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Design study of a vessel for the Arctic Scallop industry

A systematic approach

July 2021

Master's thesis

2021

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Submission date: July 2021
Supervisor: Bjørn-Egil Asbjørnslett

Norwegian University of Science and Technology
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Det skapende universitet

MASTER THESIS IN MARINE TECHNOLOGY

SPRING 2021

Stud. techn. Ingvild Wergeland Gundersen

Design study of a vessel for the Arctic Scallop industry –

A systematic approach

Spring 2021

Background
In the 1980s, there was an extensive fishing for Arctic Scallops in the Svalbard zone. However, the Arctic Scallops was harvested by shell scraping, a method that was banned in 1992. Since then, the fishery has not been utilized, due to the lack of sustainable harvesting technology.

In order to be able to utilize this resource in the Fisheries Protection Zone, a new harvesting methodology must both deal precautious with the remaining benthic fauna and for the bottom sediments that make up the habitat for benthic animals. A new harvesting technology is named the Seabed Harvester, and the Seabed Harvester is based on a suction technology lifting the Arctic Scallops from the seabed and into a collection unit.

The Seabed harvester technology will require new vessel design compared to vessel designs that used the shell scraper technology.

Overall aim and focus
The overall aim of this thesis is to come up with a conceptual design of a vessel using the new harvesting technology. This is done by a systematic approach to engineering design. By doing this gain insight in the Arctic Scallop industry, and firm up different solution alternatives of a conceptual design of a vessel for the industry.

Scope and main activities
The candidate is recommended to cover the following parts in the master thesis:

a. Review state of art within the topic. That means to document what others have done and published previously.

b. Document the system in which the problem is located.

c. Document the problem in a generic way.

d. Document relevant approaches and methods for addressing and solving the problem, and choosing an approach/method for one's own work.

e. Present an example study of a conceptual design, with specified solution variants

f. Discussion of the work and the results

g. Conclusion and further work

General

In the thesis the candidate shall present his personal contribution to the resolution of a problem within the scope of the thesis work.

Theories and conclusions should be based on a relevant methodological foundation that through mathematical derivations and/or logical reasoning identify the various steps in the deduction.

The candidate should utilize the existing possibilities for obtaining relevant literature.

The thesis should be organized in a rational manner to give a clear statement of assumptions, data, results, assessments, and conclusions. The text should be brief and to the point, with a clear language. Telegraphic language should be avoided.

The thesis shall contain the following elements: A text defining the scope, preface, list of contents, summary, main body of thesis, conclusions with recommendations for further work, list of symbols and acronyms, reference and (optional) appendices. All figures, tables and equations shall be numerated.

The supervisor may require that the candidate, in an early stage of the work, present a written plan for the completion of the work.

The original contribution of the candidate and material taken from other sources shall be clearly defined. Work from other sources shall be properly referenced using an acknowledged referencing system.

Supervision:

Main supervisor: Professor Bjørn Egil Asbjørnslett

Company contact: Bernt Rogne

Deadline: 10.07.2021

Bjørn Egil Asbjørnslett
Professor/Responsible Advisor

Summary

The goal of this thesis is to come up with a conceptual design of a vessel using a new type of harvesting technology in the Arctic Scallop industry. This is done by a systematic approach to engineering design. By doing this gain insight in the Arctic Scallops industry, and firm up different solution alternatives of a conceptual design of a vessel for the industry.

The methodology to answer this issue is based on the Conceptual Design method by Pahl and Beitz [1]. This is done by identifying the essential problems through abstraction, establishing function structures, searching for appropriate working principles and combining these into a working structure. Then solution variants is firmed up by setting criteria and using a specific location.

The final solution variants:

1 - Working Structure Set 1:

The LARS and SH is placed through a moonpool, the Arctic Scallops is retrieved from the SH subsea with the help of a pump, then processed all the way until muscle. The muscles is then frozen and stored in a freezer hold, and delivered to port with the help of technical equipment.

2 - Working Structure Set 3:

The LARS and SH is placed through a moonpool, the Arctic Scallops is retrieved from the SH on the vessel with the help of technical equipment, then processed all the way until muscle. The muscles is then frozen and stored in a freezer hold, and delivered to port with the help of technical equipment.

3 - Working Structure Set 5:

The LARS and SH is placed inside a hangar, the Arctic Scallops is retrieved from the SH on the vessel with the help of technical equipment, then processed all the way until muscle.

The muscles is then frozen and stored in a freezer hold, and delivered to port with the help of technical equipment.

These final solution variants fulfill the functions and criteria needed to perform the desired operation. In order to determine the layout and conducting a detailed design more research needs to be done. The next step would be the embodiment design.

Sammendrag

Målet med denne opgaven er å komme frem til design løsninger på et konseptuelt design nivå til et skip som skal benytte en ny type høstemetode for å høste Haneskjell. Dette er gjort med en systematisk tilnærming til ingeniør design. Ved å gjøre dette, er målet å oppnå innsikt i Haneskjellindustrien, og å komme frem til løsninsforslag for et eller flere konseptuelle design for et skip som kan bli brukt i Haneskjellindustrien.

Metodikken som er brukt for å løse oppgaven er basert på Conceptual Design method av Pahl Beitz [1]. Denne metodikken utføres ved å identifisere de essensielle problemene gjennom abstraksjon, etablere funksjonsstrukturer, søke etter passende arbeidsprinsipper og kombinere disse til en arbeidsstruktur. Deretter blir løsningsvarianter dannet ved å sette kriterier til et design og bruke et bestemt sted.

De endelige løsningsvarianten:
1 - Arbeidsstruktursett 1:
LARS og SH plasseres gjennom en moonpool, Haneskjellene blir hentet fra SH under vann ved hjelp av en pumpe, og deretter prosessert helt til det bare er muskel igjen. Musklene blir deretter frosset og lagret i et fryserom og levert til havnen ved hjelp av teknisk utstyr.
2 - Arbeidsstruktursett 3:
LARS og SH plasseres gjennom en moonpool, Haneskjellen blir hentet fra SH på fartøyet ved hjelp av teknisk utstyr, og deretter prosessert helt til det bare er muskel igjen. Musklene blir deretter frosset og lagret i et fryserom og levert til havn ved hjelp av teknisk utstyr.
3 - Arbeidsstruktursett 5:
LARS og SH plasseres inne i en hangar, Haneskjellene blir hentet fra SH på fartøyet ved hjelp av teknisk utstyr, og deretter prosessert helt til det bare er muskel igjen. Musklene blir deretter frosset og lagret i et fryserom, og levert til havn ved hjelp av teknisk utstyr.

Disse endelige løsningsvariantene oppfyller funksjonene og kriteriene som trengs for å utføre ønsket operasjon. For å bestemme utformingen og gjennomføre et detaljert design, må mer forskning gjøres. Det neste trinnet vil være ”embodiment” design.

Preface

This thesis is the final part of my Master´s degree in Marine Technology at the Norwegian University of Science and Technology. The specialization of my Master Degree is Marine Systems Design. The thesis corresponds to 30 ECTS and was written during the spring semester of 2021.

The thesis is a conceptual design study of a vessel that is going to harvest Arctic Scallop in the Barents Sea with the use of a new harvesting technology. During the writing of the thesis I have gained insight in the industry, learned new methods to find new solutions, and expanded my theoretical background.

The thesis has been written during the COVID-19 pandemic, leading to a lot of working from home, and that the supervision hours mostly has been virtual. It has at times been difficult to stay motivated, due to a lot of uncertainty and a lot of time spent at home.

I would like to thank my supervisor, Bjørn Egil Asbjørnslett, for being supportive and giving me valuable guidance during this thesis. I would also like to thank TAU Tech for giving me insight in their project, for always answering my questions and for the valuable information.

Finally I would like to extend a special thank you to my colleagues and friends at the office, Andreas, Benjamin, Dani, Malin and Vincent. For the support and for all the memories we have created together.

Ingrild W. Gundersen 07.07.21

Candidate Date

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Abbreviations

SH	=	Seabed Harvester
RSW	=	Refrigerated Sea Water
LARS	=	Launch and Recovery System
AHC	=	Active Heave Compensation
PHC	=	Passive Heave Compensation
DP	=	Dynamic Positioning
ROV	=	Remotely Operated Vehicles
CP	=	Classifisation Parameter
WP	=	Working Principle
WS	=	Working Structure
FR	=	Functional Requirement
DC	=	Design Catalogue

Chapter 1

Introduction

Back in the 1980s, there was an extensive fishing for Arctic Scallops in Norway, the fishing was done in the Svalbard zone. However, the species was harvested by shell scraping, a method that was banned in 1992[2]. Since then, the fishery is not utilized, due to both the lack of allowable harvesting technology.

Attempts to start with shellfish harvesting using scrapers in the Fisheries Protection Zone have been denied permission by the fisheries authorities in recent times. In order to be able to utilize this resource in the Fisheries Protection Zone, a new catching methodology must be more gentle both for the remaining benthic fauna and for the bottom sediments that make up the habitat for benthic animals. The new harvesting technology is called the Seabed Harvester (SH), the SH is based on a suction technology lifting the Arctic Scallops from the seabed and into a collection unit in the Seabed Harvester.

The new technology will not only be different for the Arctic Scallops and the seabed. But for the vessels as well. The design for such a vessel will look different than how they looked when the shell scrapers were used.

The Institute Of Marine Research did a research trip to test the new technology produced by TAUTech, to see how it affected the seabed. The research was done by taking a test of the seabed using a triangular scraper before and after they tested the SH to check for any difference.

The tests showed that the Atlantic scallop areas was species-rich and had a normal and good developed ecosystem. There were no registered difference in species-richness in the test before and after the SH had been operated at the field. [3].

The preciously used method to cacth Arctic Scallops was by using shell scrapers. The shell scrapers contributed to a low utilization of the Scallops due to a lot of shells being destroyed and broken in the capture process. The SH will contribute positively for the population of scallops because it does not destroy them and the small scallops that are captured are returned to the sea, without killing them, so they can continue to grow.[4].

The motivation for this master thesis, is to look into a sustainable alternative to catch Arctic Scallop. And to see how a vessel for this fishery will look like. If this fishery has a positive outcome, it could lead to that the technology will be developed further into more markets, and to replace the destructive shell scrapers used in other countries.

Chapter 2

Literature review

In the literature revies the goal is to gain insight into the Arctic Scallop industry. The literature review will start with studying the Arctic Scallops, it will then be studied how the fishery for Arctic Scallops was before, and how it is now. The goal of the new technology will be discussed, and how the market is today, and potential markets in the future. Then regulations, and design methods is

The literature review will study the Arctic Scallops which are the resource that is being harvested in this master thesis, it will then be studiet how the fishery for Arctic scallop was before and how it is now, the goal of the new technology will be discussed , the market today, existing vessels, different type of technology that could be necessary onboard the vessel, regulations, and systematic engineering.

2.1 General information about Arctic scallops

In this master thesis the Arctic Scallops are an essential part, due to them being the resource that is going to be harvested and processed. Therefore, information of the Arctic Scallops is important in order to understand the task.

The Arctic Scallops is based around Jan Mayen, in the Barents Sea and around Svalbard. They can also be found on the coast of Troms and Vesteraalen, and in small local populations in Western Norway[5]. In addition, there are also large deposits of Arctic scallops on the east of Canada, the west coast of Greenland and the west coast of Iceland [6], [7]. The sexual maturity of the scallops are 4-6 years, and they can be up to 30 years. The size of the Arctic Scallop can be up to 13 cm, but the minimum size that is allowed to catch is the catchable size of 6,5 cm [5].

Figure 2.1: Arctic scallops [8]

2.1.1 The biology of the Arctic Scallop

The Arctic scallops are a sub-Arctic scallop that grows relatively slowly. The shells often reach the catchable size of 6,5 cm within six to eight years. The shell becomes sexually mature at four to six years, and spawns millions of eggs into the free water masses, where they are fertilized. The larvae have a pelagic phase of one to two months depending on temperature, and often settle on filamentous algae[4].

In the individual fields, the shell is very spot by spot distributed and as a rule one finds areas of high density scattered around what is defined as a field. These small areas can have varying extents and between them there is lower density or no shells. The shell field itself is often delimited by conditions such as depth, bottom substrate and current conditions[4].

The large concentrations is usually found in current-rich areas between 20 and 100 meters deep. They live attached to the bottom, and thrives best in current-rich areas on hard bottoms that consist of rock, gravel or empty shells[5].

The nutrition consists of particulate matter - phytoplankton, bacteria, other microorganisms and dead organic matter - which is filtered from the water masses.

The dept the Arctic Scallops thrives the best, is varying from which area they are in. On the coast of Troms and Finnmark the highest concentration is found between 20-60 meters dept [9] . While at Bjornoya the highest concentrations is found between 60-100 meters dept[4].

2.2 The fishery for Arctic Scallops in Norway

The fishery for Arctic Scallops has changed over the years. It will now be looked at how it was in Norway before, how it is today and why it got forbidden.

In Norway the catch for Arctic Scallops took place from the mid-1970s until the 1980s and the quantities landed were relatively small and it was mostly caught in local fields in Troms and Finmark [10]. But in 1985, the catch of the Arctic Scallops in Norwegian waters hit a new dimension when two seagoing vessels were equipped to go all the way to Jan Mayen to fish for Arctic Scallops. At the same time contracts were made for building new vessel, conversion of existing fishing vessels. As well as this there was an import of other vessel types in the vessel register, to go fishing for Arctic Scallops in Norwegian waters.

The background for this new investment in Atlantic Scallop was that the cod stock in the Barents Sea was at a historic low at the same time as a collapse in the capelin stock. During 1986, there was a big increase in the number of vessels and by the end of the year, a total of 26 larger vessels had been in this fishery[4].

In addition to the field at Jan Mayen, significant shell fields were found at Bear Island, Spitsbergenbanken and north of Svalbard. Uncertain estimates at the time indicated that the standing population of Arctic Scallops in these areas could be several hundred thousand tonnes [11].

There were large sea-going vessels that participated in this fishing;rebuilt and newly built trawlers, purse seine vessels and other types of vessels. The fishing gear was large shell scrapers, which had a weight of several tonnes, the scrapers consisted of iron with a net of iron rings, and each vessel often operated three scrapers at the same time. All shells caught were produced on board and the main product was frozen muscle of various size. The total landings of frozen muscle from this fishery reached a maximum of about 4000 tonnes in 1987, but decreased rapidly to a few hundred tonnes in the following years and 1992 was the last year with catches from Norwegian shell scrapers[4].

The large investment in shellfish fishing in the 1980s led to a sharp overtaxation of this resource and all shellfish fields were depleted in a short time. The capture technology itself also contributed to an inefficient utilization of this resource in that a lot of shells were crushed and destroyed in the capture process. In addition, the strong overgrowth of the shells, especially at Bear Island, meant that they could not be processed in the process facilities on board. Large quantities of shells were therefore killed and thrown overboard without being processed [4].

Most of the vessels were in this fishery only for a short amount of time and it was the vessels that were built specially for the shell scraping that lasted the longest. Significant over investment in conversions and processing facilities also led to a number of vessels and shipping companies going bankrupt[4].

2.2.1 Why it got forbidden

During the time when the fishery for Arctic Scallops were at an all time high there were no studies on how the scraping activity affected the seabed, the bottom fauna and sediments, but there was little doubt that the impacts were large. Observations made on the fields showed that the fields that previously had a flat and plain bottom, were now characterized by large rocks lying on top of the sediment surface. This was due to the rocks, empty shells, etc, that came up with the scraper were thrown out again[4].

2.2.2 How the fishery is today

In the last years, fishing within the baseline has been modest, and in recent years the total quota has not been taken. According to statistics from the Norwegian Raw Fish Association approx. 26 tonnes of Atlantic Scallops (round weight) in the Norwegian zone in 2008 and approx 65 kilos in 2019 [12]. 26 tonnes whole shell weight corresponds to a catch of approx. 2-3 tonnes of processed muscle, i.e far below the total quota. And 65 kilos whole shell weight corresponds to a catch of 6-7 kilos processed muscle.

Until now, the fishing for Arctic Scallops has been carried out with a various type of scraping gears. In fishing within the baseline the scrapers used has been relatively small and not so heavy, and these have probably had a limited impact on bottom sediments and bottom fauna. In the fishery for Arctic Scallops in the Fisheries Protection Zone and at Jan Mayen, the scrapers conducted were large and several meters wide, and weighted several tonnes. Underwater observations in the fields at Moffen and at Bjornoya showed large changes in the bottom sediments, due to big rocks being torn loose from the bottom sediments, and deep furrows created by the scraper. This indicates that the benthic fauna must have been significantly affected, and that this harvesting method is not sustainable according to current standards. The benthic communities in these areas are likely to take a long time to re-establish themselves after such large impacts due to low temperature and short growing seasons, and this makes them vulnerable[3].

Attempts to start with shellfish harvesting using scrapers in the Fisheries Protection Zone have been denied permission by the fisheries authorities in recent times. In order to be able to utilize this resource in the Fisheries Protection Zone, a new catching methodology must be more gentle both for the remaining benthic fauna and for the bottom sediments that make up the habitat for benthic animals[3].

2.3 The new harvesting technology

As mention in the previous chapters, the use of scrapers to harvest the Arctic Scallops were not an ideal method. And since the method got banned in Norway in 1992 [2], there is a need to come up with a new harvesting technology in order to proceed harvesting the Arctic Scallops. The harvesting with the SH is planned to harvest the Arctic Scallops with suction with the help of a pump, making a vacuum. It is a goal to just catch the desired shells and that the rest will be left at the seabed.

The new harvesting technology is based on a suction technology lifting the Arctic Scallops from the seabed and into a collection unit.

As mention in Section 2.2.2 to be allowed to harvest and utilize the resources in the Fisheries Protection Zone, the harvesting technology used needs to be proved to be more gentle on the remaining benthic fauna and the bottom sediments than the previously used scrapers. So in order to be allowed to use this new harvesting technology it needs to be tested first, and proven before a possible permit for large-scale fishing in the Fisheries Protection Zone could be granted[3].

2.3.1 Testing of the new harvesting technology

All of the information from the testing of the SH is retrived from the report written by The Institure of marine reasearch [3]

The Institute of marine research in Norway, were the ones that conducted the small-scale trial of the new harvesting technology to investigate any impacts on bottom sediments and fauna. The testing of the SH was carried out on a Arctic Scallop field at Berg in the Balsfjord, just outside Tromso, Norway. The goal of the trials was to study to which extent the SH affect the bottom fauna and sediment. When the Arctic Scallop is harvesting with suction, a number of other species and loose objects on the seabed will also be sucked up. In the SH shells over a certain size, as well as other by-catch, are sorted out and collected, while smaller objects are sorted out and removed, and returned to the seabed. So there are three main questions that needs to studied. How big changes there is in the ecosystem at the seabed, as a result of the suction, and how much damage it has caused to the organisms that are sucked up but returned to the seabed. And what the possible effects of the SH are on the bottom sediments.

Changes in the bottom systems are studied sampling the animal communities on the bottom, before and after the SH have been active there. Damage to organisms that are sucked up into the gear is studied by examining the composition and condition of the organisms that are initially sorted out and returned to the seabed, but instead of returning them to the seabed they will in this experiment be caught in collection bags. Any changes in the bottom sediments was investigated using underwater video (ROV)[3].

For the first research question of ”How big changes there is in the ecosystem at the seabed, as a result of the suction", was studied taking samples of the bottom organisms with a triangular scraoer to describe the composition of the organism commmunities and any changes after using the SH. And the results showed that there were no registered differences in specie richness between the samples taken before and after the SH had been active at the area.

For the second research question of "How much damage the SH has caused to the organism that are sucked up but returned to the seabed", this was studied examining the composition and condition of the organisms that are initially sorted out and returned to the seabed but instead of returning them to the seabed they will in this experiment be caught in collection bags. The results from this was a bit varying, It was taken four tests, and there were most uninjured organisms in the collection bag from test 1, while the extent of damage varied from about 35 - 50% in the other tests. It is important that the sorting and returning of small shellfish and other organisms to the bottom ecosystem, is done in a way that enables them to survive. Undersized shelLs recruiting to catchable size and animals shall otherwise contribute to the bottom ecosystem being restored as quickly as possible after the operations with the SH. The results from the samples in the collection bags showed that sorting by size can be improved since a number of shells are still sorted out, even though they are above the minimum size, and there will probably be a number of undersized shells in the catch. The samples from test 1 were somewhat different from the other three in terms of the size of the Arctic scallops that were sorted out. But test 1 was the first test of the SH, which was not very successful because there were few Arctic Scallops caught in total. In the other three tests, the majority of the sorted shells were small[3]. The proportion of Arctic Scallops that were fatally damage was relatively small in all tests and especially low in test 4. This is probably due to the fact that the vacuum at the suction was low at the same time as using a straight nozzle without bend. This may indicate that both the design of the nozzle and the strength of the vacuuming are important measures in regards to damage on the organisms that are sorted out, as well as the shells that are included in the catch.

For the third research question of "What are the possible effects the SH have on the bottom sediments", the analysis of effects on the bottom sediments from the SH was investigated by video filming the seabed with a ROV before and after the SH had been active at the field. From the resulting video recordings, it was difficult to see any clear differences before and after the tests with the SH, but there was less Arctic Scallops after the SH had been active at the field. The only thing that was obviously visible on the recordings was that the starfish were on their backs during one of the tests, but they did not appear to be inured. The video was also showing that alive Arctic Scallops attached to the bottom substrate just behind the SH were in filtration mode and apparently little affected by the activity. The video recording thus show no effects on the fauna that remains on the seabed after testing the SH. This applies regardless of which nozzle or which strength of the vacuuming that was used.

2.4 The goal of the new harvesting technology regarding sustainability

The requirements for a new harvesting technology to be granted permission to carry out large-scale fishing in the Fisheries Protection Zone is already discussed in Section 2.3.

The fact that the vessel will no longer having to pull a several ton heavy steel scraper behind it, which leads to enormous resistance, and a heavy use of the propulsion system and the machinery, which leads to a big consumption of fuel, which then again lead to bigger pollution. The pollution and the fuel consumption is negative for the sustainability regarding both the economic, due to that the fuel cost money, and the environment due to the pollution of it. It can also be argued that it is good for the social part of sustainability as it will lead to less polluted environment for the crew to work in.

The obvious part of which the SH is better from a sustainable point of view, is for the life below water. Goal number 14 in the Sustainable Development Goals of the United Nation is "Conserve and sustainably use the oceans, seas and marine resources for sustainable development"[13]. And this was one of TAU Techs´s goals, to make more of the ocean available. To replace the destructive fishing methods that are used today on a large scale all over the world. It is on the seabed that most of the life in the ocean originates. So if the seabed is damaged, the rest of the ecosystem at sea is also damaged [8].

Another goal of the technology, is to minimise the bycatch. And by setting the right pressure on the suction performed by the SH, only catch the desired catch.

2.5 The market today

From information obtained from Tau Tech it is found that the total number of vessels globally that are scraping after shells is hard to estimate, due to lack of information about the markets such as Africa, Asia, and South-America. It is found that there are companies that are scraping for shells in France, Spain, UK, Canada, Denmark (Greenland), Russia, New Zealand, Australia, Argentina, Peru, USA and Japan. And if we look at the export numbers we see that aquaculture nations such as Peru, Japan and China has a big impact on the global shell market. Out of the total of 40 commercial shell species, does 18 of them account for the majority of the 2.5 million tonnes which is traded globally, through capture and aquaculture.

2.5.1 UK

The UK market is primarily King Scallop and Queen Scallop. It is the fastest growing fishery in the UK and is now second most valuable in terms of catch value. They have 381 vessels.

The Shoreham harbor area near Portsmouth lands 18% of all shells in the UK and is thus the largest shell harbor in the UK. Other active ports are Plymouth, Scarborough and Peterhead in Scotland.

Macduff is the largest actor of shells in the UK and they have vessels that operate on the Eastern English Channel, the vessels have a crew of 7-9 people and are out for about a week at a time.

The Bay of Seins is the fishing area widely covered in the media as a ”scallop war” between France and the UK.

2.5.2 USA

They have 347 vessels. Through American Scallop Association, it is found various actors who scrape for Arcitc Scallop. Of the 347 vessels, there are 5 actors with 15 vessels or more. The five actors are Blue Harvest Fisheries, Atlantic Capes, Oceans Fleet, Eastern fisheries, Capt. Weels.

2.5.3 Canada

Today there are 25 sea-going scrapers operated by 6 actors. The vessels are between 27-80 meters. There are uncertain numbers of coastal vessels doing scraping.

The largest company is Clearwater Seafoods, which has bought and rebuilt two Norwegian offshore vessels for scraping in Canada.

The actors on the east coast is, LeHave Seafoods, Clearwater Seafoods, Ocean Choice International, Comeaus Sea foods, and Adams and Knickle Limited.

Potential markets If the SH is a success and work as intended, it is possible to extend the use of it into more markets than only the Arctic Scallops. It could be used for all types of shell fish.

Other countries A big potential for the SH is to be utilized in more countires. As the environment is a bigger topic today, and there is more focus on carrying out a sustainable market. There is a possibility that more countries in the future will ban the destructive method of scraping for shells. If the SH then is a fully developed system, an ready for use, it will be a good alternative for the countries that will continue to harvest shells but can no longer use the scrapers.

Sea urchin On the Norwegian coast there are many different species of sea urchins. The two most common are the red sea urchin (Echinus esculentur) and the green sea urchin (Strongylocentrotus droebachiensis), these are today only harvested by divers [14]. The sea urchin among other things it grazes on algae, and when there are a large amount gathered at the same place, they can do great damage to the kelp forest[15]. This is not good for the ecosystem of the ocean. So today there are several companies that try to develop sustainable harvesting technologies that both is gentle to the seabed and the sea urchin, but also can operate in bad weather and cold conditions when it is not safe for divers. Even though the sea urchin have a bad reputation in Norway, it has a big value. And inside the sea urchin lays the gonads, which looks like five orange boats. This is a storage organ for food, and during the spawning season in the spring they contain roe and milk. The gonads are considered the ultimate luxury in sushi dishes in large parts of Asia, and it is paid up to 12.000 NOK per kilo [16].

2.6 Existing vessels

In this case it is hard to find reference vessel due to the new technology. Today there are no vessels with the same technology, so there is not possible to find reference vessels with the same type of technology. So then it was important to use the information from the technology, and the goals of the new vessels to find reference vessels that are somewhat the same and that can give interesting information in this process.

2.6.1 Vessels with relevant technology

The vessel below are vessels that are for inspiration when searching for a solution. As already mentioned it is hard to find vessels with the exact same technology because it do not exist today. So it is needed to look into technology that look somehow similar to the one that will be used.

Krill vessel - Antarctic Endurance

The first is Aker Biomarin´s patented eco-harvester technology when trawling for krill. They have a conveyor hose connected to the net, the equipment stays under water where a continuous stream of water is floating trough, so the krill is directly transferred to the vessel. The third generation of the Eco-Harvesting technology features a triple-tank-sequence system that ensures a steady flow of krill from the trawl at a constant vacuum. A hydraulic-driven wagon that runs up and down the ship side connects the Eco-Harvesting hose to the submerged inlet at 2,5 meters below the waterline. This helps reduce the risk of striking ice, avoid any possibility of air leakage and minimize bycatch [17].

Purse seine vessels

Today this is usually done by means of bucket pumps that suck and press the fish on board through a hose. The fish goes into a sieve box where the pump water and fish are separated and the water flows out through a grate while the fish goes into a storage tank [18] If the purse seine vessel has a processing facility as well, it will go from the sieve box and into the In the new system, created a vacuum in the storage tank and the fish transported to the through a closed system directly from from the sea, through the sieve box and into the tank. In this way, the fish can be sucked up from the net and to the tank[18].

Norwegian Gannet - Slaughter vessel

The slaughter vessel Norwegian Gannet goes straight to the sites where the fish is located in fish cages, and instead of pumping the fish over on Refrigerated Sea Water (RSW) tanks the vessel pumps the fish directly into the factory on board, where it is going trough stun and bleed, gutting and then taken over on RSW tanks [19].

2.6.2 Concordia

The information about Concordia is found both on Sjøviks homepage [20] and from a documentary about Concordia 1986 [21].

Norway's first specially built shell scraper was Concordia. In an otherwise bad time for Norwegian fishing, Norway wanted to pursue on the same fishery as other countries, which in this case was the Atlantic Scallop fishery. The owner of Concordia was Odd Kjell Sjøvik. Concordia was built at the yard Langsten, and after building Concordia they received many orders. Concordia is the pioneer ship within this industry. It is 67 meters long, three decks, have a factory that produces 10 tons of shells a day. The fishermen are out for a couple of months at a time- Crew up to 45. And mainly two-person cabins.

The machinery on the vessel is Winchmann WX 28V, on heavy oil, all the waste heat is utilized. The propeller is reduced to 135 rpm, to save energy to give the most possible towing effect. The vessel is also equipped with a workshop to fix minor damages on the equipment and training of the crew. The vessel is also equipped with a echo sounder.

The scrapers can take 5 cubic meters every hour, which are controlled and lifted by three cranes. The crane operator receives the information through screens and by having contact with the bridge, this way he can try to fill the bag with as many shells and as few stones as possible. However, it is inevitable to include a lot of stones in the process.

So when the catch comes up, the stone must be separated from the shells. The first task when the scrapers are up is therefore to separate the stones with the shells, this operation is done in many stages. Firstly the big stones is separated from the shells, this is done by a stone grate on deck. The shells and the small rocks find their way to the factory under deck, and the big stone is taken back to the sea. So when Concordia is getting ready for a new trawling, the processing process of the shells in the fabric starts.

The processing process on Concordia

In a vibrator the shells and the medium-sized stones are separated, and the shells are also flushed here, so the organisms that are stuck on the shells are partially removed during this operation. In this step of the operation there also a person that are watching over the operation, to ensure that nothing gets stuck, and the person are helping the flow of the shells by pushing the shells into the next step. Although most of the processing process are automated, human hands are also used in the sorting process. In the next step the shells are transported to the factory, during this transportation small rocks and other waste is removed away by the crew. The next step is to open the shells, this happens inside a maturing drum, which contains various liquids that are used to make the shells open. After this the shells goes to the shell cooker. By cooking the shells one achieves that the shell loosens from the Scallop. It then goes further on into a new drum and a new sorting process. This time for the shell and Scallop to be separated. Another round is needed to remove waste, this liquid is a salt solution. The salt solution makes the shellfish float up while the waste is left on the bottom. After the shells are transported further on yet another conveyor belt. They go to a eviscerator, here the last remaining waste is removed. Sp that after this step of the processing there is supposed to be only pure muscle left. However, not all shells are completely clean, and therefore the less good ones must be removed. This is done using a photocell. The quality of the shell comes into view through the color they have and the photocell can thus pick out the uncleaned shells and send it for a new peeling. If some shells should pass the photocell and they are still uncleaned, there are crew standing at the end as the last check.

It is important for the quality of the shells, therefore a part of the processing process includes washing the shells, it is done in purifies bacteria-free water, first in seawater and then in fresh water. After this step the shells are being frozen, this is done via a conveyor belt. And in order for the look to be in line with the taste, the freshly frozen shells get a shower and thus a delicate glazed surface. Not all shells are the same size and before they are packed they are sorted by size. On Concordia, the shells are sorted by four sizes. Lastly the shells are weighted and backed, before the processing process ends at the warehouse. The warehouse has the space for 1500 cubic meters of shells, shells that have been processed through a highly automated process. To be absolutely sure that the quality is as good as it should be, quality checks are taken regularly. Here, among other things, the PH value in the shells is measured. Everyone should be able to be sure that the shells are clean and good. Everyone benefits from it, not least the fishermen and the the shipowner themselves.

Location and marked

The resource is in the Arctic water. The catch areas is located in the Barents Sea in the North Atlantic. The delicacy will primarily be sold to the United States, but over time, France and Italy will probably become important markets. Concordia is built as a conventional trawler, and this means that the vessel can be converted to regular trawling. However, other countries have used shell scraper before us even though no previous shell scraper has had a factory on board. The Faroe Islands, Ireland, Scotland and Canada all have traditions in shell scraping. Why should things not go so well with the fishing nation Norway?

2.6.3 Information from an article back in 1986

This information is retrieved from an old article from the Norwegian magazine Fiskets gang [22] In the month change between August and September in 1986 Odd Kjell Sjøvik told that he thought Concordia would after a eight week long trip land between 150 and 200 tons processed Atlantic Scallops, and that means a big earning. With today's price (the price in 1986) for each kilo on between 60-70 NOK, against 50 NOK earlier. He estimated a gross profit on between 12 and 14 million NOK.

Roar Wolstad can tell that from experience they have learned that the earlier assumption about that the shells are laying in layers, and lie still is not correct. The shells are acting like a fish shoal, they are moving independently from each other. He mentioned that it would be profitable to do more research on this resource.

Jarle Longva the shipowner of the vessel that has done shell scraping the longest, is telling that the processing is not optimally automated now, due to the peeling machine has problems with removing the black thread of intestine. This resulting in that the black thread of intestine must be removed manually by the crew, which of course slows down the process.

There are uncertainties connected to this industries, because it is so new. Odd Kjell Søvik told that there are at least three uncertainty factors. They are the catch rate, the production and the marked. At the moment, fishing is bearable. We fish on virgin areas and it is quite clear that the catch rate will go down. The production is on the right track, but the market is fake.

2.7 Processing facility

An important part of this project thesis is how the Arctic Scallops should be processed when they enter the vessel. In Section 2.6.2 it was explained how the processing facility was in the pioneer ship for scallop harvesting in Norway. The processing facility in the vessel depends on the extent of the processing. Is the shells going to be kept alive as round shells on board the vessel, or are they going to be processed all the way to muscle.

2.7.1 Kept as whole shell

If the shell is supposed to be kept as whole shell, the processing it needs to go through when it enter the vessel is; The shell needs to be separated from the rocks. Hopefully there are none big rocks is that is harvested and collected inside the SH, but the shell still needs to go through a sorting process where the stones and waste is removed from the shells. This could be done by a gravel on deck to separate the big rocks, and then either a vibrator or another method to separate the small rocks, as well as they need to flushed to get rid of organisms and waste stuck on the shell.

2.7.2 Processed all the way to muscle

If it is planned to process the arctic scallop all the way to muscle. The shell first needs to go through the same steps as described in Section 2.7.1. After these steps are done, the round shells will be transported in to the processing plant. The first step in the processing is to open the shells, and separate the scallop from the shell. This will be done by first cooking the shell in a shell cooker, the shell cooker steams the shells and the Scallop is removed from the shell [23]. The shell is then going through a Shell separator and a Brine separator, these two steps separates the shell and the last waste from the Scallop [23]. The scallops is then brought through a Eviscerator to clean the scallops [23]. After this the scallops is going to be sort3ed by size, and graded.

After the processing the scallops are ready to be frozen. The freezing process is chosen to be done in a IQF Tunnel freezer [24].

The shells are now ready to be packed and go to the freezing storage. The packing of the shells could be done in several ways. They could be packed in bags, in vacuum bags and in boxes. After packing it will will be stored on pallets, that will be moved around with the help of a forklift. At between decks with the help of a cargo lift.

2.7.3 Storage methods

The normal method for storage the scallops when they are done being processed is in a freezer hold. After the shells are processed they will be glazed and frozen and then packed. After packing they will be stored on pallets inside a freezer hold.

Another interesting method is to live storage the shells. This is in the case when the Arctic Scallops are kept as whole shell. In the fishing industry there is a lot of vessels that live store the fish, it is often done by storing the catch in RSW tanks, to keep them cold and fresh until the processing facility has capacity to process it. Some also keep them alive until deliver if they do not have any processing facility on board. The challenge for this is to know how long the fish or the Arctic Scallops will be fresh inside the RSW tanks or if it will affect the quality of the shells. The goal is to keep them just as fresh as if they came from the ocean, and then deliver them in the freshest condition possible to the customer.

2.8 The technology

The different technology discussed in this section, is technology that is considered relevant for this type of vessel.

2.8.1 Launch and Recovery System

The launch and recovery system (LARS) for the SH will be dependent on the placement. But the components will be somehow the same, so in this section a general LARS will be explained. Since the SH in the same way as Remotely Operated Vehicles (ROV) will be launched and recovered from the vessel, it is assumed that it is the same methods that will be used to launch and recover the SH.

In order to be able to deploy the SH from the surface, the SH must be launched, recovered and safely and efficiently operated using dedicated systems. The most common ROV LARS is composed of a winch and an A-frame, yet LARS can also be composed of a heave compensated, heavy duty crane. The LARS may deploy the ROV from a vessel´s sides, stern, from a hangar or using an internal moonpool[25].

As mentioned the Launch and Recovery system consists of an A-frame. Three options are the Standard A-frame, the A-frame knuckle and the Telescopic A-frame.

The standard A-frame is a standard launch and recovery system for ROV designed for easy installation on open deck. [26].

The Telescopic A-frame is a launch and recovery system for ROV designed for easy installation in hangar or on open deck. The Telescopic A-frame provides a safe working environment for operators and equipment [27].

The A-frame Knuckle is a launch and recovery system for ROV, designed for easy installation in hangar or on open deck. The Knuckle A-frame provides a safe working environment for operators and equipment. Lower hangar sidehatch can be closed during operation[28].

The Moonpool LARS is a launch and recovery system for ROV designed for easy installation over moonpool. The Moonpool LARS is installed in areas protected from wind and weather, and provides a safe working environment for operators and equipment[29].

The launch and recovery system also consist of a winch, a winch is a machine with a drum on which a rope, cable, or chain for hauling, pulling, or hoisting can be wound [30].

The LARS often has a heave compensation when there are elements that are going to operate subsea. In Section 2.10.1 the conditions at the fishing ground that the vessel is planned to harvest the Arctic Scallops is rough. With current, wind and waves. In order to keep the heave motion from the vessel and onto the SH that is going to be launched the LARS is often. The heave compensation can be placed on deck, and subsea. And there are a lot of different technology, to achieve the heave compensation, but the principle for all of them are the same. The principle will be discussed now. The heave compensation can be active and passive. Both Active Heave Compensation (AHC) and Passive Heave Compensation (PHC) are techniques used on lifting equipment to reduce the influence of waves upon offshore operations. AHC differs from PHC by having a control system that actively compensates for any movement using external energy. Passive systems reacts to external forces without additional energy to control the motion [31].

Offshore cranes and other equipment doing subsea work are provided with AHC systems to ensure precision in high sea states and extreme weather conditions. The essential function of AHC technology is the ability to land and retrieve subsea installations to and from the seabed with precision and accuracy, while minimising the impact caused by the motion of the vessel. The major principle of AHC technology is based on advanced motion sensors that measure the vessel's heave, pitch and roll and calculate resulting geometrical estimate of heave motion of the point where a lifting wire exits the vessel. It enables modern subsea vessels to continue working with loads near the seabed under increasingly adverse weather conditions[32].

When the vessel is suppose to operate the SH subsea, there is a need to keep the vessel going in a constant velocity, and positioning. A seagoing vessel is subjected to forces from wind, waves and current as well as from forces generated by the propulsion system. The Dynamic positioning - DP automatically maintain the vessel's position and heading using its propellers and thrusters. The vessel's response to these forces, i.e. its changes in position, heading and speed, is measured by the position-reference systems, the gyrocompass and the vertical reference sensors. Reference systems readings are corrected for roll and pitch using readings from the vertical reference sensors. Wind speed and direction are measured by the wind sensors[33].

2.9 Regulations in relation to the number of crew members on board the ship

With conversation with the Norwegian Maritime Authority the regulations that will be relevant in this task on behalf of the design of the vessel. So the regulations that will be mentioned in this section is the ones that will affect the layout of the vessel.

With conversation with the Norwegian Maritime Authority the regulations relevant in this thesis are the Regulations on the construction, equipment and operation of fishing vessels with a length og 15 meters or more.

On the fishing vessel there is a requirement to have a sick bay on board the vessel. This is a requirement if there are 15 or more people on board the vessel or if the vessel has a length over 45 meters.

The bedrooms shall not be furnished for more then two people. On vessels with a length (L) of 24 meters or more, the master and officers shall each have their own bedroom equipped with a washbasin with hot and cold drinking water. And on vessels with a length (L) of 45 meters or more, there shall normally be a separate bedroom for each crew member, if the vessel´s employment and the arrangement on board make this reasonable and possible.

There must be a separate dining room for the crew and a separate dayroom.

On vessels with a length (L) of 24 meters or more, there shall be separate washing and bathroom rooms for officers and crew, and with the possibility of separate sanitary rooms for female and male crew members.

There are also requirements with regards to the safety for the crew onboard the vessel. This requirements apply when the ship is over 15 meters.
1 - Every vessel shall be equipped with at least two lifeboats
2 - For vessels with the length of 45 meters or more these requirements apply:
- One rescue vessel shall be led on each side of the vessel with sufficient capacity to accommodate at least the total number of persons on board.
- In addtion, a man overboard boat (MOB) shall be led, unless the vessel is equipped with

a lifeboat that meets the requirements for a MOB and which can be taken on board again after the rescue operation.

There are a lot of regulations for the rescue vessel and the entire regulation can be found on the Norwegian Maritime Authority´s homepage [34].

There are also regulations regarding life jackets, immersion suit, lifebuoys, line throwing devices, emergency signals, emergency radio equipment, and search and rescue facilities.

2.10 Operational profile

In this section, the planned operational profile for the vessel is stated. This is just a preliminary suggestion, and this could change. In Figure 2.2 the map of the areas the vessel will operate it can be seen. The vessel will go to Aalesund when it is going to be a crew change and when the vessel needs maintenance. Otherwise it is planned to deliver the Arctic Scallops in Tromso, but here it is important to find a port with sufficient freezing capacity.

Port:
Aalesund or/and Tromso (Need sufficient freezing capacity)
Fishing ground:
One south of Bjornoya - Bear Island på engelsk
Two between Bjornoya and Svalbard.
Length of fishery:
4-5 weeks, depending on crew change
Quota:
15.000 tonnes round mussels
1.500 tonnes muscle
Fabric:
10 tonnes a day
The empty shells can be thrown back to sea

Season:

All year, maybe not December and January due to wave height.

How the harvester locates the Arctic Scallops:

A video detection that counts the shells and say if there are shells or not. Also use of historical data from earlier fishing as a staring point.

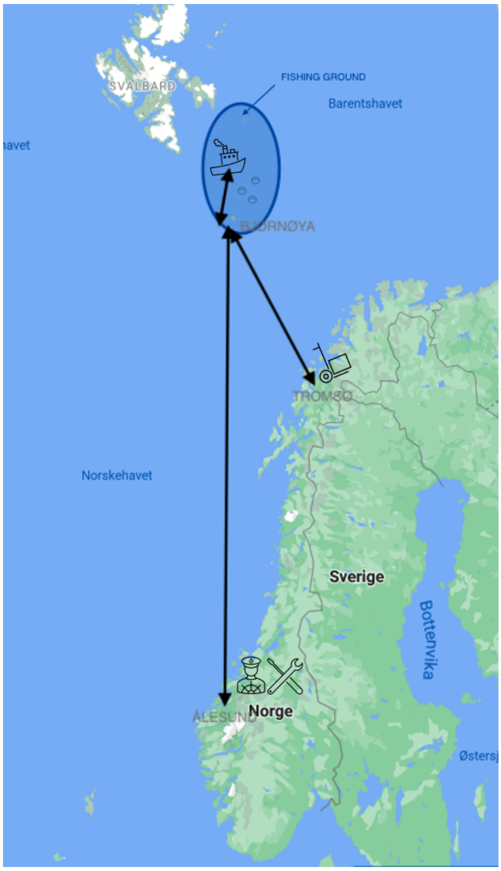


Figure 2.2: The planned operational profile of the vessel

2.10.1 The conditions on the fishing ground

The fishing for the Arctic Scallops will take place in the Barents Sea. The Barents Sea has a harsh winter climate with faster changes in weather conditions than we is used to along the Norwegian coast and in the North Sea. The rapid changes represent a greater risk of sea transport and oil activity in the northern areas than further south. The technical development has made many activities at sea less dependent on the external physical environment than before. Nevertheless, weather and climate must not be underestimated as important factors for safety at sea, both for shipping, fishing and oil activity. Weather forecast in the Barents Sea is therefore an important contribution to safety[35].

There are several factors that separate the Barents Sea from the North Sea. The northern areas have much lower temperatures, which easily gives icing, fog and snow. Parts of the sea areas in the north are covered by sea ice, which at times gives rise to rapid and surprising weather changes. Wind, current, waves and icing together with the sea ice have the greatest direct interest in safety in the northern areas. The special conditions are often associated with large temperature differences between cold air over the sea ice in the north and warm air over the sea. This often gives winds from the north and east. Storms and hurricanes are not uncommon. Very often the cold polar air over the ice spreads out over the sea. Under such conditions, with strong warming from from the sea surface, strong rain showers form, also polar low pressures can be formed, which are characterized by strong winds and poor visibility due to heavy rainfall and which occur surprisingly. Strong winds and poor visibility also often occur in front passages, and widespread fog is common during the summer. Polar low pressure depends on relatively warm sea and cold air to be able to form, and occurs most frequently in winter[35].

2.11 Systematic engineering

The chosen method to approach the task of looking into how an vessel will look like with the new type of harvesting technology, is engineering design a systematic approach. There are many steps in the systematic approach and the conceptual design phase is the main focus. The conceptual design process will now be investigated in literature.

Conceptual design is the part of the design process where—by identifying the essential problems through abstraction, establishing function structures, searching for appropriate working principles and combining these into a working structure — the basic solution path is laid down through the elaboration of a solution principle [1].

Needs-Function-Form The fundamental understanding of design is as a mapping between different representational spaces, from the needs defined by the market and key stakeholders, via the functions required to fulfill these needs, to form elements that will provide these functions, synthesized into the final design [1], [36], [37].

The need domain consist of the value proposition, and the stakeholders or costumers needs and want to achieve.

The function domain, is where the functional requirements describe what the system should do in order to meet the needs set.

The form domain consist of the design parameters which determines what the system looks like. It is often called the physical domain.

2.11.1 The stages of conceptual design

After completing the task clarification phase, the conceptual design phase determines the principle solution. This is achieved by abstracting the essential problems, establishing function structures, searching for suitable working principles and then combining those principles into a working structure. Conceptual design results in the specification of a principle solution (concept). Often, however, a working structure cannot be assessed until it is transformed into a more concrete representation. This concretisation involves selecting preliminary materials, producing a rough dimensional layout, and considering technological possibilities. Only then, in general, is it possible to assess the essential aspects of a solution principle and to review the objectives and constraints. It is possible that there will be several principle solution variants. The representation of a principle solution can take many forms. For existing building blocks, a schematic representation in the form of a function structure, a circuit diagram or a flow chart may be sufficient. In other cases a line sketch might be more suitable, and sometimes a rough scale drawing is necessary. The conceptual design phase consists of several steps, none of which should be skipped if the most promising principle solution is to be found. In the subsequent embodiment and detail design phases it is extremely difficult or impossible to correct fundamental shortcomings of the solution principle. A lasting and successful solution is more likely to spring from the choice of the most appropriate principles than from exaggerated concentration on technical details.

This claim does not conflict with the fact that problems may emerge during the detail design phase, even in the most promising solution principles or combinations of principles. The solution variants that have been elaborated must now be evaluated. Variants that do not satisfy the demands of the requirements list have to be eliminated; the rest must be judged by the methodical application of specific criteria. During this phase, the chief criteria are of a technical nature, though rough economic criteria also begin to play a part. Based on this evaluation, the best concept can now be selected.

It may be that several variants look equally promising, and that a final decision can only be reached on a more concrete level. Moreover, various form designs may satisfy one and the same concept. The design process now continues on a more concrete level referred to as embodiment design [1], p.131. So to sum it up, the steps of the conceptual design are, abstracting to identify the essential problems, establish function structures, searching for working principles, combining working principles into working structures, and selecting a suitable working structure and firming it up into a principle solution (concept) [1], p.xiii.

2.11.2 Abstracting to find the essential problems

Solution principles or designs based on traditional methods are unlikely to provide optimum answers when new technologies, procedures, materials, and also new scientific discoveries, possibly in new combinations, hold the key to better solutions [1], p. 161. In order to solve the problem of fixation and sticking with conventional ideas, abstraction is used. This means ignoring what is particular or incidental and emphasising what is general and essential. Such generalisation leads straight to the crux of the task. If it is properly formulated, then the overall function and the essential constraints become clear without prejudicing the choice of a particular solution in any way [1], p. 161. It is the identification of the crux of the task with the functional connections and the task-specific constraints that throws up the essential problems for which solutions have to be found. Once the crux of the task has been clarified, it becomes much easier to formulate the overall task in terms of the essential subproblems as they emerge [1], p. 162.

Broadening the Problem Formulation.

This is the best point in the process to bring in those designers who are actually going to be responsible for the project. Having identified the crux of the task by correct problem formulation, a step-by-step enquiry is now initiated to discover if an extension of, or even a change in, the original task might lead to promising solutions [1], p. 163. Comprehensive problem formulation on an abstract plane opens the door to better solutions [1], p. 164.

Identifying the Essential Problems from the Requirements List

Here the task is to analyse the requirements list with respect to the required function and essential constraints in order to confirm and refine the crux of the problem. That analysis, coupled to the following step-by-step abstraction, will reveal the general aspects and essential problems of the task, as follows:
Step 1. Eliminate personal preferences.
Step 2. Omit requirements that have no direct bearing on the function and the essential constraints.
Step 3. Transform quantitative into qualitative data and reduce them to essential statements.
Step 4. As far as it is purposeful, generalise the results of the previous step.
Step 5. Formulate the problem in solution-neutral terms.

2.11.3 Establishing Function Structures

Once the crux of the overall problem has been formulated, it is possible to indicate an overall function that, based on the flow of energy, material and signals can, with the use of a block diagram, express the solution-neutral relationship between inputs and outputs [1], p. 169. Overall function can be broken down into subfunctions in a further step.

Breaking a Function Down into Subfunctions

Depending on the complexity of the problem, the resulting overall function will in turn be more or less complex. Just as a technical system can be divided into subsystems and elements, so a complex or overall function can be broken down into subfunctions of lower complexity. The combination of individual subfunctions results in a function structure representing the overall function [1], p. 171..

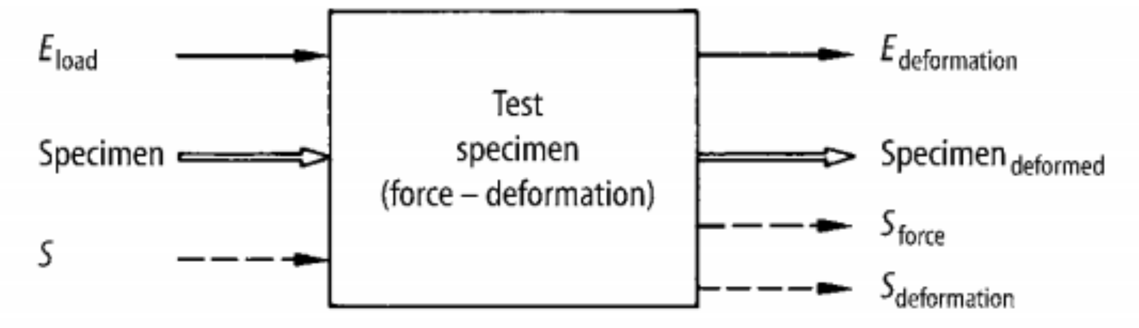


Figure 2.3: The overall Function Structure [1]

Practical Applications of Function Structures

Function structures are intended to facilitate the discovery of solutions: they are not ends in themselves. The degree of detail used depends very much on the novelty of the task and the experience of the designers. Moreover, it should be remembered that function structures are seldom completely free of physical or formal presuppositions, which means that the number of possible solutions is inevitably restricted to some extent. Hence, it is perfectly legitimate to conceive a preliminary solution and then abstract this by developing and completing the function structure by a process of iteration[1], p. 178 179.

2.11.4 Developing Working Structures

Searching for Working Principles

Working principles need to be found for the various subfunctions, and these principles must eventually be combined into a working structure. The concretisation of the working structure will lead to the principle solution. A working principle must reflect the physical effect needed for the fulfilment of a given function and also its geometric and material characteristics [1], p. 181. In the search for a solution it is often difficult to make a clear

mental distinction between the physical effect and the form design features. Designers therefore usually search for working principles that include the physical process along with the necessary geometric and material characteristics, and combine these into a working structure[1], p. 181. It should be emphasised that the step we are now discussing is intended to lead to several solution variants, that is, a solution field[1], p. 181. The search for working principles for subfunctions should be based on the following:
Preference should be given to the main subfunctions that determine the principle of the overall solution and for which no solution principle has yet been discovered. The Classifying criteria and associated parameters should be derived from identifiable relationships between the energy, material and signal flows, or from associated systems. If the working principle is unknown, it should be derived from the physical effects and, for instance, from the type of energy. If the physical effect has been determined, appropriate form design features should be chosen and varied. Designers should also enter solutions found intuitively and analyse which key classifying criteria influence particular working principles. These criteria should then be subdivided, limiter or generalised using further headings. To prepare for the selection process, the important properties of the working principles should be noted[1], p. 182.

Combining Working Principles

To fulfil the overall function, it is then necessary to generate overall solutions by combining the working principles into a working structure, that is, system synthesis. The basis of such a combination is the established function structure, which reflects logically and physically possible or useful associations of the subfunctions [1], p. 184. By systematically combining a working principle fulfilling a specific subfunction with the working principle for a neighbouring subfunction, one obtains an overall solution in the form of a possible working structure. In this process only those working principles that are compatible should be combined [1], p. 185.

Selecting Working Structures

This selection procedure involves two steps, namely elimination and preference. First, all totally unsuitable proposals are eliminated. If too many possible solutions still remain, those that are patently better than the rest must be given preference. Only these solutions are evaluated at the end of the conceptual design phase[1], p. 107.. If faced with a large number of solution proposals, the design should compile a selection chart. In principle, after every step that is, even after establishing function structures, the only solution proposals pursued should fulfill:

Criterion A: Be compatible wit the overall task and with one another

Criterion B: Fulfil the demands of the requirements list

Criterion C: Be realisable in respect of performance, layout, etc.

Criterion D: Be expected to be within permissible costs.

Developing Concepts

2.11.5 Developing Concepts

Firming Up into Principle Solution Variants

The principles elaborated up until this step in the conceptual design are usually not concrete enough to lead to the adoption of a definite concept. This is because the search for a solution is based on the function structure, and so it is aimed, first and foremost, at the fulfilment of a technical function [1], p. 190. The selection process may already have revealed gaps in information about very important properties, sometimes to such an extent that not even a rough and ready decision is possible, let alone a reliable evaluation. The most important properties of the proposed combination of principles must first be given a much more concrete qualitative, and often also a rough quantitative, definition. Important characteristics of the working principle (such as performance and susceptibility to faults), of the embodiment (such as space requirements, weight and service life) and finally of important task-specific constraints must all be known, at least approximately. More detailed information need only be gathered for promising combinations. If necessary, a second or third selection process should follow the collection of further information [1], p. 190. The variants must reveal technical as well as economic properties, thus permitting the most accurate evaluation possible. When firming up into principle solutions, it is therefore advisable to keep in mind potential evaluation criteria, as this encourages purposeful elaboration of the information[1], p. 191.

Evaluating Principle Solution Variants

When evaluating principle solution variants, the following steps are recommended: Identifying Evaluations Criteria, Weighting the Evaluation Criteria, Compiling Parameters, Assessing Values, Determining Overall Value, Comparing Concept Variants, Estimating Evaluation Uncertainties, and Searching for Weak Spots.

Parctical Application of Developing Concepts

Firming up of suitable working structures into principle solution variants and the subsequent evaluation at the end of the conceptual design phase are of major importance for product development. The large number of variants has to be reduced to one concept, or just a few, to be pursued further. This decision incurs a heavy responsibility and can only be made when the principle solutions are in a state suitable for evaluation. The selection of the concept, or the principle solution, provides the basis for starting the embodiment design phase[1], p. 198.

Chapter 3

Methodology

In Section 2.11 the conceptual design methodology represented by Pahl Beitz was discussed. The difference from the literature review and the methodology is that now it will only be discussed about the methodology that are used to solve the problem of this thesis: Design study of a vessel for the Atlantic scallop industry.

3.1 Abstraction to find essential problem

When starting to abstract the problem it is important to know what the crux of the problem is. For example whether it is to improve technical functions or to reduce weight or space. In this case the aim is to design a vessel with a new type of technology and focus on the harvesting and processing phases in the vessel, due to this being the new part that differs from the vessels being built for this industry before. Off course in the end solution there will be many requirements that needs to be met, but in the importance differ from case to case. So in this case it is important to look into the flow of the Arctic Scallop especially the harvesting and the connection from being collected and going into the factory. It is the identification of the core of the task with the functional connections and the task-specific constraints that throws up the essential problems for which solutions have to be found. Once the core of the task has been clarified, it becomes much easier to formulate the overall task in terms of the essential subproblems as they emerge [1], p. 162.

After having identified the crux of the task by correct problem formulation, a step-by-step enquiry is now initiated to discover is an extension of, or even a change in, the original task might lead to promising solutions [1], p. 162. The goal of this is to avoid to immediately beginning to think of possible improvements to the existing situation. By proceeding in this way one is likely to ignore other, more useful and more economic solutions [1], p. 162. (

There are two ways to do abstraction to find the essential problems, it can be done either by systematically broadening as talked about above or by analysing the requirement list. The choice of method depends on the information available for the task. If it is given an requirements list from the customer or the stakeholders analysing the requirement list would be the easier choice, but when lacking this requirement list the method of abstraction through broadening the problem formulation is the easier choice.

In this task, the favourable method is doing the abstraction by systematically broadening the problem formulation. This is due to the technology that is going to be used on the vessel to be designed is new. There is currently no existing vessel having that type of technology.

3.2 Establishing function structures

Once the crux of the overall problem has been formulated, it is possible to indicate an overall function that, based on the flow of energy, material and signals can, with the use of a block diagram, express the solution-neutral relationship between inputs and outputs. Just as a technical system can be divided into subsystems and elements, so a complex or overall function can be broken down into subfunctions of lower complexity. The combination of individual subfunctions results in a function structure representing the overall function. [1], p. 170. (

So in this step the overall function of Harvest and process Arctic Scallops and deliver to port will be divided into subsystems that will result in a function structure that represent the overall function. The main physical processes and their interrelationships, will be looked at step by step, and then this will lead us to the overall function. In this master thesis the focus is the harvesting and processing of the arctic scallops, so the focus is the flow of the arctic scallops throughout the operation. Therefore are the subfunctions divided between the different steps the arctic scallops will go through. .

3.3 Searching for working principles associated with functions

In this section the focus is to find the forms of the identified functions. A working principle (WP) must reflect the physical effect needed for the fulfilment of a given function and also its geometric and material characteristics [1], p. 181.

Now it is time to find the forms of the identified functions. The function structure is found, and it is time to look at what the physical effect to fulfill those functions are. A working principle must reflect the physical effect needed to fulfilment of a given function and also its geometric and material characteristics. The concretization of the working structure (WS) will lead to the principle solution. It is often difficult to make a clear mental distinction between the physical effect and the form design features. Designers therefore usually search for working principles that include the physical process along with the necessary geometric and material characteristics, and combine these into a working structure.

When searching for working principles several methods may be used, such as literature searches and intuition-based methods. In this step it is important to not exclude any options because it doesn't seem like it would fit. This step is not to make the solution field smaller, it is to make the solution field bigger. So the working principles could be found in many ways. In this master thesis it is helpful to look into the ROV-industry and vessels that use ROV, due to the SH having similar technology to them. It is also helpful to look into the shell scraping industry, to look at solutions and the vessels used there. As well as looking in literature, and explore unexplored option. So in this step it is all about being open minded and to not set any boundaries for the technology and principles needed to fulfill the overall function. The working principles is listed, combined with a sketch of the principle.

After the different working principles is found they need to be classified. This is not a straight forward task. The different principles needs to be analysed, and it needs to be looked into their characteristics and how the physical principles of the different principles go together with each other. When the analysis is done and the information of the different working principles is a bit clearer, it is time to classify them. These principles are called classification parameters (CP). When both the working principles and the classification parameters are found, it is time to put them together in a design catalogue. The design catalogues shows the combination of classification parameters, and the different working principles that goes together with the classification parameters. The design catalogue is formed like a matrix, and can be on several pages, depending of the number of classification parameters. The design catalogues shows the solutions possible. It also easy to see which ones that do not work at all, and which that can work.

In this step of the conceptual design it is needed to be open minded, and keep the functions as abstract as possible, so that it is possible to come up with multiple solutions.

3.4 Combining working principles into working structures

Now it is time to generate a solution that fulfill the overall function. This is done by combining the working principles into a working structure. The design catalogues for each step of the overall function are found and it is time to put them all together in order to make a working structure for the overall task. The overall combinations is made by choosing one working principle for each classifying parameter in each of the main functions, this is called the working structure. Now it is time to not look at each main function individually, but look at which ones that can be combined with the other main functions. In this step it is helpful to make a Morphological Matrix, which consist of all the different working principles and classifying parameters put together in one matrix. By doing this it is possible to get an overview, and then again it is easier to see which ones that can be combined and which ones that can not be combined.

So this step is the first step where the solution field is narrowed down. Until now it is kept open, and as abstract as possible. So as mentioned the Morphological matrix is helpfull to see which combinations that are possible. But there are often many combinations and solutions, so it is hard to pick which ones of the working principles that should be chosen in the large field. Up until this point in the conceptual design the functions and their respective working principles have been treated separately. This means that the compatibility between the function and the form is not investigated, and it is time to do so. Noe the compatibility matrixes is made, this is set up by putting the classifying parameters on the row and the collums there will be a short text, describing how it would be to combine them. It is important to notice that this is classifying parameters from different subfunctions. So the classifying parameters in the row is from one subfunction and the classifying parameters in the collum is from another subfunction. By doing this, it is easy to see which ones that compile with eachother, which that somehow compile with each other, and which that does not compile at all. Only the solutions that have compatibility with each other will be studied further.

3.5 Selecting suitable combinations

Now it is time to select the suitable combinations based on the solutions that are compatible with each other. This selection procedure involves the two steps of elimination and preference. As mentioned, the solutions that are not compatible with each other are eliminated. But there are often many solutions that still remain after these are eliminated. So from the compatibility matrixes it is found which classification parameters that are compatible with each other, and from the morphological matrix see which working principles this applies to. If there is a large number of solution proposals, the desgner should compile a selection chart. This is done by having criterion for what the solution pursued should fulfill. By doing this it is easier to eliminated some of the solutions.

3.6 Firming up into solution variants using specific location

Up until this step in the conceptual design the principle elaborated are usually not concrete enough to lead to a definite solution. That is because up until now the search for solution has been based on the function structure and the fulfilment of a technical function. At this step it is necessary to select between the different working structured. And as mentioned this can be done by preference and elimination. In this project the working structures will be analysed and evaluated for operation in the Barents sea, more specifically the areas around Bear Island. A description of the condition in this area can be seen in Section 2.10.1.

For this example study, the preferences and elimination are based on the following criteria:
A - Be compatible with the overall task and with one another
B - Be realisable in respect of performance, layout and costs
C - Incorporate safety measures

The criteria listed, is the focus in this project. These are the ones relevant, and that there is enough information to preference the solutions that include them.

Criteria A: This is with regards to the working principles and that they should all be compatible with each other and that they together form the overall function.

Criteria B: It is important that the selected solution is realisable in respect of performance, layout and costs. This is needed in order for the vessel to be realised.

Criteria C: In addition to the internal solution working together, it is important to look at the external conditions as well. And that this also has a focus, so that the overall solution chosen doesn't go on expense of the safety for the crew members on board the vessel. As mentioned in Section 2.10.1 the condition at the fishing ground it is planned to go fishing, are rough. With a lot of rapid change in weather, bad sight, a lot of wind and waves. Therefore the safety of the crew members are a big focus. The climate is also very cold, and it is life threatening to fall overboard and into the cold waters. Also due to a lot of motion in the vessel, safety measures must be taken in regards to that.

3.7 Summary of methodology

To sum up the methodology. The conceptual design forces you to have an open mind when starting the project. It is natural for humans to have some thoughts about the end solution, and envision it before the project has even started. It is hard for a human mind to be totally open minded, and to not eliminate solutions immediately. So the conceptual design which is a systematic approach to engineering design, forces the designer to abstract the formulations, work systematically and to follow a step by step analysis. The steps and the flow of the conceptual design can be seen in Figure 3.1.

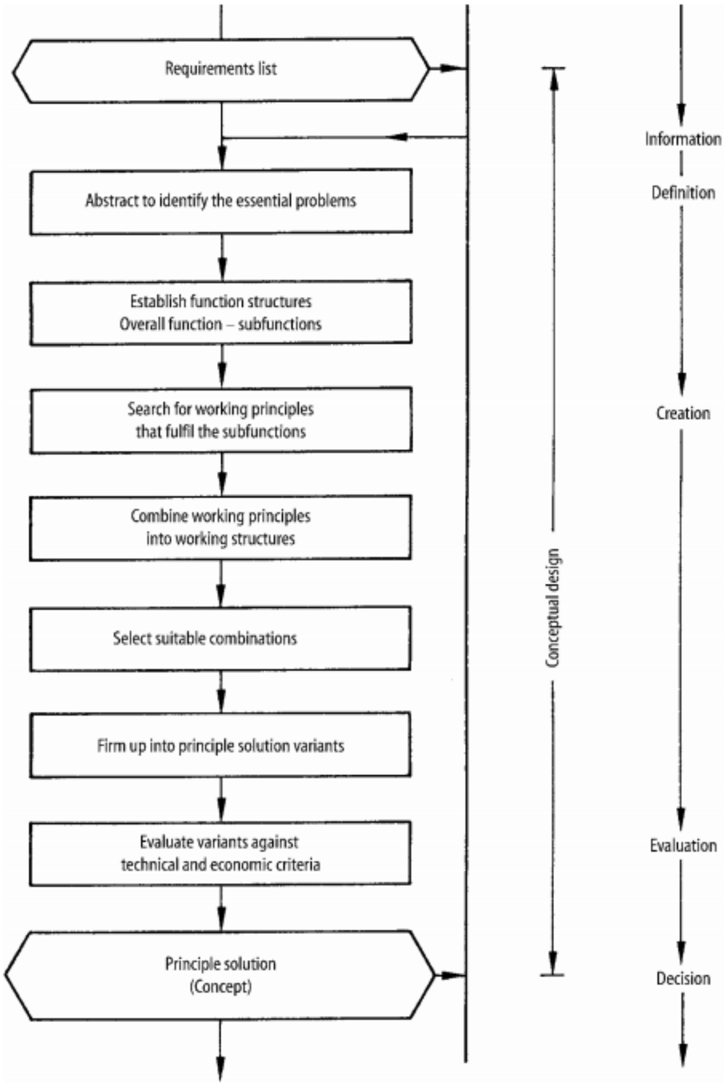


Figure 3.1: The steps in the conceptual design [1]

Chapter 4

Results

In Chapter 3 the methodology leading up to the results is explained. The results will be represented in this chapter. It starts with the problem formulation and abstraction of it by systematic broadening it, and the physical processes within the problem formulation is found. After this it is time to establish function structure, by first looking at the overall function before dividing it into main functions. Here the input, and output of each of them, and the system boundary, which means where it happens. After the function structures is established the search for working principles associated with the functions starts. Here the working principles and the classifying parameters are represented for each functional requirement. Then the working principles is combined into working structures. This is represented by Compatibility matrix. From this the working structures are found. And at the end the working structures is used in firming up solution variants. All the technology that is going to be discussed in the result section can be read about in greater detail in Chapter 2.

4.1 Abstraction by systematic broadening of problem formulation

The steps of the abstraction is listed below: Step 1. Eliminate personal preferences.
Step 2. Omit requirements that have no direct bearing on the function and the essential constraints.
Step 3. Transform quantitative into qualitative data and reduce them to essential statements.
Step 4. As far as it is purposeful, generalise the results of the previous step.
Step 5. Formulate the problem in solution-neutral terms.

Before starting with the abstraction it is important to come up with the problem formulation. This becomes the basis of the abstraction. The problem formulation for this thesis is "Harvest and process arctic scallops and deliver to port". This is a solution-neutral formulation of the goal. It is important, because on this stage it should not favour any particular design. It should be completely open at this point. The product in this case is the Arctic scallop. It has as mentioned been a fishery for on for a long time, but now it is with a new harvesting technology. Today there already exist a fishery for the Arctic Scallop, but in this project it is not longer with the use of scrapers but with the new harvesting technology SH. Due to the new technology the method selected for doing the abstraction is the abstraction by systematically broadening the problem formulation.

Firstly, it is important to identify the objects, or entities included in this problem. In Section 2.1.1, it was told that the Arctic Scallops is located at the seabed and the shells are very spot by spot distributed, and as a rule one finds areas of high density scattered around. The large concentrations is usually found in current-rich areas between 20 and 100 meters dept. They live attached to the bottom, and thrives best in current-rich areas on hard bottoms that consist of rocks, gravel or empty shells. The flow of the Arctic scallop is that they are harvester at the seabed with the help of the SH, they are then brought into the SH where they are kept until the SH i sufficiently full and will be brought up to the vessel. The shells are then brought into the vessel and through the processing facility. Then they are stored and delivered to the quayside.

The objects in this thesis is, the seabed, the arctic scallop, the SH, launch recovery system, the processing facility, the storage, the vessel and the quay.

After finding the objects in this thesis, the next step is to look into the physical processes. The starting point of the material flow is when the Arctic scallops are at the seabed, and the ending point of the material flow is the deliverance at port. There are many alternatives while doing this step, the problem formulation ”Harvest and process arctic scallops and deliver to port” does not limit any type of technology. The only part that is limited is the method of harvesting, but it does not state how the shells should be processed, how it should be transferred from the SH to the vessel, how they should be stored or how it should be delivered in port. Therefore it is important to look into many alternatives while doing this step with the physical processes.

The high-level flow of the Arctic Scallops have now been described. It will now be looked into in further detail, each step of the physical processes.

4.1.1 Step 1 - Physical process - Harvesting the Arctic Scallops

The first physical step is the harvesting of the Arctic Scallops. In this step the Arctic scallops are located on the seabed, and the SH will need to be launched from the vessel and start to located itself above the Arctic Scallops. With the help of vacuum the shells will be lifted from the seabed and into a collection unit inside the SH. When the collection unit is sufficiently full the SH will be recovered back up to the vessel.

4.1.2 Step 2 - Physical process - Transition into the processing facility

When the SH is brought up to the vessel, the shells needs to be transitioned from the SH and into the processing facility.

4.1.3 Step 3 - Physical process - Processing

After the Arctic Scallops has been transitioned into the processing facility. It is time to start processing them. The extent of the processing, depends on which end product that is wanted.So here the form of material is crucial. It could be kept as round shell or it could be processed all the way until muscle.

4.1.4 Step 4 - Physical process - Storage/Transportation

After the Arctic Scallops has been processed, the next step is to store them and transport them to port. This step is also dependent on which form the material has. The way the shells are stored decides which packing method of the shells that are relevant. As well as the length of the fishing trip is an important factor in the decision, are the shells going to be stored for weeks or only a few days on board the vessel.

4.1.5 Step 5 - Physical process - Deliverance

At the quayside, it is time to deliver the Arctic scallops from the vessel to the port. There are many methods to do this, and the methods depends on the form of material, and the storage method.

4.2 Establishing function structure

From the abstraction. It is found five steps of physical processes. These steps are: Harvesting, transition into the processing facility, processing, storage and deliverance. It will now be looked further into the overall function, and the sub-functions from the physical processes, and put them into a final functional structure.

4.2.1 Overall

The overall function structure is that the input flow is ”The Arctic scallops at the seabed”, and the final output flow is ”The Arctic scallops delivered in port. The system boundary is The vessel and the overall function is ”Harvest and process arctic scallop and deliver to port”.

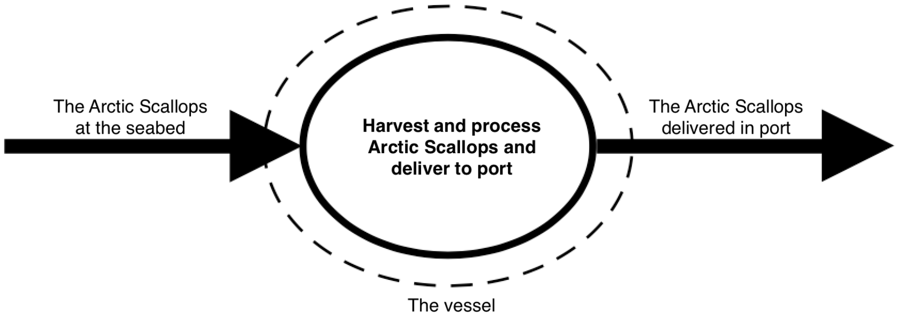


Figure 4.1: Block diagram of the material input and output of the overall function

4.2.2 For physical process step 1

The first flow input in Figure 4.1 and Figure 4.2 are the same. This is because they are both the starting point of the flow for the Arctic Scallops. The input flow is ”The arcitc scallops at the seabed”. The output from the first main function seen in Figure 4.2 is ”The arctic scallops harvested by the seabed harvester and loaded onto the vessel”. While it is loaded onto the vessel, the arctic scallops are still inside the SH. The first main function (FR1) becomes ”Harvesting the arctic scallops from the seabed”.

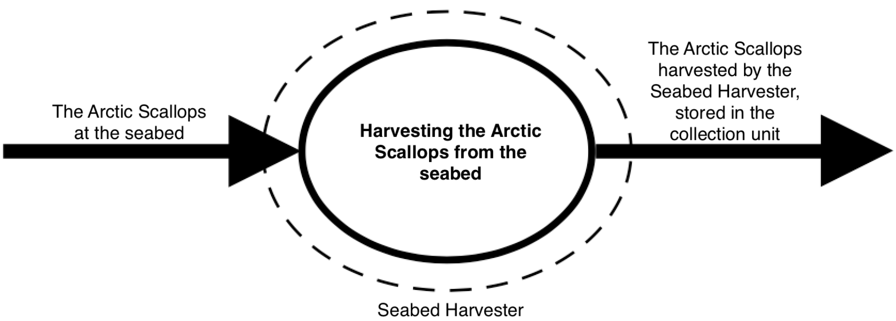


Figure 4.2: Block diagram of the material input and output for FR1

4.2.3 For physical process step 2

The input flow is ”The arctic scallops harvested by the seabed harvester and loaded onto the vessel”. The arctic scallop now needs to be transitioned into the processing facility in order to achieve the output flow of ”The arctic scallops transferred into the processing facility”. This can be done in several ways, and it depends on the where the SH is placed. The second main function (FR2) becomes ”The transition from the seabed harvester into the processing facility”. The block diagram for FR2 can be seen in Figure 4.3.

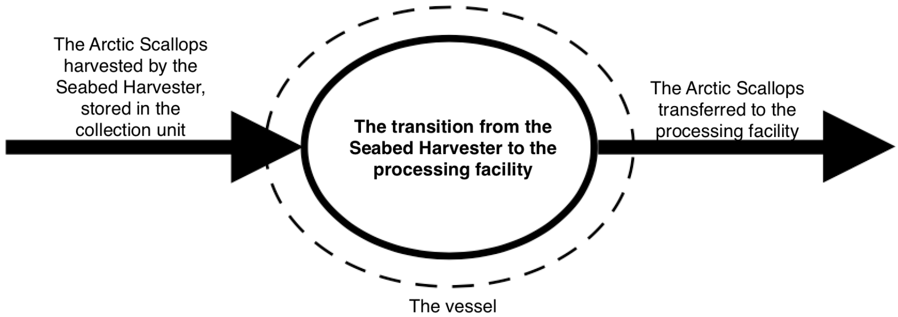


Figure 4.3: Block diagram of the material input and output for FR2

4.2.4 For physical process step 3

For the next main function the input flow is ”The arctic scallops transferred into the processing facility”. The arctic scallops are now ready to be processed and are transferred to the starting point of the processing facility. The output flow is ”The arctic scallops processed” in order to achieve this output flow the third main function (FR3) becomes ”Processing of the arctic scallops”. The block diagram for FR3 can be seen in Figure 4.4

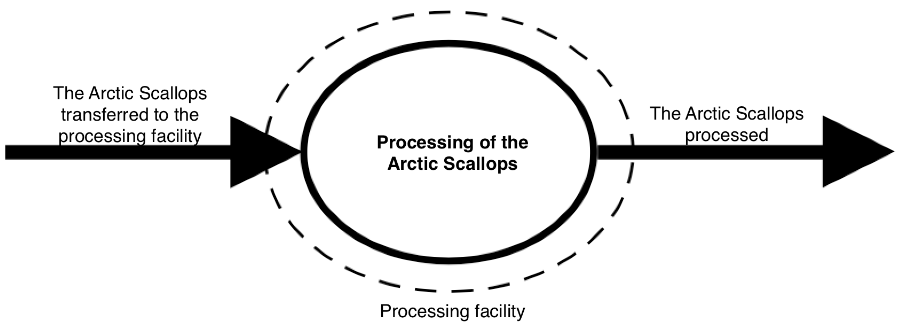


Figure 4.4: Block diagram of the material input and output for FR3

4.2.5 For physical process step 4

After the processing of the arctic scallops is done and the arctic scallops are processed it is time to store them while the vessel either is going towards the quayside or to store them while the vessel continues to harvest more arctic scallops. The output flow is ”The arctic scallops stored”. The fourth main function (FR4) becomes ”Storing the arctic scallops until deliverance at port and for further fishing”. The block diagram for FR4 can be seen in Figure 4.5.

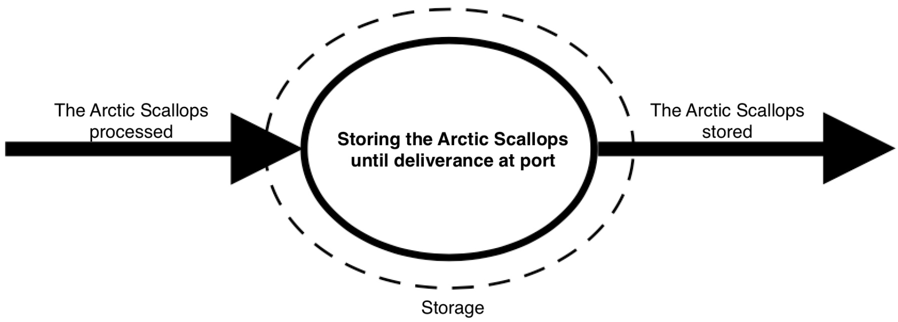


Figure 4.5: Block diagram of the material input and output for FR4

4.2.6 For physical process step 5

For the final step the input flow is ”The arctic scallops stored”, the arctic scallops are stored until deliverance at port. and the output flow is ”The arctic scallops delivered in port”. The fifth and final main function (FR5) then becomes ”Deliver the arctic scallops at port”. The block diagram for FR5 can be seen in Figure 4.6

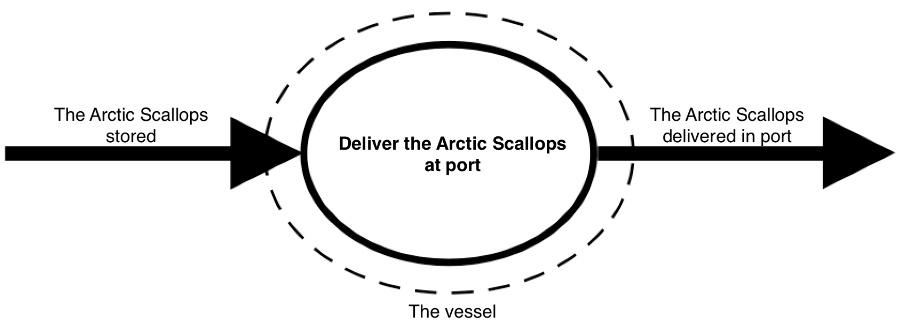


Figure 4.6: Block diagram of the material input and output for FR5

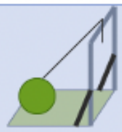
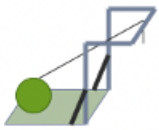
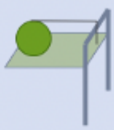
4.3 Searching for working principles associated with functions

Now that the functions are identified there is time to find the forms associated with them. The overall function is ”Harvest and process arctic scallops and deliver to port”. To make this into reality, it is time to find which working principles that fulfill the functional requirements found in this thesis. A working principle must reflect the physical effect needed for the fulfilment of identified functions. The search for the working principle will be done step by step. So by finding the working principles it is possible to find the forms that the functional requirements are associated with. So it will now be a mapping between the function to form domain. In the search for working princples associated with the function, it has been helpfull to look into the ROV-industry and vessels has a ROV onboard, due to the SH having similar technology. It has also been helpfull to look at the shell scraping industry, to look at solutions used and the vessels used there. As well as searching for literature, and explore unexplored options.

4.3.1 Functional requirement 1 - Harvesting the arctic scallops from the seabed

It is time to look at which working principles that are connected to the Funtional Requirement of ”Harvesting the Arctic Scallop from the seabed”. To be able to harvest the arctic scallops, a harvesting technology is needed. This technology is the SH. The technology itself is set, but it has a lot of support functions, that is needed in order for the SH to be able to harvest the Arctic Scallop. In Table 4.1 and Table 4.2 the working principles for FR1 can be seen.

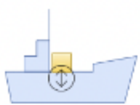
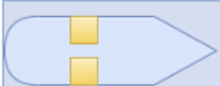
Table 4.1: Part one of the Working Principles for FR1

WORKING PRINCIPLES FOR FUNCTIONAL REQUIREMENT 1 (1/2)	
Working principle	**Description**
Launch & Recovery – Technical	
	**Classic A-frame**. To launch and recover the Seabed Harvester. Designed for installation on open deck.
	**A-frame Knuckle**. To launch and recover the Seabed Harvester. Designed for installation in hangar or on open deck.
	**Moonpool Launch and Recovery Frame .** To launch and recover the Seabed Harvester. Designed for installation in a moonpool.
	**Telescopic A-frame**. To launch and recover the Seabed Harvester. Designed for installation in hangar or on open deck.
	**Winch**. To support the launch and recovery frame. A machine with a drum for hauling and pulling.
	**Heave-Compensation placed subsea.** To help stabilize the heave-motion of the vessel in the rough conditions at the fishing ground.
	**Heave-compensation placed on deck or inside hangar.** To help stabilize the heave-motion of the vessel in the rough conditions at the fishing ground.

To start the harvesting of the Arctic Scallops the SH needs to be launched from the vessel and to go subsea, to do this a LARS is needed. LARS has already been described in

Section 2.8.1, and as mentioned there is a need for a frame and a winch in order to be able to control the launch and recovering of the SH. When th SH is subsea it will locate itself over the Arctic Scallops and start harvesting them using vacuum, where it does not need to be in contact with the seabed. This is one of the goals of the SH. Therefore is it important to keep the SH stable, and make sure that it is not affected by the motion from the vessel. To keep the the SH stable heave-compensation can be placed either subsea or on the vessel. While harvesting the Arctic Scallop the vessel will use dynamic positioning, and keep a velocity of 1-2 knots. This is not in the table, due to the technology being set, but it will be included on the vessel. When the collection unit is sufficiently full the LARS will recover it back up towards the vessel.

Table 4.2: Part two of the Working Principles for FR1

WORKING PRINCIPLES FOR FUNCTIONAL REQUIREMENT 1 (2/2)	
Working principle	**Description**
Launch & Recovery – Placement	
	**Moonpool.** The Seabed Harvester will be launched and recovered through a moonpool.
	**Deck.** The Seabed Harvester will be launched and recovered from deck.
	**Hangar.** The Seabed Harvester will be launched and recovered from a hangar.
Number of Seabed Harvesters	
	**Two.** Two Seabed Harvesters are placed on the vessel, one on each side, placed either on deck or inside hangars.
	**Three.** Three Seabed Harvesters are placed on the vessel, one on starboard, one on port and one at the stern, placed either on deck or inside hangars.

The equipment for the LARS needs to be placed on the vessel. The placement of the LARS needs to be at the place the SH will be Launched and Recovered from. Therefore will the placement of the LARS be important for the operation, and important for the outfitting of the vessel. It is also important to make a decision on how many SH that will be placed on the vessel. This will affect the stability of the vessel, and how much Arctic Scallops that can be harvested. Thus, the Classifying Parameters(CP) becomes "Physical principles" and "Placement of Seabed Harvester, as seen in Table 4.3

Table 4.3: The Classifying Parameters for WP1

CLASSIFYING PARAMETERS FOR THE WORKING PRINCIPLES	
Placement of Seabed Harvester	**Symbol**
Inside a hangar	
On deck	
Physical principles	
Launch & Recovery – Placement	
Launch & Recovery – Technical	
Number of Seabed Harvesters	

As seen the CP for placement of Seabed Harvester is that it can either be placed inside a hangar or on deck. And the physical principles which involves the placement of LARS, which technical equipment that will be used for the LARS and the number of seabed harvesters. It is now time to make a Design Catalogue (DC) for CP1 and WP1. This can be seen in Table 4.4 and Table 4.5.

Table 4.4: Part one of the Design Catalogue for CP1 and WP1

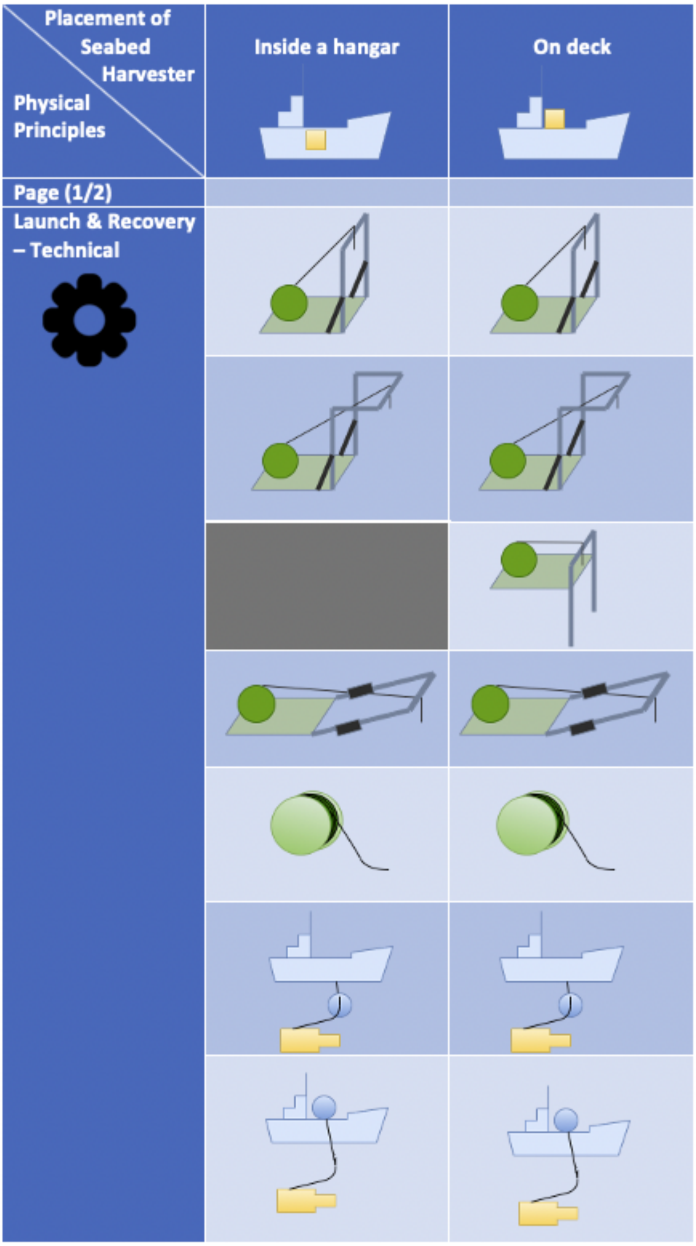
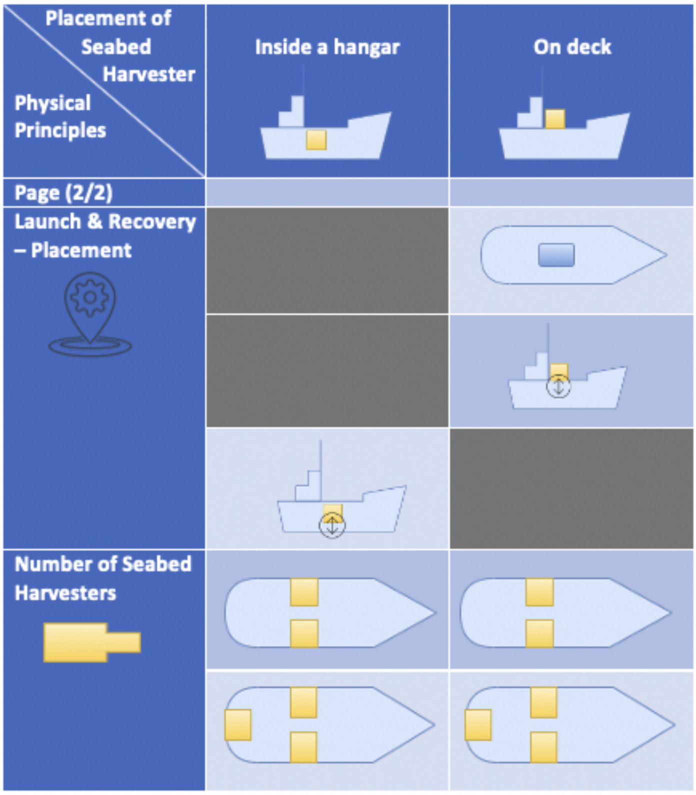


Table 4.5: Part two of the Design Catalogue for CP1 and WP1



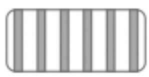
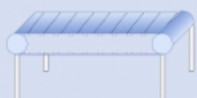
The DC shows all the different solutions for FR1. Ass seen many of the WPs are repeated and can work for more than just one CP. While others such as Moonpool launch and recovery can only be placed in a moonpool, and the moonpool can only be placed on deck. As well as the placement of the launch and recovery is dependent of the placement of the SH. So if the SH is placed in a hangar, the LARS also needs to be placed in a hangar, and so on. The number of Seabed Harvesters can be both two and three independent of the placement of the SH.

4.3.2 Functional requirement 2 - The transition from the Seabed Harvester to the processing facility

T

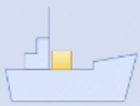
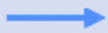
The Working principles for the FR2 ”The transition from the Seabed Harvester to the processing facility”. In this step the Arctic Scallops needs to be retrieved from the collection unit in the SH and brought to the vessel, and in to the processing facility. This requires a method for transferring them, and making them ready to go through the processing facility. The Working Principle (WP2) for FR2 can be seen in Table 4.6

Table 4.6: The Working Principles for FR2

WORKING PRINCIPLES FOR FUNCTIONAL REQUIREMENT 2	
Working principle	**Description**
Flow	
	**Pump**. To load the arctic scallops from the Seabed Harvester to the vessel.
	**Receiving bin**. To receive the catch, before it is transported towards the processing facility.
Technical	
	**Grate**. To roughly sort out the bycatch.
	**Conveyor belt**. To transport the harvested arctic scallops to the processing facility.
	**Receiving bin**. To receive the catch, before it is transported towards the processing facility.

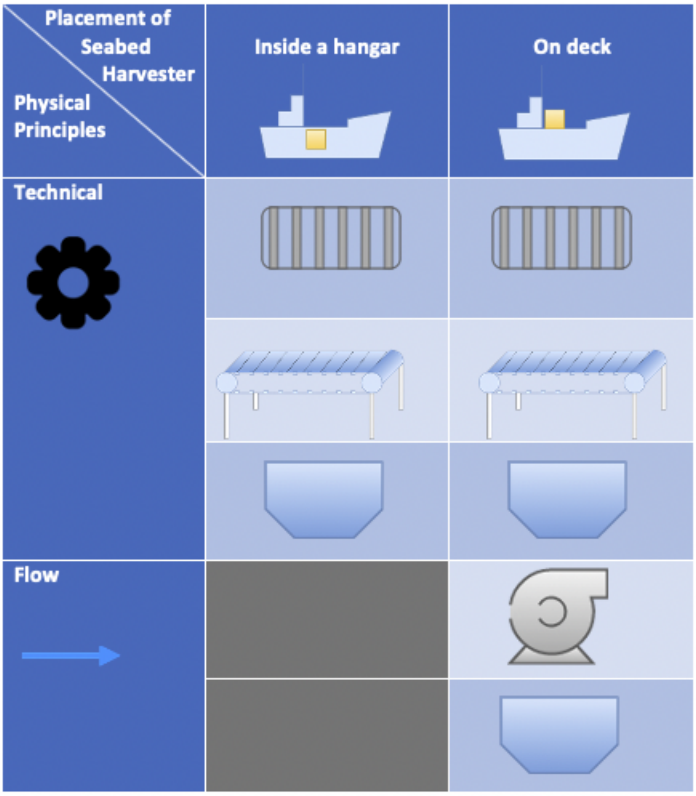
There are several method to do the transition from the collection unit in the SH to the vessel and the processing facility. One solution could be to keep the SH subsea and lower down a pump that will load the Arctic Scallops in to the vessel, and the shells can then be loaded in to a receiving bin ready to enter the processing facility. The SH could also be retrieved back up on the vessel, and from there the sides of the collection unit can be opened up, and leading the Arctic Scallops through a grate on deck and then lead with the help of a conveyor belt to the receiving bin ready to go through the processing facility. So a big decision here is if the Arctic Scallops should be kept as a flow, hence being loaded onto the vessel with the help of a pump, or if the SH should be retrieved back onto the vessel, and be retrieve with the help of technical equipment. Hence the Classifying Parameters (CP2) becomes "Placement of seabed harvester" and "Physical Principal". And can be seen in Table 4.7

Table 4.7: The Classifying Parameters for WP2

CLASSIFYING PARAMETERS FOR THE WORKING PRINCIPLES	
Placement of seabed harvester	**Symbol**
Inside a hangar	
On deck	
Physical Principles	
Flow	
Technical	

For the placement of seabed harvester, it could either be placed inside a hangar or on dekc. And for the physical principle, the shells will either be retrieved by flow (pump) or by technical equipment. It is now time to make the Design Catalogue (DC2) for CP2 and WP2. The DC2 can be seen in Figure 4.8

Table 4.8: Design Catalogue for CP2 and WP2



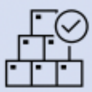
DC2 shows that the technical equipment is not affected by the placement of the seabed harvester, but the flow is. This is because it is made an assumption that in order for the vessel to be able to control the pump and the SH, and keep them stable enough to retrieved the Arctic Scallops this needs to happen through a moonpool. Hence the flow will only be possible to use when the SH is placed on deck and launched and recovered thorugh a moonpool.

4.3.3 Functional requirement 3 - Processing the Arctic Scallops

In this step the arctic scallops are already ready to go inside the processing facility. The search now is for the working principles fro FR3 ”Processing the Arctic Scallops”. In this step it is important to figure out to which extent they should be processes. As mentioned in Section 2.10, the quota is 150 tonnes muscle, and 1500 tonnes whole shells. So it is an alternative to keep them as whole shell, and there is an alternative to process them all the way until it is only the Scallop muscle left. In Table 4.9the Working Principles (WP3) for FR3 can be seen.

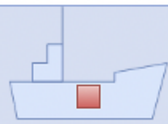
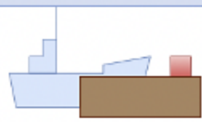
the important parts is how the shells should be processed. To which degree should they be processed? The quota for the arctic scallops is 150 tonnes muscle, and 1500 tonnes round shells. So they have the alternative to keep them as round shells and to process them in such a degree that they are left with muscles. The storage of round shells will be live storage, to keep them alive and fresh until deliverance. For the round shells the processing must either happen on shore, or at the place they are delivered. For the muscles, the best way to storage them is to keep them in a freezing storage.

Table 4.9: The Working Principles for FR3

WORKING PRINCIPLES FOR FUNCTIONAL REQUIREMENT 3	
Working principle	**Description**
Muscle	
	**Sorting and cleaning.** The Arctic Scallops are separated from rocks and waste, and flushed to get rid of organisms and waste stuck on them.
	**Processing line.** The processing line will process the Arctic Scallop all the way to muscle.
	**Packing line**. The packing line will pack the Arctic Scallops, making them ready to be stored.
Whole shell	
	**Sorting and cleaning.** The Arctic Scallops are separated from rocks and waste, and flushed to get rid of organisms and waste stuck on them.

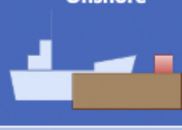
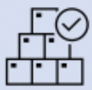
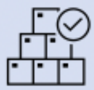
When the Arctic Scallop enter the vessel, the next step is dependent of the form of the material after the processing is done. If it is a goal to keep the Arctic Scallops as whole shell, the shells still needs to be sorted, separate the shells from the rocks, waste and other bycatch, and cleaned before going towards the storage. If the goal is to process the scallops all the way until muscle, there will still need to be sorting and cleaning of the shells, but there will also be a processing line, where the Arctic Scallops will go through many steps in order to achieve the form of muscle. Then the muscle are frozen and packed, in order to be ready to go towards the storage. It is also important whether the step of processing the scallops all the way until deliverance will happen on the vessel or if the shells will be delivered onshore as whole shells and then processed there. Hence the Classifying Parameters (CP3) becomes ”Form of material after processing” and ”Place of the processing”, and can be seen in Table 4.10.

Table 4.10: The Classifying Parameters for WP3

CLASSIFYING PARAMETERS FOR THE WORKING PRINCIPLES	
Form of material after processing	**Symbol**
Whole shell	
Muscle	
Place of the processing	
On the vessel	
Onshore	

For the CP of ”Form of material after processing”, the form can either be Whole shell or Muscle, and for the CP of ”Place of the processing”, it can happen either on the vessel or onshore after delivery of the Arctic Scallops. It is now time the make the Design Catalogue (DC3) for WP3 and CP3. The DC3 can be seen in Table 4.11

Table 4.11: Design Catalogue for CP3 and WP3

Place of the processing / Form of material at delivery	On the vessel 	Onshore 
Whole shell 		
Muscle 		
		
		

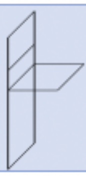
As seen in DC3 the processing process for the Whole shell or Muscle is the same, whether it happens on the vessel or onshore. It is also seen that the first step of processing the Arctic Scallops all the way until muscle is the same as the step of keeping them as Whole shell. So, if it is decided to go for processing the Arctic Scallops all the way until Muscle, it is possible to also keep them as Whole shell.

4.3.4 Functional requirement 4 - Storing the Arctic Scallops until deliverance at port

Now it time to store the Arcic Scallops. The search will now be for Working Principles (WP4) for FR4 ”Storing the Arctic Scallops until deliverance at port”. Now are the Arctic Scallop processed and are either in the material form of Whole Shell or Muscle. The next step is to make them ready to go to to the storage. WP4 can be seen in Table 4.12 When the shells are processed, it is time to store them. How it is stored depends on the form of the material, in this case how much the arctic scallops are processed. So the classifying parameters for the working principles is in this case the form of the material.

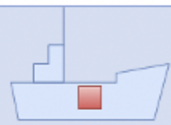
The Working principles

Table 4.12: Working Principles for FR4

WORKING PRINCIPLES FOR FUNCTIONAL REQUIREMENT 4	
Working principle	**Description**
Whole shell	
	**Live storage**. To keep the Arctic Scallops alive until deliverance.
Muscle	
	**Box**. The frozen muscles are packed in boxes.
	**Conveyor belt**. To transport the boxes to the freezer
	**Pallet**. The boxes are stacked on pallets.
	**Forklift**. To move the stacked pallets around.
	**Cargo lift**. To move the stacked pallets between decks.
	**Freezer**. The storage room is a freezer hold. Where the pallets with the stacked boxes are placed.

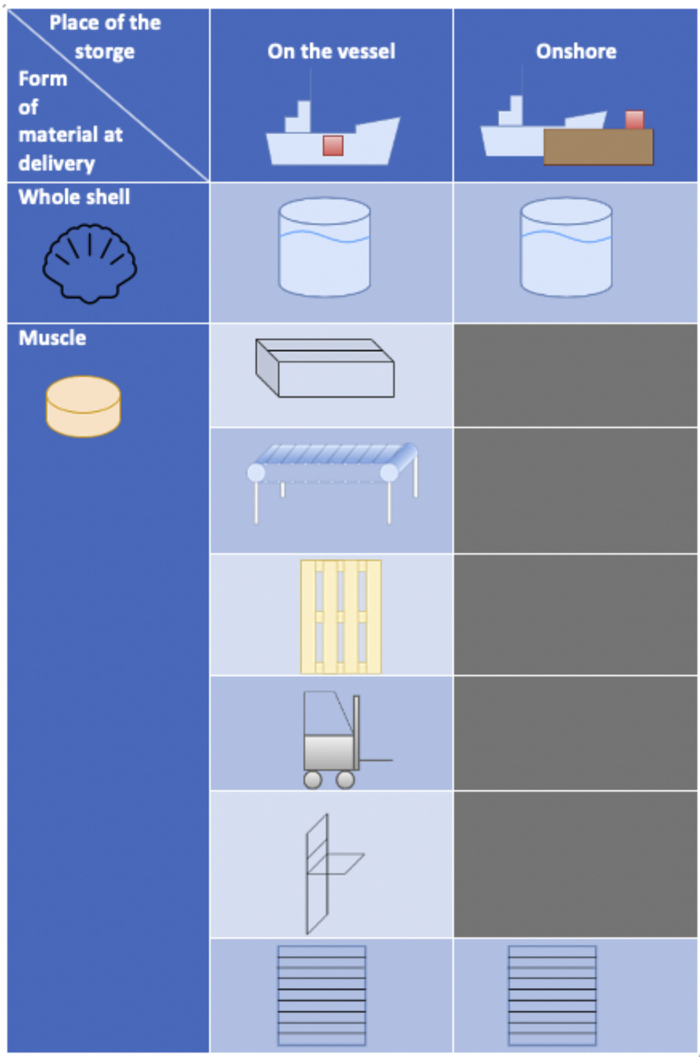
How the Arctic scallops is stored depends on the form of material. If they are kept as Whole shell, they can go directly to the live storage after being cleaned. But if they are processed until muscle, they need to be packed in boxes, after that the boxes is transported with the help of a Conveyor belt, and stacked on pallets before a forklift transport the pallets with the boxes to the frozen storage room. If the pallets is going to be moved between decks, a cargo lift will be used. The Classifying Parameters (CP4) for WP4, is "Form of material at delivery in port" and "Place of the processing", and can be seen in Table 4.13.

Table 4.13: The Classifying Parameters for WP4

CLASSIFYING PARAMETERS FOR THE WORKING PRINCIPLES	
Form of material at delivery in port	
Whole shell	
Muscle	
Place of the processing	
On the vessel	
Onshore	

The form of material at delivery in port can either be as Whole shell or Muscle, and the place of the processing can either be on the vessel or onshore. Now it is time to make the Design Catalogue (DC4) for WP4 and CP4, the Design Catalogue can be seen in Table 4.14.

Table 4.14: Design Catalogue for CP4 and WP4

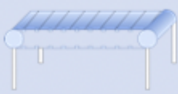


DC4 shows that if the form of material at delivery is whole shell, it will be a need for live storage both on the vessel and onshore. If the form of material at delivery is muscle, the packing must happen on the vessel, and they will be stored in a frozen storage, and there will be a need for a frozen storage onshore as well.

4.3.5 Functional requirement 5 - Deliver the arctic scallops at port

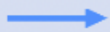
When the vessel is back in port, it need to deliver the arctic scallops. The search for the Working Principles (WP5) will be for FR5 ”Deliver the Arctic Scallops at port”. So in this step it is time to deliver the Arctic Scallop to port and bring them out to the costumers. WP5 can be seen in Table 4.15.

Table 4.15: Working Principles for FR5

WORKING PRINCIPLES FOR FUNCTIONAL REQUIREMENT 5	
Working principle	**Description**
Flow	
	**Pump**. To pump the Arctic Scallops from the live storage to port.
Technical	
	**Conveyor belt**. To transport the pallets from the vessel to port.
	**Crane**. To lift pallets from the vessel to port.
	**Forklift**. To move/lift the pallets from the storage and deliver at port.
	**Hatch**. The hatch can open up for easier delivery of the pallets from the vessel to port with the use of forklift.

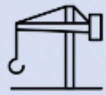
WP5 is dependent on the form of material. If the the form of material at delivery in port is Whole shell, it means that the shells are stored in live storage and can be delivered to port with the help of a pump, that keeps the flow. And delivered to a new live storage. If the form is muscle. it means that they are packed in boxes and stored in a frozen storage. And the pallets containing the boxes with scallops can be brought to port by the help of various technical equipment. One method is to transport the pallets on a conveyor belt from the vessel and all the way to port. The pallets can also be lifted to port with the use of a crane. Or a hatch on the side of the vessel can be opened, making it possible to deliver pallets from the vessel and to port with the help of a forklift. Hence, the Classifying Parameters (CP5) becomes ”Form of material at delivery in port” and ”Physicle Principles”, and can be seen in Table 4.16.

Table 4.16: The Classifying Parameters for WP5

CLASSIFYING PARAMETERS FOR THE WORKING PRINCIPLES	
Form of material at delivery in port	
Whole shell	
Muscle	
Physical Principles	
Flow	
Technical	

For the CP ”Form of material at delivery in port” the form can either be Whole shell or muscle. And for the Physical Principles it can either be Flow or Technical. And now it is time to make the Design Catalogue (DC5) for the CP5 and the WP5. DC5 can be seen in Table 4.17.

Table 4.17: Design Catalogue for CP5 and WP5

Form of Material / Physical Principle	Muscle 	Whole shell 
Technical 		
		
		
		
Flow 		

DC5 shows the solution field for FR5, and it is seen that the use of technical equipment is only possible when the material has the form of muscle, and the use of the flow principle is only possible when the form of material is Whole shell.

4.4 Combining working principles into working structures

Now that the design catalogues are made it is time to combine them and make them into the final design catalogue. The final design catalogue is called the morphological matrix and can be found in Appendix A. The morphological matrix gives an overview over the main functions that fulfill the overall solution and their respective working principles. In the morphological matrix it can be seen that there are many combinations that can lead to an overall solution. So a more systematic selection must be made, and by doing this distinguish between promising and non-promising combinations.

So now it is time to check the compatibility of the functions and the classification parameters. This is done by combining them into a matrix, called the Compatibility Matrix. For the different design compatibility matrix, the different combination will be evaluated and marked with different types of crosses all depending on how compatible they are with each other.

4.4.1 Compatibility matrix for FR1 and FR2

When looking at the classification parameters and the design catalogues for FR1 and FR2, that the placement of the Launch Recovery will affect the placement of the SH. The placement of the SH is a CP in both DC1 and DC2. So the Placement of the LARS is an important measure. As well as the physical principles of whether the Arctic Scallops should keep a flow when going from the collection unit in the SH to the vessel or if the should be used Technical Equipment instead. The Compatibility Matrix for FR1 and FR2 can be seen in Table 4.18.

Table 4.18: Compatibility Matrix for FR1 and FR2

FR1 / FR2	Placement of the Launch & Recovery		
	Inside a hangar	From deck	Through a moonpool
Flow	The Seabed Harvester is launched and recovered from a hangar. The Arctic Scallops is retrieved subsea from the Seabed Harvester to the vessel with a pump.	The Seabed Harvester is launched and recovered from the deck of the vessel. The Arctic Scallops is retrieved subsea from the Seabed Harvester to the vessel with a pump.	The Arctic Scallops is launched and recovered through a moonpool. The Arctic Scallops is retrieved subsea from the Seabed Harvester to the vessel with a pump.
Technical	The Seabed Harvester is launched and recovered from a hangar. The Seabed Harvester is recovered back to the vessel, and the Arctic Scallops are retrieved from the Seabed Harvester to the vessel with the help of technical equipment.	The Seabed Harvester is launched and recovered from the deck. The Seabed Harvester is recovered back to the vessel, and the Arctic Scallops are retrieved from the Seabed Harvester to the vessel with the help of technical equipment.	The Seabed Harvester is launched and recovered through a moonpool. The Seabed Harvester is recovered back to the vessel, and the Arctic Scallops are retrieved from the Seabed Harvester to the vessel with the help of technical equipment.

Solid cross	Very difficult to apply (do not pursue further)
Dashed cross	Can only be applied under certain circumstances (defer)
No cross	Compatible

For the physical principle of Flow, it is seen that it is important where the LARS is placed. If the LARS is placed inside a hangar and the Arctic Scallops is going to be pumped into the vessel, while the SH is still subsea, this is a possibility, but it is hard because as mentioned in Section 4.3.2, the SH and the pump must be controlled and stable enough to retrieve the Arctic Scallops, and the condition is rough at the fishing grounds, so there will be a lot of motion in the vessel, making it hard to control the pump when it is over the side. Hence, it will be hard to pump the Arctic Scallops from deck as well, with one exception, if it is done through a moonpool. So the placement of the LARS inside a hangar in combination with the physical principle of flow is marked as ”Can only be applied under certain circumstances” and the placement of the LARS on deck in combination with the physical principle of flow is marked as ”Very difficult to apply”. While the placement of LARS through a moonpool in combination with the physical principle of flow is marked as ”Compatible”.

For the physcial principle of Technical equipments, it is seen that this is compatible with all the three different options to place the LARS. This is due to the SH being recovered back up to the vessel, and locked. Then the Arctic Scallops is being retrieved by opening the collection unit in the SH.

4.4.2 Compatibility matrix for FR2 and FR3

When looking at the classification parameters and the design catalogue for FR2 and FR3, it is seen that the physical principle for FR2 is still an important parameter, in combination with the form of material from FR3. By looking at this it can be seen how the form of material affects the physical principles, and vice versa. The Compatibility Matrix for FR2 and FR3 can be seen in Table 4.19.

Table 4.19: Compatibility Matrix for FR2 and FR3

FR2 / FR3	Flow	Technical
Process until muscle	The Arctic Scallops are pumped into the processing facility. It is then further processed until it is only muscle left.	The Arctic Scallop are transported into the processing with the help of technical equipment. It is then further processed until it is only muscle left.
Keep as whole shell	The Arctic Scallops are pumped into the processing facility. They are then cleaned and washed and kept as whole shells.	The Arctic scallops are transported into the processing facility with the help of technical equipment. They are then cleaned and washed and kept as whole shells.

☒	Very difficult to apply (do not pursue further)	⋰⋱	Can only be applied under certain circumstances (defer)		Compatible

For the physical principle of Flow, it is seen from the Matrix that it is compatible both if the Arctic Scallops are processed until muscle or if they are kept as whole shell.

For the physical principle of Technical, it is also seen that it sis compatible both if the Arctic Scallops are processed until muscle or if they are kept as whole.

This could be due to that how the Arctic Scallops is brought in to the processing facility, is not affected by how they are planned to be processed, and vice versa. They are also "delivered" as Whole shell for both the physical principles.

4.4.3 Compatibility matrix for FR3 and FR4

When looking at the classification parameters and the design catalogues for FR3 and FR4 it is seen that both contains the form of material, but in different steps. For FR3 it regards how much the Arctic Scallops will be processed, and for FR4 it regards how which form the Arctic Scallops will be stored in. As seen in Table 4.14 when stating which form they will be stored in, it is also stated how they will be stored. The Muscle will be stored in a freezer, and the whole shell will be stored in live storage. The Compatibility Matrix for FR3 and FR4 can be seen in Table 4.20.

Table 4.20: Compatibility Matrix for FR3 and FR4

FR3 / FR4	Process until muscle	Keep as whole shell
Stored as muscle	The Arctic Scallops are processed until muscle, frozen, packed and stored in a freezer.	The Arctic scallops are cleaned and washed, and kept as whole shell. But stored as muscle.
Stored as whole shell	The Arctic Scallops are processed until muscle but stored as whole shell.	The Arctic Scallops are cleaned and washed, and kept as whole shell, stored in live storage.

Very difficult to apply (do not pursue further)	Can only be applied under certain circumstances (defer)	Compatible

For the Form of material after processing, it is seen that if the form of material is muscle it is compatible with the form of material at delivery if it is stored as muscle. And marked as "Very difficult to apply" if it is supposed to be stored as whole shell. That is impossible, if the Arctic Scallops is processed until muscle, they need to be stored as muscle.

It is the same if the form of material after processing is whole shell, then it is only compatible with storing it as whole shell as well and impossible to combine with storing it as muscle.

4.4.4 Compatibility matrix for FR4 and FR5

When looking at the classification parameters and the design catalogues for FR4 and FR5, the interesting part is the form of material at delivery, and combine that with which physical principle that will be used for delivering the arctic scallops from the vessel to port. The Compatibility Matrix can be seen in 4.21.

Table 4.21: Compatibility Matrix for FR4 and FR5

FR5 \ FR4	Stored as muscle	Stored as whole shell
Flow	The Arctic Scallops are packed and stored as frozen muscle. Pumped from the vessel and to port.	The Arctic Scallops are stored alive as whole shell. Pumped from the vessel and to port.
Technical	The Arctic Scallops are packed and stored as frozen muscle. Brought to port with the help of technical equipment.	The Arctic Scallops are stored alive as whole shell. Brought to port with the help of technical equipment.

Very difficult to apply (do not pursue further)	Can only be applied under certain circumstances (defer)	Compatible

For the physical principle of flow, this involves moving the Arctic Scallops with the use of a pump, this is compatible of the Arctic Scallops are stored as whole shell, du to them then being stored in live storage, which makes it possible to keep the flow. But the option of combining it with storing the Arctic Scallop as muscle, where they are packed in boxes, are marked with "Very difficult to apply". It is not possible to move pallets with boxes through a pump.

For the physical principle of technical, this involves moving the Arctic Scallops with the use of technical equipment, this could be a crane, a conveyor belt, or a forklift with the combination of a hatch that is opened on the side of the vessel. This is compatible with the form of material is stored as muscle. But marked as "Can only be applied under certain circumstances", when compiled with the form of material stored as whole shell.

4.5 Selecting working structures

Now that the compatibility matrix's is found, the compatibility between functions such as physical principle and the form of the materials, and placement of the equipment handling the material is found. It is seen that the form of the material is crucial in terms of which equipment to include on the vessel. It also affects the equipment and placement supporting the launch and recovery. It is also seen that there are multiple overall solutions. But trough the compatibility matrix's it is easy to at least eliminate the ones that er deemed not to work. But to firm of the different working structures it will be going further with the ones that are completeling compitable, and look at the different overall solutions within them. So all the ones marked as either "Very difficult to apply" or "Can only be applied under ceirtan circumstances" will not be looked at. Even though it could be possible to use the ones marked as "Can only be applied under certain circumstances" it will be to much effort, and it is more wisely to look into the ones that actually are compatible.

In Table 4.18 the placement of the launch and recovery and the physical principles looked into. It is seen that if the launch and recovery is placed by a moonpool the physical principle of flow is compatible. For the physical principles of flow, where the Arctic scallops are pumped from the SH subsea and to the vessel is compatible with placement of the launch and recovery through a moonpool. And for the physical principle of technical equipment, where the SH is lifted onboard the vessel and the Arctic Scallops are moved from the SH to the fabric with the help of technical equipment is compatible with placement of the launch and recovery system in Hangar, on deck and through a moonpool.

In Table 4.19 the physical principle of loading the arctic scallops into the vessel and the amount of processing the shells will go through is looked at. Here it is seen that all the different solutions is compatible with each other. So both the physical principle of flow, and the physical principle of technical equipment is compatible with when the shell is processed until muscle and processed to keep as round shell.

In Tabke 4.20 the amount of processing the shells will go through and the form and method the shells will be stored as is looked into. It is seen that there are two compatible solutions, the first is when the shell is processed until muscle and the shell is frozen, packed and stored in the freezer as muscle. The other one is When the shell is kept as round shell, and then stored alive.

In Table 4.21 the form and method of the shells when stored and the physical principle when they are delivered at port is looked at. Here there are also two compatible solution, and one which can only be applied under certain circumstances. But that solution will not be looked further in to. The two compatible solutions are When the shell is stored alive as round shell and delivered to port through a pump, and the other is when the shell is packed and kept frozen and delivered to port with the help of technical equipment.

So from this it is easy to see that the form of the material is an important factor in the different solutions.

From the solutions found from the compatibility matrices, it is found eight working structure sets.

4.5.1 Working Structure Set 1

In this Working structure the Launched and recovery is placed to go through a moonpool, the shells are retrived from the SH subsea and through a pump, they are being pumped in to the vessel in to a receiving bin and ready to go in to the fabric. From this the shell is processed all the way until it is only a muscle left. And it is then frozen and packed, and brought to a freezing storage, where it is kept until deliverance in port. When the vessel is at port ready to deliver the shells, the shells is delivered to port with the help of technical equipment.

$$Moonpool \rightarrow Flow \rightarrow Muscle \rightarrow Frozen\ storage \rightarrow Technical$$

Figure 4.7: Working Structure Set 1

4.5.2 Working Structure Set 2

In the second Working Structure the Launch and recovery is placed through a moonpool, and the shells are retrived from the SH subsea and through a pump, they are being pimped in to the vessel, and in to the receiving bin and ready to go in to the fabric. From there, the sehlls are cleaned and washed and har brought to live storage. When the vessel is in port the shells are being pumped from the vessel and in to port to a new live storage.

$$Moonpool \rightarrow Flow \rightarrow Round\ shell \rightarrow Live\ storage \rightarrow Flow$$

Figure 4.8: Working Structure Set 2

4.5.3 Working Structure Set 3

The flow of the Working Structure Set 3 can be seen in Figure 4.9. In the third Working Structure the Launch and revoery is placed to go through a moonpool, when the SH is ready to deliver the shells to the vessel it is lifted onboard the vessel and the shells is retrieved from the SH with the help of technical equipment. The shells are then ready to go to through the fabric. The shells are processed all the way until it is only muscle left. The shells are ten frozen and packed, and stored in a freezing storage until delivery. The shells are delivered in port with the help of technical equipment.

$$Moonpool \rightarrow Technical \rightarrow Muscle \rightarrow Frozen\ storage \rightarrow Technical$$

Figure 4.9: Working Structure Set 3

4.5.4 Working Structure Set 4

The flow of the Working Structure Set 4 can be seen in Figure 4.10. In the fourth Working Structure the Launch and Recovery system is placed to go through a moonpool. When the SH is ready to deliver the shells to the vessel it is liften onboard the vessel and the shells i retrived from the SH with the help of technical equipment. The shells are then cleaned and washed and stored in live storage. When the vessel is at port the shells will be delivered to port by being pumped from the vessel and to port.

$$Moonpool \rightarrow Technical \rightarrow Round\ shell \rightarrow Live\ storage \rightarrow Flow$$

Figure 4.10: Working Structure Set 4

4.5.5 Working Structure Set 5

The flow of the Working Structure Set 5 can be seen in Figure 4.11. In the fifth Working Structre the Launch and Recovery system is placed in hangars on the side of the vessel. The SH is then lifted in to the hangar and the shells are brought in to the fabric with the help of technical equipment. The shells are then processed all the way until it is only muscle left, the shells are then frozen, packed and stored in a freezing storage until delivery. During delivery the shells are brought to port with the help of technical equipment.

$$Hangar \rightarrow Technical \rightarrow Muscle \rightarrow Frozen\ storage \rightarrow Technical$$

Figure 4.11: Working Structure Set 5

4.5.6 Working Structure Set 6

The flow of the Working Structure Set 6 can be seen in Figure 4.12. In the sixth Working Structure the Launch and Recovery system is placed in hangars on the side of the vessel. The SH is then lifted in to the hangar and the shells are retrived from the SH with the help of technical equipment and loaded in to the fabric. From there the shells are cleaned and washed and stored in live storage. When the vessel is at port the shells will be delivered to port by being pumped from the vessel and to port.

$$Hangar \rightarrow Technical \rightarrow Round\ shell \rightarrow Live\ Storage \rightarrow Flow$$

Figure 4.12: Working Structure Set 6

4.5.7 Working Structure Set 7

The flow of the Working Structure Set 7 can be seen in Figure 4.13. In the seventh Working Structure the Launch and Recovery system is placed on deck. The SH is lifted up on deck and the shells are retrieved from the SH with the help of technical equipment and loaded in to the fabric. From there the shells are processed all the way until it is only muscle left, the shells are then frozen, packed and stored in a freezing storage until delivery. During delivery the shells are brought to port with the help of technical equipment.

$$Deck \rightarrow Technical \rightarrow Muscle \rightarrow Frozen\ storage \rightarrow Technical$$

Figure 4.13: Working Structure Set 7

4.5.8 Working Structure Set 8

The flow of the Working Structure Set 8 can be seen in Figure 4.14. In the eighth Working Structure the Launch and Recovery system is placed on deck. The SH is lifted up on deck and the shells are retrieved from the SH with the help of technical equipment and loaded in to the fabric. From there the shells are cleaned and washed and stored in live storage until delivery. During delivery the shells are brought to port by being pumped from the vessel and to port.

$$Deck \rightarrow Technical \rightarrow Round\ shell \rightarrow Live\ storage \rightarrow Flow$$

Figure 4.14: Working Structure Set 8

4.6 Firming up solution variants

Now it is time to firm up solution variants from the different sets of working structures. To do this an example study will be conducted on the fish gorund.

Up until this step, it is not enough information to lead to a definite solution. Therefore, is it now time to firm up solution variants from the different sets of working structures found in the thesis. The fishing will take place in the Barents Sea, and the conditions of the fishing ground is explained in greater detail in Section 2.10.1. The more specific area is around Bear Island. The planned operational profile for the vessel can be seen in 2.10.

For this example study the preferences and elimination are based on the following criteria:
A - Be compatible with the overall task and with one another
B - Be realisable in respect of performance, layout and costs
C - Incorporate safety measures

Before starting to search for solutions in the different working structure sets, it can already be seen that some of the working structures does not meet the set criteria.

Firstly, it is the WP where the launch and recovery is placed on deck. This will lead to that the crew on the vessel will need to be out on open deck to operate the SH. And monitoring the SH, and making sure the operations goes as planned. This is in conflict with criterion C, incorporate safety measures. It is always a risk to work on open deck, but it is especially risky due to the conditions the vessel will operate in.

Secondly, it is the WP regarding the form of material. When looking at the operational profile for the vessel it is planned to be out fishing for 4-5 weeks at a time. Due to lack of information regarding how long the Arctic Scallops can be kept in live storage, and how it will affect the quality, more information will be needed in order to conclude if it is realisable.

After the elimitation of these WPs, it is time to searching for solutions in Working Structure Set 1, Working Structure Set 3 and Working Structure Set 5.

4.6.1 Working Structure Set 1

For the WS set 1 the LARS is placed through a moonpool. And with the use of flow the Arctic Scallops are brought to the vessel and ready to be processed all the way until only muscle left, then frozen and packed, transported to the frozen storage and delivered to port with the help of technical equipment. These WPs are all compatible with each other, the safety of the crew is better ensured when the SH is launched and recovered through the moonpool, and the quality of the Arctic Scallops stays good during the 4-5 weeks of fishing.

4.6.2 Working Structure Set 3

For the WS set 3 the LARS is placed through a moonpool, and the SH is recovered back on the vessel before the Arctic Scallops enter the processing facility and is processed all the way until muscle, they are then frozen and packed and stored at the frozen storage. What differs this from WS Set 1, is how the Arctic Scallop is brought to the vessel from the collection unit in the SH. In this case this happen subsea, and a pump is lowered down to retrieve them.

4.6.3 Working Structure Set 5

For the WS set 5 the LARS is placed inside a Hangar, the SH is recovereD back on the vessel before the Arctic Scallops enter the processing facility, then they are processed all the way until muscle, frozen and packed, and stored in frozen storage. Then brought to port with the help of technical equipment. By placing the LARS in a hangar, the safety of the crew is better, and the working condition.

Chapter 5

Discussion

The aim of this discussion is to interpret the results found in the previous chapter. The results found in this thesis will be evaluated and discussed. It will start with the chosen method, and discuss how it worked in this type of task.

5.1 Results

From Section 4 it can be seen that there are several solutions to an overall system on the vessel. As seen, the system on the vessel is dependent on the form of material, which in this case is whether the Arctic Scallop is kept as whole shell or processed all the way until muscle. The first and the second step is not dependent on this, due to the Arctic Scallops always having the form of whole shell at the seabed, and when they are transitioned from the collection unit in the SH and in to the vessel. The next tree steps are dependent on the form of material. The first two steps are dependent on the placement of the LARS, and the SH. The Morphological Matrix, seen in Appendix A, is made up of all the different Working Principles and Classifying parameters. The Morphological Matrix can be used to make many different solutions.

In this thesis, the result from the conceptual design method were eight different Working Structure Sets. After firming up solution variants, where criteria needs to be fulfilled, five out of these eight were eliminated.

The Conceptual Design method, worked well in this thesis. It is hard when a new harvesting technology is involved where it has not been used on other vessels before. The method makes you think outside the box, and start from scratch with the abstraction. It is natural to already when starting new projects to eliminate alternatives, before it is even an alternative. But this method forces you to keep all alternatives possible, and through a step by step analysis firm up solutions that work together. It is not before the last few steps the elimination starts, and then maybe one of the alternatives that would get eliminated in other methods, is the ones that is one of the working solutions for this project.

After the step of firming up the compatibility matrices, the ones that were deemed not to work together were eliminated. And the result from the step of compatibility matrices, ended up in forming eight sets of working structures.

From the eight sets of working structure it was firmed up solution variants with the elimination based on the following criteria:
A - Be compatible with the overall task and with one another
B - Be realisable in respect of performance, layout and costs
C - Incorporate safety measures

The first four Working Structure sets, starts with the LARS placed to go through a moonpool. Then two of them will lift the SH onboard the vessel, for then emptying the collection unit, and the other two will lower a pump down to collect the Arctic Scallops subsea. Up until this step all four of them can are suitable. But the next step, where the form of material is determined, two of the options will be eliminated. It is the ones regarding keeping the Arctic scallops as whole shell. Due to lack of information on how to keep the Arctic Scallops fresh and alive for as long as up to 4-5 weeks on the vessel. So Working Structure Set 2, and Working Structure Set 4 is eliminated. Working Structure Set 1, and Working Structure Set 3 is still compatible. Both of them process the Arctic Scallop until it is only muscle left, and deliver to port with the help of technical equipment. The one step that differ these two from each other, is the step where the Arctic Scallops is retrieved from the collection unit in the SH. For Working Structure Set 1, this happens subsea by the use of a pump, and for Working Structure Set 3 the SH is retrieved back on the vessel before the Arctic Scallops are retrieved. Both of these methods work, but if the Arctic Scallops is retrieved subsea, it can save a lot of time, because the SH is just kept subsea. Instead of launch and recovering it many times during the harvesting.

The next two Working Structure sets, starts with the LARS placed in a hangar. And the SH is retrieved back on the vessel before the Arctic Scallops are collected. The next step regarding the form of material, the one with the option of keeping the Arctic Scallops as whole shell, is eliminated, due to the same reason as described above in this section. Therefore Working Structure Set 6 is eliminated, and Working Structure Set 5 is still compatible. The next step is that the Arctic Scallop is processed all the way until muscle, stored in a freezer hold and delivered to port with the use of technical equipment.

The last two Working Structure sets, starts with the LARS placed on deck. Both of these are eliminated due to this placement. One of the important measures in this project, is to ensure the safety for the crew onboard the vessel. When the LARS is placed on open deck, the crew will need to out on open deck to operate the SH, leaving them exposed to the rough conditions. So to avoid hazardous events, this option is eliminated.

Therefore the three Working Structure sets that's left, and is a suitable solution alternative for the vessel that is going to harvest Arctic Scallops in the Barents Sea, is Working Structure Set 1, Working Structure Set 3 and Working Structure Set 5.

This result is a bit surprising, from the initial plan to place the LARS on deck, to the final solution alternative where none of them have an option to place the LARS on deck. Through gaining information from the shell scraping industry, and vessels using ROV and vessels with similar technology, the different alternatives where made up. And by doing the abstraction step, a lot of different alternatives were kept as an option, instead of just going forward with a few.

An solution that has not been an option during the result part, is to have a combination with both frozen muscles and whole shell. If the vessel anyway is going to process the Arctic Scallops all the way until muscle, they need the processing line, this includes the washing and cleaning, that is the only processing the whole shells are going through. So that is already placed in the vessel. Another requirement is to have the live storage, which will need some space. That would be in addition to the frozen storage. So this would be an interesting option to look at for further work.

Chapter 6

Conclusion and Further Work

The results from conducting the Conceptual Design method, were three final solution variants. The final solutions variants were found through firming up solution variants using a specific location. The three final solution variants:

1 - Working Structure Set 1:

The LARS and SH is placed through a moonpool, the Arctic Scallops is retrieved from the SH subsea with the help of a pump, then processed all the way until muscle. The muscles is then frozen and stored in a freezer hold, and delivered to port with the help of technical equipment.

2 - Working Structure Set 3:

The LARS and SH is placed through a moonpool, the Arctic Scallops is retrieved from the SH on the vessel with the help of technical equipment, then processed all the way until muscle. The muscles is then frozen and stored in a freezer hold, and delivered to port with the help of technical equipment.

3 - Working Structure Set 5:

The LARS and SH is placed inside a hangar, the Arctic Scallops is retrieved from the SH on the vessel with the help of technical equipment, then processed all the way until muscle. The muscles is then frozen and stored in a freezer hold, and delivered to port with the help of technical equipment.

These final solution variants fulfill the functions and criteria needed to perform the desired operation. In order to determine the layout and conducting a detailed design more research needs to be done. The next step would be the embodiment design.

6.1 Further work

For the further work, it would be a goal to find the volumes to the form. And by finding this, make a general arrangement for such a vessel.

It would also be to interesting to gather more information on the alternative to keep the Arctic Scallops in live storage, and look into if there is a possibility to have both freezer hold and live storage on board the same vessel.

A goal for further work is to have a bigger focus on risk. Evaluating the designs in regards with the overall risk.

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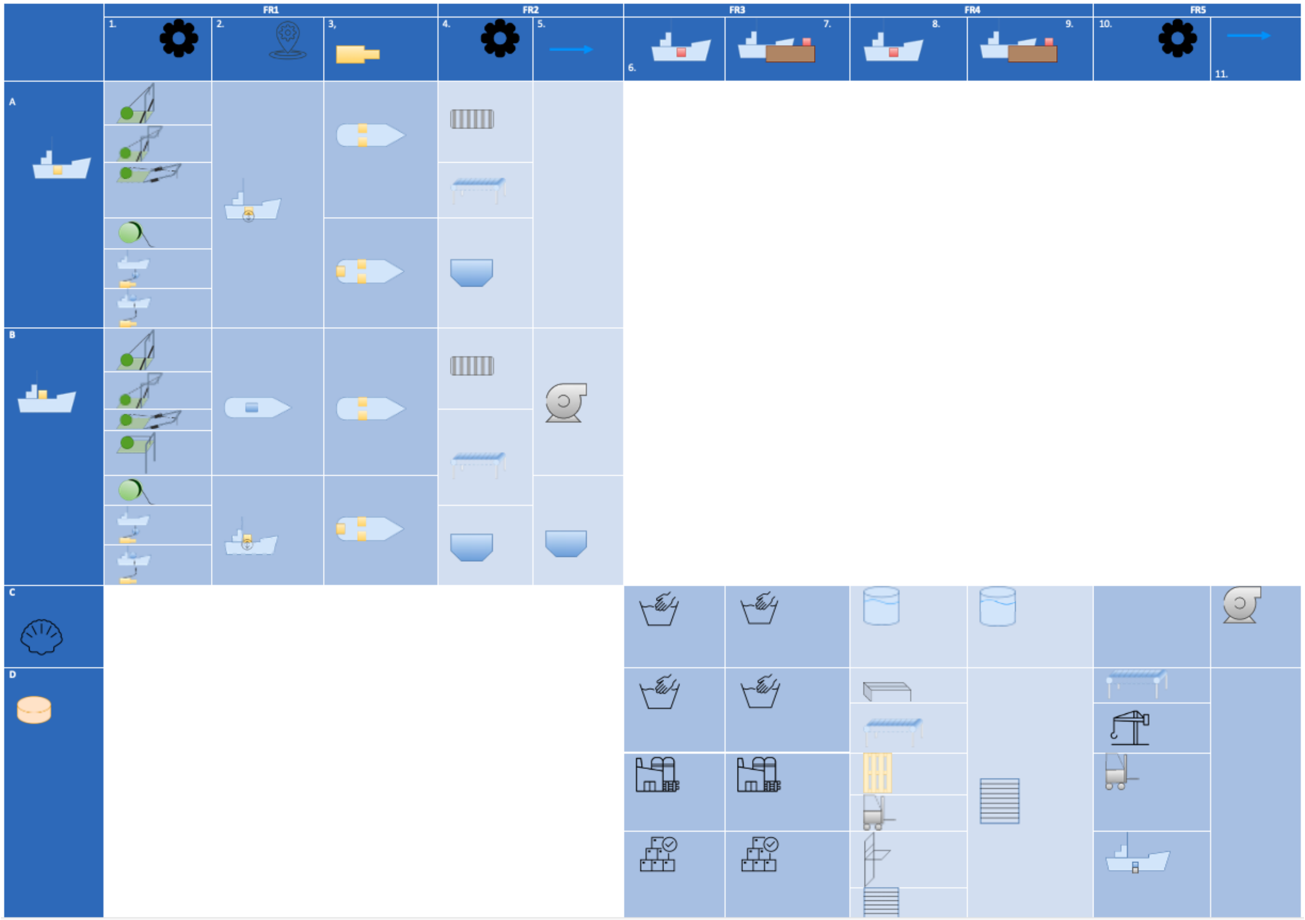
Appendix A

Morphological matrix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