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A further development of tank for oyster production

Master's thesis in product development

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Cover: The rendering for the final concept designed in this project.

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Abstract

In order to make food supply more sustainable, there is a need to redirect the protein intake from red meats to more sustainable sources like oysters or mussels since they are lower in the food chain. Thus, the growing of these kinds of organisms is an emerging market.

In analyses of the lifecycle of these organisms it has been found that they are highly sensitive to predators in the early stages of their lives, the spawn state. They need to grow in a sheltered environment with nutrients in flowing water but no excessive motions. This put high requirements on the technical systems used to grow them. Additionally, since the fishing industry has tight margins, the cost of manufacturing and maintenance of the system could be a key factor.

In the previous project, a tank for raising oyster seedlings was designed. In this project, the product development methodology is used to further develop the previous project to meet customer needs.

Keywords: aquaculture, oyster growing, sea based growing system, GRP structure, product development

Acknowledgements

I would like to thank Per Mottram Hogström, who is both my supervisor and examiner in this project, for the guidance, patience and valuable feedback from him. Secondly, I would like to thank Kristina Svedberg who spend quite much time carefully answered my background questions.
Finally I want to thank my parents for all the support from them.

Haoyuan Ren, Gothenburg, January 2022

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1
Introduction

In order to make food supply more sustainable, there is a need to redirect the protein intake from red meats to more sustainable sources like oysters or mussels since they are lower in the food chain. Thus, the growing of these kinds of organisms is an developing market (Röös et al., 2021).

In analysis of the life cycle of these organisms it has been found that they are highly sensitive to predators in the early stages of their lives, the spawn state. They need to grow in a sheltered environment with nutrients in flowing water but no excessive motions. This put high requirements on the technical systems used to grow them. Additionally, since the fishing industry has tight margins, the cost of manufacturing and maintenance of the system could be a key factor (Lindegarth, 2012).

1.1 Background

In the previous projects, a spawn growing tank for growing oyster spawns has been developed (Strand et al., 2018). It is a floating circular structure, moored to the bottom of the sea. For this system, the following main areas of improvement are identified
1. The method of assembly with bolt and glue should be improved.
2. Some components could be fabricated using more affordable materials.
3. The current packing scheme of the system requires 5 containers which increased the transportation cost and could be further optimized.

Thus, a further development is carried out in this project on the spawn growing tank to try to find an optimized concept.

1.2 Aim and background questions

The main aim of this project is to develop a tank for growing oyster or mussel spawns, the cost of it should be affordable and the growing condition of oyster spawns should be the same or better than the current one.

Before starting, background questions are raised to get an understanding of the market, the views from customers and search for available technology could be used.

The main background questions that should be answered are the following:
1. What kinds of technology is used in growing spawns?
2. How does the current spawn growth tank work?
3. What are the customer needs (what features customers will be happy to see on the new product)?

Evaluation:
1. The basic requirements are fulfilled.
2. Use finite element analysis to check if the product could withstand expected load from environment and maintenance.
3. The assembling of the product is optimized.
4. The transportation options become more affordable.
5. The cost reduced or kept the same.

1.3 Objectives

In order to achieve the aim, the objectives are set as follows:
1. Apply product development methodology to the design from the previous project.
2. Calculate and make sure the cost is still affordable since cost is a key factor since the since the fishing industry has tight margins.

1.4 Methodology

This project aims at doing an incremental improvement to existing products, which means this project may only involve adding or modifying some features of existing products in order to improve the performance or reduce the cost of current products (Ulrich, Eppinger, & Yang, 2020).

In order to make sure that the developed products from this project fulfills the needs from customers and that it does not breach any existing laws, a number of different approaches will be used to collect as much information about the current product as possible. The findings of these approaches will be presented in following chapters in the full report and the approaches used is introduced here.

The primary information sources used in the project are gathered by survey and the study of the current product. For some parts of the project, since there is no first hand information available, in these cases, secondary information sources were used, these ranged from literature to the subjective opinion from customers, as well as information about companies given by the the company itself, which might be seen as biased.

2

Pre-study

To make the new product development process smoother, a pre-study for collecting information and knowledge is necessary. In this chapter, market analysis and technical analysis are carried out. Market analysis is used to find whether there are similar products or patents registered in the current market to identify potential competitors, while technical analysis is used to find feasible technologies and learn the existing products from the previous project to find directions for improvement.

2.1 Market Analysis

A section of the market analysis was conducted through first-hand information obtained from survey and literature, mainly consisting of information regarding general information about the identified competitors and the state of the market in general was mainly sourced online and from literature.

Some of the information about the current market and competitors were either seen as biased, or was simply not available. For example, on what products in other segments might be competing with the tank.

Since this product hasn't been decided to be released to the market, the market analysis is a brief one here which aims at to get better understanding and guide the development of the product.

2.1.1 Competitor analysis

The main market segment for the product is targeted to the offshore shellfish seedling rearing equipment market. Other applications could be, after doing some adaptions, feed other kinds of species that need to be grown in a protected environment in the sea.

According to the previous report, there are 4 kinds of systems are used for growing oysters in the market: (Strand et al., 2018)
1. extensive dam cultivation
2. semi intensive pond cultivation
3. intensive cultivation system

4. semi closed cultivation systems

Among them, the companies who produce intensive cultivation systems or semi closed cultivation systems could be viewed as direct competitors.

2.1.2 Competitive strategy

There are quite many players already existed in the oyster market, since they already have technologies for growing oysters of good quality and high efficiency. Customers have accepted the current price and obviously they don't want pay more money for the same goods. Therefore, as a phase for growing oysters, the cost become very sensitive to win the market and a cost leadership strategy should be applied in developing this product.

Cost leadership strategy requires the firm to compete on production efficiency, either through economies of scale, use of superior manufacturing methods, low-cost labor, or better management of the production system. Design for manufacturing methods are therefore emphasized in the product (and process) development activities under this strategy. (Ulrich et al., 2020)

2.2 Customer Needs Analysis

In this chapter customers and possible stakeholders are identified. Due to the Covid situation, the main source of collecting qualitative data is by conducting interviews through internet.

Due to the fact that this project is being carried out without a supplier being identified, there is no possibility to ask questions directly to the supplier of the product. However, people working closely with the product are available for in-depth interviews regarding their view on it.

2.2.1 Customer and user identification

The customers for the product are identified as the companies who would like to use this product to grow oyster seeds for both research and commercial use. Therefore, the stakeholders determined are the employees, suppliers and customers of those companies. Furthermore, perhaps there will also be third part companies who take the response for installing and doing maintenance for the equipment, therefore, those companies and their employees are also considered as stakeholders.

Further, all governments and countries that have sovereignty over the sea areas where are used to grow oyster seeds could also be considered as stakeholders. As the security and safety of their environment might be related to the safe operation of the product.

2.2.2 Interview

Due to the pandemic of covid-19, the interview with Kristina Svedberg, who works as a marine biologist for Bohus Havsbruk, was carried out through E-mail. Her role in the company is to participate in research projects regarding mussel and oyster aquaculture, both on a global and national scale, as well as minor research inside the company.

2.2.3 Needs about the function

The aim of the customers who want this product to be designed is to create a barrier system between the oysters and the sea. At the moment, only flat oysters are allowed to be grow in Sweden, not pacific oysters. Since the pacific oyster is an invasive species in Sweden, and if flat oysters are grown straightly in the sea, they might get spat from the pacific oyster as well.

This system should be able to filter seawater that goes into the tank in order to get rid of the issues with other oyster species or toxic substances. The product should be able to carry a water pump of certain size and other equipment for measuring temperature, salinity, pH, etc.

Insulation of the tank and options for heating the water in the tank must be considered.

It is important that the tank can take normal wave heights in inshore habitats. The highest waves will occur in the winter/fall season, and the oyster spat is only in the water during late summer/early fall.

Thus, if the tank can sustain the wave heights during winter storms, then there is no risk of spat falling into the tank during the summer months.

The location of the tank is protected, but the construction must be able to withstand sea conditions with a significant wave height of 1.5m, which gives a good margin to the actual sea condition inland.

This controls the tank's free board to 1.5m as leakage of surrounding water into the tank can cause predators and alien species to enter the tank.

2.2.4 Some specified requirements

The volume of the tank should be about $500m^3$ and the depth of the tank must be more than 1m to enable hanging of collectors. But, the tank should also be as shallow as possible to maximize the area and minimize the depth for optimal heating.

To avoid the accumulation of sediment, the inside of the tank should be smooth and the bottom should have a slope towards a drainage hole that allows water to change during the growing season.

The maintenance of the tank should be as low maintenance as possible, and, as all industries, fairly cheap. It is the best if only one or two persons are needed when doing maintenance.

Design for manufacturing and assembling must be taken into account to make sure the transport of the tank could take place in only 40' containers.

Table 2.1: List of customer needs, collected from the interviews.

Customer needs list	
No.	**Need**
1	fairly cheap
2	create a barrier system between the oysters and the sea
3	filter seawater that goes in to the tank
4	be able to carry a water pump and other equipment
5	be able to carry a water pump and other equipment
6	Insulation and options for heating the water in the tank
7	can take normal wave heights in inshore habitats
8	good sea properties in the sea conditions that can be expected
9	could defend marine species attached to the bottom of the ship.
10	as low maintenance rate as possible
11	volume is estimated to be about $500m^3$
12	The tank must be deeper than 1m
13	be able to change water inside during the growing season.
14	manufacturing and installation of the tank must be considered
15	transport should take place in only 40' containers.
16	Easy to install or move, it's best to do it with just one boat

2.3 Technology and Product Analysis

All information regarding emerging technologies and products are acquired through patent searches in a number of different patent databases, using a variety different keywords, the results of the patent search was then put in a spreadsheet where the patents were categorized depending on relevance. Further, a bench marking study was conducted, using the competitors found in the market analysis, information regarding their products were found and compared against each other. The study on the current tank was conducted using both the results from the interviews and inspection of the product sample at hand.

2.3.1 Patent search

Before starting the develop process, a patent search on Espacenet is carried out to make sure the product to be designed will not infringe any existing patents within the scope of application and determine the freedom of design.

Firstly, an overall search of the patents was carried out to learn about the trend of this field. 5 different keywords were used and the number of the result are on the figures below. The red line in the figure means the number of patents registered during the year and the black line in the figures means cumulative.

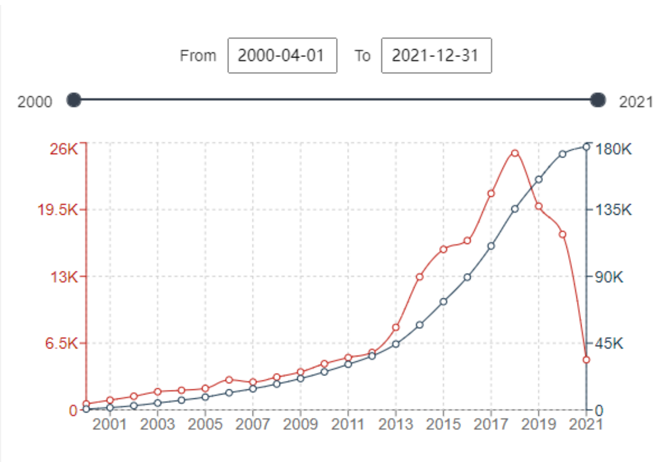

Figure 2.1: Search result from Espacenet with keywords: Aquaculture

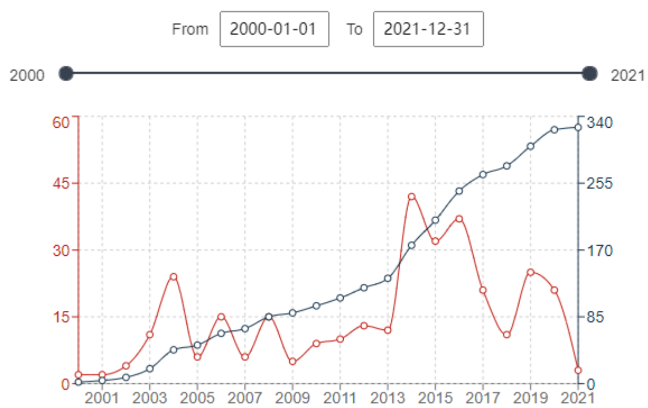

Figure 2.2: Search result from Espacenet with keywords: Aquafarm

As can be seen from the figure 2.1, the number of patent registrations for the entire field, which is represented by the keyword 'aquaculture' reached a high point in 2018 and started to decline after. And in figure 2.2, the number of patents related to 'aquafarm' has not been too many and has generally declined after 2014.

Regarding the target creatures raised, and as shown in the figures below, three keywords Shellfish, Ostrea Edulis and Flat Oyster are used here. Shellfish is one of the broadest and has the largest number of related patents. The number of patent registrations on shellfish peaked at nearly 180K in 2017 and started to fall back. As the breeding goals of the products designed in this project, the search results of the two keywords Flat Oyster and Ostrea Edulis also have similar trends.

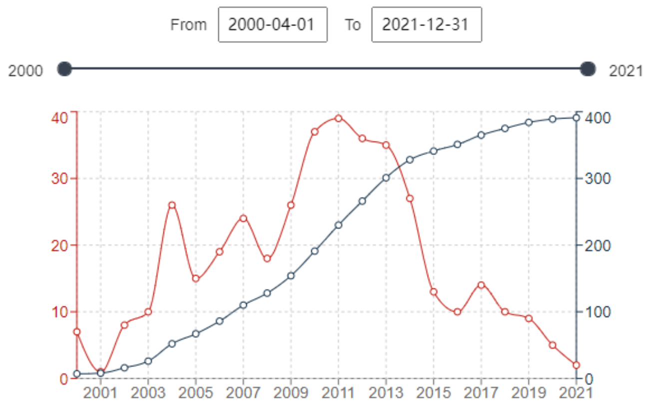

Figure 2.3: Search result from Espacenet with keywords: Ostrea Edulis

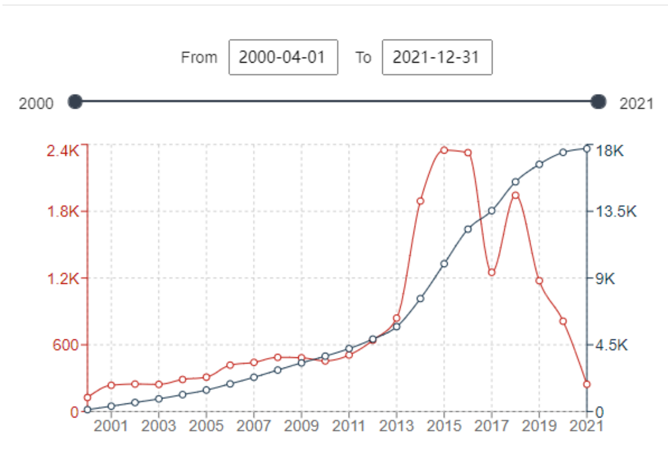

Figure 2.4: Search result from Espacenet with keywords: Flat Oyster

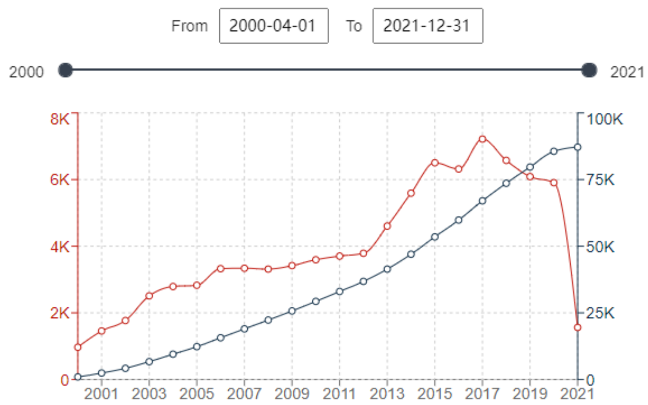

Figure 2.5: Search result from Espacenet with keywords: Shellfish

Overall, the number of related patent registrations has been decreasing year by year after 2018. Since this product is to be operated inside Sweden, patents registered inside Sweden has been checked to make sure this product will not conflict with them. At the same time, the possibility for this product to be introduced into a larger area in the future makes it also necessary for having a patent search for patents all over the world to learn some knowledge about the trend.

Inside Sweden, 19 results obtained from the keyword aquaculture and 9 from the keyword shellfish. 5 among them are relevant to this project and should be avoided, they are listed below (*espacenet*, 2021).

Table 2.2: List of customer needs, collected from the interviews.

Patent No.	Content
SE1600209A1	Growing plants in a container
SE1650586A1	Floating bioreactor
SE1751538A1	a method for feeding fish
SE0502246L	Cylindrical catchment cage for shellfish
SE1950755A1	A land-based aquaculture system

Additionally, since the Norwegian company which is called 'Aquafarm' has their product Neptune 3 referenced in the previous design is also a semi closed cultivation system, the patents registered by its developers are listed below. A total of 5 related patents were registered for their products in Norway (*espacenet*, 2021).

Table 2.3: List of patents from 'Aquafarm'

Patent No.	Content
CA157670S	Bottom central element for a fish cage
CA157671S	Wall panel for a fish cage
CA157672S	Fish cage
CA157669S	Bottom panel element for a fish cage
NO20120327A1	Luke for merd

2.3.2 Study of previous project

Since this is a further development of a previous project, a study on the previous design to see what could be enhanced is essential.

In the previous project, the structure design of a sea-based oyster system has been carried out as shown in the drawing (Figure 2.6), It has 5.5m in height and 18m in width (Strand et al., 2018).

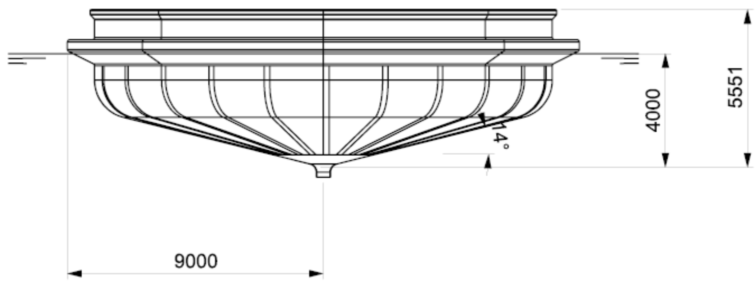

Figure 2.6: Drawing of the design from previous report

Figure 2.7 from previous report (Strand et al., 2018) shows the Isometric and Exploded view of the design from the previous project. As shown in the figure, the tank designed in the previous project consists of 8 side walls with associated floating tanks, 24 bottom sections and two different bottom parts with an integrated drainage hole. The dimensions of the parts, see drawings in the appendix for more details, means that all parts of the tank can be packed together in 5 40 'containers.

The condition of parts in containers are shown in the figure 2.8 from previous report (Strand et al., 2018).

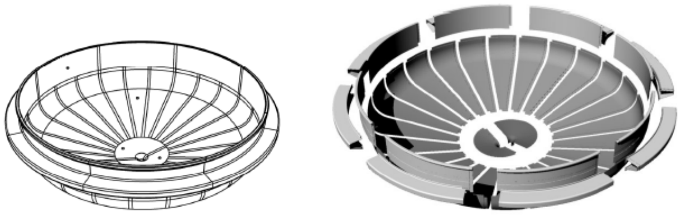

Figure 2.7: Isometric and Exploded Viewing

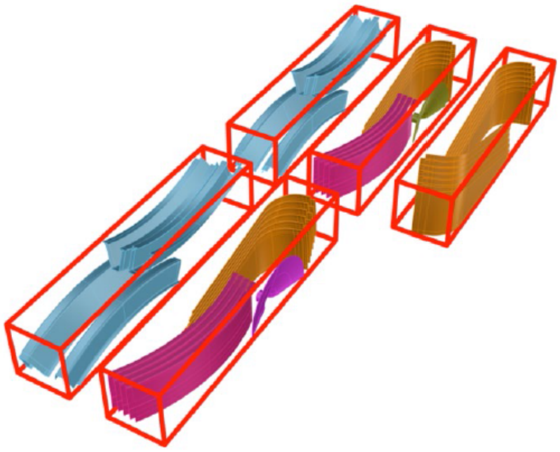

Figure 2.8: Isometric and Exploded Viewing from the design of the previous report

2.3.2.1 Filtering and pumping

A filter and pumping system are chosen in the previous project. It has a capacity of fill the entire tank in 4 hours or replace a quarter of the tank's water volume.

The Kjaergaard KSF4-pump and a Faivre Rotoclean Series 80 filter are chosen as the pump and filter equipment used on the tank.

Additionally, if there is a need for circulation of the water mass within the tank, a simple submersible propeller pump of the model generator, i.e. such a propeller pump that is normally mounted under boats and jetties during the winter to prevent icing, was chosen. A 0.5 kw Kasco De-Icer pump is easy to be lowered to the bottom of the tank using two ropes and then create a circulation of the entire tank volume.

2.3.3 Calculation

Results from the stability shows that according to the water density inside and outside the water tank, the draft of the water tank will fluctuate with 6.3 cm, which is within the error range of other stability calculations.

When the water depth in the water tank is constant, the fluctuation of the draft will also cause the load fluctuation of the water pressure inside and outside the water tank. However, this has little effect on strength.

The calculation about seaworthiness indicates that heaving and rolling of the tank are not be a significant problem for the structure.

3
Concept Development

This chapter contains the concept generation process and how concepts were compared against each other to choose the concept with the highest potential. The concept development phase starts with the requirement specification to clarify the specification of the product. Later, the morphological matrix is used to collect ideas related to functions and concepts generated evaluated by the Pugh matrix to find out the one with the highest potential to go ahead.

3.1 Requirement specification

When developing a product, the develop team must make sure they are on the right way, which means the product will fulfil the needs from the customer as a good trade-off between quality and cost.

The customer needs and requirements obtained by the develop team usually contain some relatively subjective description. In more detail, customer needs are explained in the “language of the customer.” Customer needs such as “the tank should be easy to install” or “the tank should be a stable one” are in terms of the subjective quality of the descriptions. These kinds of descriptions are literally helpful in obtaining a clear understanding of the issues that interest customers, they seldom provide specific guidance about how to develop the product (Ulrich et al., 2020).

For this reason, a set of requirement specification will be established to clarify in precise and measurable details about what the product must do. For example, in contrast to the customer need that “the suspension is easy to install,” the corresponding specification of “the tank should be easy to install” might be translated into “the average time to assemble different components into a tank is less than 2 hours” and ‘’the installation time of the tank is less than 1 hour”.

A specification in this chapter consists of a metric and a value. For example, “average time to assemble” could be a metric, while the value of this metric could be “less than 2 hours”.

The target setting of the requirement specification are mainly based on the customer’s needs and due to lack of reference, the target of the production cost are based on those common products in the same market.

The level of importance here means as follow:
the importance level 3 here means critical metrics that are essential to the product. Their absence may directly affect the realization of other metrics The importance level 2 here means important metrics that a successful design must have. The missing of them may cause disability of the product. The importance level 1 here means metrics that should be taken into consideration. When conflicting with other metrics, they may be appropriately relaxed after a trade-off.

Table 3.1: Specification of the requirements

	Requirement specification			
Metric No.	Metric	Importance	Verification	Target
1	Production cost	1	Cost calculation	2million sek
2	Be able to heat the water inside	2	Design	Have a structure
3	The interval of each maintenance of the tank (times/year)	2	Design	2 times/year
4	Volume of the tank should be about 500^3)	2	Design	500(m^3)
5	The depth of the tank should be more than 1(m)	2	Design	1m
6	Have space for pump and filter	3	Design	2(m^2)$space$
7	The number of containers needed for transport	1	Design	5 containers
8	The number of personal needed to carry out the operation	2	Design	2 person
9	Prevent water leakage from a certain height of wave (m)	3	Prototype	No water leak

3.2 Concept generation

In this section, first a function tree is created to clarify the sub-functions to be considered. Then, a morphlogical matrix is applied to make sure all potential solution for different sub-functions are included and concept based on mixing these potential solutions for sub-functions after.

3.2.1 Function Tree

To enable the function of the tank for growing oyster spawns in the sea, it is divided into different sub-functions and a function tree has been created to make the sub-functions neat.

The first is to control the water quality in the tank. According to interviews and the previous report (Strand et al., 2018), there are two main aspects. A pump is needed to pump the seawater enter the tank and those water needs to be filtered.

The temperature of the water in the tank must not be too low, which means a water heating method is needed.

The second is to ensure that the tank is moored and allowed to move the water tank in the future. Among them, mooring and moving themselves are easy to realize but on the other hand, the tank must not leak, and at the same time, it must be able to float on the water by itself.

At last is the ease of maintenance. The tank must be able to ensure the docking of ships with maintenance personnel on them, and fence are needed to prevent people from falling into the water. In addition, on the basis of the previous project, it is necessary to allow the interior of the tank to be cleaned.

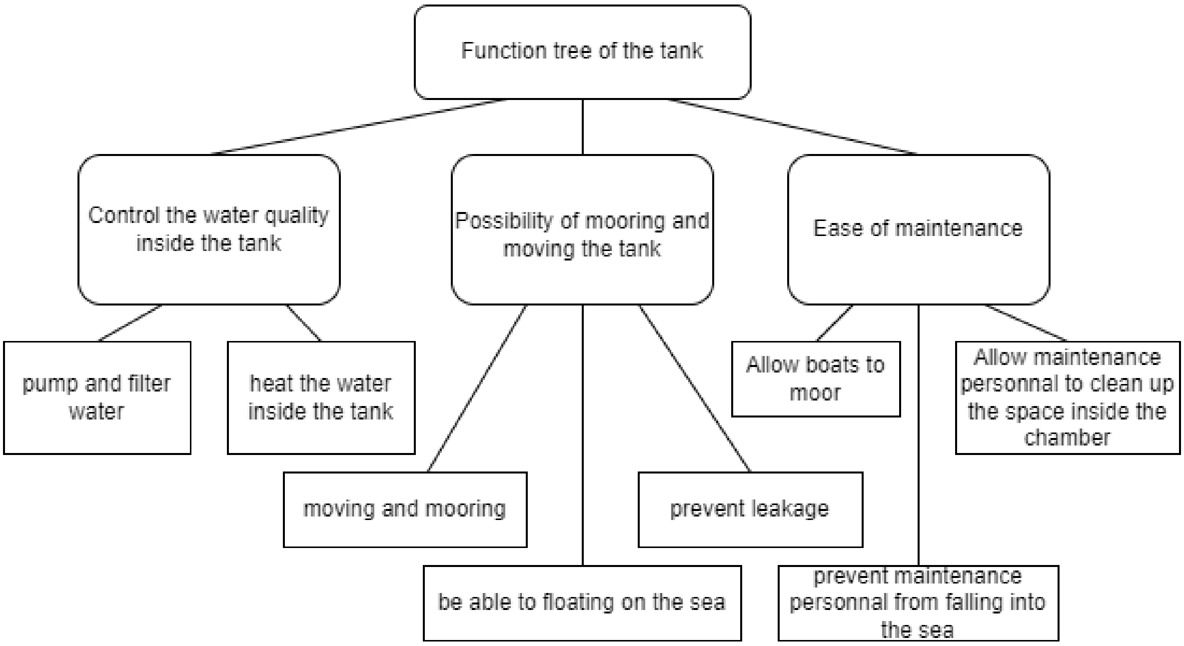

Figure 3.1: Function Tree of the product

3.2.2 Morphological matrix

Specifications generated during the previous phase are usually the quantitative requirements for a certain function at a macro level, they are good for checking if the product development is going on the right way but are not very easy to grasp closely when designing a product. Therefore, a specification could be split into a series of sub-functions and the structures which could fulfil the sub-functions are design and organized in the morphological matrix. With the morphological matrix, concepts that could realize the functional specifications can be recognized by combining these series of sub-functions.

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Morphological matrix			
Function	Solution	Solution	Solution
space for installing water pump and filter system	Space at the bottom of the tank	A space for pump and filter designed on one side of the tank	Bring the pump and filter on the boat when doing maintenance
heat the water inside the tank	'Green house'	A heating system which uses electric	
enable the tank floating on the sea	Air inside a chamber in the circumference	Foam around the main part	supporting structure build on sea bed

Table 3.2: Table of morphological matrix

3.2.3 Solutions for Sub-functions listed in the morphlogical matrix:

Space for installing water pump and filter system:
1. Leave a room at the bottom of the tank for the water pump and filter system.

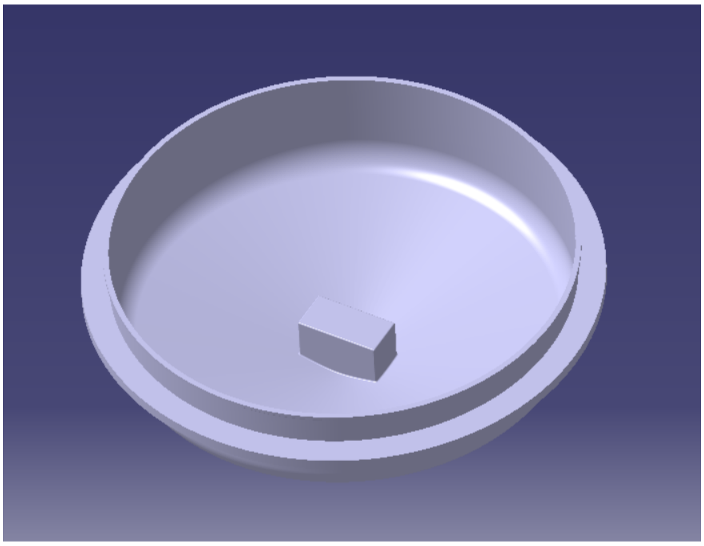


Figure 3.2: Schematic diagram of the tank with pump and filter at bottom

2. Install the water pump and filter system on the circumference of the tank.

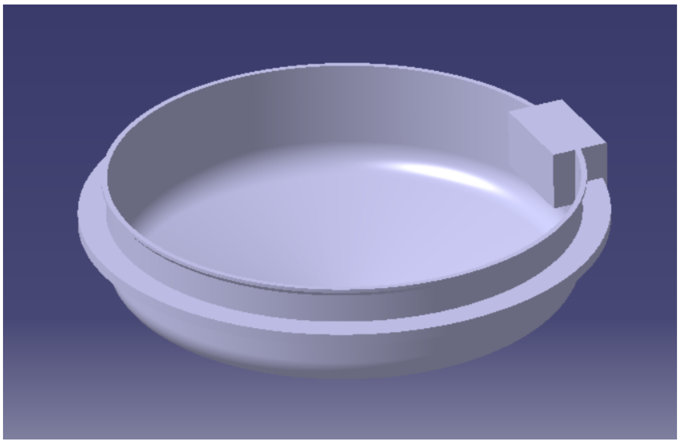


Figure 3.3: Schematic diagram of the tank with pump and filter at a side

3. The tank does not have a pump and filter system installed on it constantly, instead the personnel bring the system to the tank every time when doing maintenance.

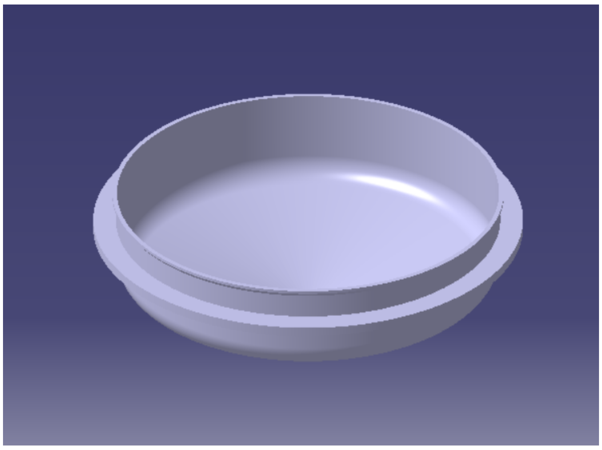


Figure 3.4: Schematic diagram of the tank without build in pump and filter

Heat the water inside the tank
1 build a 'green house' on top of the tank, heat the tank with solar
2 design an electrical heating system that share the power supply with pump and filter system.

Buoyancy for the tank
1 The circumference is designed hollow, and the air inside is supposed to provide buoyancy for the tank.
2 design foam materials around the main part of the tank to provide floating force foam materials are not stable enough when working in the sea environment, so this solution is decided not be used in concepts
3 Build a support structure on the sea bed, install the tank on the support structure after assembled on the land and let the structure support the tank to stay on the

surface of the sea.

3.2.4 Material selection

The material selection is carried out based on the level 3 database in the software 'CES Edupack 2020'. The material for the main part was chosen as GRP (Glassfibre Reinforced Plastic). The material would be used on manufacturing the tank is chosen in this part. (*CES Edupcak*, 2021)

With the consideration of current knowledge, the material for manufacturing the oyster growing tank should be able to fulfil the following requirements:
1. Work under direct sunlight.
2. Adapt to different temperature changes throughout the year.
3. Be able to work for a long time under the corrosion of seawater.
4. With high electrical resistivity since there will be electricity system on the tank.
5. Affordable cost.

Regarding the points above, the constraints applied in the software are listed in the table 3.3.

Table 3.3: Constraints applied in CES Edupack

Constraint	Target value
Tensile Strength	≤200MPa
Compressive Strength	≤20MPa
Max temperature	≥80℃
Min temperature	≤-20℃
Electrical Resistivity	$\geq 1M\Omega.m$
Fresh water	Excellent
Water (salt)	Excellent
Weak alkalis	Excellent
UV radiation(sunlight)	Fair, Good, Excellent

After screening, the remaining materials are from three categories: Fiber reinforced plastics, Composites and Thermal ceramics. As shown in Figure 3.5, FRP materials are chosen at last since they have both low price and low density which ensure a low cost and low weight for the oyster growing tank.

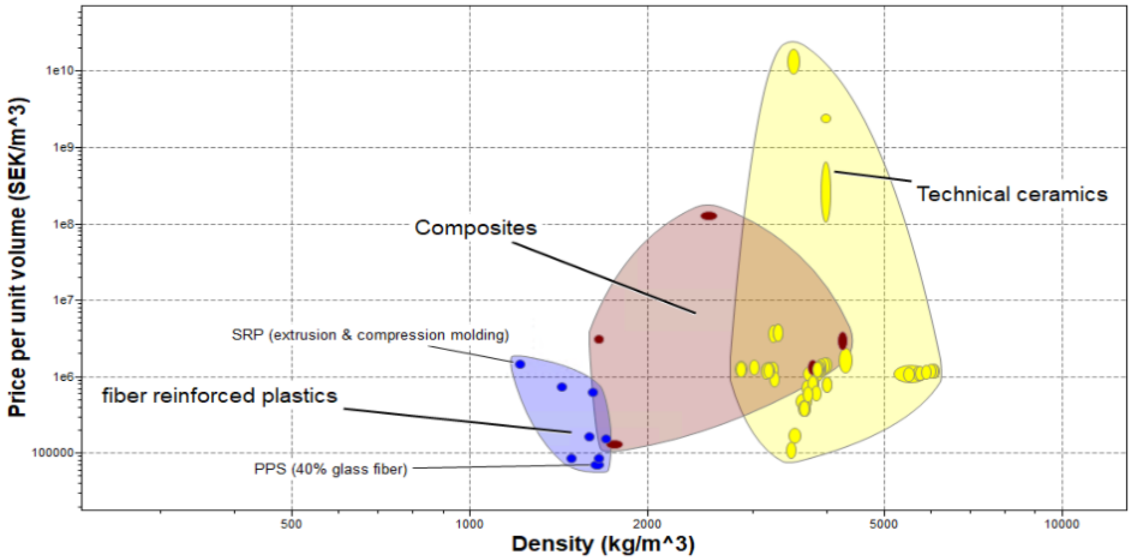


Figure 3.5: Data from CES Edupack 2020

To summarize, PPS, one of the GRP material which consists 60%Polymer and 40% Glass fiber is chosen as the material for the oyster growing tank. The price and density of this material are the most favorable and they are listed below.

Table 3.4: Material data from CES Edupack 2020

Price	40.7 - 46.7 SEK/kg
Price per unit volume	$6.51e4 - 7.8e4SEK/m^3$l
Density	$1.6e3 - 1.67e3kg/m^3$

3.2.5 Manufacturing process

There are mainly three kinds of manufacturing process for fiber reinforced plastics currently. (Zoghi, 2014)
1. Manual processes, including methods such as wet lay-up and contact molding
2. Semi-automated processes, including methods such as compression molding and resin infusion
3. Automated processes, including methods such as pultrusion, filament winding, and injection molding

Currently, for building prototype, manual processes are considered since the production batch for the prototype is small.

Manual processes is a kind of processes which don't need special expensive tooling and could be flexible enough for parts with any shape or size by choosing correct mold over which the material is layered. Additionally, this method could fit any fiber-resin combination and fiber orientation which gives designers the freedom on designing. The shortcoming of this process is it has relatively low production rate and the quality between parts could be differ from each other and there could be a considerable waste of materials depending on the skill of the technician. (Zoghi, 2014)

3.3 Generated Concepts

The concept are generated by combine different solutions of functions in the morphological matrix and listed below. By per-mutating and combining the solutions, except those concepts which are obviously impossible, 12 concepts were generated and listed below.

Concept 1	
Function	Solution
space for installing water pump and filter system	Bring the pump and filter together on the boat everytime when doing mantenance
heat the water inside the tank	'Green house'
enable the tank floating on the sea	Air inside a chamber in the circumference

Concept 2	
Function	Solution
space for installing water pump and filter system	A space for pump and filter designed on one side of the tank
heat the water inside the tank	'Green house'
enable the tank floating on the sea	Air inside a chamber in the circumference

Concept 3	
Function	Solution
space for installing water pump and filter system	Space at the bottom of the tank
heat the water inside the tank	'Green house'
enable the tank floating on the sea	Air inside a chamber in the circumference

Concept 4	
Function	Solution
space for installing water pump and filter system	Bring the pump and filter together on the boat everytime when doing mantenance
heat the water inside the tank	'Green house'
enable the tank floating on the sea	supporting structure build on sea bed

Concept 5	
Function	Solution
space for installing water pump and filter system	A space for pump and filter designed on one side of the tank
heat the water inside the tank	'Green house'
enable the tank floating on the sea	supporting structure build on sea bed

Concept 6	
Function	Solution
space for installing water pump and filter system	Space at the bottom of the tank
heat the water inside the tank	'Green house'
enable the tank floating on the sea	supporting structure build on sea bed

Concept 7	
Function	Solution
space for installing water pump and filter system	Bring the pump and filter together on the boat everytime when doing mantenance
heat the water inside the tank	A heating system which uses electric
enable the tank floating on the sea	Air inside a chamber in the circumference

Concept 8	
Function	Solution
space for installing water pump and filter system	A space for pump and filter designed on one side of the tank
heat the water inside the tank	A heating system which uses electric
enable the tank floating on the sea	Air inside a chamber in the circumference

Concept 9	
Function	Solution
space for installing water pump and filter system	Space at the bottom of the tank
heat the water inside the tank	A heating system which uses electric
enable the tank floating on the sea	Air inside a chamber in the circumference

Concept 10	
Function	Solution
space for installing water pump and filter system	Bring the pump and filter together on the boat everytime when doing mantenance
heat the water inside the tank	A heating system which uses electric
enable the tank floating on the sea	supporting structure build on sea bed

Concept 11	
Function	Solution
space for installing water pump and filter system	A space for pump and filter designed on one side of the tank
heat the water inside the tank	A heating system which uses electric ’
enable the tank floating on the sea	supporting structure build on sea bed

Concept 12	
Function	Solution
space for installing water pump and filter system	Space at the bottom of the tank
heat the water inside the tank	A heating system which uses electric
enable the tank floating on the sea	supporting structure build on sea bed

3.4 Concept elimination

The concepts generated are evaluated by a Pugh matrix with the design from (Strand et al., 2018) used as a reference. Having the current product which has the same solution choices with concept 1 as the reference ensures that all concepts move forward from the Pugh matrix are better than the current product and the one with highest score could go into the next phase first. And other concepts are scored by their functions here, ’+’ means better, ’0’ means keeps almost the same with the previous one and ’-’ means even worse. After the first iteration, only concept 2 and 5 passed. Since it cost far more money to build support structure on seabed, concept 2 is decided to be the concept to go into further development.

Table 3.5: Pugh matrix for concept 1 to 6

	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Ease of operation of the pump and filter	reference	+	+	0	+	+
Ease of water temperature control		0	0	0	0	0
Ease of mooring and moving		0	0	-	-	-
Stability		0	0	+	+	+
repairing of the installed equipment		0	-	0	0	-
Production efficiency		+	+	0	+	+
Prevent sea birds		0	0	0	0	0
Manufacturing cost		-	-	-	-	-
Total +	N/A	2	2	1	3	3
Total 0	N/A	5	4	5	3	2
Total -	N/A	1	2	2	2	3
Net	0	1	0	-1	1	0
Rank	2	1	2	3	1	2

Table 3.6: Pugh matrix for concept 7 to 12

	Concept 7	Concept 8	Concept 9	Concept 10	Concept 11	Concept 12
Ease of operation of the pump and filter	0	+	+	0	+	+
Ease of water temperature control		+	+	+	+	+
Ease of mooring and moving		0	0	-	-	-
Stability		0	0	-	-	-
repairing of the installed equipment		-	-	-	-	-
Production efficiency		+	+	0	+	+
Prevent sea birds		-	-	-	-	-
Manufacturing cost		-	-	-	-	-
Total +	1	3	3	1	3	3
Total 0	4	2	2	2	0	0
Total -	3	3	3	5	5	5
Net	-2	0	0	-4	-2	-2
Rank	4	2	2	5	4	4

After the first iteration, only concept 2 and 5 passed. Since it need specific certificate and cost a large amount of money to build support structure on sea bed, concept 5 was given up. Concept 2, which has space for pump and filter designed on one side of the tank, 'Green house' and use air inside a chamber in the circumference to get buoyancy force, is decided to be the final concept.

4

Further Development

In this chapter, the concept chosen in Chapter 3, see above, is further developed. The chosen concept has space for pumps and filters on the side of the tank, heating provided through a greenhouse concept and buoyancy with air chambers in the circumference of the tank. Section 4.1 details additional standard components required for the operation of the tank and Section 4.2 describes the design of the tank itself with the parts that are to be assembled. A cost calculation is presented in Section 4.3 and the calculations for the energy required for the operation in Section 4.4.

4.1 Development on add-on

As all solutions for some sub-functions can be applied to any conceptual machine, they are viewed as ‘add-on’ to the tank and the same tank body with different ’add-on’ are not considered as different concept. The add-on parts here include the lids of manholes, mooring piles and fence rods.

4.1.1 Choice of Lids of manholes, Mooring piles and Fence rods

There are standard products for these three parts on the market. Therefore, for this project, with the consideration of cost, trying use as many standard parts as add-on as possible.

4.1.1.1 Material selection

The material selection for add-on is also carried out based on the level 3 database in the software ‘CES Edupack’. (*CES Edupcak*, 2021)
With the consideration of the current requirements, the material for the three components Lid, Mooring pile and Fence rods should be able to fulfil the following demands:
1. Work under direct sunlight.
2. Adapt to different temperature changes throughout the year.
3. Be able to work for a long time under the corrosion of seawater.
4. Easy to process and manufacture.

Regarding the points above, the constraints applied in the software is in the table.

Table 4.1: Constraints applied in the CES Edupack

Constraint	Target value
Form	Bulk material
Max temperature	≥80℃
Min temperature	≤-20℃
Fresh water	Excellent
Water (salt)	Excellent
Weak acids	Excellent
Weak alkalis	Excellent
UV radiation(sunlight)	Excellent
Metal casting	Excellent

The materials database used for this search was of level 3, containing 4193 different kinds of materials. (*CES Edupcak*, 2021)

From the search result shown in the figure 4.1 and 4.2, among all the materials fulfill the requirement, stainless steel has the lowest price with a medium density and tensile strength. Therefore, the search for the standard parts could be limited in the products made from stainless-steel.

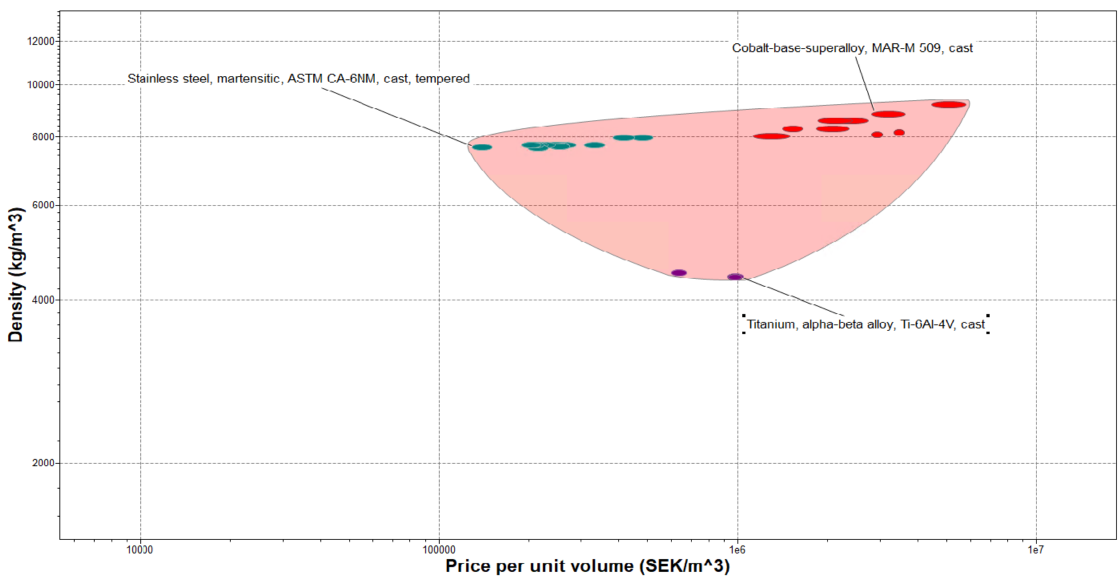


Figure 4.1: Data from CES Edupack 2020

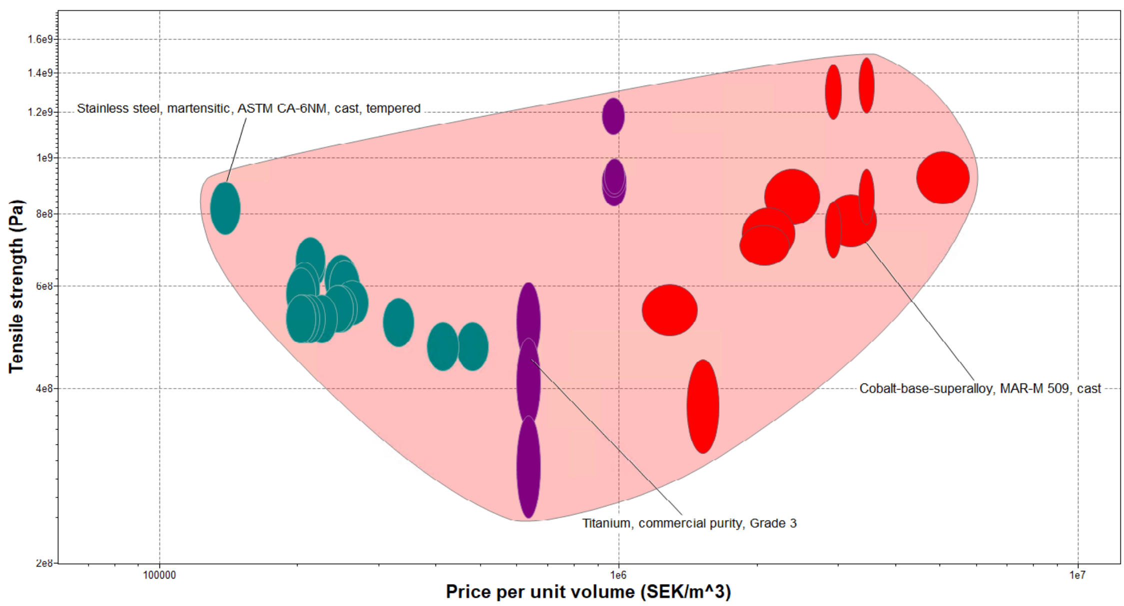


Figure 4.2: Data from CES Edupack 2020

4.1.1.2 Lid

The lid chosen is the one from Alibaba.com which has a price of 200 USD/set when the quantity ordered is larger than 10.

Since there are enough space on the tank, the largest one which sized $600mm \times 450mm$ is chosen to maximize the comfort of maintenance personnel. (Chongqing Yushuo Import Export Business Co., 2021)

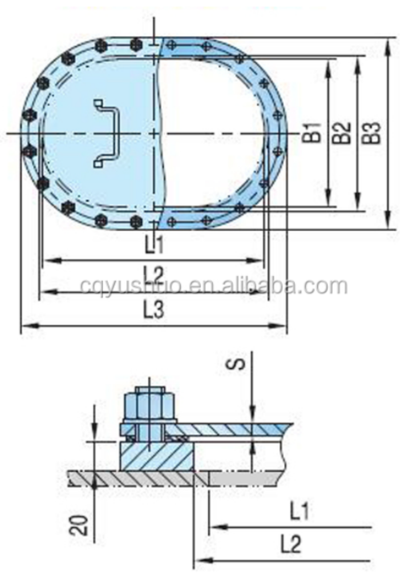


Figure 4.3: Drawing of the lid for the manhole from Alibaba

Size of clear	L1	B1	R	S	BOLT	
L*B mm	(mm)	(mm)	(mm)	(mm)	DAI(mm)	QUT
450*350	620	520	260	4	M20	20
				6		
				8		
				10		
500*400	670	570	285	6		20
				8		
				10		
				12		
600*400	770	570	285	8		24
				10		
				12		
				14		
600*450	770	620	310	8		24

Figure 4.4: table of the dimensions of the lid for the manhole from Alibaba

4.1.1.3 Mooring Piles

A mooring pile with its basement sized $180mm \times 70mm$ was chosen and the price is 229kr/st (boat accessories, 2021)

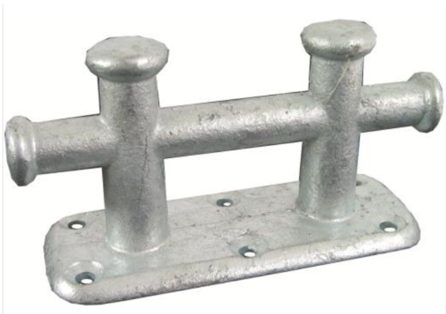


Figure 4.5: Figure for the mooring piles from Bollard

4.1.1.4 Fence rods

Standard 10 mm stainless steel pipe is chosen as the Fence rod, a further process for welding 2 'ears' and drilling holes on bottom it for fixing is needed. (Shandong Lihongyuan Metal Material Co., 2021)

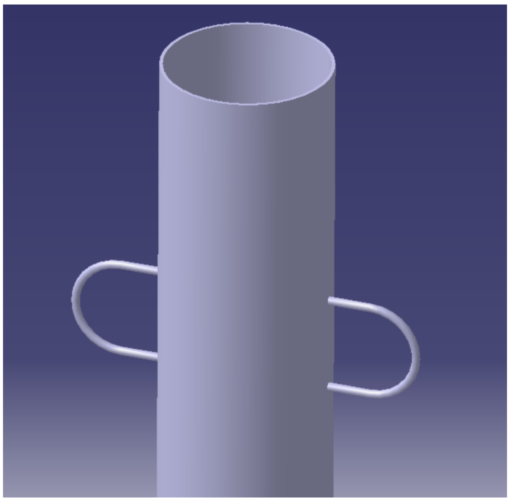


Figure 4.6: Schematic diagram 1 for the fence rod

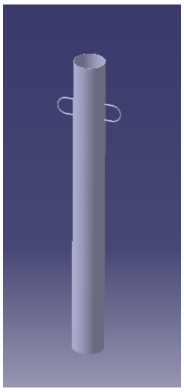


Figure 4.7: Schematic diagram 2 for the fence rod

4.1.2 Balance of the oyster growing tank

Since the pump and filter system is installed on one side of the oyster growing tank, an extra air room is added under that part in order to balance the increased weight and the moment caused by them with the extra buoyancy force created by the air in the room.

4.2 Design for assembly of the tank body

4.2.1 Connection method

Based on the functions, connections in FRP materials can divided into three categories (Clarke, 1996):
1) Primary structural connections, which provide major strength and stiffness to an assembly for the whole service life of the structure.
2) Secondary structural connections, which contribute some strength and stiffness

to an assembly.
3) nonstructural connections, which usually do not provide strength or stiffness.
In this project, primary structural connections are applied since the tank itself need to provide strength and stiffness in its working environment.

The primary structural connections could also be divided into bonded or adhesive connection and hybrid connection (Zoghi, 2014). In this project, the connection between components of the tank need provide major strength and stiffness. At the same time, it must be able to provent water leak. Thus, adhesive connection chosen again as the method for assembling. Additionally, flanges are designed on all the edges which need to connect with another part.

4.2.1.1 Bottom

As shown in figure 4.8, since the water pump and filter system is installed on one side of the tank, there is no need for a water outlet at the bottom. In addition, the overall bottom can provide a more stable structure.

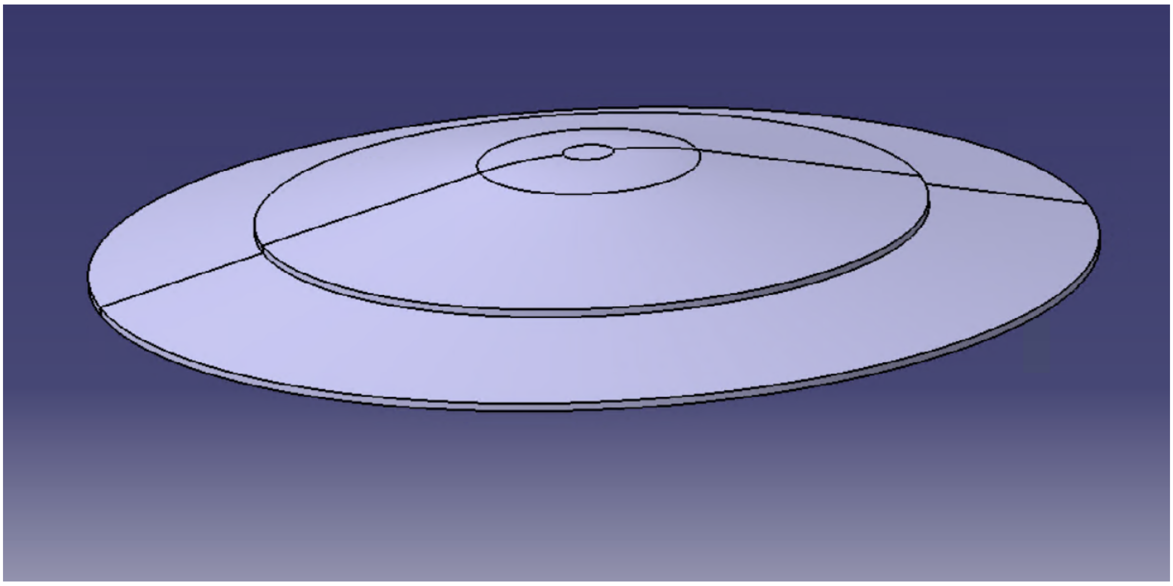


Figure 4.8: Bottom Structure

4.2.1.2 Bottom section

As shown in figure 4.9, the bottom section parts create connection between the bottom parts and the side parts, the size of it keeps the same with the one from previous project.

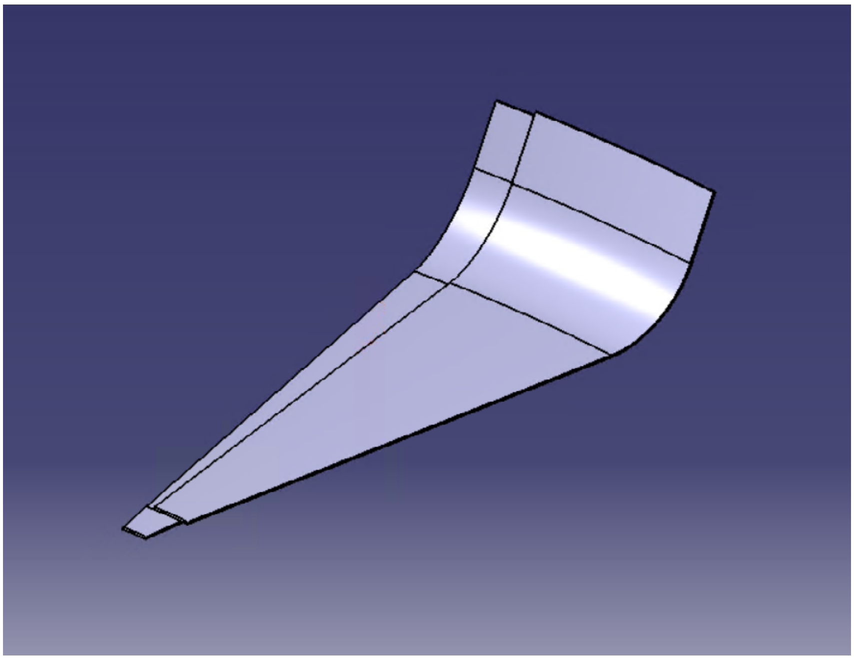


Figure 4.9: 3D view of the bottom section

4.2.1.3 Floating tank

As shown in the figure 4.10 to 4.15, compare with the one from previous project, the floating tank has been split into more parts, which makes it easier to be manufactured and transported.

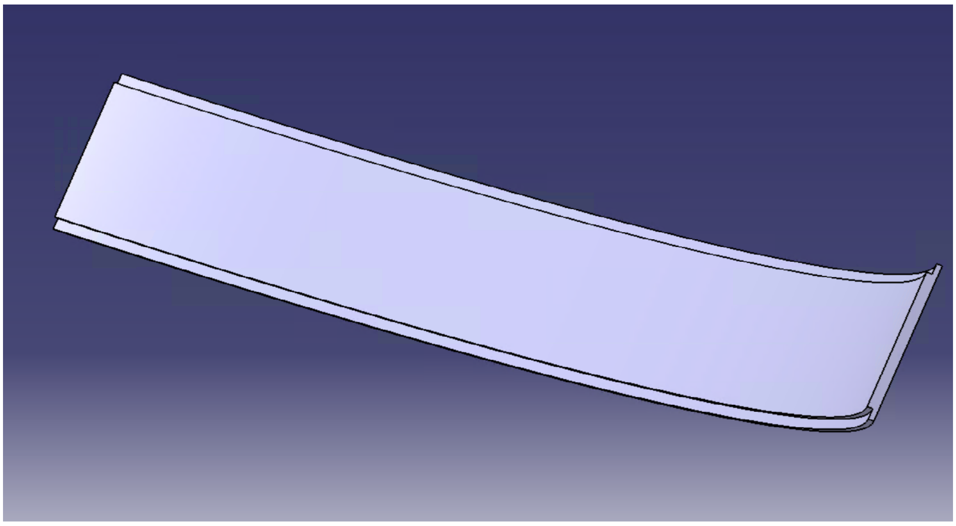


Figure 4.10: 3D view of the Inner part of the floating tank

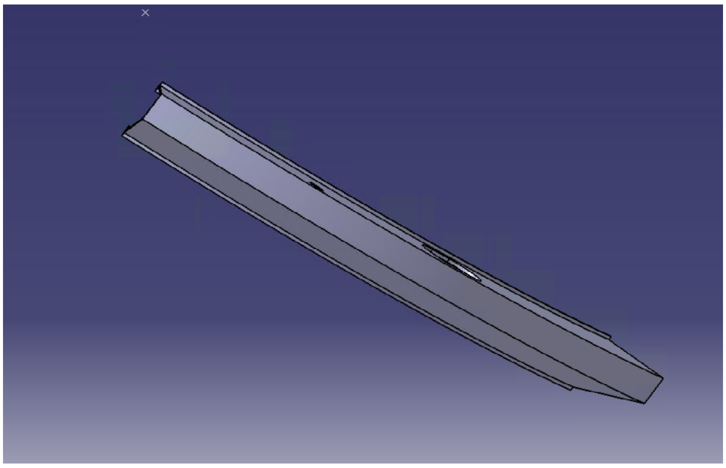


Figure 4.11: 3D view of the Outer side of the floating tank

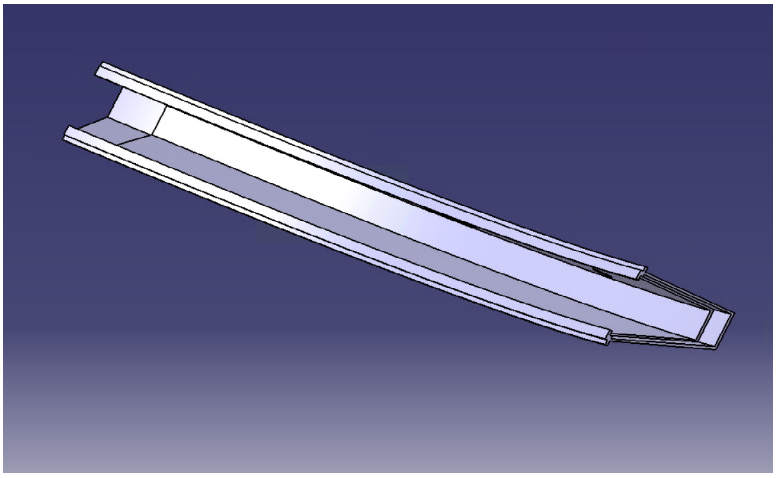


Figure 4.12: 3D view of the Outer side of the floating tank 2

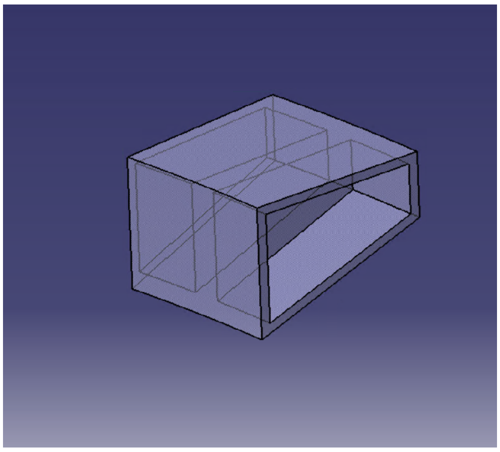


Figure 4.13: 3D view of the Support part of the floating tank

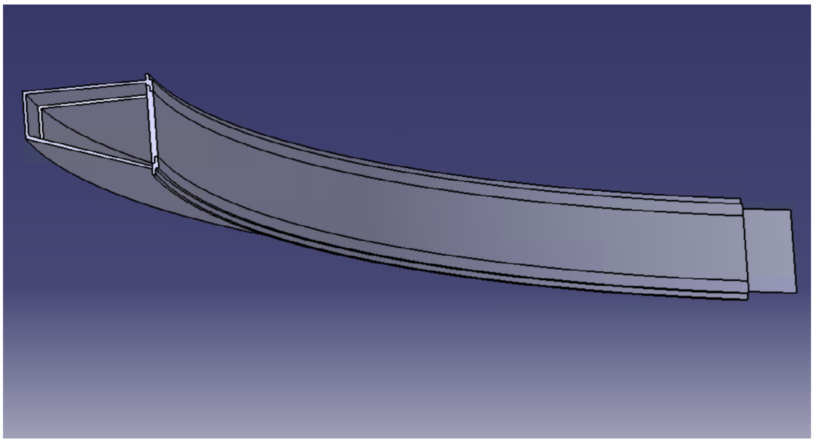


Figure 4.14: 3D view of the assembled floating tank

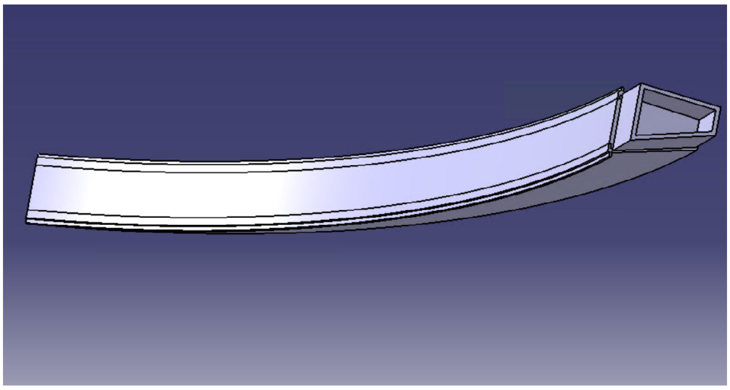


Figure 4.15: 3D view of the assembled floating tank

4.3 Cost calculation

In this section, the cost for manufacturing and assembling are calculated based on Swift Booker's method. (Swift & Booker, 2013)

The manufacturing costs were calculated with the following equation.

In the case that the number of containers required is determined, the manufacturer's method of transporting the main manufacturer. And the maintenance cost is a considerable degree of maintenance and maintenance,
The single process model for manufacturing cost Mi is formulated here

$$M_i = V \times C_{mt} + P_c \times R_c \tag{4.1}$$

Where
V = volume of material required in order to produce the component;

C_{mt} = cost of the material per unit volume in the required form;
P_c = basic processing cost for an ideal design of the component by a specific process;
R_c = relative cost coefficient assigned to a component design (taking account of shape complexity, suitability of material for processing, section dimensions, tolerances and surface finish).

The volume of the tank body is obtained by checking the profile of the product in CAD software and it is equals to $26.273m^3$

The cost of material mentioned above which is ranged from 40.7 to 46.7 sek/kg, 46.7 is used in this calculation in order to make the result reliable enough and the density is $1.67e3kg/m^3$.

In order to represent the basic processing cost of an ideal design for a particular process, it is first necessary to identify the factors on which it is dependent. These factors include:
1. Equipment costs.
2. Operating costs (labour, number of shifts worked, supervision and overheads, etc.).
3. Processing times.
4. Tooling costs.
5. Component demand.

The above variables are taken account of in the calculation of Pc using the equation:

$$P_c = \alpha \times T + \frac{\beta}{N} \tag{4.2}$$

where
α = cost of setting up and operating a specific process, including plant, labour, supervision and overheads;
β = process-specific total tooling cost for an ideal design;
T = process time for processing an ideal design of component by a specific process;
N = total production quantity per annul.

The hand lay up process is a manual process which don't need specific tooling equipment and could be operated by a single worker. From SCB, the labor cost for manufacturing industry in 2021K2 is about 142.8sek/h and the manufacturing of the tank need about 22 working days for two workers. (StatisticsSweden, 2021) Here the cost of supervision could not be calculated precisely, so just suppose the supervision cost the same as the workers which leads to double the labor cost.

Based on the chart and tables from Figure 4.16 to 4.20, the relative cost coefficient(Rc) could be calculated with the following formulate:

$$R_c = C_{mp} \times C_c \times C_s \times C_f \tag{4.3}$$

C_{mp} = cost coefficient for material processing
C_c = cost coefficient for shape complexity of the components
C_s = section coefficient
C_f = surface finish coefficient

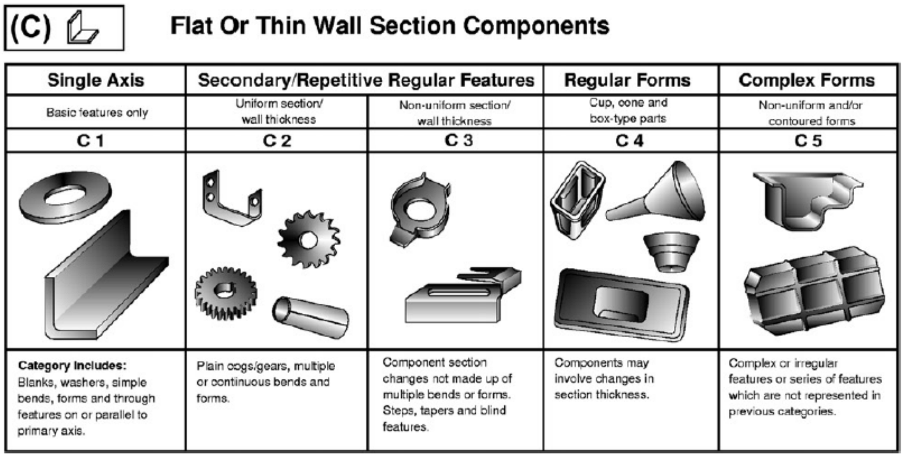
Hand lay up process could be seen as a kind of manual machining(MM) process and the material is a kind of thermoplastic. The coefficient for cost for material processing suitability is chosen as 1.1 based on figure 4.16.

Table 12.1: Relative Cost Data for Material Processing Suitability (C_{mp})

	Process																					
Material	**AM**	**CCEM**	**CDF**	**CEP**	**CF**	**CH**	**C.M2.5**	**CM5**	**CMC**	**CNC**	**CPM**	**GDC**	**HCEM**	**IC**	**IM**	**MM**	**PDC**	**PM**	**SM**	**SC**	**SMW**	**VF**
Cast iron	1.2						1	1	1	1.2				1		1.2		1.6	1	1		
Low carbon steel	1.4	1.3	1		1.3	1.3	1	1	1.2	1.4			1.3	1		1.4		1.2	1.2	1.2	1.2	
Alloy steel	2.5	2	2		2	2	1	1	1.3	2.5			2	1		2.5		1.1	1.3	1.3	1.5	
Stainless steel	4	2	2		2	2	1	1	1.5	4			2	1		4		1.1	1.5	1.5	1.5	
Copper alloy	1.1	1.1	1		1	1			1	1.1			1	1		1.1	3	1	1	1	1	
Aluminium alloy	1	1.1	1		1	1			1	1		1.5	1.1	1		1	1.5	1	1	1	1	
Zinc alloy	1.1	1	1		1	1			1	1.1		1.2	1	1		1.1	1.2	1	1	1	1	
Thermoplastic	1.1			1						1.1	1.2				1	1.1						1
Thermoset	1.2			1.2						1.2	1				1	1.2						
Elastomer	1.1			1.5						1.1	1.5				1.5	1.1						

Figure 4.16: Table for determine cost for material processing suitability of a part (adopted from Swifter and Booker)

Figure 4.17 shows the way to determine the complexity category of flat or thin wall section components. Since the components have basic features with uniform sections, they could be determined into C2 group. Then, based on the chart in Figure 4.18, the coefficient for group C2 with manual machining process is chosen as 1.5.



(C) Flat Or Thin Wall Section Components

Single Axis	Secondary/Repetitive Regular Features		Regular Forms	Complex Forms
Basic features only	Uniform section/ wall thickness	Non-uniform section/ wall thickness	Cup, cone and box-type parts	Non-uniform and/or contoured forms
C 1	C 2	C 3	C 4	C 5
Category Includes: Blanks, washers, simple bends, forms and through features on or parallel to primary axis.	Plain cogs/gears, multiple or continuous bends and forms.	Component section changes not made up of multiple bends or forms. Steps, tapers and blind features.	Components may involve changes in section thickness.	Complex or irregular features or series of features which are not represented in previous categories.

Figure 4.17: Table for determine complexity category of a part (adopted from Swifter and Booker)

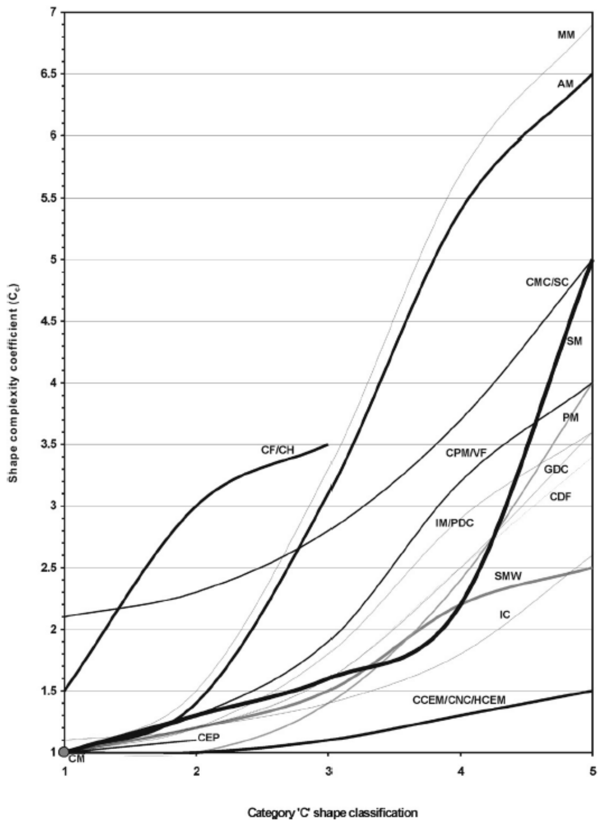


Figure 12.11: Determination of Shape Complexity Coefficient (C_c) – Category 'C' Shape Classification.

Figure 4.18: Table for determine shape complexity coefficient based on complexity category (adopted from Swifter and Booker)

According to Figure 4.19, the section coefficient is determined as 1 for components from complexity category C2.

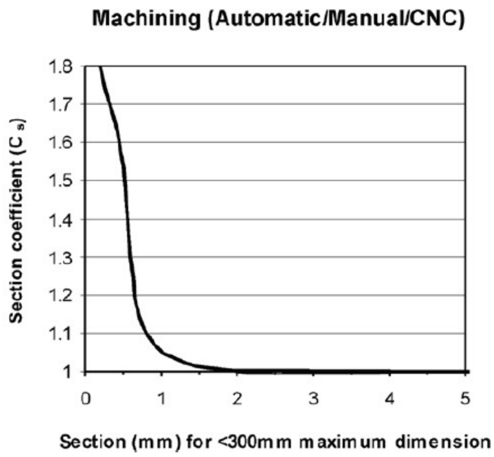


Figure 4.19: Chart for determine section coefficient (adopted from Swifter and Booker)

Since the size of the tank is large and the design of the components are robust, the tolerance of each components are supposed to be larger than 0.2mm. Therefore, according to Figure 4.20, the surface finish coefficient is determined as 1.

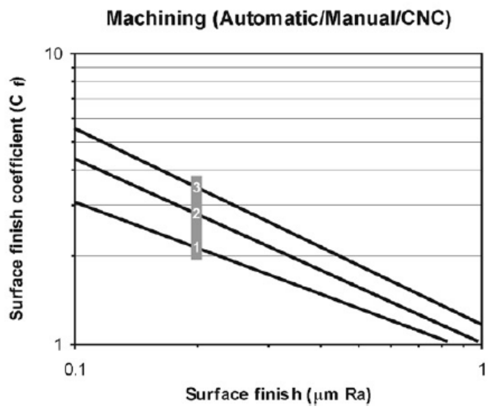


Figure 4.20: Chart for determine surface finish coefficient (adopted from Swifter and Booker)

Based on the coefficients chosen above, Rc is calculated as:
$R_c = 1.1 \times 1.1 \times 1.5 \times 1 = 1.815$

Therefore, the max cost M for a prototype is calculated as $M = 26.273 \times 1670 \times 46.7 + 142.8 \times 22 \times 2 \times 1.815 = 2060409.005Kr$

4.4 Recommendation of energy supplying

The possible way of energy supplying could be solar energy with replaceable battery. The pump and filter are chosen in the previous report (?, ?). Here a calculation about the number of solar panels needed is carried out as a reference for the future development on the energy supplying system.

From the profiles of the pump and filter:
KSF4 pump has a Hydraulic power packs: min. 4 kW. (Maskinfabrik, 2021)
Filter Motor power 3x400v (w) 50Hz: 250W (Aquacirc, 2021)
The total power the system needed is$P1 = 4.25kw$

We need the system run at least 4 hours a day

The work is $W_1 = 4 \times P_1 = 17kw$

If the solar panel and battery pack use 12V power supply system voltage Daily consumption of battery capacity
$Q_1 = W_1 \div 12V = 1417.7(Amperes)$

Calculate the number of solar panels based on the daily power consumption of the load equipment and the off-grid power supply of the system. This design intends to use a group of solar panels with a voltage of 12V and the power of a single panel is P2 = 100 (W). In the case if ignoring the charging loss, calculated according to the average daily sunshine time of 10h, the daily power generation of a single solar panel is:

$P_2 \times 10h = 1000(W)$

Under normal circumstances, the charging loss ratio is about 10%, so the actual daily power generation of a single solar panel is: 900W

Therefore, if we would like the system run at least one time everyday, the minimum number of solar panels required is:

$n = 17000 \div 900 = 18.8 \approx 19$

The above calculation of power generation is obtained under the premise that there is no shadow at all.

5

Final Concept

The final concept is originally the concept 2 from concept development in Chapter 3. It has fence rods and mooring piles installed. As shown in figure 5.1 which is the rendering of the assembled oyster growing tank, a room is designed for install pump and filter on the tank and it has holes on the fence for installing a green house.

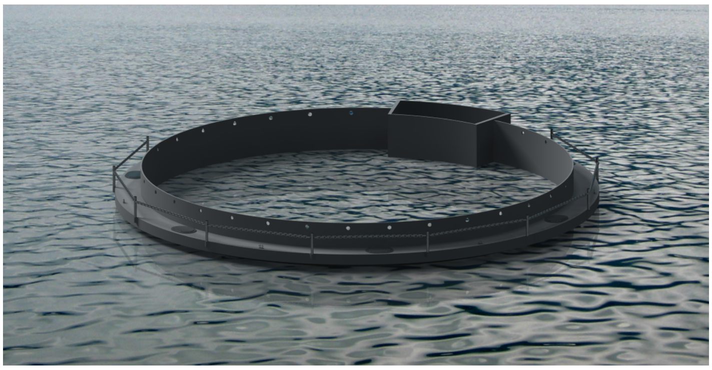


Figure 5.1: Rendering

Figure 5.2 is the schematic diagram of how different parts of the tank could be transported in 40' containers.

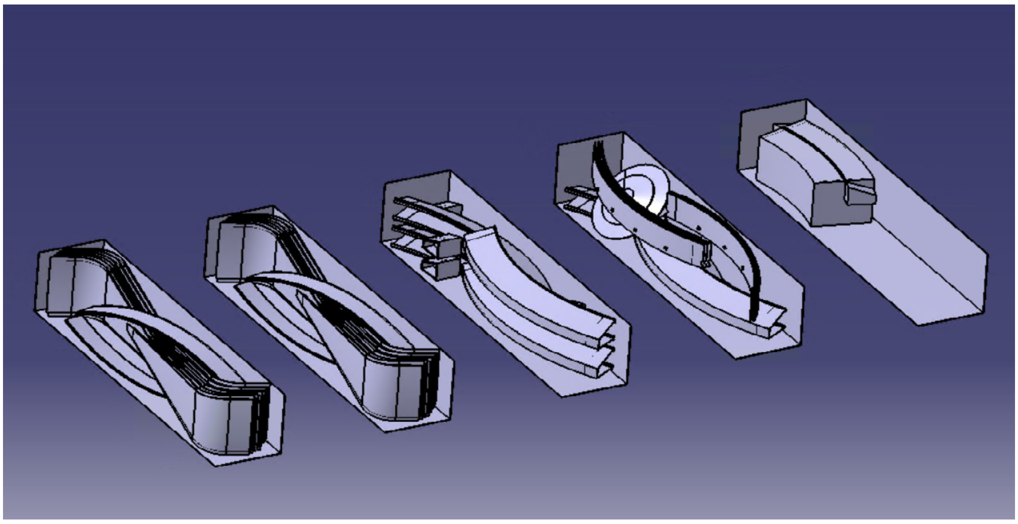


Figure 5.2: Schematic diagram of the parts of the tanks in 40' containers

Compare with the one designed in the previous project (Strand et al., 2018), the design from this project has added complexity since it fulfills more customers' needs and has more functions. Additionally, it is still affordable and Two tanks could now be transported in 9 containers at a time which also saves some cost.

6
Discussion

This chapter contains a discussion about the different possibilities of the design and what could be designed in the future development. There is also a discussion regarding the how well the final product fulfilled the requirements and at last is a discussion about the development process as a whole.

6.1 Different possibilities

In this section, some different possibilities for the further development of the oyster growing tank in the future are discussed.

6.1.1 Water heating

Heating equipment that requires additional power supply and greenhouse are both considered as potentially feasible.
Additional heating equipment could be more effective while the green house is cheaper. In this project, since the tank will be mainly used in the warm seasons, the greenhouse idea looks better. If a tank is needed to work all over the year or the heat from greenhouse is not enough, then heating equipment that requires additional power supply could be necessary.

6.1.2 Stability

The ideas about how to enable the tank floating on the sea was to use the air inside 'Flyttank' part like what was designed in the previous project or build a structure on sea bed as a support.

The reason why the support structure idea disregarded is because:
1. It is hard to measure and control the cost for building such structures. The cost depends a lot on the condition of the sea bed regarding the location, and build structure in the sea need extra permit from government.
2. People may need to move the tank depend on the season or weather, an unmovable structure could not fulfil this potential requirement.

6.1.3 Cost

Due to the lack of experience and the knowledge obtained from the company is not enough, the remaining 2 requirements about cost could not be judged, the cost of the prototype was calculated in the cost calculation chapter. The interval of each maintenance and the prevent of water leakage need be verified by experiment or in practice use in the future.

6.2 Fulfilment of the requirements

Finally, seven out of nine of the metrics are fulfilled. Due to lack of experience, it is not clear that if the tank need an interval maintenance of 2 times a year, but it should be more than enough with the robust design. The design seems could prevent water leak, but it is not verified since the simulation of it needs to use CFD methods which is out of scope.

Table 6.1: Fulfillment of the requirements

	Fulfillment of requirements		
Metric No.	Metric	Target	Result
1	Production cost	2million Kr	2million Kr
2	Be able to heat the water inside	Have a structure	A structure designed
3	The interval of each maintenance of the tank (times/year)	2 times/year	/
4	Volume of the tank should be about 500^3)	500(m^3)	520.71(m^3)
5	The depth of the tank should be more than 1(m)	1(m)	3.75(m)
6	Have space for pump and filter	2(m^2)*space*	2(m^2)
7	The number of containers needed for transport	5 containers	4.5 containers
8	The number of personal needed to carry out the operation	2 person	1-2 person
9	Prevent water leakage from a certain height of wave (m)	No water leak	/

7 Conclusion

The goal of the project was to carry out a further development on a tank for feeding oyster and mussel spawns in the sea. During this project some potential concept was listed and eliminated and for the final concept, a mechanical design has been finished with consideration of assembling, transportation and cost for prototype. Compare with the result from previous project, the new features for the final concept in this project contains manholes for maintenance, space for installing pump and filter, structure for installing green house and a fence.

Therefore, the requirement about the tank is easy to maintain, have space for pump and filter, be able to heat the water inside and the operation of mooring and moving are fulfilled. Furthermore, the cost calculated is about 2 million sek, which is still an affordable price for a prototype in this field.

8

Future Work

Due to the time limitation, some future works could be carried out in the further development of this product.

8.0.1 Further design about the piping system

In this project, enough space for installing pump and filter is left and in the future, a detailed design could be carried out on that part in order to have the pump and filter work smoothly. Further design on the pump and filter system and the power supply of them. The power supply system could also be optimized since it uses only solar power now and wind turbine could perhaps be another way to supply power.

8.0.2 Finite element analysis:

It is always expensive to carry out experiments on prototypes and in this prject, no prototypes are produced since the expense is not enough. Thus, doing finite element analysis could be reasonable to support designers doing decision. In this project, there are several results could be helpful: the motions of the water inside a filled floating tank could help to check the stability of the design.
The material and seams on bottom of the tank could be analysis to see if the material is strong enough or the tank wall is thick enough to work with the pressure from both side.
An analysis about the force from the waves around the tank could be carried out to see how much influence the waves could cause on the motions of the tank.

8.0.3 Decide the tolerance

Due to lack of experience, the tolerance of each componnets are not given in this project and which is planned to be done in the future.

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A

Appendix 1

A.1 Needs-Metrics Matrix

		1	2	3	4	5	6	7	8	9	10
	Need-metrics matrix	Production cost (sek)	Have space for pump and filter	Be able to heat the water inside	provent water leakage from a certain hight of wave (m)	The interval of each maintenance of the tank (times/year)	volume of the tank (m^3)	The depth of the tank (m)	The manufacturing cost (sek)	The number of containers needed for transport	The operation of mooring and moving can be completed by one boat and the pers
1	fairly cheap	•							•	•	•
2	create a barrier system between the oysters and the sea				•						
3	filter seawater that goes in to the tank		•								
4	be able to carry a water pump and other equipments		•								
5	Insulation and options for heating the water in the tank			•							
6	can take normal wave heights in inshore habitats				•						
7	good sea properties in the sea conditions that can be expected.				•						
8	as low maintenance as possible					•					
9	The bottom of the tank needs to be treated to prevent the parasitic of barnacles and other attachments					•					
10	volume is estimated to be about 500m^3						•				
11	The tank must be deeper than 1 m							•			
12	be able to change water inside during the growing season.		•								
13	manufacturing and installation of the tank must be considered								•	•	•
14	transport should take place in only 40' containers.									•	
15	Easy to install or move, it's best to do it with just one boat										•

Figure A.1: Needs-Metrics Matrix

A.2 Questions asked in interview

A.2.1 General questions

What is your position, or would you mind tell me something about what you are doing for Bohus Havsbruk? Would it be possible for you to forward a short questionnaire to people who really operating the product? (In English)
Is that possible for me to watch how does the current tank works? (any videos or could I pay a visit to the scene)
How is the market looks like now? I mean, as far as I have learnt, your main competitors are the fishing industry from Asia. Would you mind tell me about their advantage compare to the fish industries in EU in your mind?
What is this product supposed to do? I mean, the requirement of feeding oyster spawn and the requirement about cost limitation, maintenance etc.

A.2.2 Problems regarding the assembling and installation of the product

Is the current tank assembled and installed into the sea by you or a supplier? If so, what do you find hard with the assembling or installation of the current tank? What do you find good with the assembling or installation of the current tank? How often do you do maintenance for the tank or the oyster spawns in it? What do you usually do when doing maintenance?
Are there any new features you will be happy to see on the new product?
Are there any features you think should be removed from the product, meaning that there are unnecessary features on it?
What are your thoughts about the size/weight of the product? Does it need to get smaller, lighter or anything else?
Do you have any general ideas of improvements of the spawn growing tank?

A.2.3 Laws and regulations

Are there any laws or regulations you know that could make the development become harder than it supposed to be? Regarding the patents, will you only use this tank inside Sweden or EU?

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