendix A**.

Part 3: Influence of outlet pipe angle

To study the influence of outlet pipe angle, the idea is to set the outlet pipe angle as the only variable and other parameters to be the fixed inputs. We'll choose the values of one types of company's pump (e.g. the diameter of pipe is 4 inch) to be the fixed inputs for doing the SOLIDWORKS SIMULATION. The specific table is in **Appendix A**.

5.3 Configuration phase

5.3.1 Optimized final table

Introduction

Initial draft final table has already been designed in last phase. However, it is just a rough concept that needs to be optimized， even the input and output haven't been clarified. According to the requirements from company which is showed in Figure 5.3.1, they want to know what is the best adjusting for?***1*** to get the best results for ***?2*** and ***?3*** by a given pressure and flow rate ***A*** and ***B***. Following shows the input, output and idea of the optimized final table in detail. The whole optimized final table is shown in Appendix B.

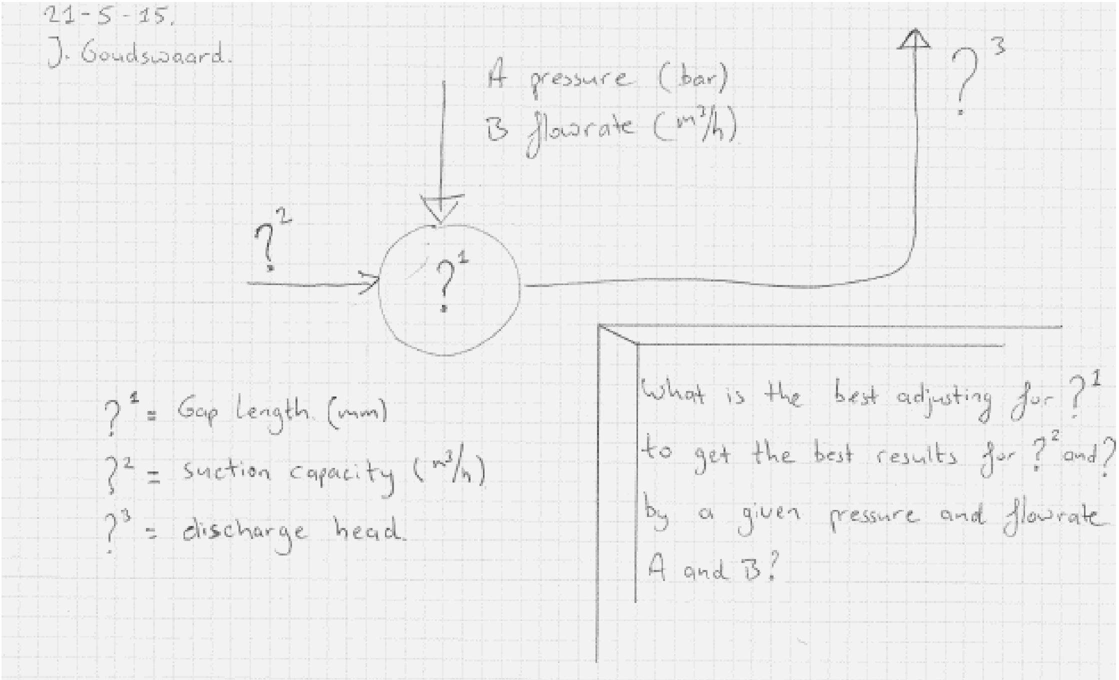


Figure 5.3.1 Company's requirements

Input

The fixed parameter (fix input) of jet pump they gave us before are shown in the following Table 5.3.1:

Angle of outside pump	Length of inlet pipe	Angle of nozzle	Diameter of diffuser	Length of diffuser
[degree]	[m]	[degree]	[mm]	[mm]
148.5	1041.68	12.5	301	550

Table 5.3.1 Fixed parameters

And the client wants to focus on the following parameters:

1) Inlet diameters 8 and 10 inch
2) Pressure Pipe diameters in a range from 4 - 10 inch
3) Throughflow surface
4) Input Flow in m3/h in a range from 200 m3/h - 800m3/h

5) Input pressure in a range from 2 - 6 bar
6) Discharge head in a range from 2 -5 meters

For some of the parameter cannot be used in the simulation directly, they're transformed into the value that can be use in the simulation(Table 5.3.2).

	Name of Parameter	Range of value client want	Simulation input value
1	Inlet diameters	8 and 10 inch	8 inch 10 inch
2	Pressure Pipe diameters	4 - 10 inch	4 inch 8 inch 10 inch
3	Throughflow surface	/	60-140mm(it depends)
4	Input Flow	200 m3/h - 800m3/h	200 m3/h 400 m3/h 800 m3/h
5	Input pressure	2 - 6 bar	as output(P6)
6	Discharge head	2 -5 meters	2 m 3 m 5 m

Table 5.3.2 Transformed parameters

Output

There are 5 outputs in the optimized final table, which are P4, V4, P5, V5 & P6, as shown in the following figure. V4 is used for efficiency calculation; P4 for judging the jet pump is suck or not; V5 for judging whether the mussels can be successfully pumping back to the ship or not; P5 for reference to the client; P6 for representing different pumps. (Figure5.3.2)

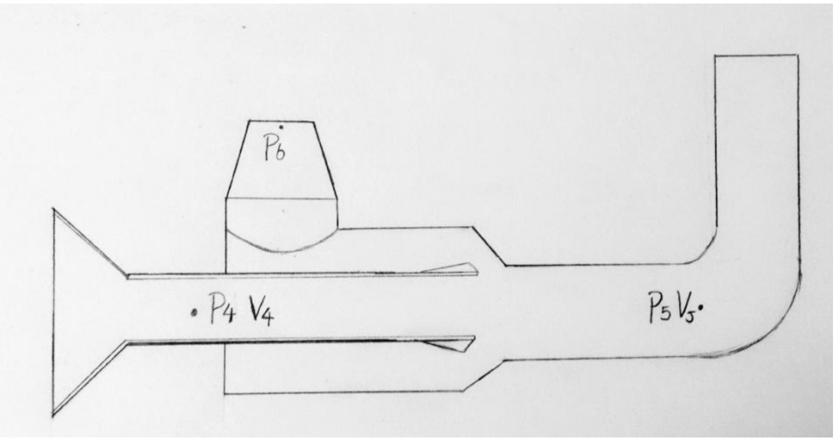


Figure 5.3.2 Outputs in the final table

Idea

Client wants the best solution for the different kinds of pump. For different pumps, volume and pressure are the most important value. However, for Solidworks it is impossible to add the volume and pressure as the boundary condition on one lid, so we can only add one parameter at a time for each lid. So the idea is to

a. Choose volume as the boundary condition for the pressure pipe lid;
b. Adjust other parameters like gap length, diameter of pressure pipe, discharge head, etc. to get the simulation result of V4,P4,V5, P5, P6(Figure5.3.2);
c. Calculate efficiency, the calculation will be done in next phase;
d. Make a the standard to choose the best result;
e. Re-organize the final table, the progress is first pick the P6 and volume from each best result to represent different pumps, and the other parameters like gap length, diameter of pressure pipe, discharge head, etc. are the best solution for different pumps.

Following shows part of the best choice table (Figure 5.3.3):

INPUT(different pump)		FIX INPUT					OUTPUT						REFERENCE				
Volume	P6	Angle of outside pump	Length of inlet pipe	Angle of nozzle	Diameter of diffuser	Length of diffuser	ŸDiameter of pressure pipe	Diameter of inlet pipe	Discharge head	Gap	Throwflow surface	Efficiency	P4	V4	V4(Predict)	P5	V5
[m3/h]	Ÿ [bar]	[degree]	Ÿ [m]	[degree]	[mm]	[mm]	[inch]	Ÿ [inch]		mm	m2	Ÿ [%]	Ÿ [bar]	Ÿ [m/s]	Ÿ [m/s]	Ÿ [bar]	[m/s]
200		148.5	1041.68	12.5	301	550											
400		148.5	1041.68	12.5	301	550											

Figure 5.3.3: Part of best choice table

(The whole optimized final table is shown in Appendix B.)

5.3.2 Optimized one-variable analysis table

The draft one-variable table has been made in the last phase, while its input and outputs hasn't been clarified just like the initial draft final table. So in this phase, the one-variable analysis table has been optimized. As mentioned in the last phase 3 parameters would be analyzed. Following shows the example of the optimized one-variable analysis table about the nozzle shape. Other two one-variable analysis tables are shown in Appendix C.

In order to find out the influence of the nozzle shape, the nozzle angle is used to represent different shapes and kept as the only variable to see how the 5 outputs(V4,P4,V5,P5(figure 5.3.4) & Efficiency) changes.

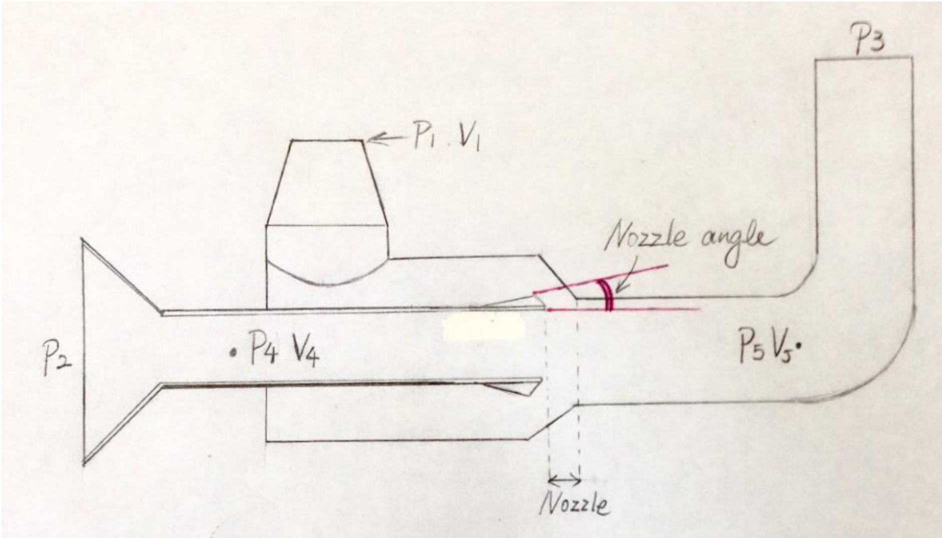


Figure 5.3.4: Parameters in the optimized one-variable table(nozzle shape)

The study is separated in to 2 parts, part 1 is for the nozzle angle above 0 degree, and part 2 is for the nozzle angle below 0 degree. For each part we choose 2 sets of data including V1,P1,P2,P3 and P3 (figure 5.3.4) from the company's 2nd test as the inputs doing 2 tests to ensure the reliability of the conclusion. The data we choose is shown below (Table 5.3.3).

Data set 1:

V1	P1	P2	P3	Nozzle
(m3/h)	(bar)	(bar)	(bar)	(mm)
540	0.6	1.063	1.063	75

Data set 2:

V1	P1	P2	P3	Nozzle
(m3/h)	(bar)	(bar)	(bar)	(mm)
530	0.5	1.063	1.063	113

Table 5.3.3 Data set

Below are the optimized nozzle shape analysis tables (Table 5.3.4):
Yellow row shows the original nozzle shape while the purple row shows the zero condition of the nozzle shape.

Test1.1 .Totally underwater1(only nozzle shape changed+)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	0.6	1.063	1.063	75	0					
540	0.6	1.063	1.063	75	2.92					
540	0.6	1.063	1.063	75	4.92					
540	0.6	1.063	1.063	75	6.92					
540	0.6	1.063	1.063	75	8.92					
540	0.6	1.063	1.063	75	10.92					
540	0.6	1.063	1.063	75	12.92					
540	0.6	1.063	1.063	75	14.92					
540	0.6	1.063	1.063	75	16.92					
540	0.6	1.063	1.063	75	18.92					
540	0.6	1.063	1.063	75	20.92					

Test1.2 .Totally underwater2(only nozzle shape changed+)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle sh	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
530	0.5	1.063	1.063	113	0					0.00%
530	0.5	1.063	1.063	113	2.92					0.00%
530	0.5	1.063	1.063	113	4.92					0.00%
530	0.5	1.063	1.063	113	6.92					0.00%
530	0.5	1.063	1.063	113	8.92					0.00%
530	0.5	1.063	1.063	113	10.92					0.00%
530	0.5	1.063	1.063	113	12.92					0.00%
530	0.5	1.063	1.063	113	14.92					0.00%
530	0.5	1.063	1.063	113	16.92					0.00%
530	0.5	1.063	1.063	113	18.92					0.00%
530	0.5	1.063	1.063	113	20.92					0.00%

Test2.1 .Totally underwater1(only nozzle shape changed-)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	0.6	1.063	1.063	75	-4.5					0.00%
540	0.6	1.063	1.063	75	-5.5					0.00%
540	0.6	1.063	1.063	75	-6.5					0.00%
540	0.6	1.063	1.063	75	-7.5					0.00%
540	0.6	1.063	1.063	75	-8.5					0.00%
540	0.6	1.063	1.063	75	-9.5					0.00%
540	0.6	1.063	1.063	75	-10.5					0.00%
540	0.6	1.063	1.063	75	-11.5					0.00%
540	0.6	1.063	1.063	75	-12.5					0.00%
540	0.6	1.063	1.063	75	-13.5					0.00%

Test2.2 .Totally underwater2(only nozzle shape changed-)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle sh	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
530	0.5	1.063	1.063	113	-4.5					0.00%
530	0.5	1.063	1.063	113	-5.5					0.00%
530	0.5	1.063	1.063	113	-6.5					0.00%
530	0.5	1.063	1.063	113	-7.5					0.00%
530	0.5	1.063	1.063	113	-8.5					0.00%
530	0.5	1.063	1.063	113	-9.5					0.00%
530	0.5	1.063	1.063	113	-10.5					0.00%
530	0.5	1.063	1.063	113	-11.5					0.00%
530	0.5	1.063	1.063	113	-12.5					0.00%
530	0.5	1.063	1.063	113	-13.5					0.00%

Table 5.3.4 Optimized nozzle shape analysis tables

5.3.3 Comparison table

As is common knowledge, there ought to be a difference between the real test and the flow simulation in Solidworks. However, it is unknown how much the difference is and whether it keeps constant or not. In order to find the difference between them, a series of comparison tables are made. The idea is to apply the company's 2nd test results (Bogerd, Testplan praktijk test 2,2015) on the jet pump model the company gave us, which has the same dimensions with the real jet pump. Make the same environment, add the same inputs(V1,P2,P3 & nozzle)(figure 5.3.5), and measure the same outputs(P4,V4,P5,V5)(figure 5.3.5). After that calculate the efficiency .The calculation method for it will be done in next phase. Finally calculate the difference between the simulation outputs, efficiency to the company's test results and analyze the difference between them.

For each test condition there are 2 tables, first is the simulation table, used for filled in the simulation data and calculate the efficiency. Second table is for comparison and calculating the difference.

For the reason that there are too many comparison tables in all, below gives an example (Table 5.3.5.) for the situation that the jet pump placing totally under the water with jet pump. The other comparison tables are shown in Appendix D. You can find the position of correspond parameters in Figure 5.3.5.

Test 1.Totally underwater(without discharge head)								
Input				Output				
V1	P2	P3	Nozzle	P4	V4	P5	V5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(bar)	(m/s)	(bar)	(m/s)	(%)

Comparation Test1: Totally underwater(without discharge head)								
P4		V4				Efficiency		
(bar)						(%)		
Simulation	Real	Simulation (m/s)	(m3/h)	Real (m3/h)	Difference1	Simulation	Real	Difference2

Table 5.3.5 Examples of comparison tables

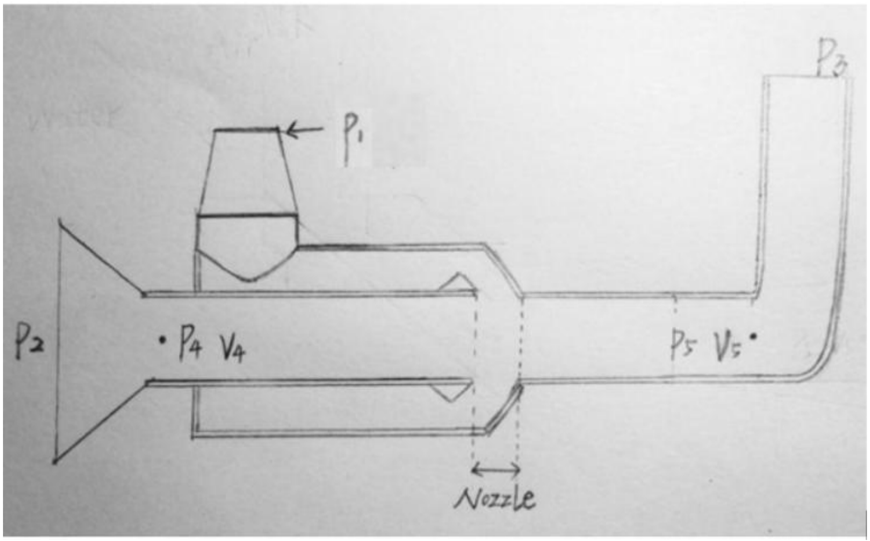


Figure 5.3.5 Jet pump totally underwater with discharge head

5.4 Parametric phase

5.4.1 Simplified Jet Pump model

Jansen Tholen has already made a model for simulation. But when we use it to do the flow simulation in Solidworks, we found it is leaking and it is hard and complex to fix it which will cost a lot o time. So a 1:1 jet pump model is made refers to the company's 2nd simulation model, it is simplified and is easier to adjust each important parameters. It consists 4 parts, which are pressure pipe, inlet pipe, main body (outlet pipe includes diffuser) and discharge as shown in Figure 5.4.1. The dimension of each part in detail is shown in Appendix E.

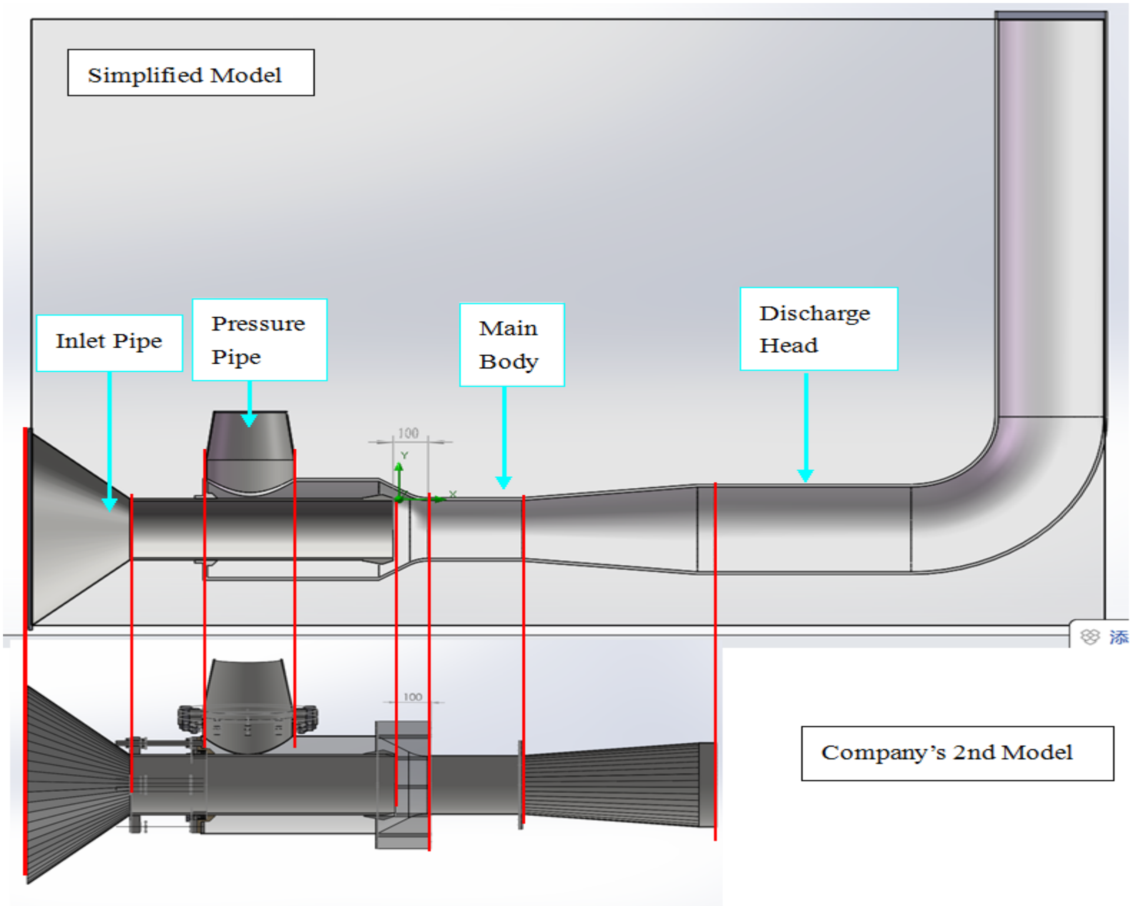


Figure 5.4.1 Comparison of simplified jet pump model and company's 2nd jet pump model

5.4.2 Calculation

5.4.2.1 Efficiency calculation

Assume we are calculating the efficiency when:

Ingoing flow rate **V1=400(m3/h)**
Diameter of inlet pipe **D=8(inch) =**203. 2**(mm) =0.**2032**(m)**
Area of inlet pipe **S=3.14*0.**1016***0.**1016=0. 03241284**(m2)**
If the result from simulation is **v4=2.5(m/s)**

We can transfer v4 (m/s) to V4 (m3/h) by multiply area of inlet pipe:

V4=v4*S*3600=2.5*0.03241284***3600=**291. 715546**(m3/h)**

Efficiency=(V4/V1)*100%=291. 715546/**400*100%=**72. 928886**%**

(This calculation process is only fit when the diameter of inlet pipe D is 8 inch, when the diameter is changed, the area of inlet pipe need to recalculation, but the method is the same.

5.4.2.2 Throughflow surface

In the final table for company, we use throughflow surface to describe the gap length which is more convenient to apply in production.
The process of calculation is shown below:

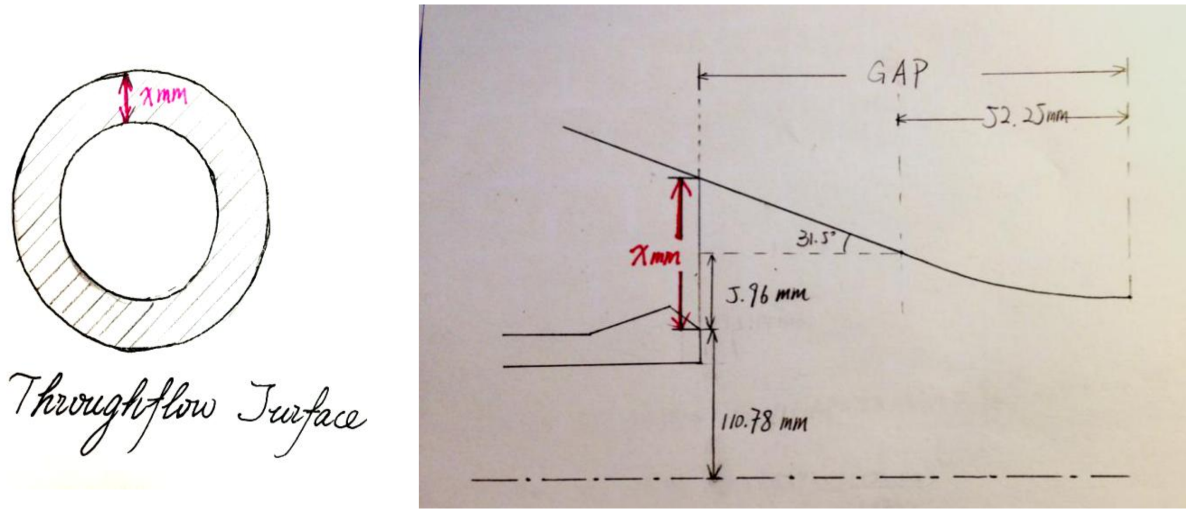


Figure 5.4.1 Thoughflow surface calculation

The throughflow surface is equal to the area in shadow (Figure 5.4.1)
Area of small circle **S1=π*r2=3.14*110.78**^{2}
Area of big circle **S2=π*R2=3.14*(x+110.78)**^{2}
=3.14*[tan31.5°*(Gap-52.25)+5.96]^2**-π*110.78**^{2}
Thus **Throughflow surface =S2-S1**
=3.14*[tan31.5°*(Gap-52.25)+5.96]^2**-π*110.78**^{2}
=3.14*[(84.8675+0.61*Gap)^2**-12271.2084]**

In addition, this calculation method is valid when the gap length is smaller than 140.8mm, if the gap length is over this value, the throughflow surface is always the same, as shown in the figure 5.4.2.
This constant throughflow has been calculated to be 0.05328 m².

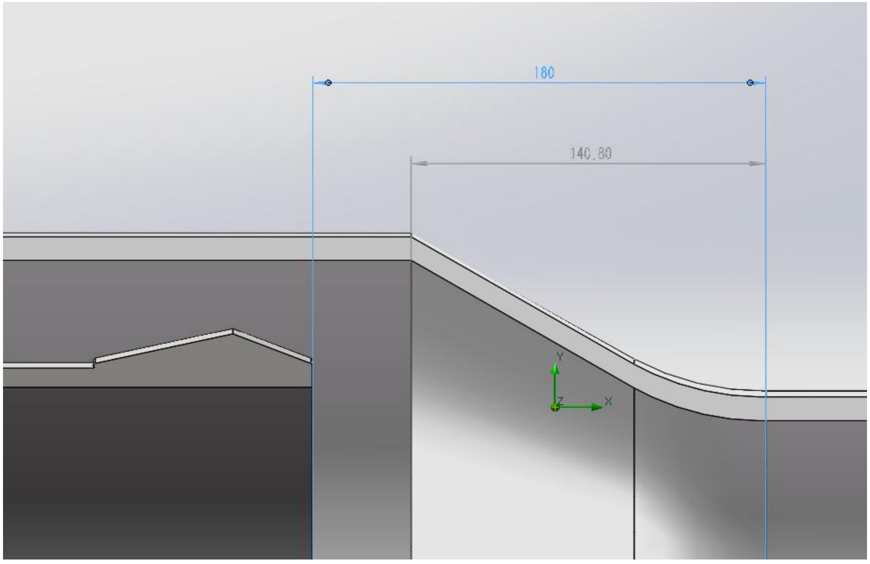


Figure 5.4.2 gap length over 140.8mm

However in the final table the maximum gap length being use is 140mm, so the calculation method is always valid in this project. The position of the nozzle in this project will always within 140.80mm like figure 5.4.3.

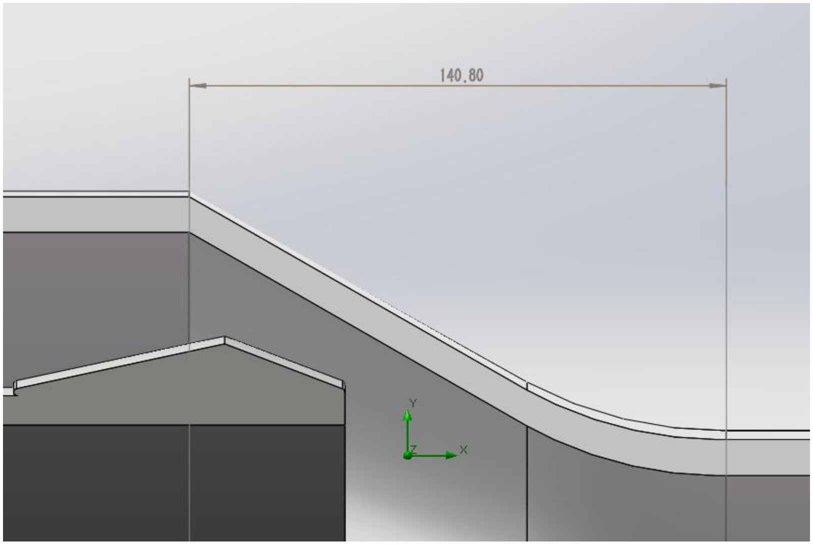


Figure 5.4.3 gap length within 140.8mm

5.4.2.3 Minimum pumping back speed

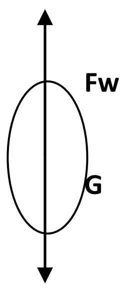


Figure 5.4.4

The force analysis of the mussels in the pump is showed on the right side (Figure 5.4.2).

To make sure the mussels can be pumped back to the ship,

$F_W \geq G$

$F_W = 1/2*\rho*Cw*v2*A$

$G = m*g$

Given:

$\rho = 1000 (Kg/m3)$

C_W=0.2

g=9.8

m=33g

A=1.5*10^{-3}

Therefore

1/2*ρ*Cw*v2*A≥ m*g

1/2*1000*0.2*v^2*1.5*10^{-3}≥0.033*9.8

V≥1.5m/s

5.4.2.4 Boundary conditions: Pressure

The boundary condition is used in Solidworks simulation to set the value of environment.
There are two main boundary conditions in our simulation process: one is pressure, the other one is velocity. The velocity is stated in 5.5.2.1, we mainly introduce the pressure calculation here.
The pressure in the air is 1.013 bar, that is to say air pressure.
The pressure under water is that:

P=ρ*g*h

P=1000(kg/m^3)

g=10

h=0.5m

Therefore **P=1000*10*0.5=5000(Pa) =0.05(bar)**
Boundary conditions under water is **P=1.013+0.05=1.063(bar)**

5.5 Detail Designed phase

During this phase the simulation for all the tables would be done by flow simulation and some calculation in Solidworks, including one variable tables, comparison tables and the final table. After doing each table the analysis would be done, in order to research the influence of each important parameter on jet pump, the difference between the Solidworks Simulation and the influence of the combination of different parameters, which can answer part of the research question. After doing the final table, the best solutions would be chosen. That's what we'll deliver to the client in the end.

5.5.1 Comparison of 2nd test and Flow Simulation

In 5.7.1 what we do is using the 2nd test data V1, P1, NOZZLE (Figure 5.5.1) and boundary conditions P2, P3 as input value to get the simulation results V4 and pressure P4, and compared them with realistic data. The comparison is separated into four tests according to different position of the jet pump.

Druk hydraulisch systeem	160	[Bar]
Persleiding		
P1	0	[Bar]
V1 KROHNE	700	$[m^3/h]$
Nozzle		
Doorstroom Opening (afstange gemeten tussen flenzen in [mm])	97	[mm]

Figure 5.5.1 2nd test results

Test 1:

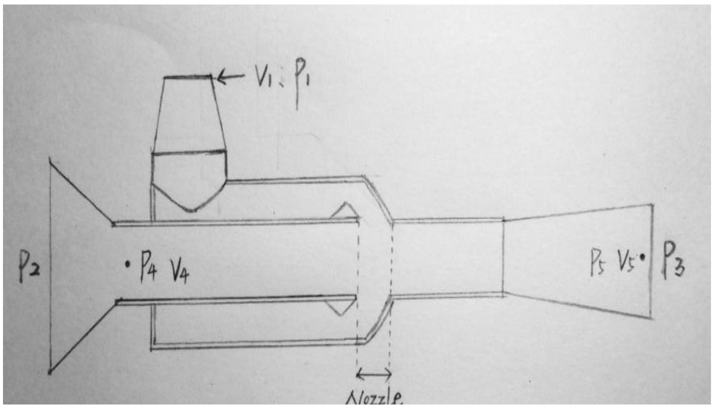


Figure 5.5.2 Jet pump totally underwater without discharge head

In Test 1, the model is totally under water without discharge head (Figure 5.5.2), so we set the boundary conditions P2 and P3 as 1.063 bar, meanwhile the changing inputs are speed V1 and Nozzle length. The simulation result is showed in Table5.5.1 and comparison is in Table 5.5.2.

Test 1. Totally underwater (without discharge head)								
Input				Output				
V1	P2	P3	Nozzle	P4	V4	P5	V5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(bar)	(m/s)	(bar)	(m/s)	(%)
700	1.063	1.063	135	1.056	1.212	1.061	3.071	20.08%
673	1.063	1.063	128	1.051	1.574	1.061	3.333	27.13%
608	1.063	1.063	123	1.047	1.779	1.061	3.159	33.94%
560	1.063	1.063	118	1.045	1.91	1.061	3.11	39.56%
530	1.063	1.063	113	1.044	1.943	1.061	3.216	42.52%

Efficiency=V4 (m3/h)/**V1*100%**

(Detailed calculation in 5.6.2)

Table 5.5.1 Simulation results of test 1

Comparation Test1: Totally underwater(without discharge head)									
P4 (bar)		V4				Efficiency (%)			
Simulation	Real	Simulation (m/s)	Simulation (m3/h)	Real (m3/h)	Difference1	Simulation	Real	Difference2	
1.056	0	1.21	140.70	190	35.04%	20.08%	27%	6.92%	
1.051	0	1.56	180.95	270	49.21%	27.13%	40%	12.87%	
1.047	0	1.77	204.84	340	65.98%	33.94%	56%	22.06%	
1.045	0	1.89	218.88	390	78.18%	39.56%	70%	30.44%	
1.044	0	1.94	224.56	450	100.39%	42.52%	85%	42.48%	

Difference= (Real-Simulation)/Simulation*100%

Table 5.5.2 Comparison Table of test 1

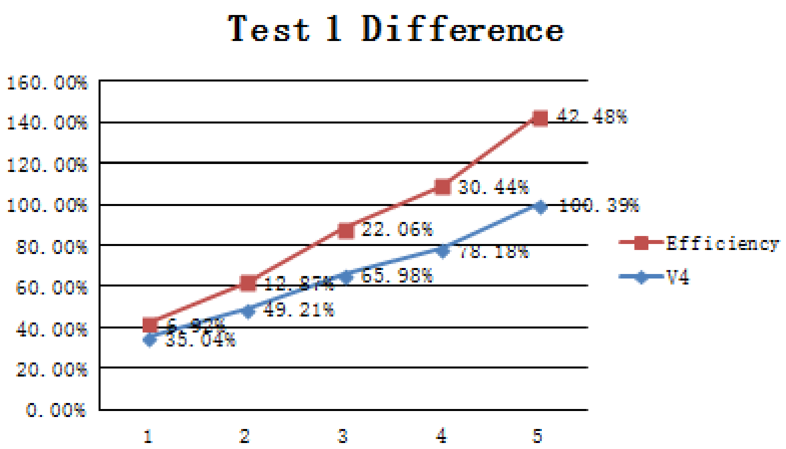


Table 5.5.3 Line graph of difference in test 1

Choosing Difference1 and Difference2 from Table 5.5.2 to make a line graph. The graph (Table 5.5.3) shows the difference between real data and simulation data is increasing along with the decrease of V1 and nozzle gap length. But we can't make a conclusion how each variable affect the result.

Test 2:

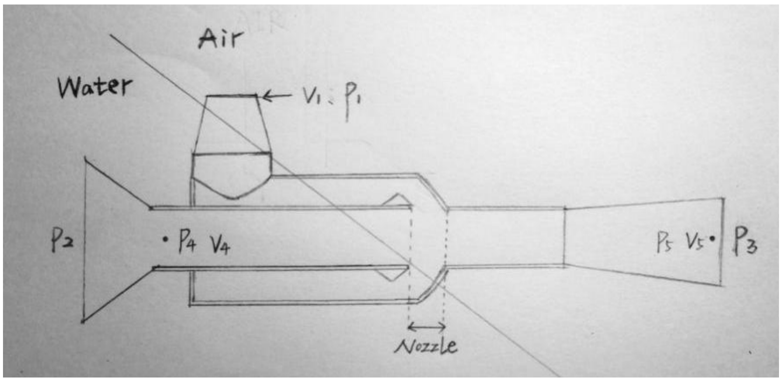


Figure 5.5.3 Jet pump partly underwater without discharge head

In test 2, the jet pump is partly put under the water without discharge head (Figure 5.5.3).The boundary condition P2 which is in the water is 1.063bar, the boundary condition P3 which is in the air is 1.013bar.

The simulation results are showed in Table 5.5.4 and the comparison results is showed in Table 5.5.5.

Test 2. Partly underwater(without discharge head)								
Input				Output				
V1	P2	P3	Nozzle	P4	V4	P5	V5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(bar)	(m/s)	(bar)	(m/s)	(%)
550	1.063	1.013	113	1.017	3.071	1.061	3.876	64.77%
300	1.063	1.013	108	1.009	2.869	1.011	2.954	110.93%
300	1.063	1.013	103	1.021	2.91	1.011	3.01	112.51%

Efficiency=V4 (m3/h)/V1*100%

(Detailed calculation in 5.6.2)

Table 5.5.4 Simulation results of test 2

Comparation Test2: Partly underwater(without discharge head)								
P4 (bar)		V4				Efficiency (%)		
Simulation	Real	Simulation (m/s)	Simulation (m3/h)	Real (m3/h)	Difference	Simulation	Real	Difference
1.017	0	3.071	356.21	370	3.87%	64.77%	67%	3.45%
1.009	0	2.869	332.78	345	3.67%	110.93%	115%	3.67%
1.021	0	2.91	337.54	300	-11.12%	112.51%	95%	-15.56%

Difference= (Real-Simulation)/Simulation*100%

Table 5.5.5 Comparison Table of test 2

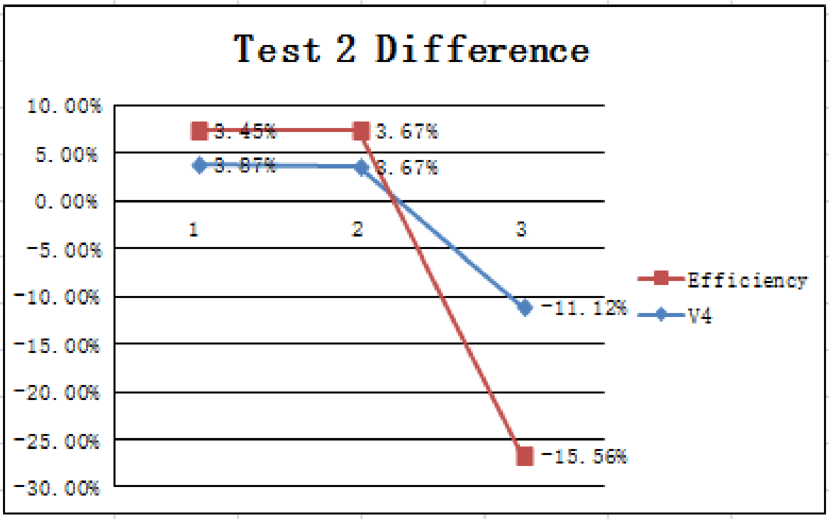
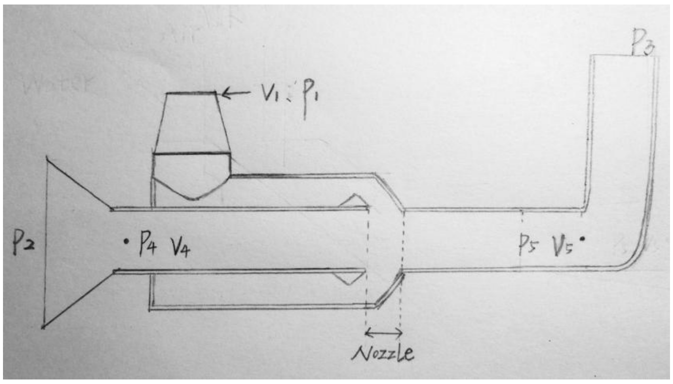


Table 5.5.6 Line graph of difference in test 2

Choosing Difference1 and Difference2 from Table 5.5.5 to make a line graph (Table 5.5.6). The efficiency in this test is high. It looks like a nice choice to set the jet pump partly in the water. And as we can see from the line graph, there is no big fluctuation in the former two parameters. But the strange appearance occurs in third one, it changes to negative rapidly. The only variable is that the nozzle changed from 108mm to 103mm.

There may be two explanations for this appearance: The first one is maybe there is something wrong when recording the data in the test; the second explanation is that maybe there is indeed some rapid change when change the nozzle gap from 108mm to 103mm.We will research on this part in our one variable test later on.

Test 3:



In test 3, the model is under water with the discharge head (3m), so we set the boundary condition P2 (which is under water) as 1.063bar, and P3 (in the air) as 1.013bar, meanwhile change input speed V1 and Nozzle length.

Figure 5.5.4 Jet pump totally underwater with discharge head

Test 3.Totally underwater(with discharge head)								
Input				Output				
V1	P2	P3	Nozzle	P4	V4	P5	V5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(bar)	(m/s)	(bar)	(m/s)	(%)
560	1.063	1.013	113	1.038	2.294	1.019	3.845	47.52%
470	1.063	1.013	108	1.039	2.241	1.018	3.527	55.31%
315	1.063	1.013	103	1.037	2.355	1.016	2.951	86.72%
330	1.063	1.013	98	1.037	2.335	1.016	2.982	82.07%
250	1.063	1.013	93	1.034	2.51	1.013	2.793	116.46%

Efficiency=V4 (m3/h)/**V1*100%**

(Detailed calculation in 5.6.2)

Table 5.5.7 Simulation results of test 3

Comparison Test3:Totally underwater(with discharge head)								
P4		V4				Efficiency		
(bar)						(%)		
Simulation	Real	Simulation (m/s)	(m3/s)	Real (m3/s)	Difference	Simulation	Real	Difference
1.016	0	2.294	266.09	100	-62.42%	47.52%	18%	-62.12%
1.016	0	2.241	259.94	135	-48.06%	55.31%	28%	-49.37%
1.021	0	2.355	273.16	160	-41.43%	86.72%	51%	-41.19%
1.024	0	2.335	270.84	190	-29.85%	82.07%	58%	-29.33%
1.021	0	2.51	291.14	250	-14.13%	116.46%	68%	-41.61%

Difference= (Real-Simulation)/Simulation*100%

Table 5.5.8 Comparison Table of test 3

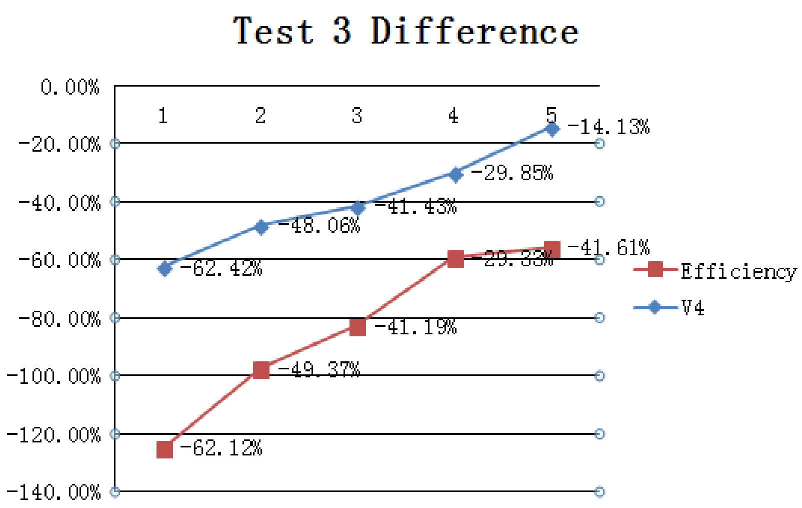


Table 5.5.9 Line graph of difference in test 3

Choosing Difference1 and Difference2 from Table 5.5.8 to make a line graph (Table 5.5.9).In test 3, the difference between simulation data and realistic data has a steady rising tendency which is similar to the tendency in test 1.But difference in test 3 is negative which means the realistic data is smaller than the data in simulation.

Because the tendency is closing to a straight line, so it provided possibilities to predict the difference in certain range.

Test 4:

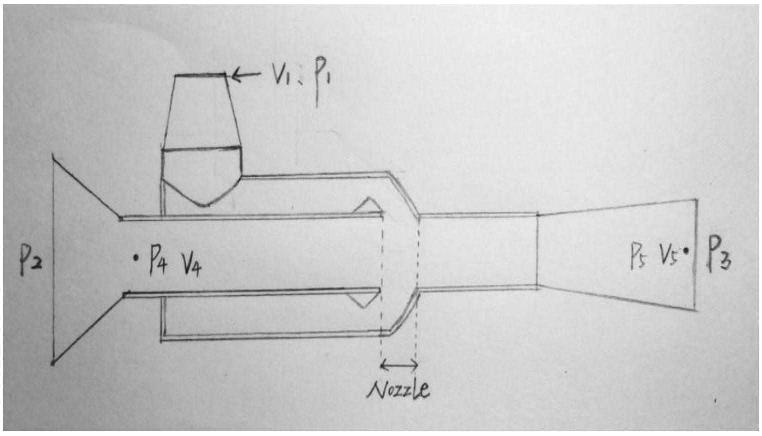


Figure 5.5.5 Jet pump totally underwater without discharge head

In test 4, the environment condition (Figure 5.5.5) is the same as test 1. The model is totally under water, so the boundary conditions P2 and P3 as 1.063bar. In this test, the nozzle (gap length)is fixed, the only variable is pump speed V1.

Test 4. Totally underwater(only change pump speed)						
Input				Output		
V1	P2	P3	Nozzle	V4	V5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(m/s)	(m/s)	(%)
540	1.063	1.063	75	3.973	4.4459	85.34%
561	1.063	1.063	75	4.125	4.56	85.29%
620	1.063	1.063	75	4.597	5.01	86.00%

Efficiency=V4 (m3/h)/**V1*100%**

(Detailed calculation in 5.6.2)

Table 5.5.10 Simulation results of Test 4

Comparison Test4: Totally underwater(only change speed)						
V4				Efficiency		
				(%)		
Simulation (m/s)	(m3/h)	Real (m3/h)	Difference1	Simulation	Real	Difference2
3.973	460.84	310	-32.73%	85.34%	55%	-30.34%
4.125	478.47	360	-24.76%	85.29%	58%	-27.29%
4.597	533.22	300	-43.74%	86.00%	55%	-31.00%

Difference= (Real-Simulation)/Simulation*100%

Table 5.5.11 Comparison table of Test 4

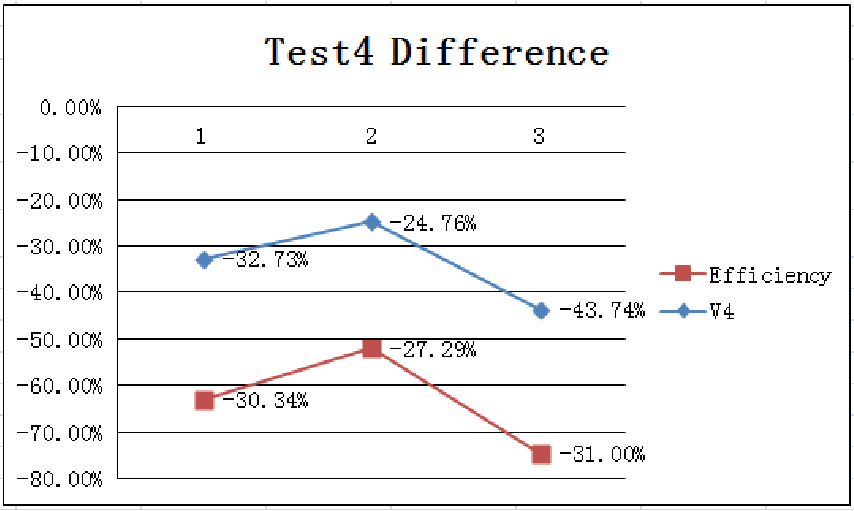


Table 5.5.12 Line graph of difference in test 4

The Table5.5.12 is using data difference 1 and difference 2 from the Table 5.5.11. In test 4, the only variable is V1, and nozzle gap length is fixed to 75mm. This test showed how pump input flow rate affects the efficiency and sucking speed. But due to some reasons only three sets of test data is showed in the report. The experimental value is limited, it is hard to estimate the tendency when the pump in this condition.

5.5.2 One variable analysis

5.5.2.1 Nozzle shape

As mentioned in last phase, In order to find out the influence of the nozzle shape, we keep the nozzle angle (figure 5.3.4) as the only variable to see how the 5 outputs(V4,P4,V5,P5(figure 5.3.4) & Efficiency) changes.

The study is separated into two parts using two sets of data. The data we choose is shown below.

Data set 1:

V1	P1	P2	P3	Nozzle
(m3/h)	(bar)	(bar)	(bar)	(mm)
540	0.6	1.063	1.063	75

Data set 2:

V1	P1	P2	P3	Nozzle
(m3/h)	(bar)	(bar)	(bar)	(mm)
530	0.5	1.063	1.063	113

All the results come from two fixed point parameters:

X [m]	Y [m]	Z [m]
-0.700	-0.099	1.486
0.870	-0.099	1.486

Part 1: nozzle angle over 0 degree

Picture below (Figure 5.5.6) shows how we change the nozzle angle in the simulation.

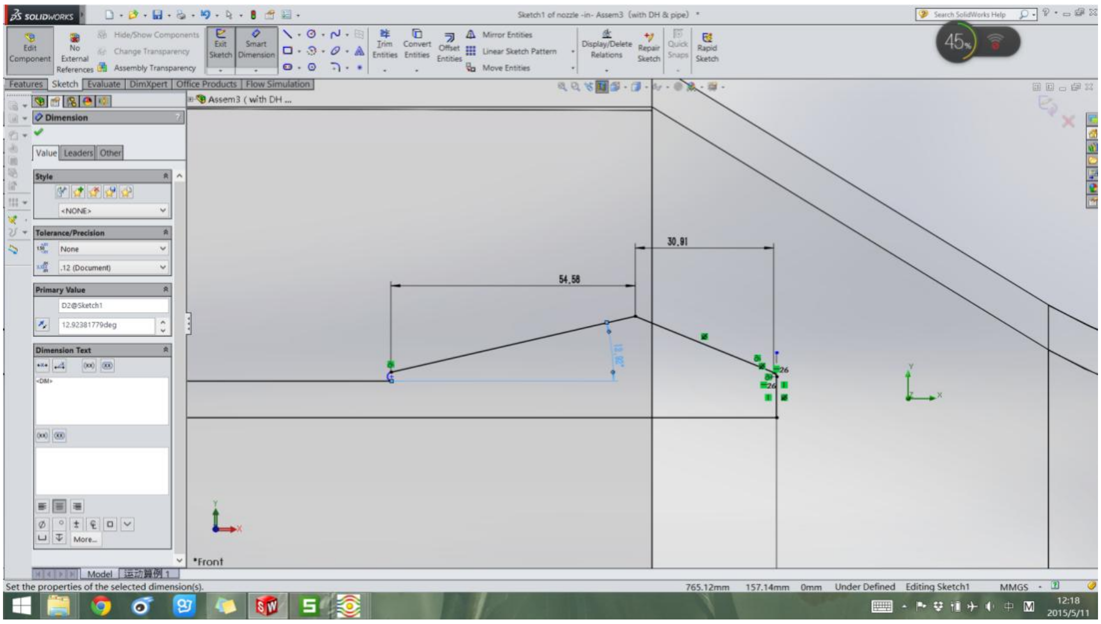


Figure 5.5.6 Nozzle change in simulation

Following are the test result:

The two sets of simulation results are showed in Table 5.5.13 and Table 5.5.19.Line graphs according to the results are from Table 5.5.14 to Table 5.5.18,and Table 5.5.20 to Table 5.5.24.

（Purple column shows the condition at zero; Yellow column shows the original condition of nozzle shape）

Test1.1 .Totally underwater1(only nozzle shape changed+)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	0.6	1.063	1.063	75	0	3.61	99789.77	4.216	105858.13	77.54%
540	0.6	1.063	1.063	75	2.92	3.858	98859.28	4.441	106035.67	82.87%
540	0.6	1.063	1.063	75	4.92	3.956	98500.94	4.449	106028.43	84.97%
540	0.6	1.063	1.063	75	6.92	4.042	98147.07	4.34	106005.4	86.82%
540	0.6	1.063	1.063	75	8.92	4.11	97870.05	4.267	106005.18	88.28%
540	0.6	1.063	1.063	75	10.92	4.16	97655.19	4.342	105997.39	89.36%
540	0.6	1.063	1.063	75	12.92	4.236	97333.02	4.452	106020.79	90.99%
540	0.6	1.063	1.063	75	14.92	4.368	96727.53	4.323	106014.07	93.82%
540	0.6	1.063	1.063	75	16.92	4.441	96421.81	4.257	106003.86	95.39%
540	0.6	1.063	1.063	75	18.92	4.471	96290.71	4	106052.55	96.04%
540	0.6	1.063	1.063	75	20.92	4.444	96409.91	4.34	106040.12	95.46%
540	0.6	1.063	1.063	75	22.92	4.309	97055.67	4.244	106076.59	92.56%
540	0.6	1.063	1.063	75	24.92	4.216	97414.75	4.51	106059.33	90.56%

Table 5.5.13 Test 1 Simulation results

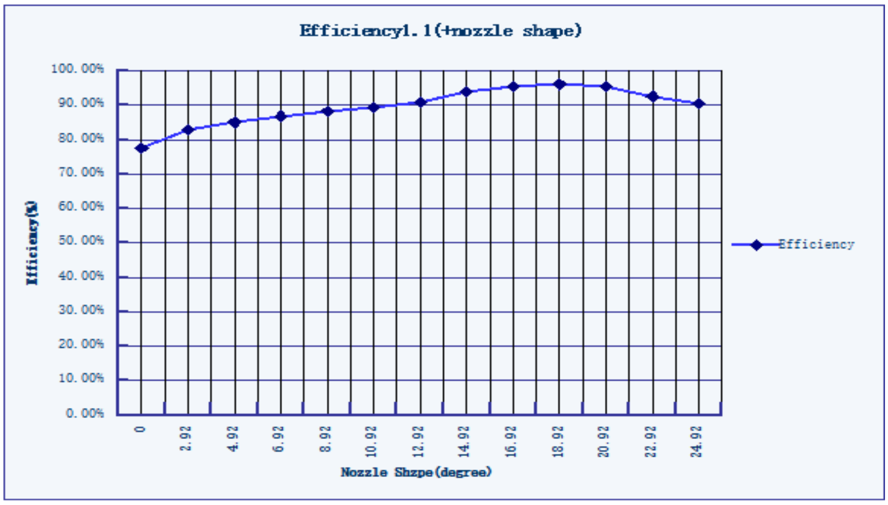


Table 5.5.14 Efficiency of nozzle shape+

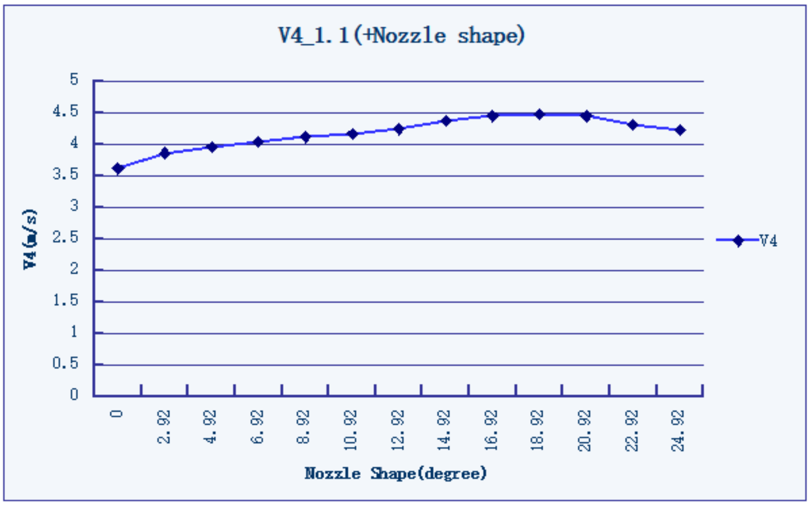


Table 5.5.15 V4 of Nozzle shape+

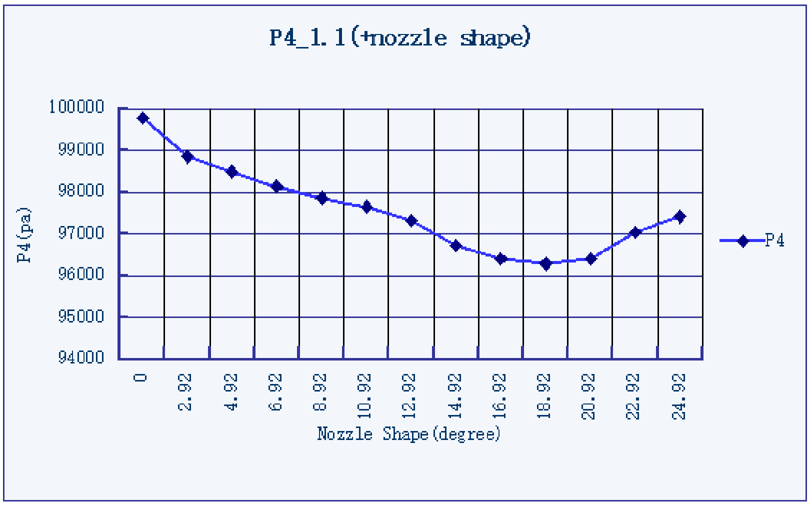


Table 5.5.16 P4 of Nozzle shape+

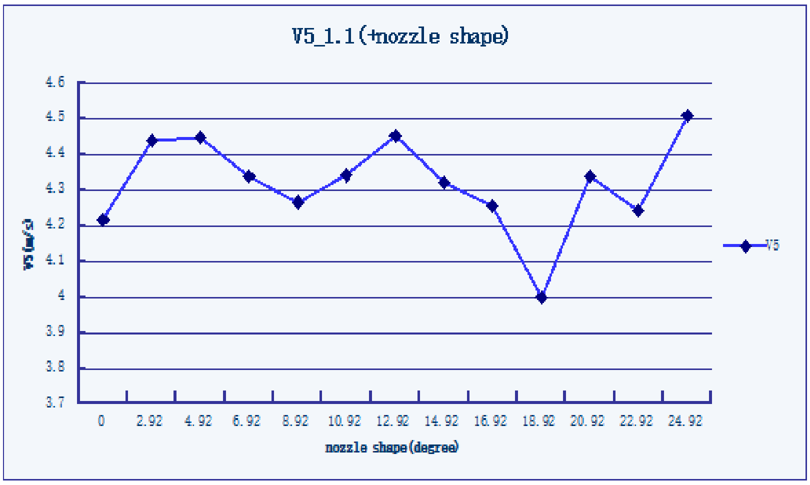


Table 5.5.17 V5 of Nozzle shape+

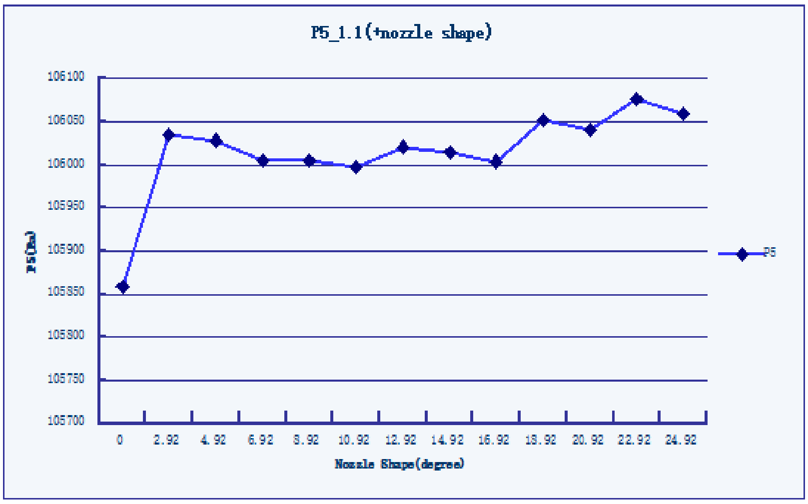


Table 5.5.18 P5 of Nozzle shape+

Test2.1 .Totally underwater2(only nozzle shape changed+)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle sha	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
530	0.5	1.063	1.063	113	0	1.838	104634.5	3.253	106033.88	40.23%
530	0.5	1.063	1.063	113	2.92	1.936	104447.52	3.161	106168.47	42.37%
530	0.5	1.063	1.063	113	4.92	1.925	104474.71	3.162	106171.94	42.13%
530	0.5	1.063	1.063	113	6.92	1.941	104444.06	3.132	106173.15	42.48%
530	0.5	1.063	1.063	113	8.92	1.96	104405.54	3.187	106174.66	42.90%
530	0.5	1.063	1.063	113	10.92	1.964	104397.36	3.176	106174.91	42.98%
530	0.5	1.063	1.063	113	12.92	1.998	104321.7	3.213	106173.91	43.73%
530	0.5	1.063	1.063	113	14.92	1.999	104324.53	3.249	106157.77	43.75%
530	0.5	1.063	1.063	113	16.92	1.973	104370.28	3.275	106162.25	43.18%
530	0.5	1.063	1.063	113	18.92	1.941	104432.29	3.265	106158.85	42.48%
530	0.5	1.063	1.063	113	20.92	1.805	104690.66	3.259	106149.64	39.50%

Table 5.5.19 Simulation results of Nozzle shape+

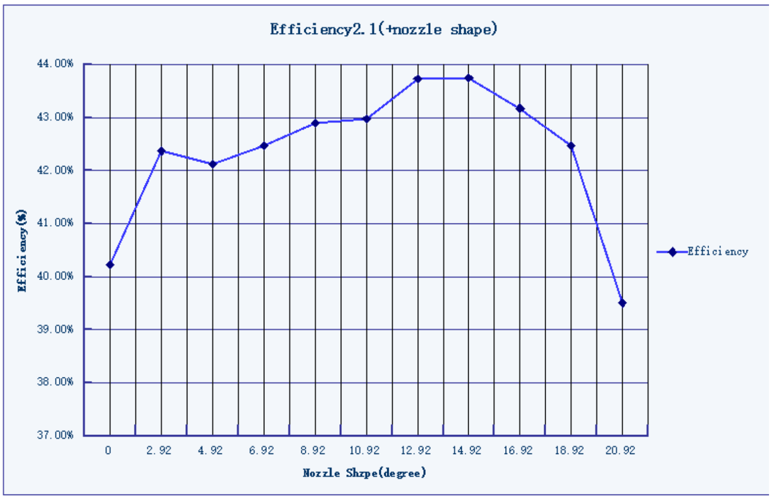


Table 5.5.20 Efficiency of Nozzle shape+

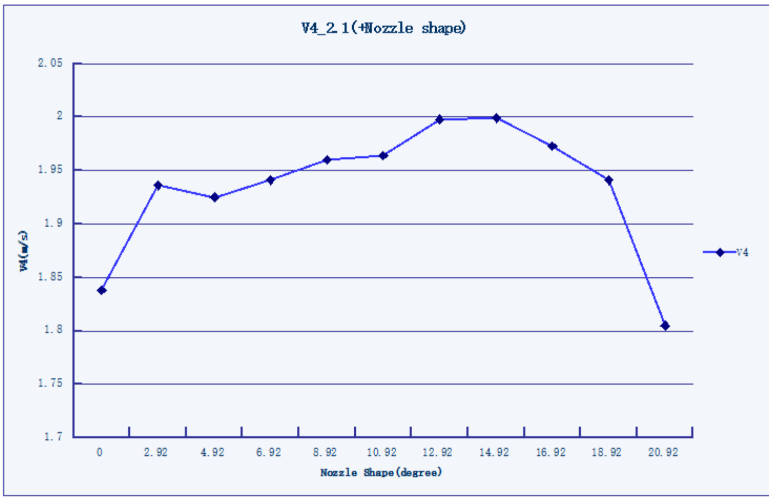


Table 5.5.21 V4 of Nozzle shape+

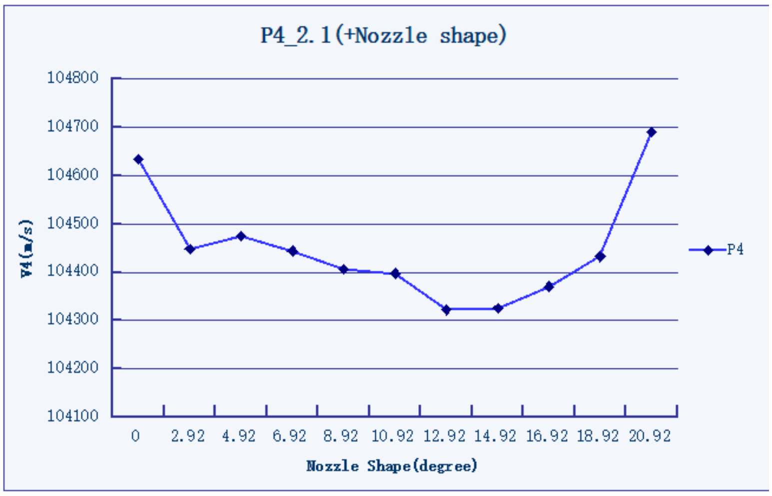


Table 5.5.22 P4 of Nozzle shape+

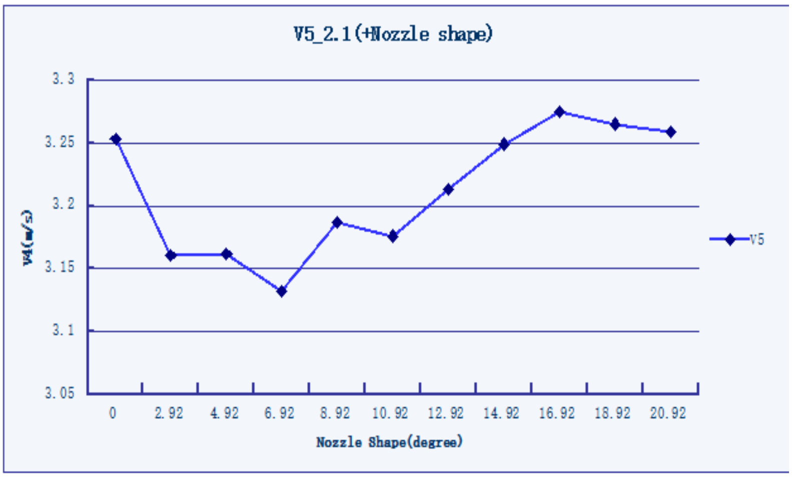


Table 5.5.23 V5 of Nozzle shape+

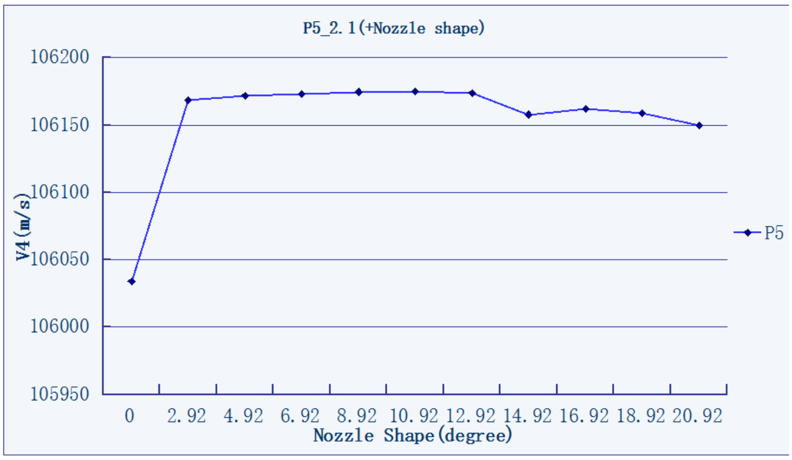
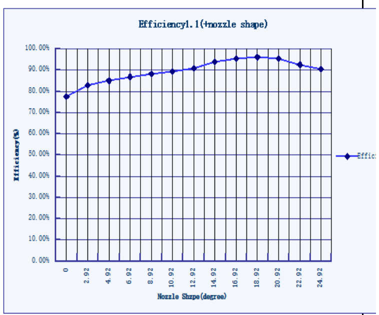
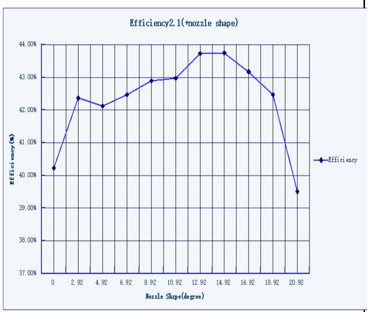
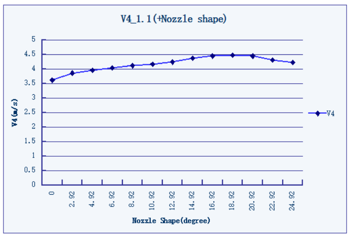
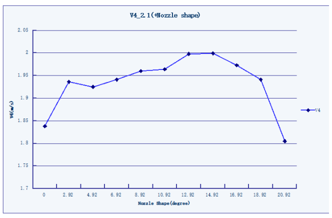
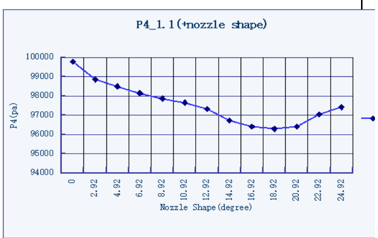
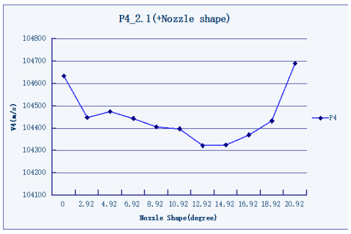
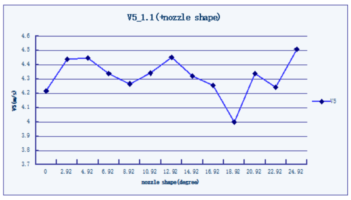
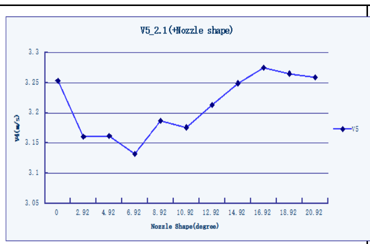
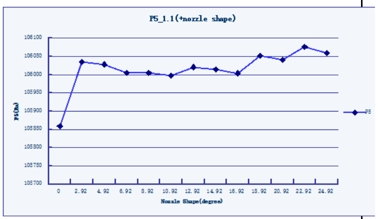
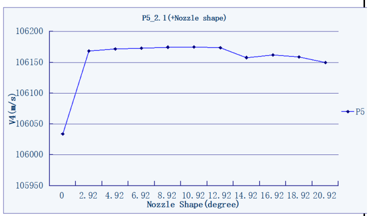


Table 5.5.24 P5 of Nozzle shape+

Part 1: Nozzle Angle Over 0 Degree			
	Data set 1	Data set 2	Conclusion
Efficiency			There is only one nozzle angle that can reach the best efficiency in each case. After the first best efficiency occur, with the increase of the nozzle angle, the best efficiency would not shown again.
V4			In this study V4 is the only influence to the efficiency. So V4 has the same property as the efficiency.
P4			P4 has an inverse relationship with V4. When V4 reach the peak, P4 reach the lowest at the same time.When V4 goes up, P4 goes down, and vice versa.

V5			V5 has a lowest value in each case and has a little vibration in a range of about ±0.25m/s in case 1 and ±0.1m/s in case 2.
P5			Except the condition at 0 degree, the value of P5 has a little vibration, but mainly maintain at a constant value.

Part 2: nozzle angle below 0 degree

Picture below shows how we change the nozzle angle in the simulation.

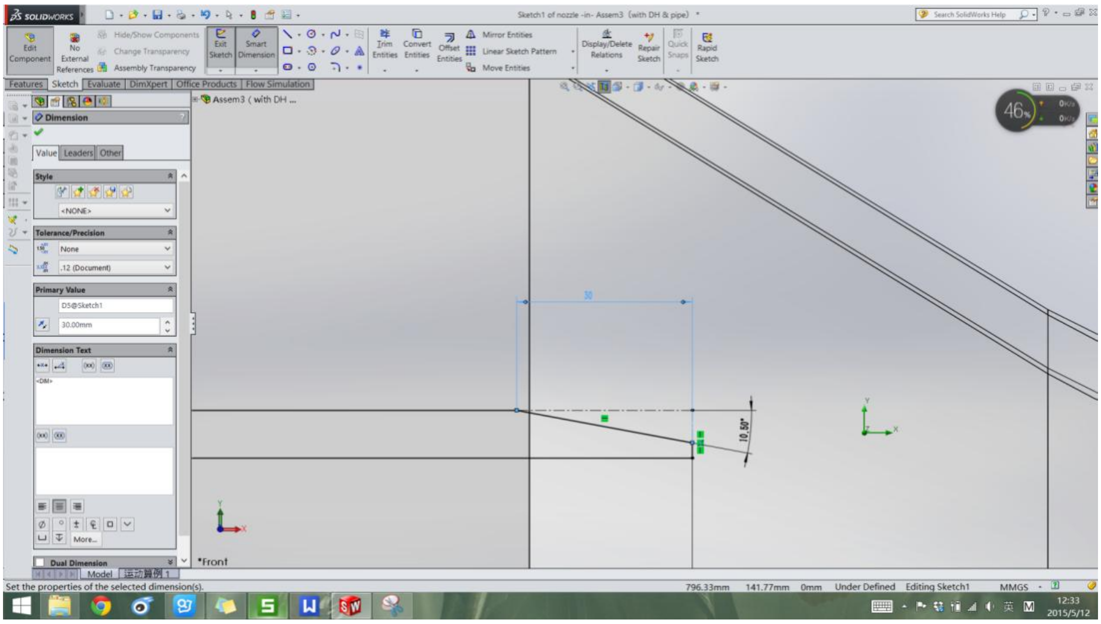


Figure 5.5.7 Nozzle angle change below 0

Following are the test result:

The simulation results of nozzle angle- are showed in Table 5.5.25.Line graphs according to the results are from Table 5.5.14 to Table 5.5.18, and Table 5.5.26 to Table 5.5.30.

Test2.2 .Totally underwater2(only nozzle shape changed-)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle sh	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
530	0.5	1.063	1.063	113	-4.5	1.424	105301.11	2.762	106190.65	31.16%
530	0.5	1.063	1.063	113	-5.5	1.413	105317.34	2.752	106190.9	30.92%
530	0.5	1.063	1.063	113	-6.5	1.388	105345.42	2.631	106203.9	30.38%
530	0.5	1.063	1.063	113	-7.5	1.361	105383.36	2.608	106200.19	29.79%
530	0.5	1.063	1.063	113	-8.5	1.347	105401.5	2.552	106195.19	29.48%
530	0.5	1.063	1.063	113	-9.5	1.322	105433.59	2.552	106206.03	28.93%
530	0.5	1.063	1.063	113	-10.5	1.306	105454.22	2.501	106205.99	28.58%
530	0.5	1.063	1.063	113	-11.5	1.284	105481.69	2.489	106204.71	28.10%
530	0.5	1.063	1.063	113	-12.5	1.267	105506.57	2.445	106212.48	27.73%
530	0.5	1.063	1.063	113	-13.5	1.254	105521.49	2.467	106211.39	27.44%

Table 5.5.25 Simulation results of nozzle shape-

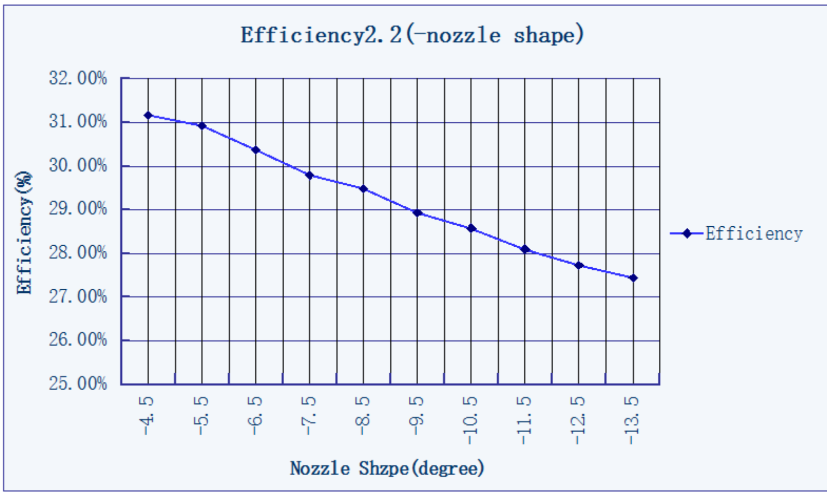


Table 5.5.26 Efficiency 2.2 of nozzle shape-

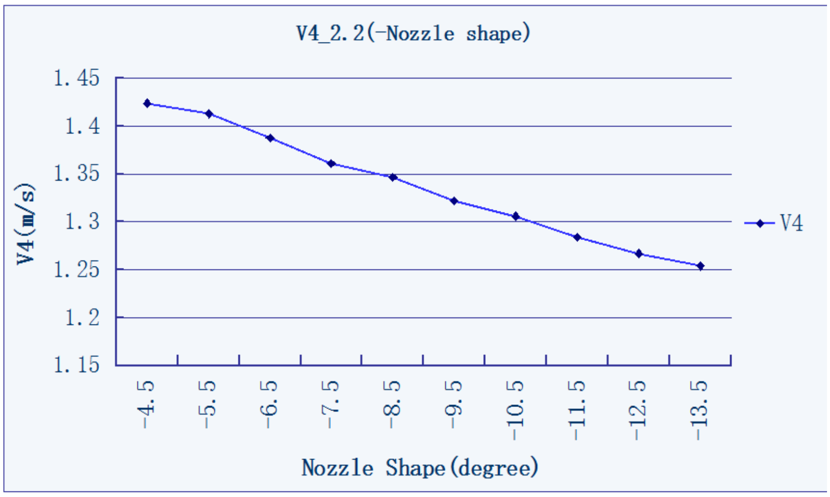


Table 5.5.27 V4 2.2 of nozzle shape-

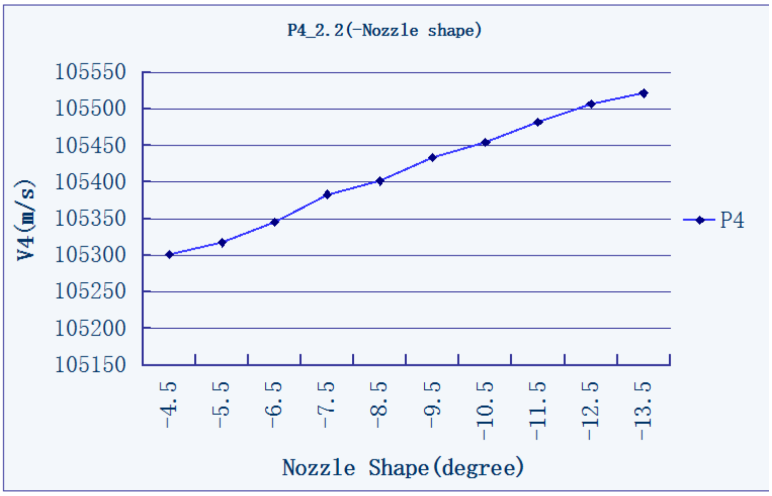


Table 5.5.28 P4 2.2 of nozzle shape-

According to the charts above, a conclusion can be made that P4 and V4 has a inverse relation no matter the nozzle angle is over 0 degree or not. And in the situation that the nozzle angle below 0, both trends of V4 and P4 tend to be linear, that with the decrease of the nozzle angle, V4 continuously goes down together with the efficiency and P4 continuously goes up.

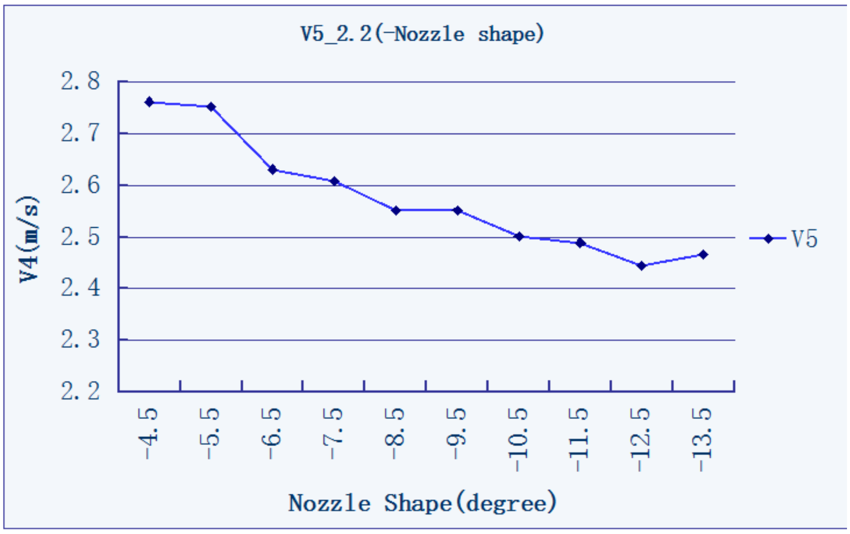


Table 5.5.29 V5 2.2 of nozzle shape-

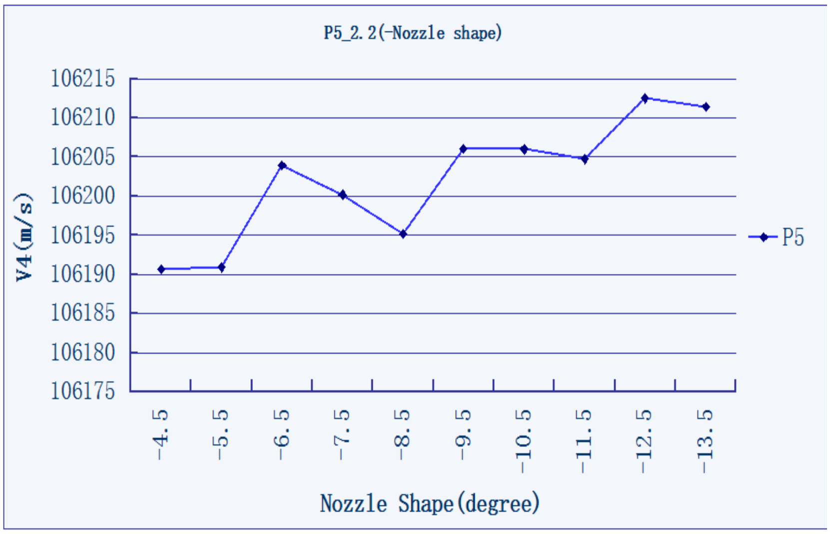


Table 5.5.30 P55 2.2 of nozzle shape-

Although P5 has a little vibration, it continuously goes up with the decrease of the nozzle angle to some extent. And V5 also has a inverse relationship with P5 like V4 and P4.

5.5.2.2 Gap length

In order to find out the influence of the gap length, we keep the gap length as the only variable to see how the 5 outputs (V4, P4, V5, P5 & Efficiency)(Figure5.5.8) changes. We choose the condition that the pump is totally underwater.

Data set:

V1	P1	P2	P3	Nozzle shape
(m3/h)	(bar)	(bar)	(bar)	(degree)
540	0.6	1.063	1.063	12.92

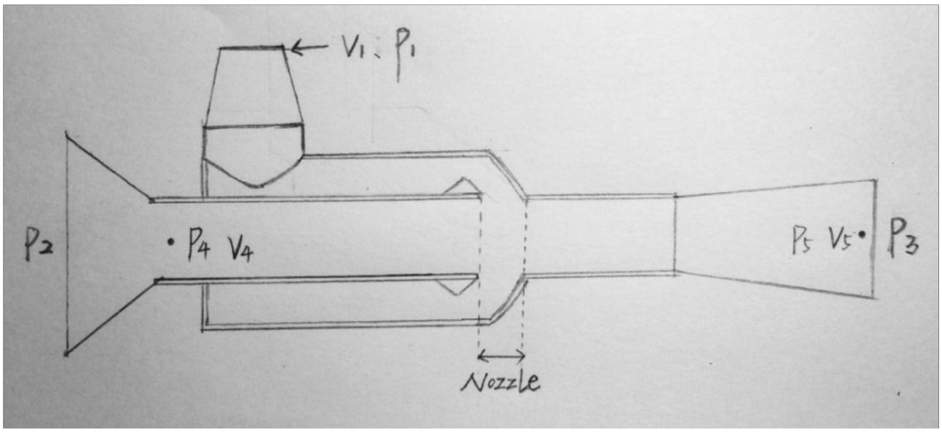


Figure 5.5.8 Parameters on jet pump

All the results come from two fixed point parameters:

X [m]	Y [m]	Z [m]
-0.700	-0.099	1.486
0.870	-0.099	1.486

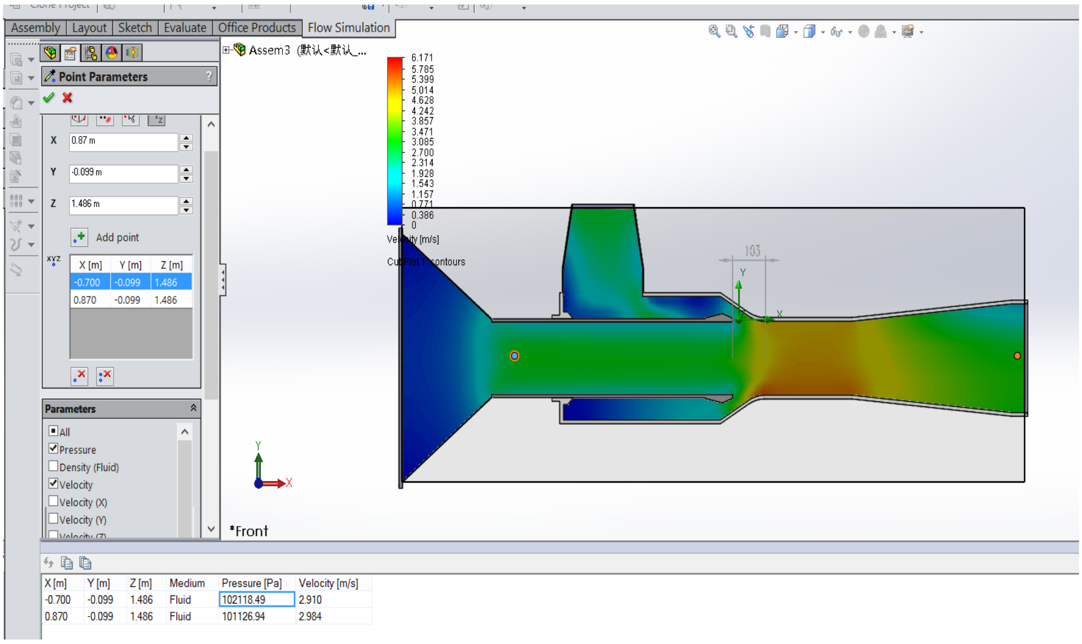


Figure 5.5.9 Flow Simulation

The simulation results are as follows:

The simulation results are showed in Table 5.5.31.The line graphs according to simulation tests is from Table 5.5.32 to Table 5.5.36

Test1. Only gap length changed (Totally underwater)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	0.6	1.063	1.063	45	12.92	10.042	58279.08	6.378	105303.19	215.70%
540	0.6	1.063	1.063	55	12.92	6.391	86983.24	5.375	105498.98	137.28%
540	0.6	1.063	1.063	65	12.92	5.034	93615.5	4.104	105966.44	108.13%
540	0.6	1.063	1.063	75	12.92	3.936	98623.58	4.262	105836.25	84.55%
540	0.6	1.063	1.063	85	12.92	3.106	101523.1	4.164	105926.54	66.72%
540	0.6	1.063	1.063	95	12.92	2.62	102896.12	3.742	105980.93	56.28%
540	0.6	1.063	1.063	105	12.92	2.377	103508.54	3.533	106019.74	51.06%
540	0.6	1.063	1.063	115	12.92	2.426	106317.01	1.386	106855	52.11%
540	0.6	1.063	1.063	125	12.92	1.362	105393.79	2.629	106163.04	29.26%
540	0.6	1.063	1.063	135	12.92	0.903	105902.26	2.388	106190.61	19.40%
540	0.6	1.063	1.063	145	12.92	0.824	105972.74	2.602	106195.03	17.70%
540	0.6	1.063	1.063	155	12.92	0.819	105969.9	3.137	106179.31	17.59%

Table 5.5.31 Simulation results of gap lengths

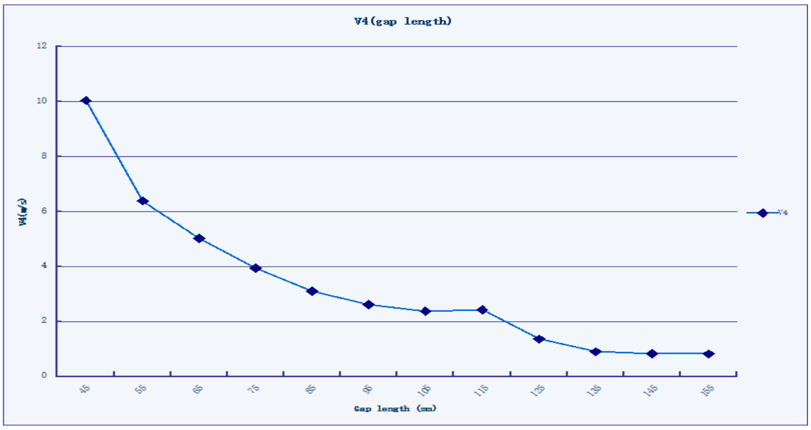


Table 5.5.32 V4 variation with gap lengths

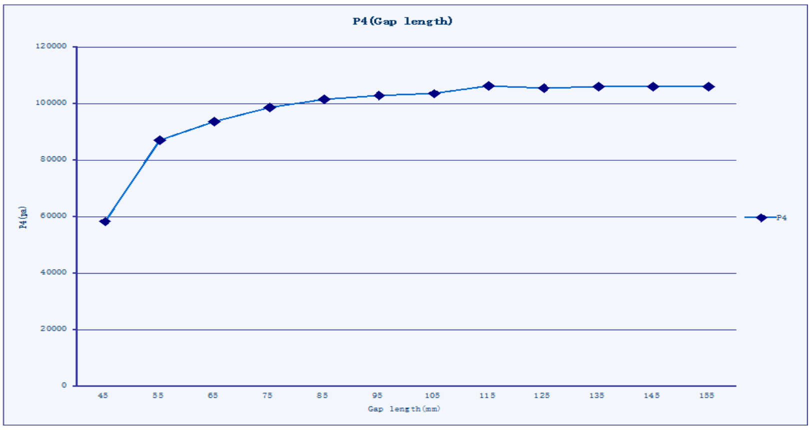


Table 5.5.33 P4 variation with gap lengths

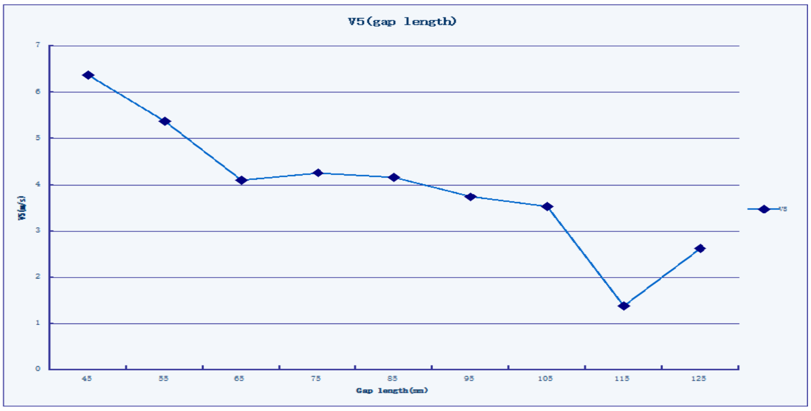


Table 5.5.34 V5 variation with gap length

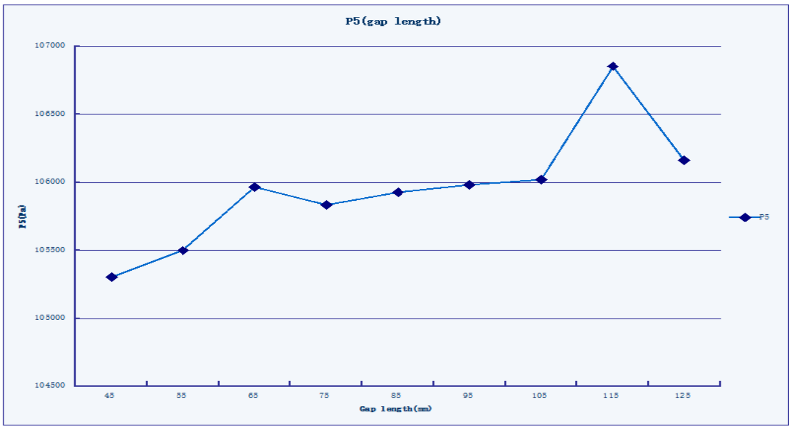


Table 5.5.35 P5 variation with gap length

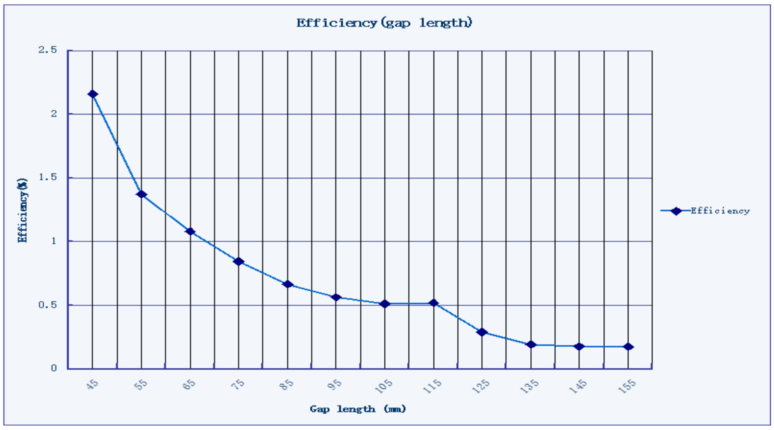


Table 5.5.36 Efficiency variation with gap length

As we can see from the graphs above, the pressure P4 is growing with the changing of gap length and gradually become steady after the gap length is 100mm. At the same time, speed V4 is decreasing with the growing of gap length. The tendency seems steady without sudden increase or decrease， we can use this to infer other speed at certain gap length.
As for V5, the general tendency of V5 is descending with the growth of gap length. But it is not a flat curve or straight line. As for the P5, pressure is getting higher with the gap length. But when gap length is 115 there is also strange change.
The line graph of efficiency is an ideal line because it is decrease with the growing of gap length.
So we get a conclusion from the one variable –gap length test that: When the gap length is getting bigger, the sucking speed V4 will be decreased, the same as V5. As for the efficiency, it will also descend when the gap length is getting bigger.

5.5.2.3 Outlet pipe angle

In this report the only variable is outlet pipe angle. We choose the outlet pipe angle ranges from 139.22 degree to 164.22 degree. We put the jet pump totally underwater. Two sets of parameters are chosen to do simulation. The data sets are showed below:

Data set:

V1	Gap length	P2	P3	Nozzle shape
(m3/h)	(mm)	(bar)	(bar)	(degree)
540	75	1.063	1.063	12.92

V1	Gap length	P2	P3	Nozzle shape
(m3/h)	(mm)	(bar)	(bar)	(degree)
540	65	1.063	1.063	12.92

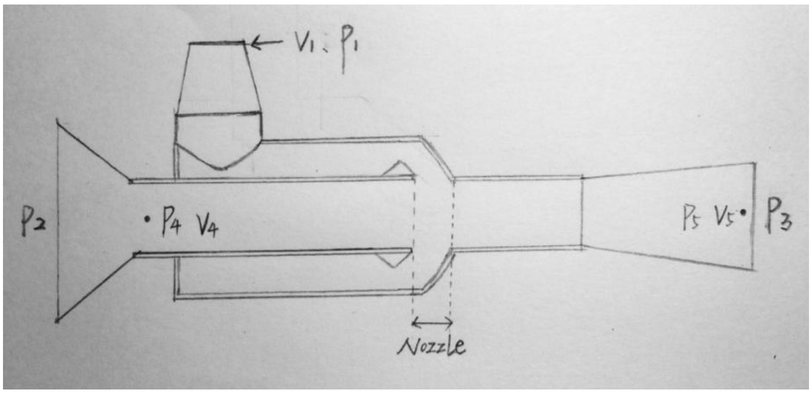


Figure 5.5.10 Parameters on jet pump

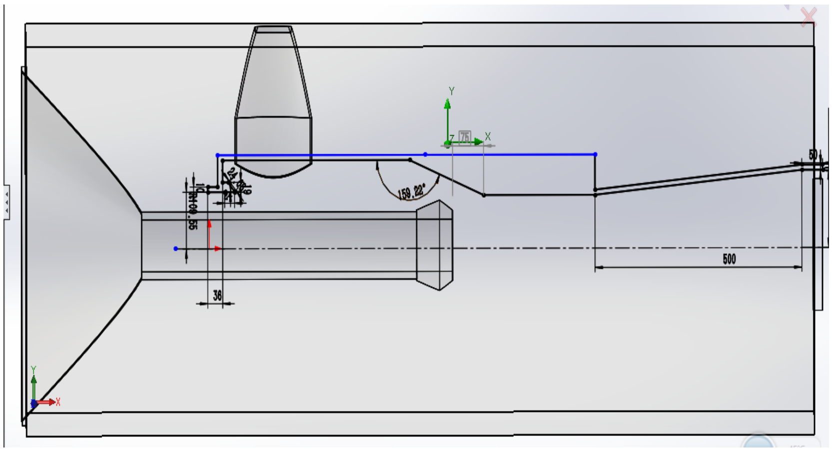


Figure 5.5.11 Sketch of simulation model

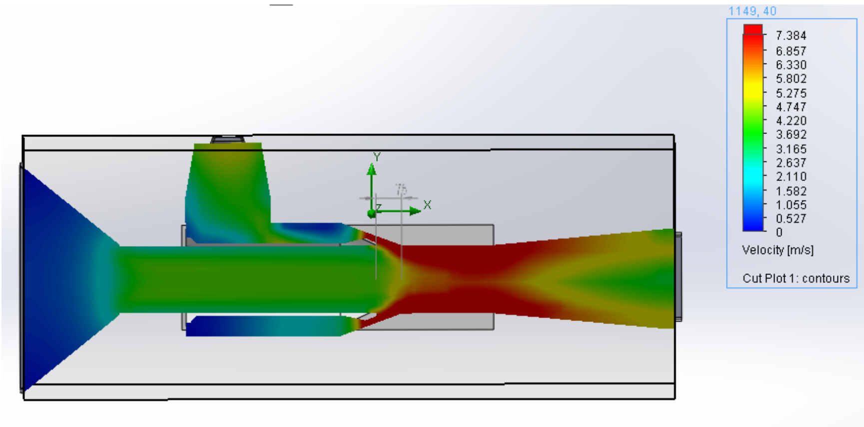


Figure 5.5.12 Flow simulation results

The simulation results are in Table 5.5.37 and Table 5.5.38.

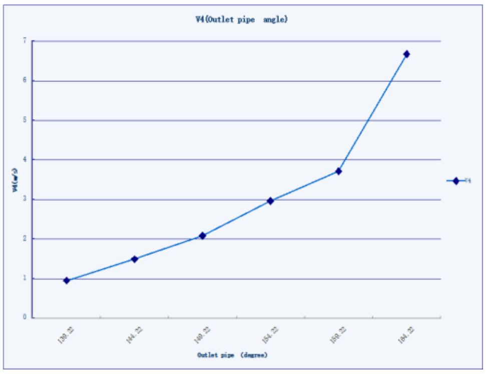
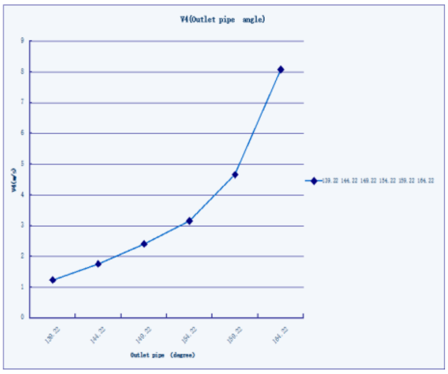
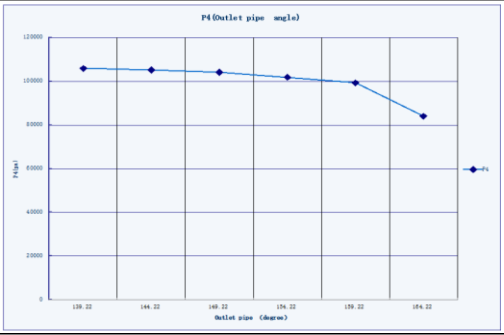
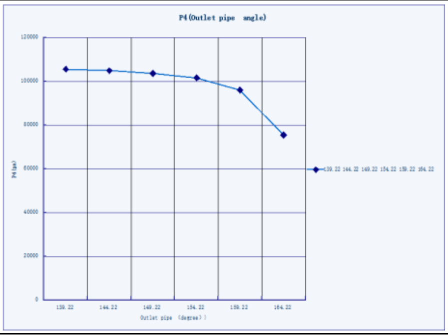
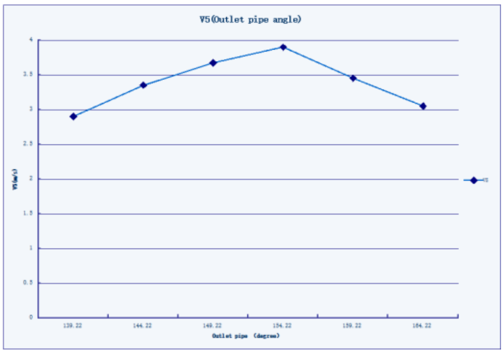
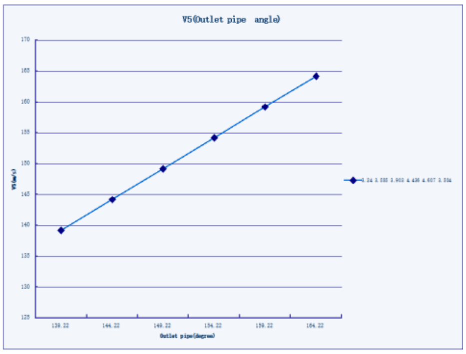
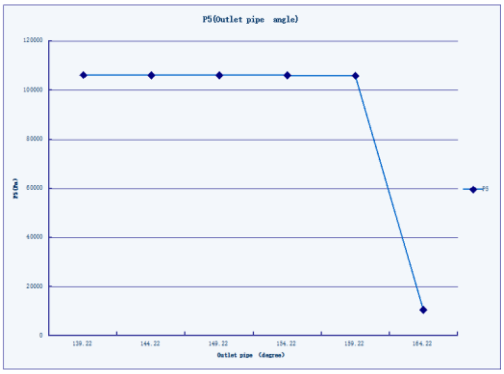
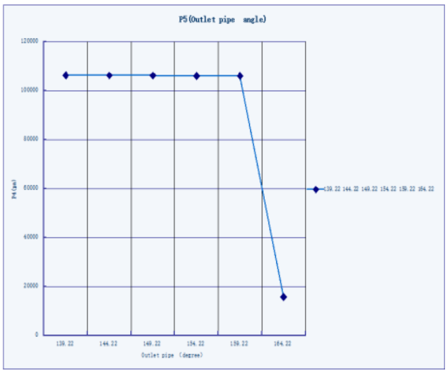
Set 1 .Nozzle length 75mm											
Input							Output				
V1	P1	P2	P3	Nozzle	Outlet pipe	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	0.6	1.063	1.063	75	139.22	12.92	0.949	105839.2	2.905	106197.7	20.38%
540	0.6	1.063	1.063	75	144.22	12.92	1.491	105185.1	3.356	106162.4	32.03%
540	0.6	1.063	1.063	75	149.22	12.92	2.081	104129.8	3.676	106136.5	44.70%
540	0.6	1.063	1.063	75	154.22	12.92	2.969	101876.5	3.901	106081.8	63.77%
540	0.6	1.063	1.063	75	159.22	12.92	3.715	99273.8	3.454	105965.5	79.80%
540	0.6	1.063	1.063	75	164.22	12.92	6.676	83992.48	3.056	10587	143.40%

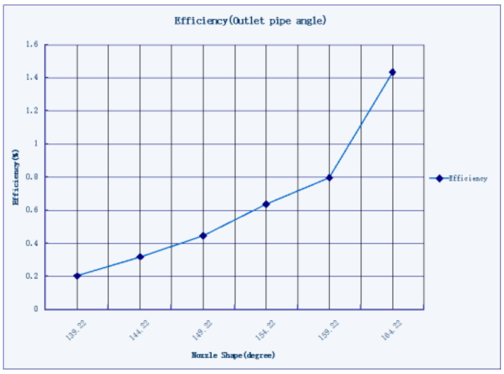
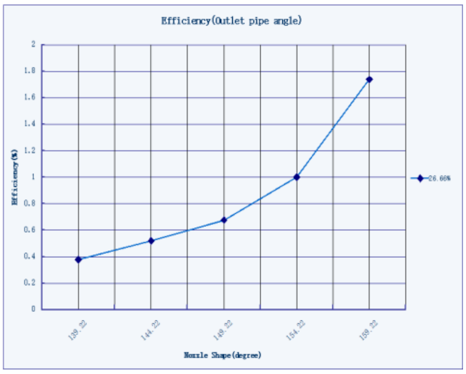
Table 5.5.37 Simulation results set 1

Set 2 .Totally underwater1(nozzle gap length 65mm)											
Input				Input			Output				
V1	P1	P2	P3	Nozzle	Outlet pipe	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	0.6	1.063	1.063	65	139.22	12.92	1.241	105574.1	3.24	106185.9	26.66%
540	0.6	1.063	1.063	65	144.22	12.92	1.767	104827.6	3.585	106140.2	37.96%
540	0.6	1.063	1.063	65	149.22	12.92	2.414	103565.5	3.903	106117.7	51.85%
540	0.6	1.063	1.063	65	154.22	12.92	3.154	101605.1	4.436	106041.6	67.75%
540	0.6	1.063	1.063	65	159.22	12.92	4.661	96073.01	4.607	105932.2	100.12%
540	0.6	1.063	1.063	65	164.22	12.92	8.09	75560.57	3.504	15816	173.77%

Table 5.5.38 Simulation results set 2

Showing the results in line graphs format to see the tendency clearly:

	Set 1	Set 2
V4		
P4		
V5		
P5		

EFFCIENCY		

From the comparison, we see that as the outside pipe angle is larger, the sucking speed v4 is gradually raises up, and meanwhile P4 is getting smaller. Compared with two sets of parameters have similar tendency, although it is not the same, but the general tendency are similar. Then we can get a conclusion that if the outside pipe angle is larger, we can get a better suction speed.

As for V5, the tendency is not as same as V4, it reaches at the peak value when the nozzle shape is 154 degree. Compared with the second set of parameters, there is not a peak value, but a straight line constantly rising up. As for P5, it is steady between 139 and 159 degree. But suddenly a drop appears at the point 164.22 degree. The two sets of parameters look similar .Maybe we can assume that there is a sudden change in 164.22 degree.

The two line graphs for efficiency have the same trend. That is to say, the efficiency continuously goes up with the increasing of the outlet pipe angle.

5.5.3 Final table

In order to fill in the final table through flow simulation, boundary conditions and point parameters needs to be set. Boundary conditions is used for simulating the environment conditions like pressure, while point parameters are used for measuring the outputs. In this chapter introduce the boundary conditions, parameters used in the flow simulation.

Boundary Conditions

The simulation is done for under water condition, so the boundary conditions are shown in the following table:

Pressure pipe lid	Inlet Volume Flow -- it depends	200/400/800
Inlet pipe lid	Environment Pressure--1.063 bar	/
Discharge head lid	Environment Pressure--1.013 bar	/

Following picture shows the position of 3 lids(figure 5.5.13):

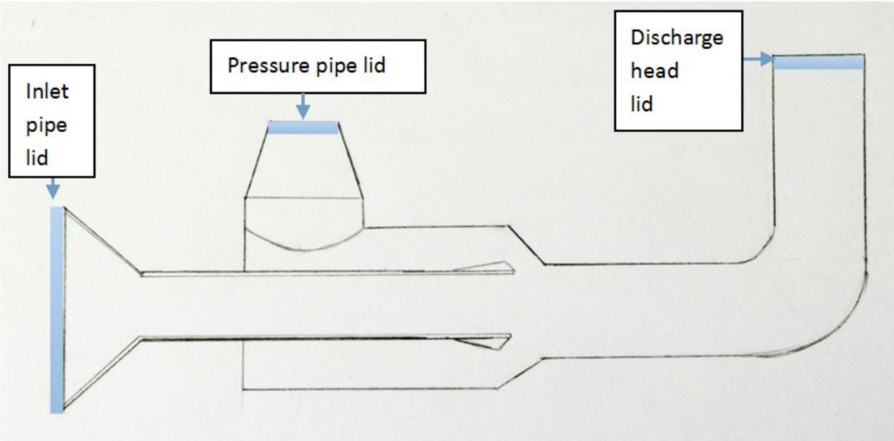


Figure 5.5.13 Position of 3 lids

Point Parameters

There are 5 outputs in the final table, which are P4, V4, P5, V4 & V6, as shown in Figure 5.5.14.

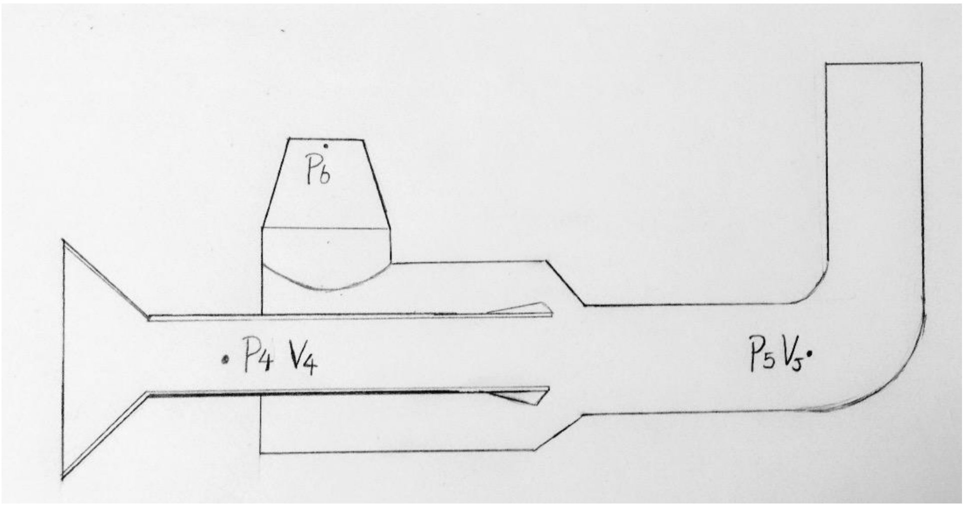


Figure 5.5.14 Outputs of the jet pump

All the outputs are measured by the Point Parameters in the Solidworks. Below shows the 3 points we choose:

Point	X [m]	Y [m]	Z [m]	Measure
1	-0.700	-0.099	1.486	V4,P4
2	0.870	-0.099	1.486	V5, P5
3	-0.426	0.306	1.486	P6

3 Points shown in the Model's sectional view(figure 5.5.15) :

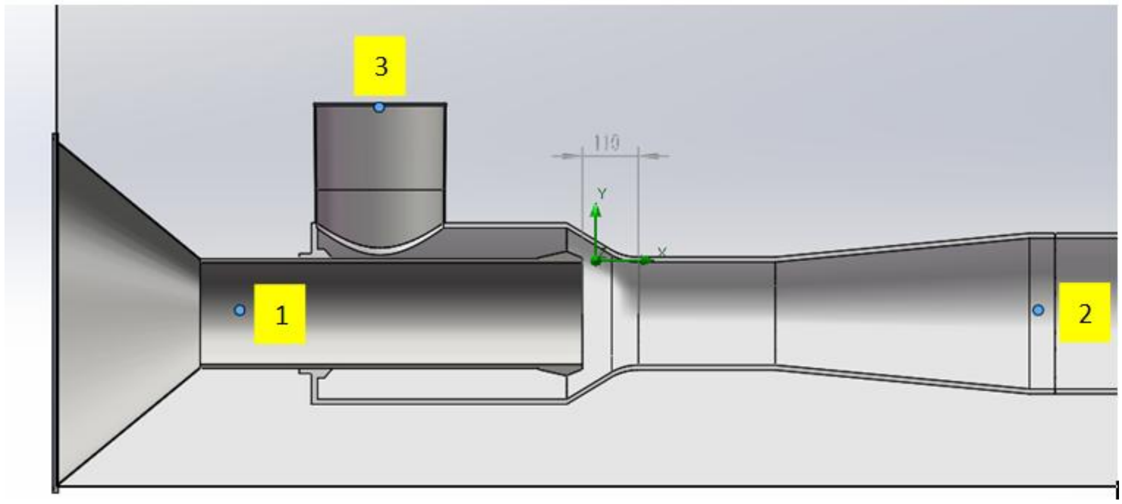


Figure 5.5.15 3 point parameters in the model's sectional view

For the simulation always has some difference with the real test, the value get from the simulation needs to be predict (add the difference) to increase the reliability.
In order to predict the theoretical value which is close to the real, following steps has been take.
First take the results from the Table '**Comparison Test3:Totally underwater(with discharge head)** ', then use the software MATHCAD applying the least square fitting method on these data and get the predicted difference at each length of nozzle which is used in the simulation. The progress in detail is described in next chapter, **'Using MATHCAD for Difference Prediction'**.
(The final table is shown in Appendix F.)

Using MATHCAD for Difference Prediction

In the final table, difference between simulation results and realistic data should be predicted in a certain range. The software MATHCAD is used to analysis the difference changing tendency between existing data and then giving relevant prediction.
As analyzed in the former report, the difference between simulation results and test is showed in the table(Table 5.5.39) below:

Comparison Test3: Totally underwater(with discharge head)								
Gap length	V4					Efficiency		
	Simulation		Real		Difference1	Simulation	Real	Difference2
(mm)	(m/s)	(m3/s)	(m/s)	(m3/h)				
113	2.294	266.09	0.862128	100	-62.42%	47.52%	18%	-62.12%
108	2.241	259.94	1.163873	135	-48.06%	55.31%	28%	-49.38%
103	2.355	273.16	1.379405	160	-41.43%	86.72%	51%	-41.19%
98	2.335	270.84	1.638044	190	-29.85%	82.07%	58%	-29.33%
93	2.51	291.14	2.155321	250	-14.13%	116.46%	68%	-41.61%

Table 5.5.39 Comparison test 3

The prediction is focus on the difference between simulation and real of speed **V4**.As you can see in the table, **Difference1** is gradually decreasing with the shrinking of gap length. **Difference1** is put into a line graph (Figure 5.5.15) to show the changes clearly.

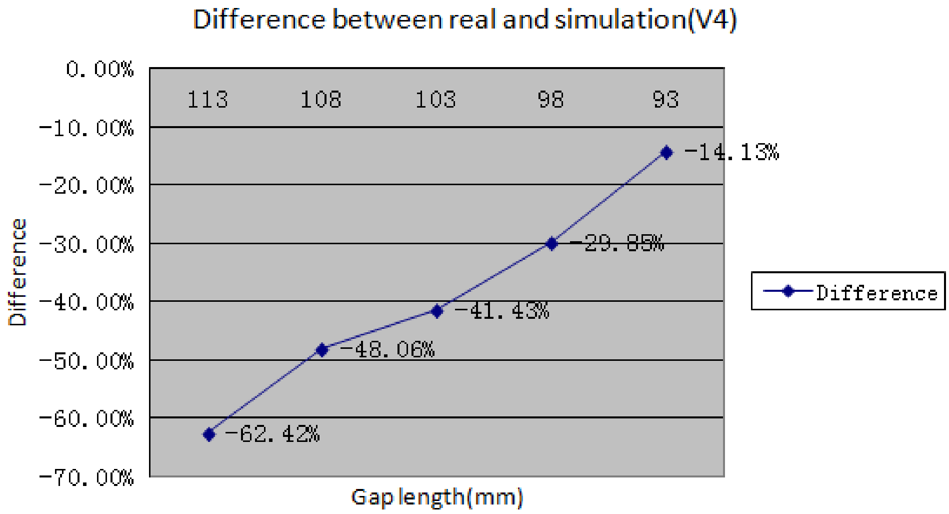


Figure 5.5.15 Difference between real and simulation

The graph shows difference in various gap lengths. But what the company wants to know is that the difference in a certain gap length which they didn't test. So some predictions need to be done to estimate the difference in certain gap length. We estimate that it has a similar tendency in other range not only in gap length from 93mm-113mm. Finally Curve Fitting tool in MATHCAD is chosen to fitting the data and do prediction.

Here's a brief introduction of curve fitting tool:

Curve fitting means finding a mathematical function or plot curve that best fits a set of data. By doing so, you can see patterns in a data set, predict future data points and understand the relationship between different factors.

MATHCAD has a number of specialized curve-fitting functions.

A least squares fit is the method most commonly used to find the line that best fits a set of data. "Least squares" refers to the sum of the squares of the distances from the individual data points to the line itself. A least squares fit finds the smallest possible sum, or closest fit.

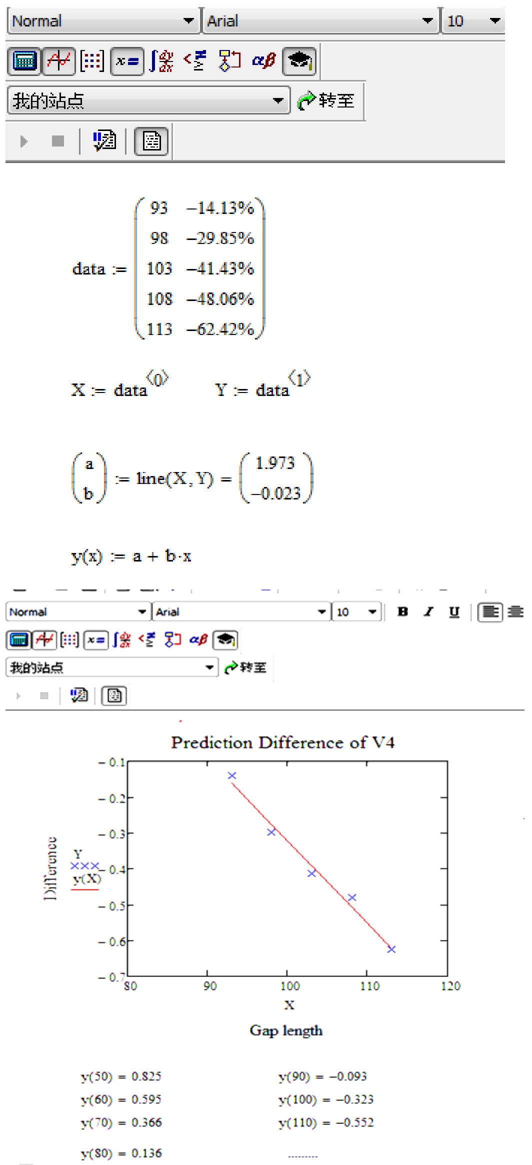


Figure 5.5.16 MathCAD fitted line

In Figure 5.5.16, the existing data are put in the matrix and figured out the fitted line. The software MATHCAD solves the value of the fitted line automatically according to the data we input.

In Figure 5.5.16, the fitted line and input data are showed in the same line graph.xxx represent the point of existing data of difference, the red line -------- represent the fitted line. We can get the desire difference value when we input the gap length.

Finally, transform the V4 to Predicted V4 in the final table by adding the difference.
Following table (Table 5.5.40.) shows the difference of V4 at each gap length. The extent of the reliability for the prediction are shown by different colors. For the gap length in sample data chosen from the 2nd test is from 90mm to 110mm, which the difference between them is 20mm. So it is thought that when the gap length is in the range of 90mm to 110mm, the prediction has the most reliability; When the gap length is from 80mm to 90mm or 110mm to 120mm , ±10mm(50% of difference 20mm) to the range of 90mm to 110mm, the prediction has less reliability; When the gap length is below 80mm or over 120mm, the prediction has the least reliability.

Table 5.5.40 difference of V4 at each gap length

Gap [mm]	Difference [%]
50	82.50%
55	71.00%
60	59.50%
70	36.60%
80	13.60%
85	2.10%
90	-9.30%
100	-32.30%
110	-55.20%
120	-78.20%
130	-101.20%
140	-124.10%

Column in **GREEN** shows the predict with the most reliability;
Column in **YELLOW** shows the predict with less reliability;
Column with **NO COLOR** shows the prediction with the least reliability.

In addition, we regard the prediction of V4 as 'N/A' in final table when the gap length is over 130mm, because the difference is over -100% and it is impossible in the real condition.

Also the efficiency can be predicted other than V4 which can increase the rigorousness of the result. But we found it impossible to do it because the result seems especially unreliable.When doing the simulation by Mathcad, the points of efficiency in the test and its fitted curve is shown below (Figure 5.5.17).

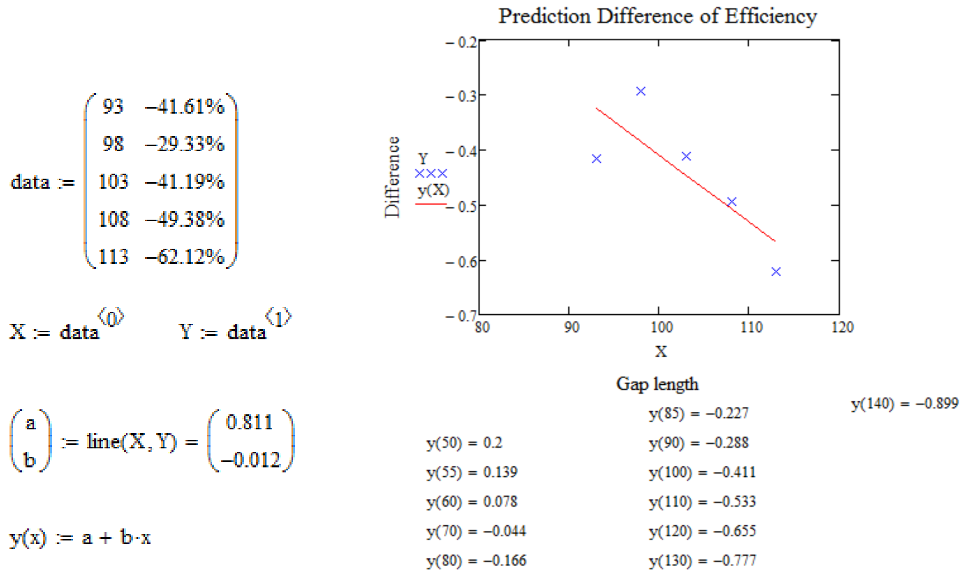


Figure 5.5.17. Prediction for efficiency

Apparently the prediction can't be reliable.It can be seen that the point around the nozzle of 90mm is not on the trend of the other 4 points and we can't be sure whether this is data is indeed the truth or just an accidental data, because in the real test some error may always occur in measuring. For there are only 5 test results can be used, how the curve will change is unknown. Will it be like a parabola or can be linear can't be predicted. So our decision is not to do the prediction for the efficiency.

5.5.4 Best choices for client

After filling in the final table and predict the parameter V4 (figure 5.5.19), it's time to set up a standard for choosing the best result and reorganize them in to the best choice table.

As client has test that the maximum velocity in a pipe is 3m/s, the predicted value for V4(figure 5.5.19) should not be over this value. And for the simulation under the condition that inlet pipe's diameter is 10 inch, V4 cannot be predicted because there is no real test doing under this situation, the comparison can't be made. Also for there is real test data for V5(figure 5.5.19), the prediction for V5 hasn't been made.

The standards for the best result are shown below:

1. Has the highest efficiency
2. Predicted V4 should not be over 3m/s
3. The predicted value should be much reliable as possible

All the standards should be met at the same time.

Take all the standards into the consideration, the best parameter have been chosen, presented by the **Red frame.** The complete final table is demonstrated in Appendix F.

The '**Best choice Table'**, which shows the best solutions of parameters for different pumps as the client required, is shown in **Appendix G.**

The directions for the use of best choice table are shown as follow:

a. Parameters V1 & P6 (figure 5.5.19) are used for representing different types of pump.
b. For the reason that the length of pipe linking the pump and the jet pump is unknown and depends on what the user need, the user needs to calculate what the exact parameter of pump is by considering the loss in the long pipe.
c. Once the user know what the pump they want to use, they can know what are the best solutions for the parameters the jet pump should have to reach the best efficiency. This jet pump refers to the jet pump from Jansen Tholen used in 2nd test. Its fix parameters and the parameters could change are shown in the table.
d. If the user has some other requirement or limitation on the jet pump, they can get help from the reference data in the table.

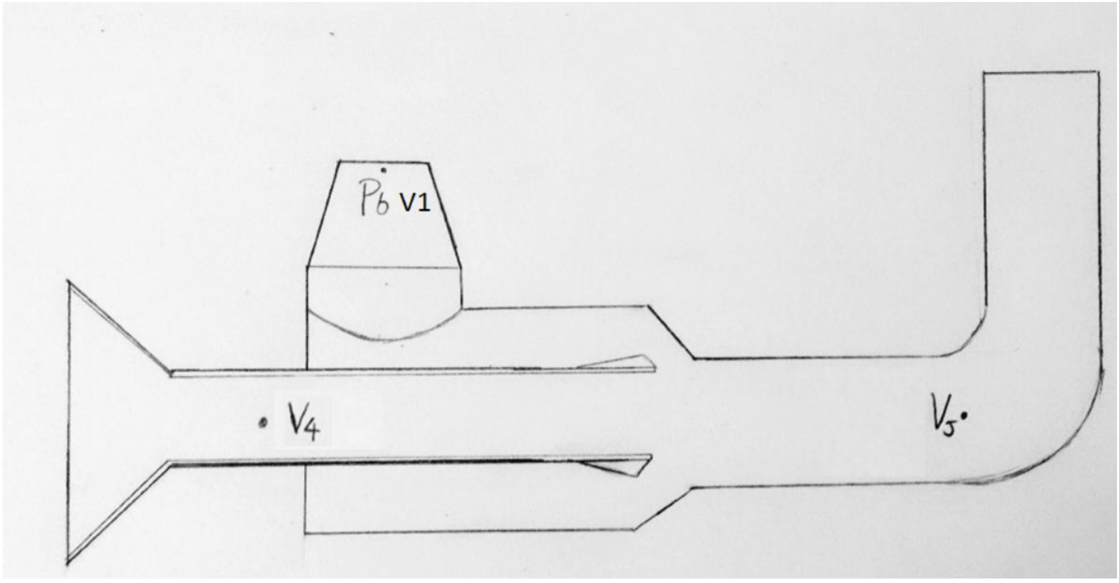


figure 5.5.19 Parameters on jet pump

(The best choice table is shown in Appendix G.)

5.5.5 Extra table of Pressure drop

As the client required for the pressure drop over the system (jet pump, inlet pipe and outlet pipe, inclusive discharge head) at flow rate 200, 400 and 800m3/h in situations as listed below:

- 8 and 10 inch suction pipe
- 3 different gap lengths
- 2, 3 and 5 meter discharge head

The variable inputs are similar to the final table, the fix inputs are completely the same, while the output has been changed to P4, P6, and P3 as shown in the figure (5.5.18). P4 is the pressure in the inlet pipe, P6 is the pressure at the pressure pipe, and P3 is the pressure at the end of discharge head. When the discharge head increase, the point of P7 also changes its position that always at the end of the discharge head.

3 Points shown in the Model's sectional view (figure 5.5.20):

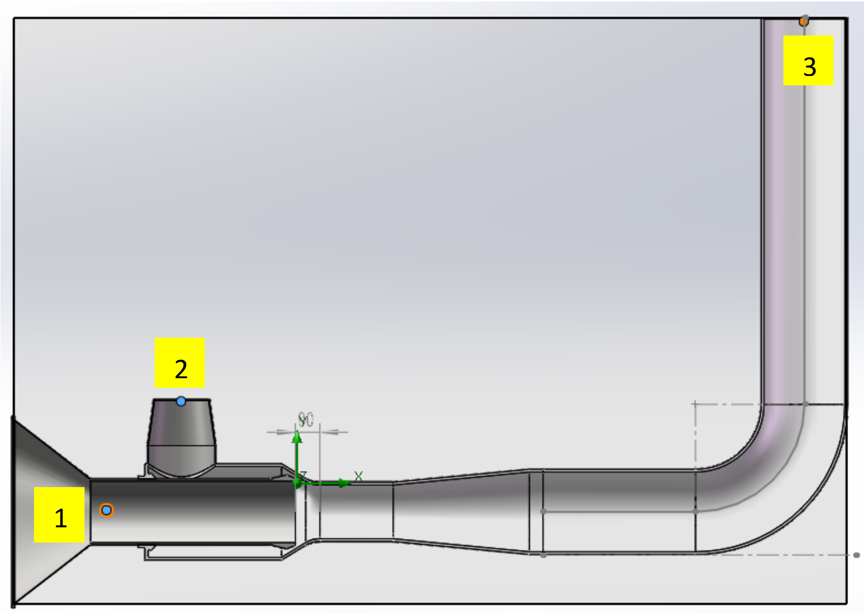


figure 5.5.20 measure points on model's sectional view

The point parameters of P4,P6,P7 is shown below.

Point	X [m]	Y [m]	Z [m]	Measure
1	-0.700	-0.099	1.486	P4
2	-0.426	0.306	1.486	P6
3	1.860	1.720	1.486(discharge=2m) 2.486(discharge=3m) 4.486(discharge=5m)	P3

The two pressure drop we calculate are P4-P3 and P6-P3.
The extra table is made which can meet all the requirements above.
(The complete table and the results are shown in Appendix H.)

6 Conclusions

As the project comes to an end, after completing the project phase by phase, a lot of results comes out. The results for the whole project includes the final table(Appendix F), the best choice table(Appendix G), the extra table(Appendix H),3 one-variable tables(chapter 5.5.2) and a lot of calculation methods(chapter 5.4.2).
The best choice table is the main final product we deliver. It offers 36 best solutions of the jet pump's parameters in all for different kinds of pumps which can fit them as well as reach the highest efficiency. The jet pump refers to jet pump used in company's 2nd test and the 4 parameters of it refers to the diameter of the inlet pipe, diameter of pressure pipe, discharge head and throw flow surface(transform from the gap length) as shown in Figure 6.1 below.

The use method of the best choice table is mentioned in chapter 5.5.4 'Best choices for client'.

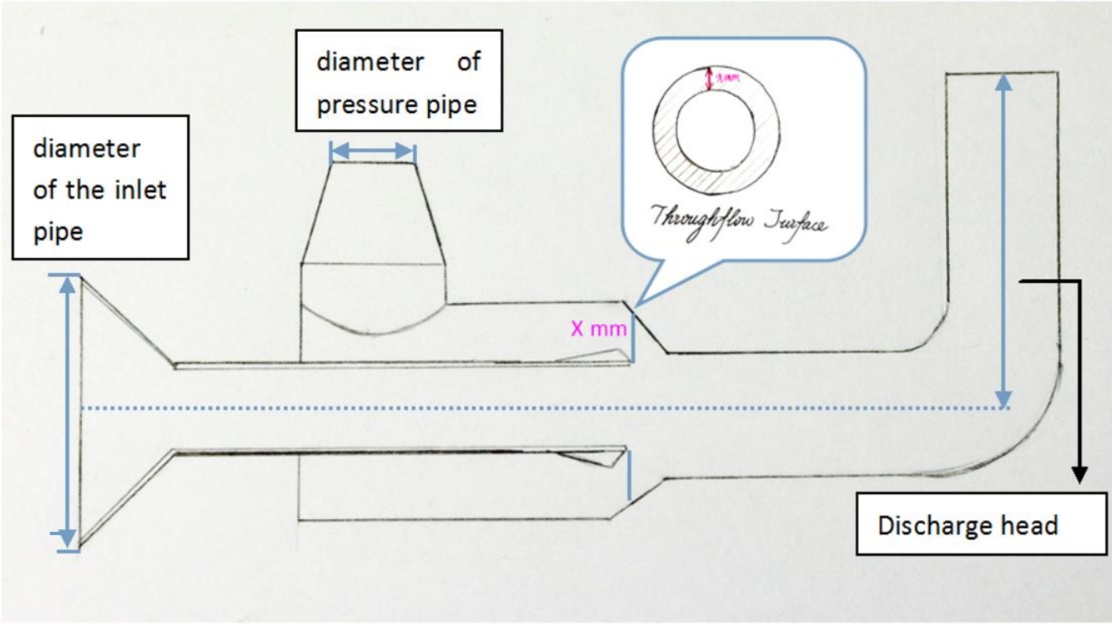


Figure 6.1 Parameters of the jet pump (in best solution)

- All the research questions has been answered.

The questions which get direct answers were answered in the theoretical framework, others were answered and discussed in the detail design phase by designing and filling in the tables mentioned above.

- The results are mutually related and interlocking with each other.

The best choice table is the direct answer to the problem statement, for it shows clearly what are the best solutions of the jet pump's parameters which can fit different pumps and reach the highest efficiency. The best choice table is made from the final table by reorganizing the best solutions in it, while the final table is made by consulting the 3 one-variable tables. The extra table is what the client asked for which is made based on the final table, because the way to do them are quite similar, the difference is that there is one more output measured in extra table and the pressure drop calculation is needed.

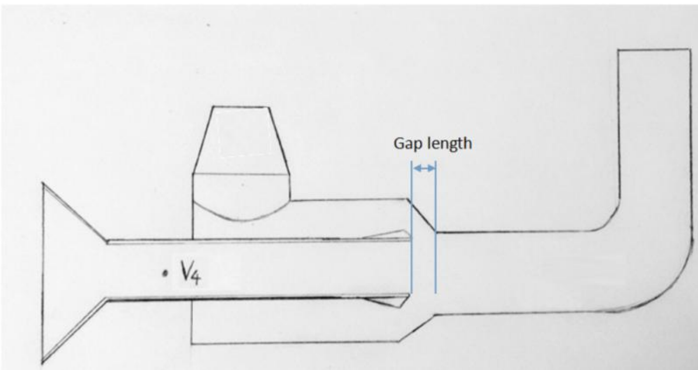


Figure 6.2 V4 and gap length in jet pump

- The results are relatively valid. The validity of the results is discussed below from 3 aspects.

From the perspective of reliability, calculating the difference V4(figure 6.2) between real test and simulation, predicting the difference through least square fit method using Mathcad and using different color to show the reliable extent of prediction, all of these increase the reliability of the result. However, there are also 4 factors that reduce the reliability of results. First is that client only has five sets of data(table 6.1) for the situation that the jet pump placing totally in the water with discharge head, and our prediction and difference calculation for V4 are only based on these five sets of testing data. This is far from enough for getting comparatively accurate result. Second is for the reliable extent of prediction, we can only divide the extent level into three parts: the most reliable, less reliable and not reliable. The less reliable extent is the range ±50% to the range of sample data, which is too wide(see in table 6.2). From now on there's no way to solve it because in sample data the gap length(figure 6.2) changes from 90mm to 110mm which the difference is only 20, if we predict the range ±10% to the sample data which seems more accurate, we can only get prediction under the condition that the gap length changes from 88mm to 90mm and 110mm to 112mm. This range is too small because it may cause almost nothing change on velocity and pressure of water flow, as well as the efficiency of jet pump. The minimum difference of 2 gap length used in simulation is 5mm. But in general the result is reliable. Third one is that we only use V4 for prediction not includes the prediction for efficiency, the results are not so comprehensive. We've done the prediction for the efficiency through Mathcad. However, the result seems not so good. The points of efficiency in the test and its fitted curve are shown below. Apparently the prediction can't be reliable. For there are only 5 test result we can use, we cannot know how the curve will change, will it be like a parabola or can be linear. We are not sure the point around the gap length of 90mm is just like this or just accidental, because in the real test some error may always occur in measuring, which is the fourth point that reduces the reliability of the results.

Comparison Test3:Totally underwater(with discharge head)								
P4		V4				Efficiency		
(bar)						(%)		
Simulation	Real	Simulation (m/s)	Simulation (m3/s)	Real (m3/s)	Difference	Simulation	Real	Difference
1.016	0	2.294	266.09	100	-62.42%	47.52%	18%	-62.12%
1.016	0	2.241	259.94	135	-48.06%	55.31%	28%	-49.37%
1.021	0	2.355	273.16	160	-41.43%	86.72%	51%	-41.19%
1.024	0	2.335	270.84	190	-29.85%	82.07%	58%	-29.33%
1.021	0	2.51	291.14	250	-14.13%	116.46%	68%	-41.61%

Difference= (Real-Simulation)/Simulation*100%

Table 6.1 five sets of sample data

Table 6.2 difference of V4 at each gap length

Gap [mm]	Difference [%]
50	82.50%
55	71.00%
60	59.50%
70	36.60%
80	13.60%
85	2.10%
90	-9.30%
100	-32.30%
110	-55.20%
120	-78.20%
130	-101.20%
140	-124.10%

Row in **GREEN** shows the predict with the most reliability;
Row in **YELLOW** shows the predict with less reliability;
Row with **NO COLOR** shows the prediction with the least reliability.

In aspect of usefulness, the final product we deliver (best choice table)(Appendix G) offers 36 best solutions in all for different kinds of pumps which ought to give the user sufficient choices and abundant solutions. This is what the client wants so it is useful. Also in the best choice table we offer some data for reference, in case the client needs. The one-variable study on the parameters nozzle shape, gap length and outlet pipe angle not only give us some reference when doing the final table but also has its value for the client, they can use these research conclusions during further design.
As regard to user friendly, the title for all the tables are clear and logical, also the direction for using the best choice table has been made, which can help the client use it and understanding it well. The reliable extent has also been clarified by different colors, which is easier for the client to use the table. The only thing that may matter the client is that the client needs to calculate what the exact parameter of pump is by considering the loss in the long pipe because the length of pipe linking the pump and the jet pump is unknown and depends on what the user need.

To sum up, this project has its own scientific meaning to some extent. Because multiple choices for the parameters of jet pump are provided, and the influence of 3 parameters (nozzle shape, gap length and outlet pipe angle) has been studied and analyzed in a scientific way, which can save a lot of time and effort for the client in the future.

7 Practice

This is the professional products and recommendations part of the report, which is also called practice part. In this chapter, we will mainly focus on the objective evaluation of the project as well as improvements in future.

The main result of project is providing a final table (**Appendix F**), as well as a research report on pressure drop (**Appendix H**) and one variable influence (**5.5.2 one variable analysis**). The practical application of the results is that it provides some evidence to prove the influence of one variable such as nozzle shape, gap length. The final table (**Appendix F**) is a possible solution with parameters when the company design new jet pump. The table of pressure drop (**Appendix H**) gives simulation data of pressure drop in the pipe, which provides referential data for the company in designing phase.

But for every report and design, it always can't reach the best level. Of course, there is still a lot of items can be improved in the future. Following every item which can be improved will be stated one by one:

1. Limitation of the realistic data.

   As you see in the report, our project is analysis and prediction based on the practical 2nd test .For example MathCAD is used to fitted the line and predict the value, but the problem is that the test data is limited, usually only 3 to 5 sets of test data for one condition. Therefore it is difficult to see the changing tendency and it is easy to get a wrong conclusion if the data is limited because of the contingency. If the company can do more test and get more test data, maybe the prediction results will be more reliable.

Test 1.Totally underwater(without discharge head)								
Input				Output				
V1	P2	P3	Nozzle	P4	V4	P5	V5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(bar)	(m/s)	(bar)	(m/s)	(%)
700	1.063	1.063	135	1.056	1.212	1.061	3.071	20.08%
673	1.063	1.063	128	1.051	1.574	1.061	3.333	27.13%
608	1.063	1.063	123	1.047	1.779	1.061	3.159	33.94%
560	1.063	1.063	118	1.045	1.91	1.061	3.11	39.56%
530	1.063	1.063	113	1.044	1.943	1.061	3.216	42.52%

2. Prediction for efficiency.

   The final table delivered at the end is based on the prediction for V4 (Figure 7.1), all the best choices are chosen from the speed prediction. But it is also important to predict the efficiency which is an essential factor for company. We tried to do prediction for efficiency in Chapter 5.5.3, but it seems hard to get a satisfied result because of the test results is limited and the data spread out of order in the region. The prediction for efficiency can be analysis again if more test data are collected, and the reliability will be higher.

3. More measuring points during test.

In the 2nd test, the company only measure the pressure V1 and speed P1 (Figure 7.1) at the pressure pipe and pressure P4 speed V4 (Figure7.1).Therefore the analysis can only based on this two points. We even can't compare the pumping back speed V5 (Figure 7.1) to see if the pump can pump back the mussels successfully. It will be a good condition to do further simulation and comparison if it is possible to the measurement at the point V5 (Figure 7.1). But new measuring equipment and the jet pump need to be changed a little to fit in the equipment, it need extra cost and labor. Maybe the enforceability is not high.

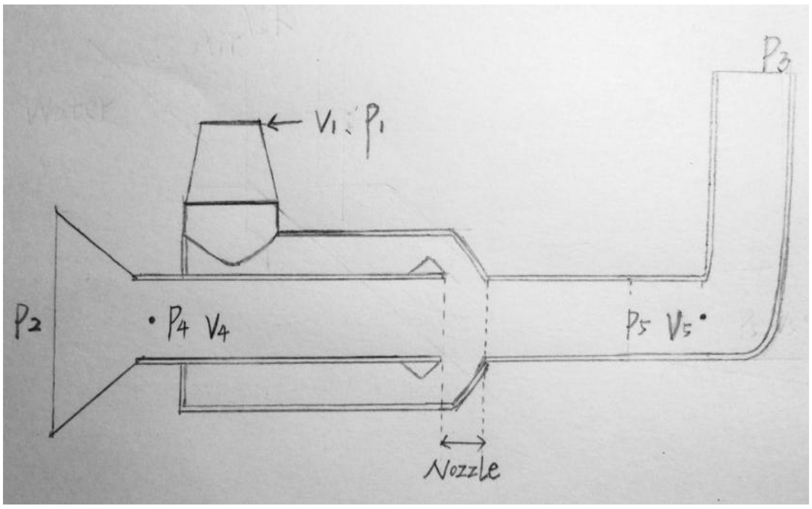


Figure 7.1

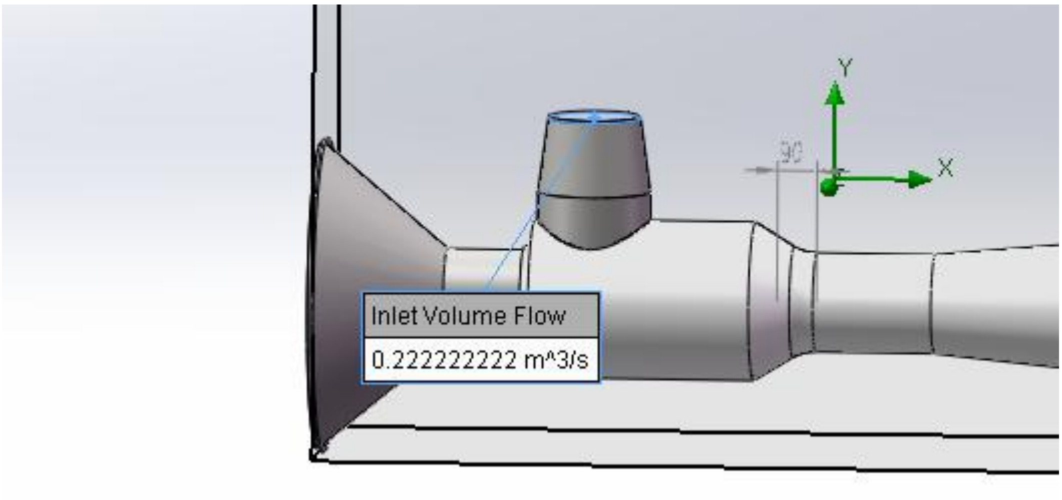
4. Reduce difference between simulation and realistic data.

Each simulation test and comparison, we can see that there always big difference between simulation and real. We have already pay effort to find out some reason that may cause the big difference, but still can't explain the phenomenon. The model itself such as material and parameter, boundary conditions or even the software Solidworks Flow Simulation maybe the reason why there is difference. In further research, improvement can be made on this to reduce the error between research and practical.

Comparation Test1: Totally underwater(without discharge head)								
P4		V4				Efficiency		
(bar)						(%)		
Simulation	Real	Simulation (m/s)	Simulation (m3/h)	Real (m3/h)	Difference1	Simulation	Real	Difference2
1.056	0	1.21	140.70	190	35.04%	20.08%	27%	6.92%
1.051	0	1.56	180.95	270	49.21%	27.13%	40%	12.87%
1.047	0	1.77	204.84	340	65.98%	33.94%	56%	22.06%
1.045	0	1.89	218.88	390	78.18%	39.56%	70%	30.44%
1.044	0	1.94	224.56	450	100.39%	42.52%	85%	42.48%

5. Only one input can be add on the lids.

As you can see in our simulation process, only one boundary condition, pressure or speed can be added on the lid at the same time. But in the realistic test, it can measure two variables speed and pressure at the same time. Therefore it is impossible to compare the two simulation results with the realistic data. Our solution to solve this problem is that we add only the speed on the lid and find another point which is really closed to the lid to measure the pressure. Unavoidable there will be error occur if we do like this, but for the position is closed to the lid which we think can ignore the small error. There may be some other software which can add two inputs at the same time, or better solutions can be found to solve this problem. The accuracy of the data will increase if the two inputs can be added at the same time.



These are some points can be improved in further research.

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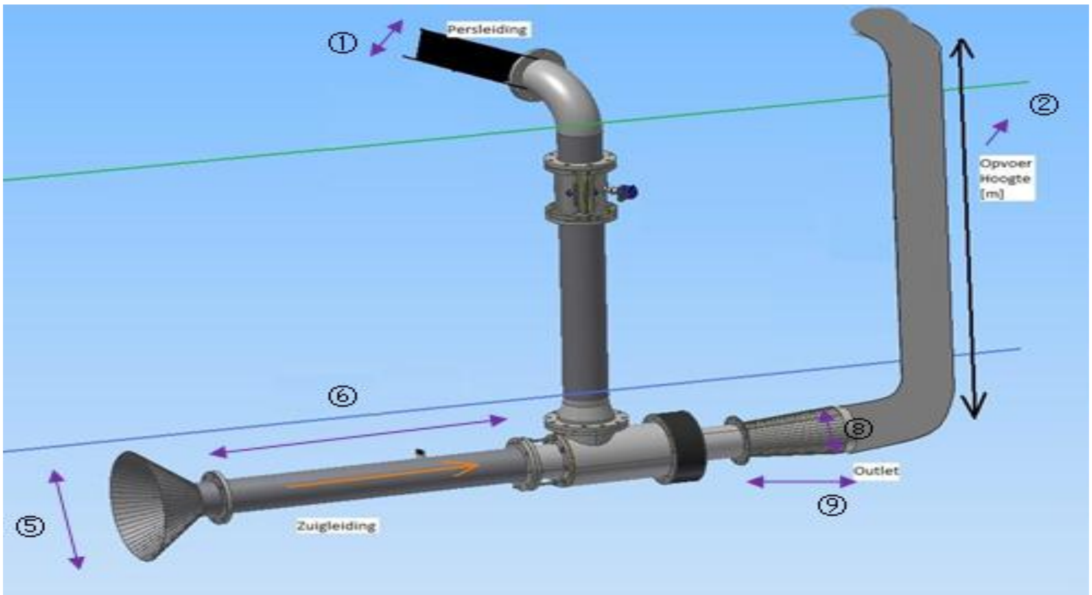
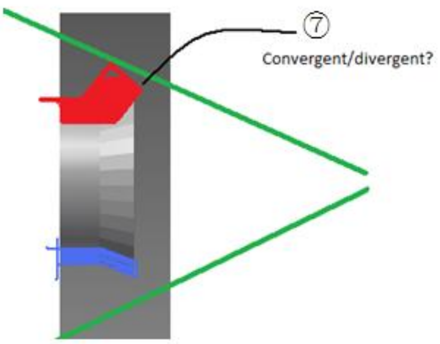
Appendix A: Initial one variable table

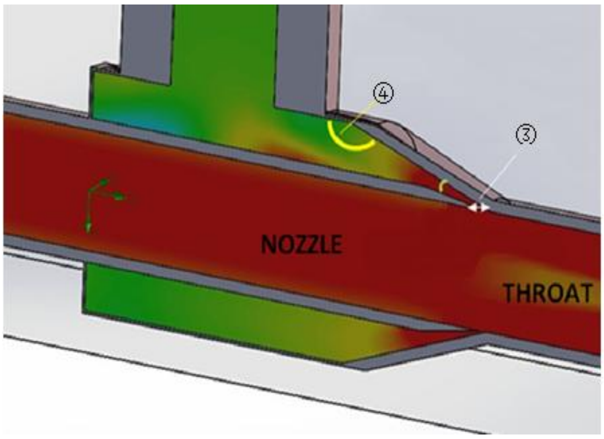
Part 1: Influence of nozzle shape

Green column: fixed value
White column: changing value

	Pump				Jet Pump								Ship
		①			②	③	④	⑤	⑥	⑦	⑧	⑨	
	Turning speed of pump [RPM]	Diameter of pipe [inch]	Volume [m3/h]	Speed [m/s]	Discharge Head [m]	Through flow surfaces [mm]	Angle of outside pump	Diameter of inlet pipe [mm]	Length of inlet pipe [m]	Angle of nozzle [degree]	Diameter of diffuser [mm]	Length of diffuser [mm]	Height of ship's deck [m]
1													
2													
3													
4													
5													
6													





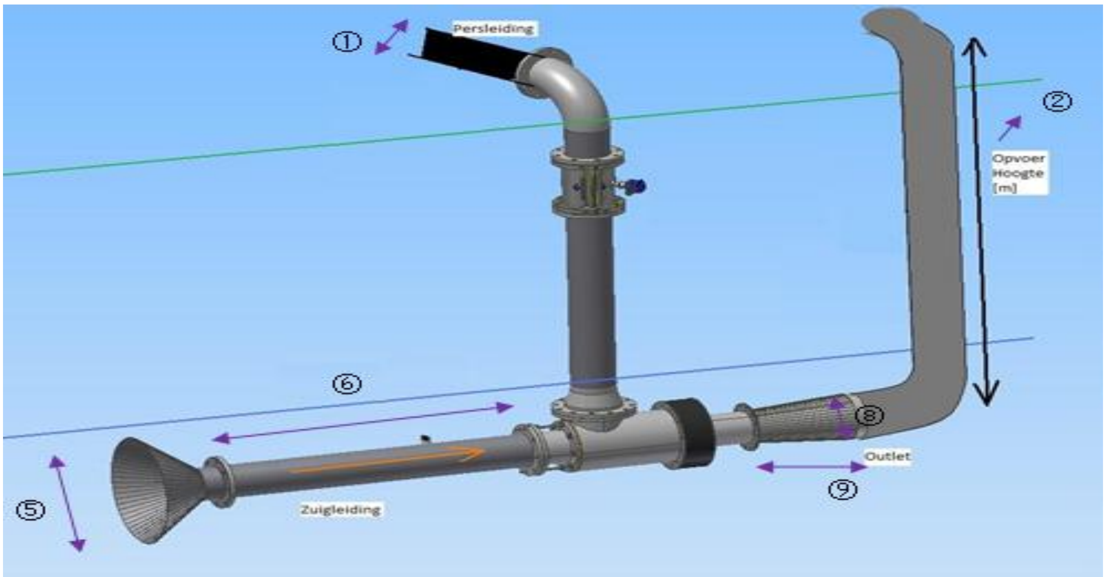


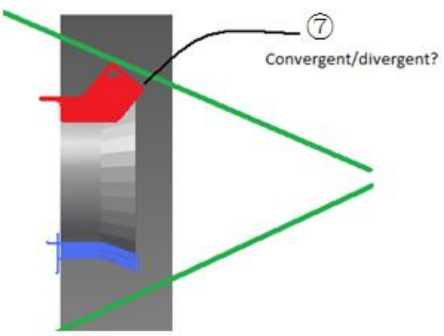
Appendix A: Initial one variable table

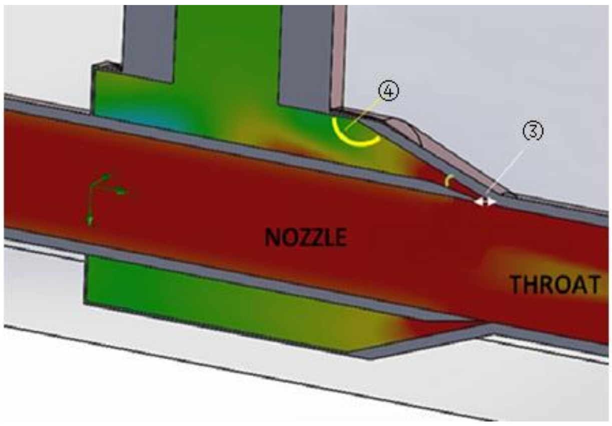
Part 2: Influence of gap length

Green column: fixed value
White column: changing value

	Pump				Jet Pump								Ship
		①			②	③	④	⑤	⑥	⑦	⑧	⑨	
	Turning speed of pump [RPM]	Diameter of pipe [inch]	Volume [m3/h]	Speed [m/s]	Discharge Head [m]	Through flow surfaces [mm]	Angle of outside pump	Diameter of inlet pipe [mm]	Length of inlet pipe [m]	Angle of nozzle [degree]	Diameter of diffuser [mm]	Length of diffuser [mm]	Height of ship's deck [m]
1													
2													
3													
4													
5													
6													





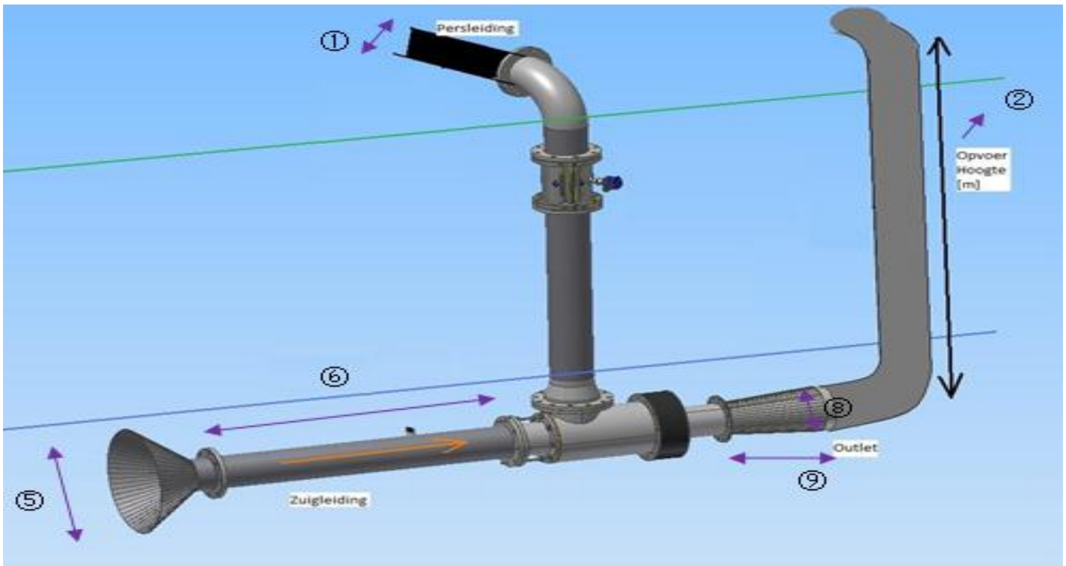


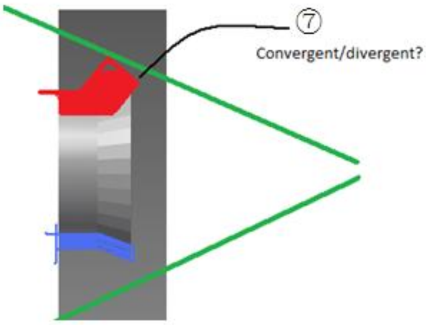
Appendix A: Initial one variable table

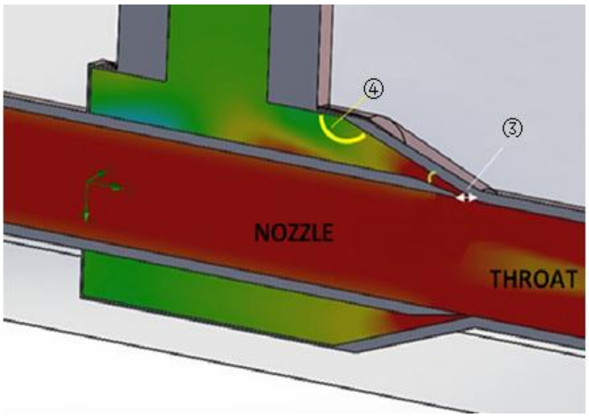
Part 3: Influence of outlet pipe angle

Green column: fixed value
White column: changing value

	Pump				Jet Pump								Ship
		①			②	③	④	⑤	⑥	⑦	⑧	⑨	
	Turning speed of pump [RPM]	Diameter of pipe [inch]	Volume [m3/h]	Speed [m/s]	Discharge Head [m]	Through flow surfaces [mm]	Angle of outside pump	Diameter of inlet pipe [mm]	Length of inlet pipe [m]	Angle of nozzle [degree]	Diameter of diffuser [mm]	Length of diffuser [mm]	Height of ship's deck [m]
1													
2													
3													
4													
5													
6													

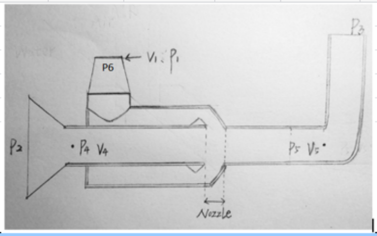






Appendix B: Optimized final table

(green)	Column in GREEN shows the predict with the most reliability;
(yellow)	Column in YELLOW shows the predict with less reliability;
	Column with NO COLOR shows the predict with the least reliability;



INPUT(different pump)					FIX INPUT					OUTPUT							
Diameter of pressure pipe	Diameter of inlet pipe	Discharge head	Gap	Volume	Angle of outside pump	Length of inlet pipe	Angle of nozzle	Diameter of diffuser	Length of diffuser	P4	V4	V4(Predict)	P5	V5	P6	Efficiency	Throwflow surface
[inch]	[inch]		mm	[m3/h]	[degree]	[m]	[degree]	[mm]	[mm]	[pa]	[m/s]	[m/s]	[pa]	[m/s]	[pa]	[%]	m2
4(50.8mm)	8	2		200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
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				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
		3		200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
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				200	148.5	1041.68	12.5	301	550								
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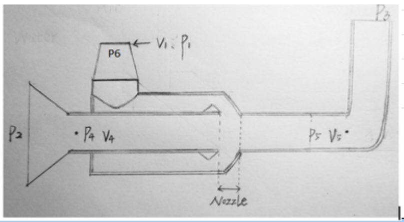
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				801	149.5	1042.68	13.5	302	551								
				800	148.5	1041.68	12.5	301	550								

Appendix B: Optimized final table

Column in GREEN shows the predict with the most reliability;
Column in YELLOW shows the predict with less reliability;
Column with NO COLOR shows the predict with the least reliability;



INPUT(different pump)					FIX INPUT					OUTPUT							
Diameter of pressure pipe	Diameter of inlet pipe	Discharge head	Gap	Volume	Angle of outside pump	Length of inlet pipe	Angle of nozzle	Diameter of diffuser	Length of diffuser	P4	V4	V4(Predict)	P5	V5	P6	Efficiency	Throwflow surface
[inch]	[inch]		mm	[m3/h]	[degree]	[m]	[degree]	[mm]	[mm]	[pa]	[m/s]	[m/s]	[pa]	[m/s]	[pa]	[%]	m2
8	8	2		200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
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				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								

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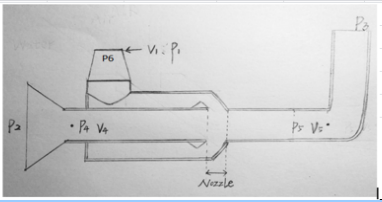
Column in GREEN shows the predict with the most reliability;
Column in YELLOW shows the predict with less reliability;
Column with NO COLOR shows the predict with the least reliability;



INPUT(different pump)					FIX INPUT					OUTPUT							
Diameter of pressure pipe	Diameter of inlet pipe	Discharge head	Gap	Volume	Angle of outside pump	Length of inlet pipe	Angle of nozzle	Diameter of diffuser	Length of diffuser	P4	V4	V4(Predict)	P5	V5	P6	Efficiency	Throwflow surface
[inch]	[inch]		mm	[m3/h]	[degree]	[m]	[degree]	[mm]	[mm]	[pa]	[m/s]	[m/s]	[pa]	[m/s]	[pa]	[%]	m2
10	8	2		200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
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				800	148.5	1041.68	12.5	301	550								
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				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
		5		200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				200	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				400	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								
				800	148.5	1041.68	12.5	301	550								

Appendix C: Optimized one variable table

Gap length:

Test1.1 .Totally underwater1(only gap length changed)									
Input					Output				
V1	P2	P3	Nozzle	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					
540	1.063	1.063		12.92					

Test1.2 .Totally underwater1(nozzle gap length 65mm)										
Input			Input			Output				
V1	P2	P3	Nozzle	Outlet pipe	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(degree)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	1.063	1.063	65		12.92					
540	1.063	1.063	65		12.92					
540	1.063	1.063	65		12.92					
540	1.063	1.063	65		12.92					
540	1.063	1.063	65		12.92					
540	1.063	1.063	65		12.92					

Angle of outside pipe:

Test1.1 .Totally underwater1(nozzle gap length 75mm)										
Input						Output				
V1	P2	P3	Nozzle	Outlet pipe	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(degree)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	1.063	1.063	75		12.92					
540	1.063	1.063	75		12.92					
540	1.063	1.063	75		12.92					
540	1.063	1.063	75		12.92					
540	1.063	1.063	75		12.92					
540	1.063	1.063	75		12.92					

Appendix C: Optimized one variable table

Nozzle shape:

Test1.1 .Totally underwater1(only nozzle shape changed+)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	0.6	1.063	1.063	75	0					0.00%
540	0.6	1.063	1.063	75	2.92					0.00%
540	0.6	1.063	1.063	75	4.92					0.00%
540	0.6	1.063	1.063	75	6.92					0.00%
540	0.6	1.063	1.063	75	8.92					0.00%
540	0.6	1.063	1.063	75	10.92					0.00%
540	0.6	1.063	1.063	75	12.92					0.00%
540	0.6	1.063	1.063	75	14.92					0.00%
540	0.6	1.063	1.063	75	16.92					0.00%
540	0.6	1.063	1.063	75	18.92					0.00%
540	0.6	1.063	1.063	75	20.92					0.00%
540	0.6	1.063	1.063	75	22.92					0.00%
540	0.6	1.063	1.063	75	24.92					0.00%

Test1.2 .Totally underwater2(only nozzle shape changed+)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle sha	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
530	0.5	1.063	1.063	113	0					0.00%
530	0.5	1.063	1.063	113	2.92					0.00%
530	0.5	1.063	1.063	113	4.92					0.00%
530	0.5	1.063	1.063	113	6.92					0.00%
530	0.5	1.063	1.063	113	8.92					0.00%
530	0.5	1.063	1.063	113	10.92					0.00%
530	0.5	1.063	1.063	113	12.92					0.00%
530	0.5	1.063	1.063	113	14.92					0.00%
530	0.5	1.063	1.063	113	16.92					0.00%
530	0.5	1.063	1.063	113	18.92					0.00%
530	0.5	1.063	1.063	113	20.92					0.00%

Test2.1 .Totally underwater1(only nozzle shape changed-)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle shape	V4	P4	V5	P5	Efficiency
(m3/h	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
540	0.6	1.063	1.063	75	-4.5					0.00%
540	0.6	1.063	1.063	75	-5.5					0.00%
540	0.6	1.063	1.063	75	-6.5					0.00%
540	0.6	1.063	1.063	75	-7.5					0.00%
540	0.6	1.063	1.063	75	-8.5					0.00%
540	0.6	1.063	1.063	75	-9.5					0.00%
540	0.6	1.063	1.063	75	-10.5					0.00%
540	0.6	1.063	1.063	75	-11.5					0.00%
540	0.6	1.063	1.063	75	-12.5					0.00%
540	0.6	1.063	1.063	75	-13.5					0.00%

Test2.2 .Totally underwater2(only nozzle shape changed-)										
Input						Output				
V1	P1	P2	P3	Nozzle	Nozzle sha	V4	P4	V5	P5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(degree)	(m/s)	(pa)	(m/s)	(pa)	(%)
530	0.5	1.063	1.063	113	-4.5					0.00%
530	0.5	1.063	1.063	113	-5.5					0.00%
530	0.5	1.063	1.063	113	-6.5					0.00%
530	0.5	1.063	1.063	113	-7.5					0.00%
530	0.5	1.063	1.063	113	-8.5					0.00%
530	0.5	1.063	1.063	113	-9.5					0.00%
530	0.5	1.063	1.063	113	-10.5					0.00%
530	0.5	1.063	1.063	113	-11.5					0.00%
530	0.5	1.063	1.063	113	-12.5					0.00%
530	0.5	1.063	1.063	113	-13.5					0.00%

Appendix D: Comparison table

Test 1. Totally underwater (without discharge head)								
Input				Output				
V1	P2	P3	Nozzle	P4	V4	P5	V5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(bar)	(m/s)	(bar)	(m/s)	(%)

Comparation Test1: Totally underwater (without discharge head)								
P4		V4				Efficiency		
(bar)						(%)		
Simulation	Real	Simulation (m/s)	Simulation (m3/h)	Real (m3/h)	Difference1	Simulation	Real	Difference2

Test 2. Partly underwater (without discharge head)								
Input				Output				
V1	P2	P3	Nozzle	P4	V4	P5	V5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(bar)	(m/s)	(bar)	(m/s)	(%)

Comparation Test2: Partly underwater (without discharge head)								
P4		V4				Efficiency		
(bar)						(%)		
Simulation	Real	Simulation (m/s)	Simulation (m3/h)	Real (m3/h)	Difference	Simulation	Real	Difference

Appendix D: Comparison table

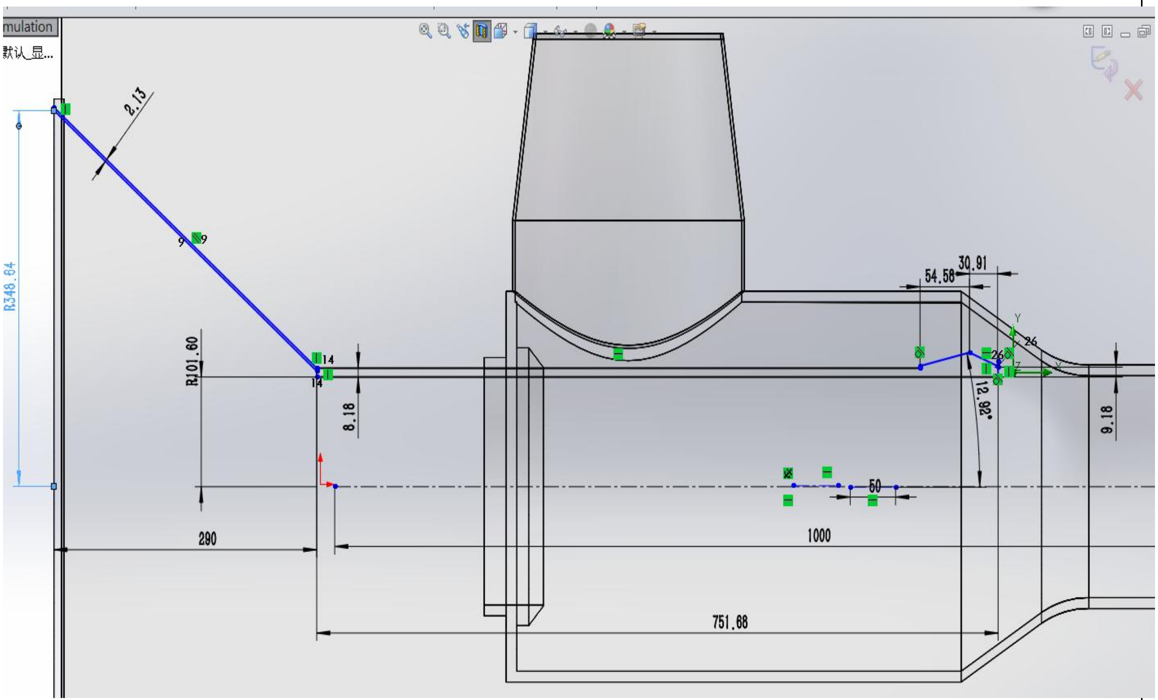
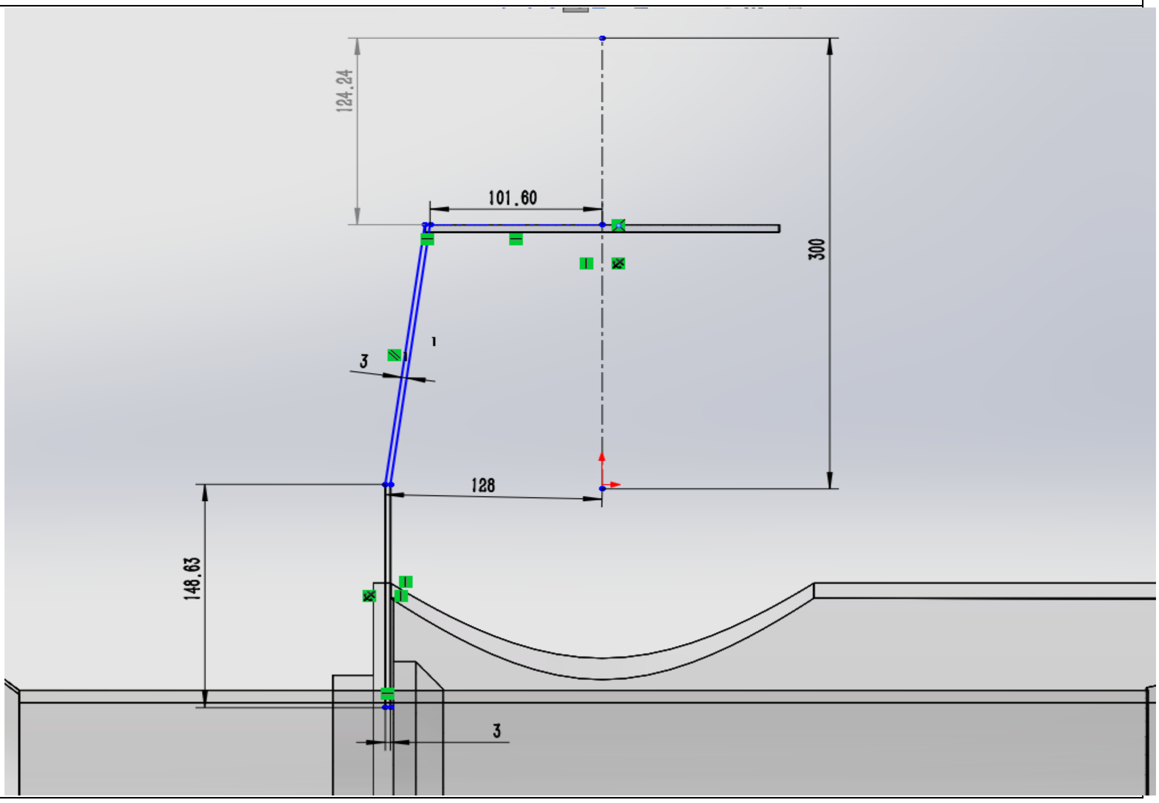
Test 3. Totally underwater (with discharge head)								
Input				Output				
V1	P2	P3	Nozzle	P4	V4	P5	V5	Efficiency
(m3/h)	(bar)	(bar)	(mm)	(bar)	(m/s)	(bar)	(m/s)	(%)

Comparation Test3: Totally underwater (with discharge head)								
P4		V4				Efficiency		
(bar)						(%)		
Simulation	Real	Simulation **(m/s)**	**(m3/h)**	Real	Difference	Simulation	Real	Difference

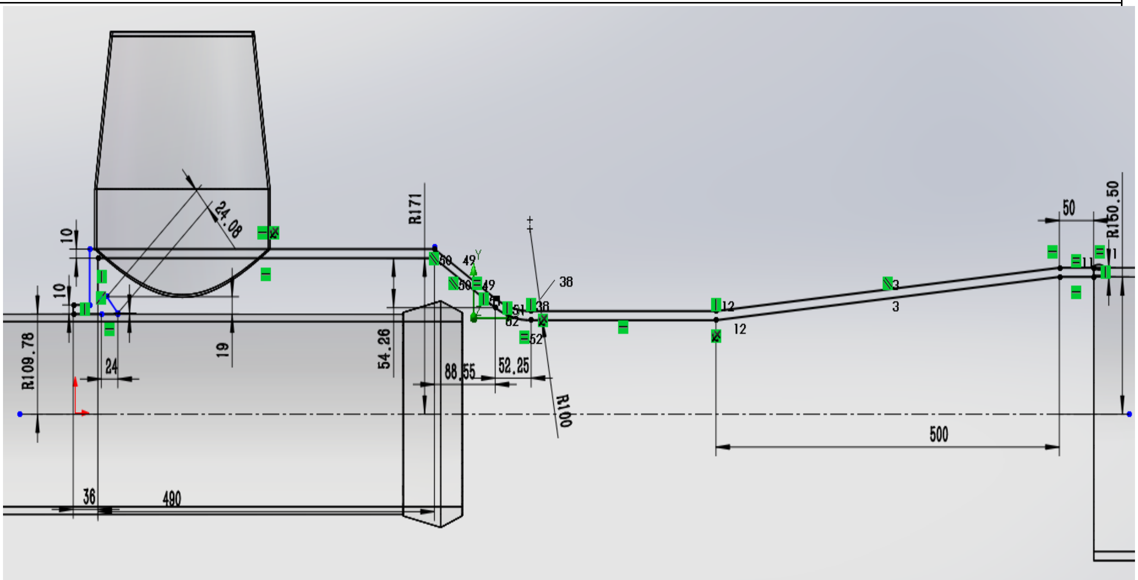
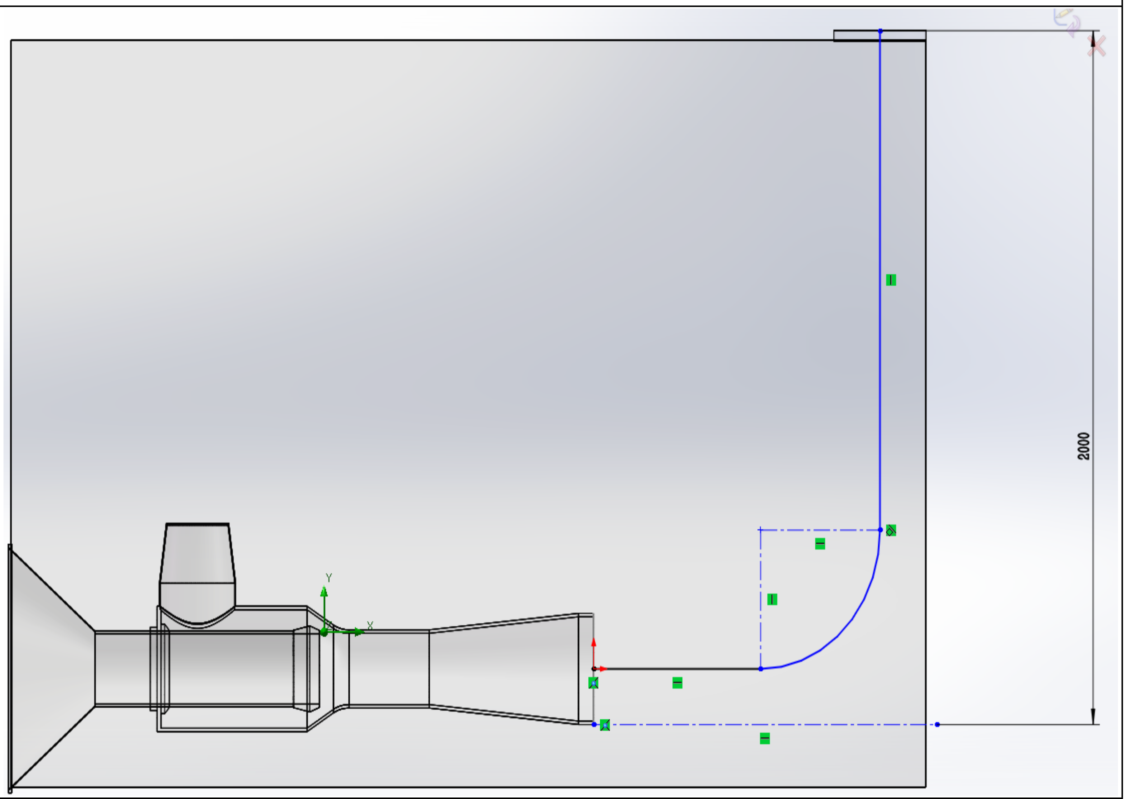
Test 4. Totally underwater (only change speed)							
Input					Output		
V1	P1	P2	P3	Nozzle	V4	V5	Efficiency
(m3/h)	(bar)	(bar)	(bar)	(mm)	(m/s)	(m/s)	(%)

Comparation Test4: Totally underwater (only change speed)						
V4				Efficiency		
(m3/s)				(%)		
Simulation **(m/s)**		Real	Difference	Simulation	Real	Difference

Appendix E: Simplified model

Inlet Pipe

Pressure Pipe


Appendix E: Simplified model

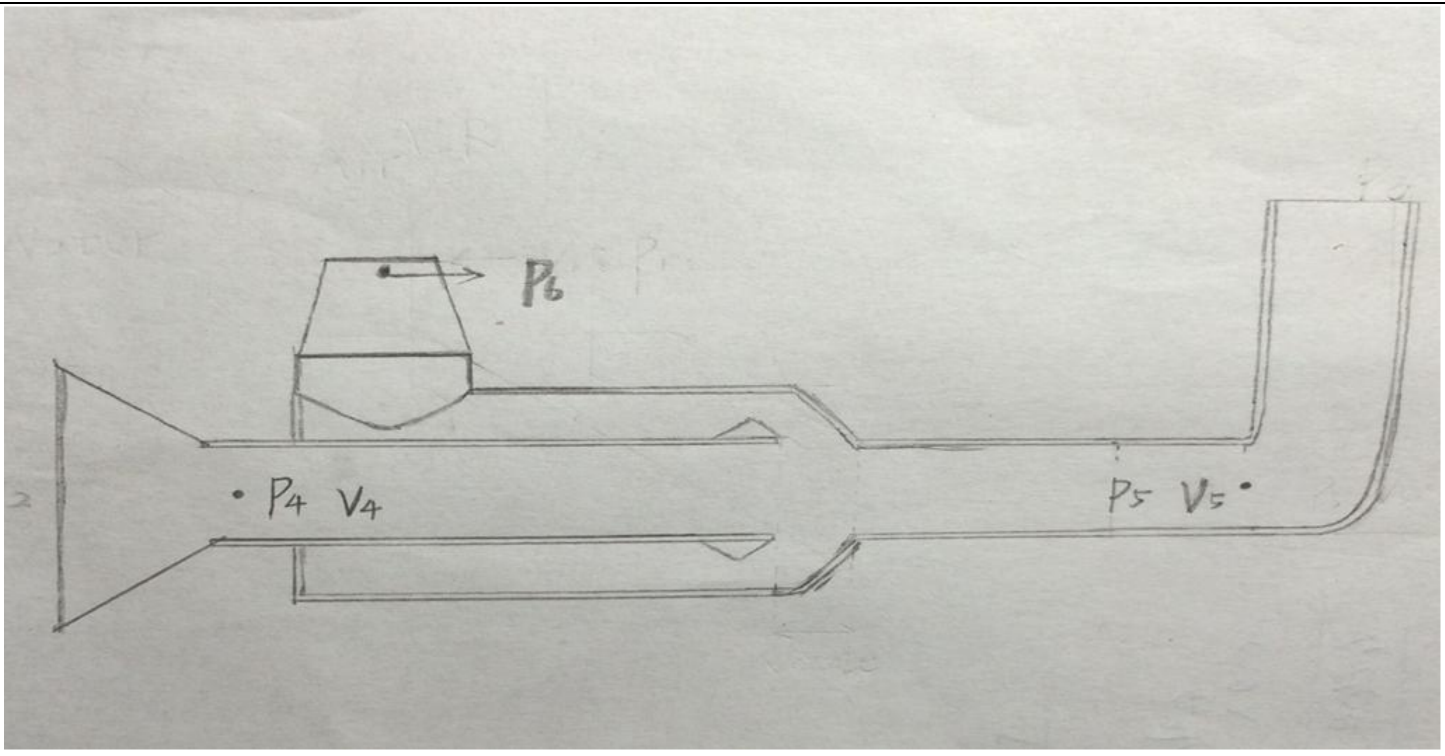
Main Body(Outlet pipe + Discharge head)

Discharge Head


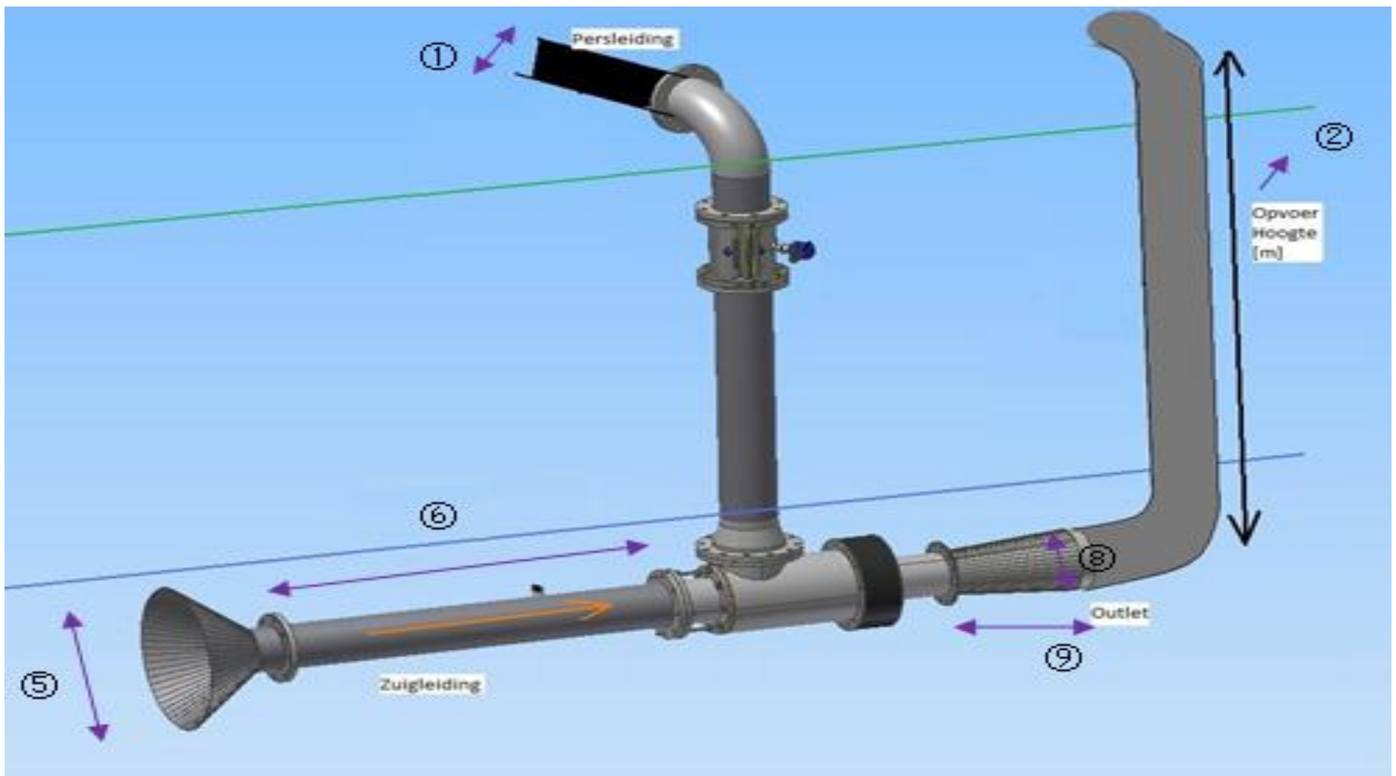
Appendix F: Final table

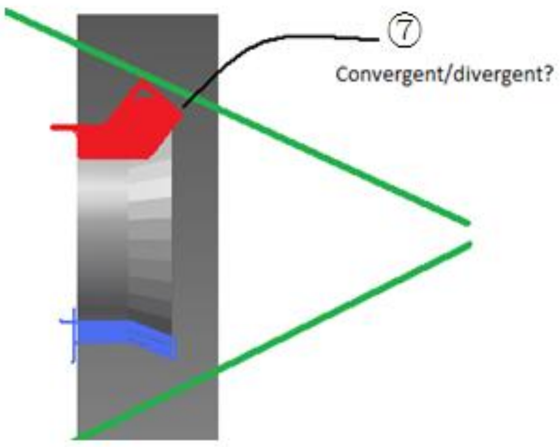
(green)	Column in GREEN shows the predict with the most reliability;
(yellow)	Column in YELLOW shows the predict with less reliability;
(no color)	Column with NO COLOR shows the predict with the least reliability;

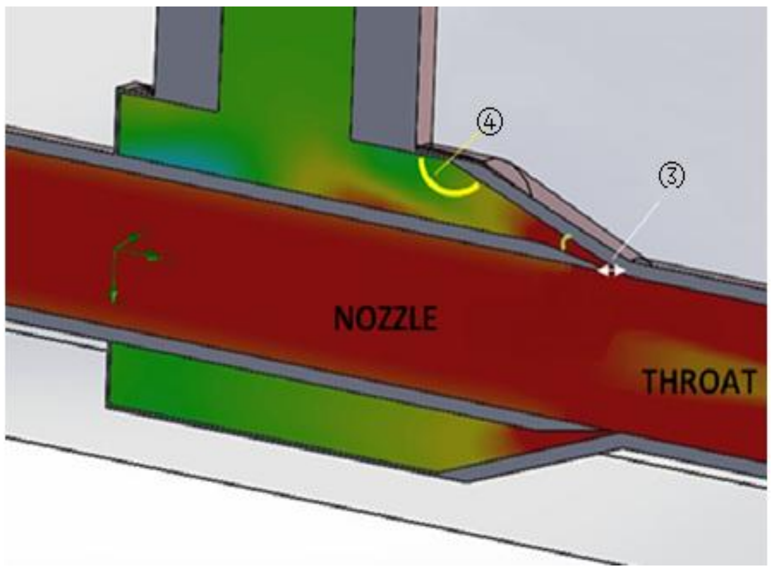
INPUT(different pump)					FIX INPUT					OUTPUT							
①	⑤	②	③		④	⑥	⑦	⑧	⑨								
Diameter of pressure pipe	Diameter of inlet pipe	Discharge head	Gap	Volume	Angle of outside pump	Length of inlet pipe	Angle of nozzle	Diameter of diffuser	Length of diffuser	P4	V4	V4(Predict)	P5	V5	P6	Efficiency	Throwflow surface
[inch]	[inch]	[m]	[mm]	[m3/h]	[degree]	[m]	[degree]	[mm]	[mm]	[pa]	[m/s]	[m/s]	[pa]	[m/s]	[pa]	[%]	[m2]
4(50.8mm)	8	2	60	200	148.5	1041.68	12.5	301	550	101647.46	3.1	4.9445	101306.02	2.89	124099.54	180.86%	0.00779
			70	200	148.5	1041.68	12.5	301	550	102185.47	2.921	3.990086	101339.08	2.695	105756.84	170.42%	0.01256
			80	200	148.5	1041.68	12.5	301	550	102427.78	2.826	3.210336	101155.74	2.461	99112.57	164.88%	0.01757
			90	200	148.5	1041.68	12.5	301	550	102465.14	2.812	2.550484	101174.84	2.536	96953.64	164.06%	0.02281
			100	200	148.5	1041.68	12.5	301	550	102478.82	2.799	1.894923	101288.54	2.63	95771.11	163.30%	0.02828
			110	200	148.5	1041.68	12.5	301	550	102830.2	2.674	1.197952	101134.44	2.436	94554.99	156.01%	0.03398
			70	400	148.5	1041.68	12.5	301	550	99694.74	3.702	5.056932	101933.04	3.739	117671.03	107.99%	0.01256
			80	400	148.5	1041.68	12.5	301	550	101221.33	3.231	3.670416	101757.75	3.649	90821.03	94.25%	0.01757
			90	400	148.5	1041.68	12.5	301	550	101910.72	3.001	2.721907	101622.54	3.3	81923.22	87.54%	0.02281
			100	400	148.5	1041.68	12.5	301	550	102612.4	2.758	1.867166	101469.93	3.151	78090.82	80.46%	0.02828
			90	800	148.5	1041.68	12.5	301	550	96746.02	4.443	4.029801	102981.55	5.796	19219.11	64.80%	0.02281
			100	800	148.5	1041.68	12.5	301	550	99155.18	3.84	2.59968	102253.12	5.359	3549.87	56.01%	0.02828
			110	800	148.5	1041.68	12.5	301	550	101647.92	3.099	1.388352	100931.72	4.767	-23673.58	45.20%	0.03398
			120	800	148.5	1041.68	12.5	301	550	102931.47	2.641	0.575738	101115.42	4.43	-42072.36	38.52%	0.03992
		3	60	200	148.5	1041.68	12.5	301	550	100824.5	3.537	5.641515	101827.35	3.006	149492.86	206.36%	0.00779
			70	200	148.5	1041.68	12.5	301	550	101858.49	3.188	4.354808	101406.44	2.968	106637.59	186.00%	0.01256
			80	200	148.5	1041.68	12.5	301	550	102254.68	3.032	3.444352	101356.79	2.887	100066.56	176.90%	0.01757
			90	200	148.5	1041.68	12.5	301	550	102497.07	2.95	2.67565	101152.94	2.655	97637.78	172.11%	0.02281
			100	200	148.5	1041.68	12.5	301	550	102587.96	2.92	1.97684	101129.64	2.611	95076.35	170.36%	0.02828
			60	400	148.5	1041.68	12.5	301	550	94261.67	5.279	8.420005	102796.56	3.767	291216.9	154.00%	0.00779
			80	400	148.5	1041.68	12.5	301	550	100796.37	3.54	4.02144	101801.74	3.813	96355.06	103.27%	0.01757
			90	400	148.5	1041.68	12.5	301	550	102042.18	3.122	2.831654	101770.7	3.635	84683.24	91.07%	0.02281
			100	400	148.5	1041.68	12.5	301	550	102828.09	2.825	1.912525	101458.68	3.344	75624.19	82.41%	0.02828
			110	400	148.5	1041.68	12.5	301	550	103242.31	2.677	1.199296	101554.72	3.183	75276.5	78.09%	0.03398
			80	800	148.5	1041.68	12.5	301	550	91626.25	5.8	6.5888	102075.78	6.568	76461.48	84.60%	0.01757
			100	800	148.5	1041.68	12.5	301	550	99453.51	3.973	2.689721	102325.41	5.818	-7950.77	57.95%	0.02828
			110	800	148.5	1041.68	12.5	301	550	101408.19	3.378	1.513344	101942.25	5.351	-15927.26	49.27%	0.03398
			120	800	148.5	1041.68	12.5	301	550	101275.82	3.455	0.75319	100838.27	4.873	-28534.7	50.39%	0.03992
		5	60	200	148.5	1041.68	12.5	301	550	101561.12	3.203	5.108785	101800.33	2.971	139936.91	186.87%	0.00779
			70	200	148.5	1041.68	12.5	301	550	102337.82	2.929	4.001014	101577.24	2.862	112528.76	170.89%	0.01256
			80	200	148.5	1041.68	12.5	301	550	102653.42	2.817	3.200112	101326.36	2.692	101527.69	164.35%	0.01757
			90	200	148.5	1041.68	12.5	301	550	102557.13	2.852	2.586764	101412.43	2.66	96395.24	166.39%	0.02281
			100	200	148.5	1041.68	12.5	301	550	102557.46	2.849	1.928773	101398.53	2.647	96391.67	166.22%	0.02828
			110	200	148.5	1041.68	12.5	301	550	102500.15	2.854	1.278592	101455.01	2.669	96129.84	166.51%	0.03398
			60	400	148.5	1041.68	12.5	301	550	96482.04	4.61	7.35295	102968.89	4.305	252477.07	134.48%	0.00779
			80	400	148.5	1041.68	12.5	301	550	101407.92	3.268	3.712448	102001.72	3.801	100438	95.33%	0.01757
			90	400	148.5	1041.68	12.5	301	550	102416.68	2.914	2.642998	101785.35	3.525	86763.43	85.01%	0.02281
			100	400	148.5	1041.68	12.5	301	550	102818.17	2.758	1.867166	101993.23	3.33	80231.75	80.46%	0.02828
			110	400	148.5	1041.68	12.5	301	550	103155.07	2.596	1.163008	101804.51	3.141	78884.14	75.73%	0.03398
			80	800	148.5	1041.68	12.5	301	550	93493.36	5.274	5.991264	103620.41	6.835	90517.02	76.93%	0.01757
			110	800	148.5	1041.68	12.5	301	550	100856.17	3.423	1.533504	102858.76	5.367	5931.92	49.93%	0.03398
			120	800	148.5	1041.68	12.5	301	550	102739.71	2.757	0.601026	102238.63	4.908	856.89	40.21%	0.03992
			130	801	149.5	1042.68	13.5	302	551	103672.33	2.354	N/A	102250.65	4.67	-13373.57	34.29%	0.04609
			140	800	148.5	1041.68	12.5	301	550	103710.1	2.34	N/A	101300.57	4.697	-26140.63	34.13%	0.05250

Appendix F: Final table







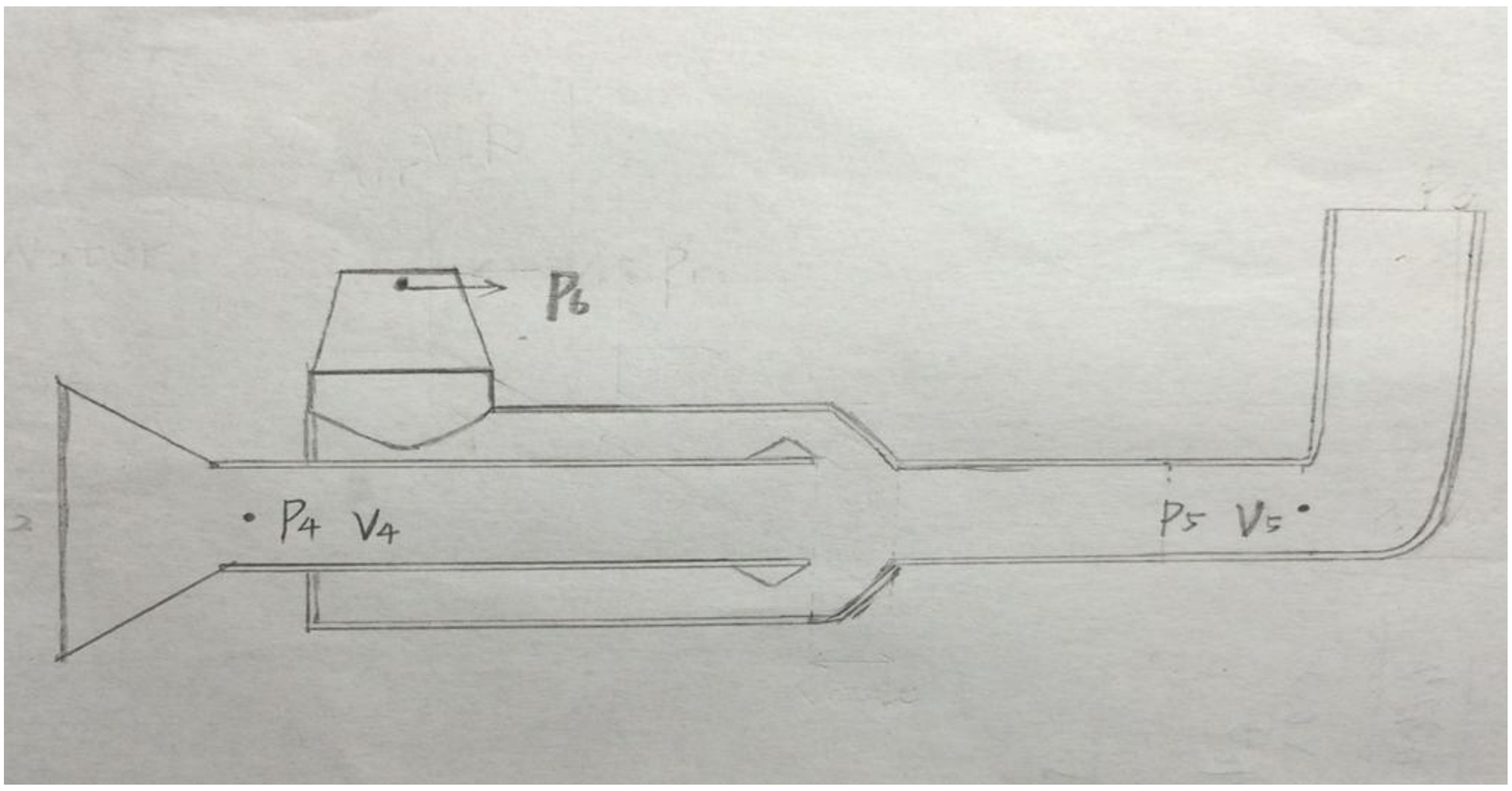


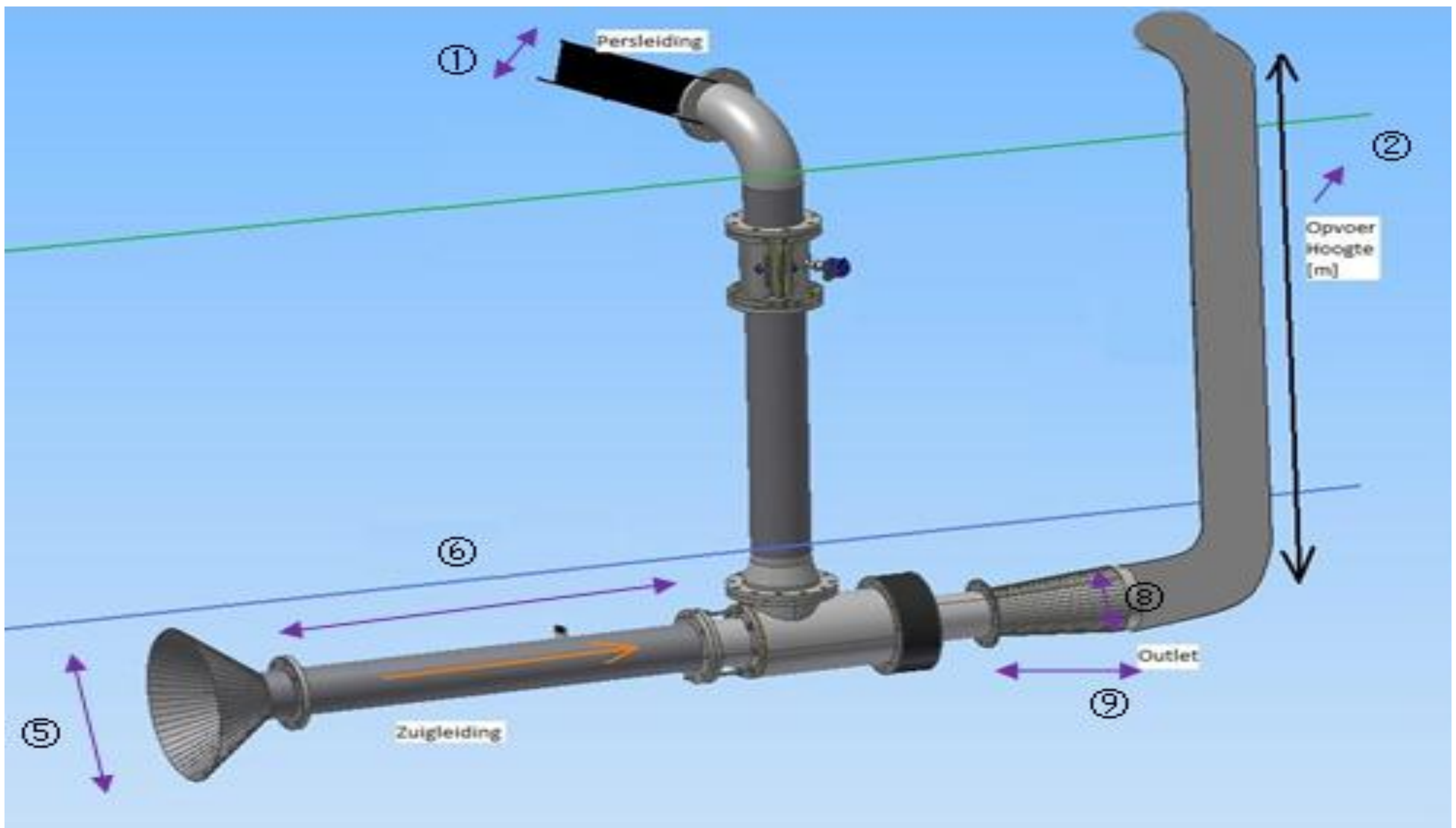
Appendix F: Final table

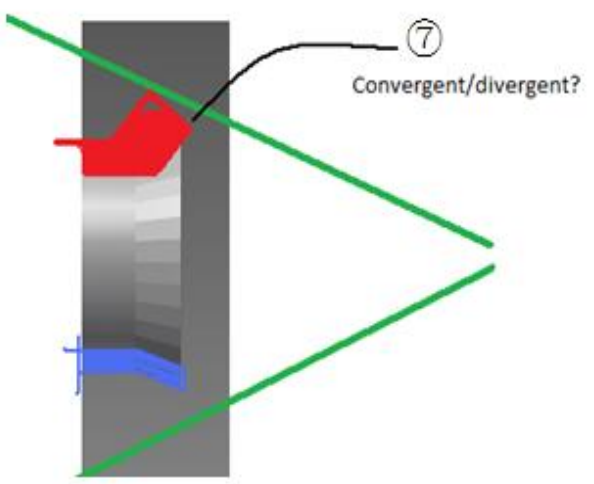
Column in GREEN shows the predict with the most reliability;
Column in YELLOW shows the predict with less reliability;
Column with NO COLOR shows the predict with the least reliability;

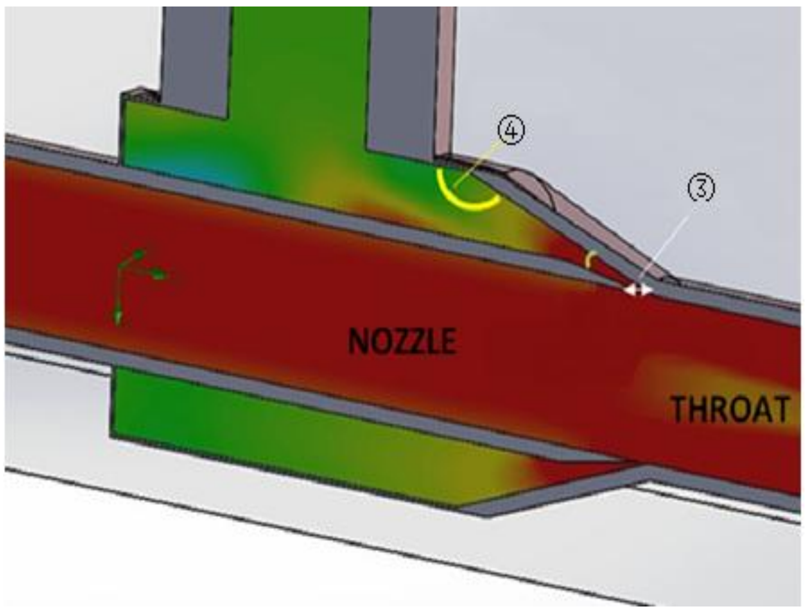
INPUT(different pump)					FIX INPUT					OUTPUT							
①	⑤	②	③		④	⑥	⑦	⑧	⑨								
Diameter of pressure pipe	Diameter of inlet pipe	Discharge head	Gap	Volume	Angle of outside pump	Length of inlet pipe	Angle of nozzle	Diameter of diffuser	Length of diffuser	P4	V4	V4(Predict)	P5	V5	P6	Efficiency	Throwflow surface
[inch]	[inch]	[m]	[mm]	[m3/h]	[degree]	[m]	[degree]	[mm]	[mm]	[pa]	[m/s]	[m/s]	[pa]	[m/s]	[pa]	[%]	[m2]
8	8	2	55	200	148.5	1041.68	12.5	301	550	99544	4.017	6.86907	101927.16	3.251	223284.11	234.36%	0.00550
			70	200	148.5	1041.68	12.5	301	550	103194.86	2.654	3.625364	101199.33	2.918	111044.63	154.84%	0.01256
			80	200	148.5	1041.68	12.5	301	550	103052.57	2.718	3.087648	101320.39	3.044	107898.44	158.58%	0.01757
			85	200	148.5	1041.68	12.5	301	550	102500.75	2.845	2.904745	101284.45	2.676	107035.15	165.99%	0.02016
			90	200	148.5	1041.68	12.5	301	550	102516.6	2.838	2.574066	101256.86	2.651	106086.11	165.58%	0.02281
			60	400	148.5	1041.68	12.5	301	550	99563.89	3.641	5.807395	100672.08	4.706	202016.61	106.21%	0.00779
			70	400	148.5	1041.68	12.5	301	550	101342.8	3.127	4.271482	101104.25	4.023	149258.42	91.22%	0.01256
			80	400	148.5	1041.68	12.5	301	550	102647.12	2.823	3.206928	101696.94	3.607	124192.92	82.35%	0.01757
			90	400	148.5	1041.68	12.5	301	550	102478.93	2.855	2.589485	101752.12	3.366	119756.99	83.28%	0.02281
			70	800	148.5	1041.68	12.5	301	550	92960.08	5.127	7.003482	98758.1	7.527	290100.22	74.78%	0.01256
			80	800	148.5	1041.68	12.5	301	550	96215.93	4.47	5.07792	101288.6	6.474	203244.92	65.20%	0.01757
			90	800	148.5	1041.68	12.5	301	550	99933.66	3.711	3.365877	102971.92	5.747	160589.04	54.13%	0.02281
			100	800	148.5	1041.68	12.5	301	550	101805.48	3.134	2.121718	101615.12	5.817	144656.25	45.71%	0.02828
		3	60	200	148.5	1041.68	12.5	301	550	101613.58	3.155	5.032225	101677.14	2.989	147462.12	184.07%	0.00779
			70	200	148.5	1041.68	12.5	301	550	102482.96	2.874	3.925884	101426.24	2.983	116297.32	167.68%	0.01256
			80	200	148.5	1041.68	12.5	301	550	103065.73	2.653	3.013808	101339.52	2.829	109916.54	154.78%	0.01757
			90	200	148.5	1041.68	12.5	301	550	102967.06	2.658	2.410806	101271.41	2.688	105394.02	155.08%	0.02281
			70	400	148.5	1041.68	12.5	301	550	100543.97	3.526	4.816516	102025.33	3.686	160830.87	102.86%	0.01256
			80	400	148.5	1041.68	12.5	301	550	102049.73	3.042	3.455712	101877.89	3.801	134002.88	88.74%	0.01757
			90	400	148.5	1041.68	12.5	301	550	103225.83	2.555	2.317385	101724.95	3.402	116534.7	74.53%	0.02281
			70	800	148.5	1041.68	12.5	301	550	89394.92	6.049	8.262934	103195.66	6.121	334490.93	88.23%	0.01256
			80	800	148.5	1041.68	12.5	301	550	95771.81	4.789	5.440304	103206.26	6.808	227338.21	69.85%	0.01757
			90	800	148.5	1041.68	12.5	301	550	100246.48	3.586	3.252502	103124.74	5.965	157834.01	52.30%	0.02281
			100	800	148.5	1041.68	12.5	301	550	102021.52	3.017	2.042509	102765.58	5.633	144625.86	44.01%	0.02828
			120	800	148.5	1041.68	12.5	301	550	103185.56	2.563	1.148224	102335.08	5.036	129950.51	37.38%	0.03992
		5	55	200	148.5	1041.68	12.5	301	550	101902.09	3.086	5.27706	101524.17	2.88	146359.01	180.05%	0.00550
			60	200	148.5	1041.68	12.5	301	550	102338.94	2.927	4.668565	101627.56	3.004	127935.6	170.77%	0.00779
			70	200	148.5	1041.68	12.5	301	550	102898.38	2.711	3.703226	101481.37	2.967	114026.49	158.17%	0.01256
			80	200	148.5	1041.68	12.5	301	550	103294.63	2.554	2.901344	101511.51	2.783	108926.51	149.01%	0.01757
			90	200	148.5	1041.68	12.5	301	550	103226.75	2.598	2.356386	101471.59	2.786	106596.23	151.58%	0.02281
			60	400	148.5	1041.68	12.5	301	550	99038.27	3.969	6.330555	102391.28	3.999	207144.5	115.78%	0.00779
			70	400	148.5	1041.68	12.5	301	550	101368.93	3.267	4.462722	102060.05	3.927	151209.77	95.30%	0.01256
			80	400	148.5	1041.68	12.5	301	550	102812.54	2.756	3.130816	101937.25	3.595	129775.21	80.40%	0.01757
			90	400	148.5	1041.68	12.5	301	550	103436.77	2.501	2.268407	101866.87	3.462	119769.98	72.96%	0.02281
			70	800	148.5	1041.68	12.5	301	550	92155.23	5.537	7.563542	103701.2	6.831	296550.17	80.76%	0.01256
			80	800	148.5	1041.68	12.5	301	550	98239.93	4.183	4.751888	103228.56	6.35	210100.92	61.01%	0.01757
			90	800	148.5	1041.68	12.5	301	550	100856.03	3.467	3.144569	103032.68	5.856	169245.1	50.57%	0.02281
			100	800	148.5	1041.68	12.5	301	550	102356.17	2.93	1.981579	102402.18	5.572	151255.4	42.69%	0.02828
			110	800	148.5	1041.68	12.5	301	550	103465.65	2.471	1.107008	102392.95	5.344	139015.74	36.04%	0.03398
			120	800	148.5	1041.68	12.5	301	550	104221.61	2.107	0.459326	102260.59	5.058	130377.42	30.73%	0.03992

Appendix F: Final table







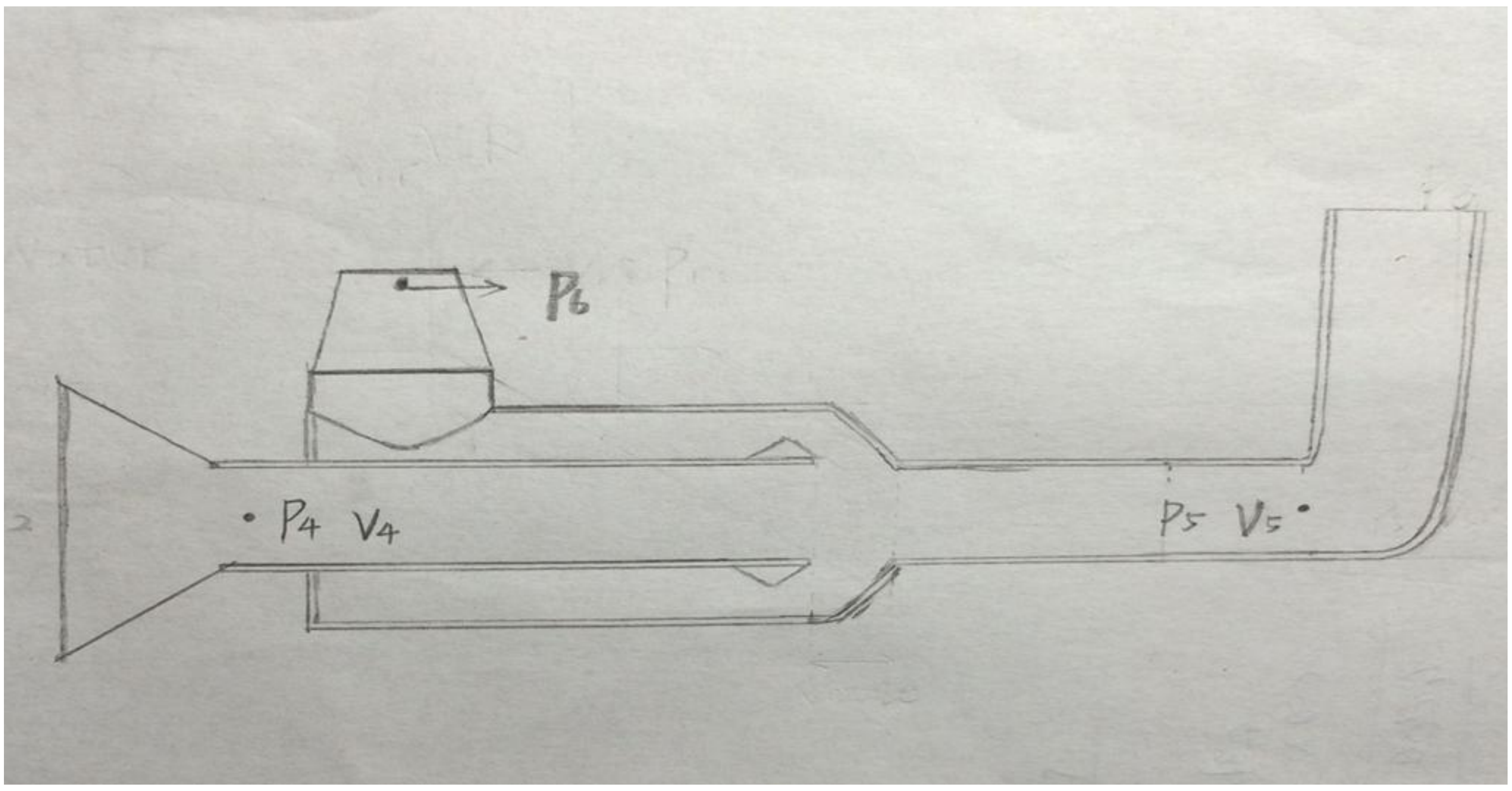


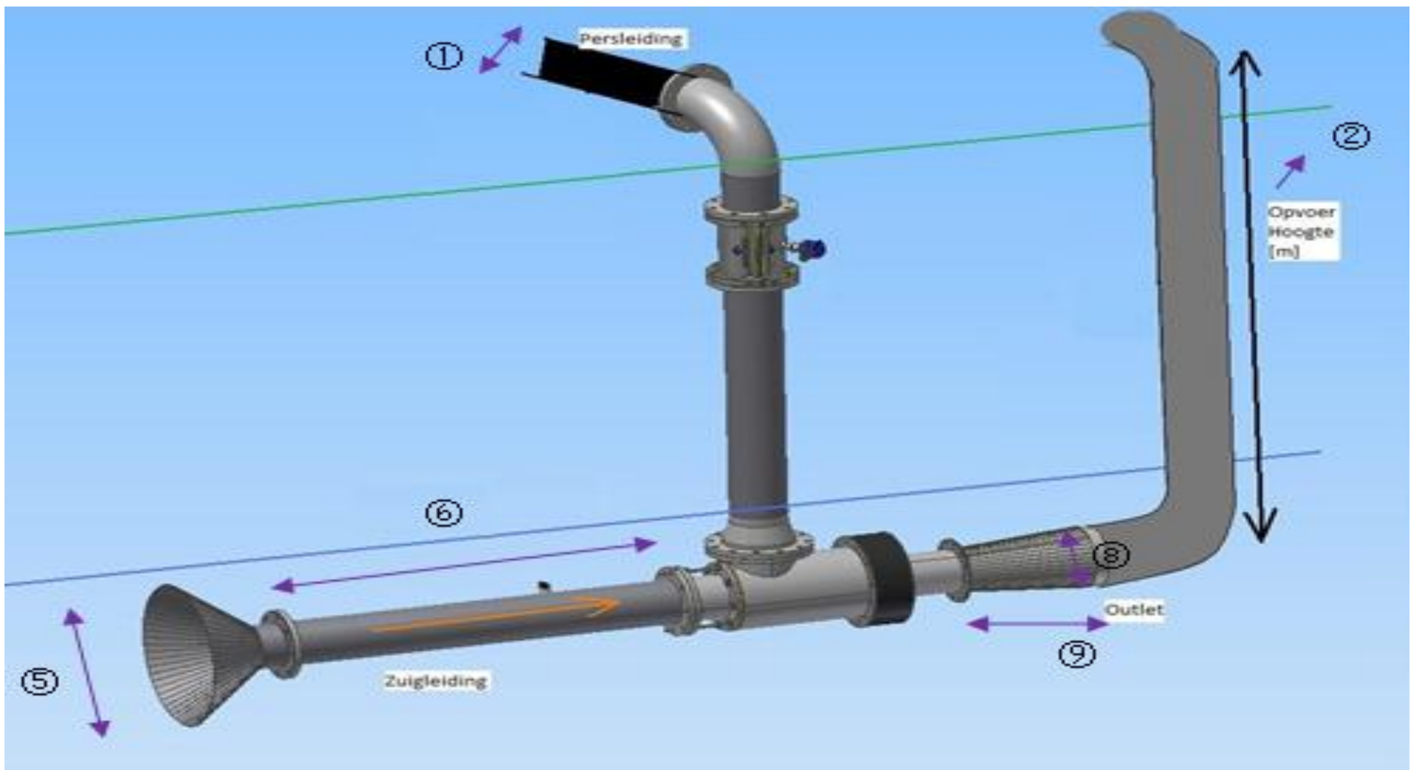
Appendix F: Final table

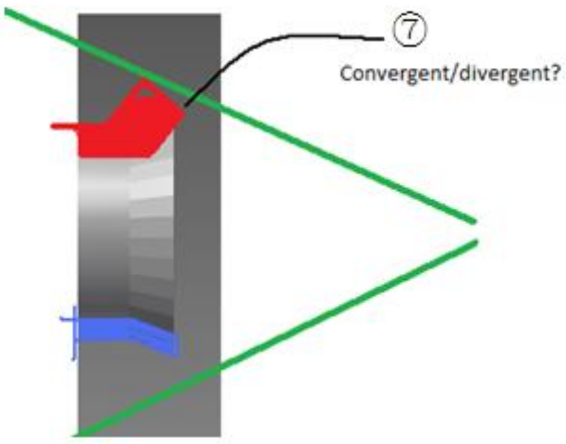
Column in GREEN shows the predict with the most reliability;
Column in YELLOW shows the predict with less reliability;
Column with NO COLOR shows the predict with the least reliability;

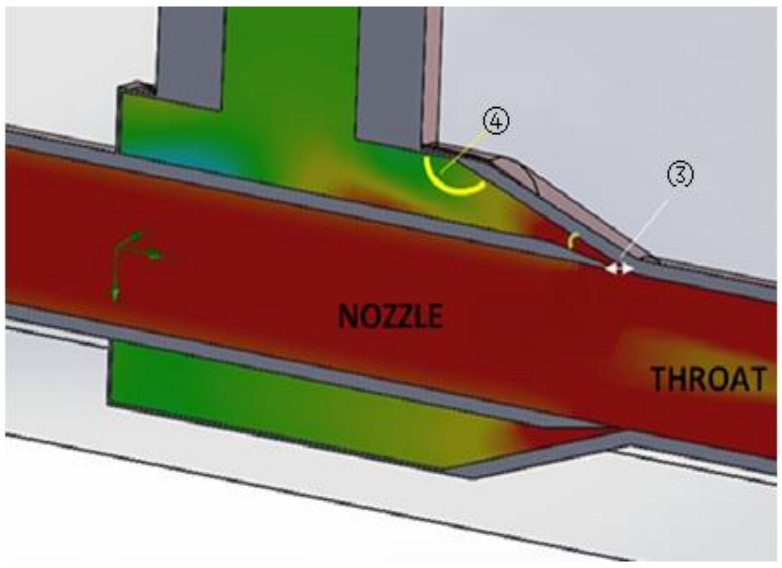
INPUT(different pump)					FIX INPUT					OUTPUT							
①	⑤	②	③		④	⑥	⑦	⑧	⑨								
Diameter of pressure pipe	Diameter of inlet pipe	Discharge head	Gap	Volume	Angle of outside pump	Length of inlet pipe	Angle of nozzle	Diameter of diffuser	Length of diffuser	P4	V4	V4(Predict)	P5	V5	P6	Efficiency	Throwflow surface
[inch]	[inch]	[m]	[mm]	[m3/h]	[degree]	[m]	[degree]	[mm]	[mm]	[pa]	[m/s]	[m/s]	[pa]	[m/s]	[pa]	[%]	[m2]
10	8	2	70	200	148.5	1041.68	12.5	301	550	102252.77	2.925	3.99555	101465.75	3.077	119120.01	170.65%	0.01256
			80	200	148.5	1041.68	12.5	301	550	102933.29	2.673	3.036528	101147.4	2.873	111340.43	155.95%	0.01757
			90	200	148.5	1041.68	12.5	301	550	103068.87	2.623	2.379061	101279.22	2.869	105874.97	153.03%	0.02281
			100	200	148.5	1041.68	12.5	301	550	103087.68	2.62	1.77374	101292.99	2.907	105326.38	152.86%	0.02828
			80	400	148.5	1041.68	12.5	301	550	101674.54	3.136	3.562496	101485.29	3.835	140328.64	91.48%	0.01757
			90	400	148.5	1041.68	12.5	301	550	103348.59	2.506	2.272942	101602.96	3.431	118351.57	73.10%	0.02281
			100	400	148.5	1041.68	12.5	301	550	103672.31	2.375	1.607875	101467.39	3.312	115629.95	69.28%	0.02828
			90	800	148.5	1041.68	12.5	301	550	101053.94	3.348	3.036636	102839.03	5.912	164574.19	48.83%	0.02281
			100	800	148.5	1041.68	12.5	301	550	102015.6	3.027	1.356096	102441.55	5.563	152953.53	44.15%	0.02828
			110	800	148.5	1041.68	12.5	301	550	103110.67	2.6	0.5668	101597.67	5.243	145316.91	37.92%	0.03398
			130	800	148.5	1041.68	12.5	301	550	103304.03	2.51	N/A	101787.24	4.689	133418.28	36.61%	0.04609
		3	50	200	148.5	1041.68	12.5	301	550	100693.58	3.461	6.316325	101179.68	2.875	193984.96	201.93%	0.00326
			60	200	148.5	1041.68	12.5	301	550	102289.48	2.92	4.6574	101396.74	2.912	131737.15	170.36%	0.00779
			70	200	148.5	1041.68	12.5	301	550	102823.16	2.719	3.714154	101285.32	2.855	116310.11	158.63%	0.01256
			80	200	148.5	1041.68	12.5	301	550	103163.08	2.583	2.934288	101245.79	2.899	110282.36	150.70%	0.01757
			70	400	148.5	1041.68	12.5	301	550	101265.37	3.272	4.469552	101741.33	3.734	160693.31	95.45%	0.01256
			80	400	148.5	1041.68	12.5	301	550	102468.62	2.853	3.241008	101589.3	3.765	135580.67	83.23%	0.01757
			90	400	148.5	1041.68	12.5	301	550	103232.74	2.564	2.325548	101384.5	3.694	124556.45	74.80%	0.02281
			70	800	148.5	1041.68	12.5	301	550	92081.5	5.5	7.513	102227.44	6.458	334460.6	80.22%	0.01256
			90	800	148.5	1041.68	12.5	301	550	99914.1	3.688	4.189568	101701.79	6.187	187948.14	53.79%	0.02281
			100	800	148.5	1041.68	12.5	301	550	102151.14	2.974	2.697418	101498.44	5.843	162472.13	43.38%	0.02828
			120	800	148.5	1041.68	12.5	301	550	104067.93	2.173	0.473714	101343.91	5.324	139120.39	31.69%	0.03992
			140	800	148.5	1041.68	12.5	301	550	103090.03	2.594	N/A	101082.22	4.801	130265.9	37.84%	0.05250
		5	50	200	148.5	1041.68	12.5	301	550	103092.4	2.592	4.7304	101635.72	2.74	129520.11	151.23%	0.00326
			60	200	148.5	1041.68	12.5	301	550	103115.55	2.576	4.10872	101479.65	2.689	117573.65	150.29%	0.00779
			70	200	148.5	1041.68	12.5	301	550	103525.66	2.407	3.287962	101302.45	2.839	111998.89	140.43%	0.01256
			80	200	148.5	1041.68	12.5	301	550	103478.29	2.43	2.76048	101347.47	2.813	107109.98	141.77%	0.01757
			90	200	148.5	1041.68	12.5	301	550	103488.63	2.429	2.203103	101359.99	2.82	107107.18	141.72%	0.02281
			80	400	148.5	1041.68	12.5	301	550	103570.18	2.406	2.733216	101670.93	3.611	126207.82	70.19%	0.01757
			90	400	148.5	1041.68	12.5	301	550	103868.13	2.263	2.052541	101651.4	3.482	119960.83	66.02%	0.02281
			100	400	148.5	1041.68	12.5	301	550	104189.02	2.108	1.911956	101666.48	3.318	115883.71	61.49%	0.02828
			110	400	148.5	1041.68	12.5	301	550	104411.53	1.993	0.892864	101702.91	3.26	113846.37	58.14%	0.03398
			80	800	148.5	1041.68	12.5	301	550	100968.49	3.35	3.8056	102448.45	6.27	194594.47	48.86%	0.01757
			90	800	148.5	1041.68	12.5	301	550	102345.69	2.894	2.624858	102216	5.954	169286.57	42.21%	0.02281
			100	800	148.5	1041.68	12.5	301	550	103614.68	2.379	2.157753	102019.36	5.659	152682.38	34.70%	0.02828
			110	800	148.5	1041.68	12.5	301	550	104289.07	2.055	0.92064	102447.25	5.274	144314.64	29.97%	0.03398
			120	800	148.5	1041.68	12.5	301	550	104628.97	1.88	0.40984	102096.42	5.038	137741.92	27.42%	0.03992

Appendix F: Final table

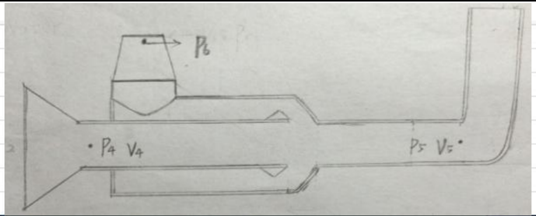








Appendix G: Best choices

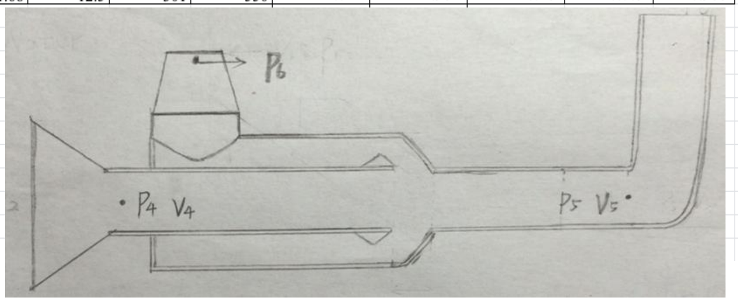


Column in GREEN shows the predict with the most reliability;
Column in YELLOW shows the predict with less reliability;
Column with NO COLOR shows the predict with the least reliability;

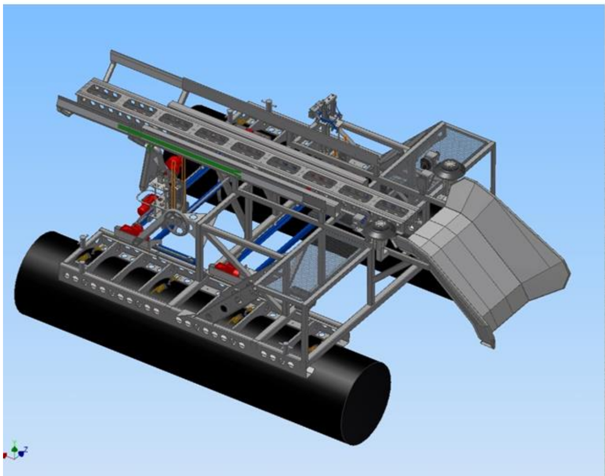
Different pumps		FIX Parameters					Best Solutions						Refference Data				
Volume	P6	Angle of outside pump	Length of inlet pipe	Angle of nozzle	Diameter of diffuser	Length of diffuser	Diameter of pressure pipe	Diameter of inlet pipe	Discharge head	Gap	Throwflow surface	Efficiency	P4	V4	V4(Predict)	P5	V5
[m3/h]	[bar]	[degree]	[m]	[degree]	[mm]	[mm]	[inch]	[inch]	[m]	[mm]	[m2]	[%]	[bar]	[m/s]	[m/s]	[bar]	[m/s]
200	0.97	148.5	1041.68	12.5	301	550	4	8	2	90	0.02281	164.06%	1.02	2.812	2.550484	1.01	2.536
200	0.96	148.5	1041.68	12.5	301	550	4	8	5	90	0.02281	166.39%	1.03	2.852	2.586764	1.01	2.66
200	0.98	148.5	1041.68	12.5	301	550	4	8	3	90	0.02281	172.11%	1.02	2.95	2.67565	1.01	2.655
200	1.05	148.5	1041.68	12.5	301	550	8	8	3	90	0.02281	155.08%	1.03	2.658	2.410806	1.01	2.688
200	1.06	148.5	1041.68	12.5	301	550	10	8	2	90	0.02281	153.03%	1.03	2.623	2.379061	1.01	2.869
200	1.06	148.5	1041.68	12.5	301	550	8	8	2	90	0.02281	165.58%	1.03	2.838	2.574066	1.01	2.651
200	1.07	148.5	1041.68	12.5	301	550	8	8	5	90	0.02281	151.58%	1.03	2.598	2.356386	1.01	2.786
200	1.07	148.5	1041.68	12.5	301	550	10	8	5	90	0.02281	141.72%	1.03	2.429	2.203103	1.01	2.82
200	1.10	148.5	1041.68	12.5	301	550	10	8	3	80	0.01757	150.70%	1.03	2.583	2.934288	1.01	2.899
200	1.22	148.5	1041.68	12.5	301	550	8	10	5	90	0.02281	229.54%	1.03	2.518		1.02	3.012
200	1.28	148.5	1041.68	12.5	301	550	8	10	3	90	0.02281	235.74%	1.03	2.586		1.02	3.336
200	1.35	148.5	1041.68	12.5	301	550	8	10	2	80	0.01757	240.48%	1.03	2.638		1.02	3.157
400	0.82	148.5	1041.68	12.5	301	550	4	8	2	90	0.02281	87.54%	1.02	3.001	2.721907	1.02	3.3
400	0.85	148.5	1041.68	12.5	301	550	4	8	3	90	0.02281	91.07%	1.02	3.122	2.831654	1.02	3.635
400	0.87	148.5	1041.68	12.5	301	550	4	8	5	90	0.02281	85.01%	1.02	2.914	2.642998	1.02	3.525
400	1.17	148.5	1041.68	12.5	301	550	8	8	3	90	0.02281	74.53%	1.03	2.555	2.317385	1.02	3.402
400	1.18	148.5	1041.68	12.5	301	550	10	8	2	90	0.02281	73.10%	1.03	2.506	2.272942	1.02	3.431
400	1.20	148.5	1041.68	12.5	301	550	8	8	2	90	0.02281	83.28%	1.02	2.855	2.589485	1.02	3.366
400	1.20	148.5	1041.68	12.5	301	550	8	8	5	90	0.02281	72.96%	1.03	2.501	2.268407	1.02	3.462
400	1.25	148.5	1041.68	12.5	301	550	10	8	3	90	0.02281	74.80%	1.03	2.564	2.325548	1.01	3.694
400	1.26	148.5	1041.68	12.5	301	550	10	8	5	80	0.01757	70.19%	1.04	2.406	2.733216	1.02	3.611
400	1.41	148.5	1041.68	12.5	301	550	8	10	5	100	0.02828	115.91%	1.03	2.543		1.02	3.764
400	1.49	148.5	1041.68	12.5	301	550	8	10	3	100	0.02828	125.62%	1.03	2.756		1.02	4.254
400	1.60	148.5	1041.68	12.5	301	550	8	10	2	90	0.02281	136.88%	1.02	3.003		1.02	4.166
800	-0.08	148.5	1041.68	12.5	301	550	4	8	3	100	0.02828	57.95%	0.99	3.973	2.689721	1.02	5.818
800	0.04	148.5	1041.68	12.5	301	550	4	8	2	100	0.02828	56.01%	0.99	3.84	2.59968	1.02	5.359
800	0.06	148.5	1041.68	12.5	301	550	4	8	5	110	0.03398	49.93%	1.01	3.423	1.533504	1.03	5.367
800	1.45	148.5	1041.68	12.5	301	550	8	8	3	100	0.02828	44.01%	1.02	3.017	2.042509	1.03	5.633
800	1.45	148.5	1041.68	12.5	301	550	8	8	2	100	0.02828	45.71%	1.02	3.134	2.121718	1.02	5.817
800	1.45	148.5	1041.68	12.5	301	550	8	10	3	135	0.04926	61.28%	1.03	2.689		1.03	5.897
800	1.51	148.5	1041.68	12.5	301	550	8	8	5	100	0.02828	42.69%	1.02	2.93	1.981579	1.02	5.572
800	1.54	148.5	1041.68	12.5	301	550	8	10	5	120	0.03992	57.43%	1.03	2.52		1.02	5.676
800	1.62	148.5	1041.68	12.5	301	550	10	8	3	100	0.02828	43.38%	1.02	2.974	2.697418	1.01	5.843
800	1.64	148.5	1041.68	12.5	301	550	8	10	2	115	0.03692	67.55%	1.02	2.964		1.02	5.813
800	1.65	148.5	1041.68	12.5	301	550	10	8	2	90	0.02281	48.83%	1.01	3.348	3.036636	1.03	5.912
800	1.69	148.5	1041.68	12.5	301	550	10	8	5	90	0.02281	42.21%	1.02	2.894	2.624858	1.02	5.954

Appendix H: Extra table of pressure drop

INPUT				FIX INPUT						OUTPUT				
Diameter of inlet pipe	Discharge head	Volume	Gap	Angle of outside pump	Diameter of pressure pipe	Length of inlet pipe	Angle of nozzle	Diameter of diffuser	Length of diffuser	P4	P6	P3	Pressure drop(P4-P3)	Pressure drop(P6-P3)
[inch]	[m]	[m3/h]	[mm]	[degree]	[inch]	[m]	[degree]	[mm]	[mm]	[pa]	[pa]	[pa]	[pa]	[pa]
8	2	200	90	148.5	8	1041.68	12.5	301	550	1.029	1.061	1.013	0.016	0.048
			100	148.5	8	1041.68	12.5	301	550	1.025	1.048	1.013	0.012	0.035
			110	148.5	8	1041.68	12.5	301	550	1.028	1.042	1.013	0.015	0.029
		400	90	148.5	8	1041.68	12.5	301	550	1.030	1.200	1.013	0.017	0.187
			100	148.5	8	1041.68	12.5	301	550	1.028	1.140	1.013	0.015	0.127
			110	148.5	8	1041.68	12.5	301	550	1.035	1.112	1.013	0.022	0.099
		800	90	148.5	8	1041.68	12.5	301	550	0.997	1.712	1.013	-0.016	0.699
			100	148.5	8	1041.68	12.5	301	550	0.999	1.479	1.013	-0.014	0.466
			110	148.5	8	1041.68	12.5	301	550	1.024	1.355	1.013	0.011	0.342
	3	200	90	148.5	8	1041.68	12.5	301	550	1.029	1.052	1.013	0.016	0.039
			100	148.5	8	1041.68	12.5	301	550	1.031	1.047	1.013	0.018	0.034
			110	148.5	8	1041.68	12.5	301	550	1.031	1.042	1.013	0.018	0.029
		400	90	148.5	8	1041.68	12.5	301	550	1.032	1.162	1.013	0.019	0.149
			100	148.5	8	1041.68	12.5	301	550	1.037	1.131	1.013	0.024	0.118
			110	148.5	8	1041.68	12.5	301	550	1.040	1.109	1.013	0.027	0.096
		800	90	148.5	8	1041.68	12.5	301	550	1.004	1.563	1.013	-0.010	0.550
			100	148.5	8	1041.68	12.5	301	550	1.019	1.430	1.013	0.006	0.417
			110	148.5	8	1041.68	12.5	301	550	1.030	1.339	1.013	0.017	0.326
	5	200	90	148.5	8	1041.68	12.5	301	550	1.034	1.034	1.014	0.019	0.019
			100	148.5	8	1041.68	12.5	301	550	1.034	1.057	1.014	0.019	0.043
			110	148.5	8	1041.68	12.5	301	550	1.034	1.050	1.014	0.020	0.035
		400	90	148.5	8	1041.68	12.5	301	550	1.034	1.221	1.016	0.018	0.206
			100	148.5	8	1041.68	12.5	301	550	1.038	1.162	1.016	0.023	0.147
			110	148.5	8	1041.68	12.5	301	550	1.041	1.125	1.015	0.026	0.110
		800	90	148.5	8	1041.68	12.5	301	550	1.004	1.791	1.020	-0.017	0.771
			100	148.5	8	1041.68	12.5	301	550	1.023	1.545	1.019	0.004	0.526
			110	148.5	8	1041.68	12.5	301	550	1.035	1.390	1.019	0.016	0.371
10	2	200	90	148.5	8	1041.68	12.5	301	550	1.033	1.179	1.013	0.020	0.166
			100	148.5	8	1041.68	12.5	301	550	1.038	1.113	1.013	0.025	0.101
			110	148.5	8	1041.68	12.5	301	550	1.038	1.084	1.013	0.025	0.071
		400	90	148.5	8	1041.68	12.5	301	550	1.021	1.640	1.013	0.008	0.627
			100	148.5	8	1041.68	12.5	301	550	1.033	1.364	1.013	0.020	0.351
			110	148.5	8	1041.68	12.5	301	550	1.038	1.241	1.013	0.025	0.228
		800	90	148.5	8	1041.68	12.5	301	550	0.952	3.450	1.013	-0.061	2.437
			100	148.5	8	1041.68	12.5	301	550	0.992	2.339	1.013	-0.020	1.326
			110	148.5	8	1041.68	12.5	301	550	1.015	1.848	1.013	0.002	0.835
	3	200	90	148.5	8	1041.68	12.5	301	550	1.030	1.306	1.013	0.017	0.294
			100	148.5	8	1041.68	12.5	301	550	1.040	1.095	1.013	0.027	0.082
			110	148.5	8	1041.68	12.5	301	550	1.039	1.080	1.013	0.026	0.067
		400	90	148.5	8	1041.68	12.5	301	550	1.004	2.139	1.013	-0.009	1.126
			100	148.5	8	1041.68	12.5	301	550	1.039	1.286	1.013	0.026	0.273
			110	148.5	8	1041.68	12.5	301	550	1.042	1.042	1.013	0.029	0.029
		800	90	148.5	8	1041.68	12.5	301	550	0.882	5.418	1.013	-0.131	4.405
			100	148.5	8	1041.68	12.5	301	550	1.014	2.027	1.013	0.001	1.015
			110	148.5	8	1041.68	12.5	301	550	1.024	1.769	1.013	0.011	0.756
	5	200	90	148.5	8	1041.68	12.5	301	550	1.034	1.248	1.013	0.021	0.235
			100	148.5	8	1041.68	12.5	301	550	1.038	1.139	1.013	0.025	0.126
			110	148.5	8	1041.68	12.5	301	550	1.039	1.095	1.013	0.026	0.082
		400	90	148.5	8	1041.68	12.5	301	550	1.019	1.895	1.013	0.006	0.882
			100	148.5	8	1041.68	12.5	301	550	1.033	1.466	1.013	0.020	0.453
			110	148.5	8	1041.68	12.5	301	550	1.041	1.279	1.013	0.028	0.266
		800	90	148.5	8	1041.68	12.5	301	550	0.937	4.452	1.013	-0.076	3.439
			100	148.5	8	1041.68	12.5	301	550	0.990	2.737	1.013	-0.023	1.723
			110	148.5	8	1041.68	12.5	301	550	1.022	1.981	1.013	0.009	0.968



BIJLAGE 10B




Europees Visserijfonds:
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Ministerie van Economische Zaken

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Jetpomp ten behoeve van MZI-oogst

Model beschrijving van Comp. Fluid. Dynamics

Het model

Doel

Doel van het modelleren van de pomp, is om de invloed te achterhalen van een aantal ontwerpvariabelen op het rendement van de pomp.
De pomp moet **met zo weinig mogelijk toegevoerd hydraulisch vermogen** aan de zuigzijde minimaal een stroomsnelheid genereren van 1 m/s. Daarbij moet het water aan de afvoerzijde 3 m opgevoerd worden (om het ruim van het schip in te kunnen).

Voorbeeld:
Vanuit de tests en latere berekeningen is voorzichtig de conclusie getrokken, dat een steilere instroomhoek een beter resultaat oplevert om de stroming te genereren. Deze conclusie is verrassend, omdat vanuit de wet van behoud van energie voor de hand ligt, dat je de richting van de snelheid van het water van de toevoerende pomp zoveel mogelijk parallel wilt hebben met de richting van de hoofdstroming

Resultaten en conclusies

Inventor, SolidWorks vs metingen.
In de cad-pakketten Inventor en SolidWorks zijn berekeningen uitgevoerd. Deze pakketten zijn ontwikkeld om snelle studies uit te voeren. Ze zijn in de afgelopen jaar wel beter geworden, maar om het gemak te vergroten, zijn veel invoer en reken parameters niet in te stellen of te achterhalen. Daarom wordt door veel experts sceptisch naar de resultaten van deze pakketten gekeken. In de studie 10A zijn vergelijkende studies uitgevoerd, waarbij de uitkomsten 20 tot 200% van de gemeten waardes vandaan zat. Extra aandacht voor de metingen die zijn uitgevoerd, gaf aan, dat er nog redelijke onzekerheid is over de waardes in de meetsituatie. De toeleverende pomp was bijvoorbeeld niet helemaal betrouwbaar. Om meer zekerheid te krijgen in de berekeningen, zouden er dus meer testen en berekeningen uitgevoerd moeten worden. Als aan de andere kant in de loop van de tijd meetgegevens van de 1 op 1 pompen verzameld worden en gecombineerd met de vermoedelijk aanwezige trends vanuit de berekeningen, kan een empirisch model (zie het resultaat van studie 10B) steeds verder verbeterd worden.

Onverwachte trends
In een poging om meer grip te krijgen op een aantal onverwachte trends die gevonden lijken te zijn in de metingen van de schaalsituaties en berekeningen in Inventor, zijn parallelle berekeningen uitgevoerd in Comsol Multiphysics. Daaruit is gebleken:

1. De situatie die berekend moet worden in numeriek lastig. Er spelen veel invloeden: de zwaarte kracht, de energie van het ingepompte water, wrijving en massa. Deze invloeden werken in

verschillende richting, wat tot instabiliteit kan leiden; kleine veranderingen hebben grote gevolgen. Indicatieve berekeningen zijn gelukt, maar nette series die een hogere betrouwbaarheid hebben, nog niet. Verwachting is, voor het einde van 2015.

2. Steilere instroomhoek leidt ondanks lagere energie in de goede richting tot hogere zuigsnelheid (waar de substraat binnen komt) door het beter mixen van de stromen. Er is in de berekeningen (Comsol) geen bevestiging hiervan gevonden. Wel duidelijke ontkenning. Eenduidige metingen van verschillende instroomhoeken moeten hier uitsluitsel over geven.
3. Verstoring van de pijpwand waar het substraat door komt (bijv door een holte op de plaats van de instroom van de leverende pomp) verhoogt de aanzuigsnelheid door beter mixen van de stromen door het genereren van turbulentie in de stroom. Er is in geen berekening bevestiging gevonden; noch Inventor, noch Comsol. In Comsol is wel gevonden, dat een verstoring van de laminaire stroom een sterk negatieve invloed heeft op de aanzuigsnelheid. Ook hier moeten metingen zekerheid geven.
4. Afrondingen, gladde pijpwanden, leiden tot verstoring van de laminaire stroming en daardoor tot beter mixen van de stroming en daardoor hogere aanzuigsnelheid. Het tegengestelde is gevonden in Comsol. De stroming wordt wel turbulenter, maar heeft daardoor zoveel meer weerstand, dat de aanzuigsnelheid niet hoger, maar lager is. Het vermoeden is daarom, dat het beste rendement voor het aanzuigen te halen is met vloeiende afrondingen, gladde pijpwanden en scherpe instroomhoek.
   Daarom is het advies om niet in de jetpomp zelf door middel van het genereren van turbulentie of kruisende waterstralen de mossels van het substraat te halen. Het lijkt veel rendement te kosten om deze twee functies te combineren. Het ontwerp kan eenvoudiger worden, het rendement en de bedrijfszekerheid hoger, als het scheiden van mossels en substraat voor of na de jetpomp gedaan wordt en niet in de jetpomp zelf.
5. Het verwijden van de pijp na de jetpomp laat de snelheid van het water afnemen en reduceert daardoor de weerstand. Uit Comsol berekeningen wordt dat bevestigd. Punt van aandacht daarbij is wel, dat de stroomsnelheid niet lager mag worden dan aan de aanzuigkant. Omdat na de jetpomp twee stromen zijn gecombineerd, hoeft dat geen probleem te zijn.

Geometrie

Zie tekening in bijlage modeltekening.

Maten:

1. Pijpdiameter 200 mm
2. Spleetbreedte 2,98 mm
3. Inspuithoek 15°
4. Tapsheid inspuithoek 5°
5. Pijplengte ~1 m voor de pomp en ~2 m erna.
6. Pompvermogen van toeleverende pomp: 530 m^3/h => 0.5 bar (overdruk)

0, bar => 672 m3/uur

0,2 bar => 608 m3/uur

0,5 bar => 560 m3/uur

0,6 bar => 620 m3/uur???

0,7 bar => 530 m3/uur

0,8 bar => 550 m3/uur
1,1 bar => 470 m3/uur
1,7 bar => 300 m3/uur
1,9 bar => 250 m3/uur

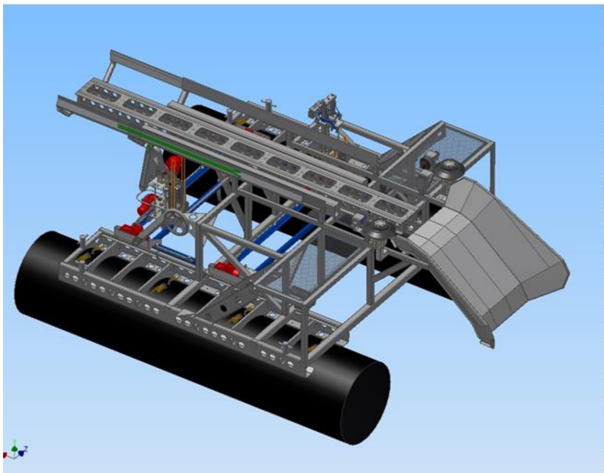
De pomp staat op het niveau van het wateroppervlak, verticaal. De opvoerhoogte (tegen de zwaartekracht in) is 3 meter.

De parameters waarvan de gevoeligheid berekend moet worden

a. Spleetbreedte. Nu weergegeven op de waarde 2,98 mm. Ik zoek die waarde die aan de zuigzijde een snelheid van 1,0 … 1,5 m/s. Als debiet kan die waarde genomen worden die resulteert in een waarde bij de instroom: ~12 m/s.
b. Debiet. Bij de beste spleetbreedte wil ik weten bij welk debiet (van 50% tot 200% van de hiervoor gevonden waarde de stroming zo slecht wordt, dat de stroming aan de zuigzijde onder + 5 m/s komt (omhoog).
c. Instroomhoek. Nu weergegeven op de waarde 15°. Ik wil weten of er tussen 5° en 45° een optimum is.
d. Opgewekte turbulentie **voor** de instroom. Nu weergegeven in de maat 10 mm, 5 ribbels. Ik wil weten bij welke maat tussen 0,5 en 10 mm de stroming zover verstoord wordt, dat de stroming aan de zuigzijde onder + 5 m/s komt (omhoog).
e. Opgewekte turbulentie **na** de instroom. Nu weergegeven in de maat 10 mm, 5 ribbels. Ik wil weten bij welke maat tussen 0,5 en 10 mm de stroming zover verstoord wordt, dat de stroming aan de zuigzijde onder + 5 m/s komt (omhoog).
f. Vergroting diameter vlak voor de instroom. Nu aangegeven op de waarde 6,91 mm. De hoek is gelijk aan de instroomhoek. Ik wil weten bij welke maat tussen 0,1 en 10 mm de stroming zover verstoord wordt, dat de stroming aan de zuigzijde onder + 5 m/s komt (omhoog).
g. Taps maken van instroom. Nu weergegeven op de waarde 5°. Ik wil weten of er tussen 0° en 45° een optimum is.
h. Afronding instroom, **zuigzijde**. Nu weergegeven in de waarde r=2mm. Ik wil weten bij welke maat tussen 0,1 en 5 mm de stroming zover verstoord wordt, dat de stroming aan de zuigzijde onder + 5 m/s komt (omhoog).
i. Afronding instroom, **uitstroomzijde**. Nu weergegeven in de waarde r=5mm. Ik wil weten bij welke maat tussen 5 en 25 mm de stroming zover verstoord wordt, dat de stroming aan de zuigzijde onder + 5 m/s komt (omhoog).

Bijlage modeltekening

BIJLAGE 11



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Winding substrate-line

Final report for the minor R&D

M. van Sighem, X. Wang, B. Li

Vlissingen, 24 June 2015

Version 2

Title: Winding substrate-line

Subtitle: Final report for the minor R&D

Authors: M. van Sighem, X. Wang, B. Li

Study program: Engineering - Minor R&D

School: HZ University of applied science

Teacher: J.C.W. Haak

Semester: 2 - 2014/2015

Vlissingen, 5 June 2015

Preface

In front of you lays the report “Winding substrate-line” A research done to design a machine witch can wind substrate-line used for mussel harvesting. This report has been written as part of the minor research and development at the HZ University of applied sciences in Vlissingen Since March we have been working on the research, design and this report.

This report has been written by order of Jansen Tholen the company for with the research has been conducted. The report has mainly been written by me, Mike van Sighem, with help on a few parts from Xinyue Wang and Bing Li. The other students in our project group.

Mike van Sighem

Vlissingen, June the fifth 2015.

Summary

Traditionally mussel seeds are being harvested from natural mussel banks. Because of stricter regulations regarding this method a new method has been introduced. This method is called “MZI”. The MZI method uses ropes witch hang in the water on which the mussels seeds can grow. Jansen Tholen is designing a “MZI” system for her client De gebroeders Schot. Apart of the “MZI” system is storing the ropes used to grow the mussels on. Currently these ropes are being put in bags by hand. Jansen Tholen assigned us the task of designing a machine that would be able to automatically store the rope on board of the Tholen 4. Preferably using a winder witch was already available.

To tackle this problem we first of all looked at research done by other students on this problem. After evaluating the information in the reports we started our own design process. What we did is use the Delft design method such as described in (Timmers & Waals, 2009) to organize the project. The basic steps were as follows. We stated in the analysis phase in this phase we focused on gathering information about our problem and did measurements on the substrate. This lead to a lot of helpful information and the requirements for the system. Continuing in the next phase, the idea phase, we generated lots of ideas to solve sub-problems. By combining the small solutions we got to 4 integral ideas and chose the best two. In the concept phase we detailed the ideas further until we got some new information from our client. The client wanted more flexibility in the layout of the machine. For this reason we dawn a new concept using the information we already acquired while detailing the two concepts made before. Once this concept was at an adequate level we stated the last phase. In this phase we did the final calculations to select dimensions and material for the parts and made the final CAD model for the machine.

The final design for the winder cannot be described in a summary like this but the basics are that we can use the winder available at the client. The design will consist out of 3 main systems the winder, the spool and the guidance. These there components can be configured in different way into the hull of the Tholen 4. To know for sure how the performance of the winder will be in combination with the rest of the MZI system we need to wait for more test results of the other parts of the MZI system but for use during this stage the winder such as we designed it should be able to do its task.

List of abbreviations

Abbreviation	*Description*
2D	Two dimensional
3D	Three dimensional
BOM	Bill of materials
CAD	Computer aided design
E.G.	For example
Etc.	Et cetera
G	Gram
HKC	Haspel klossen centrale
Kg	Kilogram
Km	Kilometer
KN	Kilonewton
m	Meter
m/s	Meter per second
mm	Millimeter
m/min `	Meters per minute
MZI	Mosselzaad invang-installatie
N	Newton
N/m	Newton per meter
NM	Newton meter
RPM	Rounds per minute
SI	Système international d'unités
Sync.	Synchronization
TH4	Tholen 4

Inhoud

1. Introduction

As part of the R&D minor at the HZ University of applies sciences are group of students is has to developed a machine for Jansen Tholen. This machine is a solution for storing substrate line used during the cultivation of mussel seed without the constant need of a worker. In this document, our final report, we will first of all describe the problem, discuss an earlier concept for this machine, and explain the method we have used. After this we start describing the results of each design phase (analysis, idea, concept and materialization). In this part you will find most of the design decisions made and thus the most valuable information. After this we end with our conclusion and the recommendations.

1.1. Assignment and background

Traditionally mussel seeds are being harvested from natural mussel banks. Because of stricter regulations regarding this method a new method has been introduced. This method is called “MZI”. The MZI method uses ropes witch hang in the water on which the mussels seeds can grow. Once the mussel seed is large enough the ropes are pulled onto a ship and the mussel seed is scraped off. This process is labor intensive that’s why mussel fishers Gebroeders Schot contacted Jansen Tholen to automate this process. (Balkenende, 2015)

Together witch students from the HZ University of Applied Sciences Jansen Tholen has developed a system to automate the seeding and harvesting of mussel seeds. The harvesting system (Figure 1) works by pulling in the main substrate on witch smaller substrate lines with mussel seed hang. The substrate with the mussel seeds attached to it is fed in a special machine. This machine scrapes off with the mussel seeds and transports it to the hull of the ship.

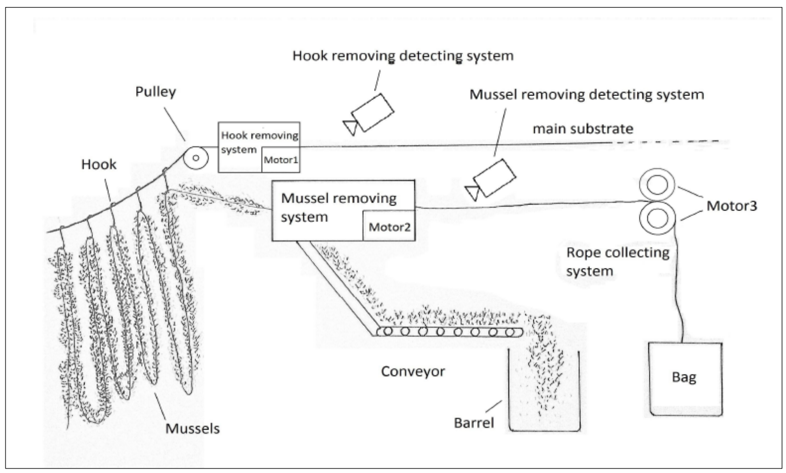


Figure 1: general overview of the MZI system

Figure 2: current storing solution

In the current prototype the cleared substrate line is pushed into bags by hand (Figure 2). This isn`t the most pleasant job because the worker has to stand under the dripping substrate all day and push the substrate into the bags. Previously students have made a concept for a system which would replace the worker but would still store the rope into bags. At first our assignment was to further engineer this concept. A simpler and more practical solution for storing rope tan putting it in bags is of course rolling it onto spools. So that’s why we aren’t going to engineer the previous concept but we are going to engineer a new machine which is able to wind the substrate onto spools. Jansen Tholen already has some hydraulic motors and gears they want to use in the first machine. This machine will be used during further tests of the “MZI” system. The first basic specifications that the client gave us are as follows:

- The rope needs to be stored on two spools;
- It needs to be possible to lift the spools from the ship;
- The first machine needs to be build using existing hydraulic motors and gears:
- The system needs to hold 6km of substrate;
- The system needs to work at the same speed as the rest of the harvesting system;

Additional information:

- The substrate does not have to be switch from the first spool to the second spool automatically.
- When the substrate is switched from the first to the second spool the rope will be cut by a worker.
- The machine can be powered by the ships hydraulic system and/or by the ships three-phase electrical system.
- Connecting the machine onto the ship will be done by Jansen Tholen.

1.2. Problem definition

Jansen Tholen has developed a machine that automates the harvesting of mussel seeds. The mussel seeds grow on ropes hanging in the water. These ropes are being pulled onto a ship and the seeds scraped off. These ropes (also referred to as substrate) need to be stored on board of the ship. Currently these rope are being guided into the bags by a worker. This is heavy and repetitive work. Previously a group of students has developed a concept to automate his process. With still included storing the substrate in bags. This is a method we aren`t going to use because it`s much easier to wind the substrate on a spool. What we need to do is engineer a machine which can wind all of the substrate on spools inside the ship. The main challenge will be to make a designs which meets the specifications and is able to operate in the harsh conditions on the ship.

Research questions:

- What are the properties of the substrate that needs to be collected?
- At what speed is the substrate supplied?
- What sort of special problem does the machine face in its environment (e.g.: shaking, salt water, etc.)?
- How does the current “rope storage system” work?
- Does the speed of the substrate line need to be monitored?
- How big do the spools need to be?
- How fast should the spool turn?

1.3. Main question

The main question for the research is: “What is the best integral solution for a machine which will store substrate line on the Tholen 4.” This main question is a bit different than a normal research question described in the pressure cookers. This is because our assignment is a design project and not only a research project. For the same reason we did not split this question up in sub questions. We used the method described in (Timmers & Waals, 2009) witch does not make use of sub questions for the whole project. We did do research to specific questions to answer the main question but they are related to a specific design phase and not the whole project. More about this can be found in chapter 3.

2. Theoretical framework

IN THIS CHAPTER, THE THEORETICAL FRAMEWORK, WE WILL MAINLY DISCUSS RESEARCH WHICH HAS PREVIOUSLY BEEN DONE TO WAYS OF STORING SUBSTRATE LINE. IN ADDITION TO THIS WE DESCRIBE OUR SOURCES THAT WE ARE GOING TO USE IN THE DESIGN PROCESS, MAINLY IN THE ANALYSIS PHASE.

2.1. Previous concept

Another group of students has developed a concept (Figure 3) for the machine we need to develop. This concept will be the starting point of our design. All their design steps and their final concept have been documented in a report. We have read through the report and summarized their final concept. With this concept there are several problems that needs to be solved. All the problems we found with this concept are listed in the second part of this chapter.

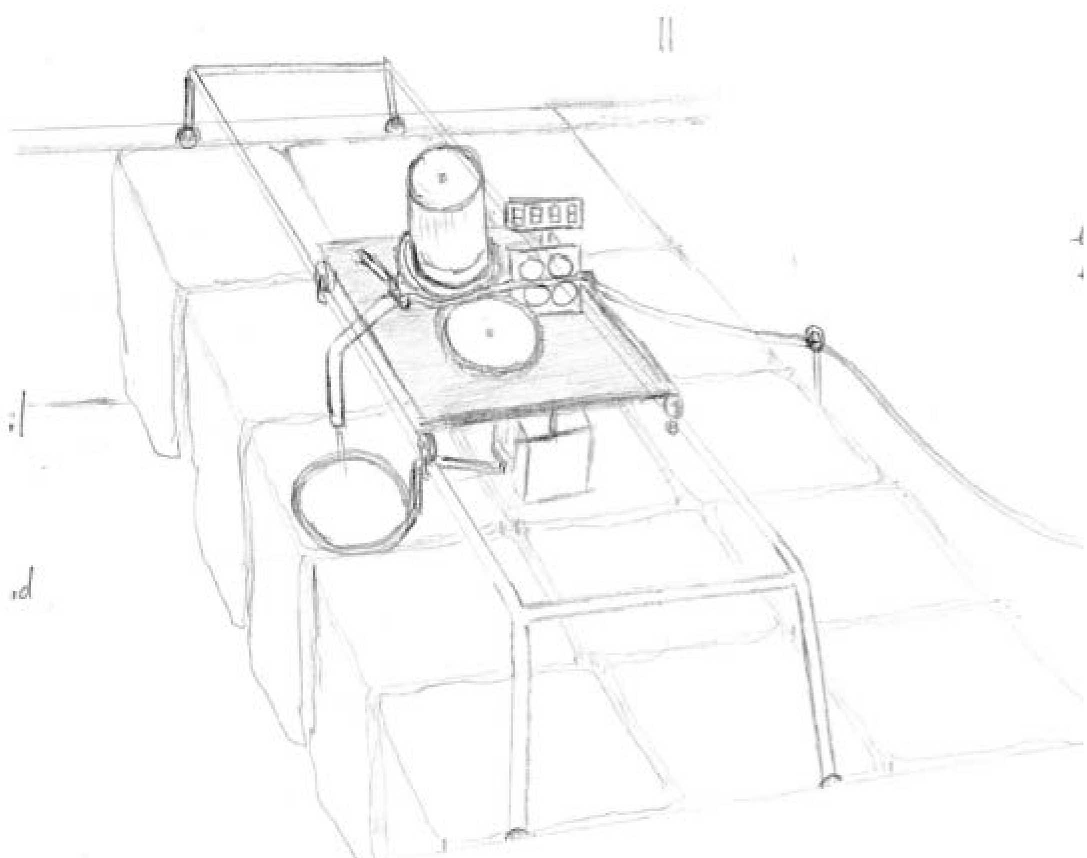


Figure 3: Final drawing of the students design

2.1.1. The concept

After reading the report we have divide the concept in 4 main functions. We have defined these functions in a function three (Figure 4). We have made this function tree to make a clear division between the several functions of the system.

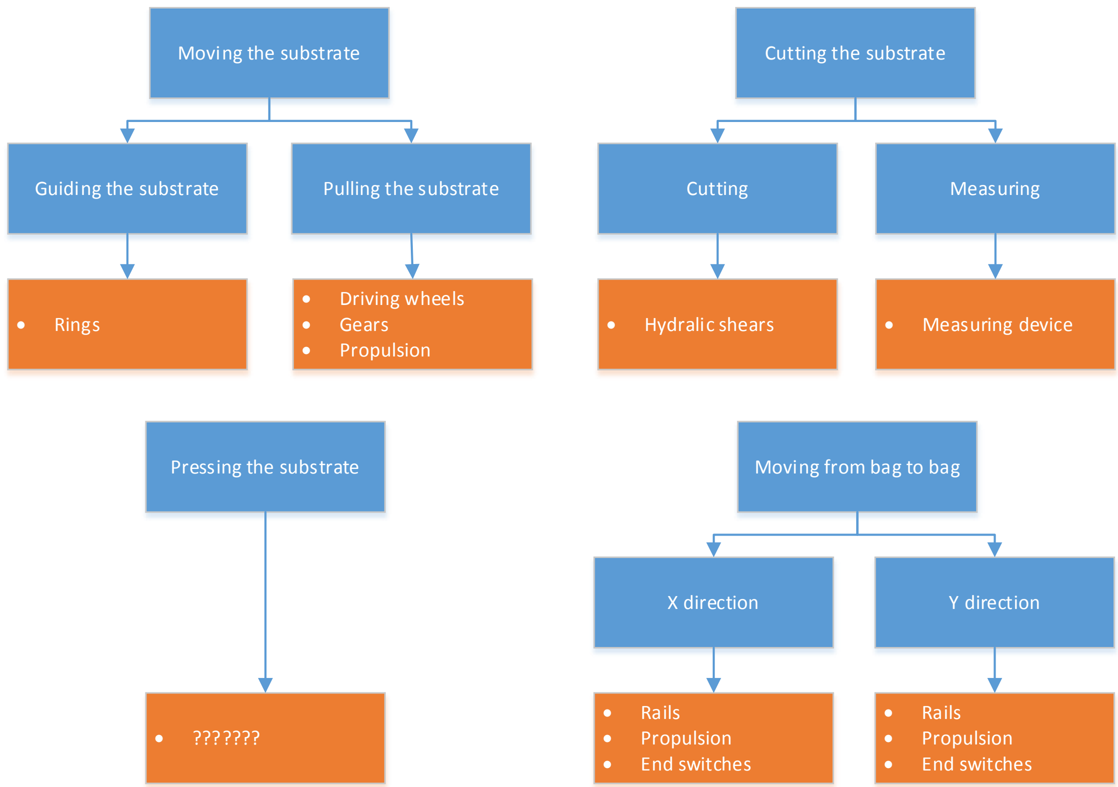


Figure 4: System decomposition

Moving the substrate: This part of the machine consists of two motors which pull the rope forward using two wheels. This is a very simple and effective way of pulling the rope forward. Another advantage of this method is that its already been used to pull the substrate and it`s proven to work. To prevent the rope from catching on something it`s guide by metal rings.

Cutting the substrate: If the bag is full the rope needs to but cut in order to lift the bags out of the ship. The cutting of the rope is done using hydraulic sheers. To determine of the bag is full a special "rope measuring device" is used. This machine determines the length of the rope by clamping it between two wheels and based on the number of revelations the distance of rope is calculated.

Pressing the substrate: The rope is pressed in the bags to allow more rope to be stored. This is done using a frame that will constantly pound on the rope in the bag. To allow this mechanism a lire number of special parts is used. To read the exact working of this mechanism we refer to the original report.

(MA, QU, DING, & NIU, 2014)

Operation

1. The machine moves to the first bag that need to be filled;
2. The rope needs to be manually fed through the machine;
3. The pressing framework moves 50cm into the bag;
4. The rope will be pulled by the driving wheels and meanwhile the length is measured;
5. When the rope reaches a height of 1 meter in the bag the pressing device will start to move up and down 30cm to press the rope;

6. As more rope is fed into the bag the pressing framework will be gradually lifted to allow more rope in the bag;
7. When 300 meter of the rope has been collected in the bag the pulling wheels will stop and the rope will be cut by the hydraulic shears;
8. The pulling mechanism will move to the next bag and the process repeats from step 3.

2.1.2. Problems of the exciting concept

In order to see what sort of problems there are with the exciting concept we have divided the whole system in subsystems and per subsystem we have described all the problems and questions.

The current concept uses a stock “length measuring device”. The function of this device is to measure the length of the device and determine if the rope needs to be cut and the machine needs to move to the next bag. The problems with this part are: It isn`t rated for marine environments. The device is made to measure a dry and constant string of wire. The substrate we don’t know if a device like this will be able to accurately measure the substrate which is wet and inconsistent. Because of these problems we think this specific part can`t be used but the principle of measuring the rope by clamping it between two wheels is a feasible solution.

For the pressing of the rope a mechanism including several motors, gears and dampers has been thought out. We are wondering if all the component included in this system are necessary. We think this part of the design can be simplified so that it will be cheaper and more reliable. The part used for is pressing itself in such a way that’s it very thin. All tough some calculations have been done we think that sturdier design is necessary to prevent breaking.

To allow the ropes to be dropped into several bags the system needs to move from bag to bag. To accommodate this a systems has been designed using a two axis positioning system. We think this principle is a good choice but more work need to be done to make sure the carriage will be secured to ship properly.

About the frame or the housing of the machine there isn`t any specific information in the report. Because the aesthetics don`t matter with a product like this we will probably dosing the frame around the other components.

In the current design hydraulic sheers will be used to cut the ropes. We are wondering if these need to be hydraulic or that teas can be electric. Powering these using electricity will enable us to reduce the number of connections that need to be made to the ship. Another problem we need to solve is to prevent the rope from jamming the machine. No reference has been made on haw to prevent this after the rope has been cut.

Other minor issues with the current concept are:

- Power need to be supplied to the motors on the carriage, currently there is no solution for this;
- The speed of witch the rope is pulled through needs to be in sync with to other substrate handling machines;
- The engines in the design need to be controlled by some sort of electronics witch aren’t specified;
- The wheels and gears which will drive the rope are custom made, stock parts are probable adequate;
- It isn’t clear it the controls are mounted onto the carriage or on the ship;
- If there is an end (bag full) on the pressing device why should the length of the rope be measured;

2.1.3. Questions that remain

After reading the report there were several questions that remained. Because they are all related to the pressing of the rope into bags it will probably not be a problem.

- Why does the pressing start at 66.5% (200m) of filling the bag?
- Does the cutting mechanism work?
- Does the rope have to be pressed?
- Are the dimensions of the pressing device adequate to effectively press the rope?

2.2. Research in general

To find general information about doing research and the structure of our reports we will use (Baarda, 2009) and (Glabbeek, 2009). Both tease sources give detailed information about the proper structure of a research project and the way you should document this. The most detailed one of the two is (Glabbeek, 2009).The other book is best used for information about the general structure of a research project.

2.3. Formulas and values

To get formulas or values regarding the calculation of strength, bend, etc. we will use (Leijendeckers, 2010) this book is a collection of the most commonly used formulas for this. Also we can find all the available pipes and profiles including their characteristics in this book we can both use the printed and the digital version. The printed one is more elaborate but the digital one is handier for obvious reasons.

2.4. Human dimensions

If we have to take into account the human dimensions for any part of the design we can use (TU Delft, 2004). This is a handy tool to determine the size of certain body part of Dutch people. This tool allows you to see the average value and also lets you dial in specific percentiles.

2.5. Winding rope

Mazella is a company specialized in overhead cranes, riggings and winders. They have released a document/book, (Mazzella lifting Technologies, 2010), describing a lot of the calculations and the things to take into account regarding lifting and winding construction/machines. We are mostly interested in the parts regarding winding material onto a drum. In this document we can find information about feed angles, winding tension, drum capacity, etc. We will go deeper into all tease topics in the analysis phase and mention the specific values relevant to this project

3. Research design

In this chapter we will describe the method used for the research conducted as part of the minor R&D. Because this project is a design assignment and not only a research project did not use the method taught in the pressure cookers. First we will give our reason for not following this method and then describe the method we did use.

Because this project is mainly a design project and less a research project we chose to use a design method to compete the project. We used the method described in (Timmers & Waals, 2009). This this the method we are the most used with. We have used this method in nearly all our previous projects. For this reason it was an oblivious choice for us to use this way of structuring our project.

This method has 4 phases and every phase has a set of products/documents/solutions that needs to be delivered. Later in this chapter we have made a description about each phase but first we will show how the phases of the design method we use relate to the phases of the minor. To make the relation visible we showed the minor phases and the design phases in Figure 5: Structure of the minor.

Minor phase	Orientation	Execution				Concluding	
Design phase	Planning	Analysis	Idea	Concept	Materialization	Final report	Presentation

Figure 5: Structure of the minor

The first phase of the minor is the orientation phase this is the phase in which we got familiar with the problem and we planned how the structure of the project would be. In this phase we wrote the research proposal. This minor phase correspond to the time we normally take to write a “Plan van aanpak”. After this follows the Execution phase of the minor, this is the phase in which the largest part of the research is normally conducted. What we did is split up this phase in 4 smaller phase as described in (Timmers & Waals, 2009). The last phase of the minor is the concluding phase this is the phase in which you normally write the conclusions and the final report. The materialization phase partially overlaps with the concluding phase because the result of the last design phase will be the final result for the whole project. Furthermore we reserved a bit of time in the concluding phase to write the final report and preparing the presentation. Now we will continue underneath with discussing each design phase.

3.1.1. Analysis

The analysis is the phase in which we will collect all the information we need to start designing and engineering the product. First of all we need to look at the given problem and come up witch a list of unanswered questions. To answer these we need to conduct research specific to that subject. A part of the research will be based on information that is provided in the report from the student who came up with the concept of this machine.

The information from the research together with input from the client will lead to the design specifications of the product and the search topics for the next phase. These are the most important products of this phase, underneath we made a list of all the products we will deliver in this phase:

- Answers on sub questions: From the problem statement we will get a list of unanswered questions witch we will try to answer. The focus will be determining the size of the spools, the speed the spools need to turn and the momentum they need to turn with. These values are important to determine if the components that are available are usable in this machine.
- Division in subsystems: We will divide the machine into sub-systems. The advantage of this is that we are able to design and engineer smaller part at a time.
- Design specifications: Using the answers on the sub-questions, input from the client and the process tree we will make a list of all the requirement of the final machine.
- Evaluation criteria: Evaluation criteria are criteria used to choose between two or more designs. They are different to the design specifications because they need to be very specific and can be answered with yes or no. With an evaluation criteria you can only be able to say whether a design is better than the other. An example of an evaluation criteria is “the weight of a product” if you are designing the product as light as possible.
- Search topics: Search topics are keywords we will use in the next phase to generate ideas. We will have separate search topics for each “sub-problem”. The combination of the solutions generated based on the search topics should be a solution for the whole problem.

3.1.2. Idea

In the previous phase we defined a set of search topics. Now we are going to brainstorm about ideas to solve these problems. During the brainstorming we will make lots of drawings of possible solutions, using the evaluation criteria will choose the

- Idea sketches: At the start of this phase we will make lots of idea sketches. These sketches are not necessarily very detailed or nicely drawn but the reason for them is to show all the different ideas we have.
- Morphological matrix: All the problems will be grouped in the morphological matrix. Using this Matrix we are going to make 4 integral ideas.
- Integral ideas: The integral ideas are combinations of solutions from the morphological matrix. The integral ideas show the basic working principle and do not necessarily need to be feasible.
- Choice based on the evaluation criteria: At the end of the idea phase we will choose 2 integral ideas using the evaluation criteria we have listed in the previous idea phase. The two chosen ideas will be further developed in the next phase.

3.1.3. Concept

In the concept phase we will further define all the subsystems of the two chosen ideas. This involves defining the all the basic properties of all the parts of the machine and proofing that the concept works. The main point what needs to be checked to show the feasibility will need to check that the motor Jansen ready owns can be used. Examples of things we are going to do in this phase are:

- Confirmation the already owned motor can be used: In the concept phase the feasibility of the concept is a big part of the phase. That is why we will check if the motor Jansen Tholen has available can be used.

- Simplified 3D model: For the concepts I will make a 3D model using dummy parts. These parts will show the general size and layout of the machine.
- Calculating the construction: I there are any parts of the concept of witch the construction could be a bottleneck for the design we will check what dimension / material combination is needed to get to the required properties.
- Making a first bill of materials: In this phase we will make a general bill of materials with in there the most important parts of the machine.
- Testing with the design specifications: To the end of the concept phase we will test our design to check whether it meets the design specifications.
- Estimating the total cost: Using the total list of parts and there production methods we will estimate the final cost of the whole machine.
- Concept choice: Just as at the end of the Idea phase we will choose the best one of the two designs based on the evaluation criteria. The chosen concept is going to be the one we will finalize in the next phase.

3.1.4. Materialization

This is the final phase of the design process in which we will fully define the product. The starting point is the concept from the previous phase. This phase mainly involves further detailing the work that has been done previously. Examples of things we are going to do in this phase are:

- Choosing weather to buy or make a part: Before we will design every part our self we need to look into whether it would be better to buy certain parts before we design it ourselves.
- Selecting applicable stock parts: For the parts we are looking to buy we will find the exact specifications for the part that needs to be bought and propose a possible supplier.
- Choosing materials for all the parts: for the part that will be special made we need to select the material. This will be done based on cost, production method, life expectancy and forces that will influence a part.
- Choosing production methods for all the parts: The production method for all special made parts will be determined based on the cost, the simplicity and the tools used for other parts of the machine.
- Determining the dimensions for all the parts: We will need to determine the final dimensions of all the parts in the machine. This will be done based on the working principle, the borders with other parts and the forces witch act upon it.
- Finalizing the electrical schematics:
- Finishing the 3D model: Once the parameters of all the parts are available we will draw and combine the parts using SolidWorks.
- Making the BOM: Once the 3D model is finished we can use Solidworks to make the bill of material for the whole machine. In this will list all the parts, the number of parts and there main dimensions.
- Making 2D drawings including production information for all the parts: For all the parts we will make 2D drawings describing that part including information for production.
- Calculating the total cost: Using the total list of parts and there production methods we will calculate the final cost of the whole machine.
- Writing an operational description: We will make a description of how the machine should be used and how it works.

4. Research results

In this chapter, the research results, I will describe what has been done in this project. This chapter has been based on the phases as described in Chapter 3. Per phase a short introduction is given about the phase followed by the products made for that specific phase.

4.1. Analysis

The analysis phase is the first phase of the design process. This part of the report shows all the results and the steps taken in this phase. First of all we answer the sub questions formulated in our problem statement. This includes measurements of the substrate, calculations of the turning speeds, a look at the interaction with the machine etc. All this research lead to the design specifications and the evaluation criteria which can be found in the following chapters. Finally we describe the search topics and the evaluation criteria we will use in the next phase.

4.1.1. Research questions

At what speed is the substrate supplied?

The speed at which the substrate is pulled onto the sip is important for us to know because we need to store the substrate at the same speed as it is pulled onto the ship. According to (MA, QU, DING, & NIU, 2014) the average speed at which the substrate is pulled onto the ships is between 0.3m/s and 1.0m/s. This value depends on how fast the "MZI" system is running. We need to take into account this is only an average speed. This 0.3m/s and 1.0m/s has been chanced as a result of new information. This says the system needs to store 6200km of substrate in 60 minutes this results in a minimum average speed of 1.8m/s.

Changes in speed

The speed at which the substrate line is pulled onto the ship can vary due to several reasons. The first way the speed of the line is influenced is the speed at which "The mussel scraping machine" runs. This machine pulls the mussels out of the water and scraped off the mussels. So how faster this machine runs how faster the substrate is pulled in. Unfortunately this is not the only factor witch influences the speed of the substrate. Other factors are:

- Slipping of the pulling system because the line is wet;
- A changing amount of mussels on the substrate line;
- A changing amount of substrate which is cut loose from the main line;
- A changing amount of current in the sea witch pulls the water in other directions;

We can`t calculate the amount of change in speed and because there won`t be any change to measure this soon. We think it is best to include some sort of system into the design witch can compensate of the changes in speed. This can be accomplished in many different ways (see section 0).

What is the substrate that needs to be collected?

Dimensions

To know how big the spools on which the substrate will be rolled needs to be we need to know the dimensions of the substrate. We have no specifications of the substrate so we had to determine it ourselves. To do this we needed to measure the diameter of the substrate. First of all we grabbed all the fringes together around the rope and we measured the diameter (see Figure 6) at different points of the substrate. Because all the measurements were a bit different we needed to see what the average diameter of the substrate is. What we did is measure the diameter every 300mm and note the values in a table (Appendix A: Measurements of the substrate).

Figure 6: measuring the substrate

Table 1: Dimensions of the substrate

Results	
Minimum:	15,0 mm
Maximum:	21,0 mm
Average:	16,8 mm
Tolerance	25,2 %

In total we did 30 measurements of these we determined the minimal, maximal and average value (Table 1). The average is the value we can use to determine how much substrate fits on a spool. The minimum and maximum values are useful for the dimensions of guidance and speeds measurements device.

Does the substrate soak up water?

We needed to know if the substrate sucks in water when it is submerged. This is important to know because if the substrate sucks up water the weight and the size could increase. If the weight and the size does change it means we need to hold tis into account while designing the machine.

To test if the substrate does suck in water we first of all cut three pieces off the string we`ve got from the client. Secondly we measured the weight of each peace when it`s dry. After that we submerged the pieces in a tray of water. After letting the substrate suck up water for 1 minute we weight it again and noted the new weight. We repeated the weighing of each single piece after 5 and 10 minutes in the water. We did this to see if the rope does suck in more water over time. The reason we used 3 pieces of substrate was to check if the results were consistent.

Table 2: Measurment of the weight of the substrate

Part	Length (mm)	Weight(g)					Increase in weight
		Dry	After 1 minute	After 5 minutes	After 10 minutes	Average	
1	32	73	105	103	102	103,3	41,6%
2	21	51	72	73	72	72,3	41,8%
3	22	53	76	75	74	75,0	41,5%
						Average in weight increase	**41,6%**

The results of the test are shown in Table 2. The first we noticed is that there is no increase in weight if the rope is submerged in water for a longer time. The second thing we noticed is that the increase in weight in percentage is very consistent over all the measurements we did. We see that there is a weight increase of 41.6 percent after submerging the substrate in water. To check if the diameter increase as a result of the water that has been sucked in we measured the diameter of the wet substrate. The diameter did not change at all.

Weight

The weight of the substrate is important to calculate the overall construction of the machine. To know the average weight of the substrate we measured the weight and the length of the substrate we`ve got from the client. The results were as follows: 20.6 meters of dry substrate weighs 5.40Kg. To determine what the weight of the 3km substrate is that needs to be stored per spool we used the measurement. We found that 3km of substrate would weigh approximately 786Kg when dry. If we add to this the 41.6 weight increase because the substrate sucks in water. We reach a total weight of approximately 1114Kg.

Table 3: Weight of the substrate

Length (m)	Weight (Kg)	
	Dry	Wet
20,6	5,40	7,6
1	0,26	0,4
10	2,62	3,7
100	26,21	37,1
1000	262,14	371,2
3000	786,41	1113,6

What diameter should the drum of the spools have?

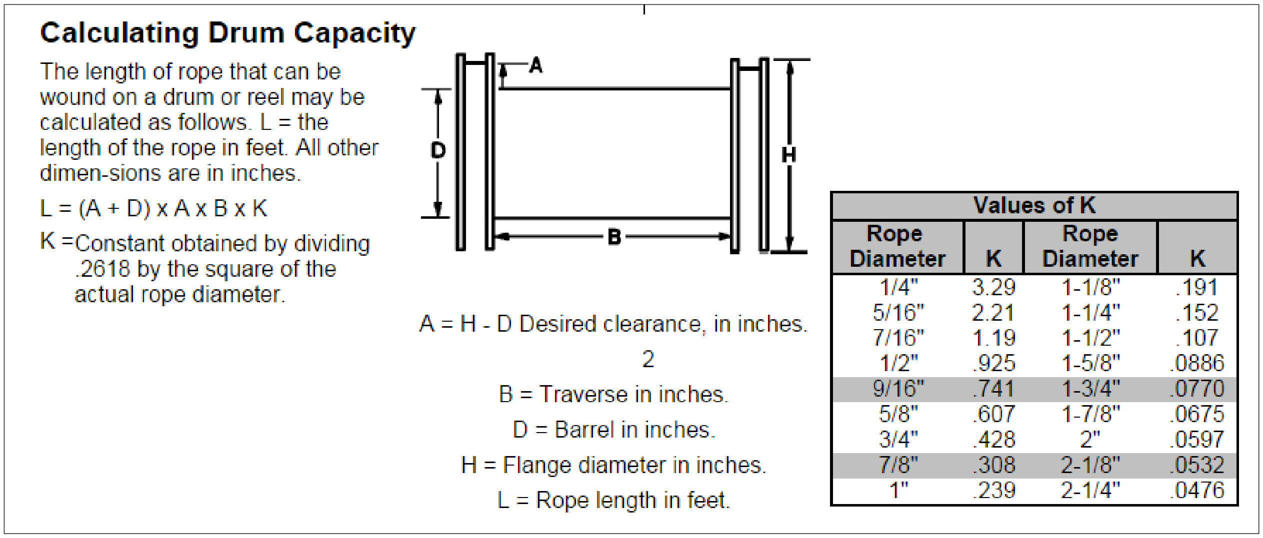
The drum of the spool is the inner part around witch the rope (substrate) is wound. Normal wear occurs each time the rope is used as the wire rope bends around the drum. The D-to-d ratio is used to indicate if a wire rope will be excessively worn or damaged during normal operations. This ratio simply compares the winch drum diameter to the rope diameter. The D-to-d ratio is calculated by adding the winch drum diameter (D) to the wire rope's size (d) and then dividing the sum by the wire rope size (d). For example, if a winch has a 240 mm (D) drum diameter and a 10 mm (d) wire rope is used, the ratio is 25:1. (Falck Productions, 2015) According to (Ingersollrand, 2014) the recommended ratio is 15:1 for pulling applications, in a formula this means: $\frac{D+d}{d} = \frac{15}{1}$. By filling in the maximum substrate diameter we get: $D = (15 \times d) - d = (15 \times 21) - 21 = 294mm$. We used the maximum diameter and not the average because a drum which is too small causes additional wear on the substrate but a drum which is to large doesn`t.

What dimensions need the spools to have?

One of the essential things to know is how big the spools to hold the substrate need to be. The information we have to calculate this is as follows:

- The total length of substrate that needs to be stored is 6,5 km;
- The substrate should be stored on two spools, so 3,25km on each spool;
- The average thickness of the substrate is 16,8 mm;
- The drum diameter should be at least 294mm;

To determine how big the spool needs to be we used the formula as shown in Figure 7 from (Mazzella lifting Technologies, 2010)



Values of K			
Rope Diameter	K	Rope Diameter	K
1/4"	3.29	1-1/8"	.191
5/16"	2.21	1-1/4"	.152
7/16"	1.19	1-1/2"	.107
1/2"	.925	1-5/8"	.0886
9/16"	.741	1-3/4"	.0770
5/8"	.607	1-7/8"	.0675
3/4"	.428	2"	.0597
7/8"	.308	2-1/8"	.0532
1"	.239	2-1/4"	.0476

Figure 7: Calculating drum capacity

The formula shown here is to determine the capacity for a known drum (spool) but by rewriting this formula we can use it to determine the size the spools need to be. How this formula works is that the width and diameter are used to determine the "Volume" of the spool and a constant $(\frac{\pi}{12})$ is used to determine the amount of properly wind rope fits in that "Volume". All the formulas from Figure 7 combined lead to the following formula: $= (A + D) \times A \times B \times \frac{\pi}{12d^2}$. The known variables are L, d and D. By filling these in we get: $3{,}25(km) = (A + 294(mm)) \times A \times B \times \frac{\pi}{12 \times 16.8(mm)^2}$. Now we are left with only two variables. By filling these in, in a table (see Table 4) we get the following dimensions for A and B. We can use this table in the next phases to determine the ideal with and diameter ratio for the design.

Table 4: Required dimensions

Dimension (mm)	
A	B
300	1638
350	1295
400	1052
450	872
500	735
550	629
600	544
650	476
600	502

What should the minimum initial winding tension be?

Winding tension is tension applied to a rope opposite of the direction the rope travels. In Figure 8 the winding tension is displayed as T. The winding tension needs to be applied to any rope to ensure it is properly wound on a spool. If the winding tension is too little the rope will start swooping and will improperly wind on the spool.

According to (Rollring, 2011) the initial winding tension of any sort of rope should be approximately 5 to 10% of tensile strength of material. Assuming the substrate is made of nylon, a 16, mm thick rope has a tensile strength of 46.48N (Engineering toolbox, 2014). So the initial winding tension should be between $86.08 * 0.05 = 4.3N$ and $86.08 * 0.10 = 8.6N$.

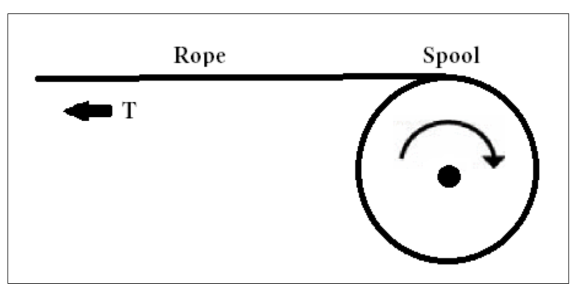


Figure 8: Winding tension

How big should the fleet angle be?

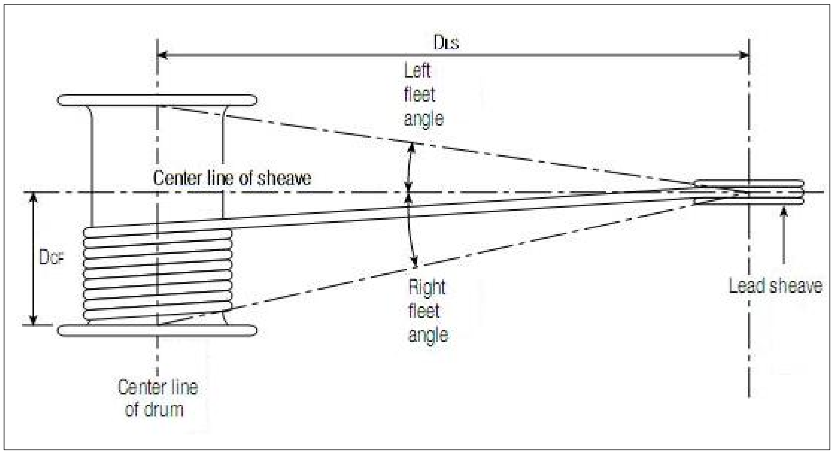


Figure 9: Feet angle

The fleet angle is the maximum angle at which the rope is wind on the drum (see Figure 9). If this angle is too large this will cause wear. A proper feed angle will also ensure that the wire is wound on the spool uniformly. According to (Pacific marine, 2015) a proper fleet angle is between 0,5° and 1,5° measured as illustrated in Figure 9. But as a general "rule of thumb", the absolute minimum distance from the winch to a fixed sheave should be equal in feet to the drum length in inches. For example, a 12" wide drum requires a fixed sheave at least 12' feet away for proper spooling. In metric units this means: $"Minimum\ distance\ from\ the\ winch"\ (mm) = 12 \times "With\ of\ the\ drum"\ (mm)$ The ideal solution would be to keep the fleet angle at 0°. How to accomplish this can be found in section 0.

At what speed should the spools rotate?

The speed at which the spools will need to rotate is dependent on several factors. The first and most obvious is the speed at which the rope needs to be collected. In section 0 we described that this speed would be between 0,3m/s and 2,0m/s. The second factor is the diameter of the drum. The diameter of the drum doesn`t change but because substrate is wound on the spool the inner diameter increases.

In Table 5 you can see the calculated turning speed of the spools. Because the dimensions of the spool aren't fully defined yet we can`t fill in one value for the diameter when the drum is full, that is why we filled in several values. In the table you can see the spool needs to have a maximum turning speed of at least 65rpm. The minimum turning speed depends on the size of spool that is chosen but it will be around 5rpm.

Table 5: Relation spool diameter and turning speed

Drum diameter (mm)	Dimeter when the spool is full (mm)	Speed of the substrate (m/s)	Turning speed (RPM)	
			Empty spool	Full spool
294	894	0,3	19,5	6,4
294	894	2,0	129,9	42,7
294	994	0,3	19,5	5,8
294	994	2,0	129,9	38,4
294	1094	0,3	19,5	5,2
294	1094	2,0	129,9	34,9
294	1194	0,3	19,5	4,8
294	1194	2,0	129,9	32,0
294	1294	0,3	19,5	4,4
294	1294	2,0	129,9	29,5

What force is needed to rotate a full spool?

The force needed to turn the spool is dependent on serval factors. The first is the speed the machine is operating at. This speed varies as a result of a changing speed the rope is being supplied and an increasing drum diameter. Another factor is the weight of the substrate and the mussels that needs to be pulled in. The last factors are the winding tension and the force applied to the substrate by the jet-pump.

How do comparable machines work?

Winding systems

The most basic system to wind rope or cable on a spool is to turn the spool and thus wind the rope on the spool. This solution is mostly used for cables or thick rope. The disadvantage of this solution is that smaller rope will wind on the spool randomly. To prevent this from happening guidance is used witch moves back and forth in front of the spool (Figure 10). This solution, using guidance in front of the spool, is the most common solution for winding relatively small rope.

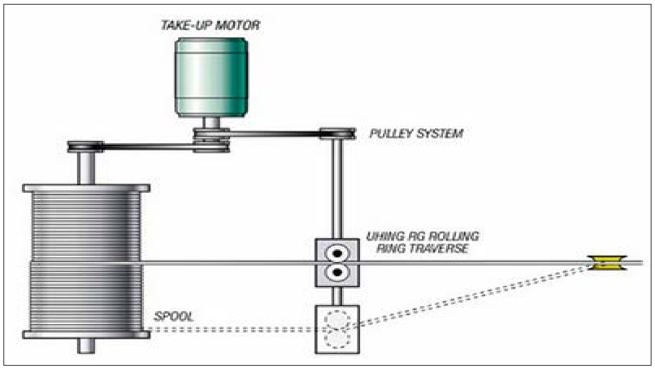


Figure 10: Winding solution 1

The moving guidance is accomplished in several ways. The first one as sown in Figure 10 uses a special type of spindle witch moves the guidance back and forth in front of the spool. The advantage of this solution is that only one motor is necessary and because of that the spool and guidance are always in sync. The disadvantage is that the speed of the guidance relative to the spool can`t be changed. So you can only wind one diameter of rope correctly.

A solution to be able to wind several diameters of rope correctly is to power the spool and the guidance speratly. This allows you to have both parts run at different speeds. This solution uses more motors but also gives you grather felxibility. A variation on this solution is sown in Figure 11. This solutution uses a simple spinde and a servomotor for the guidnce. The servo motor allows you to change the the direction the guidance move at any time. This gives a lot more fexibilty but also you need more electroncs compared to the solution sown in Figure 10, witch is a purly mecanical solution.

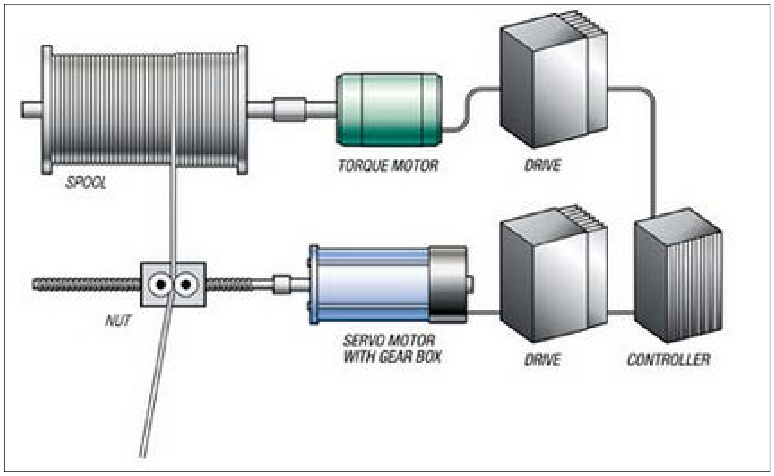


Figure 11: Winding solution 2

Tensioning systems

To ensure anything is wound properly on a spool you need Initial winding tension (see section 0). In this part we look at systems to ensure a constant winding tension. The first is shown in Figure 12. This shows a system mostly used when winding sheet material. In this system a dancing/rolling arm is used to keep the material under tension. There are several ways a dancing arm can be used. The first is using a spring to keep the dancing arm down with a constant force. This solution only allows you to overtake short changes in speed or tension.

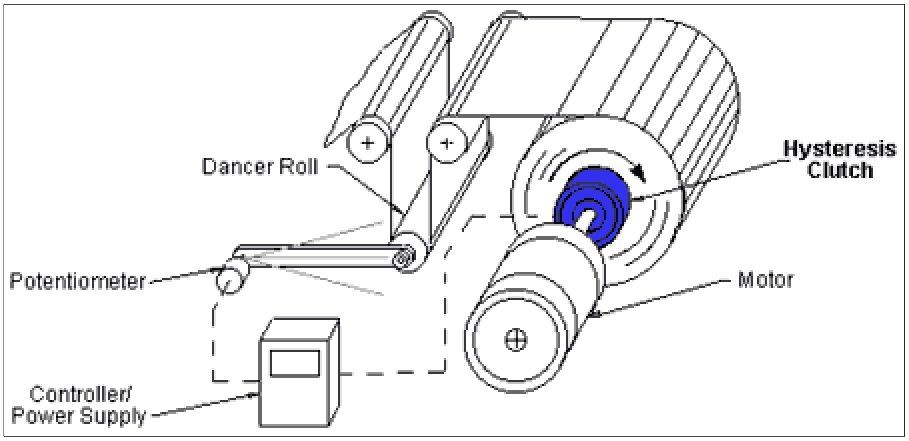


Figure 12: Tensioning using a clutch

A more advanced solution is using the location of the dancer arm to regulate the speed of the winding motor. This system can work both mechanically an electrically (shown in Figure 12). In a system like this there are three possible stances:

1. The dancer is in its normal position so the motor runs at a normal speed.
2. The dancer is lower as normal, this means the material is fed faster as it`s wound on the spool. To compensate for this the motor will turn faster.
3. The dancer is higher than normal, this means the material is wound faster as it is supplied. To compensate tis the motor will turn slower.

The advantage of this system is that you need no connection to the parts that feed the material and are still able to get a speed which is in sync. (PMD, 2014). Using a system like this would allow us to not measure the speed of the rope directly and then match the speed of the spool. With a system like this you can constantly adjust the speed of the motor as the substrate is fed. This also eliminates the hassle of compensating for the chance of drum diameter as more substrate is wound onto it.

The second solution for creating tension on the rope is shown in Figure 13. In this system the wire is wound around a captain several times. This captain can only rotate when a certain amount of force is applied to the rope. This ensures the rope is always tensioned when it is wound on the spool. But this system doesn't prevent the rope from losing tension before the capstan. If the loss in tension in front of the capstan is too large the rope could start to tangle. (Spooling new reels, 2012) A solution could be adding a buffer in front of the capstan. A buffer could be a bag or box in witch rope which is collected to fast is dropped in. Another approach is using a sensor

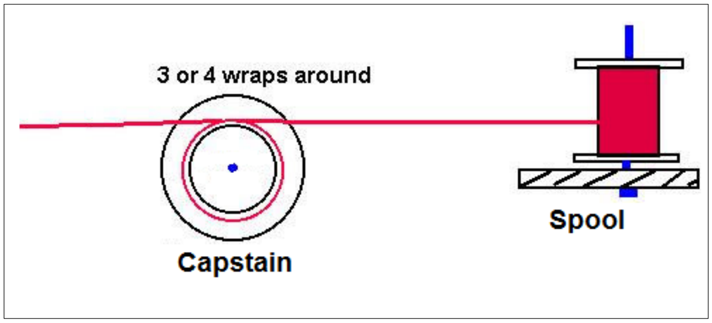


Figure 13: Capsain in front of the spool

which measures the speed at which the rope is supplied and using that information the speed of the spool is adjusted.

The last method we found (shown in Figure 14) is using two wheel around witch the rope is wound multiple times. Because the wheels have some resistance to them the rope will stay tensioned. This is similar to the previous solution. But this solution has the advantage that you can change the distance between the wheels. This allows the system to compensate for a sudden change in speed. The distance between the wheels can be changed by a spring or electrically controlled.

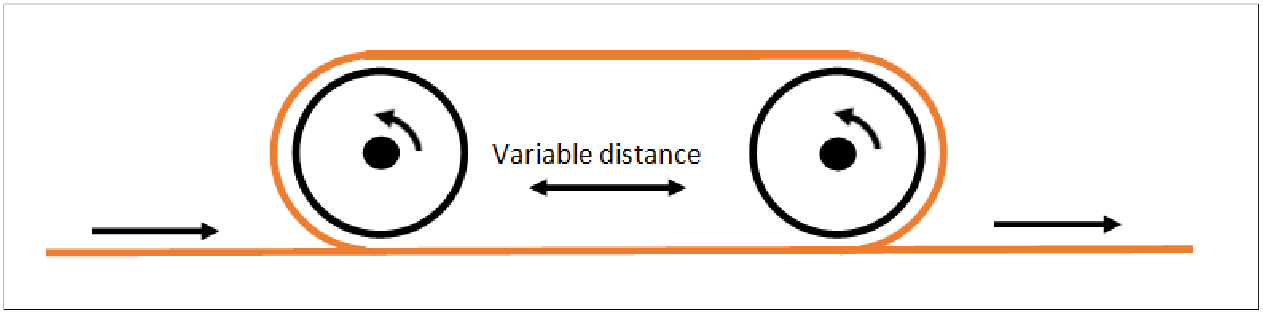


Figure 14: Tensioning reel

What interaction will there be with the machine?

To get an idea what interaction there will be with the machine we spoke to the fisherman of the Tholen 4. Using the input from these conversations and looking at comparable machines we made a “process tree”. The process tree can be found in Appendix B: Process tree. Using this tool we found a couple of useful requirements / insights witch we will describe here:

- There needs to be an easy way for the users to feed the substrate from the “scraping machine” to the spool.
- If the spool is full and the substrate needs to be cut by a worker. The worker needs to be signaled that he needs to cut the rope.
- The location where the cut will be made needs to be easily accessible.
- The “MZI” systems needs to stop when the substrate is cut and connected to the next spool. This is why it needs to be possible to make the cut and connect the substrate as fast as possible.
- There needs to be a possibility to lift the spools from the ship and store the substrate for later use.
- Its need to be possible to change a spool when the other spool is being wound. To make this possible we need to make sure that the workers don’t get tangled in the spool which is winding rope.

What dimensions should the machine have for easy reachability?

The user has to do a few actions manually on the machine witch are cutting the substrate, connecting the substrate to the spools and changing the spools. We used (TU Delft, 2004) to determine all the dimensions. The demographic we chose were Dutch males between 20 and 60 years of age. In **Fout! Verwijzingsbron niet gevonden.** and Figure 15 you can see the dimensions we have got from the database and the once we derived from that. The first value we calculated is value is the arm length measured from the chest. This is the maximal distance from the edge of the machine any action should happen. The critical value is with the smallest people so we look at the value at P10 witch is 450mm.

Table 6: Dined results

Number	Dimension	P10 (mm)	P50 (mm)	P90 (mm)
4	Shoulder height	1397	1494	1591
6	Fist height standing	757	817	877
8	Hip height	944	1022	1100
20	Arm length	700	758	816
27	Chest depth	250	299	348
20 - 27	Arm length fom chest	450	459	468
4 - 6	Arm length (top to bottom)	640	677	714

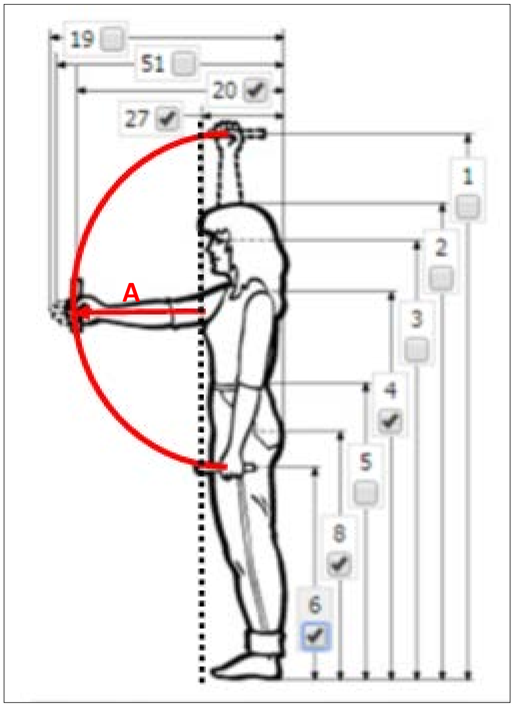


Figure 15: Human dimensions

3.1.1. System decomposition

In the next phase we will start designing the machine itself. To do help us do this in a more structured way we have split the machine up in several systems and subsystems. The hieratical decomposition can be found in Appendix C: System decomposition

- Control
  - Spool full detection: To be able to alert the workers if the spool is full we need to be able to detect weather the spool is full or not.
  - “Cut” Alert: Once it has been detected that the spool is full the user needs to be alerted.
  - Connection to the rest of the “MZI” system: When the cut needs to be made in the substrate the whole “MZI” system needs to stop. To do this a connection needs to be made between the different machines.
- Substrate pulling and winding
  - Creating winding tension: To ensure the substrate is properly wound there needs to be a system that creates winding tension.
  - Winding guidance: To ensure the substrate is properly wound there needs to be a system that guides the substrate onto the spools.
  - Spool holding: The propulsion needs to be connected to the spools to be able to wind the rope.
  - Propulsion: The winding mechanism needs to be propelled.
- Buffer / compensation for changes in speed: Because there will be small changes in the speed at which the substrate is pulled into the ship there needs to be a way to compensate to this.
- Framework: Of course the machine needs a framework to mount all the parts to. Also this is the part that will be mounted to ship and accommodate the easy lifting of the machine.
- Substrate holding: The substrate needs to be stored on something, most likely this will be a spool.
- Substrate guiding: This system will guide the substrate from the mussel scraping machine over the deck to the storing device.

3.1.2. Design specifications

The design specifications are all the requirements for the final product. The full list can be found in Appendix D: Design specifications. We have come to this list of requirements in three different ways. The first are requirements the client gave us. After checking if the requirement was reasonable we could just list them right away. The second way is using requirements witch were already listed in (MA, QU, DING, & NIU, 2014). Because the source of these requirements was not always traceable I had to check most of them by doing research myself or contacting the client. The last type of requirement comes from my own research witch I conducted in the analysis phase. Later in the concept and materialization phases I will use the design specifications to check if the design meets all the necessary requirements.

3.1.3. Evaluation criteria

In the next phases we need a way to compare the different designs to each other. For this we use a weighted matrix, in this matrix we list evaluation criteria on which we rate all the designs. Every criteria has a weight to it witch shows the importance of that specific criteria. By multiplying the rating with the weight we get the weighted rating of each design. In Table 7 you can see the matrix we are going to use. Underneath that we gave a little explanation for the choice and the weight of the criteria.

Table 7: Weighted rating matrix

Criteria	Weight	Option 1		
		Value	Rating	Weighted rating
Total cost;	1			
Time to switch from the first to the second spool;	3			
Time to change a spool;	2			
Time necessary to feed the substrate up to the spool;	3			
Maintenance costs;	2			
Use of stock parts;	1			
Time between failure;	2			

- Total cost: Of course the cost of the machine is a factor when choosing a design but we gave it a relatively low rating because a faster harvesting time has a greater impact on the profit than the acquisition costs of the machine.
- Time to switch from the first to the second spool: Because the fisherman need to be able to harvest the mussels a quick as possible they don`t want to have a lot of work swapping the substrate from the first to the second spool. This is the reason why this criteria has the highest weight.
- The time to change a spool: The fisherman need to be able to change a full spool for an empty one as quick as possible because they can`t harvest while swapping the spools.
- Maintenance: The ease of the maintenance is important because a lot of it will be done on the ship itself.
- Use of stock parts: To prevent the amount of work that needs to be done it helps to use stock parts.
- Time between failure:

3.1.4. Search topics Idea phase

The final product made in the Analysis phase are the search topics we are going to use in the next phases. These search topics will be used to generate ideas in the next phase. The way we came up with these topics is by looking at the problem statement, comparable machines and the process tree.

Technology

- Creating winding tension;
- Compensating for changes in speed;
- Guiding the rope on the spool;
- Powering two spools;
- Guiding the substrate over the ship;
- Layout of the machine;
- Lifting out the spools;

- Connecting the substrate to the spools;
- Detecting if the spool is full;
- Controlling the system;
- Changing the speed the spools rotate at;

People

- Location to cut the rope;
- Preventing the users from getting trapped by the machine;
- Warning that the spool is full;

4.2. Idea

The idea phase is the part of the project in which we actually start designing the machine. In this phase we begin by sketching lots of small ideas based on the search topics we listed in the previous phase. When we had a reasonable amount of sketches we organized them in the morphological matrix. This was done to display all the sketches in an organized manner and to check if there were any search topics for with nearly any ideas were generated. Using the morphological matrix we sketched 4 integral ideas. Finally we chose the best 2 Ideas based on the evaluation matrix.

4.2.1. Sketching

During the idea phase one of the main activities is generating ideas for all the search topics we have listed in the analysis phase. The first sketches made are most of the time not very detailed or nicely draw but this is not the point of them. The purpose of these sketches to generate lots of Ideas in a fast way. We have chosen not to put all the rough sketches in the report but the ideas witch it generated can be found in the morphological matrix.

4.2.2. Morphological matrix

The morphological matrix is a tool we used both to organize our ideas and a way to select different combinations of ideas to generate integral ideas. The matrix itself can be found in Appendix E: Morphological matrix. We started making the matrix during the sketching process. We did this to ensure had enough ideas for all the search topics. Once all our ideas were listed in the matrix we started making sensible combinations of ideas witch would lead to the integral Ideas. In the matrix the different colored dots refer to a specific idea. The resulting integral ideas will be discussed in the next part of this report.

4.2.3. Integral ideas

Using the morphological matrix we have commanded separate ideas into a set of 4 integral ideas. The combination of the ideas was done with the focus on combining solutions for different problems into one system. An example of this is combining ideas in a way that one system can both keep the rope under tension and sync the speed of the machine. The process we used to do is was first combining solutions for the most important problems (e.g. tensioning, winding and guiding) and after that selecting complementary solutions for the remaining problems (e.g. lifting the spools, warning the user and position of the spools).

Next we will, per integral idea: show the drawing made, explain the working principle, discuss the advantages and disadvantages of the solution and show the way we combined different solutions into one system.

Integral Idea 1

This idea, integral idea 1 uses the motor to control the tension and the speed of the substrate line. The advantages of this is that no additional system is necessary to measure and correct the tension of the substrate line. The other unique thing of this idea is that the axle supporting and turning the spools is only support on one side. This allows easy changing of the spools because it is possible to lift out the spool without needing to disconnect the main axle. The motor has been positioned in the center in line with both axles to prevent the need for several geared connections.

Advantages

- Fast changing of spools;
- Axes for both spools in one line;
- Tensioning by the load control;
- Adapting to changes in speed by load control;

Disadvantages

- Fragile main axle because it is only supported on one side;
- The guiding mechanism needs separate electronics to be controlled;

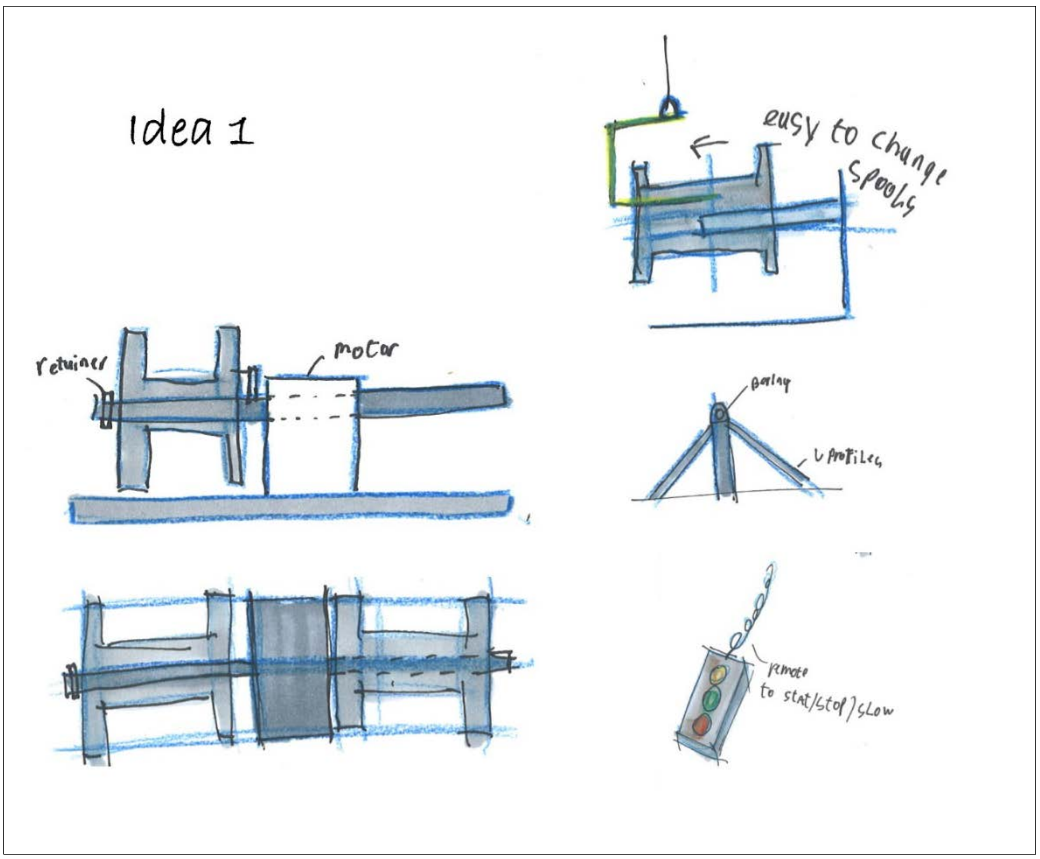


Figure 16: Integral idea 1

Integral idea 2

The second integral idea uses the motor as well to keep the rope under tension but in a slightly different way. This machine has a separate part to measure the tension on the rope and using this value the turning speed of the motor will be adjusted. The measuring device has three wheels which guide the substrate, the middle wheel can move using a spring and a sensor measures the position of the middle wheel (Figure 17: Integral idea 2). If the middle wheel goes down this means the tension on the rope is lower so the motor will speed up which leads to more tension on the rope so the middle wheel goes to the neutral position again. Furthermore this design can use only one guiding mechanism for both spools because the guidance has been mounted in the middle.

Advantages

- The guiding wheel is protected in the middle of the spools;
- Precise measuring of the amount of the rope gathered;

Disadvantages

- Axle needs to be mounted on the spool before it is placed in the machine;
- Separate system for tensioning the rope;
- There is a need to feed the rope trough the tensioning system;
- Harder to connect the substrate to the spools because the guiding wheel is in the middle;

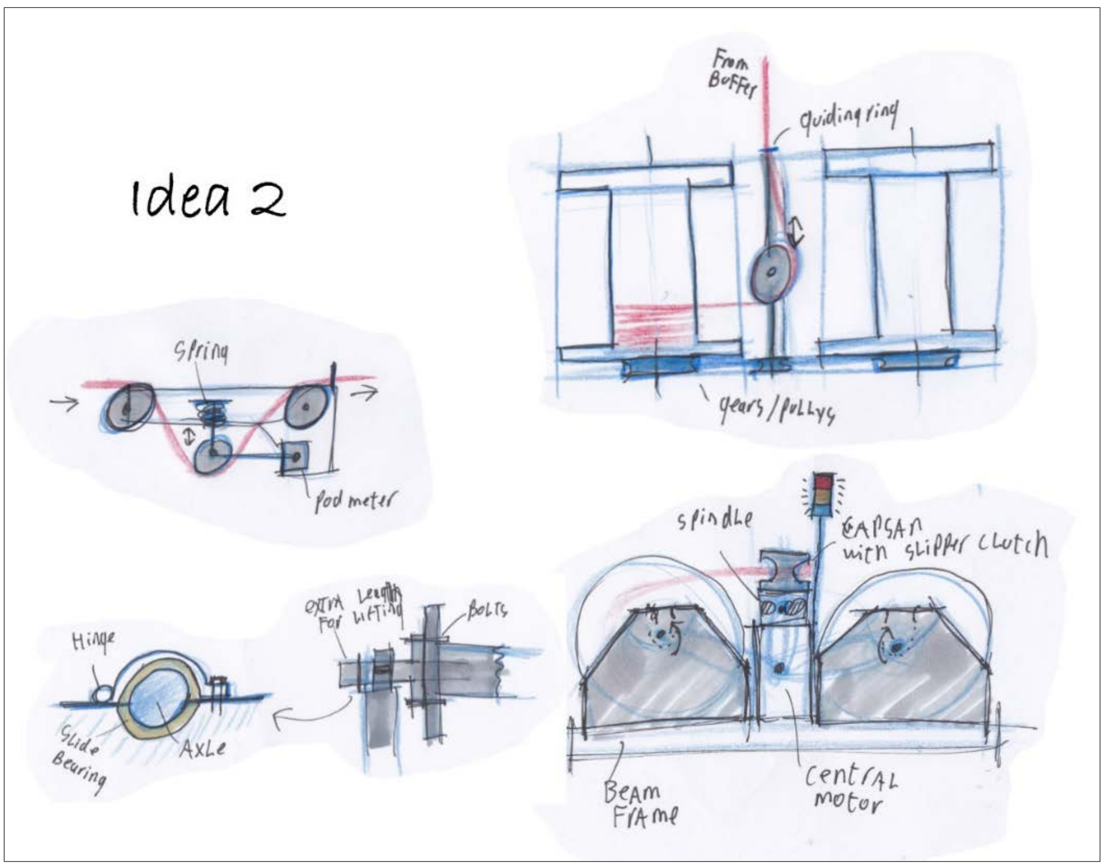


Figure 17: Integral idea 2

Integral idea 3

Integral idea three has the same layout as integral idea one. Here the motor is in line with both the axles supporting and turning the spools. But in this idea the axles are supported on both sides which makes the axle less vulnerable and doesn't have to big as big as in idea one. Also this machine uses a separate machine to measure the tension. The measuring device has three wheels which guide the substrate, the middle wheel can move using a spring and a sensor measures the position of the middle wheel (Figure 17). If the middle wheel goes down this means the tension on the rope is lower so the motor will speed up which leads to more tension on the rope so the middle wheel goes to the neutral position again. This is because the guidance is mounted onto one spindle and is separately regulated so it can move from the first to the second spool.

Advantages

- Easy access for connecting the substrate;
- Precise measuring of the amount of the rope gathered;
- Flexibility of mounting different sub-systems on different locations on the ship;

Disadvantages

- A separate tensioning system;
- The guiding mechanism needs separate electronics to be controlled;
- Axle needs to be mounted on the spool before it is placed in the machine;
- Separate system for tensioning the rope;
- There is a need to feed the rope trough the tensioning system;

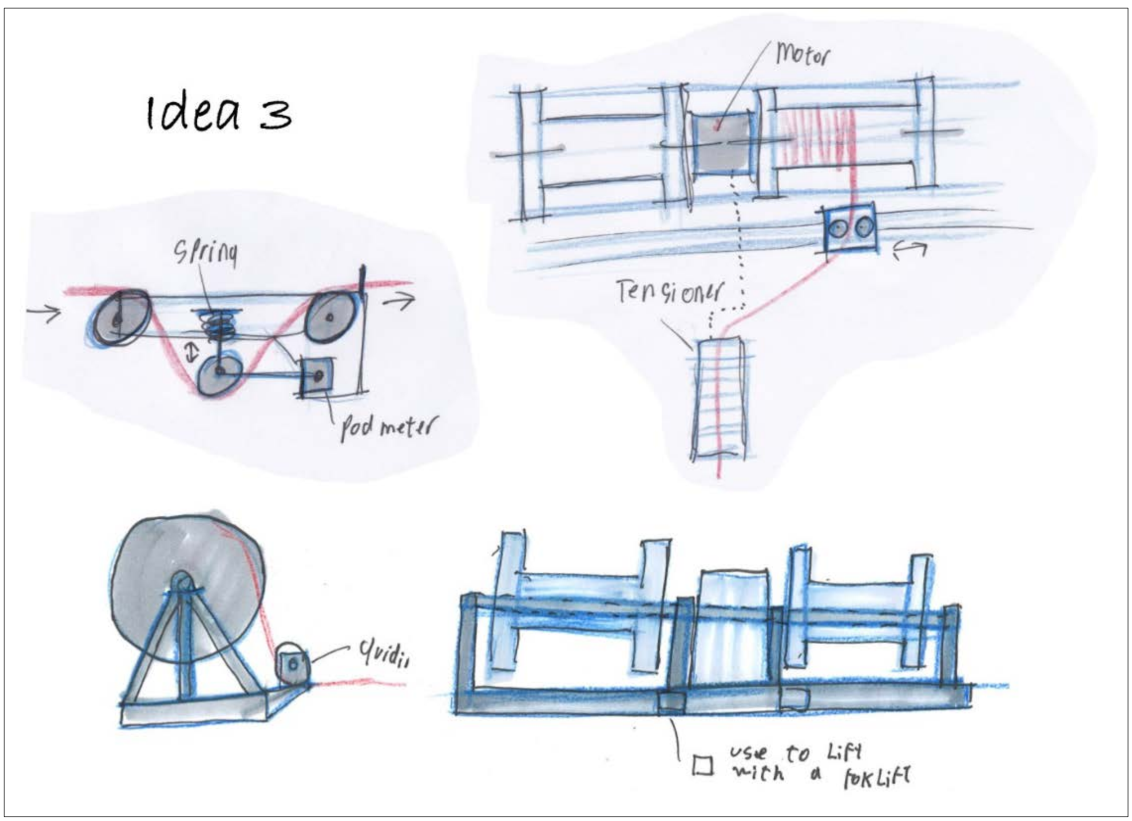


Figure 18: Integral idea 3

Integral idea 4

The last idea is integral idea 4. This idea uses the motor to adjust to changes in the tension and speed of the substrate line. If the tension and thus the force needed to wind the substrate the motor will speed up. When the tension is higher the motor will slow down and the tension will lower. Furthermore this machine has only one centrally located guiding system for both spools. On top of this guidance there is a wheel to allow easy switching between the first and the second spool.

Advantages

- Tensioning by the load control;
- Adapting to changes in speed by load control;
- Easy to lift the whole machine from the ship as a result of the compact design;
- Except the electronics of the current motor no more electronic parts are required;
- The guiding wheel is protected in the middle of the spools;

Disadvantages

- Harder to connect the substrate to the spool as a result of the compact design;
- Axle needs to be mounted on the spool before it is placed in the machine;

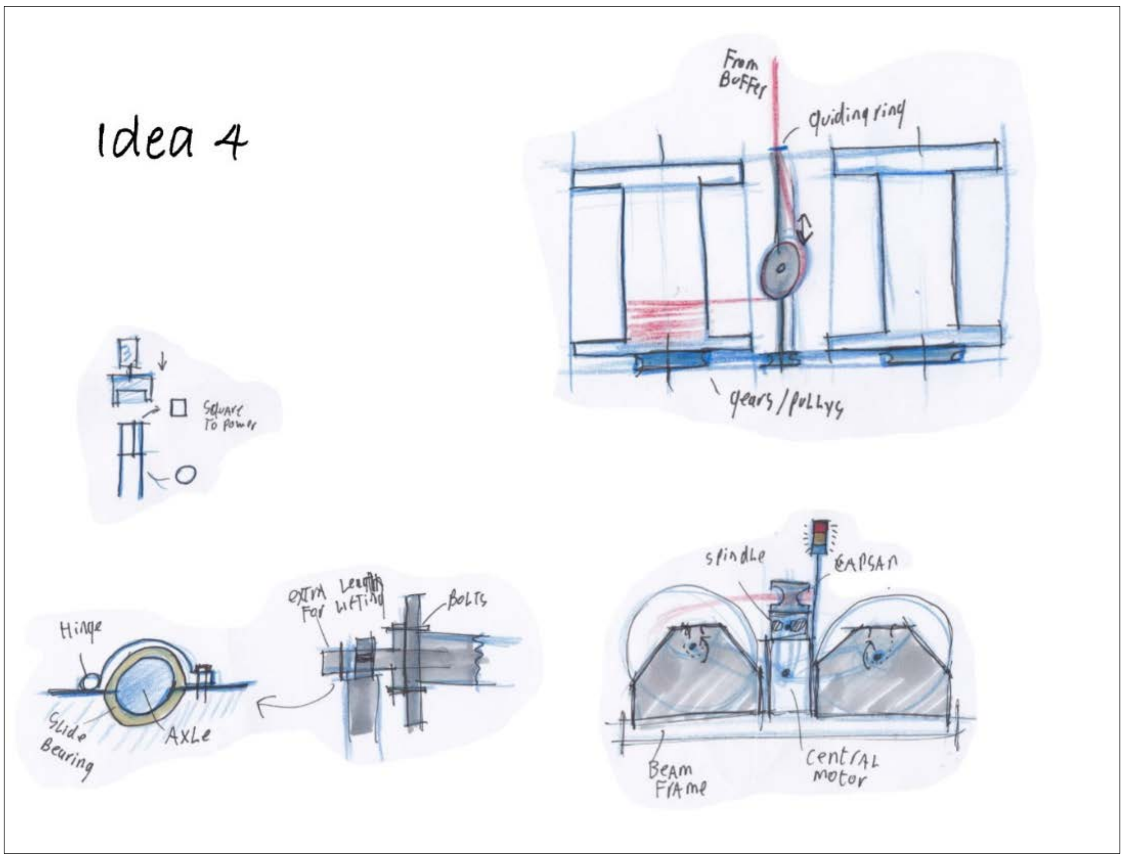


Figure 19: Integral idea 4

4.2.4. Idea choice

The final part of this phase is choosing the two integral ideas witch we will turn into concepts in the next phase. Our choice will be based on the evaluation criteria we have made in the analysis phase. For each idea we filled in the weighted rating table (see table 9 - 12) and compared the results. We based the scores in the tables on the descriptions from the previous paragraph. When three points given the integral idea was relative to the others very strong in this area when 1 point given the integral idea is weak in this area. For now we left the value column empty because it is very hard to derive exact specifications from an integral idea but later we will use this column to show the exact values (e.g. we will list the total price of the machine).

Table 8: Rating integral idea 1

Criteria	Weight	Idea 1		
		Value	Rating	Weighted rating
Total cost;	1		2	2
Time to switch from the first to the second spool;	3		2	6
Time to change a spool;	2		3	6
Time necessary to feed the substrate up to the spool;	3		3	9
Maintenance costs;	2		2	4
Use of stock parts;	1		2	2
Time between failure;	2		2	4
			Totaal	**33**

Table 9: Rating integral idea 2

Criteria	Weight	Idea 2		
		Value	Rating	Weighted rating
Total cost;	1		2	2
Time to switch from the first to the second spool;	3		2	6
Time to change a spool;	2		2	4
Time necessary to feed the substrate up to the spool;	3		1	3
Maintenance costs;	2		1	2
Use of stock parts;	1		2	2
Time between failure;	2		2	4
			Totaal	**23**

Table 11: Rating integral idea 3

Criteria	Weight	Idea 3		
		Value	Rating	Weighted rating
Total cost;	1		2	2
Time to switch from the first to the second spool;	3		2	6
Time to change a spool;	2		2	4
Time necessary to feed the substrate up to the spool;	3		1	3
Maintenance costs;	2		2	4
Use of stock parts;	1		2	2
Time between failure;	2		2	4
			Totaal	**25**

Table 10: Rating integral idea 4

Criteria	Weight	Idea 4		
		Value	Rating	Weighted rating
Total cost;	1		2	2
Time to switch from the first to the second spool;	3		3	9
Time to change a spool;	2		2	4
Time necessary to feed the substrate up to the spool;	3		2	6
Maintenance costs;	2		2	4
Use of stock parts;	1		2	2
Time between failure;	2		2	4
			Totaal	**31**

After filling in the scores for each integral idea we compared the results in Table 12. This table shows the score for each integral idea and its ranking. We can see that idea 1 and 4 are the "winners" with a score of at least 20% higher than the following ideas. Both ideas were the ones using load control on the motor for keeping the substrate tensioned and to sync the winding speed with the rest of the MZI system. This also meets the preference of the client and takes the largest advantage of the motor Jansen Tholen already owns.

Table 12: Results of the idea comparison

Idea	Total rating	Number
1	33	1
2	23	4
3	25	3
4	31	2

4.3. Concept

The goal of the concept phase is proofing the design is feasible. To show this we first of all need to detail the chosen integral ideas. In this chapter you will first read calculations witch were relevant to both concepts, after this we show the work done one both designs followed by a check of the requirement and we end with a choice for the design we will further detail in the materialization phase.

4.3.1. Selection of the spool

Because the type of the spool has a lot of impact on the design we made choosing a specific type of spool our first task in the concept phase. Examples of the influence of spool size are the following:

- The maximum diameter effects the momentum needed to rotate the spool, this in term effects if the available motor can be used;
- Connection between the main axle and the spool;
- The overall dimensions of the machine;
- The force on the axles and thus on the bearings;
- The positioning on the ship;

To select a spool we made a table (see Appendix F: Comparison of spools) to compare different types and sizes of spools. The most important part of this table is the calculation we have done in it. This was the calculation to determine the capacity of the spools. Of course this is the most important value in the table because if the capacity is too low all the other values don`t matter.

We started the comparison by searching for different manufacturers of spools and reels who had their product specifications listed on their websites. We found two parties HKC and PAGO. One of them had both steel and wooden spools and the other PAGO only supplied steel spools. For the sizes of spools we were looking at wood and steel seemed the most obvious material for a spool. Although in smaller sizes spools plastic is a more commonly used material. These plastic spools have several advantages because, they cannot rust or rot. This makes the potential lifespan much longer (Draka, 2015). After looking for a manufacturer for large plastic spools we found Hafner which makes spool in many different sizes. We added the two largest spools to our comparison.

Looking at the last two columns in our table we could see that if we would want to use the largest plastic pool we would still need 10 spools. For this application of the spools that is not a feasible solution. When we are looking at the other possibility's we saw a few spools (both wood and steel) we saw three possible choices:

Figure 20: HKC A1400

- Choosing a spool of a size that one would be enough. When we would choose this solution this would be the simplest solution because you only have to power one spool and changing the substrate from the first spool to the second isn't necessary. The problem with this solution is that the diameter of the spool will be too large to fit in the hull of the Tholen 4. For this reason the solution is not feasible.

- Choosing a spool of a size that two spools will be filled. This is according to the first idea the client had. This is the most practical solution to implement on the Tholen 4.
- Choosing a solution that three spools are necessary. In a situation where three spools are necessary one spool would need to be changed during the collecting of the rope. This could be a good solution but the problem is the Tholen 4 has no cranes above the hull where the machine would be placed. For this reason this solution is not feasible.

The choice for an exact type of spool was pretty much made for us because of the limited sizes available this is why we chose the A1400 from HKC (see Figure 20). It was not our first intend to choose the same spool for both concepts but because the range of spools applicable for this use proofed to be very small we chose the same spool for both concepts.

4.3.2. Use of the available motor

Because the concept phase is about proving the feasibility of the concept we will use this phase to show that the winder Jansen Tholen owns can be used for the winding the substrate. To check if the winder can be used we made a list of point on which we checked. Per point we used the specifications of the winder, the user manual, the values calculated in the analysis phase and the design decisions made.

Max. Diameter

The maximal diameter of the spool is an important value for checking of the winder can be used. When a larger spool is used the torque required will be higher. When the maximum value is exceeded the hydraulic unit won't be able to deliver the higher pressure necessary to move the spool and the winder will stall. The spool we chose has a maximum diameter of 1400mm so this does not exceed the maximum diameter of the winder which is 2000mm.

Min. core diameter

The minimal core diameter of the winder is determined by the minimal diameter the winder can retain its maximum winding speed. If the core diameter is lower than the minimal value there is not a sufficient flow to the hydric motor to retain the maximum speed with the required torque. Dependent on the tension on the rope this could cause the motor to stall or run slower than specified. For our application this won't be a problem because the minimal core diameter is 90mm and we will use a spool with a diameter of 720mm.

Min. tension set point

The tension set point determines the maximum tension that can be applied to the rope. As we have seen in the analysis phase the initial winding tension should be between at least 4.3N. To determine if this is within the specifications of the winder we first need to know the maximum torque of the winder because the value is described as 15 of the maximum pressure.

We can calculate the maximum pressure using the following formula: $T = \frac{D*p}{20\pi} = \frac{8.51\left(\frac{cm3}{rev}\right)*170(Bar)}{20\pi} = 23Nm$. To calculate the maximum tension in the rope we used the following formula: $F = \frac{T}{r} = \frac{23(Nm)}{(1400-710)/\ 2+710)(mm)} = 21.8N$. By dividing 4.3N by 21.8N we get a percentage of 20% which is more than the specified minimum of 15%. For this reason the winder can deliver sufficient tension on the rope. (Bogerd, 2015)

Max. pump and winding pressure

According to the specifications of the winder the maximum pressure of the hydraulic system is 180bar. If we would exceed this limit this could cause the winder to breakdown as it is not rated for this pressure. Looking at the measurements done on the pump of the Tholen 4 described in (Bogerd, 2015). We saw that the pressure of the hydraulic system has a maximum pressure of 170bar at the maximum turning speed of 1700rpm. This is ten bars lower than the maximum specified pressure of 180bar. If the pressure would be too high a solution could be lowering the turning speed of the motor to lower the pressure.

Pressure ramp

The pressure ramp value is the time it takes for the hydraulic unit to go from an output of 0 to the maximum output pressure. Both when this value is higher and lower you will get a different positive influence on the operation of the machine:

- A longer pressure ramp time causes the rope to be pulled in smoother because short peaks in the required pressure won't cause changes in the delivered pressure.
- A shorter pressure ramp time causes the machine to faster get to the required pressure when you start winding. (Wintech Winding Technology AG, 2002)

The actual value for the pressure ramp of the winder is 5 seconds. We think this value is low enough to not cause problems during the starting of the winder. When the machine will be able to get to the full speed in five seconds this is fast enough. We cannot give any predictions if this value will positively or negatively influence how smoothly the substrate is wound. This is because there are too many factors which influence how smooth the rope is pulled (e.g. weight of the substrate with mussels, the mussel scraper, the jet-pump and the length of the substrate line) (Markey, 2000)

Machine speed

The client gave us a guideline about in what time the machine should be able to collect a certain amount of substrate. The specification was as follows: "The machine should be able to collect 6.5km of substrate in 60min". Of the length 6km is the actual rope that needs to be collected and the remaining 0.5km is an additional buffer. But this actually says nothing about the minimum and maximum speed. The outermost values has been determent in the analysis phase and are shown in Table 13: Required turning speeds.

Table 13: Required turning speeds

Drum diameter (mm)	Dimeter when the spool is full (mm)	Speed of the substrate (m/s)	Turning speed (RPM)	
			Empty spool	Full spool
710	1400	0,3	8,1	4,1
710	1400	2,0	53,8	27,3

In Table 13: Required turning speeds we see that the minimal turning speed is 4,1rpm and the maximum speed is 53,8rpm. In Table 14: Calculated turning speeds we reworked the values into the same unit as in

Table 14: Calculated turning speeds

Specification			Concept		Diffrence	
Max diameter	2000	mm	1400	mm	600	mm
Min core diameter	90	mm	710	mm	620	mm
Max speed	96	m/min	120	m/min	-24	m/min
Min speed	15	m/min	18	m/min	3	m/min

the specifications and compared the specifications with the required speeds. What we see is that the minimal speed can be reached but looking at the maximum speed we have a problem. We see that we can`t reach the maximum speed but the problem is even greater because we cannot reach a speed with is high enough to collect the sufficient amount of rope in 60 minutes. Because to pull 6.5km in 60 minutes we need an average turning speed of 108m/min. for this reason we can only pull in 5.76km in 60 minutes if the winder would be working at the maximum speed. So pulling in 6500m would take 68 minutes. We discussed this problem with our client and they ensured us this isn't a big enough difference to buy a different winder.

4.3.3. Concept 1

Now we will discuss the specific parts for both concepts. Starting with concept one. Concept one is the concept that originated form integral idea one of the previous phase. We will go over particular design decisions we made in this phase specifically regarding this concept. Which includes drawings for the parts and calculation to proof the feasibility.

4.3.3.1. General description

To give a good overview of the concept we started making a 3D model (Figure 21). This model lacks most of the details and the dimensions are not final yet. We use this model only to show how the main (dummy) components fit together. Just as the other concept this machine uses the tension controlled winding of the winder Jansen Tholen owns to keep the substrate under constant tension and keep in sync. with the rest of the machine. The big advantages of using this method is that we do not need to measure the exact speed/tension of the substrate and then regulate the motor. The winder handles all of this using the load on the motor. This concept its unique selling point is mostly that the spools can easily be changed because the axle is only supported on one side. When you want to remove the spool only a small retainer must be removed and the spool can be lifted from the axle.

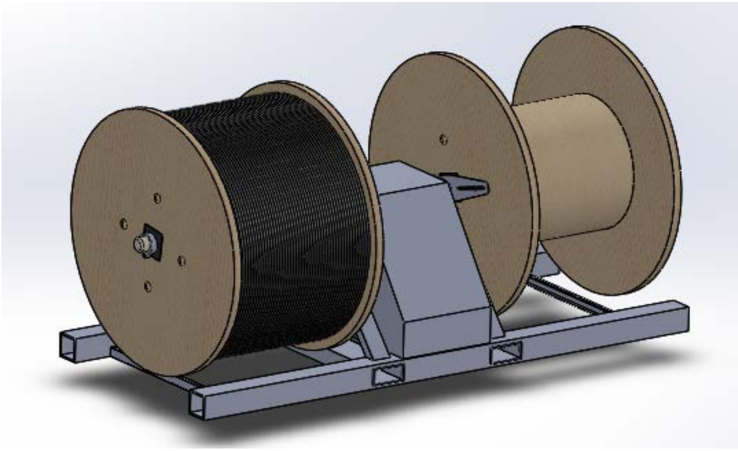


Figure 21: Dummy model concept 1

4.3.3.2. Bearings

Of course the axle which rotates the main need to run smoothly to accomplish this we need bearings. Looking at similar machines we see that both plain and roller bearings are used for this kinds of machines. Which type is the best will be decided in the next phase but we are sure it is possible either way. What we did decide is that the bearing will be mounted in a bearing block to allow an easy connection between the bearing and the frame (Figure 22).

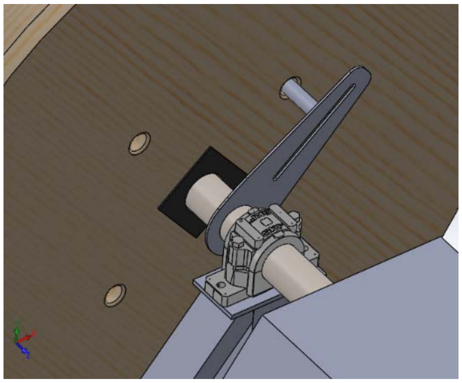


Figure 22: Bearing housing and spool pusher

4.3.3.3. Framework

The frame of the machine shown in (Figure 23) is made-up out of tubes. What we have are two large tubes which support the whole machine and prevent it from tipping over when only one spool is filled. Next we have to triangle shaped frames that are used to support the bearing and thus the whole weight of the spool. The bottom beam of the triangle frame is a tube as well, the size of this tube will have the size that allows a forklifts blades to pick the machine up easily. We are not worried that the construction of the frame won't be strong enough because the weight that will rest on it is limited.

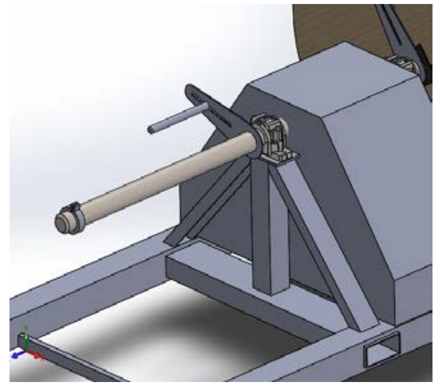


Figure 23: Frame concept one

4.3.3.4. Pushing the spool

For pushing the spool around we need a way to connect the main axle to the spool. For pushing the spools around there are holes in the spools. What we will do is have a steel plate with a rod connected which fits in the hole to push it round. Unfortunately the location of the holes is not standardized so we need to be able to adjust the position of the pushing rod. For this we made a slot in the plate and we will use bolts to adjust the position.

4.3.3.5. Guidance

The guidance which winds the substrate correctly on the spools will be placed in front of the spools. This has not yet been model but is shown in (Figure 24 and Figure 25). The guidance will consist out of a wheel to move the rope and a spindle which moves the guidance back and forth.

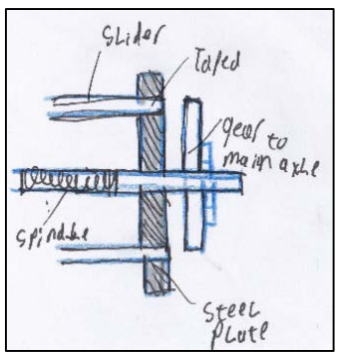


Figure 25: Slider end

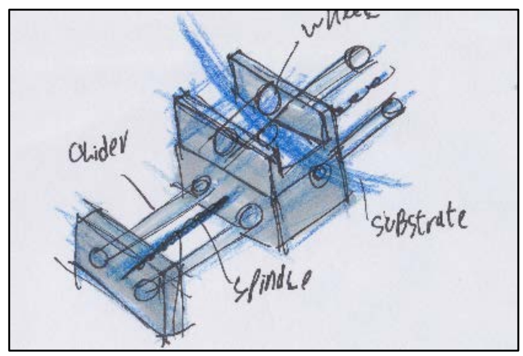


Figure 24: Slider concept one

4.3.3.6. Size of the main axle

In this concept the on one side supported main axle is a part that maybe isn't feasible. The reason for this is that the axle diameter is limited by the spool. So if the size of the axle would exceed the diameter of the hole this concept would not be possible. For this reason we will calculate the necessary diameter the axle should have.

First of all we made a force diagram for this situation (Figure 26). What we did is apply 1316kg to the end of a rod of 1100mm. We got to the value of 1300 by using the weight of the wet substrate (1236kg) and the weight of the spool (80kg).

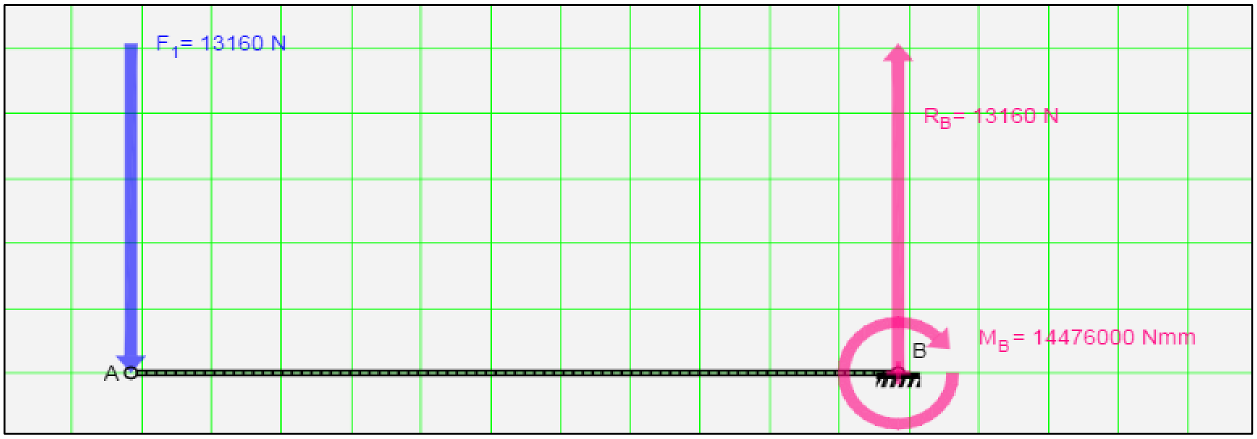


Figure 26: Force diagram singe side supported spool

The resulting shear force could easily be determined because it is equal to the applied force. The resulting momentum we needed to calculate using the following formula:

$$M = F * l = 13160(N) * 1100(mm) = 14.476Kn * m$$

We also made the momentum and force lines which is shown in Appendix J. Next we calculated the allowable stresses for, "normal", s235 steel. We used a safety factor of 0.5 times the yield strength for the bending stress and buckling stress. For the shear stress we used 0.34 times the yield strength.

$$\tau_{max} = P * v = 235 \left(\frac{N}{mm^2}\right) * 0.35 = 79.9 \left(\frac{N}{mm^2}\right)$$

$$\sigma_{max} = P * v = 235 \left(\frac{N}{mm^2}\right) * 0.50 = 117.5 \left(\frac{N}{mm^2}\right)$$

After this we calculated the required surface area and the moment of resistance:

$$A = \frac{Q_1}{\tau_{max}} = \frac{13160\ (N)}{79.9\ \left(\frac{N}{mm^2}\right)} = 1.65cm^2$$

$$W = \frac{M}{\sigma_{max}} = \frac{14.47(kN * m)}{117.5\ \left(\frac{N}{mm^2}\right)} = 12.31cm^3$$

Using these values we calculated the necessary diameter:

$$d = \frac{\sqrt{\frac{A}{\pi}}}{2} = \frac{\sqrt{\frac{1.65(cm^2)}{\pi}}}{2} = 0.36(cm)$$

$$d = \sqrt[3]{\frac{32W}{\pi}} = \sqrt[3]{\frac{32 * 12.31(cm^3)}{\pi}} = 5.00(cm)$$

By doing this calculation we saw the concept would be possible because the axle needs to be 50mm and the hole in the spool is 80mm. But what we don't know is how much the axle will bend because if the axle bends to much it isn't usable so we calculated the amount the axle bends when it is 50mm thick.

$$I = \frac{\pi * d^4}{4} = \frac{\pi * 50^4(mm)}{4} = 4{,}9 * 10^6(mm^4)$$

$$f = \frac{P * L^3}{3E * I} = \frac{13160(N) * 1100^3(mm)}{3 * 210000\left(\frac{N}{mm^2}\right) * 4{,}9 * 10^6(mm^4)} = 5.67(mm)$$

The resulting bend in the axle, 5.67mm, is low enough that we are confident that this is a feasible solution. Especially because we still make the axle 30mm thicker and we now used S235 steel and we could use others like S355. If we choose this concept we will probably not use a solid bar but a pipe to reduce the material costs but this is for the next phase.

4.3.4. Concept 2

4.3.4.1. General description

This concept stated out as idea four and just as with concept one we made a simple 3D model (Figure 27). Just as the other concept this machine uses the tension controlled winding of the winder Jansen Tholen owns to keep the substrate under constant tension and keep in sync. with the rest of the machine. The big advantages of using this method is that we do not need to measure the exact speed/tension of the substrate and then regulate the motor. The winder handles all of this using the load on the motor. There are two main differences between this concept and the other one. The first one is the orientation of the spools in relation to the motor axle. In this concept the axles trough the spools are parallel with the motor`s axles. The advantage of positioning the spools in this direction is that we can use only one guiding mechanism in the middle of the two spools.

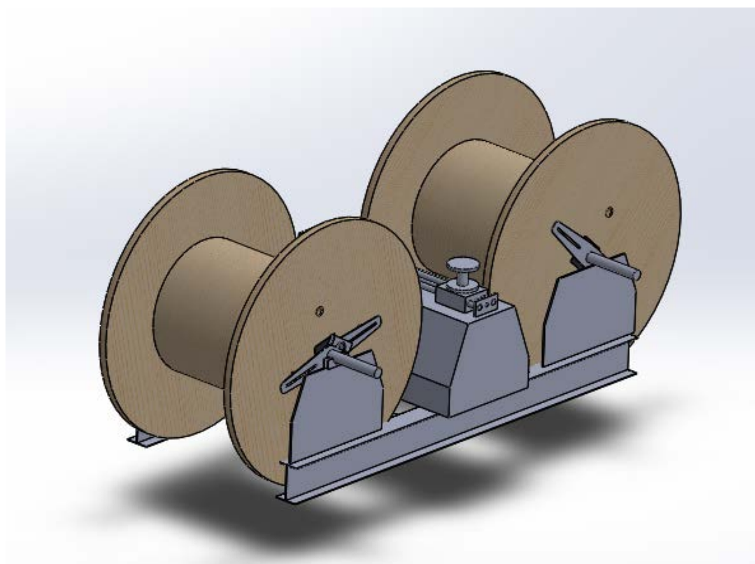


Figure 27: Dummy model concept two

4.3.4.2. Bearings

In this concept the axles running through the spools is supported on both sides. For this reason the axle can be a lot lighter and bending and/or vibrating of the axle is much less likely. The downside of this is that if the spool needs to be removed the whole axle including the spool needs to be lifted out. For this reason we need to find some way that allows us to remove the axle from the bearings. The best solution we found was using split plain bearings. How this will work is

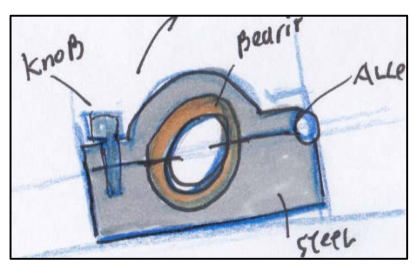


Figure 28: Bearing holder concept two

we will have a plain bearing that is split in half. Each half will be mounted inside a metal frame (Figure 28 and Figure 29). This meatal frame will be able to open and close using a hinge. When it is closed we have a fully functional plain bearing, when opened it is possible to lift the axle from the bearing and change the spool. In addition to being able to split a plain bearing the other advantage is that they are better suited for the slow turning speeds of the axle then roller bearings are.

4.3.4.3. Spool pusher

The spool pusher, the part that coupes the spool to the main axle is the same as in the other concept. We have steel plate with a rod connected which fits in the hole to push it round. Unfortunately the location of the holes is not standardized so we need to be able to adjust the position of the pushing rod. For this we made a slot in the plate and we will use bolts to adjust the position.

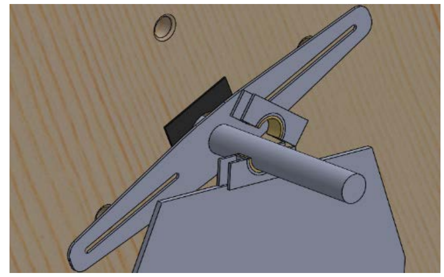


Figure 29: Spool pusher close-up

4.3.4.4. Guidance

To wind the substrate onto the spools without tangling we need some sort of guidance. In this concept the guidance which winds the substrate correctly on the spools will be placed in-between the two spools. The advantages of this is that we only need one guidance mechanism for both spools. The guidance mechanism will consist out of a wheel around with the substrate will we guided. This wheel is mounted on a slider mechanism witch can move back and forth using a diamond or winding spindle. This is a type of spindle which moves the spindle nut back and forth while spinning in only one direction. This is accompised by the special grooving.

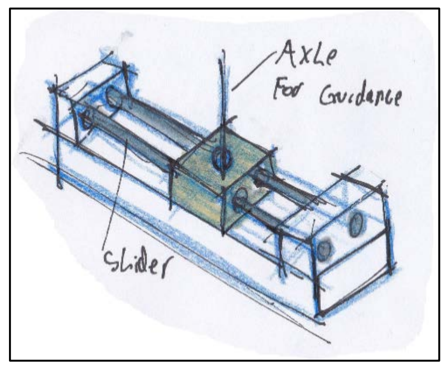


Figure 30: Slider concept two

4.3.5. Designing a new concept

Half way the concept phase I`ve talked to the client again and. This resulted in some changes in the concept. Client told us that it would be helpful if he machine can be mounted in different configurations and distances between the spools. The other input was that because this machine is will mainly be used to support the testing of the rest of the MZI system and not yet as a final part of the system. Looking at what we had so far on both concepts. We thought they would not allow for a great deal of flexibility because we focused on designing them as compact and integrated as possible.

We decided it was best to make one new concept based on information we gathered for the earlier made concept. Normally it would be better to make more than one concept so there is a choice in the end but because of the time constraints we decided not to do that. By using “the best parts” of both concepts that could be used in the new concept made that did sort of make a concept choice but just one or two levels down. In this part we will first show the different configurations we had in mind and then show with drawings how it would work.

4.3.5.1. Configurations

The reason we changed the concepts and stared making a new one is because there needs to be flexibility on how to mount the system on the ship. The first thing we decided on was that the spools would be supported on both sides for two reason. The first is that it allows us to more flexibility when positioning the spools because you can have the axle going through the spool continuing. The disadvantage of this is that it makes changing spools much more time consuming. But because we now know the spools will never be changed on board of the Tholen 4 due to its crane capacity. Changing the spools fast is no longer a necessary requirement. If the spools will be changed it will always be done at the quay using a separate crane or they will be unwound onto the quay. When the ship is in the harbor the need to change fat is much lower than when harvesting at sea.

In Figure 31 to Figure 34 you see the basic layout of the back hull of the TH4. It has two hull “compartments” on both sides and pipes running through the middle but there is no dividing wall. In Figure 31 and Figure 33 you see the two simplest configurations. What we have are pieces of framework (dark grey) supporting the main axle. This main axle connects to both spools and to the winder using coupling parts. By having a standardized frame to support the axle it allows us to make various variations seen in Figure 32 and Figure 34. These two need some will need gears and chains to connect but due to the way we design the main axle it can be done with only a few extra parts and no modifications to the axles or frames itself.

What we will have are three main assemblies:

- The first is the winder, this part houses the motor to power the spools and it will connect to the guiding mechanism. Using the winders electronics we will still tension the substrate using a load controlled method.
- The second, supports the spool. It will consist of two frames supporting the axle on both sides and a part connected to the main axle to move the spool around.
- The last is the guiding mechanism, this one will we the same guiding mechanism as in concept one. It will be a slider moved by a spindle. The spindle will be connected to the main axle to ensure the winding is in sync with the guiding.

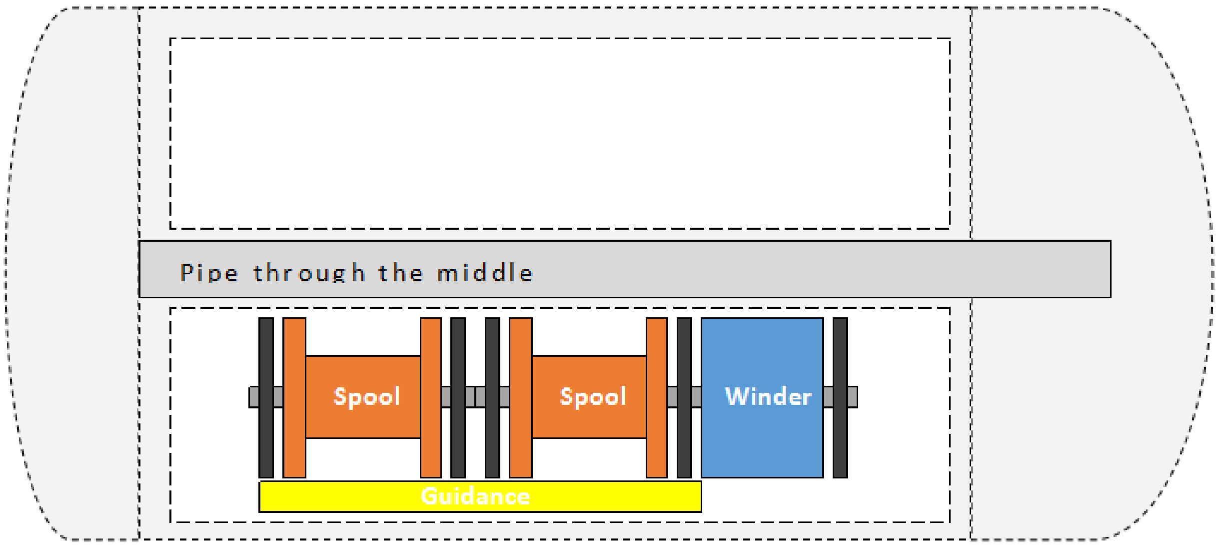


Figure 31: Configuration 1

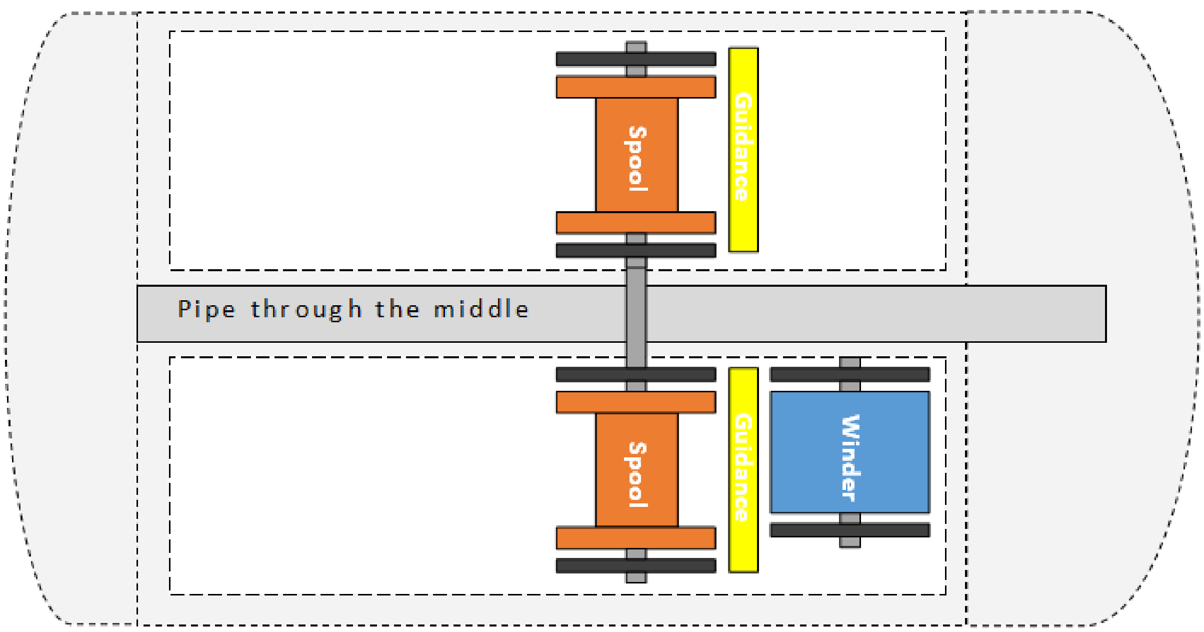


Figure 32: Configuration 2

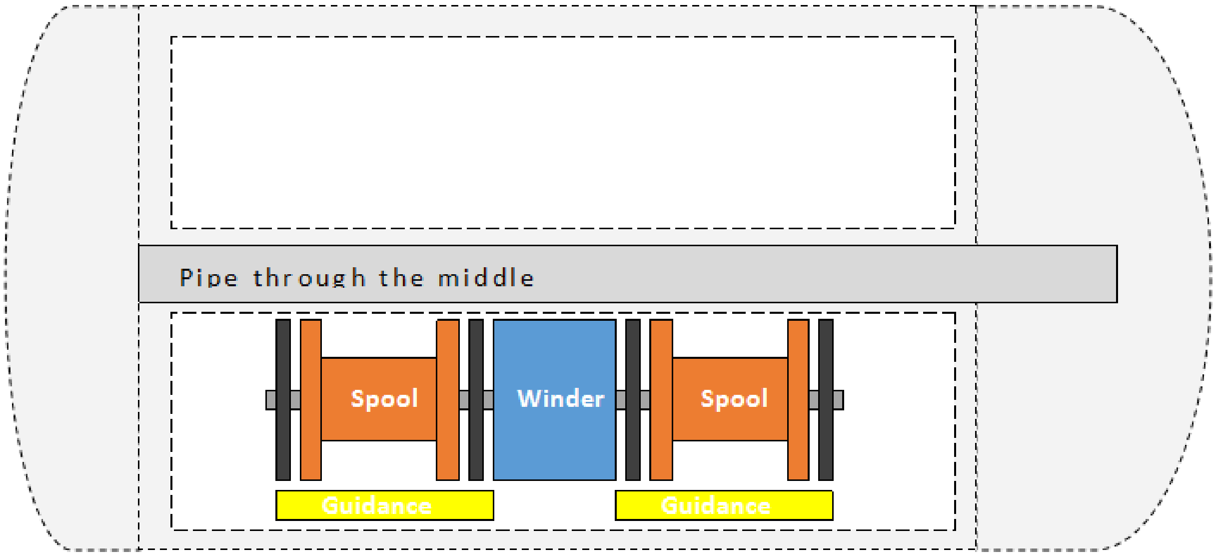


Figure 33: Configuration 3

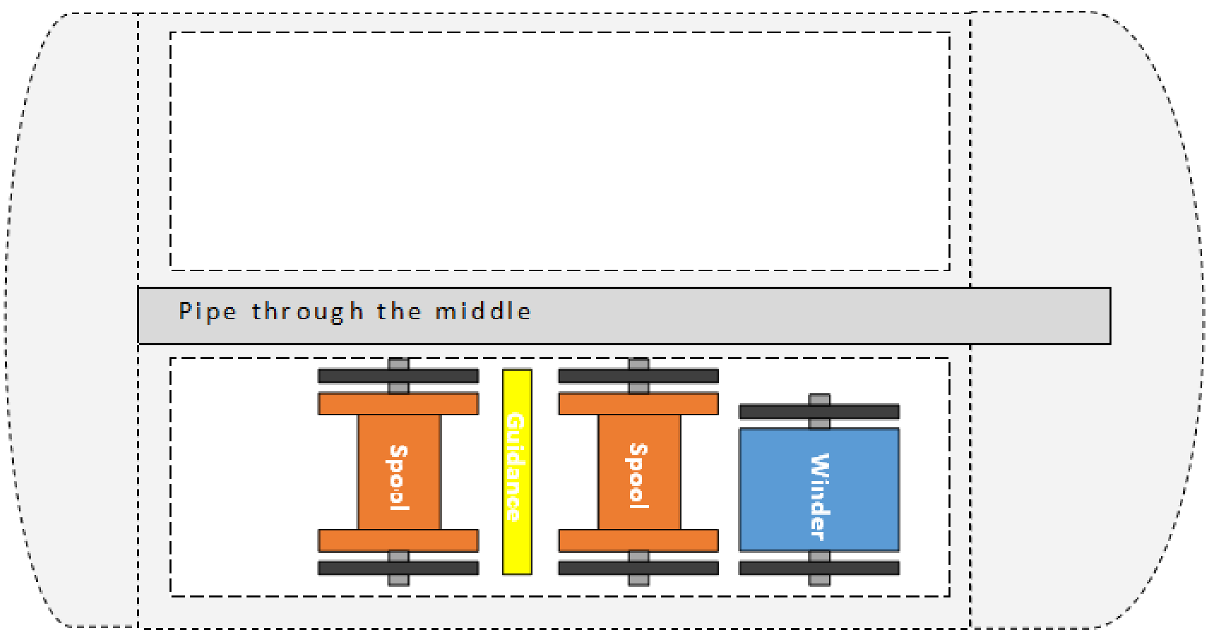


Figure 34: Configuration 4

4.3.5.2. Detail drawings

For this final concept we decided not to make a simple 3D model but only drawings and then start 3D CAD in the next phase. But because concepts one and two weren`t finished yet we have more detailed information about this final concept than we had for the earlier two. What we will do now is go over specific parts of the concept one by one.

General overview

In these crude drawings (Figure 35 and Figure 36) you see a general overview of one of the possible configurations. The machine has a frame on either side of the spool to support the main axle. The spool will be pushed by a pin witch goes into the "push holes" in the spool and the guidance will be placed in front of the machine.

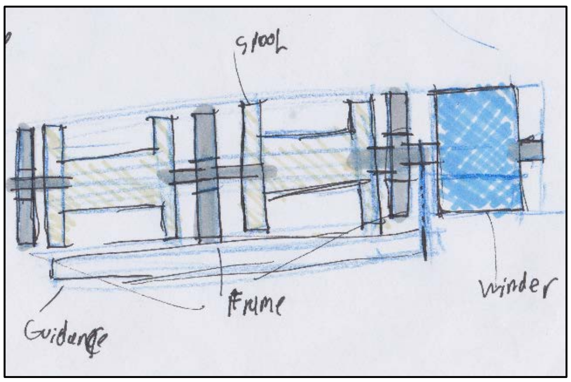


Figure 36: Basic layout

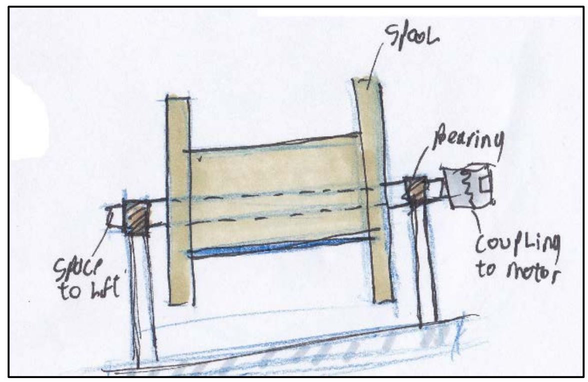


Figure 35: Spool unit

Pushing the spool

To rotate the spool and thus pull in the substrate we need a way to connect the main axle to the spool. For rotating the spool there are special holes made in it. What we do is have a plate connected to the main axle (Figure 38) and to this we connect a rod witch will go in the spool to push it around. How we will connect the plate to the rod will we decide in the next phase because this depends on the material of the main axle. We do know how we are going to connect the pushpin to the plate. The solution is shown in Figure 38 and Figure 37. We will have a taped rod screwed in the pushpin, the rod is inserted through a slot in the plate, the rod is secured with a nut and to make moving the pin easy we have added a knop at the end. It is necessary to be able to move the push pin as the position of the corresponding hole can change from spool to spool. (Spooling new reels, 2012)

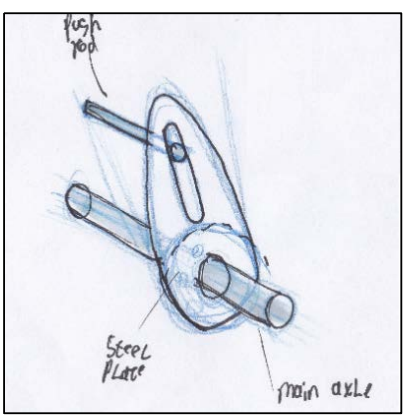


Figure 38: Spool pusher

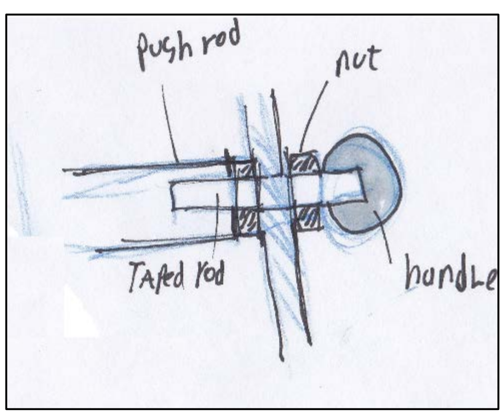


Figure 37: detail of pushing rod

Bearing and frame

To ensure the main axle with the spools connected can rotate smoothly we needed bearings. For this we found inspiration in concept two. We are using plain bearings witch will be split in half. This is done so the axle can we removed in a vertical direction which is easy for lifting the spools out. To make this possible we are will make a holder for the bearing (Figure 41 and Figure 39). This holder will consist of two parts a top and a bottom half both with a half of the bearing connected to it. Once the axle is lowered into the bottom half the top half will be bolted in place. The feasibility of this solution was something we doubted at first but later we found that a solution like this is commonly used in winders. (Dromec, 2014). In addition to being able to split the bearing, the use of plain bearings has another advantage. Roller bearings handle lower speeds much better than roller bearings do and thus the life expectancy of the plain bearings will be higher in this application.

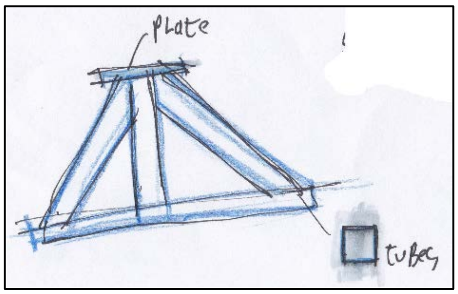


Figure 41: Axle frame

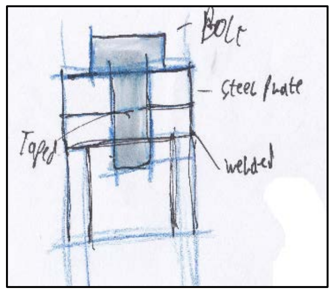


Figure 40: Detail holder

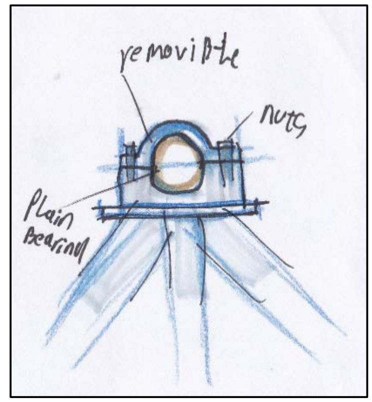


Figure 39: Bearing holder

The bearing holders will be supported by a metal frame (Figure 41). It will consist of 4 tubes the middle tube to support most of the weight, two diagonal tubes to prevent the middle beam from falling sideways and finally the beam on the bottom is to support the whole machine.

Guidance

The guidance of the machine will sit in front of the spools. This part will make sure the substrate is wound properly onto the spools. Guiding mechanism will move back and forth in front of the spool, to have it sitting tightly next to each other. How we are going to accomplish this is that we will have a slider and spindle combination (Figure 43 and Figure 42) to slide a roller (Figure 44 and Figure 46) back and forth. This whole system will be powered using the power from the winder. We will do this by having a chain connecting the main axle to the guiding mechanism. This ensures the guiding runs in sync. With the rest of the machine.

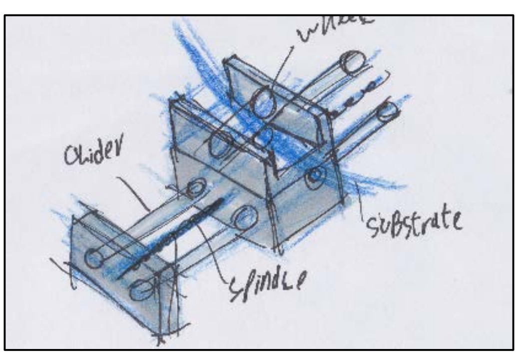


Figure 43: Guidance slider

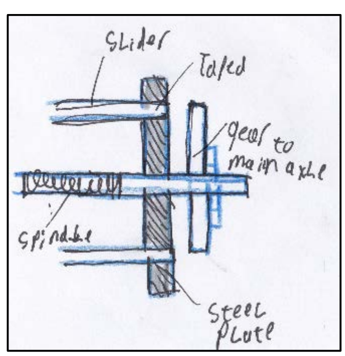


Figure 42: Spindle connection

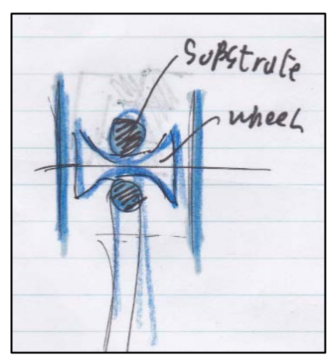


Figure 44: Guiding wheel

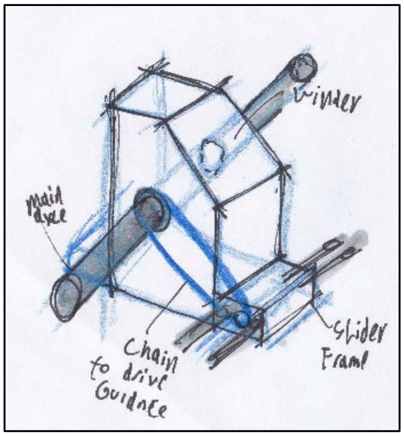


Figure 45: Connecting to the winder

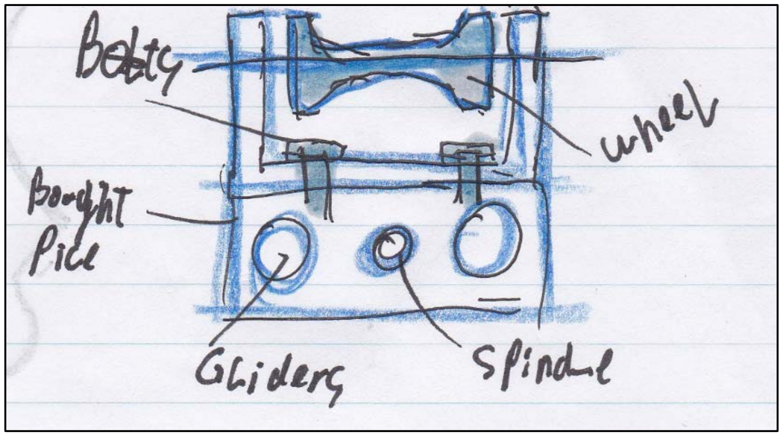


Figure 46: Guiding slider

Lifting

For lifting the spools we don`t have any special parts but we will take into account that the spools need to be lifted out. The lifting will be done by connecting lifting frames on the ends of the main axle which will be slightly extended for this purpose. See Figure 47.

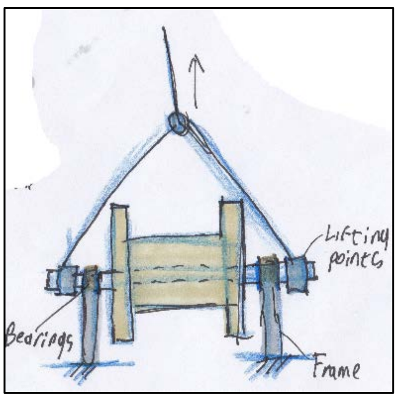


Figure 47: Lifting the spool

4.4. Materialization

In the materialization phase, the last phase of the project, we will make the final design for the machine. For this we will mostly be working on the final dimensions of the machine to do this we will we do calculations and take into account the production method. At the end of this phase we will deliver all the final drawings.

4.4.1. Design of specific parts

Now we will discuss the design decisions we made for all the parts/subassembly`s we mad in the materialization phase. These decisions lead to the final design. In this part we included some pictures of the 3D model but the final 2D drawings can be found in the separately delivered drawing package.

4.4.1.1. Main axle - spool

The main axle of the machine has several functions but the main function is holding the spool and turning it. The first aspect of the main axle we looked at is the diameter the axles has to support the weight of a full spool. First of all we made a force diagram of the axle (Figure 48: Force diagram of the main axle). The force applied to the axle is an evenly spread force of 12000N with corresponds to a full spool of substrate (See 4.1.1 Research questions). Using this we made the diagonal force and momentum lines (Appendix H:). From these lines we got the maximum force (Q1) and the maximum momentum (M).

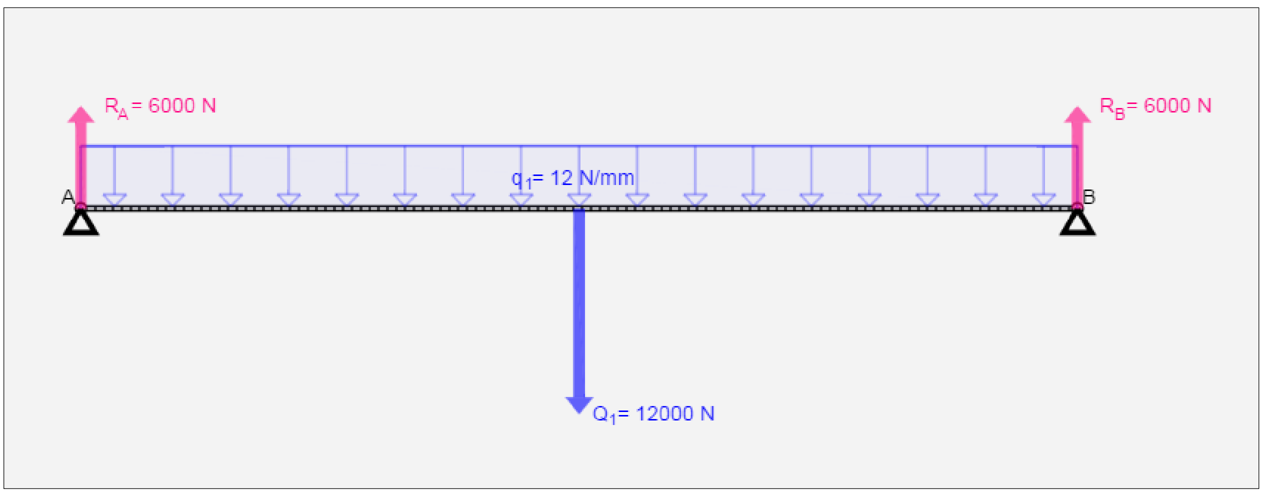


Figure 48: Force diagram of the main axle

For getting the maximum horizontal force we needed to do a little more work because this maximum force is the result of the incline of the ship. The ship has a maximum incline of 20° (Vlijmen, 2000). This results in a horizontal force (D) of 2052N (see Figure 49: Force as a result of the incline of the ship). The force in the other direction (P) is not relevant to this calculation.

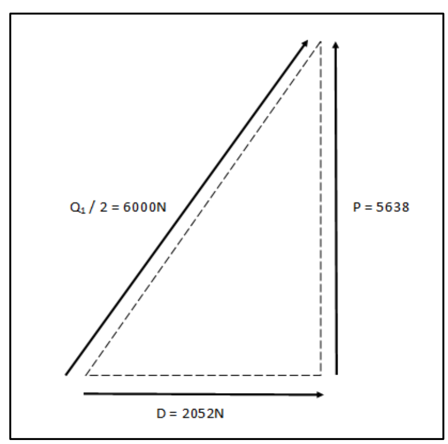


Figure 49: Force as a result of the incline of the ship

We chose to compare the needed dimensions and the corresponding price for two material choices. The first is normal S235 Steel and the other is S31600 stainless steel. Using the information from (Hasson & Crowe, 1988) we think these are the two most relevant materials, later we will explain why.

Using steel S235

The first possibility is ordinary S235 steel. This is a very commonly used and cheap material. A negative aspect is that it needs to be conserved in order to prevent rusting of the part. First of all we calculated the allowable stresses in the material. We used a safety factor of 0.5 times the yield strength for the bending stress and buckling stress. For the shear stress we used 0.34 times the yield strength.

$$\tau_{max} = P * v = 235 \left(\frac{N}{mm^2}\right) * 0.35 = 79.9 \left(\frac{N}{mm^2}\right)$$

$$\sigma_{max} = P * v = 235 \left(\frac{N}{mm^2}\right) * 0.50 = 117.5 \left(\frac{N}{mm^2}\right)$$

Then we calculated the required surface area, moment of inertia and the moment of resistance:

$$A = \frac{Q_1}{\tau_{max}} = \frac{12000\ (N)}{79.9\ \left(\frac{N}{mm^2}\right)} = 1.50cm^2$$

$$W = \frac{M}{\sigma_{max}} = \frac{1.5(kN * m)}{117.5\ \left(\frac{N}{mm^2}\right)} = 1.27cm^3$$

$$I = \frac{(D * L^2)}{(\pi^2 * \sigma_{max})} = \frac{2052(N) * 1000^2(mm)}{\pi^2 * 117.5\ \left(\frac{N}{mm^2}\right)} = 0.18cm^3$$

Using these specifications we looked for an appropriate tube for this application and found the following DIN 30.0(mm)*2.9(mm) (diameter*wall thickness). Which has the following specifications:

- A = 2.47cm^2;
- W = 1.53cm^3;
- I = 2.29cm^4;
- M = 1.94kg/m;

So we see that the moment of the resistance is the limiting factor. The problem is that a pipe of 30mm can`t properly support the spool. This is because the spool has a diameter of 85mm. For this reason we rather use a pipe with a diameter of 75 to better support the spool but still slide in easily. So a pipe which would be suitable is the following: DIN 76.1(mm)*2.9(mm) (diameter*wall thickness). (Leijendeckers, 2010) Which has the following specifications:

- A = 6.67cm^2;
- W = 11.76cm^3;
- I = 44.74cm^4;
- M = 5.24kg/m;

Using stainless steel S31600

The second material that would be a possibility is stainless steel S316000. This is a material commonly used in marine environments. The advantage of this is that the material is very corrosion resistant but it has a higher price and it as a lower maximum stress as steel. First of all we calculated the allowable stresses using the same safety factors as we used in the calculation above:

$$\tau_{max} = P * v = 200 \left(\frac{N}{mm^2}\right) * 0.35 = 70.00 \left(\frac{N}{mm^2}\right)$$

$$\sigma_{max} = P * v = 200\ \left(\frac{N}{mm^2}\right) * 0.50 = 100.00\ \left(\frac{N}{mm^2}\right)$$

Then we calculated the required surface area, moment of inertia and the moment of resistance:

$$A = \frac{Q_1}{\tau_{max}} = \frac{12000\ (N)}{70\ \left(\frac{N}{mm^2}\right)} = 1.70cm^2$$

$$W = \frac{M}{\sigma_{max}} = \frac{1.5(kN * m)}{100\ \left(\frac{N}{mm^2}\right)} = 1.50cm^3$$

$$I = \frac{(D * L^2)}{(\pi^2 * \sigma_{max})} = \frac{2052(N) * 1000^2(mm)}{\pi^2 * 100\ \left(\frac{N}{mm^2}\right)} = 0.21cm^3$$

Using these specifications we looked for an appropriate tube for this application and found the following DIN 30.0(mm)*3.2(mm) (diameter*wall thickness). (Leijendeckers, 2010) Which has the following specifications:

- A = 2.69cm^2;
- W = 1.64cm^3;
- I = 2.45cm^4;
- M = 2.11kg/m;

So we see that the moment of the resistance is the limiting factor. Just as with the steel version the problem is that a pipe of 30mm can`t properly support the spool. This is because the spool has a diameter of 85mm. For this reason we rather use a pipe with a diameter of 75 to better support the spool but still slide in easily. So a pipe which would be suitable is the same as the steel one with is the following: DIN 76.1(mm)*2.9(mm) (diameter*wall thickness). (Leijendeckers, 2010)

Conclusion

What we see is that the construction of the pipe is no limiting factor for the choice of the material. Because of this the final choice of the material will be completely made based on the price, corrosion resistance and the maintenance. Looking at the price stainless steel cost 1.05€/kg and ordinary steel 0.19€/kg. So the stainless steel is 5.5 times more expensive but the stainless steel has a big advantage for this part. If we would use steel the axle would need to be conserved but because the spool will slide over the axle the paint will probably be chip off and the axle will rust anyway. So for this reason we think stainless steel is the best material for this part.

4.4.1.2. Main axle – motor

The main axle to which the spools connect needs to be powered by the motor. For this we will have a separate axle connected to the motor by a gear and connected to the spool axles by bushings on every end. The reason we do not use a single axle is because the spools with the axles connected need to be lifted out. The other reason for this is that it allows for easier changes in the configuration of the machine.

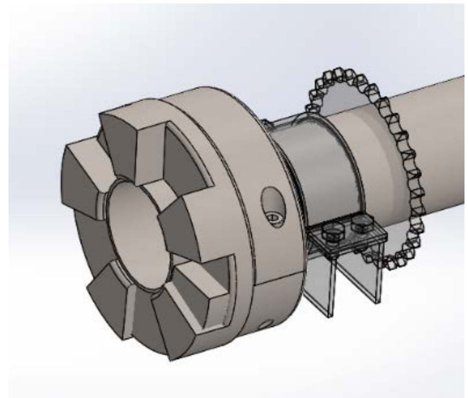


Figure 50: EKH2500 coupling

The material and the diaper will be exactly the same as it was in the main axle for the spools. This allows for an easy connection and keeps the costs down. Once this was decided we selected a proper coupling. The one we selected is the R+W EKH2500 (Figure 50). It is a coupling which can easily be disconnected (R+W, 2015).

4.4.1.3. The spool pusher

The spool pusher is the part that connects the spool to the main axle (see f) and has in the concept 2 main parts the "pushing pin" and the "connecting plate". Which we will describe in this part of the report. Also it needs a way of connecting the connecting plate to the main axle. Which will be mentioned as well.

Connection to the main axle

For connecting the connecting plate to the main axle we need a solution. We found two solutions, the first is welding it to the main axle. This seems to be the simplest solution but because the connection plate is steel and the main axle is stainless steel which makes welding hard. Also welding could cause the axle to bend. The second solution is using some sort of "detachable" solution. We think the best solution is using a bolted hub. The advantage of this is not only "not having to weld" but it also allows for changing the configuration of the machine later. A suitable hub we found is the PHH SM30-2 from SKF.

Pushing pin

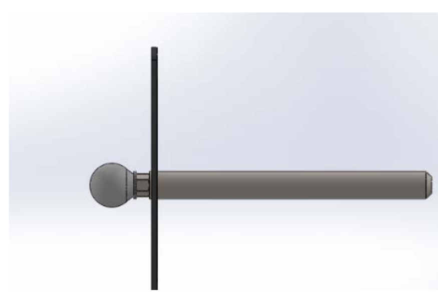


Figure 51: The pushing rod assambly

For the material we will choose stainless steel S31600 for the same reasons we made the main axle out of this material. It needs to stay resistant to corrosion even when the spool is regularly banging to it. The size of the pushing pin is determined by the force that will be applied to it and the hole in the spool. The force that will be applied to the pushing pin is the same as the maximum tension on the rope plus the force needed to rotate the axle. It is hard to calculate the exact force that will be applied to this part so we decided to go with a diameter which fits nicely in the holes in the spool. We do not know for sure but because the holes are meant to rotate the spool we assume a rod the size of the hole is "strong enough". The holes in the spool have a diameter of 40mm so we chose a diameter of 25mm to have it easily sliding in. on the end of the pushing pin there will be taped rod and a handle to fasten the pin to the connecting plate (see Figure 51).

Connecting plate

The connecting plate is the part that connects the bolt on hub and the pushing pin with each (see Figure 52). This part has a slot in the middle to allow the location of the pushing pin can be adjusted because the location of the hole in the spools can vary. The material for this part will be sheet metal that will be laser cut on size. We choice this combination because it allows a simple solution to get an adjustable pushing pin. The thickness of the sheet meatal will be detriment by the most commonly used thicknesses in the rest of the machine because this keeps the cutting costs down.

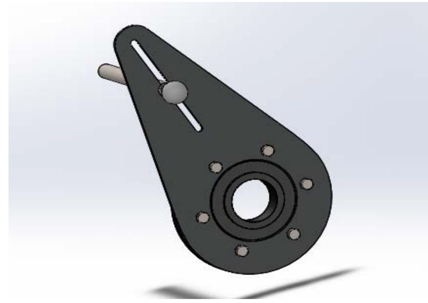


Figure 52: The spool pusher

4.4.1.4. Main axle bearings

The main axle bearings are the bearings that will be supporting the main axle on the sides of the spools. These will be plain bearings so they can be split for easy removal of the spool. For selecting the bearing we first need to calculate the static and dynamic loads on the bearing which we will show underneath.

Table 15: Radial load on the bearings

Speed of the substrate (m/s)	Amount of substrate on the spool	Turning speed (RPM)	Radial load on the bearing (N)
0,3	Empty	8,1	500
1,6	Empty	43,0	500
0,3	Full	4,1	6000
1,6	Full	21,8	6000

Static load

For calculating the static bearing load we used the formulas described by (SKF, 2015). First we looked up the values for X_0 and Y_0 for our application, then we filled out the following formula to calculate the static bearing load: $P_0 = X_0 * F_r + Y_0 * F_a = 0.6 * 6000(N) + 0.5 * 2052(N) = 4626N$. Then we calculate the equivalent static load using a value of S_0 for our application $C_0 = S_0 * P_0 = 2 * 4626(N) = 9253N$.

Dynamic load

For calculating the dynamic bearing load we used the formulas described by (SKF, 2015). First we used the following calculation: $f_0 = \frac{F_a}{C_0} = \frac{2052(N)}{9253(N)} = 0.22$. By doing this we found the following values limiting value (e) = 0,22 and axial load factor (y) = 1.99 for a situation with normal clearance from (Tribology-ABC, 2014). We will use these values later. Next we calculated that $\frac{f_a}{f_r} \leq e \ \frac{2052(N)}{6000} \leq 0.22$ is true. For this reason we need the following to calculate the final value for the dynamic bearing load: $C = 0.67 * F_r + y * F_a = 0.67 * 6000(N) + 1.99 * 2052(N) = 8104N$

Selection

First we needed to select the type of plain bearing we are going to use first of all we looked at the products from SKF. Unfortunately they had only spherical plain bearings, for our application we needed a flat plain bearing to allow the bearing to be split. Looking further we found that AST has a wide variety of different types of flat plan bearings. Using the information described in (AST, 2014) we selected the type of bearing. We chose “Bi-metallic Composite Bushings” because they are the cheapest plain bearings which need no lubrication. Based on the diameter we need we selected the following bearing AST850BM 7540. We saw that the load of the bearing was no limiting factor for this product.

4.4.1.5. Bearing holder

The bearing holder is the part which holds the two half's of the plain bearing (Figure 53). The design of this part is completely out of sheet metal prices. We chose this because only four prices need to be made. Would the amount be larger we could consider other method but for this volume and production by Jansen Tholen it is the easiest to have the parts cut from a single sheet of steel and then welded together by Jansen Tholen.

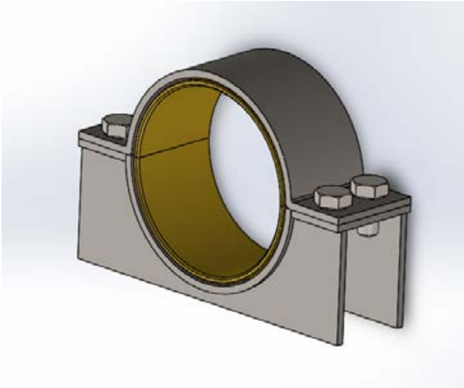


Figure 53: Bearing holder

The bearing itself will be glued in place using Chockfast Orange. This is epoxy resin widely used for marine environments especially for securing plain bearings and bushings. Furthermore the surfaces do not need any special treatment before the epoxy can be applied. (Chockfast, 2014).

4.4.1.6. Guidance

The guidance is the part of the machine which ensures the substrate is wound onto the spool correctly and to prevent tangling of the material. This system consists of three main parts the first is the wheel witch guides the substrate the second is the slider and the third is the connection to the main axle to power it. First of all we started looking at the guiding wheel for the substrate. To properly guide the substrate we needed a certain dimension and shape of the wheel. We settled on a certain type of roller wheel (Figure 54) widely available at marine suppliers. This material is very durable and commonly used for this kind of applications. (Downwind marine, 2015)

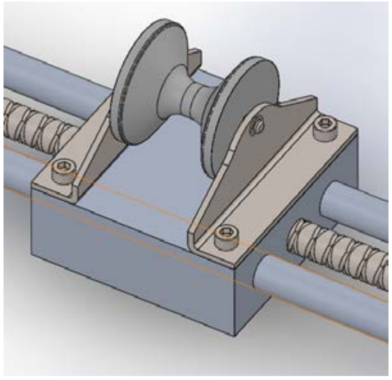


Figure 54: Guidance wheel

Slider

For the slider we could have gone two different routes. We could have used all separate parts and process them ourselves. The other option is buying a complete package (end pieces, rails, bearings and the carriage). We chose the second solution because it is much more convenient because you will get carriages with the bearings pre-selected and in place Ready to go. We chose the SKF LZBU 16 A-2LS (see Figure 55) because this meets all of our requirements. It can span the a length of 1200mm, it is suitable in marine an marine environment due to the material choices and the sealing of the bearings and it is an all in one package excluding the spindle. (SKF, 2014).

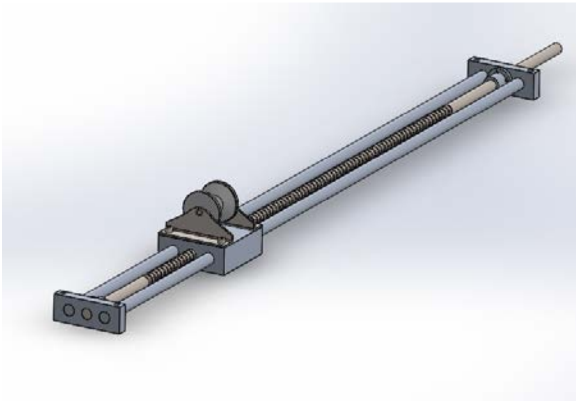


Figure 55: LZBU 16 A-2LS slider

The spindle and gearing

Off course the spindle need to run smoothly and connect to the frame of the slider. We chose to do this using a housed ball screw support bearing this is a part which combines a bearing and the mounting of it into one product. The advantage is that is can be bolted on in one piece. The product we chose specifically was the SKF FLBU16. The reason for this is that it applicable in marine environments due to the material choices and the seals on the bearing. The other advantage is that the do not neat lubrication which is convenient. (SKF, 2015)

For the spindle itself we are going to use a diamond or winding spindle. This is a special kind of spindle witch when turned in one direction will make the spindle nut move back and forth. This is possible by the specially milled pattern. But because the groove in the spindle is dependent on the specific with of spool being wound this part will need to be special made. What we will do now is calculate the rate the spool needs to have. The rate is the distance the nut travels when the spindle is turned. The rate we opt for is that the guiding carriage travels the full width of the spool in the same time as one layer of substrate is wound on the spool. To calculate this we first of all determine the amount of times the spool needs to turn until one layer of the spool is filled.

$$Turnes\ of\ the\ spool = \frac{Drum\ with}{Diameter\ of\ the\ substrate} = \frac{800(mm)}{16.8(mm)} = 47.5\ times.$$

Now we can divide the spindle length (equal to the drum width) of the spool by the turns to determine the rate.

$$Rate = \frac{Spindle\ length}{Turnes\ of\ the\ spool} = \frac{800(mm)}{47.5(times)} = 16.8mm/turn.$$

We see tis value is equal to the diameter of the substrate which is logical as the guidance needs to move the width of the line each turn. Because the main axle and the spindle will be linked the guidance will properly work at any given winding speed. The diamond shaped pattern will also ensure the rope will be stacked at the point the direction changes. This is accomplished by the special pattern at the ends. The material of the spindle will be S316000 Stainless steel for the same reason the main axle is made out of this material.

For connecting the main axle to the spindle we are going to use a chain. Gears will be connected to both spools. We selected the PHS 05B-1A15, a 15 teeth gear to connect to the spindle and PHS 05B-1A30, a 30 teeth spindle to connect to the main axle. The reason the gears have a different number of teeth's is because of the size difference between the axles it wasn't possible to have the same number of teeth on each. But because of the different number of teeth the rate of the spindle needs to be adjusted. Now the spindle is turning twice as fast as the winder so the rate needs to be slower.

$$Rate = \frac{Spindle\ length}{Turnes\ of\ the\ spool} = \frac{800(mm)}{47.5(times)*2} = 8.4mm/turn.$$

4.4.1.7. Framework

The frame of the machine consist out of two main parts/assembly`s. The first is a frame is made to support the axles used to power the main spools (see Figure 56). This frame is triangle shaped and made out of tubes. The middle, vertical tube is for supporting most of the weight of the spools. The diagonal tubes on the side are for preventing the middle column from falling over. Then there is a tube on the bottom to finish the triangle and carry the load. This tune is extended on one side because the guidance will be connected to this part of the bottom tube. This triangle shaped frame will be she same for all the different configurations of the machine. In this way we have limited the part differences between the configurations. The second part of the frame are the long tubes connecting the triangle frames to each other. These will be different for all the configurations of the machine (see Figure 57). The material for the frame is ordinary S235 steel. We did not used stainless as we did with the axles because of the high price. Also we can easily conserve the frame using spray-paint because the chance of paint chipping off is much lower as with the axles. Also if a bit of rust occurs this is not directly a problem for the working of the frame.

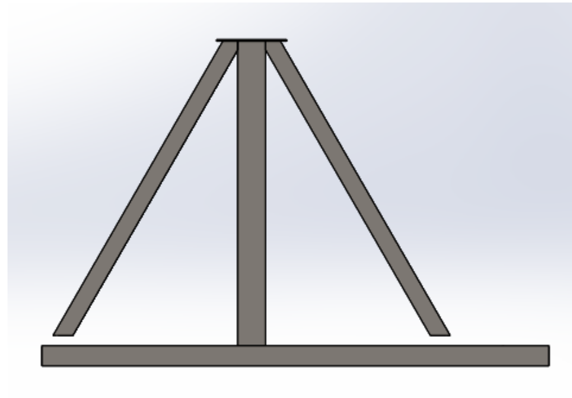


Figure 56: Triangle frame

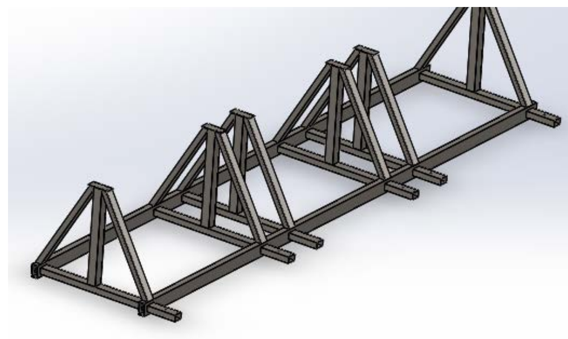


Figure 57: Complete framework

4.4.2. CAD model

All the decisions we described in the previous paragraph have been used for making the 3D CAD model of the winder. Normally we would show this model and thus the final design at the end of the materialization chapter. But because the final design is the conclusion for the whole project we put the final design in the next chapter (the conclusion). Here we will show and describe the 3D model of the design. For the 2D drawings we made we refer to the separately delivered drawing package.

4.4.3. Cost estimate

When the CAD model was finished we had the complete list of the parts. Using this information we made a cost estimate. In the cost estimate we included the purchase, material, assembly and production cost per part. The cost estimate itself can be found in Appendix I: Cost estimate. According to our estimate the total cost will be € 5.503,10.

5. Conclusion

In this part of the report, the conclusion we show the final model of the machine. Describe different configurations of the machine. Explain the operation of the machine and describe the values that need to be set into the winder.

5.1. Operation of the final design

The operation of the machine is the same for every configuration. For this reason we describe this first before diving deeper into the different configurations.

5.1.1. The winder

The machine uses the Wintech winder as the main actuator and regulator of the machine. This winder will be powered using the hydraulics and electricity of the TH4. The advantage of this winder is that it uses so called load control to pull the substrate onto the spool. What this means is that the motor will keep the substrate under a constant tension by increasing and decreasing the speed at which it turns. This allows the substrate to be wound with exactly the same speed at which the rest of the MZI system is working at without the need of a fiscal (mechanical or electrical) connection between the two.

5.1.2. The spools

The spools are the parts of the machine which actually hold the collected substrate line. To place a new spool into the winder the following steps need to be done. First the bearing holders need to be "opened" to allow the axle on which the spool sits to be lifted out. This axle can now be shoved into the spool and the pushing rod adjusted to the corresponding hole. Once this has been done the axle including the spool can be lifted into the bearings. The bearing holders will be shut and you are ready to go.

5.1.3. Collecting substrate

To actually start collecting substrate we will need to make sure all the setting of the winder are filled in correctly. The values we recommend can be found in Appendix G: Settings of the winder. Next we need to connect the substrate to do this we first need to rotate the spool so the hole in it is facing us. The rotation can be done by switching to the slow winding mode (F10 ON) and rotate the spool until the hole faces you. Now feed the substrate through the guiding wheel and put about half a meter of line in the hole. At this point you can start the winding at normal speed (F10 OFF). As soon as the spool is full the winder will stop automatically at this point the user can cut the substrate line and connect it to the second spool in the same way as described above.

5.2. Different configurations

For the machine we have made 4 variations. Each variation has the three main components (the motor, the spools and the guidance). This has been done so the client has the flexibility to choose the most suitable layout later. For doing this only a few specific parts need to have different dimensions from one configuration to the next. The parts that will be changed slightly for one layout to the next are the beams supporting the machine and the axles connecting the machines. Dependent on the configuration there may be a need for some additional part of a specific type such as the slider or gears. The design isn't made to allow easy changing of the layout because this was not our intend. Also this would make the winder much more complex but if necessary it can be done. Now we will go over the different configurations on by one.

5.2.1. Configuration 1

This configuration, configuration one (Figure 58 to Figure 61) is the solution which is in our opinion the best solution because it is the most compact and it is the easiest to operate. This configuration is made up out of 6 triangle frames which hold the main axle (Figure 61). The main axle is split-up in three parts, the first is the axle that connects to the winder this one will always stay in the same position. The other two axles are the ones that go through the spools, these axles are connected using the couplings and because of this they can easily be lifted out. The motor is positioned in the middle of the two spools which allows easy access to the controls when starting the machine (see operational description). The guidance is positioned in front of each spool and powered by a chain connected to the main axle. For easier access of the control panel, the guidance has been placed on the opposite side from the control panel.

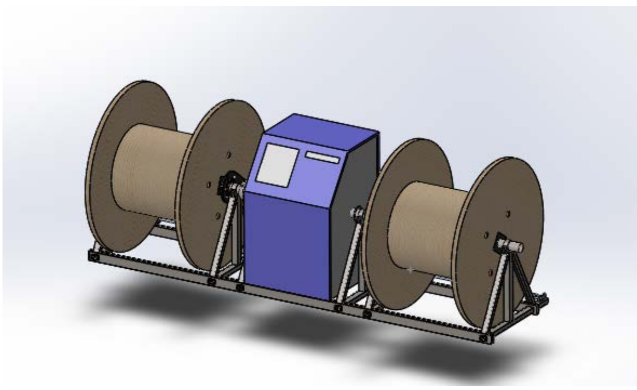


Figure 61: Config. 1 overview

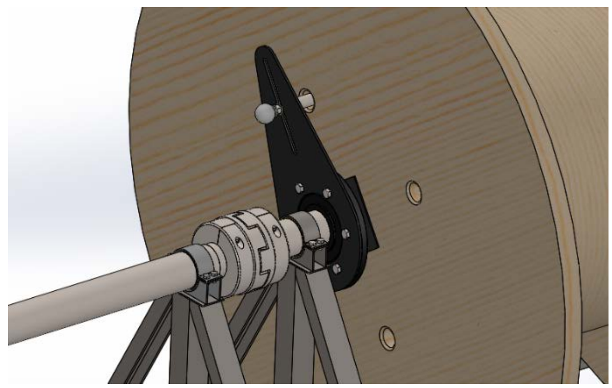


Figure 60: Config. 1 spool pusher

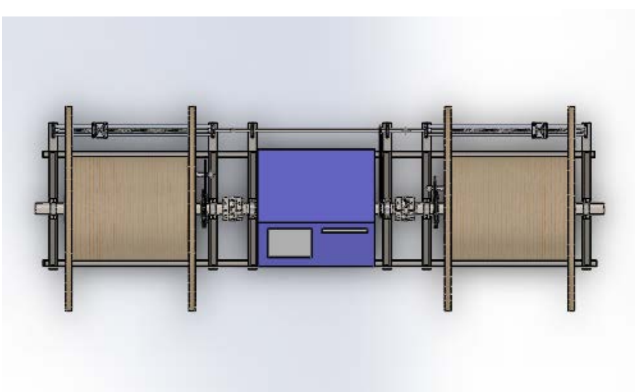


Figure 59: Config. 1 top view

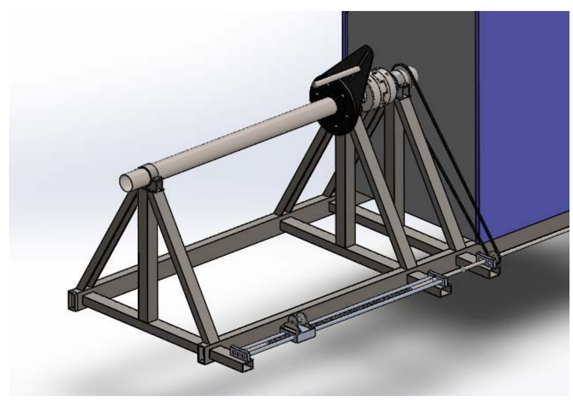


Figure 58: Config. 1 empty frame

5.2.2. Configuration 2

The second configuration (Figure 62 to Figure 65) is not that different from the first one. The difference between the two is that the winder isn`t placed in the middle but on the side. This could be useful to reach the winder without the need of walking under or over the moving substrate. The only thing that needs to be changed from configuration one is the bottom beam. The holes in this need to be slightly different.

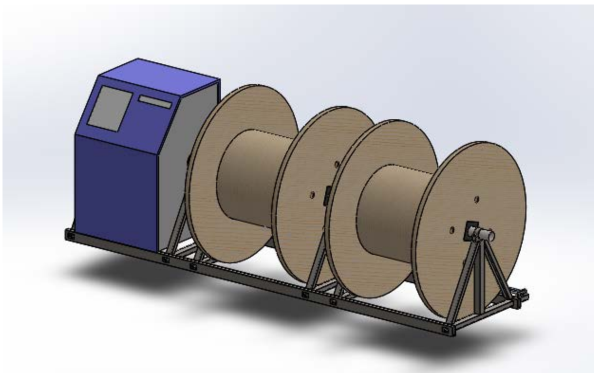


Figure 62: Config. 2 overview

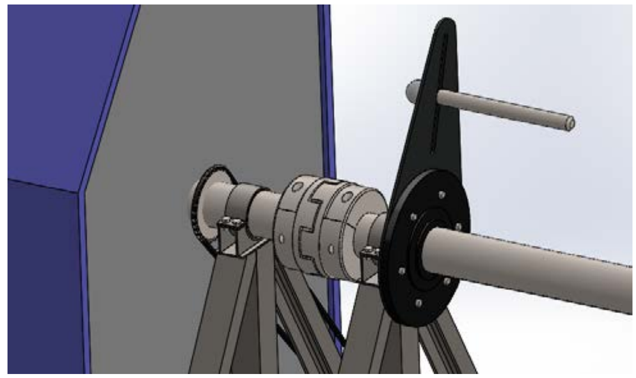


Figure 63: Config. 3 spool pusher and connector

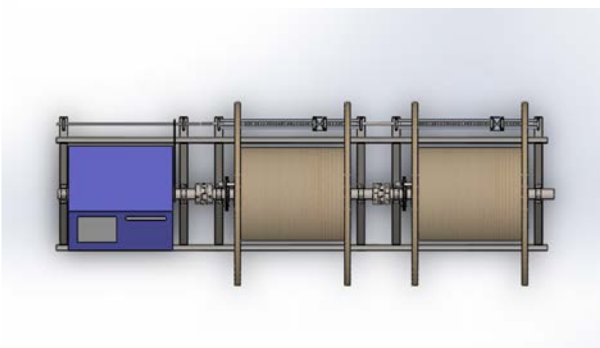


Figure 65: Config. 2 top view

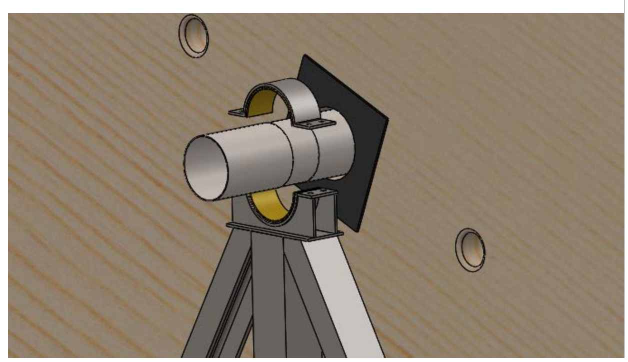


Figure 64: Config. 2 opened bearing holder

5.2.3. Configuration 3

This configuration (Figure 66 to Figure 69) is more complicated than the other two. The main difference between this configuration and the first two is the orientation of the spools. Because of the different orientation it is necessary to power all the spools using chains. The first chain connects the winder to the first spool, the second chain connects the first winder and the guidance and the last chain connects the guidance and the second spool. Because we use chains instead of the couplings this configuration approximately 5oo euros cheaper as the first two. However changing the spools will be slower when using this configuration because the chains will need to be removed.

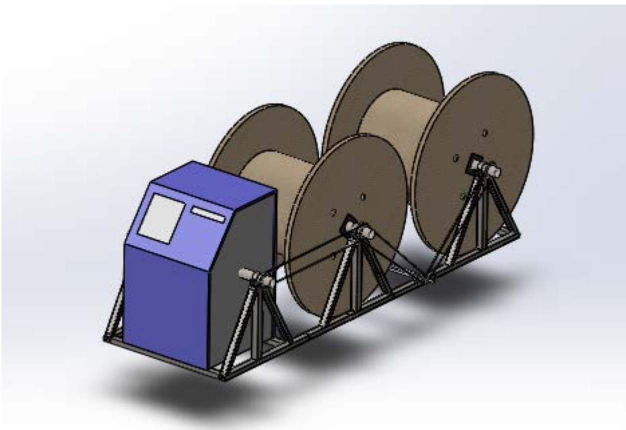


Figure 69: Config. 3 overview

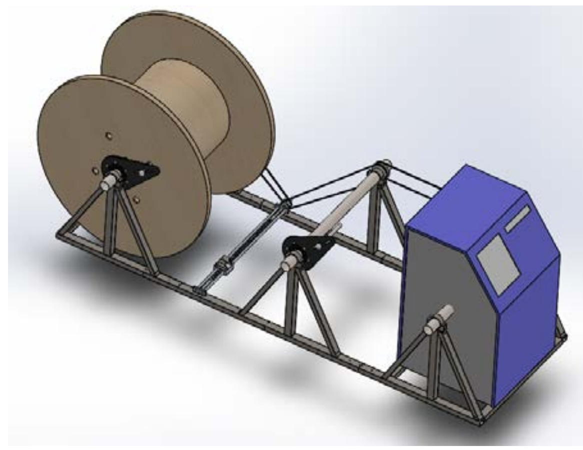


Figure 67: Config. 3 One spool removed

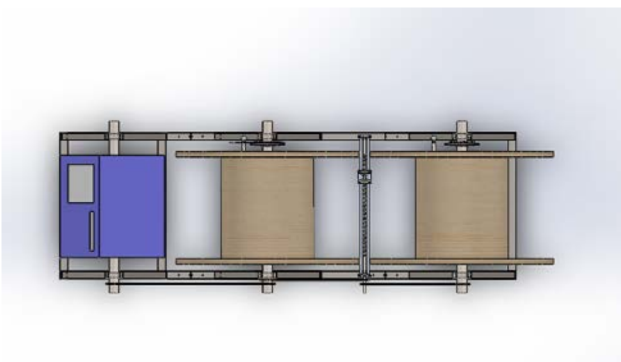


Figure 66: Config. 3 top view

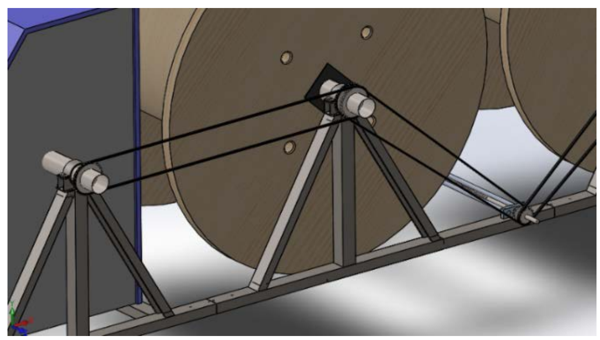


Figure 68: Config. 3 Chain connections

5.2.4. Configuration 4

The last configuration is the most remarkable one of all (Figure 70 to Figure 73). This one is designed so it will hold one spool on each side of the hull. To achieve this we placed both the spools in one line and power them using the same axle. This axle is powered by a chain which connects to the winder. Each spool has its own guiding mechanism powered by a separate chain connected to the main axle. It was a possibility to connect the two guidance slider to each other using a separate axle but we chose not to do this in order to limit the amount of "things" going from one side of the hull to the other.

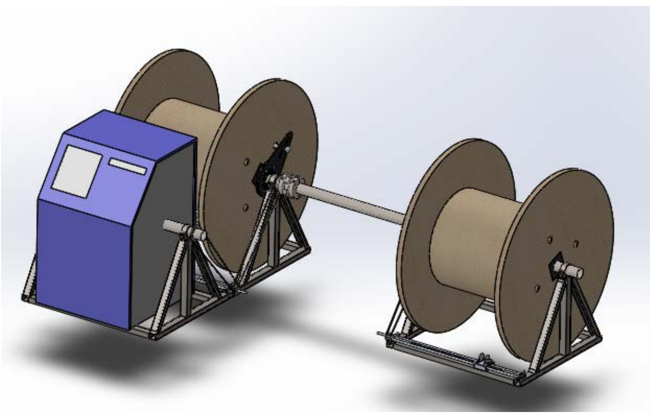


Figure 70: Config. 4 overview

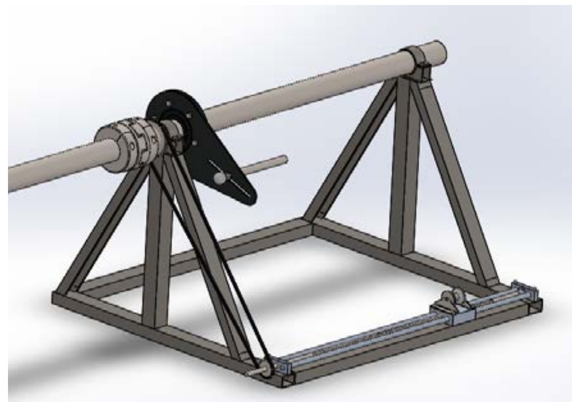


Figure 71: Config. 4 empty frame

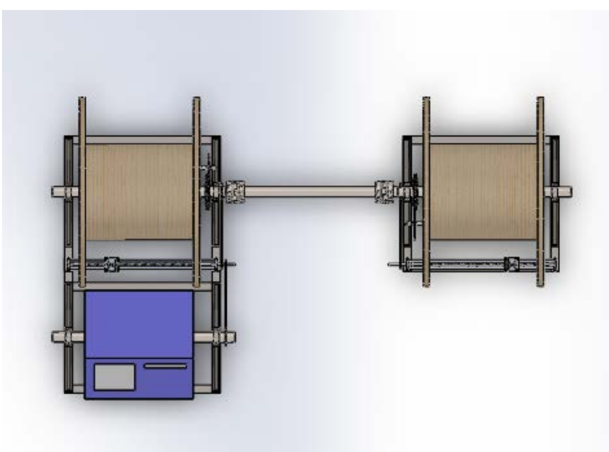


Figure 73. Config. 4 top view

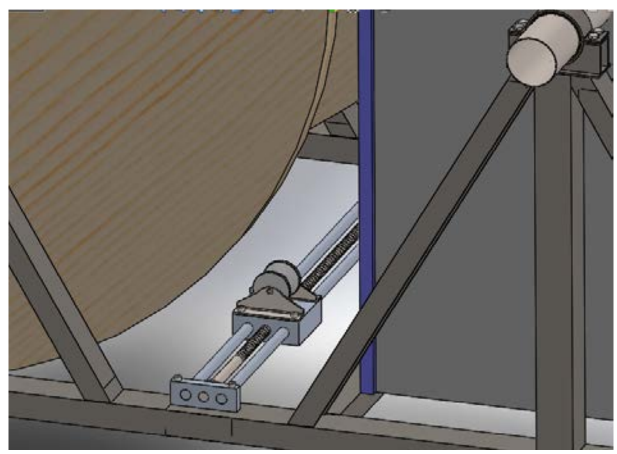


Figure 72: Config 4 Guidance

5.3. Using the current winder

Using the current winder has two main advantages. The first is that it isn`t necessary to buy new parts for the first tests. The second reasons is that the winder has built in electronics and hardware for controlling the speed and tension of the material. In this part of the report we will describe how the values need to be set. The reason why we have a separate paragraph dedicated to this is because the winder is originally build to wind film and not rope. Because of this some values that need to be entered into the machine are different than your fist expectation. The reason we put this information in the conclusion and not in the results is because this information actually need to be entered into the machine. Now we will go over each setting one by one. For the convenience we included a list of all the settings in Appendix G: Settings of the winder.

Note: All of the winder specifications used for determining these values came from: (Wintech Winding Technology AG, 2002)

5.3.1. Values to be set

Core diameter

The core diameter of the spool should be entered here the winder uses this value to determine the appropriate speed and tensions vales of the motor. Earlier in this report we referred to the core dimer as the drum diameter as this is a more commonly used word when winding cable or rope. For the spool chosen in our design the core diameter is 710mm so this value should be entered in the machine when using this specific spool. When a different spool is mounted this value should change but is should stay in between 90mm and 2000mm because according to the specifications these are the maximum values this winder can be used.

Thickness

When using the winder to wind film the thickness of the material should be filled in here. In our application we are not winding film but rope. When film is wound on a spool the material is evenly spread over the spool for the rope is this different. When winding rope the material is guided onto the spool in by guiding wheels. For this reason we cannot fill in the thickness of the rope here but we need to do a calculation first.

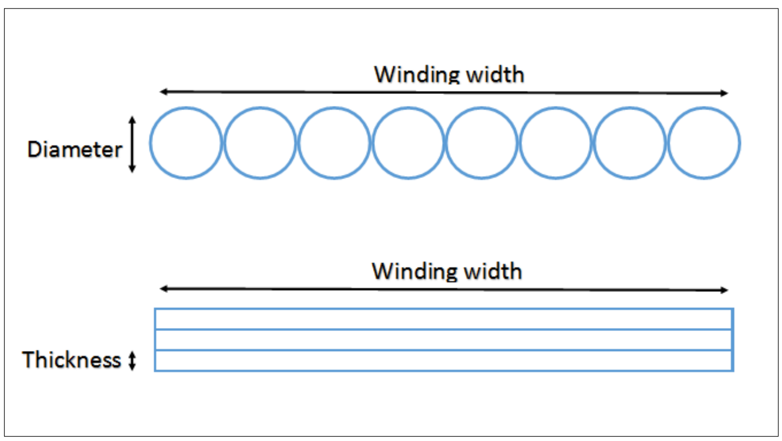


Figure 74: Winding

To calculate the thickness that needs to be filled in we formulated the following formula: $Thickness = \frac{Diameter}{Winding\ width\ /\ Diameter}$. Before calculating we will describe how we got this formula. First we used this formula to calculate the amount of rope next to each other: $Ropes\ next\ to\ each\ other = \frac{Winding\ width}{Diameter}$. The amount of ropes next to each other is equal to the amount of times the axle has turned. So we filled in the result in the following formula: $Thickness = \frac{Diameter}{Times\ the\ axle\ has\ turned}$. Using this formula the thickness will be correct each time the full width of the spool is filled with rope. This is the closest we can come to correctly filling in this value. The resulting value that should be filled in is: $Thickness = \frac{Diameter}{Winding\ width\ /\ Diameter} = \frac{16.8mm}{800mm\ /\ 16.8mm} = 0.35mm$. See Figure 74 for clarification of where the specific values come from.

Tension set point

The tension set point determines the maximum tension that can be applied to the rope. As we have seen in the analysis phase the initial winding tension should be between 4.3kN and 8.6kN. To determine the value that has to be set we first need to know the maximum torque of the winder because the value will be set as a percentage of the maximum pressure.

We can calculate the maximum pressure using the following formula: $T = \frac{D*p}{20\pi} = \frac{8.51\left(\frac{cm3}{rev}\right)*170(Bar)}{20\pi} = 23Nm$. To calculate the maximum tension in the rope we used the following formula: $F = \frac{T}{r} = \frac{23(Nm)}{(1400-710)/\ 2+710)(mm)} = 21.8N$. By dividing the values from the analysis phase by the maximum value we get the percentages which are 20% and 40%. The value set in the winder should be between these values. We chose the middle value of 30% because this allows variations in both directions.

Tension reduced (taper)

The tension reduced taper can be set if you want the tension to decrees as the material is wound onto the spool. Generally this function is used when it is a requirement to pack very tightly at core, but looser as more material is wound. This is used when winding materials with either very high slip characteristics (to prevent blowout at core), or on pressure sensitive materials that require very gentle handling. (Sinclair, 2003) With the type of spool we are using we don`t expect the need for a reduced tension for this reason the vale can be set to 0%.

Gearbox

Here the ratio of the gearbox connected to the winder should be entered. Some examples are:

- Using a gearbox with a ratio of 1:2, a two should be entered;
- Using a gearbox with a ratio of 2:1, 0.5 should be entered;

Because no gearbox is needed in our design the ratio is 1:1 so the value should be set to one. If because of the use of a gearbox or the reversed mounting of the machine it is running in the worn direction this can be corrected. This can be done using function key K4/K12. Please note that the specifications do not describe weather this value is saved after the machine is powered down. This could lead to a situation where the machine is unexpectedly running in the wrong direction.

Line speed

This value controls the maximum speed at with material will be wound onto the spool. For our application this will always be set to the maximum speed, in SI units this is 1.6 m/s but because the machine uses a different unit 96m/min should be entered. This value can be set higher than the maximum speed but this should only be done when using core diameters below the set minimum value of 90mm. This is because setting a higher than maximum speed results in a lower hydraulic pressure and thus a momentum. If it is necessary to have the machine running at a reduced speed for a limited amount of time this can be done using the feeding mode describe underneath. For this the line speed does not have to be changed.

Feeding mode

The feeding mode can be used to momentarily lower the speed of the winder. This mode can be used during the testing of the MZI system to check the substrate runs smoothly through all the different machines. In the settings menu the actual speed of the feeding mode can be set between the outermost values of 15m/min and 96m/min. During operation the machine can switch into this mode by pressing function key K10. If a value of 0 has been entered into the machine it isn't possible to change into the slower feeding mode and the machine will continue running normally.

5.3.2. Values to be monitored

Actual roll diameter

The actual roll diameter can be monitored to see how far the spool is filled. But for several reasons you cannot completely rely on this value. The first reason is that the machine does not display a measured value but a calculated value using the material thickness and the times the axle has turned. The second reason is that we are not winding film but a rope this causes inconsistencies in when calculating the diameter witch we described in paragraph 5.3.1. The time you will get the closest to the actual value is when the full with of the spool is filled with substrate right before it starts overlapping.

Actual tension set point

This vale shows the percentage of the maximum tension the machine is currently trying to match. When the advised value of zero is filled in for the "tension reduced (taper)" the displayed value will always be zero.

Feeding mode

In contrast to the others this value doesn't change unless the user will switch the machine into a different mode. The reason we still list this value here is because it does show up on the display on all times and we would like to give a complete list of information. The feeding mode can show two things:

- "OFF" this means the machine will run in normal operation
- "ON" this means the machine will run with a reduced speed entered in the appropriate menu.

6. Recommendations and discussion

In this chapter, recommendations and discussion, we will describe the parts of the design and research which we are not sure of or could be done better. These point do not make the design unfeasible but improving these parts would mean a better optimized machine.

6.1. Measurement of the substrate

The size of the spool has been determined by measuring the average diameter of the used substrate and then using a calculation to determine the size of spool necessary. We think this was the proper way to do this but there're are some uncertainties. The first is we never know if the substrate will wind the way we expect until we tried I. The second thing we still don`t know is how clean the substrate will be after the mussels are scraped off. We expect as clean as our test price but we don`t know yet. For these reasons the necessary size of the spool may change. Because of this uncertainty we kept a margin of 0.25km per spool.

The second thing we are not sure about is the actual weight of the substrate when wound on the spool. We did tests to determine the weight of the material both dry and wet. What we don`t know is how fast the material will dry because of water draining out and the packing of the material onto the spool. To be sure we used the weight of the full length of substrate completely soaked in water in our calculations. This situation is highly unlikely so lowering this value after more tests have been conducted could result in a better optimized and thus cheaper machine.

The last thing which needs to be considered is the condition the winder is in. It is some considerable time ago the winder has been used extensively so we are not sure how it will perform when used for a longer period of time. The only thing we know is that it works now and usable in this application but not how long it will last.

6.2. Using the winder

In our design we use a winder Jansen Tholen has available. For now this is a good solution because it cuts the costs. But by doing this we add some uncertainties and inconveniences into the operation of the machine. We used the specifications of the machine so we could say whether this winder is usable at all and the result was it is if you are willing to make a small compromise in the guaranteed winding speed. But because it is not clear what amount of force the winder will deliver in combination with the hydraulics on the TH4 and because we don`t know the actual force needed to pull the substrate from the water it is hard to give an reliable answer about the speed the machine will run at. But during the testing of the MZI system using this winder we can get better measurement on this and use these results for designing a winder that can be produced for other ships.

A final thing we did not take into account in using the winder is whether it is weather sealed. We assumed it is but we don`t know for sure. For this we should probably look in more detail at the build of the machine as it isn`t possible to recall the specifications about this.

6.3. Configurations

Currently we have made different configurations for the machine. At this stage this is helpful because it isn`t clear yet how the spools will be configured in the hull. But this lead to some compromises is the design. For example if you compare concept one and two with the final concept you can see these concepts needed less framework and were much compacter. At the stage that the MZI system would be sold to other clients of Jansen Tholen we think they should look at the concepts and consider a more other solution. But at this stage they probably aren't using this specific winder anymore so this enlarges the design flexibility they have.

6.4. Remaining for the client

As our assignment was described it wasn`t necessary to think about the connections with the ship. For this reason the client will still need to design the hydraulic connections to the winder, the fixation of the machine in the hull of the Tholen 4 and the power connection of the winder. Other things the client still needs to decide or do are choosing which parts will be made by themselves and which ones will be made by a third party and they need to optimize the 2D drawings for their personnel. The reason for this is that the production personnel is probably used to a specific layout of the drawing.

The last note we have is that we selected stock parts for the machine mostly on the given specifications and did not look for the best price. The parts we selected are usable but maybe different manufacturers or suppliers can deliver similar product at a lower price.

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List of figures

List of tables

Appendix A: Measurements of the substrate

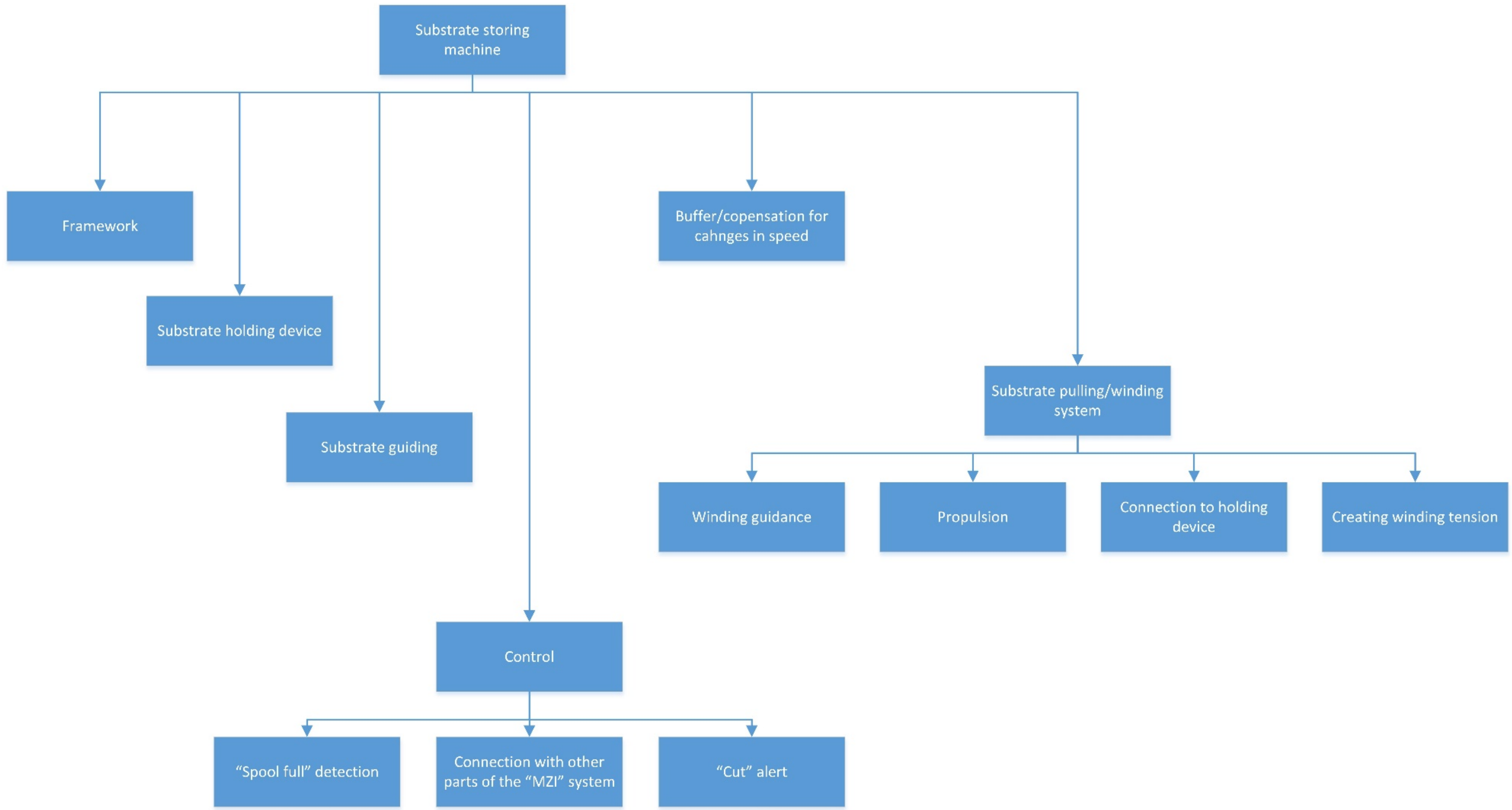
Measurements		
Measurement	Distance (mm)	Diameter (mm)
1	0	15
2	100	17
3	200	16
4	300	17
5	400	15
6	500	16
7	600	16
8	700	18
9	800	21
10	900	20
11	1000	19
12	1100	18
13	1200	17
14	1300	18
15	1400	16
16	1500	17
17	1600	15
18	1700	16
19	1800	15
20	1900	17
21	2000	16
22	2100	17
23	2200	15
24	2300	16
25	2400	15
26	2500	18
27	2600	16
28	2700	17
29	2800	15
30	2900	19

Appendix B: Process tree

Product phase	Activity	Specification	Comments
Pre-use	Installing	Lifting the system into the ship.	In one or several parts?
		Shipping the system.	
		Connecting the electrical network.	
		Connecting to the hydraulic system.	
		Connecting the system to other parts of the "MZI" system.	One main control or several linked control units?
	Calibrating	-	Is it necessary to calibrate the measuring device?
	Testing	-	Are there any special tests apart from running the device?
Use	Intended use	Feeding the substrate trough the guidance rings.	How big needs the guidance to be?
		Feeding the substrate trough the measuring device.	
		Feeding the substrate trough the pulling wheels.	
		Feeding the substrate trough the winding guidance.	
		Connecting the substrate onto the spool.	How will the connection be made?
		Starting the machine.	
		Connecting the lifting support to the spool.	What sort of support?
		Lifting a full spool from the ship.	
		Lifting an empty spool into the ship.	
		Securing the spool.	
		Securing the spool.	
		Cutting the substrate line when the spool is full.	Where will the cut be made? Does there need to be a signal when the substrate line needs to be cut? Will the whole system pause when a cut needs to be made?

Product phase	Activity	Specification	Comments
Use	Intended use	Restart for winding on the second spool.	
		The end of the substrate line is reached.	Does the line spin around?
		Secure the end of the substrate on the spool.	
	Unintended use	Cutting the substrate line on a wrong place.	
		Not cutting the substrate line at all.	
		Not cutting the substrate line and restarting	
		Not securing the substrate line substrate properly.	
		Improperly feeding the substrate through the system.	
		Mussels aren`t scraped of properly.	Do they damage the guidance? How much do they fill the spool extra?
		Not securing the end of the substrate on the spool.	
	Maintenance	Lubricating the gears.	
		Chancing tubing.	
		Chancing motors.	
		Recalibrating the measuring device.	
		Changing bearings.	
		Changing sensor.	

Appendix C: System decomposition

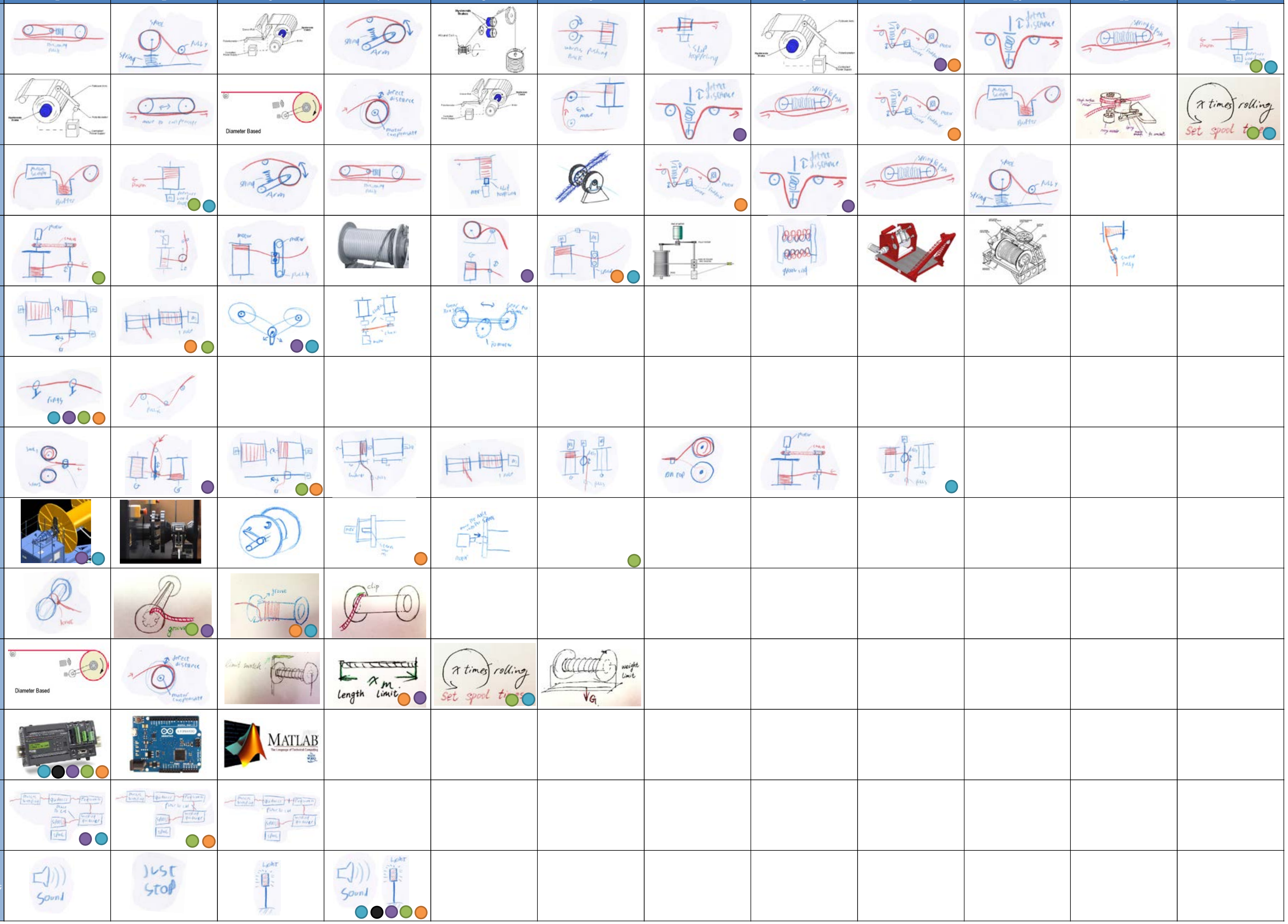


Appendix D: Design specifications

No.	Group	Specification	Comments	Source
1	Tech / Human	The machine can be lifted with a forklift		(MA, QU, DING, & NIU, 2014)
2	Tech	The machine will wind the substrate with a speed of at least 0.3 m/s		(MA, QU, DING, & NIU, 2014)
3	Tech	The machine has a mean time between failure (MTBF) of 2400 hours		(MA, QU, DING, & NIU, 2014)
4	Market	The total cost of the machine is less than 2000 euros	Including production / installing?	(MA, QU, DING, & NIU, 2014)
5	Tech	When the rope is removed from the spool it doesn`t tangle.		Processtree
6	Tech	The system can hold 6 km of substrate.		Client
7	Tech	The machine will wind the substrate with a speed of at least 0.3 m/s		Client
8	Tech / Human	The spools can be lifted off the ship.		Processtree
9	Tech	The speed at witch the substre is wound on spools os in snc. with the rest of the "MZI" system.		Client
10	Tech	Every spool holds at least 3 km of substrate.		Analysis phase
11	Tech	The speed at witch the substre is wound on spools can vary between 0.3 m/s and 2.0 m/s.		Analysis phase
12	Tech	The initial winding tension should be between 4.3kN and 8.6kN.		Analysis phase
13	Tech	The feed angle is`t larger than 1,5 degrees.		Analysis phase
14	Tech	Each spool should be able to support at least 1113,6 kg of substrate.		Analysis phase
15	Tech	The spools have a drum diameter of at least 294mm.		Analysis phase
16	Human	The crew of the ship are warned when the substrate needs to be cut 2 minutes in advance.		Analysis phase
17	Tech	The machine has a mean time between failure (MTBF) of 2400 hours.		(MA, QU, DING, & NIU, 2014)
18	Tech	The inital winding tension is between 4.3kN and 8.6kN during normal operation.		Analysis phase
19	Tech	The machine is able to store substrate at a minimum speed of 0.3m/s		Analysis phase
20	Tech	The machine is able to store substrate at a maximum speed of 2.0m/s		Analysis phase
21	Tech	Tehe machine will automatcally stop when the rope needs to be cut.		Processtree
22	Market	The machine will use the motor currently owned by Jansen Tholen		Client
23	Tech	The machine will use the hydraylic system onboard the Tholen 4 as the main power source		Client
24	Tech	The machine uses the ships power grid as for powering the electronics of the machine		Client
25	Ecology	The machine will not leak any fluids		Processtree
26	Tech / Human	The machine has connection point to allow easy lifting by crane.		Processtree
27	Human	All the gears / pully`s of the machine are shieled in a way to prevent the user from being pulled in.		Processtree
28	Tech / Human	All bearings suppoting the main axle can be changed in under an hour.	The main axle is the axle supporting the spool.	Processtree
29	Human	The substrate can be connected to the first spool in less than 5 minutes		Processtree
30	Human	The substrate can be connected to the second spool in less than 2 minutes		Processtree
31	Market	The design allows the use of diffrent kinds of motors.	This doen`t mean no modifications nessisary	Analysis phase
32	Market	The machine can be mounted both on the deck and in the hull of the Tholen 4		Client

Appendix E: Morphological matrix

	Search topic	1	2	3	4	5	6	7	8	9	10	11	12
Technology	Creating winding tension;												
	Compensating for changes in speed as a result of a chancing diameter;												
	Compensating for changes in speed as a result of a variating feeding speed;												
	Guiding the rope on the spool;												
	Powering two spools;												
	Guiding the substrate over the ship;												
	Layout of the machine;												
	Lifting out the spools / connecting to the spools;												
	Connecting the substrate to the spools;												
	Detecting if the spool is full;												
	Controlling the system;												
People	Location to cut the rope;												
	Warning that the spool is full;												



Idea 1: Tension control by the load on the motor and spool connection by "hanging" the spools on an axle

Idea 2: Using a dancer arm for creating winding tension and conpensation for changes in speed

Idea 3: Based on a dancer arm for tensioning and speed compensation

Idea 4: By measuring the load of the motor there will be compensated for changs in speed and tension.

Appendix F: Comparison of spools

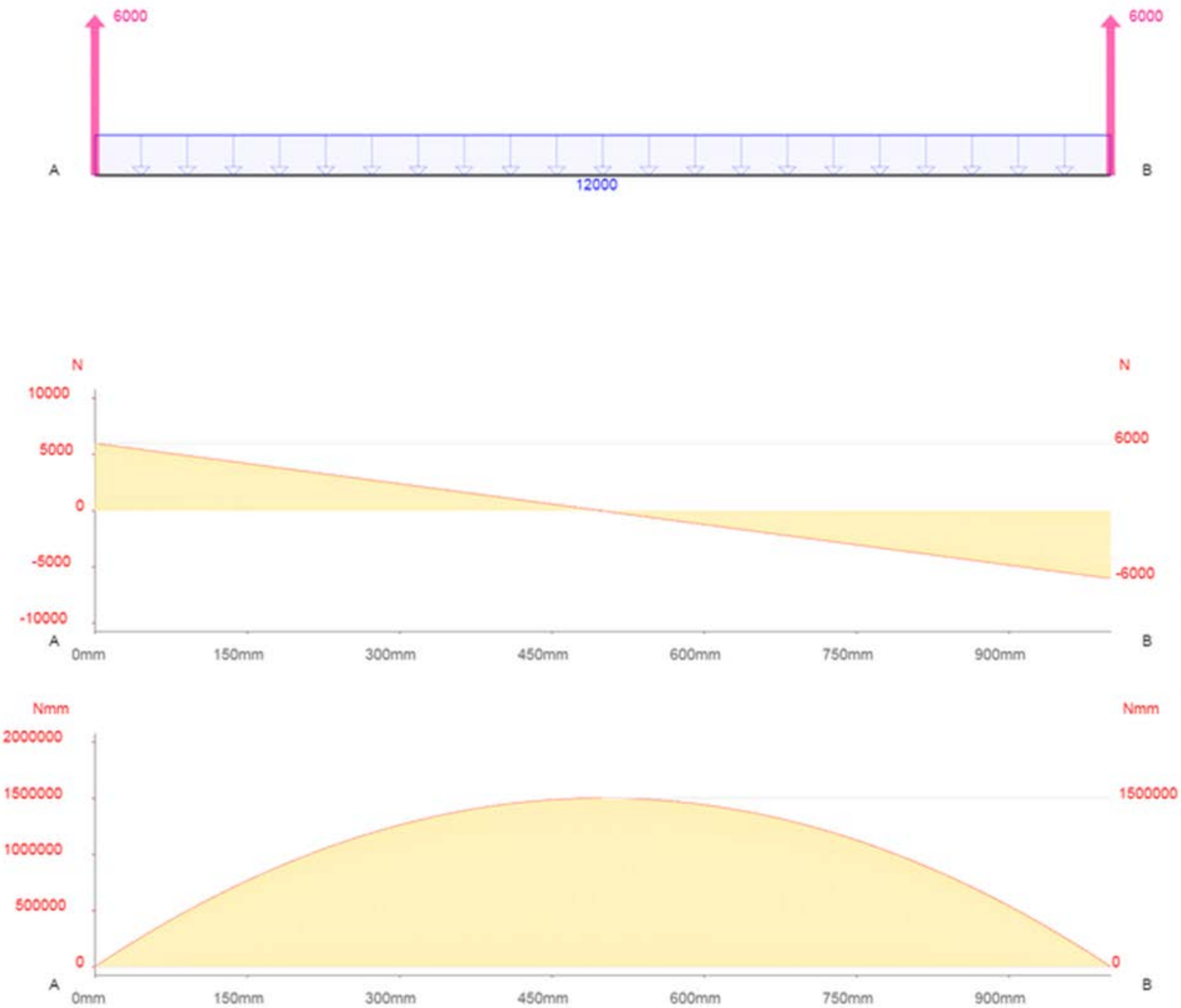
Name			Dimensions				Other			Specifications - Calculated			
Supplier	Part	Material	Drum diameter	Flange diameter (mm)	Winding width (mm)	Total width (mm)	Axle hole (mm)	Maximum weight (kg)	Weight (kg)	Flange depth (mm)	Capacity (km)	Spare length (km)	Total amount of spools needed
HKC	A 1400	Wood	710	1400	800	886	85	2000	137	345	3,24	0	2
HKC	A 1200	Wood	650	1200	780	872	85	1000	99	275	2,21	-1,04	3
HKC	AG 1200	Wood	500	1200	640	720	80	N/A	N/A	350	2,12	-1,13	3
HKC	SA 760	Steel	400	760	270	280	40	N/A	N/A	180	0,31	-2,93	21
HKC	SA 1040	Steel	540	1040	300	380	40	N/A	N/A	250	0,66	-2,59	10
HKC	SA 1900	Steel	1160	1900	1000	1117	93	N/A	N/A	370	6,30	3,05	1
HKC	SA 1950	Steel	800	1950	970	1070	90	N/A	N/A	575	8,54	5,28	1
Hafner	KCS 1000 ND	Plastic	500	1000	560	700	80	500	N/A	250	1,17	-2,08	6
Hafner	KCS 900 N	Plastic	450	900	560	700	80	400	N/A	225	0,95	-2,3	7
PAGO	1200 SP 3	Steel	540	1200	400	380	55	N/A	N/A	330	1,28	-1,97	5
PAGO	1200 SD 3	Steel	300	1200	650	700	93	N/A	N/A	450	2,44	-0,8	3
PAGO	1500 SP 3	Steel	700	1500	970	1000	95	N/A	N/A	400	4,75	1,5	1
PAGO	1200 SH 2	Steel	650	1200	800	912	85	N/A	N/A	275	2,27	-0,98	3

Appendix G: Settings of the winder

Values to be set		
Description	**Value**	**Comment**
Core diameter	710	This is the drum diameter of the chosen spool
Thickness	0.35	This is the value for substrate with a diameter of 16.8mm
Tension set point	30	This value should be set between 20 and 40 to ensure a proper tension
Tension reduced (taper)	0	This value should be set to zero because this function isn`t used
Gearbox	1	One is selected if no gearbox is used
Line speed	1.6	Set to the maximum speed of the winder
Feeding mode	OFF	During normal operation this function should be switched off

Values that can be monitored	
Description	**Comment**
Actual roll diameter	This is the calculated value of the current diameter. Because this is the calculated value the value is not exact.
Actual tension set point	This displays the currently set tension in percentages of the maximum. When using the advised setting this should display "0" at all times
Feeding mode	During normal operation this function should display "OFF"

Appendix H: Force diagrams for the main axle

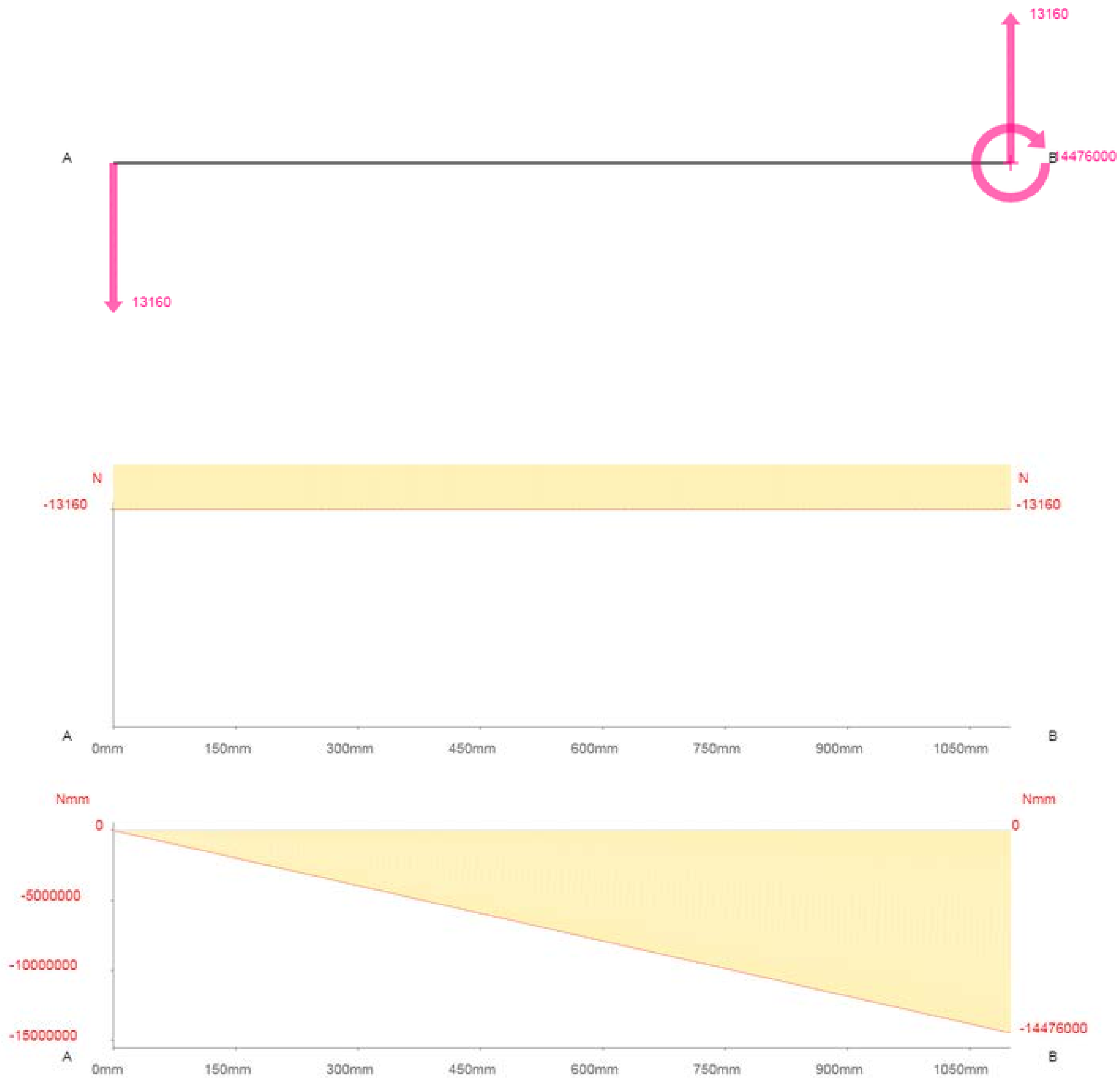


Appendix I: Cost estimate

Number		Name or type	Cost buid-up		Price per pice (Exl. TAX) (€)	Amount	Combined price (Exl. TAX) (€)	Source
Assambly	Part		Cost aspect	Specification				
0	0	Assambly	Welding	20 min of welding costs € 29,00	36,33	1	37,33	Metaalgroothandel Metaalwinkel, 2010
			Bolting together	10 min of assambly costs € 7,33				Assemblagebedrijf Perfect, 2014
1	0	Assambly	Bolting togheter	10 min of assambly costs € 7,33	7,33	1	7,33	Assemblagebedrijf Perfect, 2014
	1	Pushing pin	Material	940 gram S316 costs € 75,20	80,78	2	161,57	Ijzershop, 2015
			Milling	5 min of milling costs € 5,58				Metaalgroothandel Metaalwinkel, 2010
	2	Connecting plate	Material	2666 gram S316 costs € 12,96	19,89	2	39,78	Ijzershop, 2015
			Cutting	4 min of cutting costs € 2,93				Metaalgroothandel Metaalwinkel, 2010
			Powdercoating	2666 gram powdercoating costs € 4,00				Prodin, 2014
	3	SKF PHH SM30-2 (Bold on hub)	Purchase	N/A	143,23	2	286,45	Berg AB, 2015
	4	A 1400 (Wooden spool)	Purchase	N/A	65,00	2	130,00	HKC, 2015
	5	M12*20 Bolt (Stainless steel)	Purchase	N/A	0,11	6	0,66	Hansen schroeven, 2015
	6	M12 Nut (Stainless steel)	Purchase	N/A	0,07	2	0,13	Hansen schroeven, 2015
	7	M12 Washer (Stainless steel)	Purchase	N/A	0,03	2	0,06	Hansen schroeven, 2015
	8	Handle	Purchase	N/A	1,80	2	3,60	Bunnings, 2015
	9	Taped M12 rod (Stainless steel)	Purchase	N/A	0,80	1	0,80	Hansen schroeven, 2015
2	1	Assambly	Bolting togrther	20 min of assambly costs € 14,67	14,67	1	14,67	Assemblagebedrijf Perfect, 2014
		SKF LZBU 16 A-2LS (Slider assambly)	Purchase	N/A	152,10	2	304,20	Berg AB, 2015
			Drilling	10 min of milling costs € 11,17				Metaalgroothandel Metaalwinkel, 2010
			Taping	8 min of taping costs € 8,93				Metaalgroothandel Metaalwinkel, 2010
	2	Nylon roller	Purchase	N/A	6,00	2	12,00	Downwind marine, 2015
	3	Roller axle	Material	15 gram S316 costs € 0,07	2,31	4	9,22	Ijzershop, 2015
			Milling	2 min of milling costs € 2,23				Metaalgroothandel Metaalwinkel, 2010
	4	Retainers (c-rings)	Purchase	N/A	0,02	4	0,08	Hansen schroeven, 2015
	5	Roller supports	Material	107 gram S316 costs € 0,52	8,10	4	32,41	Ijzershop, 2015
			Drilling	5 min of drilling costs € 5,58				Metaalgroothandel Metaalwinkel, 2010
			Folding	1 fold costs € 2,00				Metaalgroothandel Metaalwinkel, 2010
	6	M8*30 bolt (stainles steel)	Purchase	N/A	0,08	16	1,20	Hansen schroeven, 2015
	7	M3*15 bolt (stainless steel)	Purchase	N/A	0,02	20	0,44	Hansen schroeven, 2015
	8	Spindle	Material	1410 gram S316 costs € 6,85	229,56	3	688,69	Ijzershop, 2015
			Milling	30 min of milling costs € 33,50				Metaalgroothandel Metaalwinkel, 2010
	9	Spindle nut	Material	87 gram nylon S316 costs € 0,42	3,31	2	6,61	Ijzershop, 2015
			Milling	7 min of milling costs € 7,82				Metaalgroothandel Metaalwinkel, 2010
	10	SKF FLBU16 (housed support bearing)	Purchase	N/A	62,43	4	249,72	Berg AB, 2015
	11	PHS 05B-1A15 (gear)	Purchase	N/A	4,79	1	4,79	Berg AB, 2015
3	1	Main axle	Material	7545 gram S316 costs € 603,60	620,35	2	1.240,70	Ijzershop, 2015
			Milling	15 min of milling costs € 16,75				Metaalgroothandel Metaalwinkel, 2010

Number		Name or type	Cost buid-up		Price per pice (Exl. TAX) (€)	Amount	Combined price (Exl. TAX) (€)	Source
Assambly	Part		Cost aspect	Specification				
4	0	Assambly	Welding	15 min of welding costs € 21,75	28,35	4	113,40	Metaalgroothandel Metaalwinkel, 2010
			Glueing	7 min of glueing costs € 5,13				Assemblagebedrijf Perfect, 2014
			Bolting together	2 min of assambly costs € 1,47				Assemblagebedrijf Perfect, 2014
	1	Top plate	Material	22 gram S235 costs € 0,11	0,82	8	6,59	Ijzershop, 2015
			Cutting	1 min of cutting costs € 0,72				Metaalgroothandel Metaalwinkel, 2010
	2	Side plate	Material	180 gram S235 costs € 0,87	2,03	8	16,23	Ijzershop, 2015
			Cutting	2 min of cutting costs € 1,15				Metaalgroothandel Metaalwinkel, 2010
	3	Round part - bottom	Material	126 gram S235 costs € 0,61	1,37	4	5,47	Ijzershop, 2015
			Cutting	1 min of cutting costs € 0,75				Metaalgroothandel Metaalwinkel, 2010
	4	Rond part - top	Material	170 gram S235 costs € 0,83	1,84	4	7,38	Ijzershop, 2015
			Cutting	1 min of cutting costs € 1,02				Metaalgroothandel Metaalwinkel, 2010
	5	RVS M8*16	Purchase	N/A	0,08	16	1,28	Hansen schroeven, 2015
	6	AST850 7540 (Main axle bearing)	Purchase	N/A	56,70	4	226,80	Bunnings, 2015
5	0	Assambly	Welding	30 min of welding costs € 43,50				Metaalgroothandel Metaalwinkel, 2010
			Spraying	50 min of spraying costs € 43,75		1	0,00	Hulsbosch, 2012
	1	Top plate	Material	178 gram S235 costs € 0,87	2,01	4	8,02	Ijzershop, 2015
			Cutting	2 min of cutting costs € 1,14				Metaalgroothandel Metaalwinkel, 2010
	2	Middle collum	Material	4003 gram S235 costs € 19,45	19,45	4	77,82	Ijzershop, 2015
	3	Side collums	Material	3565 gram S235 costs € 17,33			156,21	Ijzershop, 2015
			Grinding	3 min of grinding costs € 2,20	19,53	8		Metaalgroothandel Metaalwinkel, 2010
	4	Bottom collum	Material	5337 gram S235 costs € 25,94	25,94	4	103,75	Ijzershop, 2015
	5	Main beams	Material	31425 gram S235 costs € 152,73	152,73	2	305,45	Ijzershop, 2016
6	0	Assambly	Bolting togheter	8 min of assambly costs € 5,87	5,87	1	5,87	Assemblagebedrijf Perfect, 2014
	1	Motor axle	Material	5936 gram S316 costs € 474,88	488,28	2	976,56	Ijzershop, 2015
			Milling	12 min of milling costs € 13,40				Metaalgroothandel Metaalwinkel, 2010
	2	PHS 05B-1A30 (gear)	Purchase	N/A	5,13	1	5,13	Berg AB, 2015
	2	EKH2500 (coupling)	Purchase	N/A	124,00	2	248,00	R+W, 2015
7	0	Assambly	Bolting togeter	4 min of assambly costs € 2,93	2,93		0,00	Assemblagebedrijf Perfect, 2014
	1	Wintech winder	Pre-owned	N/A	0,00	1	0,00	Jansen Tholen, 2015
	3	Chain	Purchase	N/A	6,70	1	6,70	Berg AB, 2015
Total cost of the winder in the default configuration:							**€ 5.503,10**	

Appendix J: Force diagrams for the one side supported main axle



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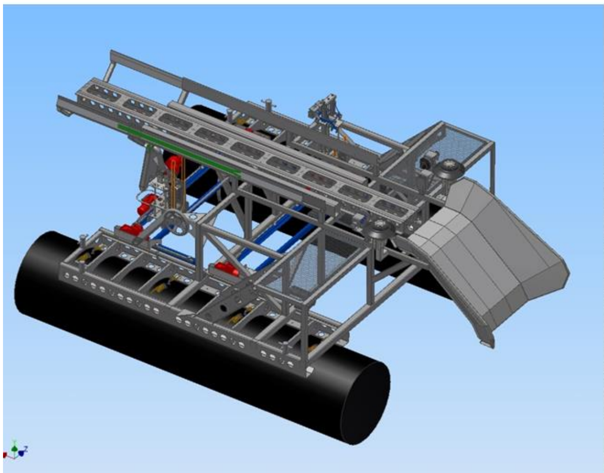


Europees Visserijfonds:
Investering in duurzame visserij

Ministerie van Economische Zaken

Jansen Tholen B.V.

Provincie Zeeland

HZ UNIVERSITY OF APPLIED SCIENCES

Communicatieplan

Doelgroepen

Jansen Tholen B.V. communiceert met verschillende doelgroepen. Het is belangrijk om voor ieder verschillende doelgroep een andere aanpak en andere boodschap van communiceren te nemen.

(Potentiële) Klanten
De eerste en belangrijkste doelgroep zijn (potentiële) klanten. Dit zijn bedrijven die een samenwerking aangaan met Jansen Tholen B.V. om samen een oplossingsgericht product te bedenken en te produceren.

De (potentiële) klanten van Jansen Tholen B.V. zitten zelf ook in de technische sector en/of houden zichzelf bezig met technische ontwikkelingen voor hun eigen bedrijf. Hierdoor is de doelgroep makkelijk te bereiken, omdat het een bekende groep is.

Medewerkers
De tweede belangrijkste doelgroep voor Jansen Tholen B.V. zijn de medewerkers. De medewerkers zijn het visitekaartje van het bedrijf en het is belangrijk om hun te voorzien van belangrijke informatie.

Daarnaast is het belangrijk om ook de naaste familie van de medewerker op de hoogte te houden. Vaak vertellen medewerkers nieuws niet door aan familie, terwijl het eventueel belangrijke dingen zijn om door te geven.

Pers
Ter promotie is het altijd goed om een goede relatie met de pers te onderhouden. Dit kan door middel het gebruik van verschillende kanalen. Door een goede relatie met de pers te onderhouden, zijn zij sneller geneigd om een leuk stuk te plaatsen in de krant of op een ander kanaal te delen.

Communicatiedoelstelling

Voor Jansen Tholen B.V. is het relevant om verschillende communicatiedoelstellingen te hanteren, voor zowel het vergroten van de naamsbekendheid als het afnemen van producten.

Awareness opbouwen
Als nieuwe producten op de markt verschijnen is het belangrijk om awareness op te bouwen. Dit wordt gedaan door middel van het effectief bereiken van de klant via de juiste kanalen en door de voordelen te benoemen.

Verstrekken van informatie
Nadat het nieuwe product al een naam heeft opgebouwd, is het belangrijk om (potentiële) klanten te voorzien van informatie. Hoe werkt het product, wat gaat het kosten. Jansen Tholen B.V. heeft op het gebied van de MZI weinig tot geen concurrentie. Hierdoor is het goed genoeg om alleen informatie te geven over de werking van het product en kosten die er bij komen kijken.

Vraag stimuleren
Doordat Jansen Tholen B.V. te maken heeft met samen werkingen met de klant, in plaats van afname van product, is het belangrijk om de vraag te stimuleren. Dit kan door middel van een gratis consult aan het begin van het proces, of door tijdens een beurs een gratis klein consult aan te bieden.

Doelstelling
De doelstelling die hier bij past:
"In December 2016 moet 50 procent van de huidige klanten bekend zijn met de Mossel Zaad Invanginstallatie."

"In December 2016 moet de Mossel Zaad Invanginstallatie bij 10% van de potentiële klanten geïnstalleerd zijn."

De doelstellingen zijn per product/dienst aan te passen voor Jansen Tholen B.V.

Boodschap bepalen

Per doelgroep is het belangrijk om een algemene boodschap te formuleren, zodat alle toekomstige berichten hier op gebaseerd kunnen worden, of dat de boodschap als voorbeeld gebruikt kan worden.

(Potentiële) klanten
Awareness - "Jansen Tholen B.V. gaat samen met u kijken naar de best mogelijke oplossing voor uw technische probleem. Co-creatie is belangrijk voor Jansen Tholen en wij waarderen een langlopende samenwerking met u als klant."

Verstrekken van informatie – "Met de Mossel Zaad Invanginstallatie wordt de mosselzaad invang lichamelijk minder zwaar. Daarnaast gaat er minder mosselzaad verloren tijdens de invang."

"Jansen Tholen werkt op een dichte basis samen met u. Het gaat om een partnerschap…"

Vraag stimuleren – "

Medewerkers
Voor medewerkers is het belangrijk om awareness te creëren van leuke en/of interessante gebeurtenissen binnen het bedrijf. Het kan gaan om een zender die komt filmen, of om een verjaardag/jubileum van een andere medewerker.

Awareness – "Op DATUM komt RTL 7 filmen voor een nieuwsitem! Doe je haren goed, poets je schoenen op en neem je beste humeur mee!"

Pers
Voor een bedrijf is het altijd goed om contact met de pers te houden. Hierdoor leert de pers het bedrijf te kennen en zijn ze eerder geneigd om er een stuk over te plaatsen, of om te bellen voor een interview als er een opening is. Er moet wel opgelet worden dat er niet te vaak berichten aan de pers gestuurd worden, omdat dit voor irritatie kan zorgen. Eén keer in de maand is een redelijke tijdspan.

Hieronder staan algemene berichten, die aangepast kunnen worden per situatie.

Awareness – "Jansen Tholen B.V. heeft in samenwerking met …. Een nieuw product gerealiseerd dat het probleem …. Oplost binnen de …. Sector."

Er kan altijd gekeken worden of er een belangrijk evenement en/of gebeurtenis gepland staat. Er kan een klein persbericht over geschreven worden die verspreidt wordt aan de pers. Mocht de pers het bericht interessant vinden, pikken ze het vanzelf op.

Communicatiemiddelen

In dit deel van het onderzoek wordt er per doelgroep gesproken over communicatiemiddelen.

(Potentiële) Klant
Om de potentiële klanten te benaderen moet er gebruik gemaakt worden van zowel offline als online communicatiemiddelen. Hierdoor wordt het bereik vergroot en wordt de boodschap vaker herhaalt.

Via deze kanalen is het belangrijk om nieuwe ontwikkelingen en nieuwsitems te verspreiden.

Owned Media
Owned media is de media die van het bedrijf zelf is. Het gaat hier om nieuwsbrieven, mailings, eigen geschreven persberichten en eigen sociale media kanalen.

Offline
Nieuwsbrief per kwartaal – Voor bestaande klanten die met e-mail en woonadres in het bestand staan is het leuk om een nieuwsbrief per kwartaal te verspreiden. In de nieuwsbrief kunnen nieuwsitems over Jansen Tholen Technology Group verspreidt worden. Er kan een stuk afgezet worden voor een bericht van een klant die een tevreden samenwerking heeft gehad met Jansen Tholen, of die al (bijvoorbeeld) 15 jaar samenwerkt met Jansen Tholen.

De nieuwsbrief wordt gebruikt voor luchtige weetjes en feitjes van het bedrijf, naast leuke nieuws items en het communiceren van evenementen. Het wordt gebruikt om de awareness te verhogen en om informatie op oppervlakkig gebied te verstrekken. Deze nieuwsbrief kan zowel via de e-mail als via print verspreidt worden. Er kan van te voren een e-mail uitgaan naar de klanten, met de vraag of zij een nieuwsbrief willen ontvangen en of zij de voorkeur hebben via digitaal of via print.

Introductiebrief – Om potentiële klanten te vinden kan er via de Kamer van Koophandel gekeken worden in het bestand naar bedrijven waarmee Jansen Tholen B.V. graag mee samen wil werken. Naar deze (nieuwe) bedrijven kan een introductiebrief gestuurd worden. Hier in kan Jansen Tholen B.V. zichzelf introduceren en vertellen wat Jansen Tholen B.V. voor hun een keer in de toekomst kan betekenen.

Dit geeft op de korte termijn niet meteen nieuwe klanten, maar als een bedrijf in de technische sector groeit en ze komen op een moment om samen te werken, dan denken ze terug aan de brief. In de brief kan er gevraagd worden of zij eventueel geïnteresseerd zijn in de nieuwsbrief die per kwartaal verspreid wordt.

Online

Facebook – Facebook is een handig kanaal om langere teksten te verspreiden en foto's op te plaatsen. Berichten kunnen ingepland worden via de pagina. Dit is een handige tool. Begin van de week kunnen alle berichten geschreven en ingepland worden, zodat er de rest van de week niks meer bedacht hoeft te worden. Toch moet er altijd teruggekeken worden en gereageerd worden op vragen van klanten.

De Facebook pagina van Jansen Tholen kan gebruikt worden voor awareness en informatie verspreiding. Facebook is een handige verzamelplek voor alle (online) nieuwsartikelen die geschreven worden over het bedrijf. Er kan gedeeld worden van andere pagina's, bijvoorbeeld als de PZC iets geschreven heeft over Jansen Tholen.

Ook kan er een directe link geplaatst worden naar het artikel. Facebook plaatst automatisch een klikbare foto er bij. In het bericht kan het eerste alinea van het artikel overgenomen worden, met nog een persoonlijk stuk van uit Jansen Tholen erbij (bijvoorbeeld: wij zijn vereerd dat… Vandaag is er een leuk bericht over ons geplaatst…)

Om te voorkomen dat er te veel van hetzelfde geplaatst wordt of dat er te veel geplaatst wordt, kan er gekozen worden voor enkele dagen om te posten. Elke dag krijg zijn eigen thema om iets over te plaatsen.

Het is belangrijk om minimaal drie keer in de week iets op Facebook te plaatsen. De beste tijden zijn: maandag ochtend, woensdag middag, vrijdag middag. Goed reageren op reacties is ook belangrijk. Dit laat zien dat het bedrijf betrokken is.

De bijgevoegde content kalender laat zien hoe het Facebook schema er uit ziet.

Twitter – Twitter wordt voornamelijk gebruikt voor korte en snelle berichten, vaak gekoppeld met een link en een relevante hashtag (#). Deze hashtags zorgen ervoor dat het bericht gevonden kan worden in een massa van andere berichten. Het moeten wel relevante hashtags zijn, anders haken lezers snel af.

Relevante hashtags voor Jansen Tholen kunnen zijn:
#technologie, #nieuws, #ontwikkeling, #innovatie, #familiebedrijf, #techniek

Twitter is een handige plek om vragen te beantwoorden van (potentiële) klanten. Het kan als een soort klantenservice gebruikt worden, waar klanten met hun vragen komen en waar snel gereageerd kan worden.

Ook kunnen hier nieuwsberichten geretweet (gedeeld) worden van andere pagina's. Bijvoorbeeld nieuwsberichten van de PZC of Omroep Zeeland of een ander nieuwsplatform kan hier op gedeeld worden. Dit hoeft niet te vaak gedaan worden, omdat de nieuwsberichten natuurlijk ook op de Facebook pagina gedeeld worden.

Twitter kan ook gebruikt worden voor kleine, leuke feitjes die tussendoor geplaatst kunnen worden. Het gaat om berichten die te klein zijn voor Facebook (onder de 140 tekens).

Voor Twitter geldt hetzelfde als Facebook: Minimaal drie keer in de week iets plaatsen met relevante hashtags, op maandag ochtend, woensdag middag en vrijdag middag, en goed reageren op reacties.

De bijgevoegde content kalender laat zien hoe het Twitter schema er uit ziet.

LinkedIn – LinkedIn is het perfecte platform om potentiële klanten te benaderen. Er kan een pagina gemaakt worden voor het bedrijf zelf om, net als op Facebook, nieuwsberichten te plaatsen. LinkedIn is een meer zakelijke omgeving.

Als bedrijf zijnde is het relevant om aan te sluiten om discussiegroepen of groepen die dezelfde interesses hebben als het bedrijf. Om naam te maken op LinkedIn is het belangrijk om actief in de discussies mee te doen.

Om de zoveel tijd kan er ook zelf een discussie gestart worden op LinkedIn. Dit zorgt ervoor dat de naam van het bedrijf herhaald blijft worden, doordat iedereen die mee doet een melding krijgt als er een nieuwe toevoeging is in de discussie.

Door actief mee te doen aan discussies krijgt het account ook een status. LinkedIn geeft bij bepaalde niveaus van betrokkenheid. Hierdoor groeit het account en wordt hij ook vaker voorgesteld om te 'volgen' voor mensen.

Ook hier is regelmatig actief zijn goed. Dezelfde dagen gelden voor LinkedIn. Maandag ochtend, woensdag middag, en vrijdag middag zijn goede dagen om op te posten. Mensen zijn het meest actief op deze tijden.

De bijgevoegde content kalender laat zien hoe het LinkedIn schema er uit ziet.

Inlogcodes

Facebook:

Twitter:

LinkedIn:

Medewerkers
De betrokkenheid van medewerkers (en familie) is een belangrijk punt. Medewerkers zijn een visitekaartje. Als die goed geïnformeerd zijn en ook tevreden zijn, kan dit ook leiden tot meer klanten of een grotere naamsbekendheid.

Owned Media
Owned media is de media die van het bedrijf zelf is. Het gaat hier om nieuwsbrieven, mailings, eigen geschreven persberichten en eigen sociale media kanalen.

Offline
Nieuwsbrief – Er gebeuren veel interessante dingen bij Jansen Tholen, maar niet alle medewerkers zijn hier van op de hoogte. Een leuke en makkelijke manier om zowel de medewerkers als het thuisfront op de hoogte te houden is door per maand of per kwartaal een nieuwsbrief uit te brengen in print, en deze naar het huisadres te sturen.

De nieuwsbrief kan onderwerpen bevatten als:
- Verjaardagen, jubileum, geboorte (enzovoort)
- Belangrijke gebeurtenissen zoals een filmcrew die langskomt, of wanneer het item op TV komt enzovoort.
- Een 'column' geschreven door een collega – Er wordt gesproken over iets wat hem interesseert, waar hij zich mee bezig houdt na het werk. Zo leert iedereen de collega's beter kennen.
- Een bericht van de eigenaar, ook een persoonlijk stuk. Medewerkers vinden het leuk om hier over te lezen.

De nieuwsbrief is voor het thuisfront ook leuk om te lezen. Medewerkers vertellen alles niet thuis wat ze horen op de werkvloer, of ze zijn het tegen die tijd al weer vergeten. Door de nieuwsbrief op papier naar huis te sturen, wordt het vaak en sneller opgepakt en gelezen.

Online
Facebook – Een Facebook groep is een online manier voor medewerkers om samen te komen en te discussiëren. Hier kunnen eventueel diensten geruild worden of snelle berichten gedeeld worden. De Facebook groep kan als een online nieuwsbrief gebruikt worden.

Vraag aan medewerkers om berichten van de algemene Facebook pagina van Jansen Tholen B.V. te delen op de persoonlijke pagina. Dit zorgt ervoor dat een nieuwsartikel die geplaatst is op de algemene pagina meer bereik heeft en door meer mensen gezien wordt. Hiermee wordt misschien niet direct de klanten doelgroep bereikt, maar de naamsbekendheid groeit wel.

Twitter – Een leuk idee om de medewerkers te betrekken is door iedere week een andere medewerker het Twitter account te laten beheren. Hierdoor groeit de betrokkenheid onder de medewerkerkers en krijgen de klanten een 'behind the scene'. Dit laat zien dat Jansen Tholen B.V. betrokken is door open te tweeten en foto's te plaatsen van werkzaamheden.

Dit kan op woensdagmiddag of vrijdagmiddag ingepland worden.

Pers
Door de pers blijvend te informeren over Jansen Tholen blijft het bedrijf langer in het achterhoofd hangen. Hierdoor bestaat de kans dat een journalist eerder aan Jansen Tholen denkt voor een interview. Daarnaast kan er ook betaalt worden voor een interview of een nieuwsitem.

Earned Media
Earned Media is de media aandacht die verdient is door het bedrijf. Dit kan zijn doordat er een award gewonnen is, of doordat er toevallig een opening was voor een interview. In het laatste geval moet er goed contact onderhouden worden met de pers, zodat de naam Jansen Tholen B.V. blijft hangen.

Offline
Persbericht – Als er een speciale gebeurtenis is kan er een persbericht worden verstuurt naar de pers. Dit houdt niet in dat het bericht geplaatst wordt, maar het wordt wel gelezen. Als het persbericht qua nieuwswaarde relevant is, wordt er een plek gezocht. Mocht het interessant zijn, dan wordt er vaak op het einde gekeken of er nog plek is in de krant voor het persbericht.

Het doel hoeft niet te zijn dat het persbericht geplaatst wordt, maar zo krijgt de nieuwszender of krant wel de naam van het bedrijf onder ogen. Hoe vaker dit gebeurt, hoe langer de naam blijft hangen. Het moet niet te vaak gebeuren, want dan is de kans groot dat het verwijderd wordt.

Persoonlijke relatie – Een persoonlijke relatie aangaan met een journalist is een makkelijke manier om snel het persbericht bij de redactie te krijgen. Op evenementen lopen journalisten vaak rond, op zoek naar een interview. Een gesprek aangaan kan makkelijk met deze journalisten, gewoon op persoonlijke basis. Het einddoel is geen interview, maar het feit dat ze het bedrijf kennen en weten welk gezicht er bij hoort. Na het gesprek kunnen er visitekaartjes uitgewisseld worden. Journalisten bewaren deze vaak, voor het geval dat zij later een interview nodig hebben of een nieuwsitem moeten schrijven met een relevant thema (zoals techniek).

Online
Facebook – Door journalisten en nieuwskanalen te volgen op Facebook wekt dit interesse op bij de nieuwskanalen en de journalisten. Het laat zien dat het bedrijf, of de persoon, geïnteresseerd is in de onderwerpen waar de journalist over schrijft. Door eens in de zoveel tijd te reageren op een artikel, o

Budget

Tijd

PERSBERICHT

Aan: Redactie
Datum: 6 november 2015
Onderwerp: Jansen Tholen wint de Zeeuwse Emergo Publieksprijs

Jansen Tholen B.V. wint de Zeeuwse Emergo Publieksprijs

Tholen – Jansen Tholen B.V. wint de Zeeuwse Emergo Publieksprijs van 2015, met een machine die volledig automatisch een MZI systeem installeert. De machine is ontwikkeld in samenwerken met Firma Schot van de TH4. Jansen Tholen B.V. is dankbaar voor alle steun van iedereen die gestemd heeft.

MZI staat voor Mossel Zaadinvang Installatie en is een alternatief voor de traditionele bodemvisserij. Het zaad wordt niet meer opgevist van natuurlijke mosselbanken, maar ingevangen op net- of touwconstructies. Aan de lijnen en netten onder de drijvers hecht en groeit het mosselzaad. Een nog nieuwe, innovatieve methode om de mosselkwekers van voldoende mosselzaad te voorzien. Het ingevangen zaad wordt na het invangen overgebracht naar mosselkweekpercelen. Op deze manier wordt het mosselzaad ingevangen zonder de bodem in de Waddenzee te beroeren en wordt het milieu gespaard.

Het is de bedoeling dat de mosselvisserij uiteindelijk geheel op MZI's overschakelt als milieuvriendelijk alternatief voor de traditionele bodemvisserij, de zogenaamde transitie. Om de doorontwikkeling van verdergaande MZI te ondersteunen ontwikkelde Jansen Tholen de geautomatiseerde Mossel Zaadinvang- en Oogstinstalatie. De bestaande systemen werken erg arbeidsintensief en inefficiënt. Ook plegen ze een aanslag op het lichaam, omdat personeel langdurig buiten boord moet hangen. Veel mosselzaad gaat tijdens de oogst verloren. De MZI van Jansen Tholen ondervangt al deze problemen.

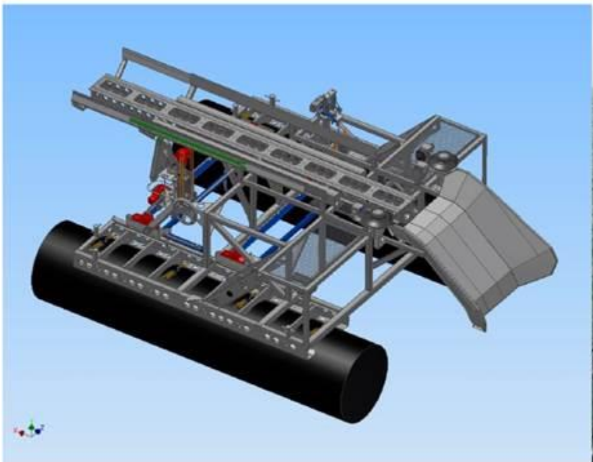
Het project "Ontwikkeling geautomatiseerd MZI systeem" is een initiatief van Firma Gebr. A.J. Schot TH 4 en Jansen Tholen B.V. en wordt mede mogelijk gemaakt door het Europees Visserij Fonds (EVF) en het Ministerie van Economische Zaken ter investering in duurzame ontwikkeling van visserijgebieden.

EINDE PERSBERICHT

Voor meer informatie kunt u contact opnemen met Irene Lam, Light Up Advertising.
Contactgegevens
E: Irene@Lightupadvertising.nl
T: +31(0)646274340

BIJLAGE:
Foto 1

Ontwikkeling geautomatiseerd MZI systeem



Ministerie van Economische Zaken

Jansen Tholen B.V.

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PERSBERICHT

Aan: Redactie
Datum: 5 november 2015
Onderwerp: Jansen Tholen wint de Zeeuwse Emergo Innovatieprijs

Jansen Tholen B.V. wint de Zeeuwse Emergo Innovatieprijs

Tholen – Jansen Tholen B.V. wint de Zeeuwse Emergo Innovatieprijs van 2015, met de door hun bedachte MZI, die een alternatief voor de traditionele bodemvisserij is.

MZI staat voor Mossel Zaadinvang Installatie. Het zaad wordt niet meer opgevist van natuurlijke mosselbanken, maar ingevangen op net- of touwconstructies. Aan de lijnen en netten onder de drijvers hecht en groeit het mosselzaad. Een nog nieuwe, innovatieve methode om de mosselkwekers van voldoende mosselzaad te voorzien. Het ingevangen zaad wordt na het invangen overgebracht naar mosselkweekpercelen. Op deze manier wordt het mosselzaad ingevangen zonder de bodem in de Waddenzee te beroeren en wordt het milieu gespaard.

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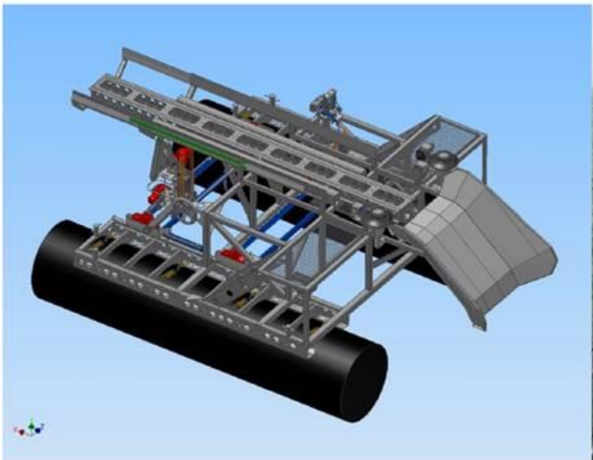

Ministerie van Economische Zaken

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Beste,

Er is weer leuk nieuws te brengen over Jansen Tholen B.V. deze week. Hier onder kunt u de hoogtepunten lezen van afgelopen week!

Zeeuwse Innovatieprijs Emergo 2015
Jansen Tholen B.V. is genomineerd voor de Zeeuwse Innovatieprijs Emergo 2015 en er kan vanaf heden gestemd op ons worden! De Emergo is een prijs van de Kamer van Koophandel en de Provincie Zeeland. Deze wordt jaarlijks uitgereikt aan een Zeeuwse onderneming die een succesvolle innovatie heeft gerealiseerd.

Dankzij de Mossel Zaad Invanginstallatie is Jansen Tholen B.V. genomineerd voor deze mooie Zeeuwse prijs. Helpt u ons mee naar de overwinning? Stemmen kan hier en is mogelijk tot dinsdag 3 november.

Ondernemend Nederland
Op zondag 15 november 2015 om 9:55 is het tijd om naar Ondernemend Nederland op RTL7 te kijken, want Jansen Tholen B.V. is deel van de aflevering. Het thema is Industrie en Techniek, wat wij als bedrijf ons mee bezig houden. Neem een kijkje in het bedrijf tijdens deze aflevering en hoor wat wij te vertellen hebben over het thema Industrie en Techniek. Komt zondag 15 november niet uit? Op zaterdag 21 november 2015 om 12:30 is de herhaling op RTL7!

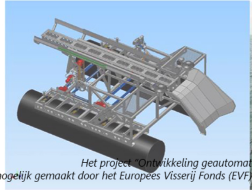
Ondersteun Jansen Tholen B.V. door op 15 of 21 november te kijken naar RTL7 en door op ons te stemmen voor de Emergo prijs, want samen kom je verder!

Met vriendelijke groeten,

Siem Jansen
Jansen Tholen Technology Group

Ministerie van Economische Zaken

Jansen Tholen B.V.



Bedankt voor de Emergo publieksprijs van 2015!

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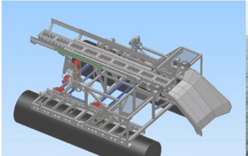
Ministerie van Economische Zaken

Jansen Tholen B.V.



Nummer 62 in de Top 100 Meest Innovatieve Bedrijven 2015!

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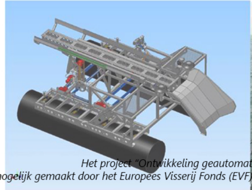

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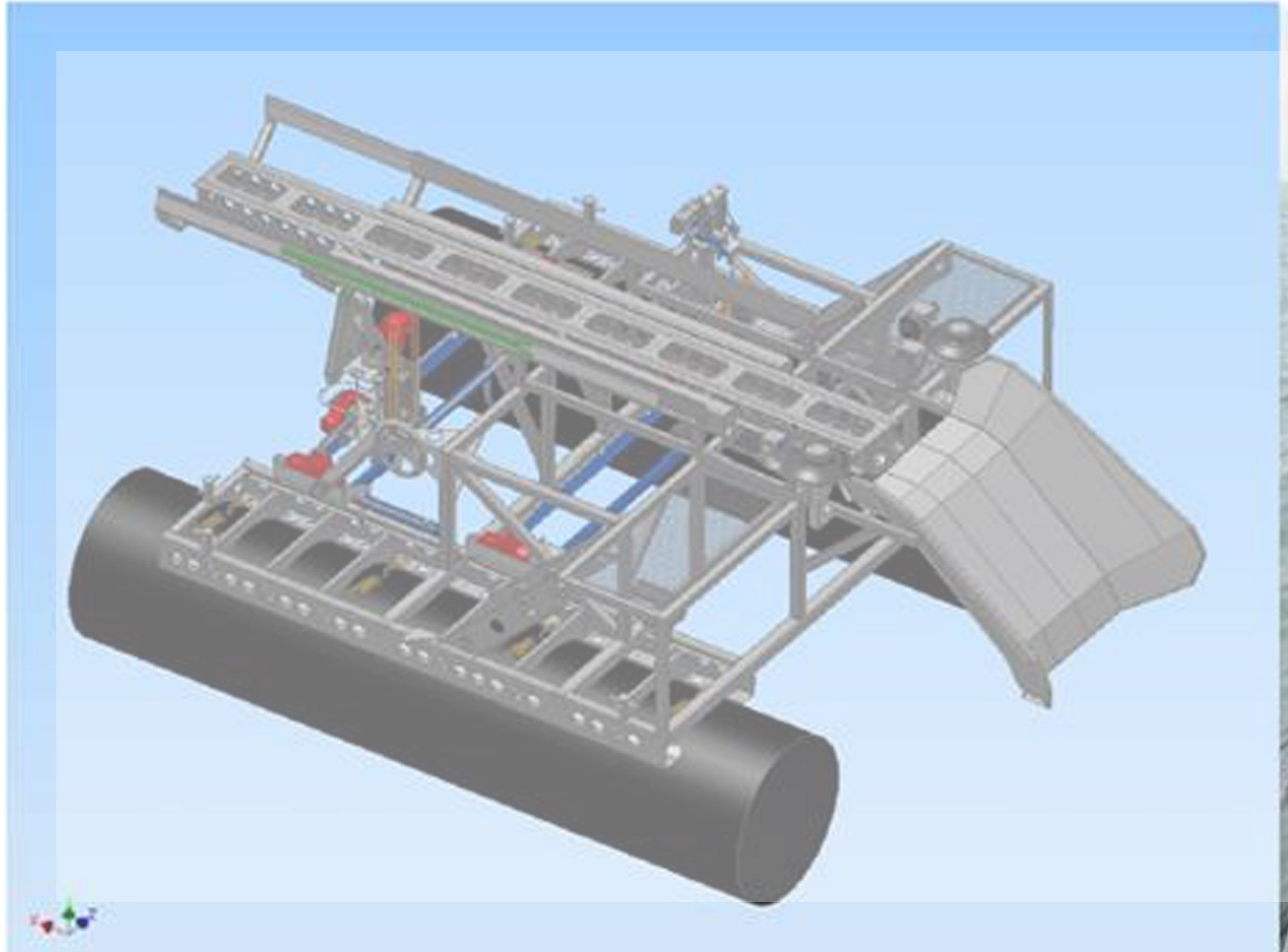

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