

Sensur av hovedoppgaver

Høgskolen i Sørøst-Norge

Fakultet for teknologi og maritime fag



Prosjektnummer: **2016-5**

For studieåret: **2015/2016**

Emnekode: **SFHO3201**

Prosjektnavn

Offshore LøfteClamp

Offshore Lifting Clamp Engineering

Utført i samarbeid med: FMC Technologies Kongsberg

Ekstern veileder: Einar Totland

Sammendrag:

Å løfte sirkulære rør offshore er krevende og utfordrende. I dag brukes en løfteclamp ved denne typen løft. FMC ønsker å se på en mulighet for redesign eller ny design av eksisterende løfteclamp, for blant annet å redusere kostnad, vekt og riggetid.

Stikkord:

- Offshore løft
- Konseptutvikling
- DNV standarder/ offshore reglement

Tilgjengelig: JA / DELVIS / NEI

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OFFSHORE LIFTING CLAMP ENGINEERING
VERSION 1.0

DOCUMENT COLLECTION

22.05.2016

Pages:

Document collection: 6 pages

Project plan: 45 pages

Design report: 190 pages

Requirement specification: 26 pages

Test specification: 80 pages

Risk assessment: 58 pages

Iteration evaluation report: 55 pages

Total: 460 pages

PREFACE

This document is a compilation of all the reports produced by group 5; Offshore Lifting Clamp Engineering, while working on the bachelor project at HSN Kongsberg 2016. The project has been provided by FMC Technologies Kongsberg.

This document collection consist of six different reports:

1 PROJECT PLAN REPORT

The planning of our project period, including presentation of the group and the project, the project model, time schedule, activity specification and a Gantt chart.

2 DESIGN REPORT

Documentation of the design concept development and selection. This document will provide a description of how the design process has been throughout the project period. The report presents the work done from the idea stage up to the final result and product, with a recommendation for further work and development.

3 REQUIREMENT SPECIFICATION REPORT

This report presents the situation analysis and the stakeholder in the project. Based on this, in addition to the requirement given from FMC Technologies and the requirements connected to the regulations in DNV 2.22 and DNV 2.7-3, OLC have developed a set of requirements for the process of designing the product in the bachelor project.

4 TEST REPORT

Based on the requirement specifications, we have developed a set of test specifications. Each requirement shall be tested to verify that it is according to the product our customer is asking for. In addition to the test specifications, the test report also presents the test plan with a description of the performance of the tests done during the project period and the results found.

5 RISK ASSESSMENT REPORT

The risk assessment contains a risk analysis of the execution of the project in the project period and risk analysis done throughout the iterations in the project period. OLC has done a risk assessment on the different concepts in the beginning of the project period in addition to several risk assessment of the chosen concept.

6 ITERATION EVALUATION REPORT

OLC has chosen to follow the spiral model throughout the project period. The project period consist of a total of five iterations as well as a startup and project completion phase. The evaluation of each iteration and a presentation of the work done are presented in this report.

Abbreviations	Terms and definitions
<p>CE = Conformité Européenne</p> <p>DNV = Det Norske Veritas</p> <p>GARA = Grade After Risk Actions</p> <p>GOR = Grade Of Risk</p> <p>ID = Identification</p> <p>ISO = International Standardization Organization</p> <p>MBL = Minimum Breaking Load</p> <p>MGW = Mass Gross Weight</p> <p>OLC = Offshore Lifting Clamp Engineering</p> <p>PO = Units = Portable Offshore Units</p> <p>Pri = Priority</p> <p>Req = Requirement</p> <p>R45 = Operation class wave height 4,5 m</p> <p>SWL = Safe Working Load</p> <p>TM = Tightening Mechanism</p> <p>USN = University College of Southeast Norway</p> <p>V = Versions</p> <p>WLL = Working Load Limit</p>	<p>Forerunner <i>Connection used between the sling and the lifting appliance.</i></p> <p>Lifting accessories <i>Equipment used between the load and the lifting appliance such as lifting gears.</i></p> <p>Lifting appliance <i>Machine used for lifting objects such as a crane.</i></p> <p>Lifting equipment <i>A collective term for equipment that has to do with lifting.</i></p> <p>Padeye <i>Metal plate welded onto a frame with a hole for attaching a shackle.</i></p> <p>Shackle <i>A metal link with a locking bolt shaped either as a U or a D.</i></p> <p>Sling <i>Connection used between the load and the forerunner.</i></p>



OFFSHORE LIFTING CLAMP ENGINEERING
VERSION 5.0

PROJECT PLAN

22.05.16

ABSTRACT

The project plan report describes the project planning throughout the project period. This report includes a description of the bachelor group and project, the chosen project model, a time schedule planned for the whole period, the activities to be done and OLC activity time tracking. The purpose with the project plan is to present the planning and the structure of the work done in the project.

This report will give the opportunity to get an insight in the process planning and progress and get an overview of the project from start to project completion.

CHANGES

The changes will be listed here:

Version	Date	Description
4.1	21.05.2016	<ul style="list-style-type: none">• Updated text and content in document
3.1	20.05.2016	<ul style="list-style-type: none">• Added: List of figures and list of tables.• Created: Table name
3.0	11.05.2016	<ul style="list-style-type: none">• Updated <i>Figure 3.5 OLC spiral model with detailed iterations.</i>• Removed 8.0 <i>ITERATION EVALUATION</i>•
1.2	07.03.2016	<p>Changed Colors scheme</p> <ul style="list-style-type: none">• Updated 1.0, 1.1, 1.3.5, 1.4.5, 2.0, 3.0, 4.0, 4.1, 4.2, 5.3, 7.0,• Added Responsibility Areas to 1.1 OLC Engineering• Edited Introduction• Created: 7.1, 7.2, 7.3, full chapter 8.0
1.1	06.03.2016	<ul style="list-style-type: none">• Added table to 4.0 TIME SCHEDULE OVERVIEW• Changed colors
1.0	01.02.2016	<ul style="list-style-type: none">• Changed colors• Changed pictures• Added picture text
0.3	01.02.2016	<ul style="list-style-type: none">• Create numbers for chapters• Spelling check and changes in content to: Introduction, 1.1, 1.2, whole 1.3.x, 2.0, whole 4.x, 5.0, 6.0, 7.0• Created: 1.3.5, whole 1.4.x, 5.1, 5.2, 7.1

In addition to the above.

There may be spelling mistakes that are corrected. It is possible that these changes are not listed.

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INTRODUCTION

OLC Engineering is a bachelor group consisting of five mechanical engineering students from HSN, Kongsberg. The bachelor degree is taken in Mechanical Engineering: Product development, and the graduation is in June 2016.

The bachelor project provided for OLC Engineering is a problem given by FMC Technologies Kongsberg:

- *To optimize the design of an offshore lifting clamp -*

An offshore lifting clamp is a lifting gear used for lifting cylindrical subsea equipment like pipes, joints and risers. The clamp is mounted on the circular subsea equipment, and will then be lifted further by crane. This is for lifting subsea equipment individually.

The goal of the project is to optimize the existing design of a clamp. The starting point for designing an optimal design for the clamp is based on FMC's lifting clamp for general use, with part number P6000065400. The minimum requirements for the design are given by FMC:

- *Under the same conditions of use today, the production costs and the weight of the clamp shall be reduced.*

The purpose of the project plan is to present the planning of the project throughout the project period. This is being done in a straightforwardly way, so that OLC can reach the goals.

This document will give you an indication and understanding of how OLC are planning to accomplish the work procedures and routines, in order to assure that the project will be on schedule, that the deadlines are held and the work is structured throughout the project.

1. PRESENTATION OF THE PROJECT

This project plan is a presentation of the bachelor project given by FMC Technologies Kongsberg. The project is suited for mechanical engineers from HSN Kongsberg.

The mission of the project will include, among others, techniques in 3D design, FEM analysis, material selection, strength calculations and testing. The workload expected in the project period is approximately 600 hours per student. In this case, a workload of around 3000 hours in total.

1.1 OLC ENGINEERING

Offshore Lifting Clamp Engineering, from now on only called OLC, are consisting of five students at HSN Kongsberg, all graduating in June 2016 in Mechanical Engineering, Product development.

All of the team members has been assigned their respective main responsibility areas. The purpose with delegating responsibility areas between the members in the team is to predetermine who shall monitor a specific project content and progress.

All members of OLC will be involved in the various tasks throughout the project, to a greater or lesser extent. In this way, all the group members will have the ability to participate and learn about the different areas, and not only in their own dedicated areas of responsibilities.

1.2 OLC TEAM MEMBERS



Nelly Marie Larsen

System Engineer

Web Design



Magne Rasmussen

Construction

Economical Management



Samrit Kaur

Test & Verification

Documentation



Hasan Güven

Design Development



Hanne Lode

Test & Verification

HSE

1.3 OLC ENGINEERING VISION

The OLC vision is to hand in a bachelor project with high quality and in respect with the expectations and requirements of FMC Technologies. OLC goal is to earn benefit from the project by having instructive processes and obtain experiences that each of the group members can use in their future career.

The conclusion is that this is achievable by:

- High level of performance
- Dedication
- High ambitions
- Show great interest for the task
- Have good cooperation both internally and externally
- Good communication

1.4 OLC ENGINEERING COMMUNICATION

Good and functional communication is essential when it comes to getting prosperity and cooperation in a project. Some predetermined rules are set for how the communication should take place in the project:

1.4.1 COMMUNICATION WITHIN THE GROUP

The main communication channel is set to be on a private Facebook group and through Facebook messenger. This is for sending messages and sharing files. The benefits of this is that the communication is online at any time, and everything is saved and easy to find at later occasions. The main storage is determined to be on DropBox. This allows all members to have access to all necessary material at any time, and it ease the sharing of files and work done in the project. During working hours, small group meetings can be arranged when need of discussions or questions.

Meeting minutes shall be written and stored after every external or internal meeting, giving written common overview of the content of each meeting.

1.4.2 COMMUNICATION WITH INTERNAL SUPERVISOR

OLC has been assigned an internal supervisor from HSN; Amin Hossein Zavieh with predetermined weekly meetings on Wednesdays at 11:00 AM. The purpose of the weekly meetings is to update the supervisor about the project status and progress, and to get feedback, inputs and help concerning the project process.

1.4.3 WEEKLY FOLLOW UP DOCUMENT

A weekly follow up document shall be written every week, with information about activities done the past week, the activities planned for the next week, the workhours of each team member connected to their activities done and an evaluation of the project so far.

1.4.4 COMMUNICATION WITH EXTERNAL SUPERVISOR

The external supervisor from FMC Technologies is Einar Totland. He has accepted to be contacted on phone or by e-mail when need of answers on questions or for setting up meetings.

1.4.5 WEBSITE

All bachelor groups are expected to create a project website. The OLC website will give a presentation of the group and the given project. This is an opportunity for those interested to follow the project and the process.

This site includes:

- ➔ Introduction of the OLC team members
- ➔ Project description
- ➔ Introduction of the Customer – FMC Technologies
- ➔ Project status

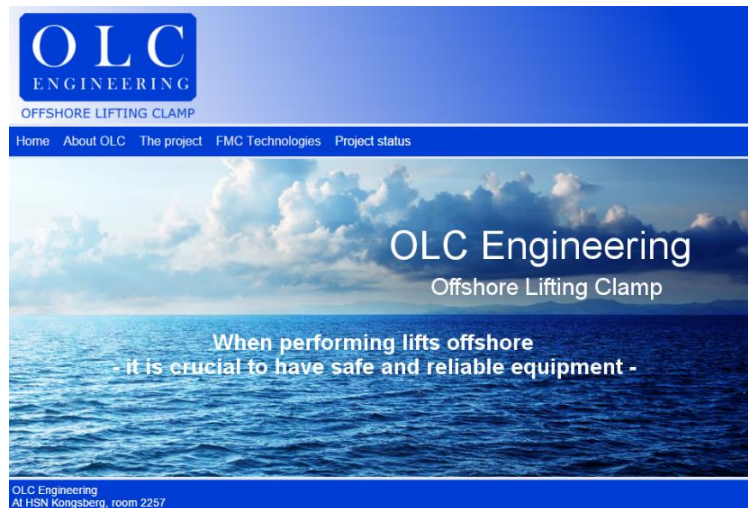


FIGURE 1: OLC Website

<https://home.hbv.no/web-gr5-2016/>

1.5 TEMPLATES

All work done in the project shall be presented in a final report. A united template with a default page including logos from HSN, FMC Technologies and OLC are created, to give structure and a uniform presentation of all the documents. All the templates includes version number, title of the document and a uniform standard for the written content.

2. DESCRIPTION OF THE PROJECT

The bachelor project provided by FMC Technologies Kongsberg is about looking at the possibility *to optimize or redesign a lifting clamp for lifting cylindrical pipes offshore*.

It is a big difference from lifting subsea equipment offshore compared to lifting equipment onshore. When lifting subsea equipment offshore you need to take into account several factors, such as weather conditions, wave height and the availability of necessary equipment for lifting. Offshore lifting is required to follow strict requirements and regulations including DNV 2.22 and DNV 2.7-3. This is to ensure that lifting occurs in an appropriate and responsible manner. Lifting circular pipes offshore is in particular challenging, as there is a great danger of sliding of the equipment during lifting because of the difficulty of mounting the lifting equipment. There is always a risk of equipment slipping or a change in the center of gravity. It is therefore necessary to have higher safety regulations regarding lifting accessories offshore than onshore. To secure and perform a lift of circular pipes offshore, FMC uses a specially designed lifting clamp. A lifting clamp is a device mounted on to the subsea equipment, either before shipping or before performing the lift.



FIGURE 2: Lifting Clamp [5]

The lifting clamp is a customized tool for this type of lift, and is the link between the object to be lifted and the crane. It is a dedicated offshore lifting gear, and it needs to follow the offshore requirements and regulations in order to ensure a safe and secure lift. For safety reasons stated in offshore regulations, the lifting clamp needs to have double barriers. Practically it means that it must include two safety guards, so that for the lifting equipment to fail it needs to have two separate barriers to fail.

FMC have specially designed lifting clamps, depending of the type of pipes that are to be lifted offshore. Because of this, they have a several number of different lifting clamps today, specially made for each pipe. The lifting clamps all have different fixed diameter, meaning that they are only suitable for one specific size of pipe. The large stock of lifting clamps and the fixed

diameter of each clamp clearly provides a number of disadvantages. It is also an expensive solution, since there is a need for a large amount of clamps, each at a high cost.

FMC Technologies has given OLC a mission to come up with a possible redesign or new design of the existing clamp, which is in use today. The starting point is a specific clamp with a weight of 58kg. It has a fixed diameter of 348.3 mm, has a safe working load (SWL) of 4100kg, and can be used in a lift with an angle of up to 45°.

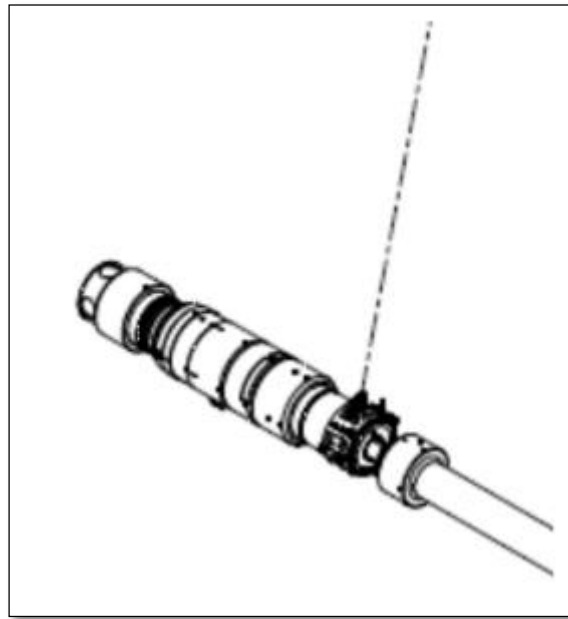


FIGURE 3: FMC clamp P6000065400 from Visund Sor [6]

The main factors in the demands of FMC Technologies is to reduce the weight of the clamp and the production cost. They also want a solution that makes it possible to use the same equipment at various diameters, and to bring down the rigging hours.

3. PROJECT MODEL

When carrying out a project it may be an advantage to follow a project model.

A project model will help to keep the structure in a project process and provide guidance for conducting various processes in a project. There are different types of models to suit different types and sizes of projects. Some of the most common project models that exist are; Waterfall model, V- model and Spiral model. OLC has compared different models against each other and reached a conclusion of using the spiral model for project.

Each project model will not be described, only an explanation of the spiral model.

3.1 SPIRAL MODEL

The spiral model combines features of the Waterfall model (Fig 3.2) and the Prototyping model (Fig 3.3). The spiral model contains repetition in the same way as in the prototyping model and the progress is done like in the waterfall model. The model is most suitable for large projects and projects that often need risk assessment. The spiral model has four major processes, which it goes through during one round, after each iteration the outcome will be a small prototype. These iterations are repeated as often as needed. [1], [2]

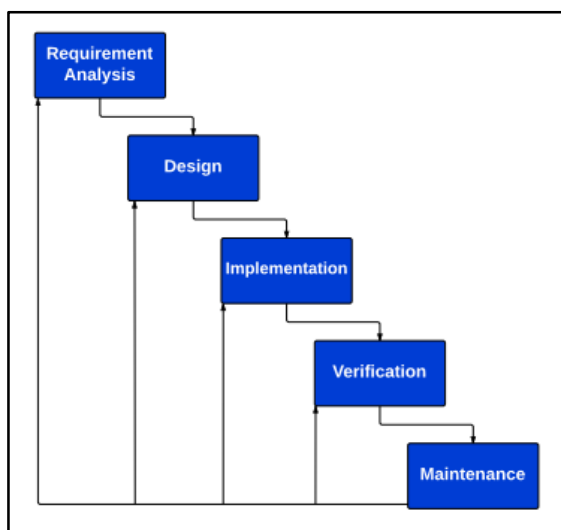


FIGURE 4: Waterfall model [4],

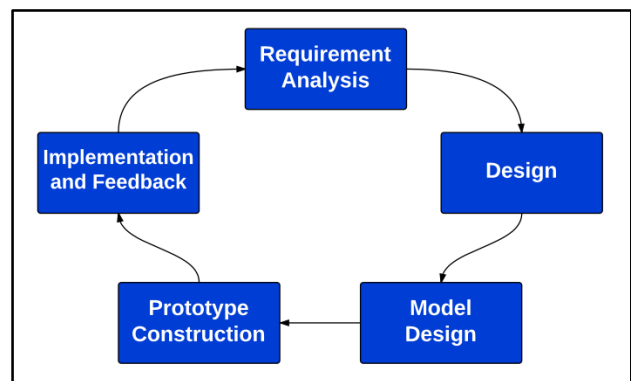


FIGURE 5: Prototyping model [4]

The four processes in one iteration are divided into:

1. Plan and create specifications. This is going to determine objectives, alternatives and constraints.
2. Go thru a risk assessments, to evaluate alternatives identify and resolve risks.
3. Develop and verify next level product. It is in this process includes going to construct, realize and test the part of the project that has been planned.
4. Evaluate and plan next phases. This requires input from both the developers and the customers. All the modifications that has to be done with the product must be included in the next round, beginning with process 1. [2]

The processes are starting in the top left of Figure 3.1 and moving clockwise. The increasing radius of the spiral is directly proportional to the work performed. The angular dimensions represent the progress made in completing each process of the spiral. For each completed round of the circle, you achieve an improved and more developed product. [2]

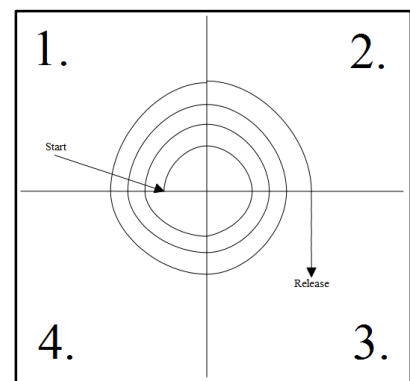


FIGURE 6: Spiral model [3]

3.2 WHY THE SPIRAL MODEL?

OLC chose the spiral model for the project “Offshore Lifting Clamp Engineering” in order to follow the waterfall model structure while focusing on the prototype models repetition and high priority to risk assessment. The model is easy to understand. A project can choose the number of cycle's to go through, and determine the period of each process to get a quick preferentially time of each cycle. By doing this it is possible to review each category at multiple levels so that small defects are easier to detect. A product is therefore possible to be presented even if it has not had enough time to implement all the planned cycles. This can occur in any project due to a tight schedule or unpredicted circumstances.

Figure 3.4 shows how OLC is combining the waterfall model and the prototyping model.

2gs

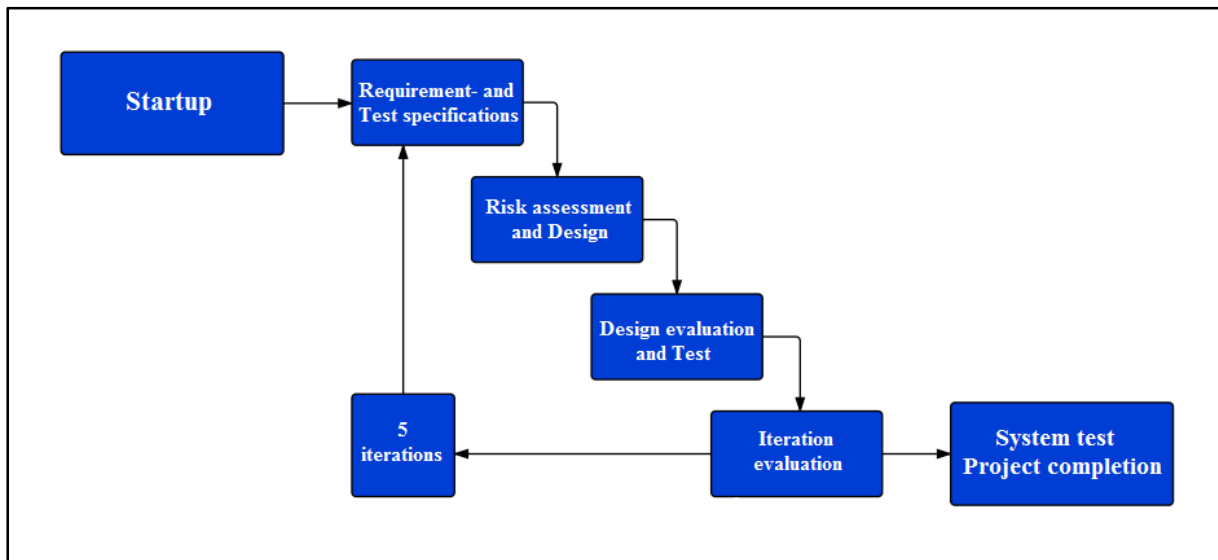


FIGURE 7: OLC spiral model

OLC spiral model starts with a startup phase. In this phase, a project plan will be created and requirement specifications and test specifications will be written. In this way OLC will have a good overview of the time estimation and activities planned for the different iterations.

Next there will be four processes in each upcoming iteration. To customize the processes in the spiral model for the project, the names of the processes are changed. So they fit the tasks through the project. The four processes are divided into:

1. Review of requirements specifications and test specifications.
2. Create or improve a risk assessment. As well as working with a design or design concepts, depending on where the project is in the process.
3. Evaluate design. It is in this process an evaluation of the design, calculations and tests to see if the design meets the requirements will be one.
4. Evaluation of the iteration. A research on what went well or wrong and a plan on what is going to be done in the next iteration, is performed.

OLC has planned that one iteration are going to last for two weeks. The aim is to do the first and second processes in the first week, followed by the third and fourth process the last week. OLC consist of five group members that often work with different activities at the same time.

It will therefore be a swift transitions between the processes, because there are going to be work done with some activities in parallel.

In the schedule there is planned five iterations before proceeding to the last phase.

The last period of the project will consist of a system test and a project completion phase. At this point it is planned to create a prototype for testing. This in addition to completing all the documentation that needs to be delivered, and create and present the main and final presentation.

Figure 3.5 is showing the performed tasks in the OLC spiral model, and will be updated after each iteration.

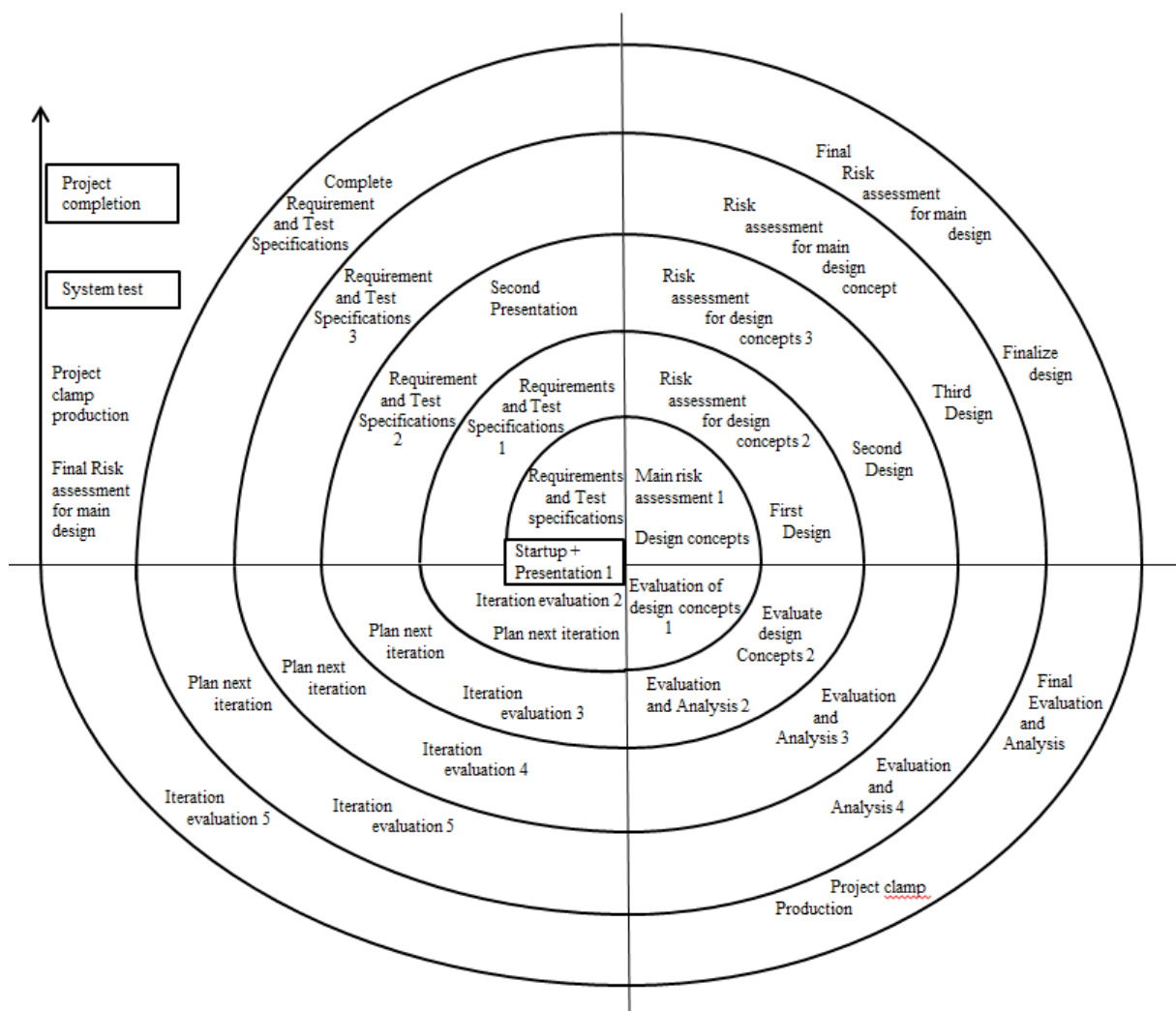


FIGURE 8: OLC spiral model with detailed iterations.

4. TIME SCHEDULE

The period of the bachelor project is from the start of January 2016 until 23th of May 2016. The estimated workload expected of each student is approximately 600 hours. That means that the estimated workload for OLC, consisting of five students, is 3000 hours in total. OLC will in addition to the bachelor thesis, have an obligatory subject that will be focused on until the end of March. This causes a reduction of work during this period.

A time schedule has been worked out to get an overview and separate the tasks that need to be done throughout the project. A roughly estimated workload for each group member is predicted to be ~ 25 hours per week until the Easter holiday is over. After Easter holiday and until the final presentation on 25th of May, the group members will work ~ 45 hours a week. This will give a total work load of 2725 hours in the project.

This is below the expected total workload of 3000 hours, but is without calculating the expected overtime in the period. This will be a minimum requirement for what is expected workload per group member.

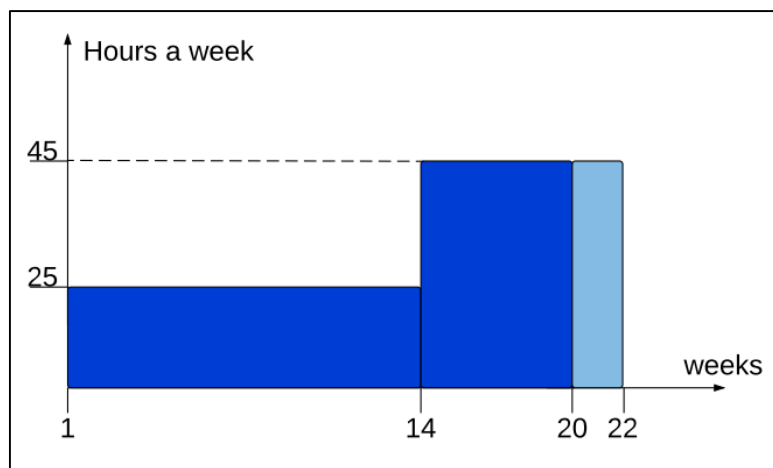


FIGURE 9: Expected working hours per team member

4.1 ITERATIONS

According to the project model, there is planned five iterations during the process, in addition to a Startup-phase and a System test and Project completion –phase. In total, this gives the project seven working periods.

The planning of the project for the whole process has been based on the project model. The time schedule presented is divided into the different iteration, to clearly state how it uses the project model to execute the project. The iterations are all built up in a similar way, consisting of the same types of repeating activities. The plan is to do several iteration of design concept building and modelling, followed by evaluations and analysis of the designs. By doing several iterations, it forces the project to control and evaluate the process and design, giving the opportunity of keeping the development on track and regularly compare the design up against the requirement specifications and the customer expectations and feedback. An evaluation of the progress and project in each iteration will be presented in the “**Iteration Evaluation Report**”.

4.2 TIME SCHEDULE OVERVIEW

Project name		Offshore Lifting Clamp Engineering		Version number	2.1
Group name		OLC Engineering - Group 5		Date	05.03.2016
TIME SCHEDULE					
Month	Week	Estimated hours	Activities to be done		
	2-5	550	STARTUP		
J A N	2/3	275	<ul style="list-style-type: none">• Startup• Preparations• Contract• Template • Project Model• Activity Specifications• Time Schedule• Gantt chart• DNV• Requirement Specifications		
	4/5	275	<ul style="list-style-type: none">• Requirement Specifications• Test Specifications• Situation Analysis• Activity Specification• Project plan • FIRST PRESENTATION 4th of February		
F E B	6/7	250	FIRST ITERATION		
	6/7	250	<ul style="list-style-type: none">• Requirement Specification• Test Specification• Risk Assessment 1 • Evaluate Design Concepts 1• Evaluation and Analysis 1		

M A R A P R	8/9	250	SECOND ITERATION
	8/9	250	<ul style="list-style-type: none"> Review Requirement Specifications 1 Review Test Specifications 1 Risk Assessment 2 Evaluate Design Concepts 2
	10/11	300	THIRD ITERATION
	10/11	300	<ul style="list-style-type: none"> First Design Evaluation and Analysis 2 Web site
	10/11	300	<ul style="list-style-type: none"> Review Requirement Specifications 2 Review Test Specifications 2 Risk Assessment 3 Second Design Evaluation and Analysis 3
	10/11	300	<ul style="list-style-type: none"> SECOND PRESENTATION 10th of March 11:30 AM.
	12	0	<i>Easter holiday</i>
	13/15	250	FOURTH ITERATION
	13/15	250	<ul style="list-style-type: none"> Review Requirement Specifications 3 Review Test Specifications 3 Risk Assessment 4 Third Design Evaluation and Analysis 4
	13/15	250	(06.04.2016 – Examination in subject: Mechatronics)

M A Y	16/17	450	FIFTH ITERATION
	16/17	450	<ul style="list-style-type: none"> • Close Requirement Specifications • Close Test Specifications • Final Risk Assessment • Finalize Design • Project clamp to Production
	18-21	675	SYSTEM TEST AND PROJECT COMPLETION
	18/19	450	<ul style="list-style-type: none"> • Testing of project clamp • Review documentation • Test Documentation
	20/21	225	<ul style="list-style-type: none"> • Finalize testing • Finalize project report • Deliver final Project report and product Deadline: Monday 23th of May, at 09:00 AM • THIRD AND FINAL PRESENTATION Wednesday 25th of May Room: Hegstad 11:30 AM
		Total 2725	

TABLE 1: Time schedule

5. ACTIVITY LIST

As shown in the time schedule, the project consist of various activities throughout the project period. The activities listed, are all the tasks believed needed to go through, to finalize the project and creating a product. In the activity list, all of the activities are listed after different types of categories, giving each activity:

- *An ID-number*
- *A description*
- *Information of the members working on each activity*
- *The start- and stop-date and expected working hours*
- *A reference to corresponding requirement for the specific activity*

5.1 TRACEABILITY

- The ID-number of the activity list all starts with the letter A. This letter refers to the activity list. In all the documentation, a number written in the form of: Ax.x.x, will refer to this activity list, and gives an easy traceability in the project.
- To be able to trace back to the persons working on one specific activity, we have signed each activity with the initials of the members working on the task. The initials written in a bold type, is the person responsible for the activity.
- A column for date, time and working hours gives a traceability back to in what time period the activity is planned to be executed.

This type of traceability are conducted throughout the project in all of the written reports. The aim of OLC is to work parallel with the iterations in the spiral model and always be able to trace activities back to persons and dates. This will help the project keeping the time schedule and reaching the goals during the project.

5.2 ACTIVITY CATEGORIES

The OLC members have chosen to divide the activity list into different categories, listing same type of work into the same category.

- **A1.0 - Start- up of project**

All of the activities connected to the startup of the project, including the project plan

- **A2.0 Risk, requirements and tests**

The activities connected to risk analysis, requirement specification and test specification during all of the iterations throughout the project

- **A3.0 Design**

Activities connected to the design of the product, including Solid Works and FEM-analysis

- **A4.0 Submissions and presentations**

All of the activities connected to hand-ins and presentations in the project period

- **A5.0 Administrative task**

All of the administrative tasks, such as all kind of meetings and writing documents.

5.3 ACTIVITY SPECIFICATION LIST

	Offshore Lifting Clamp Engineering	Version number	3.0
Group name	Group 5	Date	20.05.2016
Activity Specification List			
ID	Activity name and description	Res.	Date, hour
A1.0	Start-up of project		
A1.1	Kick off Startup of project	ALL	17.01.16 08.01.16 12 h
A1.2	Preparation Gathering information about bachelor projects, decide a project model to use	ALL	08.01.16 11.01.16 45 h
A1.3	Group contract Write a contract for the members of the group	HG HL	12.01.16 12.01.16 2 h
A1.4	Templates Design an unified template for the project	HG	13.01.16 13.01.16 6 h
A1.5	Logo Design a project logo	ALL	25.01.16 29.01.16 20 h
A1.6	Project model Design project model specifically for the group project	HL SK MR	12.01.16 15.01.16 20 h
A1.7	Time schedule Design a time schedule for the project throughout the project lifetime	NL MR HG	12.01.16 14.01.16 10 h

A1.8	Activity specifications Design an activity-list with descriptions of activities during the project	NL MR HG	12.01.16 21.01.16 60 h
A1.9	Gantt chart Design a Gantt-diagram based on the time schedule and action plan	MR SK	12.01.16 22.01.16 35 h
A1.10	Project plan Complete the project plan document	NL SK	20.01.16 27.01.16 50 h
A1.11	Web site Create a web site with information about our group	NL	22.02.16 02.03.16 20 h
A2.0	Risks, requirements and tests		
A2.1.0	Research pre-design phase		
A2.1	DNV Get to know the regulations in DNV 2.22 and DNV 2.7	ALL	15.01.16 20.01.16 25 h
A2.2	Situation analysis Analysis of the enviroment, workinghabits, limitations, product lifte-time, ...	SK ALL	13.01.16 30.01.16 60 h
A2.2.0	Requirements		
A2.2.1	Research on requirements Reasearch on requirement, find out how to write, what is important, how to link, etc...	ALL	21.01.16 22.01.16 20 h
A2.2.2	Requirement Specification 1 First attempt writing requirements for the project	HL MR HG	21.01.16 29.01.16 94 h
A2.2.3	Requirement Specification Document Complete the first document for requirement specification	HL MR HG	25.01.16 29.01.16 15 h

A2.2.4	Review Requirement Specifications 1 Review and update the previous requirement specification and the requirement document in the second iteration	MR	22.02.16 24.02.16 20 h
A2.2.5	Review Requirement Specifications 2 Review and update the previous requirement specification and the requirement document in the third iteration	HL HG MR	09.03.16 11.03.16 20 h
A2.2.6	Review Requirement Specifications 3 Review and update the previous requirement specification and the requirement document in the fourth iteration	HL MR	07.04.16 08.04.16 10 h
A2.2.7	Complete Requirement Specifications Finish and complete the requirement specification document		18.04.16 19.04.16 30 h
A2.3.0	Test specifications		
A2.3.1	Test Specification 1 First version of test specifications, finding information and implementing this into our project, what kind of tests do we need to perform to meet the requirements of the project?	NL SK HG MR	25.01.16 29.01.16 70 h
A2.3.2	Test Specification Document Complete the first document for test specifications	NL SK	28.01.16 29.01.16 15 h
A.2.3.3	Review Test Specifications 1 Review and rewrite the test specification in the second iteration	MR	22.02.16 24.02.16 20 h
A2.3.4	Review Test Specifications 2 Review and rewrite the test specification in the third iteration	HL HG MR	09.03.16 11.03.16 20 h

A2.3.5	Review Test Specifications 3 Review and rewrite the test specification in the fourth iteration	HG MR	07.04.16 38.03.16 10 h
A2.3.6	Complete Test Specifications Finish and complete the test specification document		18.04.16 19.04.16 30 h
A2.3.7	Testing of produced prototype Testing of a final model of the lifting clamp	ALL	02.05.16 13.05.16 220 h
A2.3.8	Review Test Documentation Go through, review and update all of the test data in the project, based on test results	HL SK	02.05.16 08.05.16 80 h
A2.3.9	Test Documentation Complete the test report	HL SK ALL	09.05.16 13.05.16 80 h
A2.4.0	Risk Assessment		
A2.4.1	Risk Assessment 1 Perform a risk analysis of the project based on current information; requirement specification and test specification	SK HL	08.02.16 10.02.16 40 h
A2.4.2	Risk Assessment 2 Perform a risk analysis of the project based on current information in the second iteration; requirement specification and test specification	SK HL	22.02.16 24.02.16 40 h
A2.4.3	Risk Assessment 3 Perform a risk analysis of the project based on current information in the third iteration; requirement specification and test specification	HL SK	09.03.16 11.03.16 15 h
A2.4.4	Final Risk Assessment Perform a final risk analysis of the designed product, in cooperation with FMC	HL SK	25.04.16 01.05.16 50 h

S2.4.5	Risk Assessment 4 Perform a risk analysis of the project based on current information in the fourth iteration; requirement specification and test specification	HL SK	07.04.16 08.04.16 10 h
A3.0	Design		
A3.1.0	Design concepts		
A3.1.1	Evaluate Design Concepts 1 Discuss and design different design concepts, calculate strength measurement	ALL	08.02.16 11.02.16 75 h
A3.1.2	Evaluate Design Concepts 2 Re-discuss and design different design concepts after the first iteration	HL HG MR SK	25.02.16 25.02.16 45 h
A3.1.3	Project clamp production Produce a model of the clamp for physical testing	ALL	120 h
A3.2.0	Design in SolidWorks		
A3.2.1	First Design Create and work on a first design of the lifting clamp	NL HG MR HL	10.02.16 16.02.16 80 h
A3.2.2	Second Design Continue working on the design, based on the evaluation of the first design	ALL	10.03.16 16.03.16 75 h
A3.2.3	Third Design Continue working on the design, based on the results from the second design	ALL	08.04.16 17.04.16 75 h
A3.2.5	Finalize design Finalize the design of the product, based on the results from the fourth design	ALL	18.04.16 29.04.16 120 h

A3.3.0	Evaluation and Analysis		
A3.3.1	Evaluation and Analysis 1 Perform evaluations, FEM analysis` and calculations based on the design	HG MR SK	17.02.16 21.02.16 35 h
A3.3.2	Evaluation and Analysis 2 Perform evaluations, FEM analysis` and calculations based on the design	ALL	02.03.16 06.03.16 25 h
A3.3.3	Evaluation and Analysis 3 Perform evaluations, FEM analysis` and calculations based on the design	ALL	16.03.16 20.03.16 50 h
A3.3.4	Evaluation and Analysis 4 Perform evaluations, FEM analysis` and calculations based on the design	ALL	13.04.16 15.04.16 50 h
A3.3.5	Final Evaluation and Analysis Perform evaluations, FEM analysis` and calculations based on the final design	ALL	25.04.16 29.04.16 50 h
A4.0	Submissions and presentations		
A4.1.0	Submissions		
A4.1.1	First report Complete and hand in a full first report	ALL	27.01.16 01.02.16 30 h
A4.1.2	Second report Complete and hand in a full second report	ALL	03.03.16 07.03.16 50 h
A4.1.3	Third and final report Complete the final report for the project	ALL	11.05.16 20.05.16 50 h
A4.1.4	Deliver final Project Report and product Due-date: Last check before handing in final report	ALL	23.05.16 15 h

A4.2.0	Presentations		
A4.2.1	Design first Presentation Design the layout and practice before the first presentation	ALL	02.02.16 03.02.16 30 h
A4.2.2	First Presentation Prepare for and hold the first presentation for the examitators	ALL	04.02.16 04.02.16 10 h
A4.2.3	Design Second Presentation Design the layout and practice before the second presentation	ALL	08.03.16 09.03.16 30 h
A4.2.4	Second Presentation Prepare for and hold the second presentation for the sensors	ALL	10.03.16 10.03.16 10 h
A4.2.5	Design third Presentation Design the layout and practice before the third presentation	ALL	18.05.16 24.05.16 30 h
A4.2.6	Final Presentation Prepare for and hold the final presentation for the sensors	ALL	25.05.16 15 h
A5.0	Administrative tasks		
A5.1	Group Meeting Group meetings for discussion of project, plans, design etc.	ALL	07.01.16 25.05.16 200 h
A5.2	Meeting Internal Supervisor Weekly meeting with internal supervisor Amin Hossein Zavieh	ALL	07.01.16 24.05.16 100 h
A5.3	Meeting External Supervisor Meetings with external supervisor Einar Totland, throughout the project period	ALL	07.01.16 24.05.16 100 h
A5.4	Meeting Minute A summary of every meeting with internal/external supervisor shall be written	ALL	07.01.16 24.05.16 25 h

A5.5	Follow up Document A follow up document shall be written every week in beforehand of the internal supervisor meetings	NL	07.01.15 24.05.16 16 h
A5.6	File Sorting Sorting files and documents during the project	ALL	07.01.16 23.05.16 50 h
A5.7	Administrative Open activity, including all other administrative tasks like e-mailing or calling internal/external supervisor, finding rooms, prepare drinks/snacks for presentations, etc	ALL	07.01.16 23.05.16 150 h
A5.8	Web site update Update of information and progress in project, on group web site.	NL	04.03.16 25.05.16 25 h
A5.9.1	Iteration Evaluation 1 Evaluation of the progress and work done in the Startup-phase. Preparations for the next iteration. Documentation in an Iteration Evaluation Document.	HL	05.02.16 07.02.16 12 h
A5.9.2	Iteration Evaluation 2 Evaluation of the progress and work done in the First Iteration. Preparations for the next iteration. Documentation in an Iteration Evaluation Document.	HL	19.02.16 21.02.16 12 h
A5.9.3	Iteration Evaluation 3 Evaluation of the progress and work done in the Second Iteration. Preparations for the next iteration. Documentation in an Iteration Evaluation Document.	HL	04.02.16 06.02.16 12 h
A5.9.4	Iteration Evaluation 4 Evaluation of the progress and work done in the Third Iteration. Preparations for the next iteration. Documentation in an Iteration Evaluation Document.	NL	18.03.16 20.03.16 12 h

A5.9.5	Iteration Evaluation 5 Evaluation of the progress and work done in the Fourth Iteration. Preparations for the next iteration. Documentation in an Iteration Evaluation Document.	SK	15.04.16 17.04.16 12 h
A5.9.6	Iteration Evaluation 6 Evaluation of the progress and work done in the Fifth Iteration. Preparations for the next iteration. Documentation in an Iteration Evaluation Document.	NL	29.04.16 01.05.16 12 h
A5.9.7	Iteration Evaluation 7 Evaluation of the progress and work done in the Systest and Project Completion- phase. Preparations for the next iteration. Documentation in an Iteration Evaluation Document.	HL	19.05.16 20.05.16 12 h
A5.10	Document update Update of documents in the project throughout the period; documents in the Project plan and Design report	ALL	04.03.16 23.05.16 80 h

TABLE 2: Activity specification list

ID: Identification number

Res: Responsible (in initial)

Initial:

- Nelly Marie C. Larsen: NL

- Hasan Güven: HG

- Hanne Lode: HL

- Samrit Kaur: SK

- Magne Rasmussen: MR

6. GANTT DIAGRAM

To describe the time schedule and activity plan during a project, it is often preferred to design a Gantt-chart. Chosen tool to use for creating a Gantt chart that provides a graphical illustration and representation of the progress in the project, is the tool “Ganttter” in Google Drive.

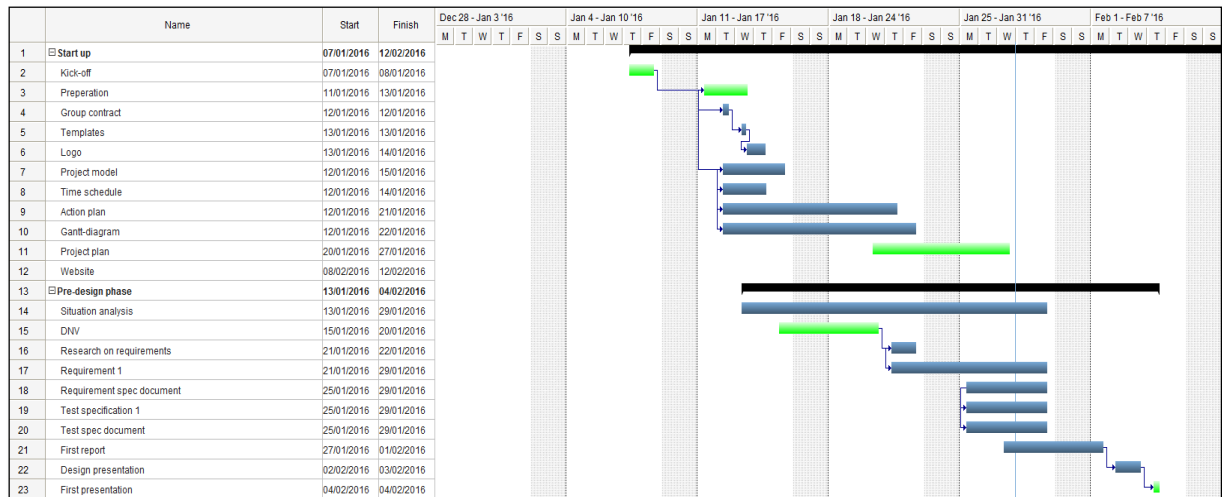


FIGURE 10: A small clipping of the OLC Gantt-diagram

Full project Gantt chart on the next page

The Gantt-chart provides an overview of the various project tasks, milestones and estimated time used on each activity. The activities are divided into different phases, following the time schedule and activities for the project.

- The black line separates each phase in the diagram.
- The green line describes the presentations in the period.
- A blue line describes different tasks and time-period for all of the activities, including the members that shall perform the activity.
- The yellow line describes holidays.
- The red line describes the period for examination in Mechatronics.
- The solid blue line at the bottom of the chart describes administrative tasks that shall be executed continuously throughout the whole project period.

6.1 OLC GANTT DIAGRAM

7. TIME TRACKING

A timesheet keeps track of the hours spent by each team member during the project period. It is advantageous to track the hours put into the project during the entire period, because the tracking provides a detailed overview of how many hours each member have spent in the project, and what kind of activities has been executed. Another advantage is that the tracking system connects to the activity list, which is used to estimate the time consumption for the project and to check whether the estimated hours corresponds to elapsed time. The OLC members fill in two types of time tracking sheets:

- **Individual Time Tracking**
- **Activity Specification Time Tracking**

7.1 INDIVIDUAL TIME TRACKING

To have an overview of the workhours of each group member, a time tracking sheet is created. By using Microsoft Excel, we have made a time tracking template. The time tracking table describes each team members work performance in hours throughout the project. It describes the activity and the hours the OLC members has spent on each activity. Each working period is divided into weeks, dates and weekdays, and summarize the number of hours spent every week. Having the time sheet tracking both the hours and activities done, it supplies an overview over the projects progress and content.

Offshore Lifting Clamp Engineering								
[Ola Nordmann]'s Timesheet			Total hours worked		0,0			
Date	Day	Task #1	Hours	Task #2	Hours	Task #3	Hours	Total
04.01.2016	Monday							0,0
05.01.2016	Tuesday							0,0
06.01.2016	Wednesday							0,0
07.01.2016	Thursday							0,0
08.01.2016	Friday							0,0
09.01.2016	Saturday							0,0
10.01.2016	Sunday							0,0
Total hours								0,0

FIGURE 11: Time Tracking

7.2 ACTIVITY SPECIFICATION TIME TRACKING

Planning the progress of the project in advance, has proven to be challenging. It has not been easy to predict how many hours each activity will take. It has therefore been necessary to bring about a method to keep track of the activities that have been performed, how many hours have been spent on each activity, and how many hours have been spent on the project, both in each iteration and in total.

To have an overview of the hours put in to the project in total, an activity specification time tracking sheet, from now on called ASTT, has been created.

The ASTT follows the Activity Specification List and the project model throughout the iterations in the project period. This tracking sheet gives detailed information about the hours spent on each activity, each iteration and in the project in total. This sheet enables OLC to follow the progress of the project and to control if the hours corresponds with the pre-estimated working hours of each activity. If any deviation occur, it will show in the tracking sheet and necessary adjustment in the project plan and time schedule throughout the process can be done.

7.3 OVERVIEW OF THE PROJECT HOURS

The table underneath is from the OLC ASTT. It gives an overview of the hours spent in the project throughout the project period, up until the end of week 20. It is interesting to see how the hours of the project have been spent in the project. The working hours has been adjusted a few times during the project period. Still, in some of the activities there has been some deviation in expected working hours and actual working hours.

In the second iteration OLC experienced some sickness and vacations in the team members. This becomes evident in this document, we see a discrepancy in the number of hours put in the second iteration, compared with the estimated time consumption expected for the same period. A small setback was experienced a small setback during this period. However, this was overtaken in the next period, which also appear on the form.

For the rest of the project period the total working hours has complied with the expected workload set for OLC in total.

It has been very interesting and useful to follow up the hours in the activities during the project. OLC has tracked the hours put into each activity, both for the whole team in total, for the team after every iteration and for each team member alone. It provides a good overview of how the hours spent in the project has been divided into the activities in the project.

To read the evaluations of each iteration and to see how the project has been executed together with the activities done, the workhours put in and the challenges met, see the “**Iteration evaluation report**” in back of the submitted report.

7.4 ACTIVITY SPECIFICATION TIME TRACKING

Activity specification time tracking						OLC Engineering				
ID	Activity	Project period								
		Startup	1. iteration	2. iteration	3.iteration	4. iteration	5. iteration	System test and project completion	Total hours in activity	Estimated working hours in activity
A1.0 STARTUP										
A1.1	Kick-off	10							10	12
A1.2	Preparation	25							25	45
A1.3	Group contract	6							6	2
A1.4	Templates	21,5							21,5	6
A1.5	Logo	10							10	20
A1.6	Project model	24,5		3					27,5	20
A1.7	Time schedule	15							15	10
A1.8	Activity specifications	25,5							25,5	60
A1.9	Gantt-digram	18,5							18,5	35
A1.10	Project plan	48,5		3					51,5	50
A1.11	Web site		3,5	20,5					24	20
Pre-design phase										
A2.1	DNV	40							40	25
A2.2	Situation Analysis	28					1	3	32	60

A2.2.1	Research on requirements	8						8	20
A2.2.2	Requirement Specification 1	71	11,5					82,5	64
A2.2.3	Requirement Specification Document	18						18	15
A2.3.1	Test Specification 1	29						29	40
A2.3.2	Test Specification Document	11,5						11,5	15
A4.1.1	First report	24						24	30
A4.2.1	Design first presentation	82						82	30
A4.2.2	First presentation	17,5						17,5	10
A5.9.1	Iteration Evaluation 1			8,5				8,5	12

FIRST ITERATION									
A2.2.2	Requirement Specification 1		9,5					9,5	30
A2.3.1	Test Specification 1		20					20	30
A2.4.1	Risk Assessment 1		26,5					26,5	40
A3.1.2	Evaluate design concepts 1		68,5	3				71,5	75
A3.3.1	Evaluation and Analysis 1		9,5	5				14,5	35
A5.9.2	Iteration Evaluation 2			4	0,5			4,5	12

SECOND ITERATION									
A2.2.4	Review Requirement Specifications 1			3				3	20
A2.3.3	Review Test Specifications 1			3				3	20
A2.4.2	Risk Assessment 2			30,5				30,5	40
A3.2.2	Evaluate design concepts 2			37,5				37,5	45
A3.2.1	First Design			92,5				92,5	80
A3.3.2	Evaluation and Analysis 2			11,5				11,5	25
A5.9.3	Second Report			53,5	46			99,5	50
A4.1.2	Iteration Evaluation 3			13	0,5			13,5	12

THIRD ITERATION									
A2.2.5	Review Requirement Specifications 2				8,5			8,5	20
A2.3.4	Review Test Specifications 2				4			4	20
A2.4.3	Risk Assessment 3				3			3	15
A3.2.2	Second design				67,5			67,5	75
A3.3.3	Evaluation and Analysis 3							0	50
A4.2.3	Design Second Presentation				86			86	30
A4.2.4	Second Presentation				7,5			7,5	10
A5.9.4	Iteration Evaluation 4				4	1,5		5,5	12

FOURTH ITERATION										
A2.2.6	Review Requirement Specifications 3					2			2	10
A2.3.5	Review Test Specifications 3					3,5			3,5	10
A2.4.5	Risk Assessment 4					1			1	10
A3.2.3	Third Design					179,5			179,5	75
A3.3.4	Evaluation and Analysis 4					25,5			25,5	50
A5.9.5	Iteration Evaluation 5					7			7	12

FIFTH ITERATION										
A2.2.7	Complete Requirement Specifications						24	9	33	30
A2.3.6	Complete Test Specifications						14	10,5	24,5	30
A2.4.4	Final Risk Assessment							51,5	51,5	50
A3.2.5	Finalize design						255,5	120	375,5	120
A3.3.5	Final Evaluation and Analysis						47,5	46,5	94	50
A3.1.3	Project clamp production					8	2,5	63	73,5	120
A5.9.6	Iteration Evaluation 6						2,5	3	5,5	12

SYSTEM TEST AND PROJECT COMPLETION									
A2.3.8	Review Test Documentation					4,5	1	5,5	80
A2.3.7	Testing of produced clamp model						31	31	220
A2.3.9	Test Documentation					5	87	92	80
Project completion									
A4.1.3	Third and Final Report					29,5	252	281,5	50
A4.1.4	Deliver final Project Report and product							0	15
A5.9.7	Iteration Evaluation 7						1	1	12
A4.2.5	Design Third Presentation						52,5	52,5	30
A4.2.6	Final Presentation							0	15

ADMINISTRATIVE TASK										
A5.1	Group meeting	19	1,5	37	36,5	10	30	24,5	158,5	50
A5.2	Meeting Internal Supervisor	9,5	2	6,5	5	7	7	11	48	100
A5.3	Meeting external supervisor	24,5		22,5		16	34		97	100
A5.4	Meeting minute	5	1	7		1,5	5	1,5	21	25
A5.5	Follow up document	2,5	1,5	2	1	1,5	1,5	3	13	16
A5.6	File sorting	6		4,5	2,5	1	0,5		14,5	40
A5.7	Administrative	28,5	5,5	9,5	22	15	12,5	10,5	103,5	120
A5.8	Web site update				1	4,5	1,5	2	9	25
A5.10	Document update				4	2	8	72,5	86,5	80
Total hours in period:		628,5	160,5	380,5	299,5	286,5	486	856	3097,5	

Estimated working hours for period:	550	250	250	300	250	450	675	2725
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TABLE 3: Activity specification time tracking

8. OLC ENGINEERING BUDGET

The project period with all work done and prototypes made has inflicted the project with some expenses. To be able to have an overview of the consumption in the project, a budget was made. The budget covers the necessary purchases required to complete making and testing of the prototypes in the project period and various other project work in the period.

OLC Engineering Budget			
Activity	Expences	Total estimated cost	
Making prototypes in workshop	Raw material, hired help, paint	kr	3 000,00
Making prototypes in 3D-print	Raw material, equipment wear	kr	1 500,00
Clothes for final presentation	Logo print	kr	500,00
Food for presentations	Coffee, tea, cookies	kr	500,00
Printing out the final report	Paper, hardcover	kr	1 500,00
		kr	7 000,00

Table 4 OLC engineering budget

9. CONCLUSION

This project plan includes the planning of our whole project period. The OLC members are following the spiral model, planning several iteration to be able to go through the requirements specifications, test specification, risk analysis and evaluation of design concept several times. The spiral model will fit the OLC project, enabling the project to focus on renewing and evaluating the specifications and design by each iteration. Based on the project model, the time schedule is divided into periods of two weeks. The project plan is also an introduction of the OLC group and the project. The project plan discusses the goals, visions and plans consisting communication and work. The results of the project plan is presented in a time schedule, activity specification list and Gantt-diagram. These documents gives a detailed presentation of the planning of the project period with the planned activities during the whole project.

The experience gained after completing the whole project period, is that a good thought-out project plan, a good project model and a willingness to get the job done is necessary for a smooth project. OLC has experienced some setbacks and big challenges in the project. By using the project model and having continuous iteration evaluations, the project is forced to be aware of where OLC are in the process and is guided and helped when continuing further.

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FINN STRØM AS



OFFSHORE LIFTING CLAMP ENGINEERING
VERSION 2.0

DESIGN REPORT

20.05.2016

ABSTRACT

The design report describes and present the whole design process throughout the project period.

The report includes the startup phase with concept building and concept selection, further developing of designs until a chosen final design. The final design of the product is presented with design and dimensions, material selections, 3D modelling and analysis done through Finite Element Method (FEM).

The purpose of the design report is to show all the work done by OLC in the project. This report will give the reader insight of what the various processes in the project contains, and also technical knowledge of the final product and solution.

CHANGES

The changes will be listed here:

Version	Date	Description
1.4	19.05.2016	<ul style="list-style-type: none">• Added: Abstract, 7.1.1, 7.1.2,• Edited content in: Introduction, 1, 6, 6.1, 7, 7.1• Removed: 6.3 Completed the document
1,1	09.03.2016	<ul style="list-style-type: none">• Added missing concept
1.0	07.03.2016	<ul style="list-style-type: none">• Written the conclusion
0.6	07.03.2016	<ul style="list-style-type: none">• Added: - 6.0, 6.1, 6.2, 6.3• Edited layout
0.5	07.03.2016	<ul style="list-style-type: none">• Added concepts and pictures
0.4	07.03.2016	<ul style="list-style-type: none">• Removed table from 3.2 requirement description and requirement description to 8.0 requirement description table• Edited:<ul style="list-style-type: none">- Risk in requirement description table- Text size and color- Headlines• Added picture and picture text
0.3	06.03.2016	<ul style="list-style-type: none">• Edit:<ul style="list-style-type: none">- Introduction- 1.0, 2.0, 2.1,
0.2	06.03.2016	<ul style="list-style-type: none">• Created front page• Edited text size and color• Created list of contents

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In addition to the above:

There may be spelling mistakes that are corrected. It is possible that these changes are not listed.

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INTRODUCTION

The design report is an important document that gives an understanding of the development of OLC's solution for a lifting clamp. The design report contains information about the process and the technical areas around the product. It will be usable as an instruction manual and a source to gain information about the development of the design process and the final product.

OLC has chosen to follow the spiral model as a project model for project period. The spiral model gives the project the opportunity to often evaluate and control the progress and result in the development process. By doing several iterations during the project period, it forces the project to do analysis, evaluations and risk assessments of the work done in every iteration. By working by this model, the project will be able to control whether or not the solution offered by OLC, is on track with the requirements given by the customer. More detailed information about the spiral model is given in the "Project Plan" document. An evaluation after each iteration in the project is documented in the "Iteration Evaluation Report".

The purpose with this design report is to present the work done by OLC throughout the project period since the first presentation. The report provides a description of the design development and progress through the period up to the final product and result of the project. It will give an introduction of the important factors for the development of OLC's solution, and the evaluation and selection process. OLC have come up with a solution for lifting pipes offshore and off-board, and this document will present the results and design of the solution.

1. FOUNDATION FOR THE DESIGN CONCEPTS

As described in the “Requirement Specification Report”, OLC has a set of requirements to follow, given by their employee; FMC Technologies, DNV and by OLC themselves. These requirements establish the foundation for the design concepts.

The foundation represent the main condition for selecting a design concept to continue working on. When selecting a concept, it is important for it to meet the requirements set for the project. It is crucial for a concept to meet the A-requirements to even be considered being further developed. The probability of developing a clever product with a high quality increases when it fulfills the conditions set in the requirements. The challenge is to combine all of the requirements into one design. OLC has focused on knowing and meeting these requirements, to succeed and proceed with developing a satisfactory concept.

During a process and a development of a product, there is always a possibility that the customers’ expectations, opinions and ideas might change. OLC has received several new and unexpected requirements from the customer on the product and solution. A new requirement was introduced early in the process, which led to challenges related to the development of a satisfying solution. After working on finding a solution for this, OLC got two additional new requirements that the customer wanted to implement in the product late in the project period. This has proven to be a big challenge, which OLC has been working on solving.

OLC’s high priority is to develop a product and solution that fulfills the requirements set for this type of equipment and that satisfies the wishes made by the customer. The final design and product has been discussed and evaluated both internal in OLC, and in meetings together with the customer. By inviting the customer to join in the design concept phase, it enables OLC to control and ensure that the product is developed according to the expectations of the customer, and also by the requirement specifications.

2. START UP

In week 6, the project went into the first iteration of designing, according to the project plan. Based on a foundation made up of a well understanding of the requirements for the desired product, OLC could start working on different ideas for design concepts. The startup of the design concepts consisted of brainstorming on ideas. All suggestions and ideas was taken into consideration, to ensure that so many solutions as possible was mentioned, to meet the customer expectations of a product. OLC did research on already existing concepts and their components, and also on the ideas of the brainstorming. Through discussions and researches, it was determined whether the concepts could be a realistic solution for a product.

The result of the brainstorming and discussions was put into a list, to explain and separate the different design concept ideas. The list ended up consisting of fifteen different solutions for a concept, divided into two main categories:

1. **Clamp** – *a solution based on a redesign or remodeling of an existing lifting clamp*
2. **Other concepts** – *a solution that is based on lifting without a traditional lifting clamp*

The different concepts are described in the following table, and are the foundation for the determination and evaluation of which concepts is worth doing further developing on.

2.1 CLAMP CONCEPTS

This table on the next page describes the different concepts after the first brainstorming and development of design concept ideas.

- **The left column** are concepts based on a redesign or a variant of an existing lifting clamp.
- **The right column** describes concepts that are based on a solution without the use of a traditional lifting clamp.

CLAMP	OTHER CONCEPTS
Linked clamp: Adjustable clamp with the possibility for taking pipes with different sizes. Consisting of many links, similar to the links on a wristwatch.	Wire sling clamp: Adjustable clamp with the possibility for taking pipes with different sizes. Wire sling snared around a mat made of an elastic material, like rubber. The mat has grooves where the wire sling will lie in.
Re-design of existing clamp: Similar to the existing design, but built with a reduced weight and price. Focusing on improving the A-requirements given by FMC.	Adjustable belt: Adjustable clamp with the possibility for taking pipes with different sizes. A strap that is snared around the pipe having a buckle preventing it from open.
2-part clamp: A clamp consisting of two individual parts where each part has a weight of 25kg or less. Each part of the clamp can therefore be carried by hand.	Magnetic clamp: Clamp with an integrated magnet used for lifting.

<p>Insert clamp:</p> <p>A clamp with different inserts to compensate for the different diameters to the pipes.</p>	<p>Vacuum clamp</p> <p>Clamp with an integrated vacuum system used for lifting.</p>
<p>Drill Chuck fastening:</p> <p>A clamp that is fastened on a pipe using a similar tightening mechanism like a drill chuck uses.</p>	<p>Pipe tongs:</p> <p>A clamp working like a big scissor tong that tightens around the pipe when the crane starts lifting.</p>
<p>Automatic clamp:</p> <p>A clamp with an automatic locking and opening mechanism, with no need for manual assembly or disassembly.</p>	<p>Chain sling clamp:</p> <p>Adjustable clamp with the possibility for taking pipes with different sizes. Chain sling snared around a mat made of an elastic material, like rubber. The mat has grooves where the chain sling will lie in.</p>
<p>Sliding 2-part clamp</p> <p>A clamp that closes when you slide the two half-circled parts towards each other.</p>	<p>Ratchet belt:</p> <p>Adjustable clamp with the possibility for taking pipes with different sizes. A belt that tightens by using a buckle that engages with notches in the belt.</p>
	<p>Steel strips:</p> <p>Adjustable clamp with the possibility for taking pipes with different sizes. Work like the same way as normal plastic strips.</p>

TABLE 1: Clamp concept

3. DESIGN CONCEPT PUGH MATRIX

After coming up with different ideas for design concepts, it is important to have a method to evaluate and shorten down the number of input. The number of concepts developed in the design concept table, is too many to be working on. The necessity of deciding which concepts is best suited for further developing, is therefore major.

OLC used a Pugh matrix as a tool for deciding which concepts is most beneficial and will satisfy most requirements. A Pugh matrix is a decision-making matrix which evaluates different options against the same criteria [1]. Giving all of the concepts a score on each criteria based on the projected impact of the criteria, will give a result that suggest which concept that would most likely have the best outcome of a successful product.

In the Pugh matrix for the concept evaluation, there is already been done a selection of the concepts. Some of the concepts was rejected beforehand, because they would not be able to fulfill the DNV requirement. The matrix only consist of nine of the design concepts in the design concept table, after the selection.

3.1 CONCEPT NAMES

Following concepts was evaluated in the Pugh matrix. In the matrix, their respective concept number will refer to each concept.

Concept number:	Concept name:
Concept 1:	Two-part clamp
Concept 2:	Redesign of existing clamp
Concept 3:	Wire sling clamp
Concept 4:	Chain sling clamp
Concept 5:	Linked clamp
Concept 6:	Drill chuck fastening
Concept 7:	Adjustable belt
Concept 8:	Pipe tongs
Concept 9:	Sliding two-part clamp

TABLE 2: Concept names

3.2 REQUIREMENT DESCRIPTION

All of the concepts in the matrix are evaluated up against the same criteria, which are some of the main requirements for the product. **A description of each requirement is offered in the “Requirement description “-table on page 167.**

The concepts are scored after the probability of achieving a desired outcome of each requirement. The higher the score, the higher is the probability of a good result.

3.3 CONCEPT MATRIX

The matrix helps in deciding in which concepts OLC should focus their attention. The different concepts are measured up against the criteria, which are some of the most important requirement set for the product. Each concept gets a score on each criteria, based on how easy it would be to fulfill the respective requirement. A higher score suggest that the concept easily will fulfill the requirement, whilst a lower score predict an uncertainty and difficulty of managing to fulfill the requirement.

The requirements are divided into A-, B- and C-priorities. Their max score is therefore different for each priority, to distinguish the results in each priority.

A priority: min 0 - max 10

B priority: min 0 - max 5

C priority: min 0 - max 3

3.4 PUGH MATRIX TABLE

	CONCEPT									
Req	1	2	3	4	5	6	7	8	9	PRI
Weight	6	2	10	10	4	2	8	2	6	A
Productions cost	2	2	8	8	2	2	6	4	3	A
Risk	6	8	4	4	6	8	6	2	6	A
Temperature	5	5	2	2	5	5	3	5	5	B
User friendly	3	4	3	3	2	2	3	3	3	B
Robust	4	4	2	2	3	4	2	4	4	B
Different diameters	1	1	3	3	3	2	3	1	1	C
Mounting time	2	1	3	3	1	1	3	2	2	C
Storage space	2	2	2	3	3	2	3	1	2	C
Maintenance	2	2	2	1	1	1	2	1	2	C
Number of loose parts	2	3	2	2	3	3	3	3	2	C
Portable	3	1	3	3	1	1	3	1	3	C

TOTAL	38	35	44	44	34	33	45	29	39
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TABLE 3: Pugh matrix table

3.5 PUGH MATRIX RESULT

The results of the matrix gives an indication of which concepts are preferable to develop further, though the scores are close. These results was taken into discussion in a meeting with FMC Technologies. OLC thought it was important to have a dialogue with the customer, to present the different concepts, to get feedback and to get their opinions. There was an agreement of choices after the meeting.

Based on the matrix and the dialogue with FMC, OLC chose to work on developing solutions within the four highest coring concepts:

1. **Concept 7** - Adjustable belt
2. **Concept 3** – Wire sling clamp
3. **Concept 4** – Chain sling clamp
4. **Concept 9** – Sliding two-part clamp

In the next iteration of the project, OLC will be focusing on developing different solutions within these four concepts.

4. FIRST CONCEPT DESIGN

In week 8, the project went into the second iteration in design, according to the project plan. After having a concept developing and evaluation phase, and narrowing the number of concepts down to four, OLC started to have a closer look at the different concepts. Based on the chosen concepts to work on, the OLC members started working on different ideas for solutions. After working on different designs and ideas, it was clear that there was another four main principles of mechanism for how to solve the lifting challenge, developing from the four concepts.

The principles and the concepts will be further described:

4.1 CIRCULAR SLIDING

The circular sliding concept is a development from the sliding two-part clamp concept. It is based on a redesign of an existing clamp.

4.1.1 CIRCULAR SLIDING CONCEPT

This concept is based on a clamp consisting of three half-moon shaped parts. These parts are formed in such a way that they can slide into each other and make a closed circle around a pipe. The upper crescent has a built-in pad eye for the use of a wire sling when lifting

How to mount the clamp:

1. Put the upper crescent on the top of the pipe.
2. Take one of the existing half-moon shaped parts, and push it into its track from the bottom of the upper crescent.
3. Push it all the way until it reaches the stop notch, here it is fastened with a bolt.
4. Repeat process 2 and 3 with the other half-moon part, pushing this one into the remaining track.
5. Make sure that the bolts on the top are tighten firmly.

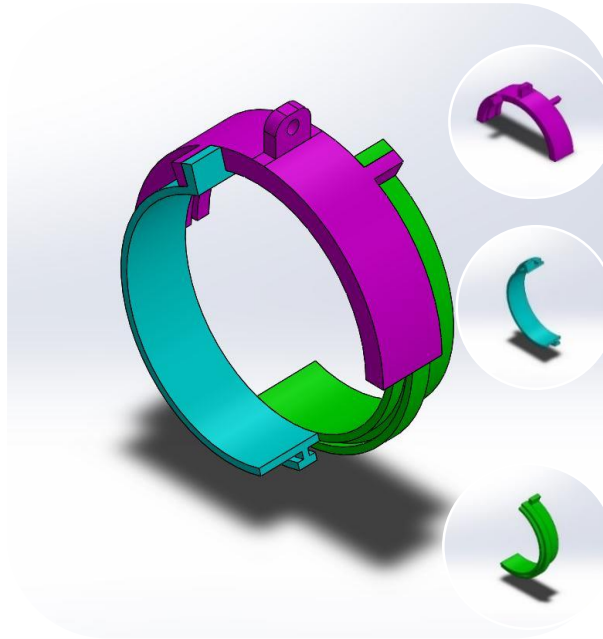


FIGURE 1: Circular sliding concept

This clamp does unfortunately not achieve too many of the requirements given by FMC. For instance, the clamp does not have the option to lift pipes with different diameters. However, it will most likely achieve a reduced production cost in addition to a reduced weight, even though it is not much.

When it comes to the advantages and disadvantages of this clamp these are the most mentionable:

Advantages:

- Since the clamp consist of three individual parts, you are able to carry the parts to the pipe and mount them, without the need of a crane.
- The clamp has a material and a construction that makes it easy to make.

Disadvantages:

- The clamp might be difficult to assemble both when thinking about the friction that occurs when sliding the parts into each other, and that you might need to be two people in order to keep the parts still until the mounting is completed.
- It is uncertain if the locking mechanism using the two bolts is enough to prevent it from sliding, after it has been mounted on the pipe.

4.2 SIDE BY SIDE SLIDING

The circular sliding concept is a development from the sliding two-part clamp concept. It is based on a redesign of an existing clamp.

4.2.1 SIDE BY SIDE SLIDING CONCEPT

This concept is based on a clamp consisting of two half-moon shaped parts. On the top of each of these parts there is a slot where the parts can interlock. On the bottom there is a locking mechanism that makes the clamp fit on tight to the pipe, preventing it from sliding.

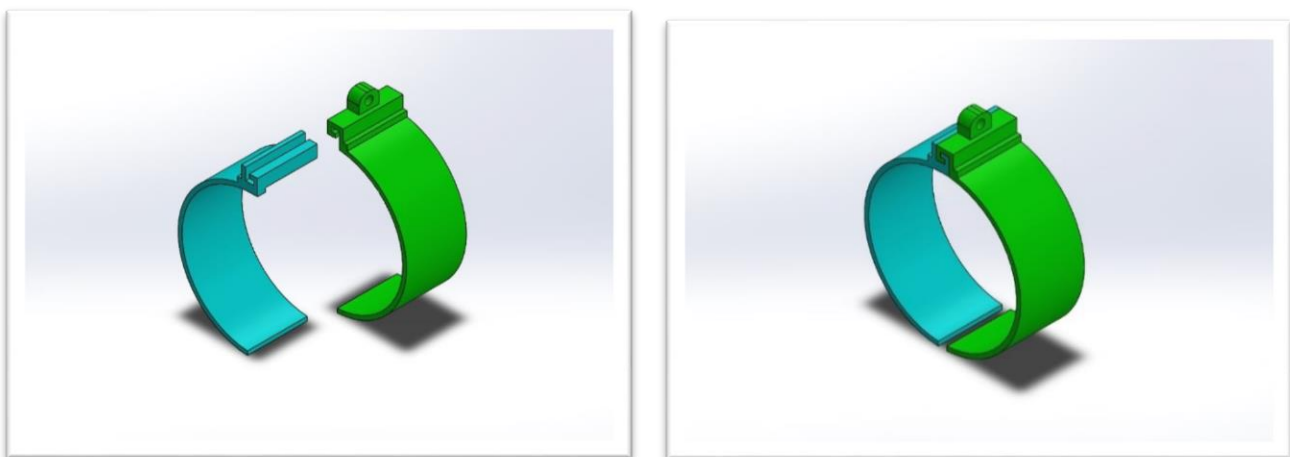


FIGURE 2: Side by side sliding concept

How to mount the clamp:

1. Put the left crescent onto one of the sides of the pipe.
2. Put the right crescent (the one with the built in pad eye) onto the other side of the pipe slightly offset from the other crescent.
3. Slide the right crescent alongside the pipe and interlock it with the left crescent.
4. Tighten the upper locking mechanism to prevent the parts from separating.
5. Tighten the lower locking mechanism to ensure that the clamp sits tight on the pipe.
6. Make sure that all bolts are tighten firmly.

This clamp fulfills the requirement about the no tolerance for sliding. Both before the lift and while performing lifting operations. The production cost and the weight of this clamp will also be reduced.

When it comes to the advantages and disadvantages of this clamp these are the most mentionable:

Advantages:

- Since the clamp consist of two individual parts, you are able to carry the parts to the pipe and mount them, without the need of a crane.
- The clamp is easy and cheap to produce.

Disadvantages:

- The locking mechanism in the bottom is difficult to access.
- Sliding it alongside the pipe might be difficult due to friction.

4.3 MAT

The mat-concept and design is a development from both the adjustable belt and the wire- and sling chain concept. In the industry, there is already many different types of certified and approved lifting equipment. There is an easy access to lifting wires, -slings, -chains and –ropes for offshore use already on the market. The challenge is when you are going to lift pipes and such, with a requirement stating that there shall be no sliding of the lifting gear on the pipe before or during the lift.

The plan behind the mat-concept is that it should be possible to use already existing and certified lifting gears to perform a lift, only by having a tool that holds the lifting gear at place both before and during the lift, and that ensure that the equipment will not slide on the pipes. In this case, there will be no design of a dedicated lifting equipment, but rather a helping-tool while lifting. This will ensure the reduction of the production cost by a maximum.

4.3.1 PROTECTIVE LIFTING MAT

The concept is based on using already existing equipment on the market, ensuring a maximum reduction of the production cost.

By designing a rubber mat for lifting of circular pipes, you will have the benefits from both lower weight, lower production cost, use on multiple diameters and easy maintenance and handling. By designing the mat in a correct composition of the rubber material, and ensuring a tight fit to the pipe, you can prevent sliding of the mat on the pipe. If a solution for implementing the lifting gear to the mat is in place, you can use already existing lifting gear in a safe and reliable matter.

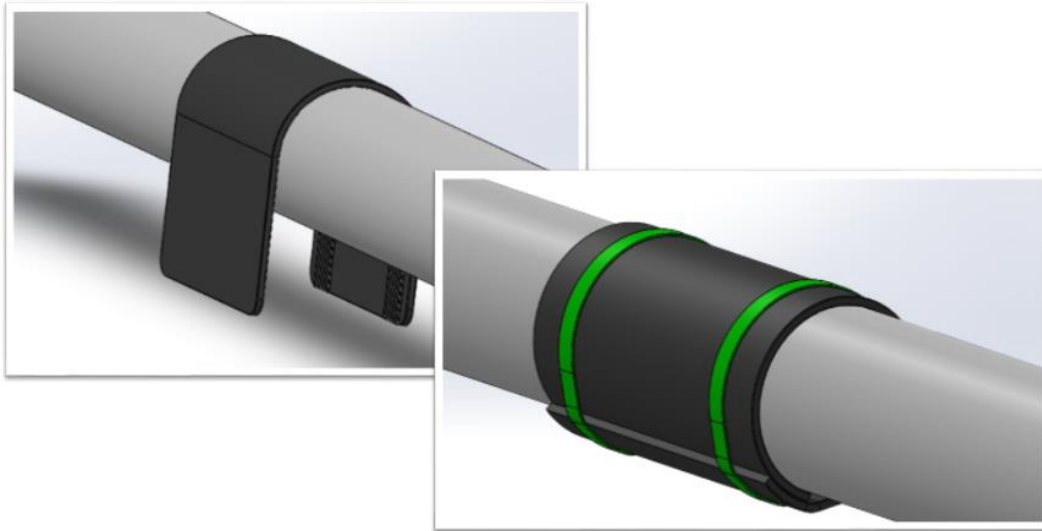


FIGURE 3: Protective lifting mat

The base of the protective mat is a rubber mat with two implemented ratchet tie-downs. Since the mat will not be considered as a lifting equipment, a ratchet tie-in will be enough for securing the mats position on the pipe and tightening the mat to the pipe to prevent sliding. By implementing different kinds of modelling to the mat, you can design the mat to secure lifting with different types of equipment.

Use of a protective mat for lifting, will ensure easy handling. It is also possible to design the mat to stay on the pipe at sea. If the mat stays on the pipe while lowering into the sea, there will be a minimum mounting time of the product, since there will be no necessity of taking it off after the lift.

4.3.2 PROTECTIVE MAT FOR CHAIN AND TEXTILE SLING

By implementing a securing pocket on each side of the protective mat, you can easily use the mat to perform lift with regular lifting chain or textile sling. The pocket can be designed to hold the chain or textile sling in place and tighten them before performing the lift.

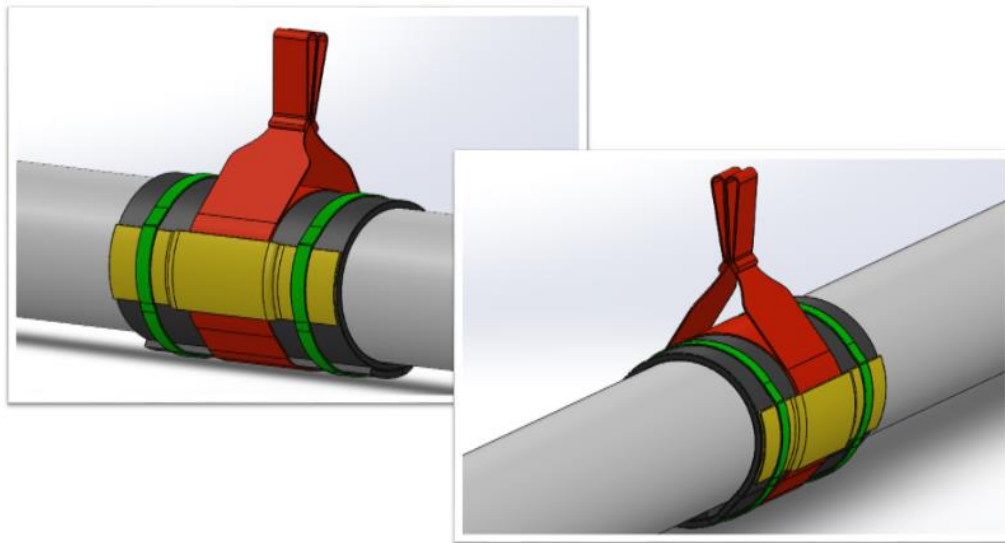


FIGURE 4: Protective mat for chain and textile sling

Example of mounting the system:

1. Place the mat over the pipe.
2. Tighten and secure the mat in position, using the implemented ratchet tie-in.
3. When the mat is in position, pull the chain or textile sling through the side pockets and two rounds around the pipe and connect it to the crane.
4. The lifting chain or textile sling is now in position and secured, and ready for lift.

This concept is easy to mount and easy to handle. It will be able to reach all of the requirement set for the product. And it will be a really affordable alternative to the solution of today.

Advantages:

- Low weight
- Low production cost
- Easy handling and mounting
- Variable diameters
- Can be adjusted to fit both chains and textile slings

Disadvantages:

- Needs a solution for tightening of the chains and textile slings before the lift
- Uncertain whether it is secure against slippage in wet weather

4.3.3 PROTECTIVE MAT FOR WIRE SLING

The same mat as above can be used for wire sling. You only need to be aware that wire slings are not as flexible as chains and textile slings.

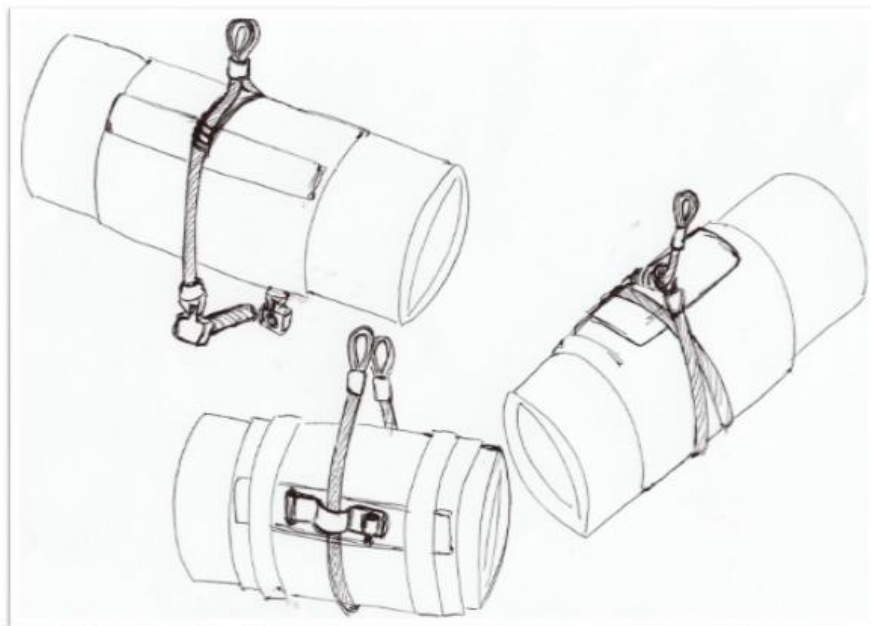


FIGURE 5 Protective mat for wire sling

The figure is presenting three different solution of how to implement the wire sling to the mat. In all of examples it will be the wire performing the lift, whilst the mat will protect the pipe from the wire and hold the wire in position. The mounting of the system will be the same as for the protective mat for chain and textile slings.

Advantages:

- Low weight
- Low production cost
- Easy handling and mounting
- Variable diameter
- Uses already existing and certified lifting wires

Disadvantages:

- Needs a solution for tightening of chains and slings before the lift
- Uncertain whether it is secure against slippage in wet weather

4.4 TIGHTENING BLOCK WITH PAD EYE

This fourth and last principle are based on a development from both the adjustable belt and the wire- and sling chain concept. These concepts are all based on a system mounted on top of the pipe, which will tighten the lifting chain, wire, belt or textile sling. On the system there is a pad eye for connecting it to the crane. The tightening block will be the system performing the lift, together with the tightening material around the pipe.

4.4.1 PROTECTIVE MAT WITH CHAIN TIGHTENING BLOCK

This concept is using the principle of the protective mat combined with a tightening method of the chain. In this concept the lift will be performed with a shackle through the pad-eye of the system connected to a crane.

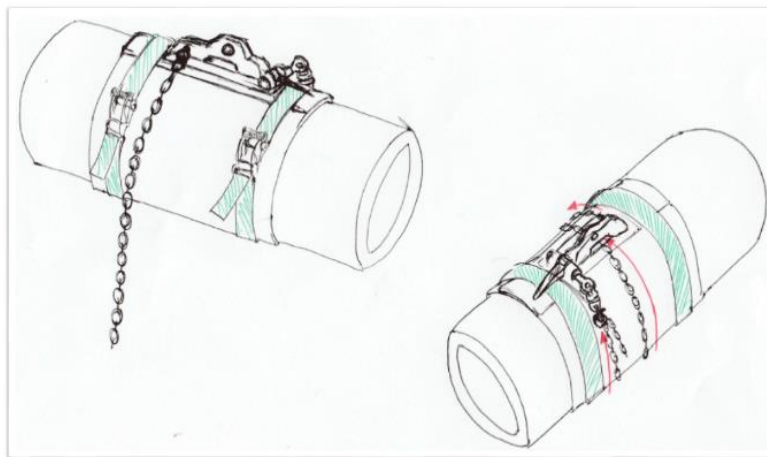


FIGURE 6: Protective mat with chain tightening block

Example of mounting of the system:

1. Place the mat over the pipe.
2. Tighten the mat in position with the ratchet tie-downs.
3. Pull the chain around the pipe and through the hole under the pad eye. Pull the chain one more time around the pipe.
4. Connect the chain to the chain tensioner.
5. Tighten the chain.
6. Connect the shackle on the pad eye to the crane.
7. The system is ready to perform the lift.

Advantages:

- Light weight
- Easy to mount and handle
- Handles different diameters
- Can tighten before lifting
- Reduced production cost compared to the solution today

Disadvantages:

- Uncertain whether it is secure against slippage in wet weather

4.4.2 COMBINATION TIGHTENING BLOCK WITH PAD EYE (WIRE, CHAIN OR SOFT SLING) CONCEPT

This concept is based on a block with a hook on one side and a tightening mechanism on the other side. The position of the hook can be adjusted, depending on the diameter of the pipe you are going to lift in addition to what sling you are using. The tightening mechanism is similar to a chain tensioner or like a turnbuckle, using a shackle to fasten either a chain, wire or soft sling. The eye of the turnbuckle also have a built in swivel to prevent the sling from twisting. On the top of the block sits the pad eye.

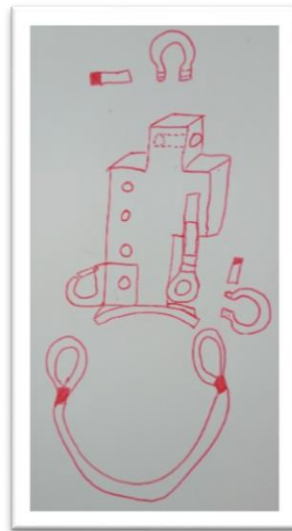


FIGURE 7: Combination tightening block with pad eye concept

How to mount the tightening block:

1. Put the hook in the correct position corresponding to the diameter of the pipe.
2. Fasten the sling you are going to use on the chain tensioner with a shackle.
3. Place the block on top of the pipe.
4. Bring the sling two times around the pipe and attach it to the hook.
5. Tighten the chain tensioner to ensure that the clamp sits tight on the pipe.

This clamp achieves many requirements. Since it is made the way it is, you have the option to choose which type of sling you want to use. The clamp easily achieves the requirement about the

adjustable diameter in addition to a reduced weight. There is a possibility that it will become quite pricy to make, it is therefore uncertain if the production cost will go down.

When it comes to the advantages and disadvantages of this clamp these are the most mentionable:

Advantages:

- You have the option to choose what type of sling you want to use.
- The clamp can lift pipes with various diameters.

Disadvantages:

- Consist of many parts.
- Has a high center of gravity.

This clamp is a good alternative to the task and by doing some adjustments and improvements it could become even better than it is now.

4.4.3 CHAIN BLOCK CONCEPT

The concept is designed for lifting pipes with different diameters. The method is based on using a chain. The chain is locked in place on one side of the block, it then goes around the pipe and is tightened on the other side.

The block consists of parts that are assembled and should not have any loose parts.

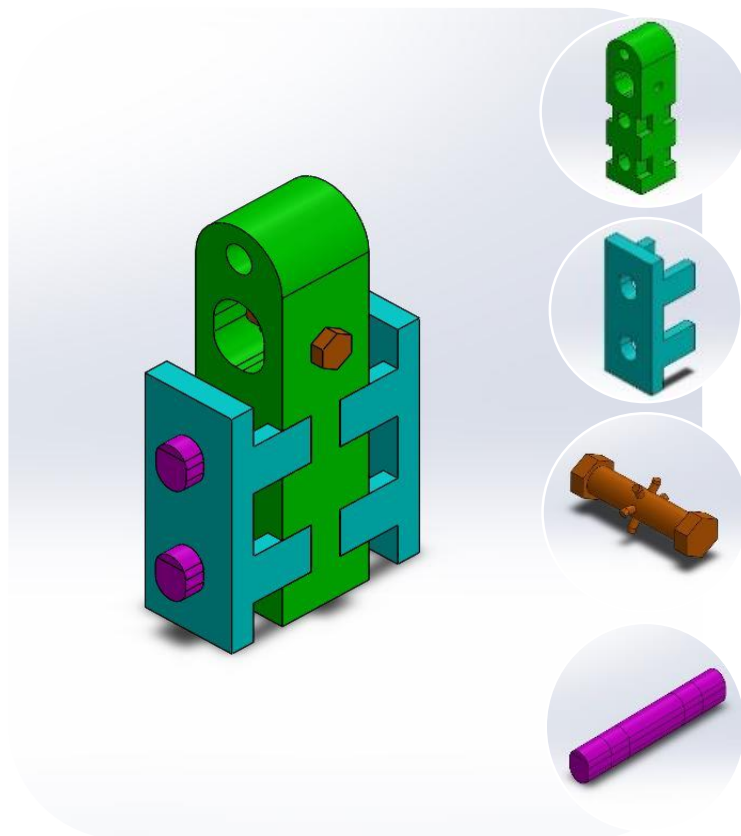


FIGURE 8: Chain block concept

Chain block in use:

1. Place the block on the top of the pipe.
2. Attach the chain on the left side of the block.

Each link (chain) have spaces available. The space will be used to attach the chain with a bolt. The chain will be placed in the first input of the block, and the bolts shall be put in the holes in the link. This will ensure that the chain is locked to the block.

3. Take the chain around the pipe and through the second input. Here hook it onto the gear.
4. Tighten the chain by rotating the gear.
5. When the chain is tightened, push the bolts all the way through the block and through the holes in the chain on the other side.

The block can also include a mat so that the chain does not slide.

The chain block might be able to satisfy the customer with A, B and C requirements. The two main points that this concept satisfies is that it is easy to be carried by one person (R5.3.1), and that it can be used for different pipe diameters (R3.2.1).

The chain block has some advantages and disadvantages:

Advantages:

- Easy to carry for one person. Both the block and the chain.
- Easy to understand and use.
- Low production cost.
- Can be used for different pipe diameters.

Disadvantages:

- Sometimes the bolt might not hit the space in the link. Which means that the chain will be loose.
- Requires approval for lifting offshore.

4.4.4 ADJUSTABLE BELT - QUICKLOADER WITH FRAMEWORK

This concept is based on a quickloader tightening system, using a strap around the pipe that is going to be lifted. The fastening mechanism is not intended to take the load during the lift. The load is supposed to be carried by a much stronger framework.

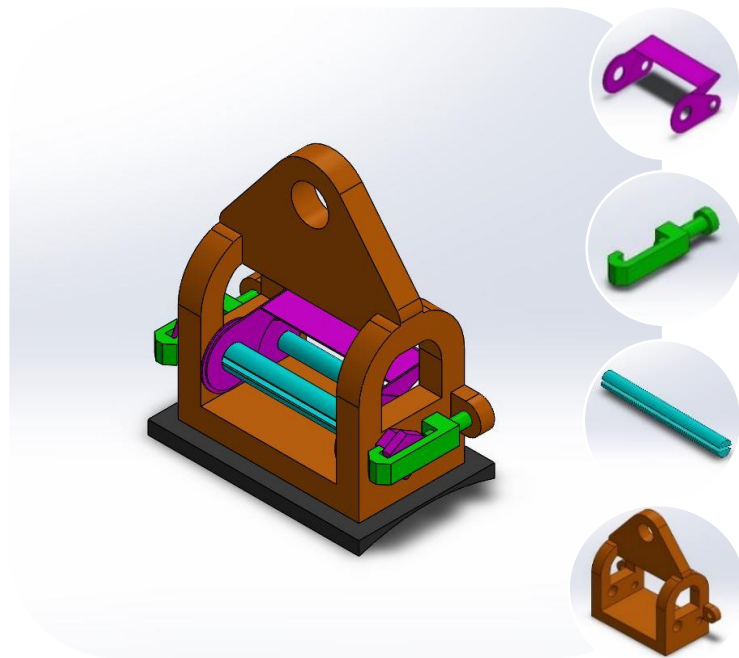


FIGURE 9: Chain block concept

How to mount the clamp:

1. Put the buckle onto the pipe which is about to be lifted.
2. Take the strap which is attached at one end of the buckle around the pipe and up to the other side of the buckle.
3. Attach the end of the strap to the quickloader and start to tighten the strap with the buckle.
4. After the strap is tightened the bolts on the sides must be tightened. These shall relieve the buckle and take the weight of the lift.
5. The pipe is now ready to be lifted.
6. The lifting gear can fulfil the no tolerance for sliding requirement, if the strap is coated with rubber on the inside. The weight of this lifting equipment will be lighter, and manufacturing/documentation costs will be cheaper than the existing clamp.

When it comes to the advantages and disadvantages of this clamp, these are the most mentionable:

Advantages:

- The lifting equipment will weigh less than 25 kg, meaning it can be lifted by hand. This will reduce the mounting time.
- The clamp is easy and cheap to produce.
- It has the possibility for lifting pipes with various diameters.

Disadvantages:

- A quickloader is not an approved lifting equipment and it can be challenging to get it approved.
- The framework can be large and difficult to handle.

4.4.5 DOUBLE BELT TIGHTENING BLOCK

The double belt tightening block makes use of rubber belts, to prevent sliding after mounting. The system consist of a tightening block implemented on a smaller protective mat. The mat is built in only for protection of the pipe from the tightening block, and to ensure the systems use on different diameter. The lifting mechanism is the tightening block together with the belts. The crane will be hooked on a shackle through the pad eye on the tightening block, and the belts will tighten and hold the system in position on the pipe.

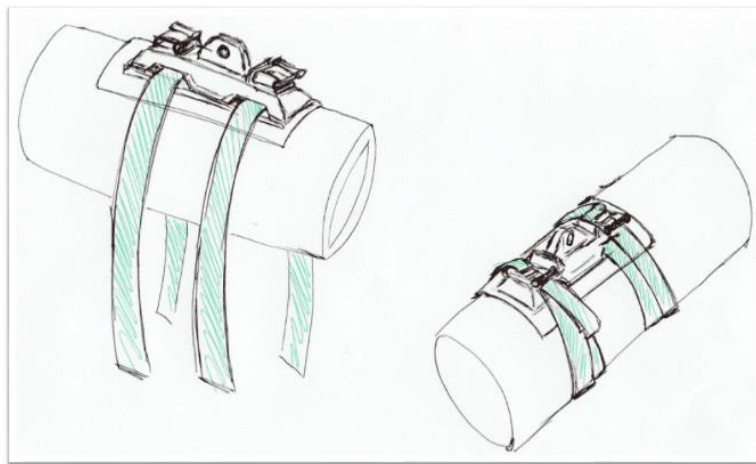


FIGURE 10: Double belt tightening block

Example of mounting the system:

1. Put the tightening block with the mat on top of the pipe.
2. Pull the two belts through the two holes in the tightening block.
3. Pull the ends of the belts on top of the tightening block, and insert them into the tightening mechanism.
4. Tighten the belts.
5. Lock the tightening mechanism with an extra locking mechanism to ensure double barriers for failure.
6. Connect the tightening to the lifting crane.
7. Perform the lift.

Advantages:

- Easy to mount
- Light weight
- Can be tighten before lifting
- Adjustable diameters

Disadvantages:

- Needs a locking mechanism that will be certified and approved for lifting offshore

5. DESIGN PRINCIPLE SELECTION MATRIX

At this point in the process, OLC has come up with several solutions of principles and designs that are developed from the concept selection earlier in the process. It is important to be able to evaluate and compare these principles against each other, to come up with a solution OLC can proceed working with.

To execute this evaluation OLC have made a new selection matrix to compare the designs against each other. OLC have chosen to only compare the principles of designs, and not each and every design. This is reasoned by the similarity in the designs that can be categorized in four design principles.

5.1 CONCEPT NAMES

Following concepts was evaluated in the Pugh matrix. In the matrix, their respective concept number will refer to each concept.

Concept number:	Concept principle:
Concept 1:	Mat
Concept 2:	Tightening block with pad eye
Concept 3:	Circular sliding
Concept 4:	Side by side sliding

TABLE 4: Concept names 2

5.2 REQUIREMENT DESCRIPTION

All of the concepts in the matrix are evaluated up against the same criteria, which are some of the main requirements for the product. **A description of each requirement is offered in the “Requirement description “-table on page 167.**

The concepts are scored after the probability of achieving a desired outcome of each requirement. The higher the score, the higher is the probability of a good result.

5.3 DESIGN PRINCIPLE MATRIX

The concept selection matrix helps in deciding in which design principle OLC should focus their attention on, based on the first design development after the concept selection. The different principle are measured up against the criteria, which are some of the most important requirement set for the product. These are the same requirement made for the first concept selection matrix.

The design principles gets a score on each criteria, based on how easy it would be to fulfill the respective requirement. A higher score suggest that the concept easily will fulfill the requirement, whilst a lower score predict an uncertainty and difficulty of managing to fulfill the requirement.

The requirements are divided into A-, B- and C-priorities. Their max score is therefore different for each priority, to distinguish the results in each priority.

A priority: min 0 - max 10

B priority: min 0 - max 5

C priority: min 0 - max 3

This matrix is used to choose which design principle OLC are going to continue working with. The design principle chosen is most likely to be recommended to the customer as a preferred solution.

5.4 DESIGN PRINCIPLE MATRIX TABLE

	CONCEPTS				
Req	1	2	3	4	PRI
Weight	9	8	5	6	A
Productions cost	9	6	1	2	A
Risk	8	7	5	6	A
Temperature	5	5	5	5	B
User friendly	4	4	2	3	B
Robust	2	4	4	4	B
Different diameters	3	3	1	1	C
Mounting time	3	3	1	2	C
Storage space	3	3	2	2	C
Maintenance	1	1	2	2	C
Number of loose parts	3	1	1	2	C
Portable	3	3	3	3	C

TOTAL	53	48	32	38
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TABLE 5: Design concept matrix table

5.5 DESIGN PRINCIPLE MATRIX RESULT

The results of the design principle matrix gave a clear indication of which principle is preferred to continue focus on. It is quite clear that it would be beneficial to focus on a new concept, rather than further development of an existing lifting clamp.

Based on the result from the matrix, further development will be:

Concept 1 – Mat (Protective mat for lifting)

6. CONCEPT SELECTION FOR PROJECT

At the end of the second iteration of the project period, OLC have done an evaluation of the design concept principles developed from the first iteration concept selection. After discussing the principles internally in OLC, together with the customer at FMC and getting results from a design principle matrix, OLC concluded that it is preferable to continue developing a solution based on the mat-principle.

The mat-principles is most likely to be able to fulfill the requirement specifications for the product. The A-requirements, together with the other requirements, might be met easily. The most important requirements set by the customer is possible to achieve with this solution:

- ***The production cost will be remarkably reduced:***

The mat-solution is based on using existing lifting gears, and will only be used as a protective mat for the pipe and a solution for keeping the lifting equipment in position. The mat itself will be made in a rubber material with no machining is needed. The ratchet tie-in will not be used as a lifting tool, so there will be no need for approving this for lifting. This will reduce the production cost by a maximum.

- ***Adjustable diameter:***

The mat will be wrapped around the pipe and tied in. This gives flexibility of adjusting the diameter to fit different diameter pipes.

- ***Reduced weight:***

By only focusing on protecting and keeping already existing lifting gear in position, and making the mat in a rubber material, it is possible to reduce the weight by a maximum compared to the existing lifting clamp. A very small amount of metal is used in the solution. The weight will only be of the mat itself including the ratchet tie-in and by the chosen lifting gear; wire sling, chain sling and textile sling rope.

- ***Portable and rigging hours:***

Since the weight of the solution will be significantly reduced, it will be possible to handle without a need of a crane. It is easy to mount on a pipe, either on deck or beforehand. It might also be a possibility to design the mat to stay on the pipe while it is lowered down in the sea. If the mat is designed to stay on the pipe, then this will reduce the rigging hours dramatically. The mat can be installed before shipping. The only need for performing the lift will then be to install the lifting gear (wire, chain or sling) before performing the lift. The mat also consist of only one part. The parts needed will be implemented in the mat, which makes it user friendly and easy to handle.

6.1 CHALLENGES IN CHOSEN CONCEPT

The mat has a lot of potential and it will most likely meet the requirements for the product. It still have some challenges:

- The last requirement given by FMC was:
«The lifting clamp shall be tightened in such a way that there is no danger of the clamp to slide or move out of position after it has been mounted on the pipe»

The solution offered will be locked in position after mounting, and there will be no sliding before lifting. Even though the mat is fixed on the pipe after mounting, it is not certain that the lifting gear will be tightened in the correct position before lifting. *The challenge is to find a solution that also tighten the lifting gear in position after installation and before lifting.*

- It is a challenge to find the right material for the mat to achieve the desired properties in terms of high coefficient of friction against steel surface and durability of the material. The material needed for durability depends on the application; if the solution is meant to perform only above sea level or subsea.

6.2 RECOMMENDATION OF SOLUTION FOR FMC TECHNOLOGIES

After an evaluation of the several concept ideas and design principles made in the last two iterations, and based on the knowledge of the requirements specifications and the solutions today, OLC has chosen to continue the further development of the protective mat with existing lifting gear solution.

This solution is beneficial for FMC Technologies. It will reduce production cost by a maximum, and still execute the lifting process by the requirements that is set for the product.

7. CONCEPT RESEARCH

After OLC's second presentation in the bachelor project period with a concept selection and recommendation for FMC, a concept research has been conducted. The purpose of the research is to come up with different solutions for the various parts of the recommended solution that are more detailed and descriptive. This research is beneficial for OLC as it will give knowledge and the ability to look at different solutions and their modes of action and how things work. This will give data and information about the pros and cons of the various solutions and the opportunity to compare them against each other. With this concept research it is possible to find out if the different solutions meets all the requirements, or which of them that meets most requirements.

7.1 TIGHTENING THE SLING

The first part of the research consisted in studying how various slings are mounted and tightened to a pipe before and during a lift. The use of chain-, wire- and soft slings was researched and documented. This study is based on the requirement stating that the lifting equipment must be tightened before performing a lift:

“R5.1.4

The lifting clamp shall be tightened in such a way that there is no danger of the clamp to slide or move out of position after it has been mounted on the pipe.”

7.1.1 CHAIN TIGHTENING SOLUTION

Tightening a chain to a pipe for lifting is based on a double wrapped basket hitch. This is basically a basket lift that is performed by wrapping a chain twice around the pipe and then attach both ends of the chain to a forerunner using a shackle. Tightening of the chain can be done by using a tensioning mechanism on both ends of the chain.

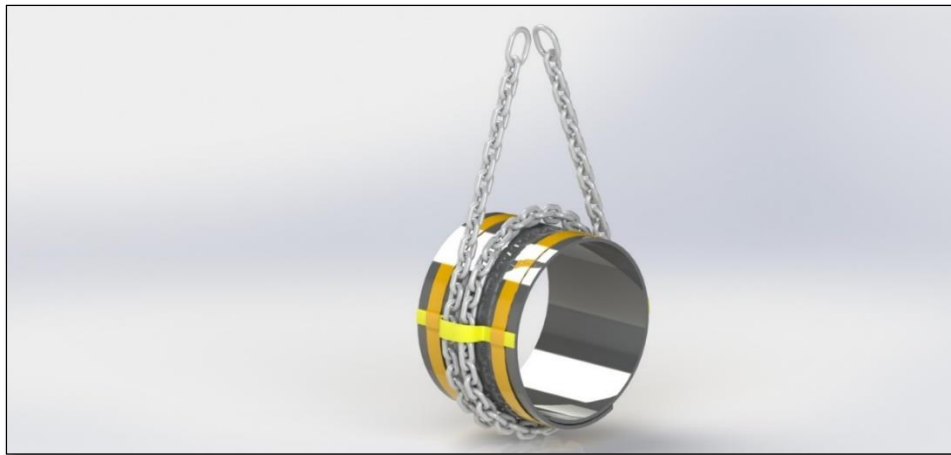


FIGURE 11: A chain wrapped around a pipe in a double wrapped basket hitch

7.1.2 WIRE- AND SOFT SLING SOLUTION

When performing a lift with a wire- or soft sling, the principle of tightening the sling on to the pipe can be performed as for chains. The wire- or soft sling is wrapped twice around the pipe in a double wrapped basket hitch. The ends of the sling is then attached to two short forerunners using a shackle. These are further connected to the main forerunner by using one more shackle.

By using a shorter sling around the pipe, it allows the system to use the sling eyes as an extra joint which a tensioning mechanism can be secured in for tightening the sling before lifting.

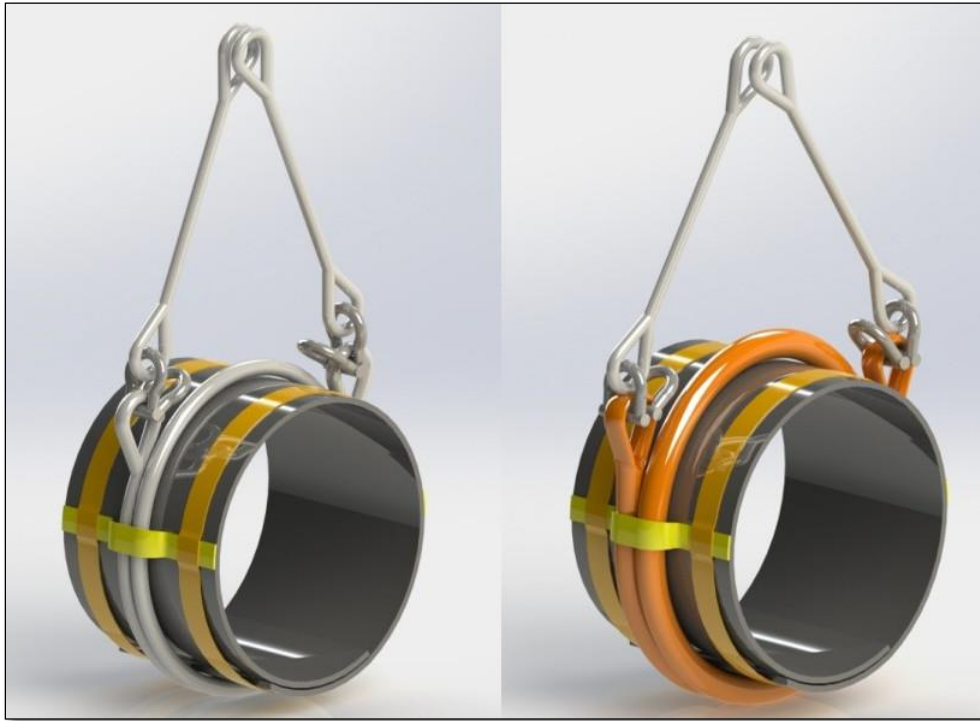


FIGURE 12: A double wrapped basket hitch using a wire sling and a soft sling

A tensioning mechanism for the wire or soft sling can be attached to the free shackles at the ends of the slings, enabling the tensioning mechanism to fully tighten and secure the lifting equipment before performing the lift.

7.1.3 DOUBLE CHOKE HITCH

A double choke hitch is a commonly used method for tightening soft slings when performing an onshore lift. While performing a lift offshore, it is recommended to use a wire for lifting. This method is based on wrapping a wire twice around the pipe, and then lead one of the ends of the sling through the eye on the other end of the sling. By using this method only one end of the sling will be connected to the forerunner through a shackle. By using a wire clamp it is possible to tighten and secure the lifting equipment before the lift is performed.



FIGURE 13: A double choke hitch

One end of the sling is lead through the eye on the other end of the sling. A wire clamp can be used to tighten and secure the sling before lifting.

7.2 SLING STUDY

The type of sling used to perform a lift affects the different hitches for mounting and securing the slings to the pipe. Chain, wire and soft slings all have their own characteristics. To be able to decide what solution is best for the mat concept, a detailed sling study was performed. This study is based on products approved for offshore use. The products must fulfill these criteria:

- ➔ CE marked
- ➔ DNV certified
- ➔ Must be able to lift 4100 kg as described in requirement R3.1.2
- ➔ Wires rope must have a $D \geq 18\text{mm}$ to be dimensioned for R60 described in requirement R1.1.19
- ➔ Chains must have $D \geq 10\text{ mm}$ to be dimensioned for R60 described in requirement R1.1.19

Specific factors are used to calculate the SWL in the various lifting options.

Calculation of SWL (safe working load):

- If the sling is used in choke hitch $SWL = WLL \times 0.8$ ^[17]
- If the sling is used in basket hitch $SWL = WLL \times 1.4$ ^[30]
- If the sling is used to lift in 45 ° $SWL = WLL \times 0.707$ ^[17]
- $WLL = \text{Min breaking force} / \text{Safety factor}$ ^[29]
- Wire sling, Safety factor = 5:1^[28]
- Chain sling Safety factor = 4:1^{[36][33]}
- Soft sling, Safety factor = 7:1^[39]

7.2.3 WIRE SLING

One of the options is to use wire sling. Wire sling are used in concept:

- Wire / Soft sling solution:
This is a double wrapped basket lift, with either wire or soft sling. It is used shackles between the thimbles in the ends of the wire rope for attaching them to one another and the tightening mechanism.
- Double choke hitch:
This is a choke hitch with the wire wrapped twice around the pipe.

STRUCTURE AND MATERIALS

The wire rope is made up of several steel threads spun together, with a core in the middle. It can be many layers with steel threads around the core, depending on the desired properties of the wire rope. The description of one rope is given by example 6x36-FC, where 6 is the number of wires in the rope, 36 is the number of threads in the string and FC describes the type of core. ^[19]

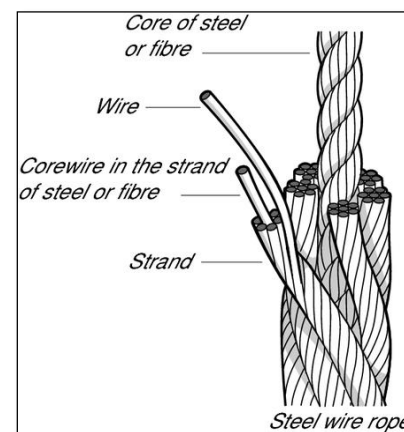


FIGURE 14: Wire Rope^[19]

The material of the wire is wire rod. The material is cold-drawn to wires of various diameters, which may have different strengths. The steel wires may be: untreated, either galvanized or stainless. When used in corrosive environments, it may be wise to use a galvanized steel wire, alternatively stainless steel or a plastic impregnated wire. [20]

The core of the rope is made of fiber, steel or plastic. If the rope is exposed to large stresses, high work capacity or high working temperature it should be selected steel core. This core provides good support for the wire strings, that make sure that the wire rope keeps its shape, and gives a good distribution of stresses in the individual wires. [22]

The most common structure of steel wires are:

- *Ordinary: Ordinary lay wires - all wires are in the same size.*
- *Seale (S): Parallel lay wires - different size, same number of wires in outer and inner layer.*
- *Warrington (W): Parallel lay wires - the outer layer of wires has two different sizes, twice as many outer wires as inner wires.*
- *Warrington-Seale (WS): Parallel lay wires - a combination between Seale and Warrington, with three or more layers of wire.*
- *Filler wire (F): Parallel lay wires - twice as many outer wires as inner wires, with small wires to fill the spaces between the large wires.*
- *Compacted strand: A strand that has been formed through compaction maintaining the steel area whilst increasing the fill factor.[21]*

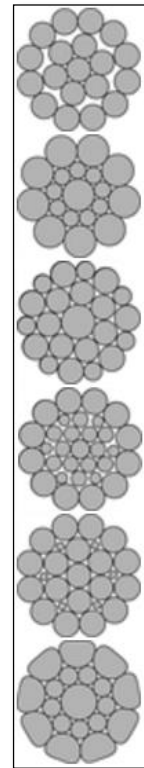


FIGURE 15: [21]

The layers of threads around the core are twisted to the right or left. With multiple layers, each layer is twisted in opposite direction. These ropes with many layers "rotation resistant" or "Low Rotation" is used at high lift heights. The torque in the various layers of these ropes balances the opposing forces of the rope. [23] [24]

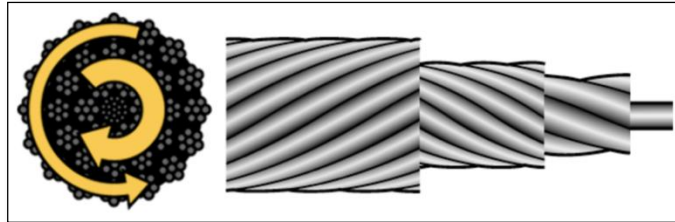


FIGURE 16: Twisted threads around the core [23]

Regardless of the used wire rope it will be extended in three separate phases when subjected to a tensile load. [25]

1. Initial extension - This extension of the rope occurs when it is subjected to tensile stress, which extends the rope so that the diameter is reduced. This phase can not be determined absolutely and depends on the different loads and the particular frequency it is subjected for. The rope design can also have an impact.
2. Elastic extension - The elastic extension continues until the elastic limit is reached, that is the highest load the rope can be exposed to and still return to its original length. When the load exceeds this limit the rope will go in to the third phase.
3. Permanent extension - During this phase it occurs a permanent elongation of the rope caused by tensile stresses exceeding the yield limit of the material. [25]

The phases occur in order, when a rope is exposed to gradually increasing load. It is not possible to set some specific values for the structures, but it can be used approximate values that give fairly accurate results. [25]

Certex produces wire slings on request. Certex can produce wires according to DNV 2-7.1, that will satisfy the strict offshore regulations. They are available in standard lengths of 1,2,3,4,5,6,7,8,9 and 10 meters. Longer lengths are available on request. [18]

WIRE SLING FOR OFFSHORE USE

Wire rope 6x36WS-IWRC

The wire consists of wire rod, and the core of steel.

Rope Ø mm	Steel area mm ²	Min breaking force		Mass kg/ 100m
		1960 N/mm ² kN	2160 N/mm ² kN	
10	46	69.8	76.9	41
11	55.7	84.4	93	50
12	66.2	100	111	59
13	77.7	118	130	69
14	90.2	137	151	80
16	118	179	197	105
18	149	226	249	133
19	166	252	278	148
20	184	279	308	164
22	223	338	372	198
24	265	402	443	236
26	311	472	520	276
28	361	547	603	321
32	471	715	787	419
36	596	904	997	530
38	664	1008	1110	591
40	736	1116	1230	654
44	891	1351	1489	792
48	1060	1608	1772	942
52	1244	1887	2079	1106
56	1443	2188	2411	1283
60	1656	2512	2768	1472

TABLE 6: Wire rope 6x36WS-IWRC [26]

Choke hitch, 45° lift:

$$\varnothing = 24\text{mm}, 1960 \text{ N/mm}^2$$

$$\text{WLL} = \frac{402000\text{N}}{5} = \frac{80400\text{kg}\cdot\text{m/s}^2}{9.81\text{m/s}^2} = 8195\text{kg}$$

$$\text{SWL} = 8195\text{kg} \cdot 0.8 \cdot 0.707 = 4635\text{kg}$$

$$4635\text{kg} > 4100\text{kg}$$

Basket hitch, 45° lift:

$\varnothing = 18 \text{ mm}, 1960 \text{ N/mm}^2$

$$WLL = \frac{226000N}{5} = \frac{45200kg \cdot m/s^2}{9,81m/s^2} = 4607kg$$

$$SWL = 4607kg \cdot 1,4 \cdot 0,707 = 4560kg$$

4560kg > 4100kg

Wire rope 6x36-FC

The wire consists of wire rod, and the core of fiber.

Rope Ø mm	Steel area mm ²	Min breaking force		Weight kg/ 100m
		1960 N/mm ² kN	2160 N/mm ² kN	
8	25.2	41.4	45.6	24
9	31.8	52.4	57.7	30
10	39.3	64.7	71.3	37
11	47.6	78.3	86.2	44
12	56.6	93.1	103	53
13	66.4	109	120	62
14	77	127	140	72
16	101	166	182	94
18	127	210	231	119
19	142	233	257	132
20	157	259	285	147
22	190	313	345	178
24	226	373	411	211
26	266	437	482	248
28	308	507	559	288
30	354	582	642	330
32	402	662	730	376
36	509	838	924	476
38	567	934	1029	530
40	629	1035	1140	587
42	693	1141	1257	647
44	761	1252	1380	711
48	905	1490	1642	846
52	1063	1749	1927	992
56	1232	2028	2235	1151
60	1415	2328	2566	1321

TABLE 7: Wire rope 6x36-FC [27]

Choke hitch:

$$\varnothing = 24\text{mm}, 1960 \text{ N/mm}^2$$

$$\text{WLL} = \frac{373000\text{N}}{5} = \frac{74600\text{kg}\cdot\text{m/s}^2}{9,81\text{m/s}^2} = 7604\text{kg}$$

$$\text{SWL} = 7604\text{kg} \cdot 0,8 \cdot 0,707 = 4300\text{kg}$$

$$4300\text{kg} > 4100\text{kg}$$

Basket hitch, 45° lift:

$$\varnothing = 18 \text{ mm}, 1960 \text{ N/mm}^2$$

$$\text{WLL} = \frac{210000\text{N}}{5} = \frac{42000\text{kg}\cdot\text{m/s}^2}{9,81\text{m/s}^2} = 4281\text{kg}$$

$$\text{SWL} = 4281\text{kg} \cdot 1,4 \cdot 0,707 = 4237\text{kg}$$

$$4237\text{kg} > 4100\text{kg}$$

EVALUATION WIRE SLING

Both Wire rope 6x36WS-IWRC and Wire rope 6x36-FC is approved on offshore and off board use when they are certified according to Standard EN 12385-4. [26] [27]

In the *Wire / Soft sling solution*, it must be used a wire of 18 mm or bigger regardless if it is used steel or fiber core. It is not allowed to attach thimbles together with a shackle, since only the round end of the shackle can be attached in a thimble. To solve this problem it must be used a plate between the links designed specifically for this task. This solution can be a good alternative in the task.

In the *Double choke hitch* solution, it must be used a wire of 24 mm or bigger regardless if it is used steel or fiber core. The downside of this solution is the buoy the rope gets in the point where it is choked. In this point there will be a large load which could permanently damage the wire. This solution is therefore not the best for the task.

7.2.4 CHAIN SLING

One of the options is to use chain sling. Chain sling are used in concept:

- Chain tightening solution:
This is a double wrapped basket lift, with chain. Tightening mechanism is going to be attached to the links in the chain.

STRUCTURE AND MATERIALS

Chains are divided into different grades describing the ultimate breaking strength of the chain. This number is describes as G30, G45, G70, G80 and G100. G stands for grade, and the number stands for the maximum load on the chain. As for example G80 has a breaking strength of 800 N / mm². For an overhead lift it has to be used grade G80 or higher. [31]

Alloy chain grade 80 or 100 shall be able to be extended 20% before breach. Alloy elements of the steel that is used in the chain can vary slightly from company to company.[31]



FIGURE 17: Alloy Steel grade 8 chain (round) [34]

There are different types of chains, with different properties. Some of these have short and long links. When performing an offshore lift, only short linked chains are approved for use [36].

Chain with short links is available in different forms. The most usual are round, but increased competition in the market has led to several good results, and therefore there are links with for example an outer shell as is flat. According to the manufacturer Pewag which makes flat outer shell, have these chains properties to increase the lifting capacity considerable compared to their chains which are round. [32]



FIGURE 18: Chain with flat outer shell [35]

CHAIN SLING FOR OFFSHORE USE

Chain-Short Link Grade 8

Material: Alloy steel grade 8.

Marking: One link per m chain is marked with grade.

Finish: Painted.

Standard: EN 818-2.

[33]

Art.no	Code	Chain	WLL	Min breaking load	E	H	Weight
		ØD	tons	kN			kg/m
11.64SL07.8	KL-7-8	7	1,5	61,6	21	9,1	1,1
11.64SL08.8	KL-8-8	8	2	80,4	24	10,4	1,4
11.64SL10.8	KL-10-8	10	3,15	126	30	13	2,2
11.64SL13.8	KL-13-8	13	5,3	212	39	16,9	3,8
11.64SL16.8	KL-16-8	16	8	322	48	20,8	5,7
11.64SL20.8	KL-20-8	20	12,5	503	60	26	9
11.64SL22.8	KL-22-8	22	15	608	66	28,6	11
11.64SL26.8	KL-26-8	26	21,2	849	78	33,8	15
11.64SL32.8	KL-32-8	32	31,5	1290	96	41,6	23

*For lifting, safety factor 4:1

TABLE 8: Can dimensions [17]

Basket hitch, 45° lift:

$\varnothing = 13 \text{ mm}$, $G80 = 800 \text{ N/mm}^2$

$SWL = 5300\text{kg} \cdot 1,4 \cdot 0,707 = 5246\text{kg}$

$5246\text{kg} > 4100\text{kg}$

EVALUATION CHAIN SLING

Chain-Short Link Grade 8 sling is approved for offshore and off board lifts because it is certified according to Standard: EN 818-2. [33]

In the *Chain tightening solution*, a chain with a diameter $\geq 10\text{mm}$ must be used, in order to be approved offshore. Chain-Short Link Grade 8 has a $D=13\text{mm}$, $13\text{mm} > 10\text{mm}$.

Tightening mechanism can easily be attached to the links in the chain. This solution can be a good alternative in the task.

7.2.5 SOFT SLING

Soft sling are used in concept:

- Wire / Soft sling solution:

This is a double wrapped basket lift, with either wire or soft sling. It is used shackles between the thimbles in the ends of the soft sling for attaching them to one another, and the tightening mechanism.

STRUCTURE AND MATERIALS

Material

A soft sling is a sling made out of soft fibers, either natural or synthetic. When it comes to heavy-duty lifts, the synthetic made slings are most preferred because of their durability and strength.

There are four types of synthetic materials that are used, these are: Polyester, nylon, polypropylene and Kevlar. Where polyester is the most commonly used. [37][38]

Different types of soft sling

The soft sling can be made in several different configurations and be used in many different hitches. The most common one is the webbing sling. This sling has a flat surface and an eye in each end. It is very strong in the longitudinal direction. [39]



FIGURE 19: Webbing sling [39]

Another type of soft sling is the round sling. This sling has no end, and the point where to hook it onto the hook can therefore be wherever you want. Since this sling is round, it is easy to make a hitch around non-normal shaped objects. [40]



FIGURE 20: Round sling [40]

One type, named the duplex webbing sling is a sling that are very similar to the webbing sling. The difference is that the duplex webbing sling consist of two webbing slings sewn together. This makes the sling incredibly strong. [41]



FIGURE 21: Duplex webbing sling [25]

SOFT SLING FOR OFFSHORE USE

Webbing sling

Material: Polyester.

Marking: Blue label with manufacturer's symbol, WLL, length, CE marking and label with handling instructions.

Working temperature -40°C - +100°C.

Standard: EN 1492. [39]






Colour	Webbing width	Working load limit (WLL) in tons				
						
	mm	Straight pull	Choke hitch	Basket hitch		
				0°	0°-45°	45°-60°
Violet	50	1	0,8	2	1,4	1
Green	60	2	1,6	4	2,8	2
Yellow	90	3	2,4	6	4,2	3
Grey	120	4	3,2	8	5,6	4
Red	150	5	4,0	10	7,0	5
Brown	180	6	4,8	12	8,4	6
Blue	240	8	6,4	16	11,2	8
Orange	300	10	8,0	20	14,0	10
		1	0,8	2	1,4	1

TABLE 9: Webbing sling table [39]

Choke hitch:

Blue webbing sling, width 240 mm.

$$SWL = 8000\text{kg} \cdot 0,8 \cdot 0,707 = 4524,8\text{kg}$$

$$4524,8\text{kg} > 4100\text{kg}$$

Basket hitch, 45° lift:

Red webbing sling, width 150 mm.

$$SWL = 5000\text{kg} \cdot 1,4 \cdot 0,707 = 4949\text{kg}$$

$$4949\text{kg} > 4100\text{kg}$$

7.2.6 COMPARISON OF THE DIFFERENT SLINGS

- **Wire sling solution:**

To use this solution it must be designed a plate that can be between shackles. The solution will consist of many different components, which is not desirable as it will take longer time to inspect and maintain all components. There will also be a challenge when it comes to the length of the wire, due to the different diameter of the pipes.

- **Double choke hitch:**

The choking will inflict a big tension in the breakpoint, which is not desired. This solution is therefore excluded as a solution.

- **Chain tightening solution:**

The chain solution consists of only one component that takes the lift. The Chain is the heaviest part per meter, compared to wire and soft sling. Attaching the tightening mechanism will be easy.

- **Soft sling solution:**

Soft sling is only approved for offshore lifting and not for off board lift. Since it is a requirement that the product shall be used in off board lift this solution cannot be chosen.

On the basis of this research the chain tightening solution is chosen to continue with in the task. If it turns out that this solution not will be possible to use, the wire sling solution will be applied.

7.2.7 CALCULATIONS CONCERNING THE LENGTH OF THE CHAIN

Calculations was done to find out how long of a chain is needed. The different pipe diameter sizes that was included in this calculation went from a five inch pipe and up to a twenty-two inch pipe.

The chain length must be such that it can reach two laps around the pipe in addition to an extra length in order to obtain a correct hitch in any angle up to 45°. By multiplying the circumference of the pipe with a factor of 2,5 the chain will get a suitable length to perform lifting.

The table below shows the recommended length of chains, together with pipes diameter in inch and cm and the circumference in cm.

Diameter [inches]	Diameter [cm]	Circumference [cm]	Length of chain [cm]
5"	12,7	39,89	99,72
6"	15,24	47,87	119,67
7"	17,78	55,85	139,62
8"	20,32	63,83	159,57
9"	22,86	71,81	179,52
10"	25,4	79,79	199,47
11"	27,94	87,77	219,42
12"	30,48	95,75	239,37
13"	33,02	103,73	259,32
14"	35,56	111,71	279,27
15"	38,1	119,69	299,22
16"	40,64	127,67	319,17
17"	43,18	135,65	339,12
18"	45,72	143,63	359,07
19"	48,26	151,61	379,02
20"	50,8	159,59	398,97
21"	53,34	167,57	418,92
22"	55,88	175,55	438,87

TABLE 10: Chain length for pipes

When calculating the length of the chain used for a prototype on the concept used on a 16" pipe, the starting point was in standardized lengths of chains of three and four meters. This to see if these lengths could be suitable to use without modifications.

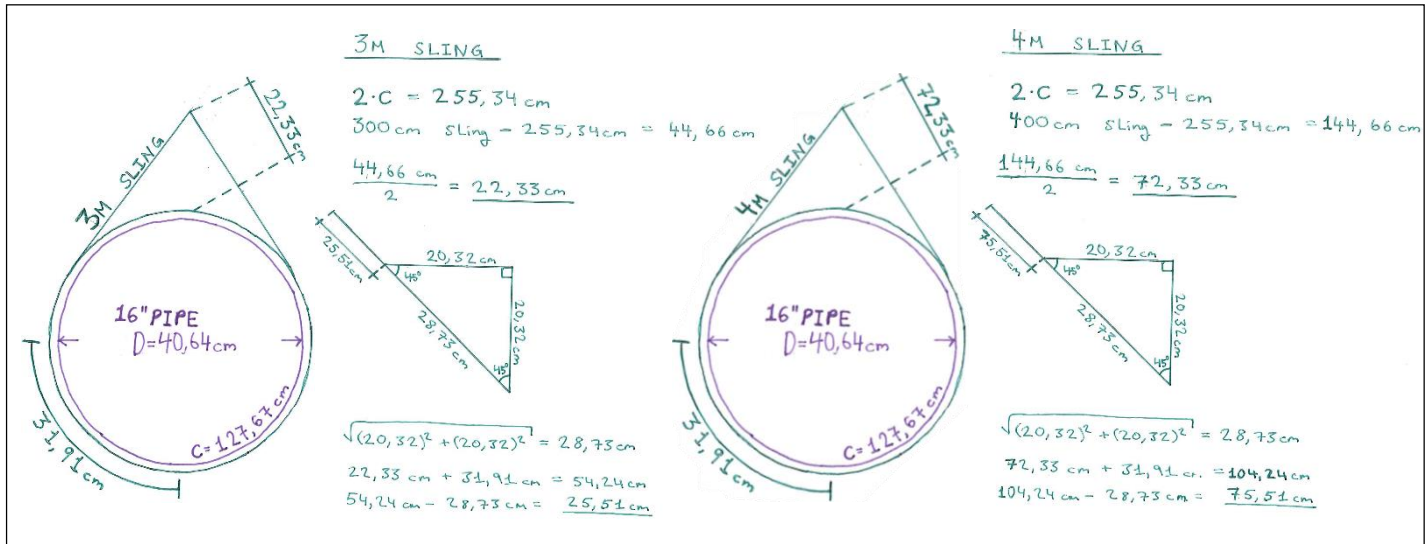


FIGURE 22: Chain length calculations

The conclusion is that on a 16" pipe a 3 m chain will be too short, while 4 m chain is too long. The length should be somewhere in between, which confirms the use of a factor of 2,5 for calculations of the needed length of chain.

7.3 IDEAS FOR TIGHTENING SOLUTIONS

No matter what type of sling is chosen to perform a lift, the sling must be tightened and secured to the mat to prevent it from moving out of position before, during or after the lift. Different ideas for both elastic and non-elastic solutions for tightening the sling was presented after brainstorming and discussions. The ideas presented could be used alone by itself, or interchangeably. The tightening solution must be able to be attached to the sling. Some of the ideas is to use shackles or carabiner hook. There is also a possibility of having a fastener such as different types of open hooks.

Some of the solutions are based on tighten the slings by hand, but other solutions have improved tightening methods such as ratchet strap or belt mechanism.

7.3.1 SPRING TIGHTENING

Description:

Tension spring that connects double wrapped basket hitch, by using carabiner or shackle.

Mechanism:

Elastic: The spring stretches so it tightens sling before lifting by hitching it to the sling, and return to its original position after the lifting is performed.

Tightening: By hand. There might be necessary to use pliers.



FIGURE 23: A tension spring mounted by hand or with the use of pliers

7.3.2 SPRING ATTACHED TO BLOCK

Description:

Two tension springs are attached on each side of the block.

Mechanism:

Elastic: Each individual spring is attached to the sling on opposite side of the pipe. Tensile springs will reach out and the block will hold the springs in position/place. The springs will return to its original position after the lifting is performed.

Tightening: By hand

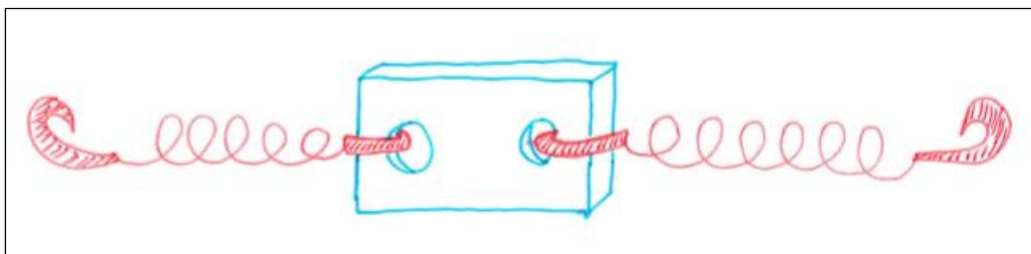


FIGURE 24: Tensioning springs attached to a block fixed on the mat

7.3.3 SPRING WITH BELT MECHANISM

Description:

Two tension springs are attached on either side of the belt, one connected to the pin and the second at the buckle.

Mechanism:

Elastic: The springs are attached to the pin and buckle, and connected to the slings, and then stretched when the belt is fastened. Tighten extra by pulling the ribbon.

Tightening: By hand

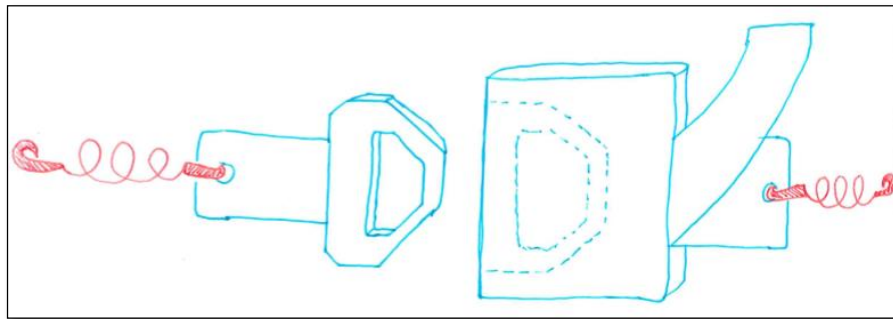


FIGURE 25: Spring with belt mechanism

7.3.4 BELT TIGHTENING

Description:

Two shackles attached to either sides of the belt, and connected to the sling.

Mechanism:

Non-elastic: The shackles are used only to connect the belt to the slings. The belt tightens the sling, by attaching the pin and buckle and then pull the ribbon.

Tightening: By hand

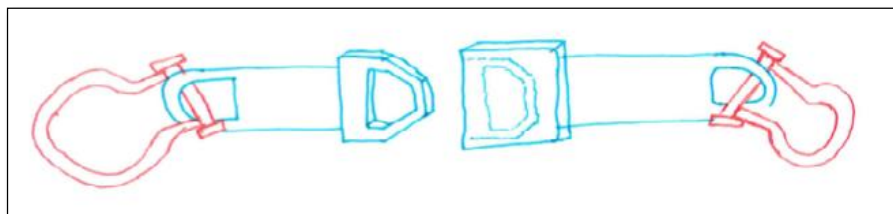


FIGURE 26: Belt tightening

7.3.5 RUBBER BAND TIGHTENING

Description:

A rubber band that is integrated inside a fiber strap.

Mechanism:

Elastic: Both of the hooks are attached to the sling. The rubber band is placed along the fiber strap that extends and tightens the sling.

Tightening: By hand.

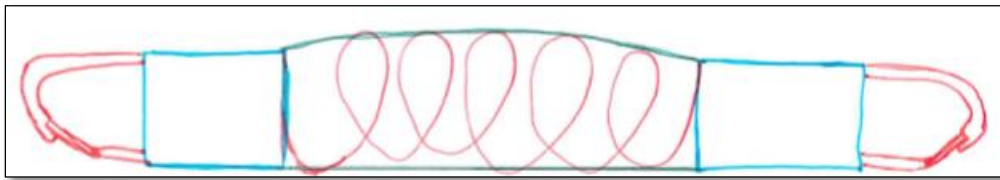


FIGURE 27: Rubber band tightening

7.3.6 RATCHET TIGHTENING

Description:

Each end of the ratchet belt is attached to shackles, which are connected to the slings.

Mechanism:

Non-elastic: Tightens by attaching the strap to the buckle, and then jack the buckle for optimal tension of the sling.

Tightening: By hand.

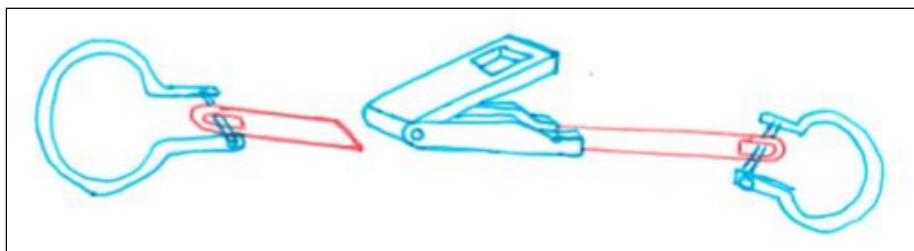


FIGURE 28: Ratchet tightening

7.4 IDEAS FOR RUBBER MAT

Simultaneously with working on the solution for tightening of the lifting equipment, OLC also looked at different solutions for placing and securing the sling on to the mat. The use of different types of pockets and tracks was discussed. The presented solutions below are all presenting different methods for securing the sling on to the mat and prevent sliding during a lift.

7.4.1 TRACKS IN THE MAT

The use of tracks in the mat can be a good concept and solution as long as it does not weaken the characteristics in the mat. A track in the mat will keep the sling in position, preventing sliding. Installing magnets inside the tracks might also help preventing the sling from falling off when mounting.

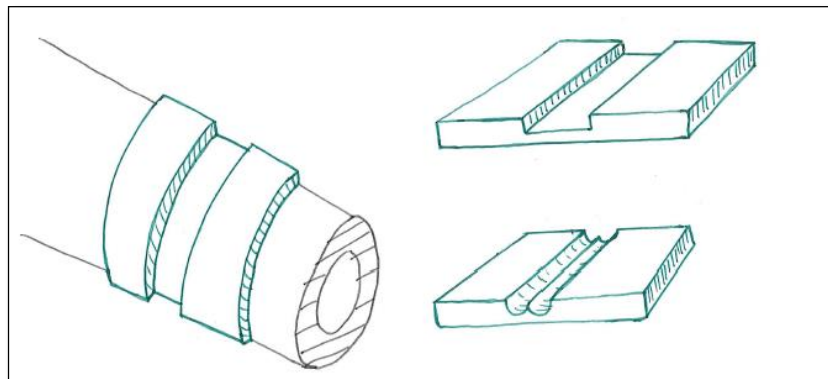


FIGURE 29: Tracks in the mat

7.4.2 SLING POCKETS ON MAT

Different types of pockets fixed on to the mat was discussed for securing the sling. One solution is to have a small pocket on the center of the mat on each side of the pipe. It could either be fixed in position, or designed to be able to be moved and adjusted for each individual lift.

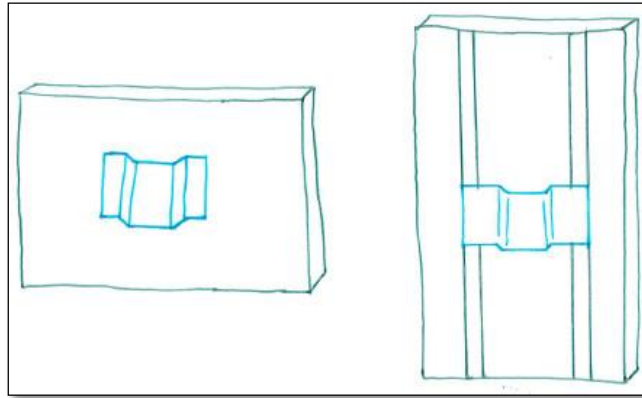


FIGURE 30: Small pockets on mat

The use of several pockets on each side of the pipe is also a solution. Having several pockets either woven into the mat or in other ways attached to the mat, enables the opportunity to choose the best suited pocket for each lift.

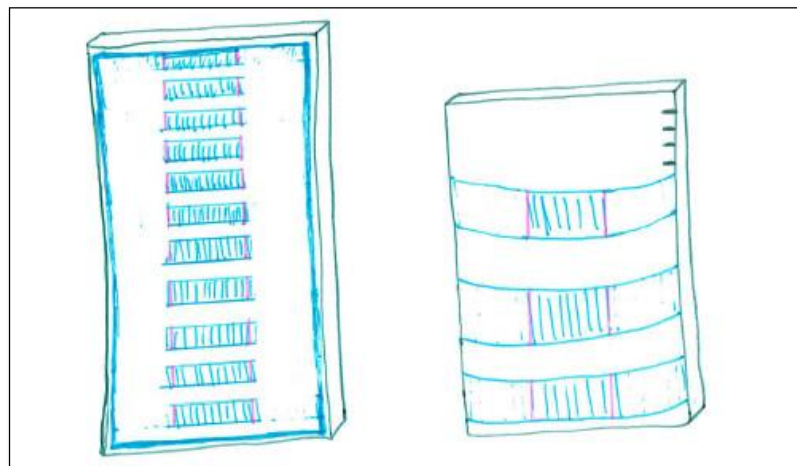


FIGURE 31: Multiple pockets on mat

Small pockets that can be opened and closed will ease the mounting of the chain. A solution with adjustable width of the pocket will help tighten the sling on to the mat, and enables the possibility of using the same pocket for different types and sizes of slings.

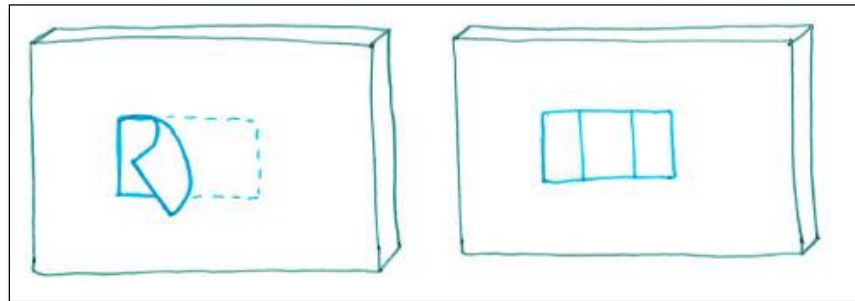


FIGURE 32: Adjustable pockets on mat

A pocket with reinforcement through steel entries can make the pockets stronger. This might reduce the risk of destruction of the pockets and prevent tearing and wear of the product.

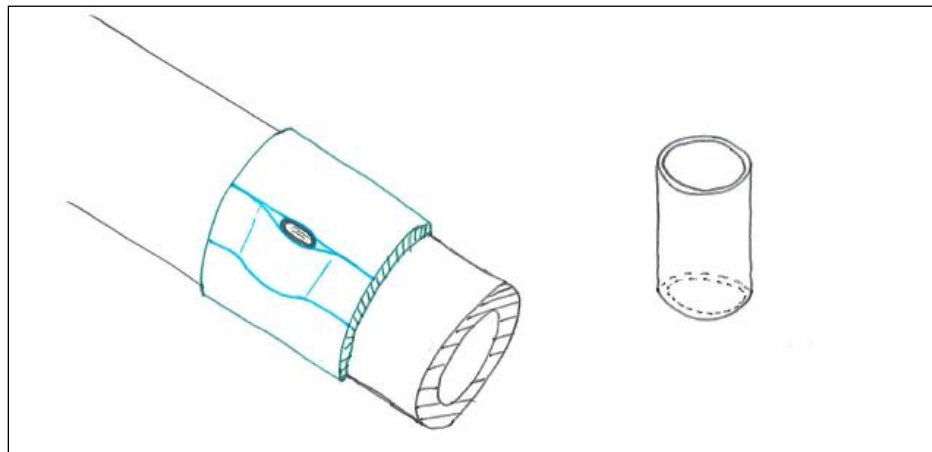


FIGURE 33: Pockets with steel entries on mat

7.4 EVALUATION OF TIGHTENING SOLUTIONS

Evaluation Meeting FMC

OLC arranged a meeting with FMC to discuss and get feedback on the ideas of different mechanisms for tightening the slings before lifting. It got clear that some of the concepts and ideas would not be approved for execution of an off board lift. Connecting two lifting eyes to the same shackle is also not applicable. This may however be solved by using a plate between two shackles and connect the lifting eyes to these.

When it comes to performing an off board lift FMC stated that the use of any type of soft slings are not allowed and will not be accepted. To be able to follow the requirements of the project and the wishes made by FMC, OLC then had to put away all ideas including the use of a soft sling for lifting. The use of wire or chain on the other hand is approved for lifting off board. The recommendation from FMC was to concentrate on using a chain as a sling for lifting for further work on the solution for the product.

Internal evaluation after the concept research

After carrying out the concept research and the evaluation meeting with FMC, an internal evaluation was done. OLC concluded that using a chain sling in the product is preferred, and that chains will be the lifting gear focused on for further work. Using a chain makes it easier to attach the tightening mechanism by using a hook connected to the links of the chain. Chains are also easier to store and handle compared to wires, because it is more flexible.

The different solutions of pockets on the mat for securing the lifting slings was also discussed. Since OLC decided on chain slings for further work, it was also concluded that small pockets on each side of the pipe would be a good solution. This will help getting the chain in the correct position during the assembly of the system. A pocket or flip on the top side of the mat and chain is also preferable. This flip or pocket should be able to be opened and closed for easier mounting of the chain. Further description on the mat can be read in “**9. Lifting mat solution**”

7.5 CHAIN TIGHTENING MECHANISM SELECTION

OLC chose to continue focusing on the use of chains for lifting of pipes offshore. To secure sufficient tightening of the chain before lifting, it is necessary to select a concept for a chain tightening mechanism (TM) for further development. A comparison of different solution was put in a pugh matrix to help with the selection. These TM was compared and put into the matrix:

TM number:	TM name:
TM 1:	Ratchet tie-down
TM 2:	Ratchet tie-down with suspension
TM 3:	Belt tightening
TM 4:	Belt tightening with suspension
TM 5:	Diagonal tension spring
TM 6:	Diagonal rubber band
TM 7:	Two attached tension springs/ rubber band

TABLE 11: Tightening mechanism names

7.5.1 CHAIN TM PUGH MATRIX

This matrix is used to compare and choose the tightening mechanism (TM) OLC are going to continue working with. The different solutions are compared up against each other.

	TIGHTENING MECHANISMS (FOR CHAIN)						
Req	1	2	3	4	5	6	7
Productions cost	3	2	3	2	3	3	1
Injuries	3	2	3	2	1	2	1
Installation	3	3	3	3	1	2	1
Consequence of twist	1	1	1	1	3	3	3
User friendly	3	3	3	3	1	1	1
Possibility of tightening	3	3	2	2	1	1	1

TOTAL	16	14	15	13	10	12	8
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TABLE 12: Chain TM pugh matrix

A high value means that it is easy to achieve it, while a low value means that it is difficult to achieve.

Point: min 1 – max 3

The requirements used in the matrix are described below.

7.5.2 MATRIX SELECTION CRITERIA DESCRIPTION

Requirement:	Description:
Production cost:	This includes materials, production and documentation.
Injuries	Possibility of injuries when dealing with the tightening mechanism.
Installation	The risk of incorrect installation and tensioning of the tightening mechanism.
Consequence of twist	Negative consequence if twisting occurs, during and/or after the lift.
User friendly:	How easy it is to assemble the tightening mechanism.
Possibility of tightening	Sufficient tensioning of the tightening mechanism by hand.

TABLE 13: Matrix selection criteria description

7.6 PUGH MATRIX RESULT

From the results from the Pugh matrix OLC concluded that a tightening mechanism based on a ratchet tie down would be a preferred solution to continue working on developing. OLC has worked with developing a ratchet solution that would be able to tighten the chain in a sufficient way.

7.7 FURTHER DEVELOPMENT OF THE CHAIN TM

While working on a ratchet tie down solution the thought of swapping the belt with a wire occurred. A wire is quite smaller than a belt while still having enough strength to tighten a chain around a pipe. The new idea is based on a wire tensioner for tensioning wires in a fence. Developing the design on a TM for chain continued with both the focus on ratchet tie down and wire tensioner.

One of the challenges of the TM was the placement of the mechanism on the system. OLC concluded that the most appropriate location of the TM would be on top of the mat. This location is constant regardless of the size of the pipe to be lifted, and it will ensure that the TM will not be in conflict with the chain during lifting. Two different solutions for placement was proposed; mounted on top of the mat and mounted on the middle chain link.

7.7.1 CHAIN TM CONCEPTS

Duplex ratchet tie down

This TM is based on a placement on the top of the mat above the chain. The use of two straps on a single ratchet will ease the tightening.

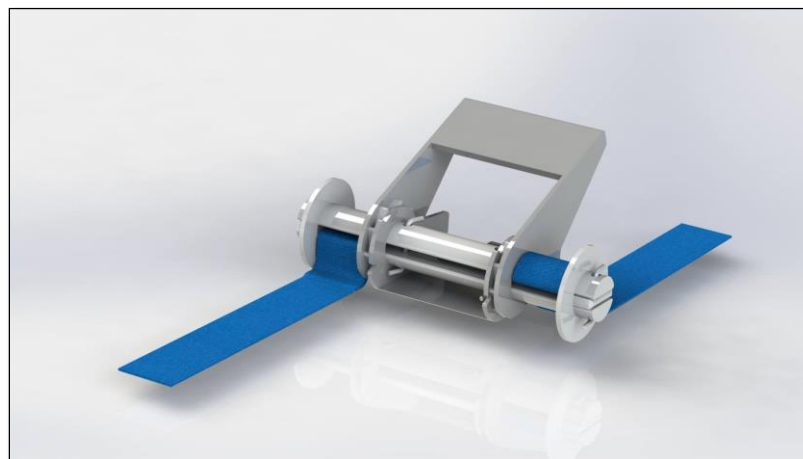


FIGURE 34: Duplex ratchet tie-down idea

Wire tensioner

The wire tensioner is based on a placement on top of the mat above the chain. The concept is based on two layers of drums each having its stock with wire.

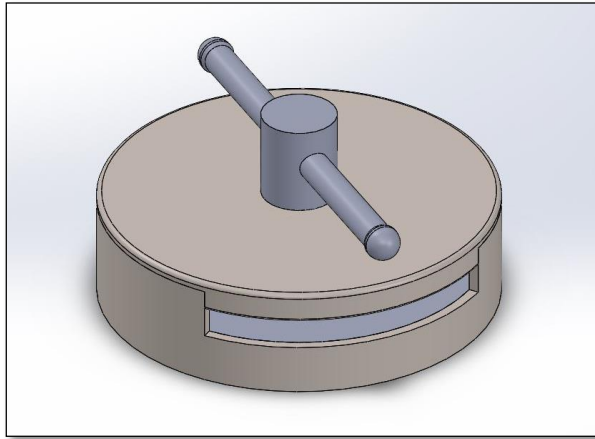


FIGURE 35: Wire tensioner concept for chain

Vertically double strap tightening

This tightening mechanism is based on mounting on the middle chain link. When mounted on the middle chain link and placed on top of the mat, it will secure centering of the chain before lifting. On each side of the TM is a drum for straps to be used for tensioning the chain.

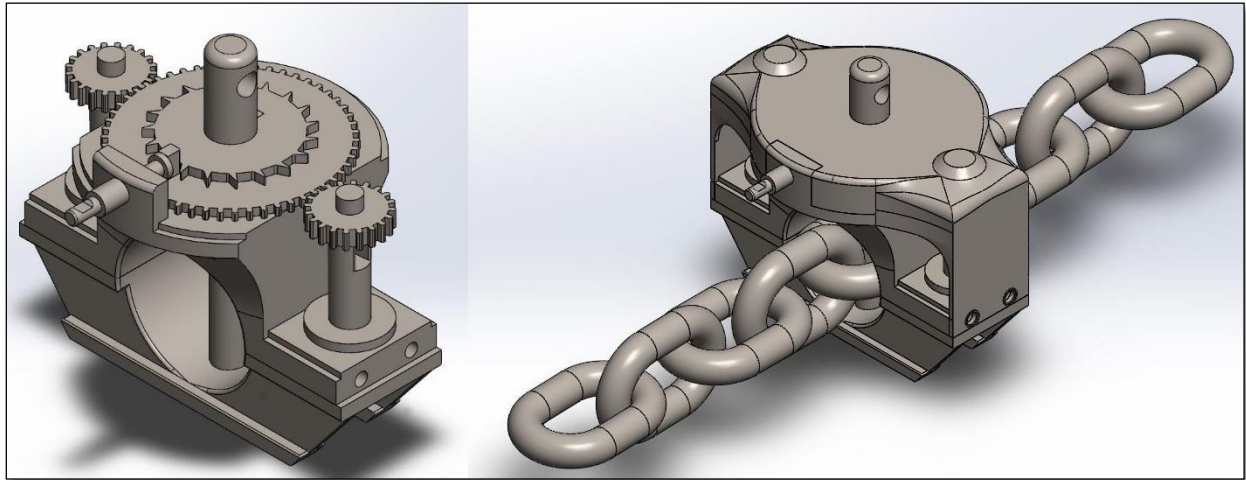


FIGURE 36: Double strap tightening mounted on chain

In line double wire ratchet

This TM is based on a molded form fitted for the selected chain for lifting, and mounted on the middle chain. The use of an inline double ratchet adjusted to be used with wires are mounted on top of this. By having the TM directly mounted on the middle link of the chain will secure centering of the chain before lifting.

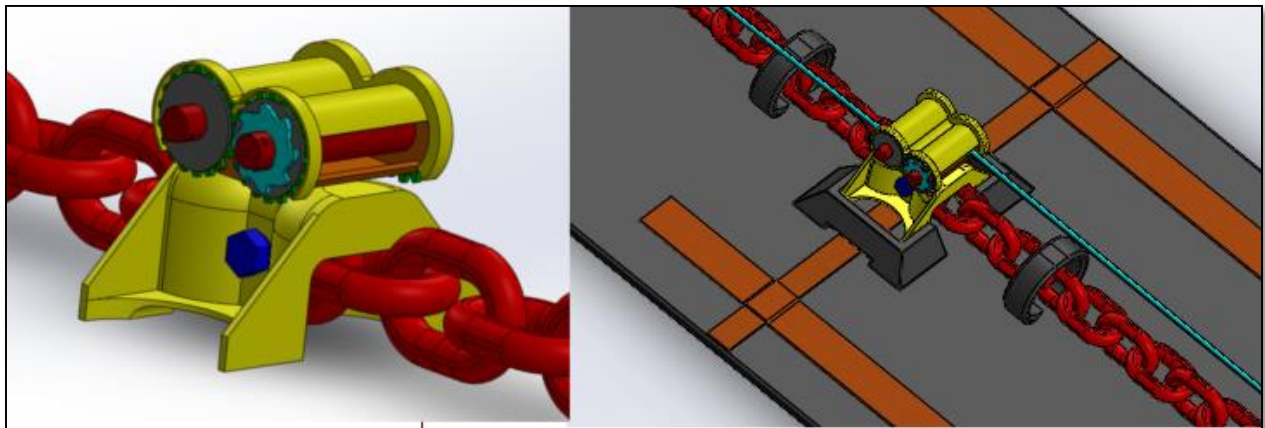


FIGURE 37: Double inline wire tightening mounted on chain

7.7.2 HOOK FOR ATTACHEMENT TO THE CHAIN

When working on developing a TM for tightening of the chain, a prototype of the whole system was made. When mounting the mat with different types of tightening mechanism a new challenge occurred. On the prototype the attachment to the chain was done by using a carabiner hook or a shackle. This proved to be quite challenging and troublesome. It was hard getting the hook connected in a correct position, and after the chain was tightened it was difficult getting the hook off the chain again. Also, it is not allowed to use carabiner hooks in offshore lifting. OLC have looked on other more user friendly and simple solution for fastening the TM strap or wire to the chain.

The chain hook was a challenging product to design. A research on different hooks that are specially designed for hooking onto a chain was performed. Particularly interesting was a device called a shortening clutch, used for shortening in the length of a sling. OLC used the research as inspiration when designing a hook for the TM. The idea of the shortening clutch was to hook it onto one of the links in the chain, making it easy to adjust since it would fit over any one of the links on the sling.

TM shortening clutch 1

The first design of the shortening clutch is similar to an original shortening clutch. The hook is attach onto one of the chain link, being locked in position by the chain links on each side.

The hook is mounted perpendicular to the chain, which might be a problem causing the chain to twist.

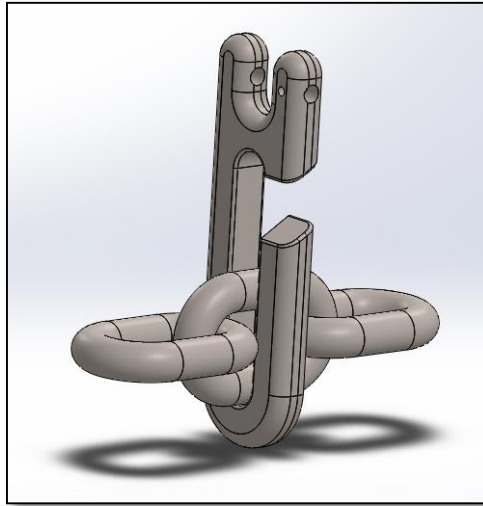


FIGURE 38: Shortening clutch design

TM shortening clutch 2

The situation when tightening the chain on the mat is in a vertical direction, the same direction as the chain. A new design was developed being able to hook on a chain link in the correct direction with the same possibility for hooking onto the most favorable link as the one shown above. A chain link will rest in the hook, enabling the hook to be tighten in the correct direction.

This hook did not have this “claw” on the left side. This was because OLC did not think that the chain sling would slide of the mat during a lift with a high angle, then again this was before OLC received the new requirement about having a mat not exceeding 300 mm in width.

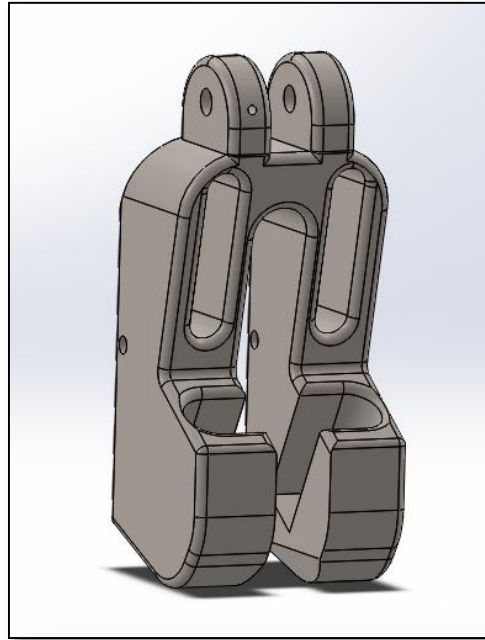


FIGURE 39: Shortening clutch design

7.8 SECOND EVALUATION OF TIGHTENING MECHANISM

Second evaluation meeting with FMC

After working on these concepts for tightening of the chain around the pipe, a new evaluation meeting got arranged with FMC. The different types of tightening concepts and hooks was presented and discussed in order to get input and feedback. FMC showed interest in the hook that was designed. The hook had the possibility of keeping the chain in place during a lift, and also control the start of the angle of the chain during the lift. A further work on developing the hook was asked for.

In addition to this FMC showed interest in the wire tensioner, and thought that it could be a possible solution for tightening of the chain.

During the second evaluation meeting with FMC, two new requirements for the project was introduced:

“R3.1.4 Width of the lifting clamp

The width of the clamp shall not exceed 300 mm.”

“R5.1.5 Force on tightening mechanism

If a tightening mechanism is chosen to tighten an existing lifting gear, the tightening mechanism must withstand an increase of applied force during lifting.”

These two requirement was introduced because of the concept and solution that was presented. It is important that the width of the mat will fit all the types of pipes to be lifted, and a maximum width is therefore necessary. And by designing a tightening mechanism for tightening the chain, it must be designed to withstand any increase in applied force that may occur during unexpected situations during lifting, even though the TM itself shall not take any of the forces in the lift.

7.9 FINAL DESIGN SELECTION

Based on the work done when developing these concepts and the evaluation meeting with FMC, OLC had an internal meeting discussing and evaluating the concepts for final design selection. The final design and product will consist of three parts, in addition to the lifting chain:

Lifting mat

The lifting mat must be designed in terms of dimensions and materials. It must consist of all the necessary components needed to secure the lifting chain when performing the lift, and it must have a layout fitting according to the new requirement stating the maximum width of the mat.

Tightening mechanism

OLC chose to focus on further developing the wire tensioner for the final design. This concept will be 3D designed and tested with FEM analysis. A prototype and 3D printed model is also planned

for the final design. The new requirement stating that the tightening mechanism must withstand extra force during lifting, applies an extra challenge in the further work.

In addition to the wire tensioner, it is wanted to produce a prototype of the duplex ratchet tie down. This will give a comparison to the wire tensioner, both dimensionally, functionally and when performing tests.

Tightening hook

A specially designed tightening hook is important to be developed to be able to secure the chain in an easy, effective and safe matter. The requirements introduced new challenges regarding the hook: The restriction on the width of the mat poses a challenge in terms of how the chain angles during a lift. For a larger pipe at a lift in a 45° angle the chain will most likely end up outside the area of the mat and thus could cause damage. It is necessary to control the start of the angle of the chain so that the chain does not angle before the mid side of the pipe. By specially designing a hook it can take care of this by locking the chain completely in position before lifting.

By using a hook in this matter, it sets stricter requirements to the performance of the hook. It is now considered as a lifting equipment, which means that it will have to endure the same strict requirements for verification, documentation and marking as other offshore lifting equipment must undergo. This means that it has to fulfill all the requirements from the DNV standards.

7. FINAL DESIGNS

Three parts characterize OLC's lifting clamp:

- ➔ Lifting mat
- ➔ Tightening mechanism for chain
- ➔ Chain hook

Throughout the iterations in the projects there have been made many different design concepts for each of these three components. The final designs, results, products and work will now be presented.

9 LIFTING MAT SOLUTION

The recommended concept solution given to FMC for performing a lift off-board is to use already existing and approved lifting equipment in combination with a rubber mat that is tightened to the pipe. The mat will keep the equipment in place and prevent slippage on the pipe, and it will enable the possibility of using the same equipment for lifting pipes of different diameters.

9.1 CHALLENGES

When designing the lifting mat for performing an off-board lift, various challenges that the mat might be exposed to needed to be taken into account:

Slippage:

Two mats will be mounted on a pipe. A chain will be connected to the center of each mat and perform a lift in an angle of up to 45°. This will apply a force on the mats, pushing them towards

the center of the pipe. The mats has to withstand this force, keeping the chosen lifting gear secure in place throughout the whole process, with no possibility of the mats sliding toward the center of the pipe.

Environmental impact:

The mat shall secure an off-board lift – a lift from a boat to a rig. When performing these types of lifts, the mat need to withstand the environmental impact, such as waves up to 6 m, weather conditions (dry/wet weather, variating temperature, wind, seawater, etc.), and challenges from the working environment (oil spill, dirt, damage from mishandling etc.). The mat must secure the lift and meet the requirements at all time, no matter the environmental conditions.

Different diameters:

One of the requirement from FMC is to be able to perform a lift on pipes of different diameters using the same equipment. The design of the mat must take care of this requirement, while still securing the lift and preventing sliding on the pipe surface.

Maximum width of mat:

The mat is supposed to be used on different types of pipes. These pipes will have different designs. Some will be completely slick (so-called slick-pipes), while others will have a more complex design where the placement of the lifting equipment is determined in advance. If the mat including the lifting equipment shall be adapted to the use of different type's circular tubes, the mat must be adapted and designed proper to the given dimensions for placement of lifting equipment on existing pipes.

Wear:

The solution that OLC is working on in this project, is with the use of a mat in combination with a chain sling. The use of chain sling as a lifting equipment, will give a lot of wear on the mat. Both the ratchet tie-downs and the chain sling will transfer force onto the mat that will wear the material in the mat. It is important to design the mat having the correct materials and structure, so that it can withstand the stresses it is applied.

Storage:

Mounting of the equipment can be done both before shipping and on deck/on the rig. After performing the lift, the equipment is dismantled. The equipment needs to be stored safely and secure, with easy access and protection against damage, before, after and between uses.

Number of parts:

When working offshore, having equipment in several loose parts is a big disadvantage. If the mat and equipment corresponding to it consist of several different loose parts, the possibility of mishandling, misplacement, abuse of and losing equipment will increase. It is a challenge to implement all the necessary equipment needed into the mat, this in addition to avoiding any loose parts.

Correct and easy installation:

The installation of this equipment must be easy, quick and understandable. This includes installation of the mat itself, and installation of the chain sling onto the mat afterwards. The design and layout of the mat must be clear and simple, so that the installation cannot be misunderstood. The design of the mat must also include a solution that allows the chain to easily be mounted correctly afterwards, and be held constantly in the right position.

The placement of fixed components on the mat:

The mat is supposed to be used on pipes of different diameters, and there must not be any loose parts. This means that the needed components in the system must be attached to the mat. The challenge here is to have the components fixed on the mat and still having the mat functioning as it should, taking the different diameters of the pipes into consideration. Since the mat is going to be wrapped around the pipe, this means that the components will be placed differently on each pipe. The measurements of the mat and placement of the components must ensure that the components will not fall under the overlap at smaller diameters. Having the components too far at the top of the pipe should also be avoided in order to secure the mat on the pipes with larger diameters, in addition to having a hassle free lift.

9.2 DESIGN DIMENSIONS AND LAYOUT

The mat must be designed and dimensioned to withstand the challenges mentioned above. In addition to this, the layout of the mat must be designed to contain the necessary components needed to perform an off-board lift in a safe and secure manner.

9.2.1 MAT DIMENSIONS - WIDTH

The width of the mat is given through a requirement from FMC:

“ R3.1.4 – Width of the lifting clamp

The width of the lifting clamp shall not exceed 300 mm “

This requirement is constant, no matter the pipe diameter. The maximum width of the mat is set to ensure that the lifting equipment will fit the pipe, no matter the design and complexity of the actual pipe to be lifted.

9.2.2 MAT DIMENSIONS – LENGTH

The length of the mat is depending mainly of the pipe dimensions it is supposed to be used on. It is also necessary to take into consideration the usability and handle ability of the product in terms of mounting the equipment onto the pipes.

When designing a mat to fit different diameters of pipes, it means that the mat will have an overlap on pipes of smaller diameters. The overlap of the mat on a pipe should not exceed 1/3 of the smallest pipes circumference, considering the usability during installation. The larger the pipe size, the bigger is the challenge to wrap a mat around the pipe if there is a large overlap. This immediately puts some limits on the size of the length of the mat.

OLC's project is based on a pipe size of 16", but the variations in diameters of pipes used offshore and for subsea are quite large. OLC therefore recommend mat dimensions in these four categories, covering pipe diameters from 8" to 20":

- **8" → 10,5":**

Mat length (Circumference: C of 10,5" pipe = 837 mm) = **835 mm**

Overlap on 8" tube = 201 mm < 1/3 of a 8" pipe circumference (212 mm)

- **10,5" → 13":**

Mat length (C of 13" pipe = 1037 mm) = **1035 mm**

Overlap on 10,5" tube = 198 mm < 1/3 of a 10,5" pipe circumference (279 mm)

- **13" → 16":**

Mat length (C of 16" pipe 1276 mm) = **1275 mm**

Overlap on 13" tube = 240 mm < 1/3 of 13" pipe circumference (345 mm)

- **16" → 20":**

Mat length (C of 20" pipe = 1596 mm) = **1595 mm**

Overlap on 16" tube = 319 mm < 1/3 of 16 pipe circumference (425 mm)

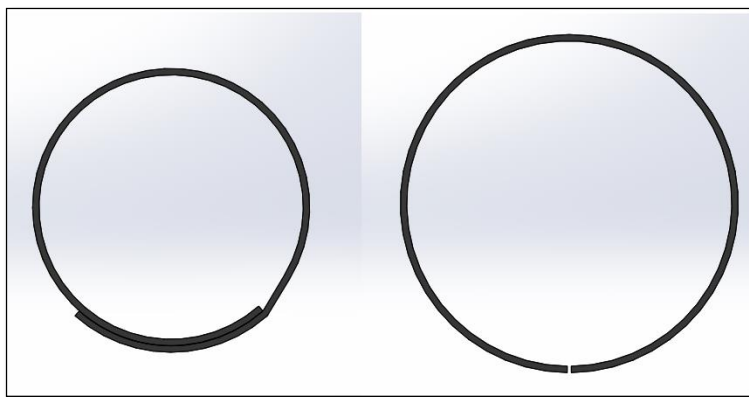


FIGURE 40: Showing the same mat used on a 13" pipe and a 16" pipe

The length dimensions of the mat are scaled in such a way that they will be able to handle the largest variety of pipe diameters, without affecting the usability and the handling of the product. These four lengths of the mat will cover the need for lifting pipes with diameter varying from 203 mm (8”) up to 508 mm (20”)

9.2.3 MAT DIMENSIONS –THICKNESS

The mat must withstand the wear that occurs due to applied forces from the lifting equipment. It must also be flexible enough to easily be wrapped around pipes of varying diameter. The mat thickness will thus depend on the choice and structure of the materials used. The materials and the structure of the mat is described in *”10. Rubber mat material selection”*

9.2.4 MAT DESIGN LAYOUT

When designing the lifting mat, in addition to the outer dimensions of the mat, OLC need to take into consideration the layout of the mat and its components. Due to the restricted width of the mat and use of existing lifting equipment, there will not be a lot of space to place different components onto the mat. The mat solution gives some challenges in respect to the layout of the mat and its components.

Tightening system of mat:

The mat must have space for a tightening system that tightens the mat onto the pipe. The mat is dependent upon a contact surface with applied force against the tube, to prevent slippage during the lift.

Space for the lifting equipment:

The recommended solution proposes the use of existing lifting equipment when carrying out the offshore lift. OLC have decided to concentrate on the use of chains for performing lifts. Chains

used for lifting offshore must be of grade 8 or greater. These chains have a larger safety factor, and depending on the lifting capacity, the dimensions of the chain can be relatively large and coarse. When performing the lift, the chain must also pass two rounds around the pipe. A combination of these factors makes it necessary to arrange space on the layout of the mat to ensure that the mat can be used for various dimensions of chains.

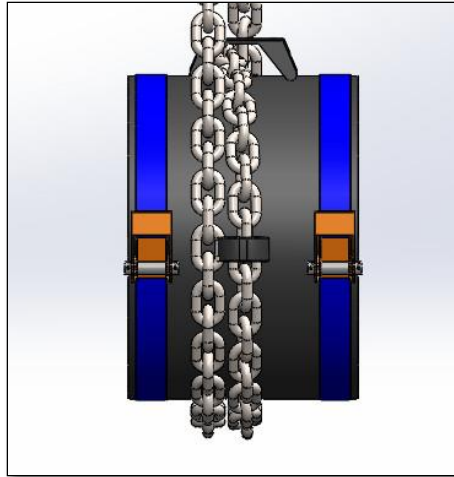


FIGURE 41: The mat must have space for both tightening of the mat and for the lifting chain

Chain tensioner:

By using existing lifting equipment, such as chains, OLC need a method to tighten and secure the lifting equipment before, during and after the lift. This is also determined by the requirement, stating:

“ R5.1.4 Tightened to pipe

The lifting clamp shall be tightened in such a way that there is no danger of the clamp to slide or move out of position after it has been mounted on the pipe. “

This means that the system must have a tightening mechanism that tightens up the lifting equipment on the mat. The mechanism should be located on the mat or chain, and it must be taken into account when designing the layout of the mat.

Angled lift must not come in conflict with components on mat:

Lifting of circular pipes occurs in an all-point lift. This is done through the attachment of two (or more) clamps on each end of the pipe, where a forerunner goes from each clamp and up to a common point that will be attached to the cranes hook before lifting. By performing a lift like this, there will always be an angle on the lifting equipment. The maximum angle which the lifting clamp shall be designed to handle, is determined by:

“ R5.1.2 Sling angle

The angle of the sling during a lift shall not exceed 45°. “

In the existing solution for lifting pipes by using a lifting clamp, there is a padeye on top. A sling is connected to the padeye, and the angle that occurs during a lift, will be on top of the clamp, above the lifting clamp itself.

When lifting using a chain that passes two rounds around the pipe, the lifting angle of the chain will be arranged on the side of the pipe. This creates a challenge when designing the layout of the mat, because the chain must not come in conflict with any components attached to the mat. If the chain and the various component are in conflict, it will translate into a risk of damage to equipment and faults during lifting.

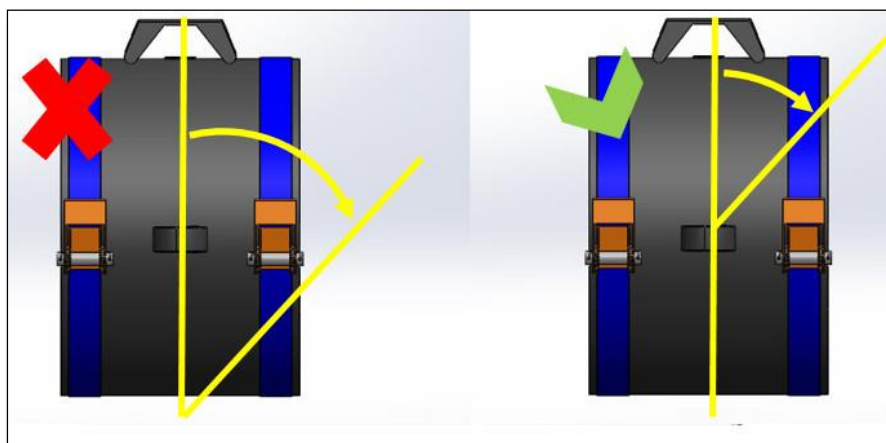


FIGURE 42: The chain must not come in conflict with any components on the mat when angled during a lift

9.2.5 MAT COMPONENTS

In OLC's proposed solution for lifting equipment designed for circular tubes, the mat will consist of three different main components:

- ratchet tie-downs for tightening of the mat
- pockets and pin for securing the chain in position
- a flip for mounting the tightening mechanism

Ratchet tie-downs for tightening of mat

The mat must be tightened and secured to the pipe before the lifting equipment can be mounted onto the mat. By using a material with high friction against steel, and apply force to the contact surface between the mat and the pipe, OLC can achieve a large enough safety factor to prevent the equipment from sliding on the pipe.

The tightening mechanism of the mat to the pipe will not take any of the forces during the lift. It will only tighten and secure the mat onto the pipe. The forces encountered during a lift will be absorbed by the lifting gear and it will tighten the mat further during the lifting process. This will help to reduce the forces on the tightening system of the mat. The system for tightening the mat to the pipe will therefore not require the same documentation and verifications which any offshore lifting equipment must undergo. Based on this, OLC recommend tightening the mat to the pipe using two ratchet tie-downs permanently attached to the surface of the mat.

To satisfy the requirement stating the need of double barriers on equipment offshore, the ratchet tie-downs should have double locking on the ratchet barrel, preventing loosening of the mat during a lift.

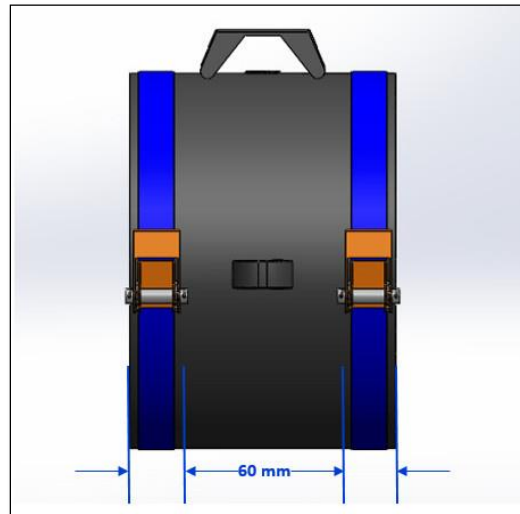


FIGURE 43: Space for ratchet tie-down on mat

The ratchet tie-downs will apply force onto the contact surface between the mat and the pipe. The contact surface should be as large as possible, giving the mat the greatest contact area achievable to prevent sliding. Because of the maximum width of the mat and the space needed for the lifting chains, it is realistic to set of 6 cm on both sides of the mat, a total of 12 cm, for the ratchet tie-downs to tighten the mat. This will provide a possible width of the straps of 4 cm on each side, which will measure the contact surface area between the mat and the pipe.

Rubber pockets and pin

Mounting a loose chain onto a pipe and center it before performing a lift, can prove to be a challenge. A chain has a large specific weight, and the fact that it consists of several links will make it more difficult to handle. In OLC's solution, using a mat to secure an already existing lifting gear, it is crucial to fasten the equipment in a fixed position before performing a lift. It is therefore essential to center the chain during assembly to prevent a distorted lift.

By firmly attach a pin in the middle of the mat the lift can be centralized. This is done by attaching a marked middle chain link onto the pin. By additionally having two fixed pockets on each side of

the mat, the chain then may easily be slipped through. It is ensured that the chain is in the proper position before tightening of the chain is carried out.

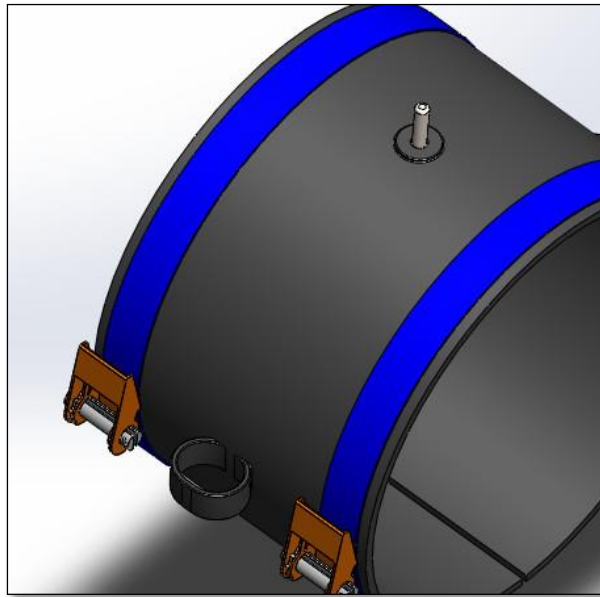


FIGURE 44: Pin and pocket for chain

Flip for mounting the tightening mechanism

The chain must be firmly tightened and secured before, during and after the lift. To be able to do this, there must be attached a mechanism to tighten the chain either to the mat or to the chain itself. If the tightening mechanism shall be fixed on the mat, it must be placed in such a way that it will not be in conflict with the chain during a lift, and the location should be predictable regardless of the diameter of the pipe to be lifted. The only point on the mat that will be in the same position regardless of the diameter of the pipe is the centerline in the middle of the mat. It would be natural to place a tightening mechanism at this spot. Placing the mechanism like this, will also ensure that it will be centered relative to the chain to be tightened, and it will end up in a triangle on the upper side of the pipe which is not in contact with the chain.



FIGURE 45: The placement of the tightening mechanism on the pipe

OLC's solution to the placement of the tightening mechanism is a flip covering the chain after it is mounted on the pin on the mat, and locked in position. This will ensure an easy mounting of the chain on to the mat, and at the same time place the tightening mechanism firmly on top of the pipe and chain.

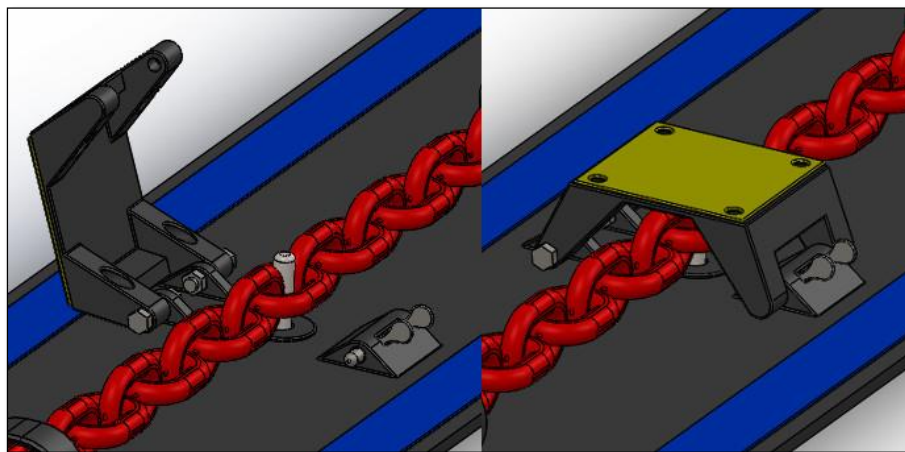


FIGURE 46: Flip for mounting of the tightening mechanism above the chain

The different tightening mechanism concepts and chosen mechanism for OLC's product, is described in ***"11. Tightening mechanism"***

9.2.6 COMPONENTS PLACEMENT

Based on the requirements for the product, the challenges mentioned above and the components needed for performing and securing a lift, OLC have calculated the recommended placement of components onto the mat:

Angle of chain when lifting

Due to the restricted width of the mat, it is important to be able to control where the chain has its starting angle on the mat during a lift. On a larger pipe diameter, during a 45° lift where the angle starts at the bottom of the pipe, the chain will end up on the outside of the mat, and could cause damage to the pipe and equipment. Controlling the angle of the chain will also help in placing the fixed components on the mat, preventing conflict between the chain and the components.

Because of the restriction due to the width of the mat, it is recommended to start the angle of the chain on the mid side of the pipe. By using a specially designed hook for tightening the chain to the pipe, the start angle of the chain can be controlled. By having the angle of the chain starting at the mid side of the pipe, damage to the pipe can be prevented, despite the restricted width of the mat. The chain will be less in contact with the equipment from this point due to the periphery of the pipe and the angle formed by the lifting chain. A description of the hook is given in “**12. Chain hook**”

To secure correct placement of the hook on the chain relative to the pipe diameter, OLC recommend to have clear and visible markings on the side of the mat, which confirms how the hook should be placed when tightened.

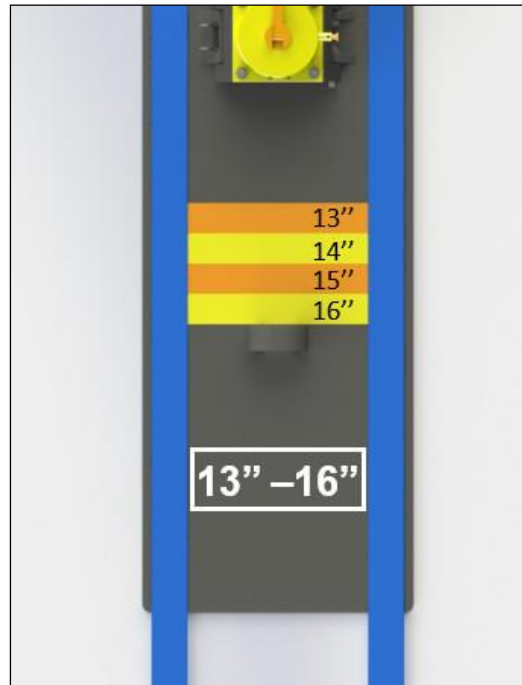


FIGURE 47: Markings on the mat showing mat size and the placement of the chain hook when mounting of the chain

Ratchet tie-downs

When mounting the mat, it would be preferable to place the ratchet tie-downs on the upper half of the mat, to enhance the usability of the product. The challenge by doing this is that the ratchets most certainly will come in conflict with the chain, increasing the risk of damage to the equipment or that the equipment loosens.

The ratchet tie-downs should be placed close up to, but not above, the mid side of the pipe. The overlap that occurs when a mat is used on a smaller diameter also needs to be taken into consideration. There cannot be placed any components that has the risk of ending up in the overlap. This means that no components can be placed onto the ends of the mat contained in 1/3 of the smallest circumference.

Measures for the placement of the ratchet tie-downs are described below in the mat dimension table.

Rubber pockets and pin for chain

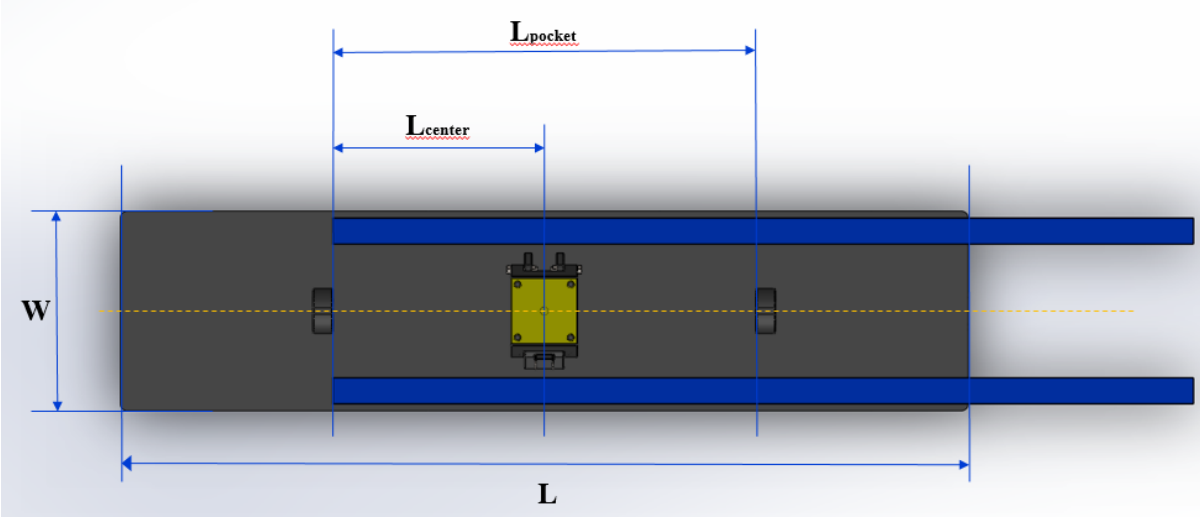
The chain pin is firmly attached onto the mat at the center. The middle chain link will be clearly marked, making it easy to place this correct on the mat.

The rubber pockets should be placed as low as possible on the sides of the mat, giving the chain a greater length for being positioned correctly onto the mat. It is also important that the rubber pockets will not be in conflict with the tightening hook, which further confirms the location of the pockets on the lower half of the pipe. The recommended placement of the pockets is as low as possible on each side of the mat, taking into the consideration of the overlap that occurs in smaller diameter pipes. Measures for placements of the pockets are described below, in the mat dimension table.

Component placement:

Comparing the criteria for the placement of components with the different mat sizes and pipe diameters, it was discovered that the placement of the ratchet tie-downs and rubber pockets must be placed at the same distance from the center line of the mat. The calculated placement will ensure that both the rubber pockets and ratchet tie-downs will be placed mid-side on the larger pipe diameter. This will take care of the challenges mentioned above, while avoiding conflict in the overlap of the mat on smaller diameters. Measures for placement of components are described below, in the mat dimension table.

9.3 MAT DIMENSION TABLE

Mat dimensions:		
		
8" → 10,5" pipe		
8"	10,5"	Dimensions:
D = 203 mm C = 638 mm Maximum distance component placement from center: 213 mm	D = 267 mm C = 839 mm Minimum distance component placement from center: 210 mm	Mat size: L = 835 mm W = 300 mm Recommended component placement: L _{pocket} = 420 mm L _{center} = 210 mm Overlap on smallest diameter: 201 mm

10,5" → 13" pipe		
10,5"	13"	Dimensions:
<p>D = 267 mm C = 839 mm</p> <p>Maximum distance component placement from center:</p> <p>280 mm</p>	<p>D = 330 mm C = 1037 mm</p> <p>Minimum distance component placement from center:</p> <p>259 mm</p>	<p>Mat size:</p> <p>L = 1035 mm W = 300 mm</p> <p>Recommended component placement:</p> <p>L_{pocket} = 520 mm L_{center} = 260 mm</p> <p>Overlap on smallest diameter:</p> <p>198 mm</p>
13" → 16" pipe		
13"	16"	Dimensions:
<p>D = 330 mm C = 1037 mm</p> <p>Maximum distance component placement from center:</p> <p>346 mm</p>	<p>D = 406 mm C = 1276 mm</p> <p>Minimum distance component placement from center:</p> <p>319 mm</p>	<p>Mat size:</p> <p>L = 1275 mm W = 300 mm</p> <p>Recommended component placement:</p> <p>L_{pocket} = 640 mm L_{center} = 320 mm</p> <p>Overlap on smallest diameter:</p> <p>240 mm</p>

16" → 20" pipe		
16"	20"	Dimensions:
D = 406 mm C = 1276 mm Maximum distance component placement from center: 426 mm	D = 508 mm C = 1596 mm Minimum distance component placement from center: 399 mm	Mat size: L = 1595 mm W = 300 mm Recommended component placement: L_{pocket} = 800 mm L_{center} = 400 mm Overlap on smallest diameter: 319 mm

TABLE 14: Mat dimension table

9.4 LIFTING MAT DESIGN CONCLUSION

The lifting mat is designed in four different sizes for performing lifts of circular pipes in varying diameters from 8” to 20”. The width of the mat is set to be 300 mm, given by a requirement from FMC. This provides some challenges in relation to the placement of components on the mat relative to the lifting angle of the chain. But by controlling the start of the angle of the chain, OLC can design the mat including necessary components to perform safe and secure lifting of circular pipes.

The mat consists of fixed components to secure proper lifting:

- Ratchet tie-downs to tighten the mat and ensure enough force and friction to hold the mat in place whatever the conditions
- Pin and rubber pockets to ensure centralizing and correct placement of the lifting chain on the mat
- Flip on top of the mat which ensures proper and stable positioning of the system for tightening the chain

The use of a designed rubber mat for securing existing lifting equipment for lifting pipes offshore, will fulfill several of the requirements provided by FMC for the project. Some of the benefits of the mat solution compared to today's solutions, are:

- Reduced production cost
- Reduced weight
- The use of the same product for lifting pipes of different diameters
- Reduced rigging hours

OLC recommend FMC to have a further look at the design and layout of the mat, to secure correct placement of final components needed in the lifting equipment system.

10. RUBBER MAT MATERIAL SELECTION

One of the main requirement for the project is that there shall not be any possibilities for slippage on the pipe after the clamp is mounted.

“ R5.1.4 Tightened to pipe

The lifting clamp shall be tightened in such a way that there is no danger of the clamp to slide or move out of position after it has been mounted on the pipe. “

Another requirement is that the lifting equipment shall be “hands-off”, meaning there shall not be any human interference on the equipment after it is mounted on the pipe, before and during the lift.

“ R5.1.6 Hands off

The lifting equipment must be “hands off”, meaning after it has been installed it shall perform the lift with no human contact or interference. “





The solution proposed for FMC is to use a mat that is tightened to the pipe with such high friction that it will be locked and secured in position, while still keeping the weight as low as possible. This solution requires materials that are designed and manipulated in such a way that it will glue itself to the pipe when tightened, due to high friction. Rubber has the possibilities of very high friction against steel depending on the composition of the material. OLC believe that designing a specialized rubber mat with the desired properties will take care of these requirements.

10.1 POLYMER MATERIALS

Polymers is a synonym for plastic, and is a collective term for a type of material built of long or large natural or synthetic molecules. The meaning of “poly” is “many”, and it refers to the materials as consisting of many monomers (“mono” equals to “one”). A monomer is the smallest repeating structure unit in a polymer molecule. The way the monomers are structured and linked in the polymer molecule, helps to classify the type of polymer. The various categories differ partly out of the molecular structure and the chemical composition of the polymer. As main classification, the polymers can be divided into these categories:

- **Thermoplastic** – polymers that consist of linear or branched chain molecules that are recyclable. These polymers can be heated and melted into new products, and can be used over and over again
- **Thermosetting** – polymers which are tightly connected chain molecules. These polymers are rigid, hard and brittle. They will decompose when exposed to a high temperature, and is therefore not recyclable.
- **Elastomer** – polymers which are loosely connected chain molecules. These polymers are highly elastic, and can gain back to their original shape even after large elastic deformations (> 200%). Elastomer will burn and not melt when exposed to too high temperatures, and is therefore not recyclable.

[2][3]

			
Lineære kjedemolekyler	Forgrenede kjedemolekyler	Løst tverrbundne og myke kjedemolekyler	Tett tverrbundne kjedemolekyler
Termoplast		Gummi, elastomer	Herdeplast

● = kovalent tverrbinding

FIGURE 48: Description of the structure of the various polymer categories [2]

Polymer as materials alone has poor properties for construction. These properties include low strength and stiffness and high thermal expansion, making them unsafe as building materials. They also have relatively low thermal resistance, only up to ~ 350 degrees, making them unsuitable for certain structures. Compared to traditional building materials such as steel, polymers do have some clear advantages. Polymers are passive and resistant to corrosion with respect to various chemicals, they have a very high production rate, they have low density providing a low weight on the product at the end, and they are relatively cheap to use, compared with other metal materials.

[2][3]

By choosing the right type of polymers for the product and manipulating the content in the material structure and composition, OLC can gain the advantages from polymer materials combined with a reinforcement of the material so that it is suitable as materials for constructions.

10.2 ELASTOMER

Elastomer is a synonym for rubber. Elastomer is built as one giant polymer molecule with high elastic properties. It can withstand a great amount of elastic deformation, and still obtain its original shape and size. Elastomer can be made of both natural and synthetic rubber. Natural rubber has excellent friction properties and good resistance to abrasion and fatigue. They are however poor against the influence of heat, UV rays and oil. Synthetic oil is made from petroleum, and has good resistance to abrasion and fatigue, as well as impact from oil and UV. Both natural and synthetic rubbers can be designed to desired characteristics by changing the composition of the material.

[2][3][7][8]

10.2.1 VULCANIZATION

Elastomers in general has a limited temperature of use. All polymers has a glass transition temperature (T_g) and a melting temperature (T_m). If an elastomer is used in temperatures below T_g area, it will become hard and brittle, and more easily break and get destroyed. If an elastomer is

used in temperature above T_m , the molecules will decompose and burn. By letting elastomers undergo a procedure called vulcanization, the properties of the material can be improved. Vulcanizing means crosslinking the elastomer chains in the molecule by introducing sulfur. This procedure prevents a polymer to deform plastically, it increases the tensile strength and makes the material stronger, gives the product a wider temperature range for use and increases the elasticity even further. In this way, elastomer can be used for a wide variety of products and areas where properties such as strength, resistance against abrasion, flexibility in the material and large friction properties are essential.

[2][7]

10.2.2 DUROMETER SHORE HARDNESS SCALE

The hardness of polymers and elastomers are defined and categorized by the Durometer Shore Hardness Scale. The most common scale for soft rubbers and polymers are shore A, grading from 0 to 100, where the higher the value the stiffer the material. As a comparison, a car tire is commonly in 60-70 shore A.

[9][10][11]

Elastomer is the material used in car tires. Car tires has a high requirement for quality and good frictional properties. The tires are the single point of contact between the car and the ground, and they must keep the car stable and secure whatever the conditions, speed and forces that influence. OLC are convinced that using an elastomer mat to secure and prevent sliding of the lifting equipment while lifting pipes offshore, is a working solution, based partly on the knowledge and technology that is already in products with high performance needs.

10.3 COMPOSITE

A composite material is a composition of two or more chemically distinct and insoluble phases of materials^{i ii}. This means that each of the phases and materials will include their own specific characteristics to the overall properties of the composite. The composite characteristics are determined by the volume fraction of each including phase, as well as the shape, size, orientation

and distribution of the phases in the composite. This gives the possibility to manipulate the materials into having the desired properties needed with respect to the applications the material is intended.

Composites are categorized into three different categories depending on the matrix used:

- MMC – Metal Matrix Composite
- CMC – Ceram Matrix Composite
- PMC – Polymer Matrix Composite

[4] [5]

In the project and the product, it is necessary to look at PMC composite, since OLC are looking to use polymers in the mat. By combining polymer as a base material with reinforcement through fibers of other materials, higher strength and resistance to abrasion on desired areas of the mat can be achieved.

Polymer materials are basically unsuitable as construction materials because of its properties. But polymers also possess a great deal of positive characteristics that more traditional construction materials do not have; low specific weight, excellent formability and resistance to water and various chemicals. To obtain satisfactory properties with the polymeric material so that it becomes beneficial to use in construction materials, it must be reinforced with armoring. In PMC it is common to use particles or fibers as reinforcement. The use of particles is advantageous when the goal is to increase compressive strength and E-modulus. The use of fibers increases the tensile strength in the fiber length direction. When use of fibers, the direction and orientation of the fiber is essential for the composite characteristics. Among other things, the composite can be manipulated to be flexible and tolerate bending in one direction, while it is completely rigid in a different direction.

[4] [5]

10.4 TRELLEBORG OFFSHORE NORWAY

In addition to the knowledge of polymer materials from written documents, OLC got a meeting with Svein Gabrielsen, Design and Engineering Manager at Trelleborg Offshore Norway in Krokstadelva, on 18th of April 2016. Trelleborg is a world leading company in polymer solutions, and their factory in Krokstadelva is one of few factories, and the largest factory, producing polymer materials in Norway. Trelleborg in Krokstadelva focuses only on elastomer materials in various fields, including offshore industry and subsea equipment. Svein Gabrielsen is therefore qualified to comment and give feedback on material properties and recommendations regarding material selection towards the proposed design of lifting mat for lifting of pipes offshore.

Svein Gabrielsen was positive to the idea of using a rubber mat for securing the lifting equipment during a lift to prevent sliding of the equipment on the pipe. Rubber is already in use in different areas of the offshore and subsea industry. Among others, rubber is used to dress in and insulate pipes subsea, as entries in clamps to prevent among others things, slippage on pipes when lifting, and as anti-slip mats with high friction and fire safety to prevent accidents on platforms offshore. As Svein Gabrielsen explained, rubber materials can be manipulated to support the criteria needed to fulfill the requirements of the product in the project and to ensure that the mat will not slip on the pipe during a lift offshore. It is a big possibility that the design and concept will work, but it will require a study of the appropriate composition of materials along with thorough testing of the mat friction against steel pipes under harsh conditions that simulate realistic stresses offshore.

10.5 MAT MATERIAL STRUCTURE

Based on the knowledge in polymer materials and composite structure, and given information from Svein Gabrielsen at Trelleborg Offshore Norway, OLC now have a recommendation for the structure of the mat.

The mat must withstand various challenges related to the environment, the handling of the

equipment and its expected properties connected to the work it shall do. A uniform mat with one type of rubber will not be enough to satisfy the criteria for the product. The mat must be layered with different types of rubber materials and reinforced with fibers to resist abrasion from the lifting equipment (chains and/or wires).

The underside of the mat must consist of a high friction soft rubber material that will prevent slippage of the system on the pipe. The whole surface of the mat will be in contact with the pipe, and will help the system prevent sliding. But extra force on the mat will only be added to a smaller surface area of the mat; underneath the ratchet tie-downs that tightens the mat to the pipe, and under the lifting equipment itself. This means that the chosen materials must be certain to maintain the friction needed to prevent slippage on the confined surface area of the mat.

The topside of the mat must consist of a tougher and stiffer material, to withstand abrasion due to environment, handling and components used on the mat. The stiffness in the material on the topside of the mat will also help keeping the mat in place, preventing excessive expansion of the mat during use of the mat.

Reinforcement of the mat is needed in the area where the lifting equipment will be connected to the mat. The lifting equipment will be mounted on the mat in retrospect, incurring varying forces and wear on the mat depending on the type of lifting equipment used and the weight of the pipes to be lifted. This provides a vulnerable surface area on the mat, which will need reinforcement to prevent abrasion, tearing and destruction after use.

10.4.1 BOTTOM LAYER OF MAT

The most important characteristics needed in the bottom layer of the mat, is high and good frictional properties. To achieve this it is necessary to have a softer elastomer material. After advice from Trelleborg it would be appropriate to use elastomer in hardness grade 60 sh A. This will secure the material to be soft enough to achieve high frictional properties against steel when tightened to the pipe. It will also make the mat flexible and easily wrapped around the pipe.

A material that might be suitable for these requirements is Chloroprene. This is a good material for outdoor applications with good resistance to diverse weather conditions and it has good adhesion against steel.

[12]

10.4.2 TOP LAYER OF MAT

In the top layer of the mat the most important factors are resistance to abrasion and weather conditions. This layer must be stiffer than the bottom layer to stiffen the mat so that it is easier to handle. The top side must be tough enough to withstand abrasion from the environment, including the lifting equipment to be used on the mat. An elastomer material in hardness grade 75 sh A should be able to provide the necessary stiffness to the mat.

A material that is suitable for the criteria of the top layer is EPDM sheeting. This is a polymer with excellent properties for outdoor applications. It can withstand extreme external conditions and has a wide temperature range of use. By using a material such as this, the mat will resist influences from the environment and protect the properties of the bottom layer of the mat standing against the pipe.

[13]

10.4.3 REINFORCEMENT OF MAT

The mat must withstand a lot of abrasion and forces exerted by the lifting equipment. By using a chain to perform the lift, the wear on the mat will be uneven, depending on where the various links of the chain will hit, tighten and rodent the mat. It is important that the mat is reinforced in the area where the chain will be tightened to the mat. It is advisable to use thin steel wire being placed in +45 / -45 layer between the elastomer layers. The reinforcement with steel wires will strengthen the mat in the needed area and make the mat more resistant to abrasion and tearing. The flexibility of the mat is maintained by adding the steel wires as suggested, giving the mat the possibility to be wrapped around the pipe.

10.6 FRICTION TEST OF RUBBER AGAINST STEEL

During the tests of OLC's product and solution of lifting equipment, friction test of a rubber material against steel was performed. There was used a vulcanized rubber sheet in grade 70 sh A, with measurements 700 x 500 x 4 mm. This rubber sheet was wrapped around a capped steel pipe with diameter 260 mm and a weight of ~50 kg.

The rubber sheet used in this test was not specially designed for the product, and the steel pipe was under dimensioned compared to realistic pipes to be lifted. The intention with the test was only to control how the mat would react under harsh conditions in a vertical lift. The mat was installed on the pipe using two ratchet tie-downs with a 20 cm distance to each other. There was drilled two holes at the top of the mat to be able to lift the mat and pipe vertically by the use of a chain connected to a crane. The only thing lifting the steel pipe was the friction and contact between the mat and the pipe.

OLC conducted the test three times with three different measures: dry, wet and oily. There was rubbed water and oil into the mat and onto the steel pipe for the second and third attempt. When lifting by crane, harsh conditions was simulated by letting the crane hoist and shake the mat continuously during lifting. It was interesting and encouraging to see that whatever OLC did, the mat would not drop the steel pipe. There was no change in the positioning of the mat on the pipe before and after the tests.

Even though this test was in a small scale, OLC believe that it gives an indication on the possibility and realistic opportunity of using this type of solution for securing and preventing sliding of lifting equipment when lifting pipes offshore. More test should be carried out with properly fitted composition of materials in the mat together with pipes in the correct dimensions and weight.

The different tests conducted in the project is further described in “**Test report**”

10.7 MAT MATERIAL CONCLUSION

The material construction of the mat will be a decisive factor in whether or not the mat will be able to maintain the requirements set for the lifting equipment. The lifting mat needs to be light enough to be carried by hand and flexible enough to be wrapped around a pipe. It must also withstand wear and tear of the lifting equipment and the environmental influences.

OLC recommend the use of elastomeric materials with a structure designed to deal with the specifications set for the product. The mat will be divided in layers:

- A bottom layer in direct contact with the pipe to be lifted will consist of a softer and flexible elastomer to maximize the coefficient of friction.
- A top layer in a stiffer elastomer material more resistant to external influences.
- Reinforcement through steel wires in the mat to increase the resistance of wear and tear in those areas in direct contact with the lifting equipment.

Recommendation for future work will be to run demanding friction tests with an optimally matched and designed mat, to confirm that the equipment will in fact withstand the stress and forced it will be exposed to when performing an offshore and off-board lift.

11. TIGHTENING MECHANISM

The tightening mechanism is something OLC have been working on for quite some time. There have been many creative and good ideas when it comes to tightening the chain. The final design and solution landed on the wire drum tensioner.

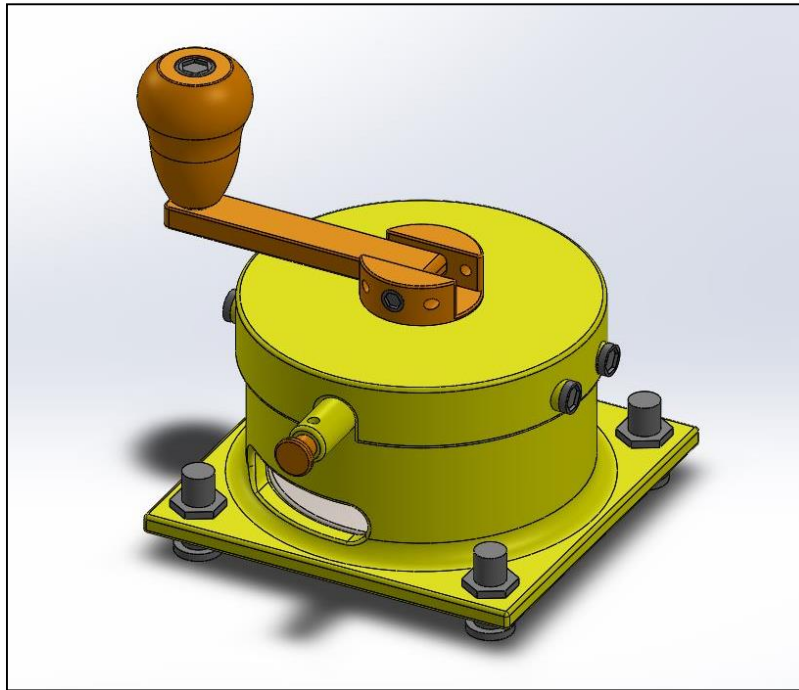


FIGURE 49: Tightening mechanism final design

11.1 WIRE DRUM TENSIONER DESCRIPTION

The tightening mechanism consist of several different parts made in different alloys of steel. Further details concerning the choice of materials are described in the FEM analysis found later in the report.

The tightening mechanism is bolted onto a rubber pocket that sits on the middle of the mat.

The purpose of the tightening mechanism is to tighten the double wrapped basket hitch in a sufficient way, so that the sling already has tension before the lift is performed. This is achieved by turning a hand crank, winding up two wire ropes. The wire ropes are in one end fastened to the same shaft. To prevent the wires from tangling, they are separated with a disc that are fitted in the frame.

In the other end of the wire, they are connected to the chain sling, each with a hook on both sides of the pipe.

The shaft has a gear on it that acts with a special shaped bolt. The gear has its teeth shaped so that the bolt easily slides over its teeth, turning the gear in one direction. However, the gear will not turn the opposite direction since the teeth then face a flat surface on the bolt, forcing the bolt to interlock with the gear.

The bolt sits in the frame wall of the tightening mechanism. It has a spring on the inside of the wall so that it will interlock with the gear as the tightening occurs. On the other end of the bolt on the outside of the wall there is a knob which by pulling out easily releases the wire ropes.

A hole is made through the bolt and frame to fit a safety pin. The requirement stating the need of double barriers, demands that the equipment has an extra safety barrier. By implementing a safety pin the requirement is fulfilled. If the spring should break, the bolt will still be interlocked with the gear.

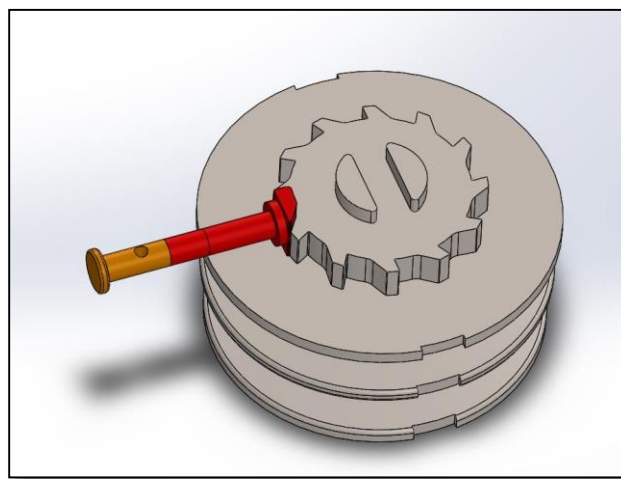


FIGURE 50: Gear interlocking with bolt

The hand crank is fastened to the shaft using a bolt that goes across the shaft. This enables the crank to fold down when it is not in use. A safety pin is also installed here, going through both the shaft and the crank. This is to prevent the crank from moving back and forth.

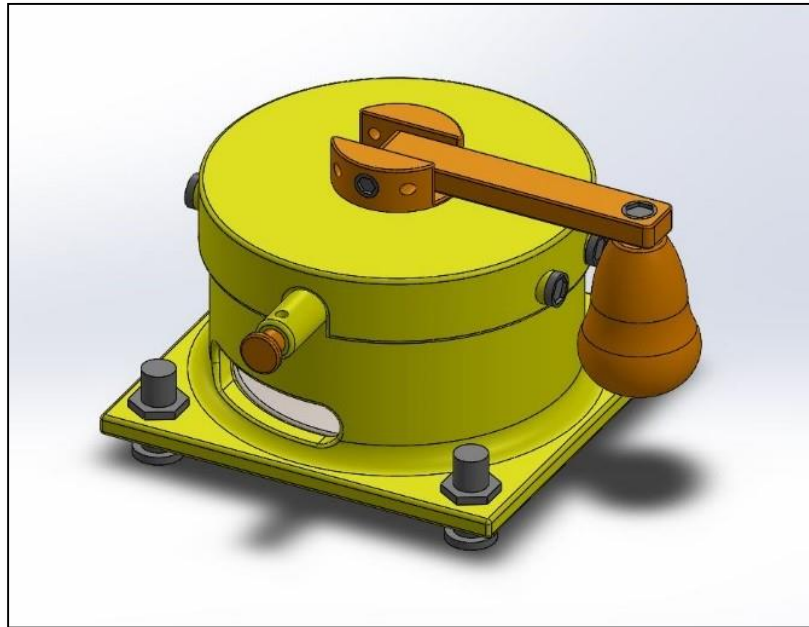


FIGURE 51: Hand crank not in use

11.2 WIRE DRUM TENSIONER INSTRUCTION FOR USE

When using the wire drum tensioner, the first thing that must be done is to remove two safety pins. Instructions of use is as followed:

1. Pull out the safety pin for the hand crank, tilt it up and put the safety pin the other hole in the shaft preventing the crank from tilting back.
2. Remove the safety pin from the locking bolt and place this one in the hole where the first safety pin originally was.

3. Pull out the locking bolt and hold it there. At the same time, turn the hand crank in the anti-clockwise direction to let out some slack of the wire rope. The locking bolt can then be released, and it will again interlock with the gear.
4. Fasten the two chain hooks onto the chain. (How to fasten the hooks will be further explained later in the report.)
5. Start tightening by turning the crank in the clockwise direction. (There is no need to pull out the locking bolt, this because of the shape of the bolt in addition to the spring used.)
6. Turn the crank until the chain is tightened firmly.
7. Put the two safety pins back to where they belong. Starting with the pin going thru the locking bolt, and then the other one for the down folded crank.
8. After the lift is performed repeat the process from the beginning. Removing the safety pins and putting them into the holes in the shaft having the crank in the upward position. Then simply pull out the locking bolt to release the tension.

11.3 CALCULATIONS CONCERNING THE TIGHTENING MECHANISM

The tightening mechanism from here on called: TM must satisfy the requirements:

“R5.1.4 Tightened to pipe

The lifting clamp shall be tightened in such a way that there is no danger of the clamp to slide after it has been mounted on the pipe.”

“R5.1.5 Force on tightening mechanism

If a tightening mechanism is chosen to tighten an existing lifting gear, the tightening mechanism must withstand an increase of applied force during lifting.”

It is carried out an analysis to see how much weight the TM must lift to hold the chain in the right position, and how much it should be tightened to overcome the friction between the chain against the mat. The TM will be placed on top of a pocket on the mat, which the middle chain will go through.



FIGURE 52: Hand crank not in use

The tightening wire shall be attached to hooks that are attached to the chain on the middle of the sides on the mat, as shown in Figure 52.

The analysis provides an indication of the size of the force, but it is important to take into account that not all the parameters are accurate. Several assumptions have been done, which will be described later.

11.4 KEEPING THE CHAIN IN POSITION

The weight of the chain is 3.8 kg per meter. The chain selected is to be used on a 16 " pipe and the length are and measures to be $> 319.17\text{cm}$, which is the minimum length for a chain used on a 16 " pipe (see “7.2.4 Chain sling” and “7.2.7 Calculations concerning the length of the chain”).

The first calculation to be done is for finding out how much weight of the chain that the TM must hold. The length of the chain that affects the TM is shown in Figure 53



FIGURE 53: The length of the chain that affects the TM

$$\frac{\text{Entire chain length} - 180^\circ \text{ on top of tube}}{2 \text{ length}} = \frac{319,17 - 127,67}{2} = 95.75 \text{ [cm]}$$

On each side of the TM the wire must pull with a force of 36 N just to keep the chain in the right position, as shown in the calculation below.

$$0,958 \text{ m} \cdot 3,8 \frac{\text{kg}}{\text{m}} = 3.65 \text{ kg} \cdot 9.81 \frac{\text{m}}{\text{s}^2} = 35,7 \text{ N} \approx 36 \text{ N}$$

These 36 N is just to keep the chain in position. To tighten the chain to its maximum, meaning how much tension it can tighten with before it starts to slip due to friction, is described below.

11.5 FRICTION AGAINST MAT

To find out how large the friction between the rubber mat and the chain is, there has been performed an analysis of how a massless rope passes over a cylindrical object. The rope is thought of as the chain, while the cylindrical object is imagined to be a pipe. The following analysis is performed with a double wrapped basket hitch.

As shown in Figure 54 it occurs a normal force that increases towards the top of the pipe and decreases on the way down. This means that the greatest normal force is at the top of the tube. This applies when the force $T_1 = T_2$. [14]

If one of the forces is larger than the other one, there will also occur a frictional force acting in the opposite direction of the largest force. As shown in Figure 55 when $T_1 < T_2$. [1]

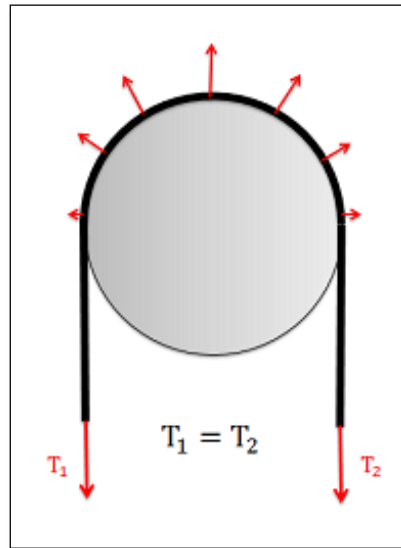


FIGURE 54: A normal force that increases towards the top of the pipe and decreases on the way down

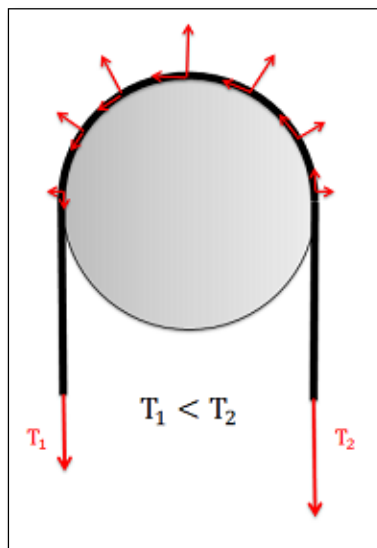


FIGURE 55: If one of the forces is larger than the other one, there will also occur a frictional force acting in the opposite direction of the largest force

In this analysis, Capstan Equation is used to calculate the belt friction. This equation explains how much force T_2 must have before the slip point is reached. The meaning of slip point is the force that must be applied before the chain starts to slip on the pipe. [14][15]

Capstan Equation:

$$T_{2MAX} = T_1 e^{\mu\beta}$$

β = Angle of contact in radians

μ = Coefficient of friction between surface and belt

e = Euler's constant [14][15]

It is assumed that the middle part at the top of the chain are to be restrained with a force of 36N. It is intended that only one wire end are tensioned at a time.

$$\beta = 4,71 \text{ rad}$$

$$1,5 \text{ round} / 2 \text{ TM} = 0,75 \text{ of a round} = 275^\circ = 4.71 \text{ rad.}$$

If the TM tightens in parallel on both sides, it will be tightening from the middle and around the pipe on each side. Each side of the TM will tighten 270° of the chain.

$$\mu = 0.64$$

Friction for rubber with a hardness of 60 against Stainless Steel 316. [16]



FIGURE 56: Calculating friction of the chain

$$T_1 = 36 \text{ N}$$

The force that keeps the weight of the chain in position.

$$T_{2MAX} = 36Ne^{(0.64 \cdot 4.71)} = 733.57 \text{ N}$$

$$\frac{733.57 \text{ N}}{9,81 \frac{m}{s^2}} = 74.78 \text{ Kg}$$

$$74.78 \text{ kg} \cdot 2.5 \text{ (safety factor)} = 186.9 \text{ kg} \approx 200 \text{ kg.}$$

When the chain is tensioned maximum (before it starts to slip around the tube), it must be tightened with a force of 733.57 N, on each side of the TM. If the TM tightens the chain sufficiently, the requirement “**R5.1.4 Tightened to pipe**” will be fulfilled. At least it will be fulfilled theoretically, this of course depends on the testing.

To meet the requirement “**R5.1.5 Force on tightening mechanism**” the safety factor of 2.5 is chosen. The TM shall not break when a higher load than usual is applied. It shall then withstand a load of 200kg.

In order to find the force needed for the entire chain to slip around the pipe the following calculation is done:

$$\beta = 9.425 \text{ rad } (540^\circ = 1,5 \text{ round})$$

$$T_{2\text{MAX}} = 36Ne^{(0.64 \cdot 9.425)} = 14996 \text{ N}$$

$$\frac{14996 \text{ N}}{9,81 \frac{\text{m}}{\text{s}^2}} = 1528,6 \text{ Kg}$$

The chain will move if a force greater than 1,528.6 kg is applied. This is the maximum force before slipping. This power is very high; it is due to the large angle and high friction coefficient.

Each wire connected to the TM must be tightened with a force of 733.57 N so the chain will be maximum tightened. If a wire should tighten more than the other, it must exceed 14 996 N + possible counterforce on the other end of the chain, to start sliding. At worst, this stress can damage the pocket that the chain is attached to.

An important factor to take into account during this analysis is the difference between a rope and a chain. The contact surface of a chain is less than the contact surface of a rope. By taking into account that the chain is wrapped around 1.5 times around a 16 " pipe, which corresponds to 1915mm contact surface, it consists of $\frac{1915\text{mm}}{65-13\text{mm}} = 36,8$ links.

Each link has a contact surface of 47 mm: $36,8 \text{ (link)} \cdot 47\text{mm (contact)} = 1729.6 \text{ mm}$ total contact surface.

$$\frac{1915\text{mm} - 1729.6\text{mm}}{1915\text{mm}} \cdot 100\% = 9,68 \%$$

Meaning that it is 9.68% less contact surface using chain instead of rope.

This means that it actually needs less tightening force to tighten the chain optimally, because the friction surface will be reduced.

12. CHAIN HOOK

The chain hook was a challenging product to design. At first, OLC thought about using either carabiner hooks or shackles to tighten the chain, however this was something FMC could not approve. It was then performed research about different hooks that was specially designed for hooking onto a chain. OLC got ideas for a hook when looking at a device called a shortening clutch, used for shortening in the length of a sling.

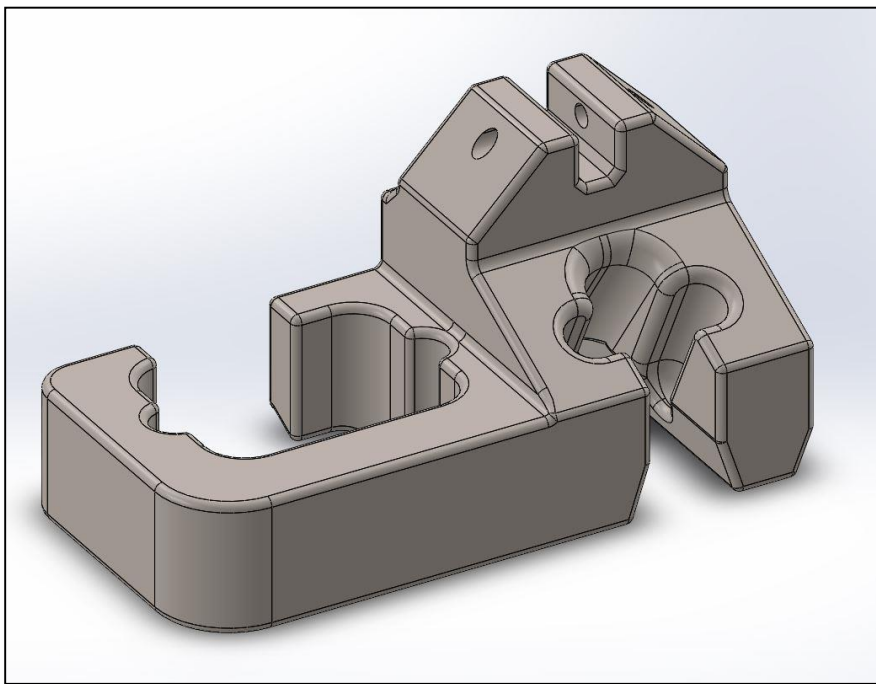


FIGURE 57: Chain hook final design

12.1 CHAIN HOOK DESCRIPTION

The chain hook is a hook made by alloy steel. The choice of material is further described in the FEM (Finite element method) analysis section, found later in the report.

The purpose of the chain hook is divided into two main purposes. The first purpose is to be able to hook onto the sling and tighten it with the help of the tightening mechanism keeping the chain firmly in place on the mat. The other purpose is to guide the angle of the sling when performing different lifts.

The chain hook fits perfectly with one of the links from the chain sling by the way it is shaped. On the left side of the hook, it has a bended claw shaped piece of steel in order for it to go over the chain that lies in the middle of the hitch. The hook has a “claw” going over the tightened middle chain to be able to use this as an anchor. Since the angle of the sling might be as high as 45° during a lift, the hook needs to be manipulated for controlling where the angle is going to start. Without this, the start point of the angle would occur at the bottom of the pipe instead of at the middle of the sides. The chance of the sling sliding off the mat and damaging the pipe will be higher if this is the case

.

The lifting clamp consist of two chain hooks, which both are connected to the tightening mechanism mounted on top of the mat. Although the two hooks have different kinds of stresses when performing a lift, OLC managed to come up with a design that withstands the exposed stresses. During a lift one of the hooks will receive strain while the other one will receive pressure, this will also be more described in the FEM analyses part.

12.2 CHAIN HOOK INSTRUCTION FOR USE

When tightening the chain before the lift, the tightening mechanism is used together with the two chain hooks.

1. The eyes of the chain hooks, seen on the top of the hook are attached to the tightening mechanism with a wire rope that is kept in place with a bolt. The wire is loosened and the hooks are lowered down to the middle of the pipe on each side.
2. The two hooks are then hooked onto the “outer chain” on each side of the pipe while the “claw” goes over the chain in the middle. With “outer chain”, this means the end chains that are coming up on each side of the pipe.
3. The tightening mechanism is then tightened which makes the wire rope to tighten, pulling the chain hooks up alongside the pipe. This again makes the chain hitch become securely tightened before the lift is to be performed.

13. FEM ANALYSIS RESULTS

While working on designing the tightening mechanism and chain hook for the lifting equipment, it is crucial that tests are performed to ensure that the mechanism can withstand the forces applied during work. OLC have performed tests on the design using Finite Element Method (FEM), a simulation tool in SolidWorks that simulates the forces applied and analyses the results on a designed 3D model and analyses the results.

13.1 MATERIAL SELECTION

Both the tightening mechanism and the chain hook will be produced mainly in steel. Steel is a well known and used material for constructional purpose, and is an alloy from iron. The most common name of steel is alloy steel. Alloy steel is an umbrella term for carbon steel, which are carbon steel combined with one or several alloying elements. Pure metals are often quite soft, but by adding alloying elements you can reinforce the carbon steel and both enhance and provide the desired properties in the metal. For steel in use offshore for lifting equipment, it is important to have high mechanical properties in areas such as yield strength, fatigue and resistance against corrosion and wear.

[42]

13.1.1 MATERIAL FOR ANALYSIS IN SOLIDWORKS

To simplify the analysis done in SolidWorks, OLC have chosen to run the tests of both the tightening mechanism and the chain hook in the material Alloy Steel, pre-defined in SolidWorks:

Property	Value	Units
Elastic Modulus	210000	N/mm ²
Poisson's Ratio	0.28	N/A
Shear Modulus	79000	N/mm ²
Mass Density	7700	kg/m ³
Tensile Strength	723.83	N/mm ²
Compressive Strength		N/mm ²
Yield Strength	620.42	N/mm ²
Thermal Expansion Coefficient	1.3e-005	/K
Thermal Conductivity	50	W/(m·K)
Specific Heat	460	J/(kg·K)
Material Damping Ratio		N/A

TABLE 15: Material data sheet SolidWorks

These settings will not give completely accurate results since the realistic material properties may vary from the pre-defined values of alloy steel in SolidWorks. Still, they will give an approximate result based on average values for steel, which in turn will give a good indication of how the design of both the tightening mechanism and the hook will work in real life.

13.2 TM ANALYSIS

The functionality of the tightening mechanism is to tighten the chain.

The TM shall continuously hold the chain in tension keeping the chain firmly in place before and after the lift. In to have a goal to work towards, OLC asked themselves the following question: *Will the tightening mechanism be able to withstand the forces it is exposed for and will it work in reality?* This helped OLC to have an objective they needed to complete.

13.2.1 TM CONSTRUCTION

The TM is designed so that the persons who use it easily can get familiar with the procedures. As previously mentioned there is a crank with a handle on top of the TM. When turning the crank the wires will either unwind or wind in depending on the direction it is turned. At the end of the wires there is a hook attached. As the wires are collected on a shaft located inside the TM, the tension in the wires increases.

The locking mechanism is based on a locking bolt that interlocks with a gear inside the TM.

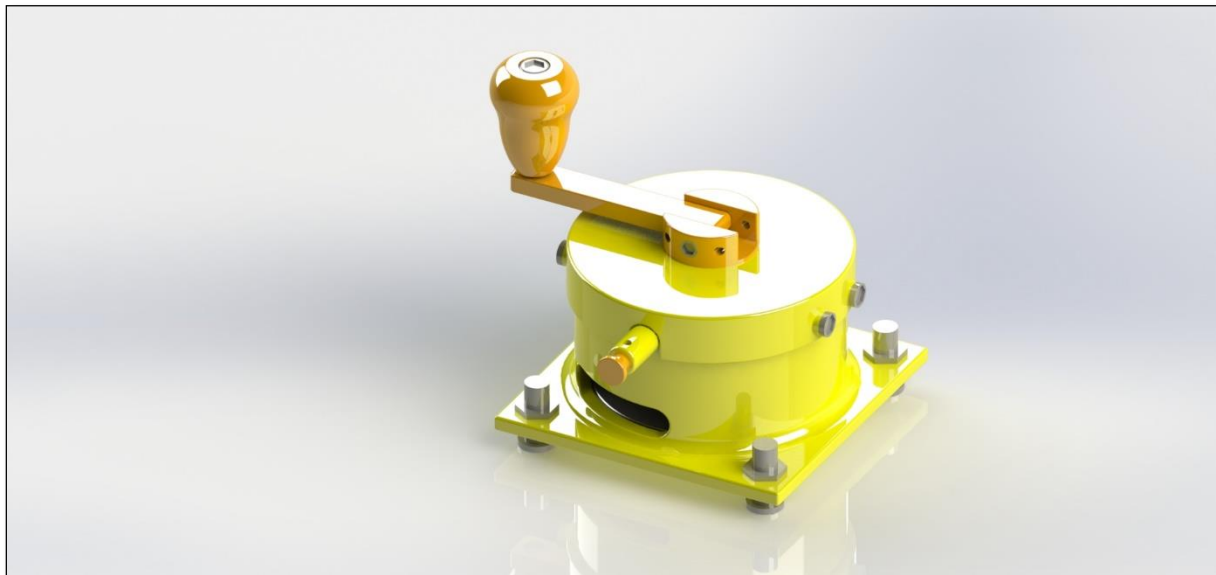


FIGURE 58: Tightening Mechanism

13.2.2 FORCES THAT OCCUR ON THE TM

The TM will be exposed to two main stresses: Torsion and pressure. The TM with its parts must withstand these forces.

When the TM is tightened, the pressure occurs in the holes in the shaft where the wires are connected. The torsion occurs on the locking bolt because of the forces it receives from the interlocking gear.

The force needed for tightening the chain with the TM is explained at “**11.5 Friction against mat**”.

The pressure is applied at the holes in the shaft. Each of the wires creates a pressure force that works in separate directions. With an added safety factor of 2,5 the force is at:

$$200\text{kg} * 9.81 \text{ m/s}^2 = 1962\text{N}$$

working on each side of the shaft. These forces will in reality act like torsion forces, which is applied in the analysis. The illustration seen below is included simply for understanding the mechanism of what is happening.

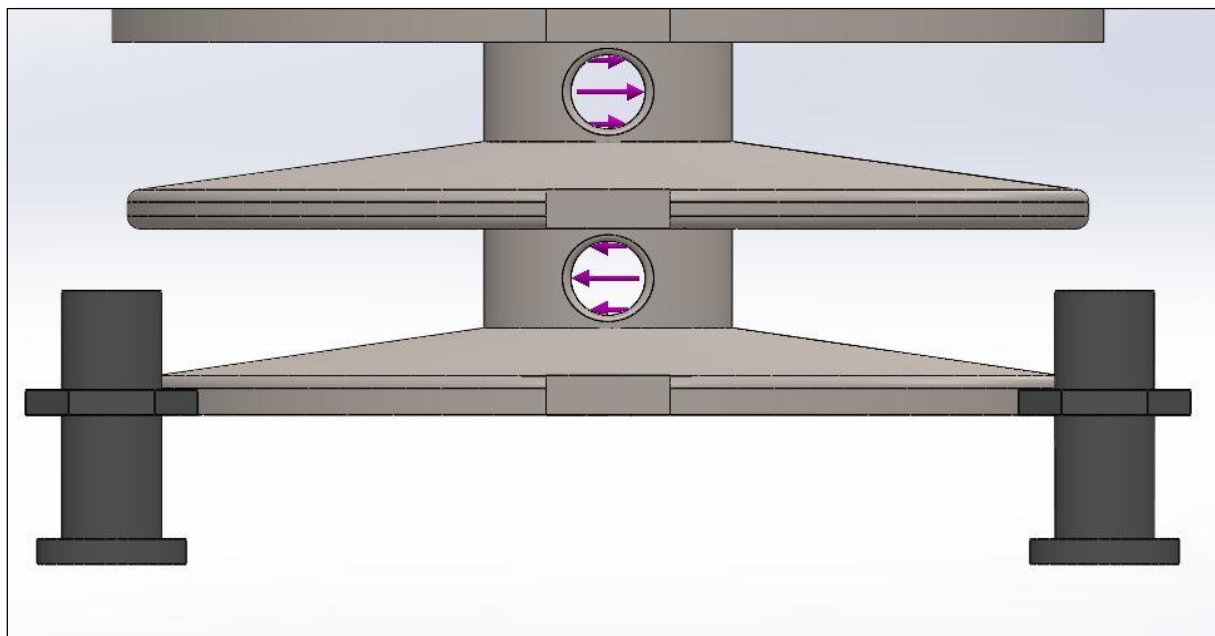


FIGURE 59: Pressure forces acting on each of the holes in the shaft, seen in a cross sectional view

When it comes to the total amount of force acting on the shaft, this will affect the gear with a torsion force. These forces are the total amount of force acting on the shaft added together:

$$1962\text{N} + 1962\text{N} = 3924\text{N}.$$

The torsion acting on the locking bolt from the gear is calculated by finding the momentum that the gear receives from the wires that winds up on the shaft. The radius from the shaft and up to the inner wall of the frame is 37,5 mm. Since this is the maximum width that the wires can achieve, this is this what OLC have used in their calculation. The torsion is calculated as follows:

$$3924\text{N} \cdot (37,5 \cdot 10^{-3}\text{m}) = 147,15\text{Nm} \approx 150\text{Nm}.$$

This force is applied on the gear in the direction where the teeth of the gears stops against the locking bolt. More specifically in the anti-clockwise direction. More figures are to be found in the appendix.

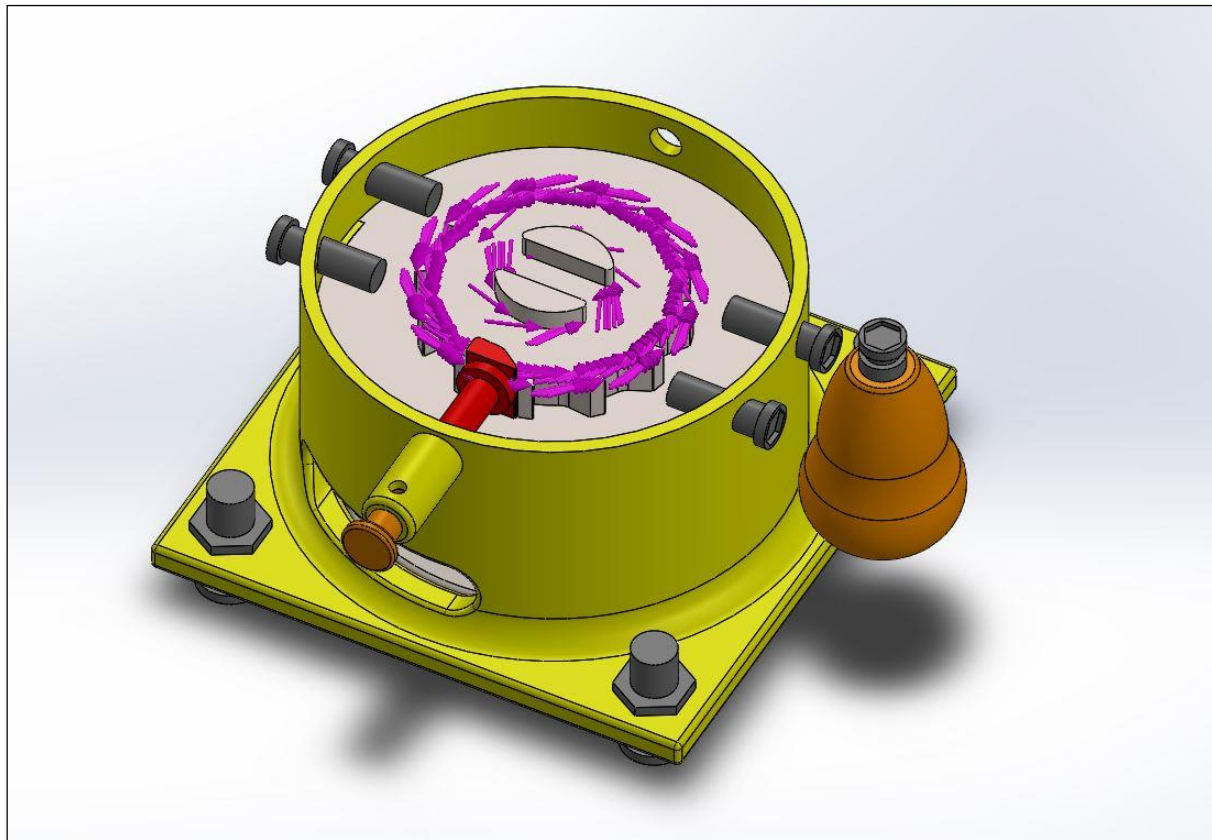


FIGURE 60: Torsion forces acting on the gear

13.2.3 FIXTURES

A fixture is applied on each of the M8 bolts located at the bottom of the frame. This is fixed points where the bolts keeps the TM fastened on the top pocket of the mat. The reason for why there are no other fixtures is because OLC have made use of another method. This method is based on using a function in FEM called no penetration. This means that the moving parts are not allowed to move into the other parts. The remaining parts have been selected a global contact surface. By doing this the analysis becomes easier to perform. More details concerning no penetration are to be found in the appendix.

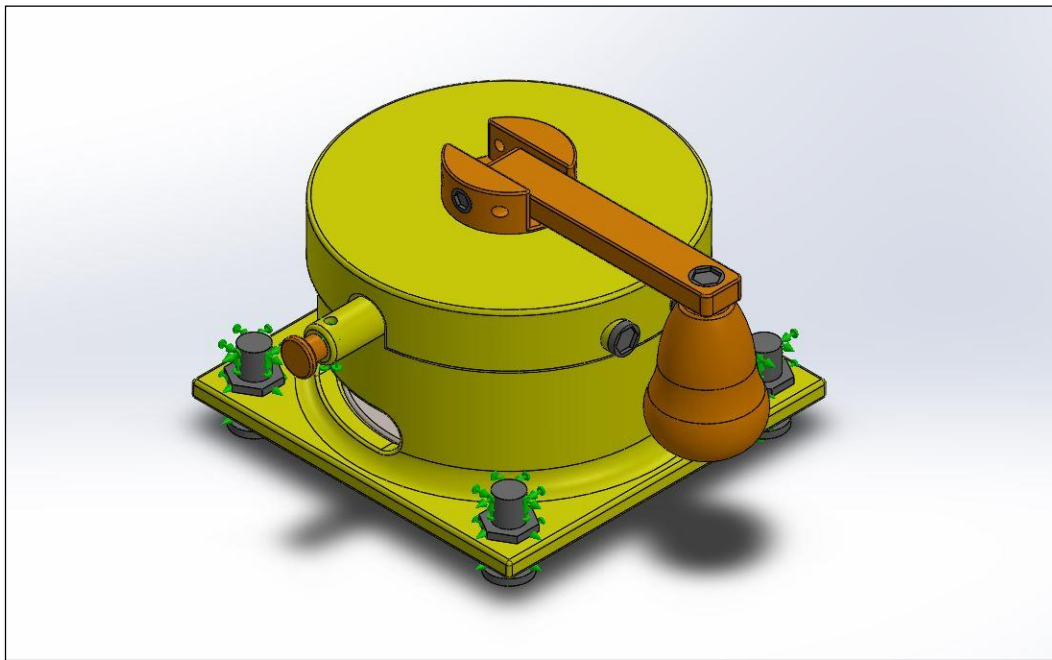


FIGURE 61: All the M8 bolts are applied fixtures

13.2.4 ANALYSIS OF THE TIGHTENING MECHANISM

After applying the materials to the TM and placing all the fixtures and forces needed, it is now ready for analyzing.

To achieve the correct simulations and results it is important to have an aspect ratio with a value lower than five in the areas that receive a high load. Having the correct mesh takes care of this.

13.2.5 MESH CONTROL

A global size of 1,0mm and a tolerance of 0,05mm is used on the entire TM. To achieve an even higher accuracy mesh control has been used on the areas where the stresses are the highest. At these areas an element size of 0.7mm and a ratio of 1,5 is used.

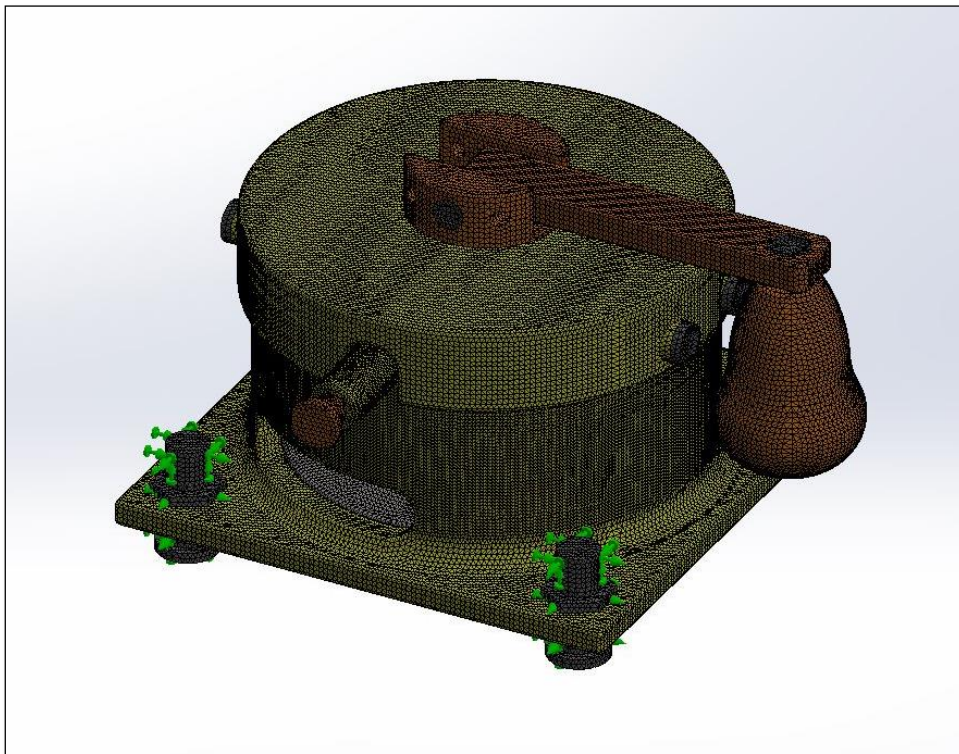


FIGURE 62: The mesh of the tightening mechanism

Mesh Details	
Study name	Static 1 (-Default-)
Mesh type	Solid Mesh
Mesher Used	Standard mesh
Automatic Transition	Off
Include Mesh Auto Loops	Off
Jacobian points	4 points
Mesh Control	Defined
Element size	1 mm
Tolerance	0.05 mm
Mesh quality	High
Total nodes	3140071
Total elements	2188456
Maximum Aspect Ratio	31.075
Percentage of elements with Aspect Ratio < 3	99.4
Percentage of elements with Aspect Ratio > 10	0.00105
% of distorted elements (Jacobian)	0
Remesh failed parts with incompatible mesh	Off
Time to complete mesh(hh:mm:ss)	00:04:40
Computer name	

TABLE 16: Mesh details TM analysis

13.2.6 ASPECT RATIO

To get good results which are to be trusted, testing of the aspect ratio needs to be done. Having an aspect ratio lower than five on the areas with the most stress are preferable. Some plots were selected with a probe to find out what the stresses are at certain points. Through this process the areas having the highest stresses were found.

Because OLC used a fine total mesh (global size 1,0mm) when doing the analysis, the results are positive.

As shown below the aspect ratio values are below five at the critical areas. The few areas having an aspect ratio above five are areas that does not affect the analysis in a negative way because of their low stresses. The Von Mises analysis that are to be performed later will not have any

problems. The area having the highest aspect ratio with a value of 31.07 is a small area that does not affect the final result. More figures concerning this is found in the appendix.

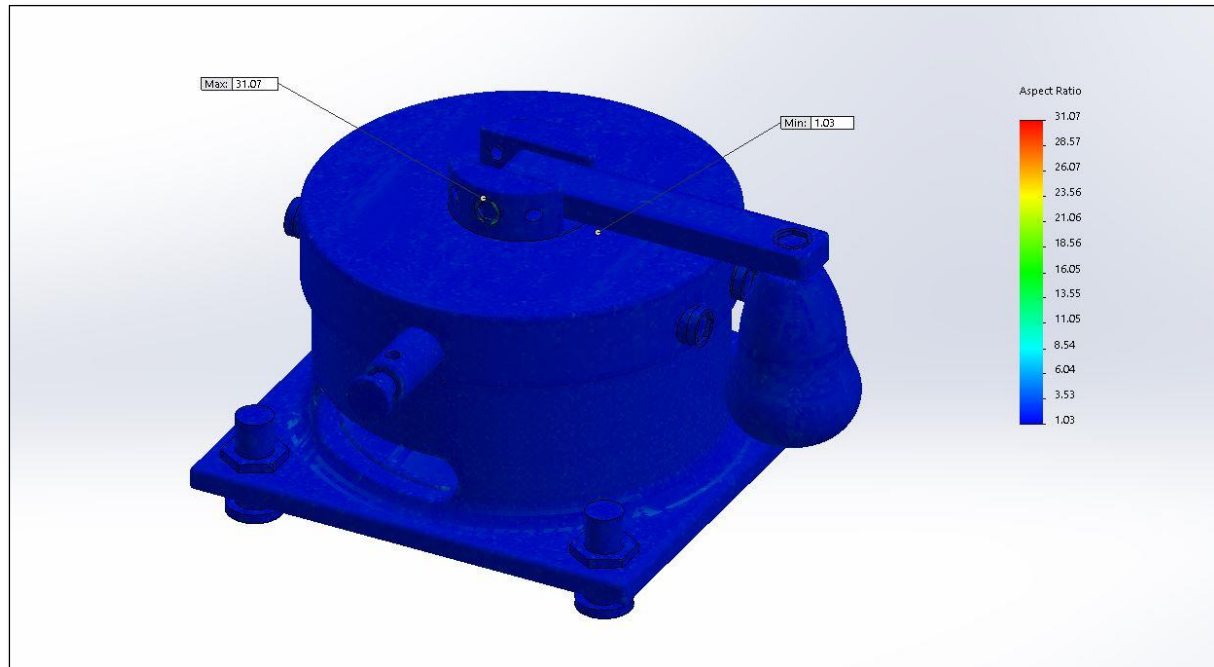


FIGURE 63: Aspect ratio results of the entire tightening mechanism

13.2.7 TM ANALYSIS RESULTS

The results from the Von Mises analysis confirms the correct dimension for the TM. The forces applied to the tightening mechanism was 2,5 higher than what the TM are expected to receive during normal use. This is done in order to have a safety factor that satisfies FMC's requirements.

As previously mentioned the moving parts in the TM had a contact surface with no penetration, while the remaining parts had a so-called global contact surface.

Through simulations, test with FFE+ have been performed.

The values from the Von Mises analysis goes from 0 MPa and up to 104,58 MPa. This is great results, having values way below the yield strength of 620,42MPa.

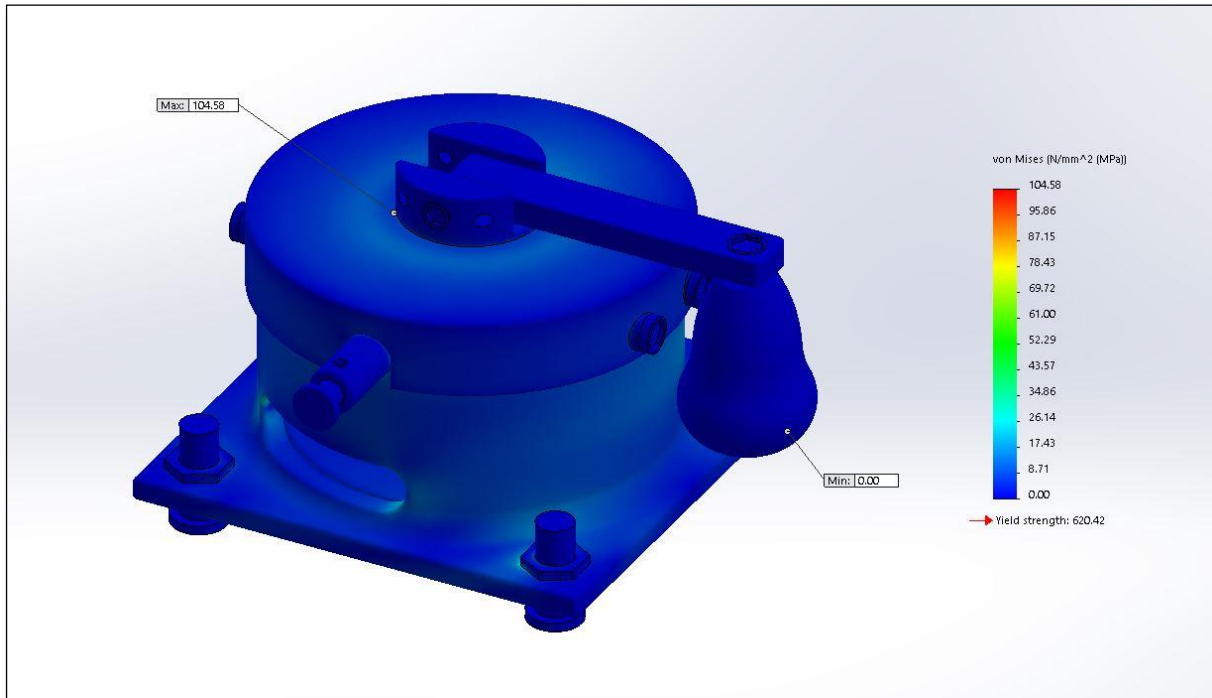


FIGURE 64: Von Mises values

The highest occurring stresses is mostly on the gear. The other stresses are located on the locking bolt and in the holes in the shaft. These other stresses have a stress value below half of the highest Von Mises values. See the appendix for more figures concerning the stresses applied on the TM.

OLC can conclude that the tightening mechanism is a product that is successfully designed and that it can perform its task in reality without failing.

13.3 CHAIN HOOK ANALYSIS

The FEM analysis have been performed using data from FMC's existing lifting clamp. The project is based on a lifting clamp with a SWL of 4100 kg designed to lift pipes with a 16" diameter. Since it is acquired to use two clamps when lifting a pipe having a total SWL of 8200kg, the pipes used as weight in the test has a simulated weight of 8200 kg.

As previously mentioned the purposes of the hook is to tighten the chain and to guide the sling angle.

In order to have a goal to work towards, OLC asked themselves the following question: *Will the hook be able to withstand the forces it is exposed for and will it work in reality?* This helped OLC to have an objective they needed to complete.

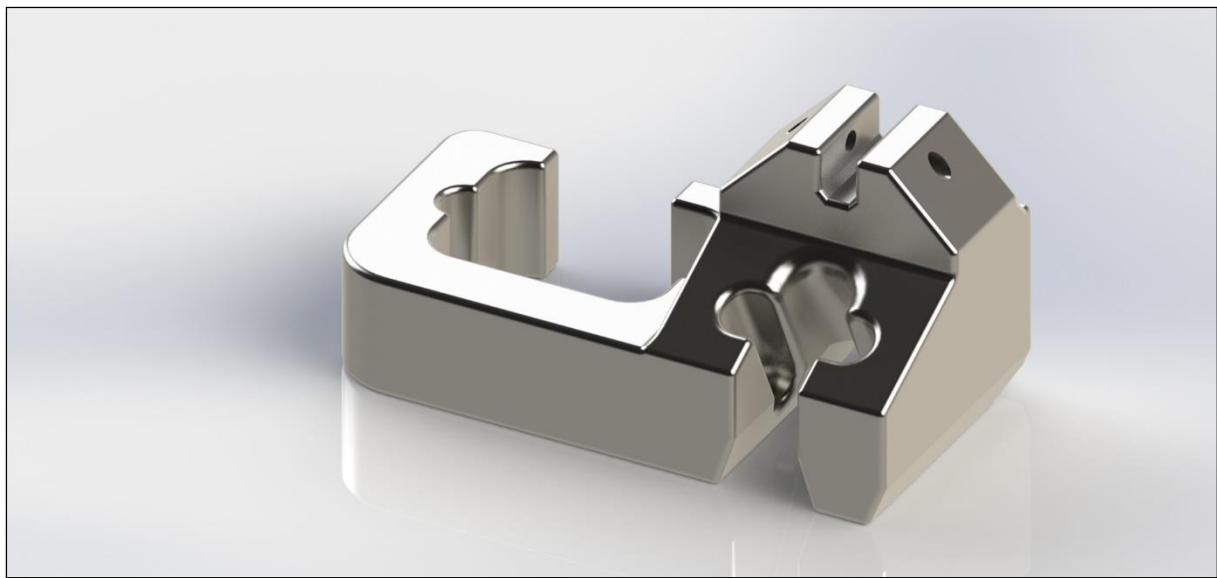


FIGURE 65: Chain hook

13.3.1 CHAIN HOOK CONSTRUCTION

The hook is exposed to high forces, both strain and pressure. It is important that the hook can withstand the forces that occur during normal use, in addition it needs to be able to withstand 2,5 times more than the normal forces for it to have a sufficient safety factor. The construction of the hook must be so that it fits a chain size of 13 mm. The chain that OLC have decided to use after thorough research is a short link chain with a grade 8. [43]

When the construction of the chain hook was created, OLC used reasonable lengths and widths so that it would not interfere with other objects such as the rubber pockets nor the ratchet tie-downs that already was on the mat.

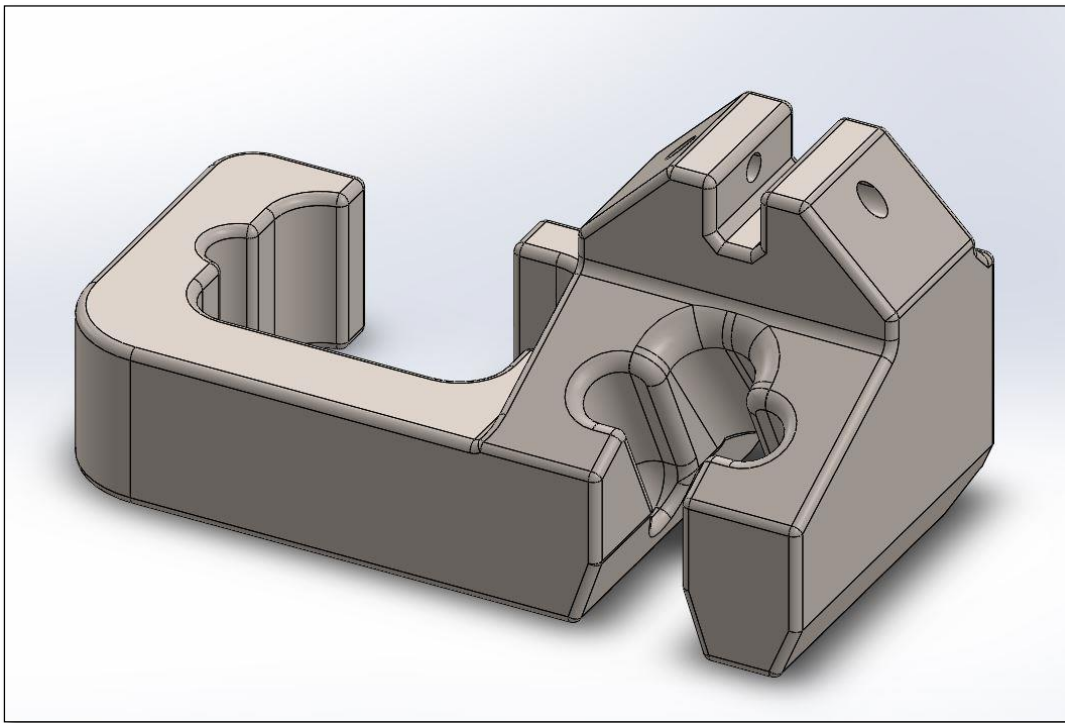


FIGURE 66: Chain Hook

13.3.2 FORCES THAT OCCUR ON THE CHAIN HOOK DURING A LIFT

The chain hook is exposed to different forces, depending on where the hook is placed.

When lifting a pipe there are always used two lifting clamps. Each lifting clamp has two chain hooks, one for each side of the pipe. The total amount of chain hooks is four, the same amount as the number of loose chain ends after making the correct hitches. The point of where the crane hook will be is a bit above the middle of the pipe. The hooks will therefore receive different forces of strain and pressure, because the sling angles from both the clamps will go towards the crane hook in the middle. The location of the four chain hooks are shown in the figure below.



FIGURE 67: Chain hooks seen from above

13.3.3 STRAIN SCENARIO

The chain hook is being exposed to strain both in the vertical direction and the horizontal direction. The forces working in the vertical direction is the forces from the tightening mechanism working in the eye of the chain hook. There is also a counterforce from the link of the chain that the chain hook is hooked onto.

The forces working in the horizontal direction is from the lift itself, where the chain sling tries to pull the chain hook sideways. But since the chain hooked is anchored in the middle-chain the forces occur in the grooves where the one link from the chain sling is attached. The reason for why there are no forces working in the vertical direction when the lift occurs creating an angle of 45° is because it is the chain sling itself that takes over these forces.

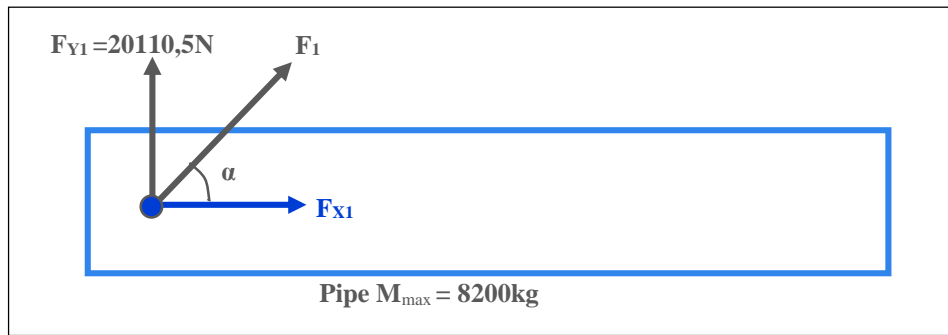


FIGURE 68: Forces acting on the chain hook when performing a lift at 45 °

For further explanations of the forces, OLC have performed some calculations.

The acceleration of gravity is used $g = 9.81 \text{ m/s}^2$.

As already mentioned on clamp has a SWL of 4100 kg and one pipe weighs 8200 kg. To convert the weight of the pipe from kg to newton the following calculation have been done:

$$8200\text{kg} * 9,81\text{m/s}^2 = 80442\text{N}.$$

This force divided on four chain hooks equals a force of 20110,5N in the vertical direction.

The horizontal force on the chain hook is found by:

$$F_{Y1} = 20110,5\text{N}$$

$$F = \frac{F_{Y1}}{\sin \alpha} = \frac{20110,5\text{N}}{\sin 45} \approx 28440,54\text{N}$$

$$F_{X1} = F \cdot \cos 45 = \left(\frac{20110,5\text{N}}{\sin 45}\right) \cdot \cos 45 = 20110,5\text{N}$$

The horizontal force is the same as the vertical force. Since OLC need to have a hook that can take 2,5 times more, the force is multiplied with 2,5. In SolidWorks Simulation the force then becomes 50276,25N.

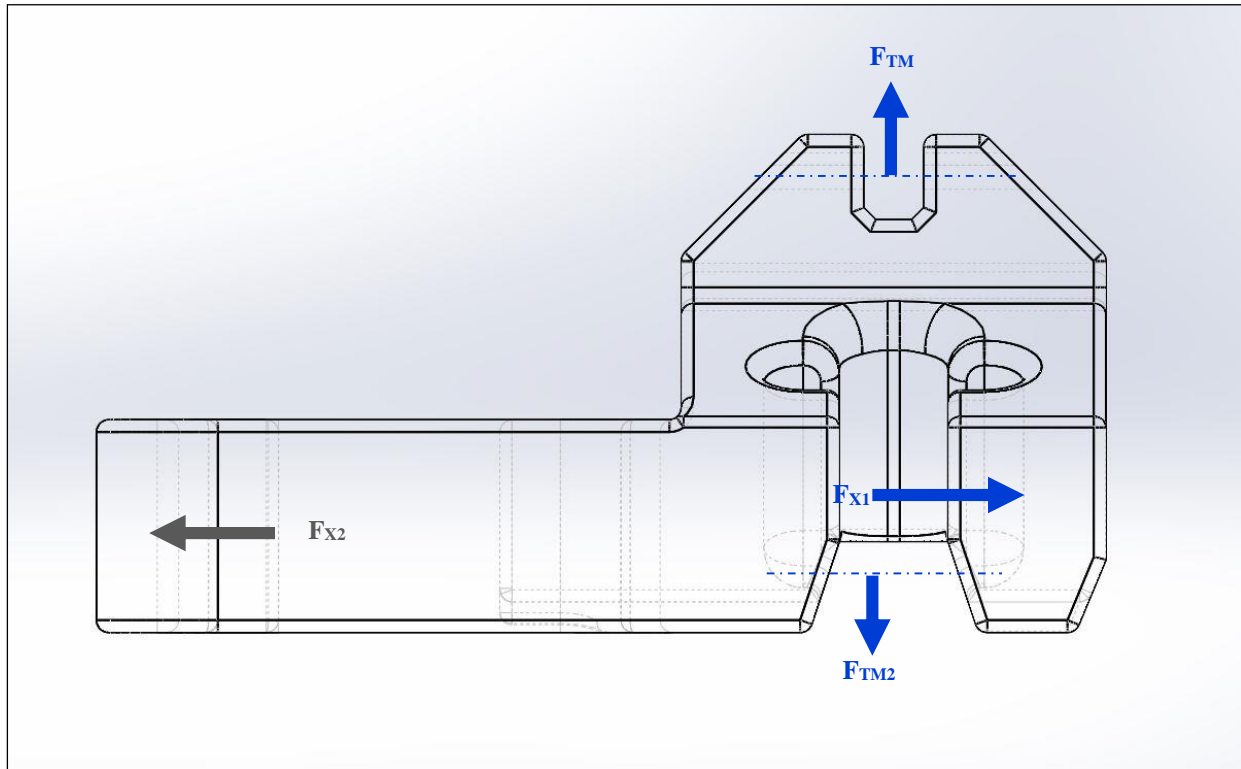


FIGURE 69: A closer look at forces occurring at a strain scenario. F_{X2} is where the link is placed and fixed in the arch. This is an counterforce to F_{X1}

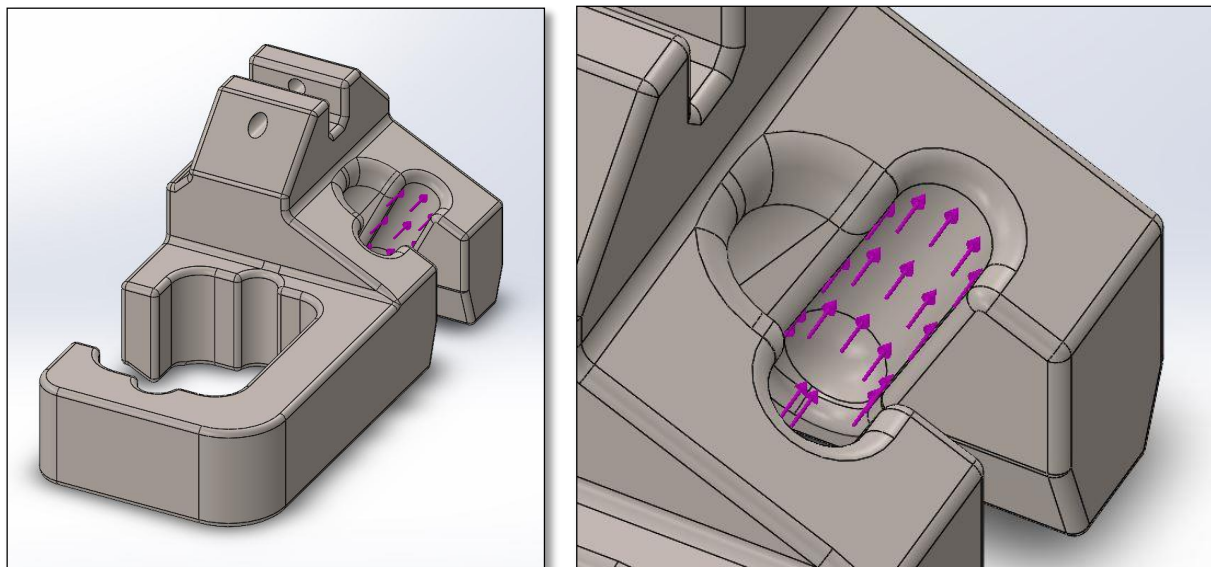


FIGURE 70: Horizontal forces applied on the chain hook

The vertical forces working on the chain hook is from the tightening mechanism during tightening of the chain before the lift. The forces from the tightening mechanism is 200 kg, equivalent to 1962N. Also here adding a safety factor of 2,5 the force that needs to be applied is corresponding to 4905N. The force is divided on two surfaces, placed inside the lifting eye. There is also a counterforce at the bottom of the grooves where the chain link is placed.

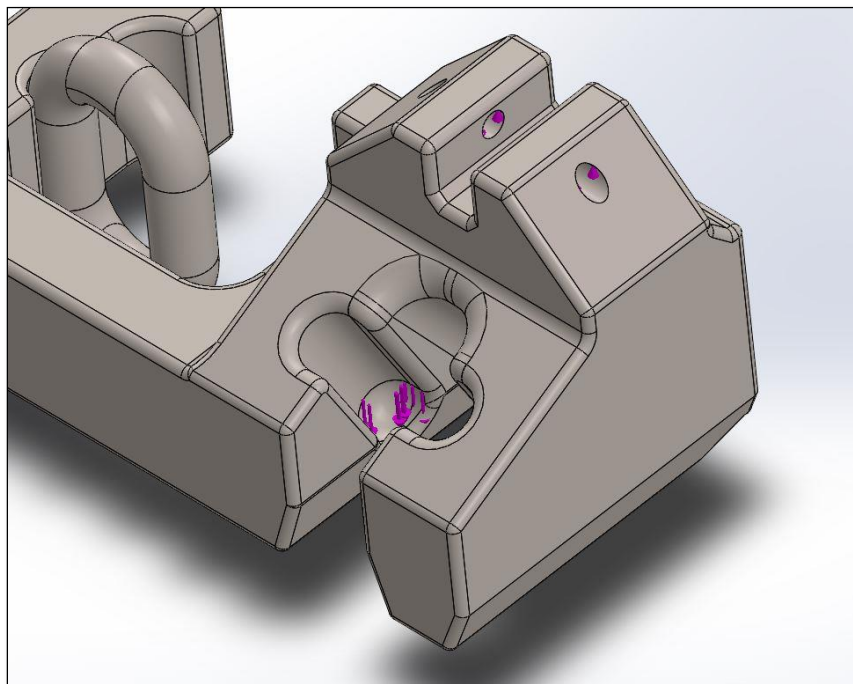


FIGURE 71: Vertical forces applied on the chain hook

13.3.4 PRESSURE SCENARIO

For the chain hook on the opposite side of the pipe the chain hook receives pressure when the lift is performed. The amount of force is equal to what the other hook was applied; 50276,25N. This force is applied in the grooves where the one link from the chain sling is attached, only this time it

is on the opposite wall. The vertical forces is the same as for the other chain hook caused by the tightening mechanism, 4905N with the included safety factor.

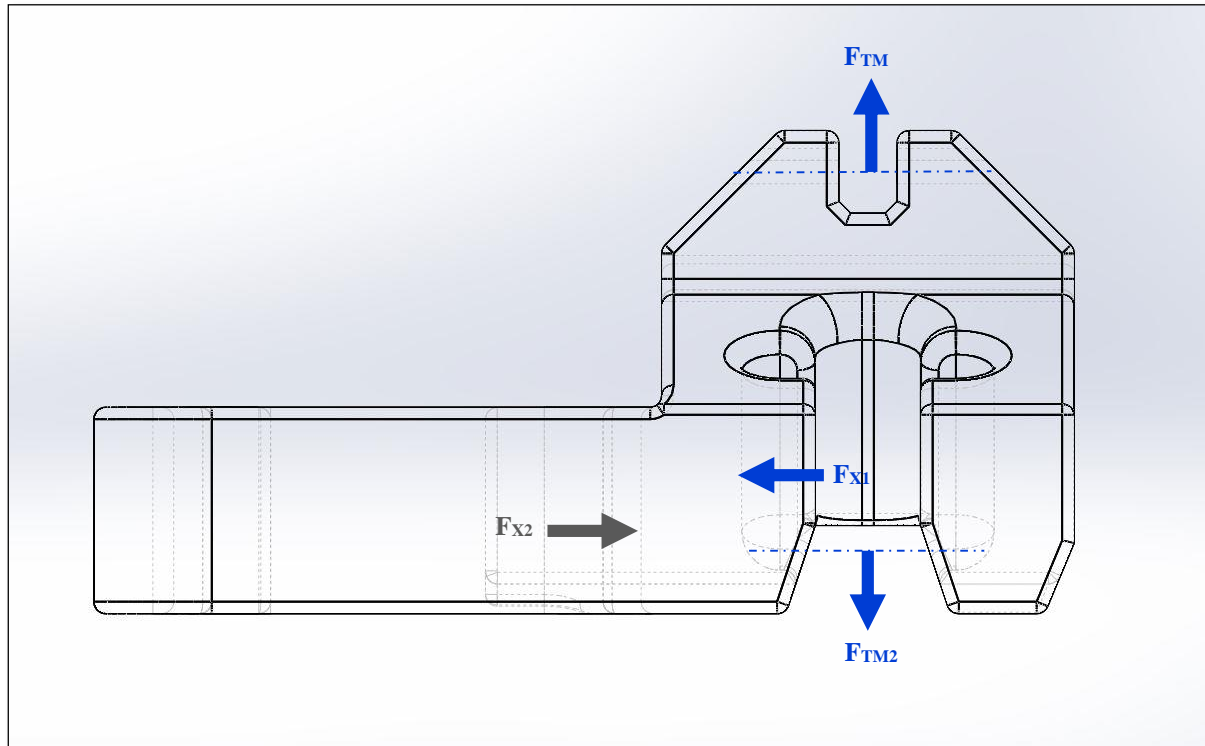


FIGURE 72: A closer look at forces occurring at a pressure scenario

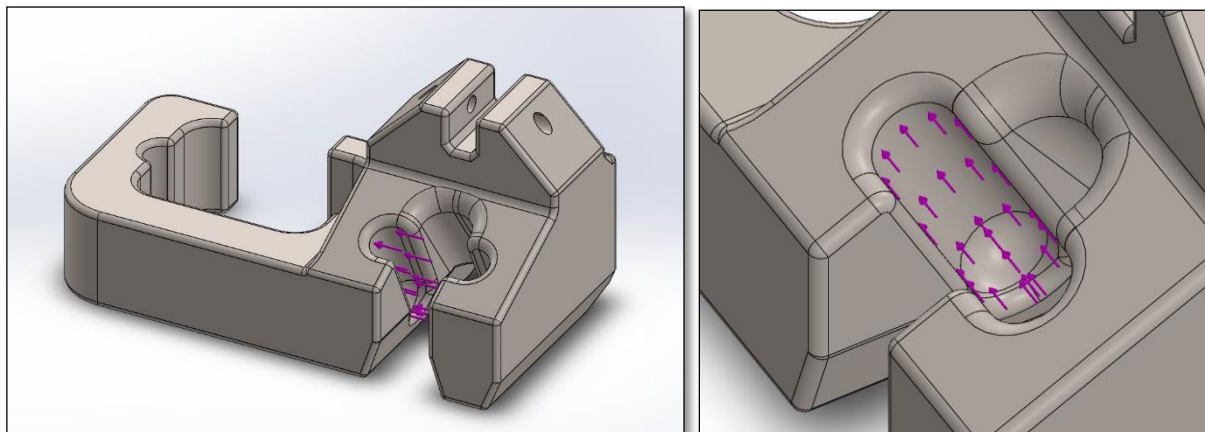


FIGURE 73: Horizontal forces applied on the chain hook on the other side of the pipe

13.3.5 FIXTURES (STRAIN SCENARIO)

On the chain hook the fixtures have been placed on a link from the middle-chain that lies inside a track in the “claw”. This link is a part of the analysis, but it is not a part of the evaluation of the results. During the analysis, this link will help to make the scenario more real with the respect to the acting forces. It also makes is so that there are no need to place fixtures in the track where the chain lies. In reality, there is a possibility where half of two links could hit the wall, but to simplify the analysis it has been decided to use link.

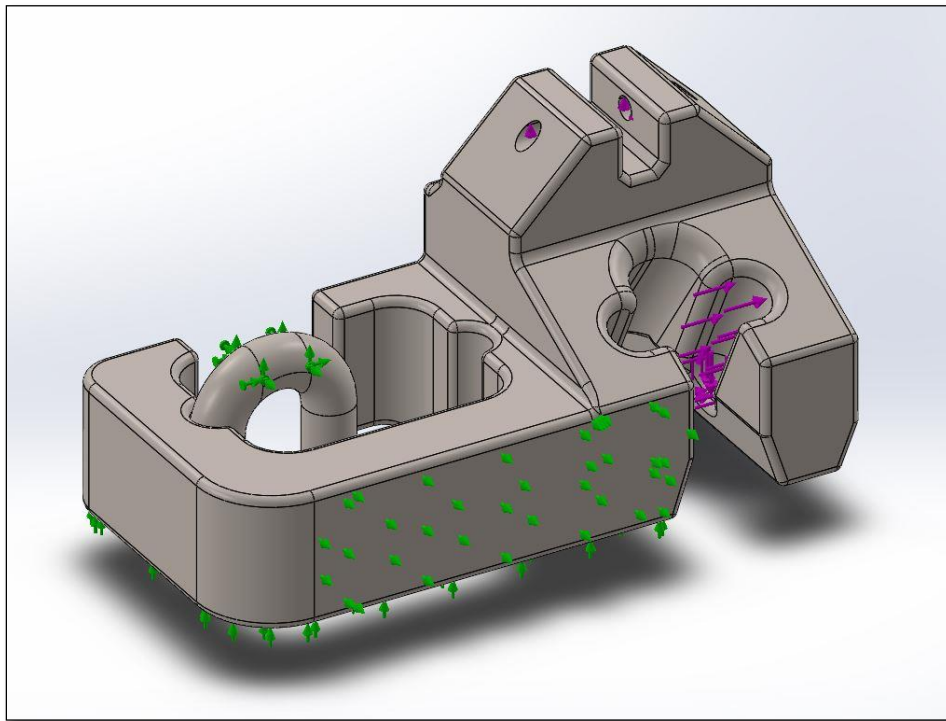


FIGURE 74: Fixtures on both the chain hook and the link, in addition to applied strain forces

Since it is not sufficient to have fixtures on only the link there have also been placed roller/slides fixtures on the front surface in addition to the bottom of the chain hook. The choice of not placing reason any roller/slides fixtures on the side of the chain hook, is because the chain hook in reality freely is going to move in that direction.

13.3.6 FIXTURES (PRESSURE SCENARIO)

Here there has been placed fixtures on a link from the middle-chain that lies inside a track on the inside of the starting point of the claw. This link is a part of the analysis, but it is not a part of the evaluation of the results.

Just like in the strain scenario there are placed roller/sliders fixtures on the front and the bottom of the chain hook.

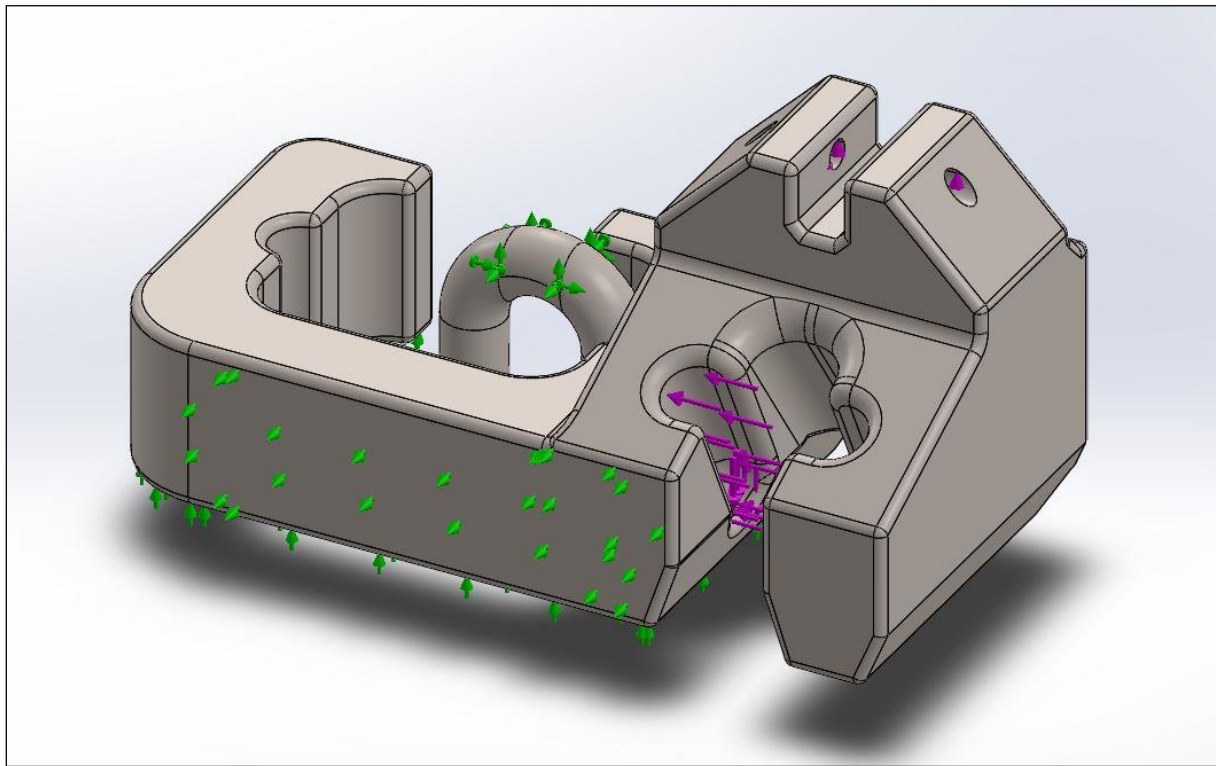


FIGURE 75: Fixtures on both the chain hook and the link, in addition to applied pressure forces

13.3.7 ANALYSIS OF THE CHAIN HOOK

The hook is now ready for analyzing. In addition to the applied forces and fixtures there has also been selected alloy steel as material. In addition, the chain hook has a selected contact surface with no penetration in order for the simulation to run correctly.

To achieve the correct simulations and results it is important to have an aspect ratio with a value lower than five in the areas that receive a high load. Having the correct mesh takes care of this.

13.3.8 MESH AND MESH CONTROL

The mesh chosen on the chain hook has a global size of 1,5 mm and a tolerance of 0.075 mm on the entire hook, with the chain link included. This mesh is considered a very fine mesh. The same mesh is used on both the strain scenario and the pressure scenario. To achieve an even higher accuracy mesh control was used on areas where the stresses where the highest. In this areas an element size of 1,2mm and a ratio of 1,5 are used.

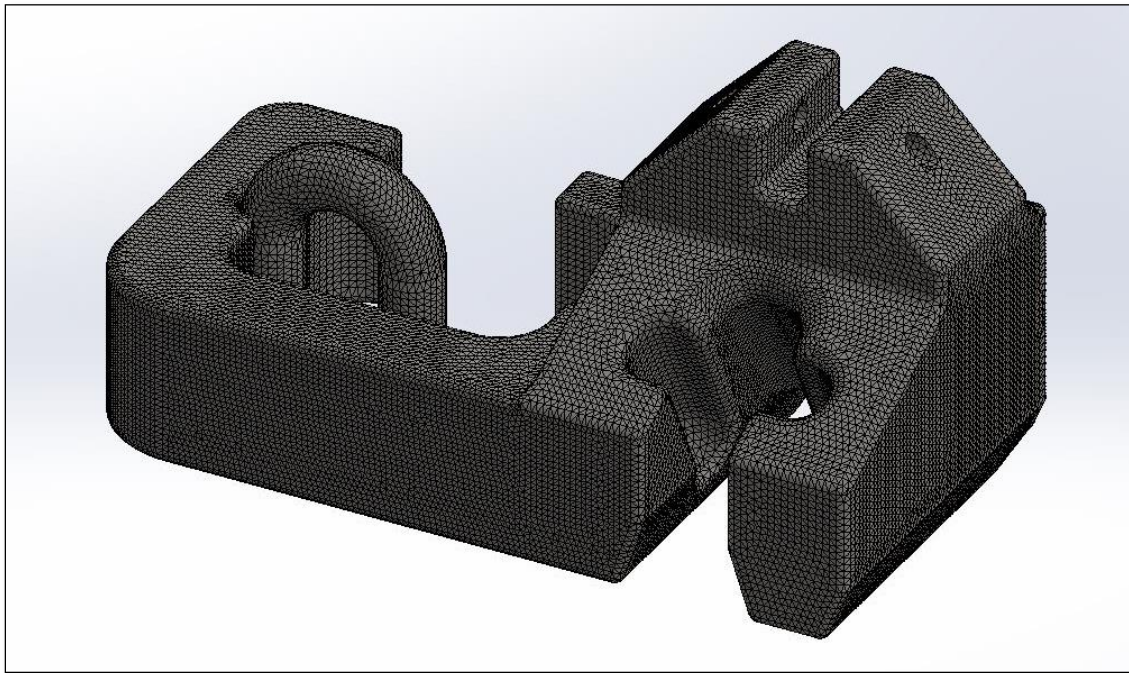


FIGURE 76: The mesh of the chain hook

Mesh Details	
Study name	Static 1 (-Default-)
Mesh type	Solid Mesh
Mesher Used	Standard mesh
Automatic Transition	Off
Include Mesh Auto Loops	Off
Jacobian points	4 points
Mesh Control	Defined
Element size	1.5 mm
Tolerance	0.075 mm
Mesh quality	High
Total nodes	1014280
Total elements	718492
Maximum Aspect Ratio	10.723
Percentage of elements with Aspect Ratio < 3	99.9
Percentage of elements with Aspect Ratio > 10	0.000696
% of distorted elements (Jacobian)	0
Remesh failed parts with incompatible mesh	Off
Time to complete mesh(hh:mm:ss)	00:00:29
Computer name	

TABLE 17: Mesh details chain hook analysis

13.3.9 ASPECT RATIO

To achieve good results the aspect ratio needs to be tested. In order to be able to trust the results from the simulations as earlier mentioned the aspect ratio should have a value lower than five at the areas where the highest stresses occur. The way this test is performed is by selecting plots to see how high the stresses are in these areas. This is done at both the strain simulation and the pressure simulation. Because of the fine mesh that was chosen to use, having an element size of 1,5mm, the results from the plots are good. The aspect ratio proves to be below five at the areas with the highest stresses. The areas where the value is above five are areas where the stresses are low, meaning that it will not cause any trouble for the Von Mises analysis that are to be performed later. The area having the highest aspect ratio with a value of 10,72 is a small area that does not affect the final result. More figures concerning this is to be found in the appendix.

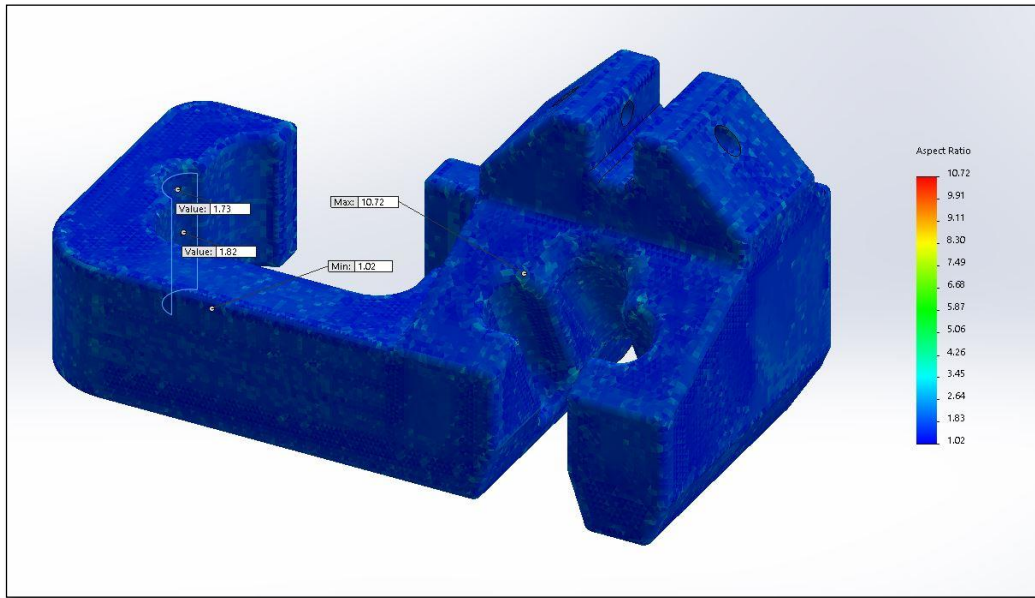


FIGURE 77: Plot values showing the Aspect Ratio in the track in the inside of the claw, strain scenario

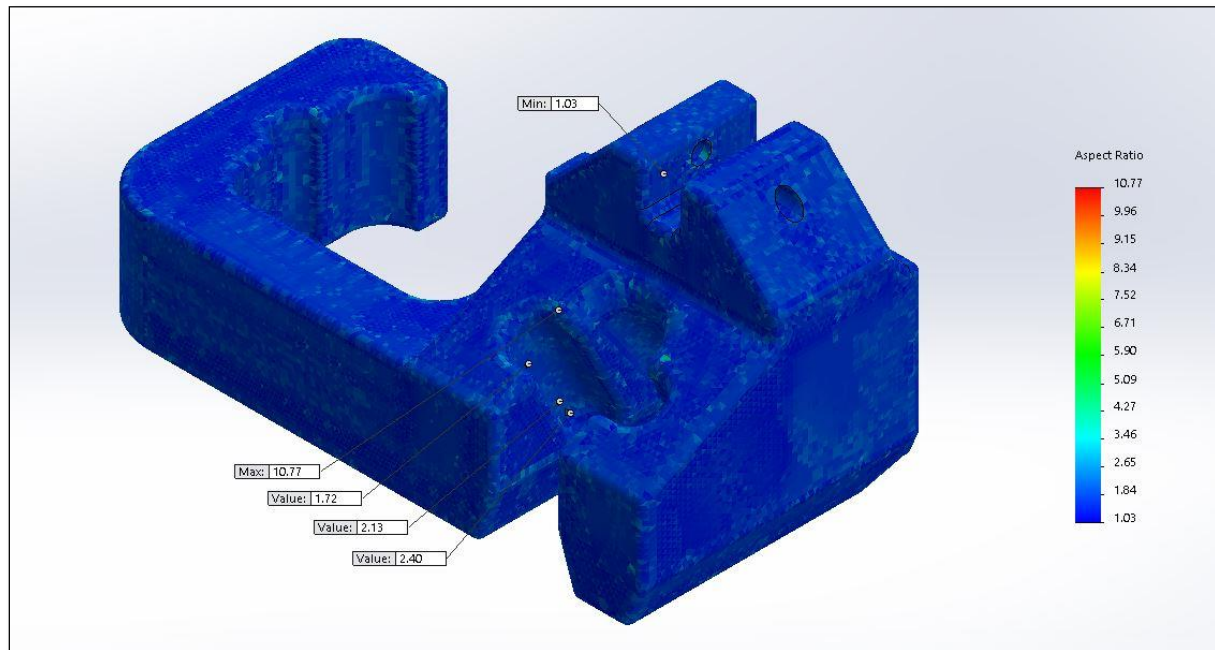


FIGURE 78: Plot values showing the Aspect Ratio in the grooves of the hook, pressure scenario

13.3.10 CHAIN HOOK ANALYSIS RESULTS

The results from both the strain scenario and the pressure scenario are presented. The forces applied to the chain hook is 2,5 times higher than expected during normal use in order to have a safety factor that satisfies FMC's requirements.

Through simulation, tests with FFE+ has been performed.

The values at the Von Mises analysis in the strain scenario has values going from 0,01 MPa up to 2591,97 MPa. The pressure scenario has Von Mises values going from 0,00 MPa up to 1816,40 MPa. In both cases the yield strength of 620,42 MPa and the ultimate tensile strength of 723,83 MPa is breached. Meaning that the chain hook will fail at such high level of stress.

These results are very disappointing. Despite OLC continuously asking themselves the question if the hook would be able to withstand the forces it is exposed for, and if it would work in reality the design did not manage withstand the forces and be strong enough having a safety factor of 2,5. This being said, the chain hook was strong enough for the stresses it would be applied during normal use.

OLC does also have some suspicions about SolidWorks not being able to calculate the correct stresses. This because the correct placement of the chain sling in the claw, and the chain link in the hook is very difficult to achieve. Since this it not something that can be proofed, OLC advices FMC to continue working on the design of the chain hook in order for it to be able to withstand the stresses with a safety factor of 2,5.

In the strain scenario the highest stresses occur in the track inside the claw, where the chain link lies. There are also quite high stresses in the area where the claw takes its first bend. Also in the grooves where the hooked on link is, there are high stresses. See in the appendix for more figures concerning the stresses the chain hook is applied.

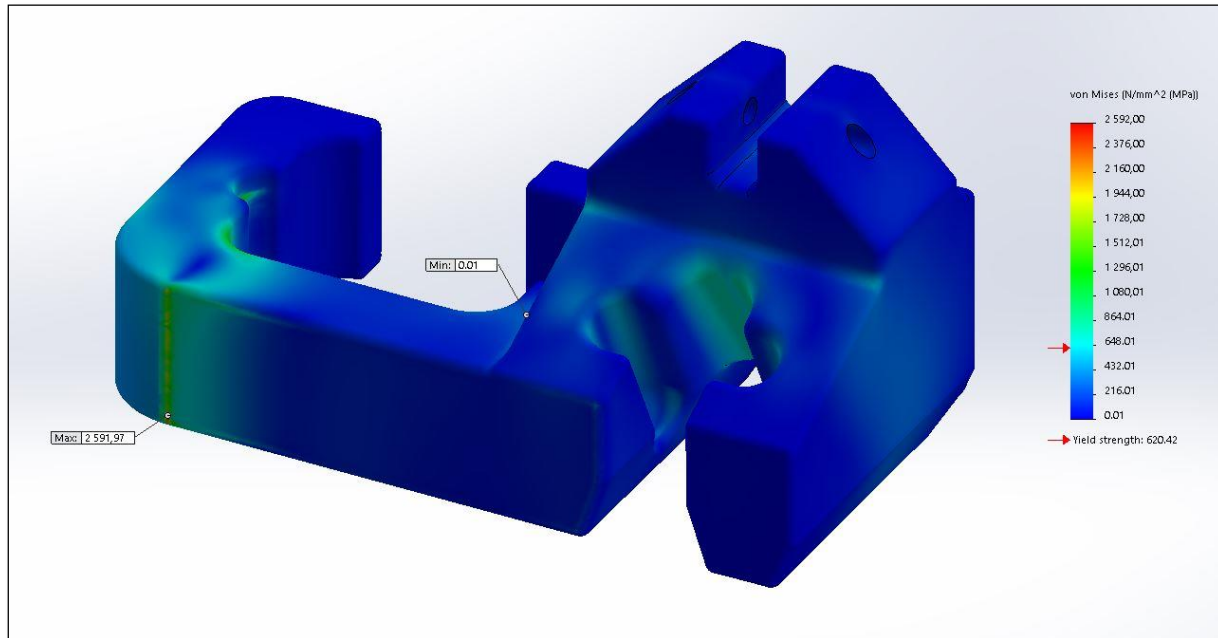


FIGURE 79: Von Mises values in the strain scenario

In the pressure scenario the highest occurring stresses is to be found in the track facing the hooked chain link. Also in the groove where the hooked on link lies, the stresses are high. See the appendix for more figures concerning the stresses the chain hook is applied.

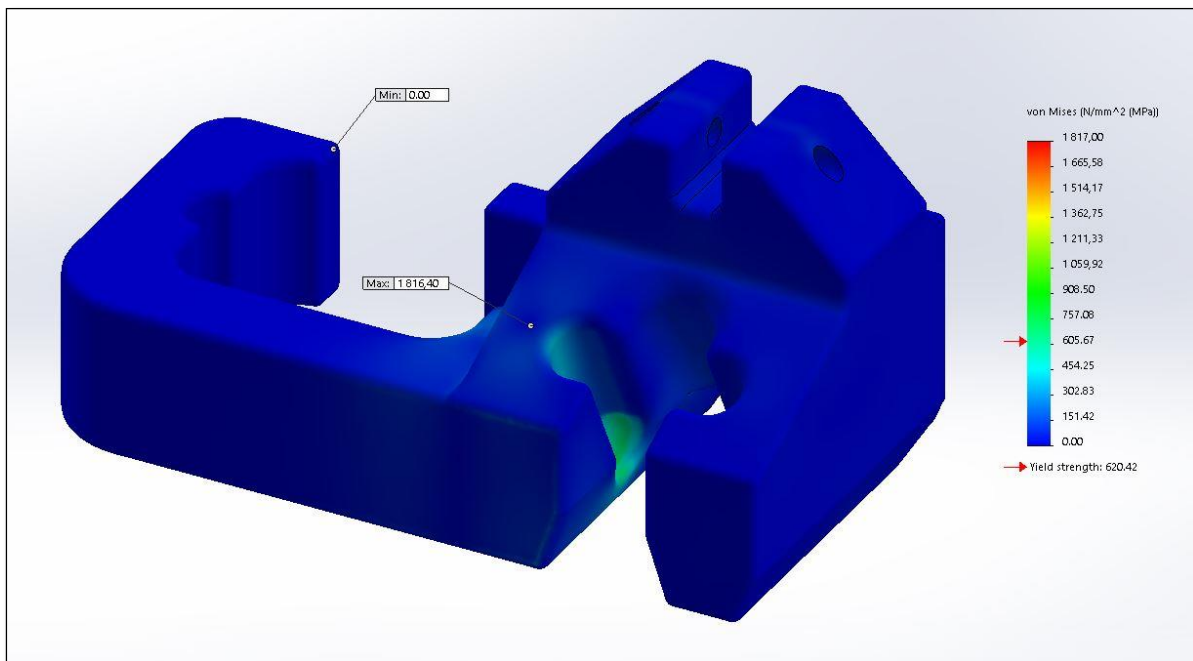


FIGURE 80: Von Mises values in the pressure scenario

14 DESCRIPTION OF PROTOTYPES

14.1 PROTOTYPE 1 – USE OF ISOLATING MAT

This prototype is an isolation mat placed on a cardboard pipe with a diameter of 8 inches. It was made to see how having a mat on a pipe that was fasten with ratchet tie-downs would work in reality.



FIGURE 81: Prototype 1: Isolation mat

14.1.1 STRUCTURE

Here an isolation mat is placed on a cardboard pipe and kept in place with the help of two ratchet tie-downs. There is a chain that is hitched around at the middle of the pipe. This hitch is a double wrapped basket hitch. There has also been mounted a tightening mechanism for the chain.

14.1.2 FUNCTION

The isolation mat is kept firmly in place with two ratchet tie-downs, preventing the mat from sliding sideways on the pipe. On the middle, the chain has been fastened around the pipe also using a ratchet tie-down. The ends of the straps have been fastened to the chain links with the help of some carabiner hooks.



FIGURE 82: Ratchet tie-down used as tightening mechanism for the chain

14.2 PROTOTYPE 2 – USE OF YOGA MAT

This prototype is a yoga mat placed on a cardboard pipe with a diameter of 8 inches. It was made to see how having a soft mat that had permanently fastened ratchet tie-downs to it would work in reality.



FIGURE 83: Prototype 2: Yoga mat

14.2.1 STRUCTURE

Here a yoga mat is placed on a cardboard pipe and kept in place with the help of two ratchet tie-downs that are sewn into the mat. There is a chain that is hitched around at the middle of the pipe. This hitch is also a double wrapped basket hitch. Here there are made a pocket on the top of the mat in order to mount the chain as easy as possible. Also on this prototype a ratchet tie-down is used as the tightening mechanism. This ratchet tie-down are a bit special since the straps are elastic. The TM is supposed to be attached to the pocket on the top. By having it like this, OLC avoids having any loose parts.

14.2.2 FUNCTION

The yoga mat is mounted on the pipe and the built in ratchet tie-downs are tightened, preventing the mat from sliding sideways on the pipe. The pocket on the top of the mat is opened and the chain is placed on the mat and the hitch is made. The pocket is then closed and the tightening mechanism on the middle of the pipe is connected to the chain and then tightened. However the tightening mechanism is only tightend so much that it prevents the chain from moving. It is not tightened to its maximum in order for the elastic straps to be flexible at different angles during lifting.



FIGURE 84: Elastic straps on the tightening mechanism

14.3 PROTOTYPE 3 – USE OF RUBBER MAT

This prototype is a rubber mat with pockets placed on a PVC pipe with a diameter of 16 inches. This was made in order to see how the real rubber mat would work in reality.



FIGURE 85: Prototype 3: Rubber mat

14.3.1 STRUCTURE

Here a rubber mat is placed on a PVC pipe and kept in place with the help of two ratchet tie-downs that are glued onto the mat. There is a chain that is hitched around at the middle of the pipe. This hitch is also a double wrapped basket hitch. There are made two rubber pockets that the middle chain goes through.

14.3.2 FUNCTION

The rubber mat is easily mounted on the pipe and the built in ratchet tie-downs are tightened, preventing the mat from sliding sideways on the pipe. The chain is thread through the rubber pockets and the double wrap basket hitch is made. The tightening mechanism is placed on top of the pipe, on top of the mat. The tightening mechanism have two chain hooks that are hooked onto the sling ends. The chain is then tightened by the help of the TM and the lift it ready to be performed.

14.4 PROTOTYPE 4 – DUPLEX RATCHET TIE-DOWN

This prototype is a tightening mechanism. It was made to see if it was a good solution for the tightening mechanism in OLC's lifting clamp.

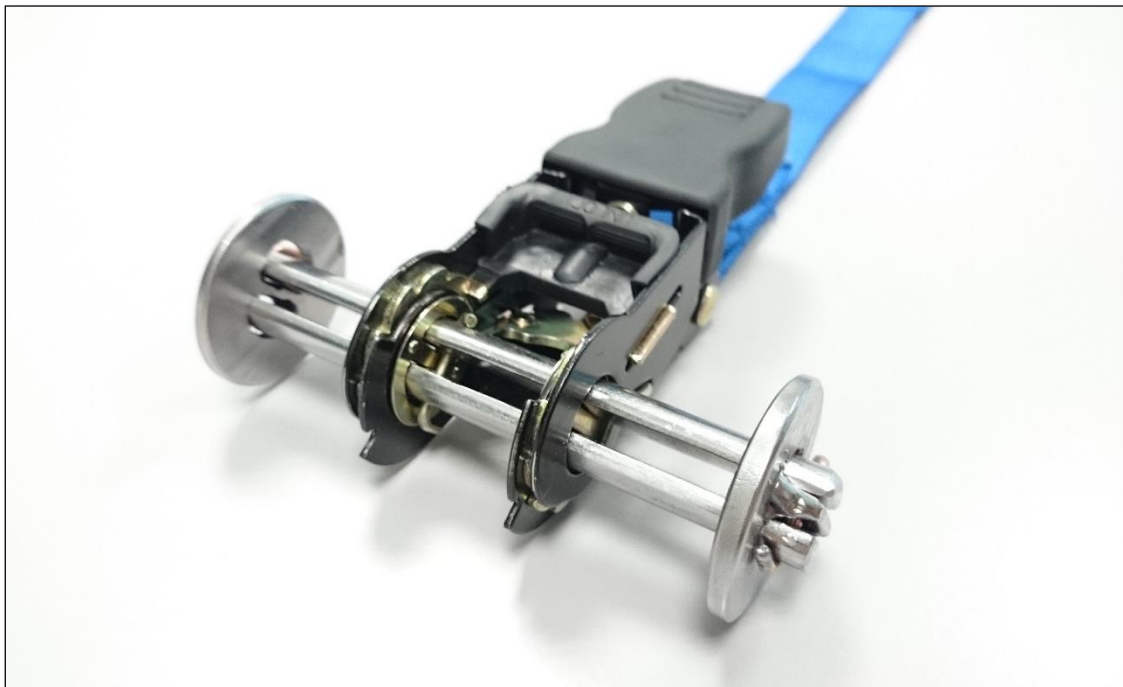


FIGURE 86: Prototype 4: Duplex ratchet tie-down

14.4.1 STRUCTURE

The prototype is basically based on a normal ratchet tie-down, although there has been done some smaller modifications.

The body of the ratchet tie-down is the original body, but the pins that were used to thread the strap thru are replaced with some longer ones. There has also been made some new cover walls on the ends of the new pins. In order to keep all the parts in place there has been drilled some holes, which the four locking pins are passed thru.



FIGURE 87: Parts made for prototype 4

14.4.2 FUNCTION

This prototype works in such a way that you can tighten two straps coming from different directions simultaneously. This instead of only one strap coming from one direction.

The prototype is fastened on top of the rubber pocket on top of the mat. On each of the ends for the two straps the chain hook is to be found.

The space in the middle of the ratchet tie-down is no longer functional, this because of the necessary locking pins. Instead, there are two new slots on each side, which are ready to be used. Simply thread one of the two straps in one of the slots coming from the front, take the other strap into the other slot coming from behind. Keep both of the straps in tension by pulling them and then start jacking with the ratchet.

Other options for use is to have a fixed length of the two straps, which are permanently fastened in each of their slots. When jacking with the ratchet, the length of the straps can be tightened in by 58cm each. This because of the high cover walls. In this case instead of straps, wire also can be used.

14.5 PROTOTYPE 5 – STEEL MADE WIRE TENSIONER

This prototype is also a tightening mechanism. It was made to see if it was a good solution for the tightening mechanism in OLC's lifting clamp. This prototype is a simplified solution for the final TM, which is the tightening mechanism OLC ended up with.

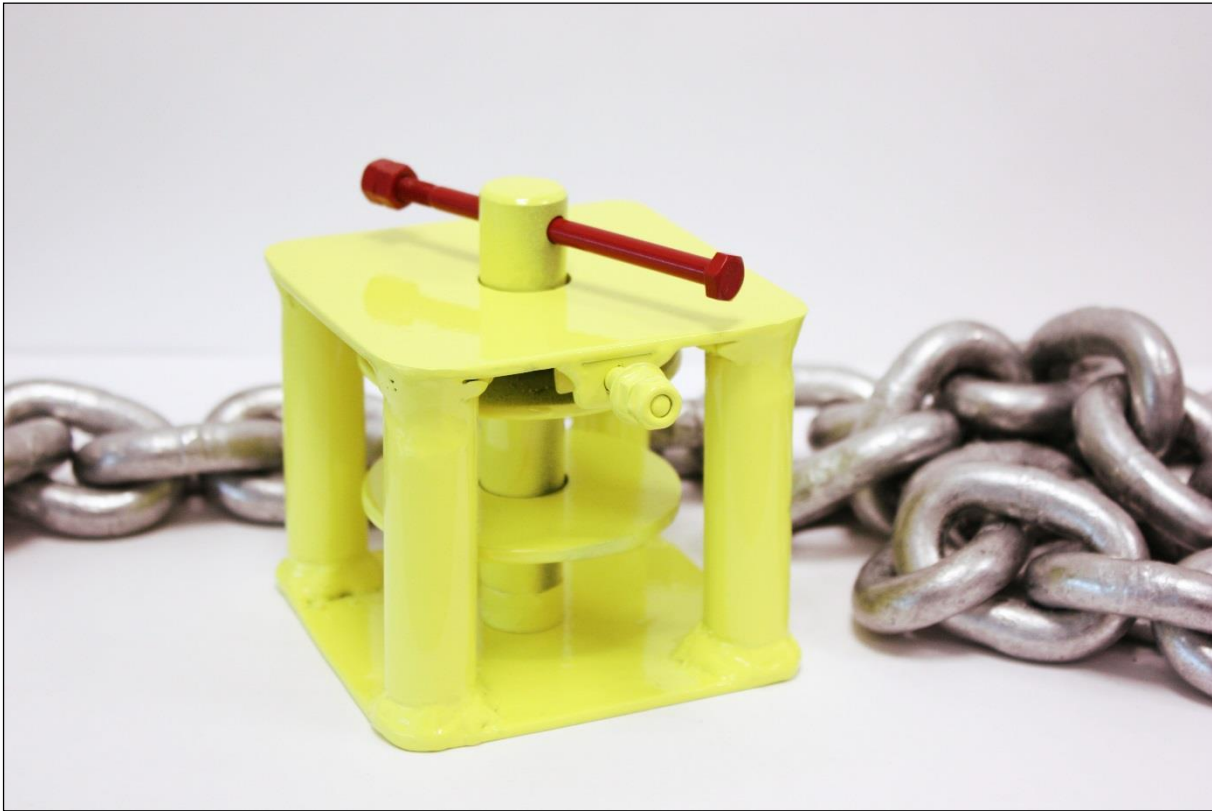


FIGURE 88: Steel made wire tensioner

14.5.1 STRUCTURE

This prototype is based on a device used for tightening wires on a fence.

The prototype is made up from a house consisting of a floor and a roof in addition to four corner columns. In the middle there is a turning rod with some discs attached to it. This in order to separate the two wires that are to be tightened. The rod has also a sprocket wheel for a locking pin to interact with. This to prevent the wire from unwinding when you stop tightening. On top of the rod there is a turning pin sized to fit a hand. This turning pin can slide in the horizontal direction in order to get the desired momentum when tightening.



FIGURE 90: Prototype 5 frame



FIGURE 89: Prototype 5 turning rod

14.5.2 FUNCTION

This prototype also works in such a way that you can tighten two wires coming from different directions simultaneously

The prototype is fastened on top of the rubber pocket on top of the mat. On each of the ends for the two wires the chain hook is to be found.

Here there are being used two wires that have a predefined length. These wires are fastened in each their hole in the rod, separated by one of the discs.

To tighten the wires simply turn the turning pin, the same way as you would do when tightening a wise. To unwind the wires simply pull out the locking pin. The locking pin is spring-loaded and will interlock with the sprocket wheel as soon as you let go of the locking pin again.

This prototype is quite similar to the Duplex ratchet tie-down. The difference is that while on the Duplex ratchet tie-down the wind-up happens on the sides, on the Wire tensioner it happens above each other. By having the tightening over and under it doesn't create such a big torsion as you

would get with the Duplex ratchet tie-down, which again leads to less of a load on the mat it is fastened to.

14.6 PROTOTYPE 6 – 3D-PRINTED WIRE TENSIONER

This prototype is the 3D-printed model of OLC's actual tightening mechanism.



FIGURE 91: Prototype 6: 3D-printed wire tensioner

14.6.1 STRUCTURE

The structure is the same as the model made in SolidWorks. The only difference is that the 3D-printed model does not include the safety pins for the double barrier as described previously in the report. This is simply because the 3D-model was made before the double barrier had been implemented.

14.6.2 FUNCTION

The 3D-printed model works in the same way as the real model and similar to prototype 5.

14.7 TECHNICAL BUDGET

One of the main requirement from the customer is to reduce the production costs by a maximum. Based on this requirement, a technical budget has been made, estimating the expected production costs of a lifting mat with chain and tightening mechanism.

OLC Engineering Technical Budget

Quantity	Expenses	Calculation of cost	Total estimated cost
3,1917m	Chain	13mm chain, 200 NOK pr meter = 200NOK * 3,1917m	NOK 638,00
1	Rubber	Estimated 1NOK pr cm ³ Dimension; 1*30*127,5 [cm] = 3825cm ³ + reinforced rubber and ratchet tie-downs.	NOK 4 500,00
1	Tightening mechanism	Documentation, certification and milling.	NOK 6 000,00
2	Chain hooks	Documentation, certification and milling.	NOK 8 000,00
			NOK 19 138,00

TABLE 18: Technical budget

This is a conservative estimation of the budget, and it is assumed that it will be possible to reduce the costs further with larger production and procurement. But even with this budget the production costs reduces by at least 50% compared to todays solution.

15. RECOMMENDATION FOR FUTURE WORK

The solution presented in this document has big potential to take over the current solution using a lifting clamp. The lifting mat has a great deal of advantages compared to the clamp. By using this solution it is possible to greatly reduce the production costs, the weight of the equipment and the rigging hours will be decreased and it will be possible to use the equipment on pipes of various diameters. Based on this, it is recommended to continue working on the design and make a full and realistic model for testing.

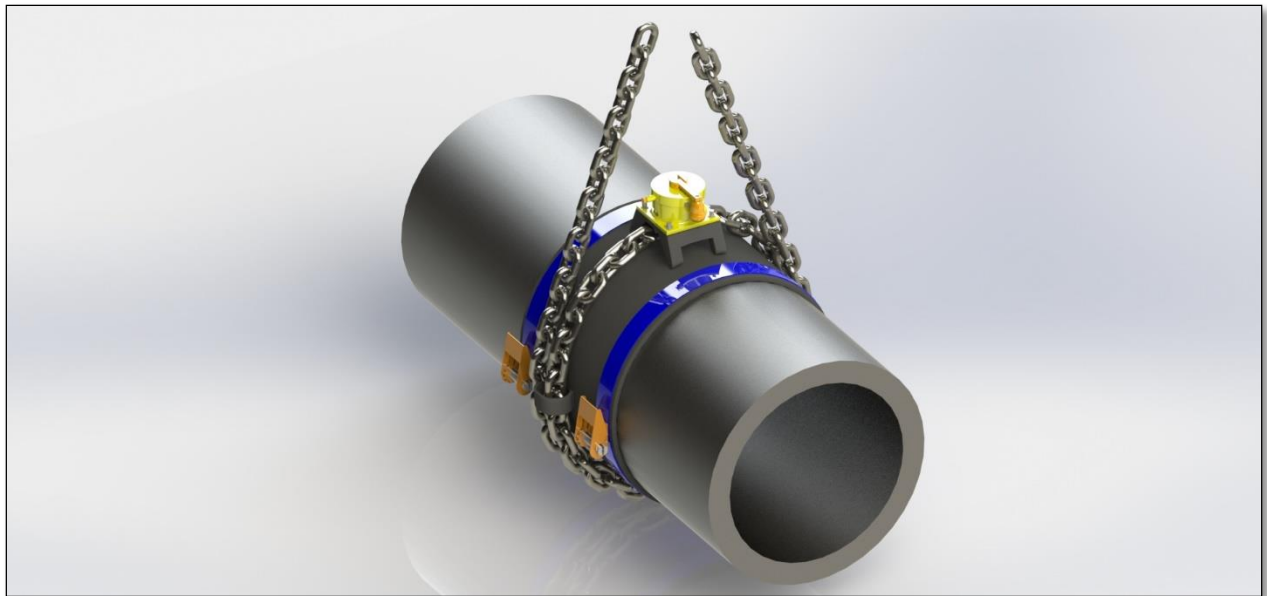


FIGURE 92: Fully mounted lifting mat and equipment

By further work it will be advisable to have a look at the tightening mechanism and chain hook to optimize these in relation to performing off-board lifts. In addition it will be necessary to run tests on the mat with use of full custom materials and equipment in realistic dimensions.

16 CONCLUSION

The design report has given an insight regarding the development of the final design and results in the bachelor project. It describes the progress throughout the period and presents several ideas, concepts and designs.

The final design and recommendation of a lifting equipment for lifting cylindrical pipes off-board, consist of:

- ➔ A high friction specially design lifting mat
- ➔ A tightening mechanism for tightening the chain before performing a lift
- ➔ Specially designed chain hooks

17 REQUIREMENT DESCRIPTION TABLE

Requirement:	Description:
Weight:	The total weight of the lifting clamp/gear with the sling included.
Production cost:	This includes materials, production and documentation.
Risk:	The risk of incorrect installation, lifting operation failure, sliding of the lifting clamp/gear on the pipe and the possibility of injuries when dealing with the equipment.
Temperature:	Can the lifting clamp/gear withstand temperatures between -20 and 50 degrees Celsius.
User friendly:	How easy is it to assemble the lifting clamp/gear and to understand the user manual.
Robust:	Are the lifting clamp/gear robust.
Different diameters:	Can the lifting clamp/gear be used for lifting pipes with different diameters.
Mounting time:	Time it takes to pick up and mount the lifting clamp/gear.
Storage space:	Does the lifting clamp/gear require a lot of space when it is stored.
Maintenance:	How easy it is to replace parts, make repairs and to visually inspect the lifting clamp/gear.
Number of loose parts:	Regardless if it has an adjustable diameter, how many parts the lifting clamp/gear consists of.
Portable:	Are the lifting clamp/gear portable. Meaning that it has a weight of 25kg or less.

TABLE 19: Requirement description table

APPENDIX

TM ANALYSIS RESULTS

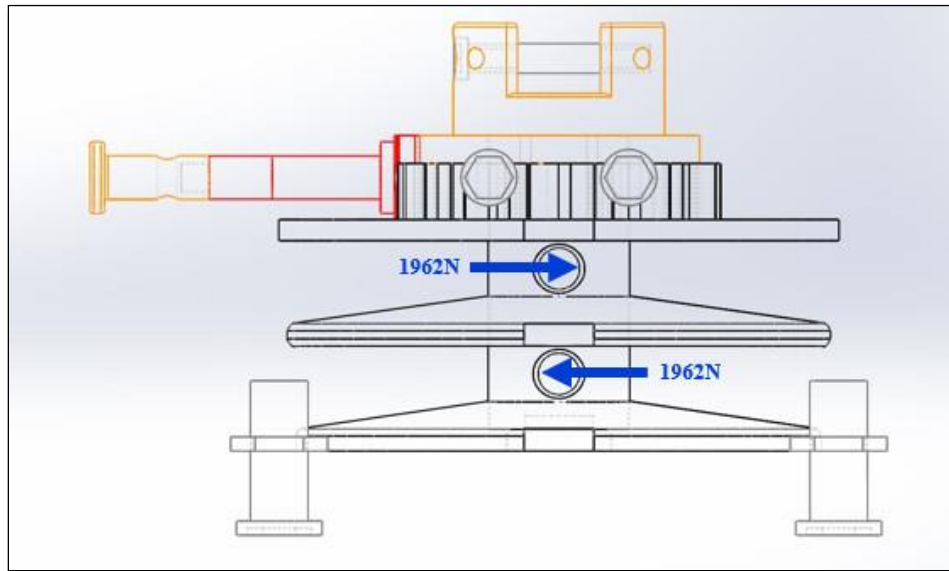


FIGURE 93: The shaft is applied a force from each side, seen in a cross sectional view

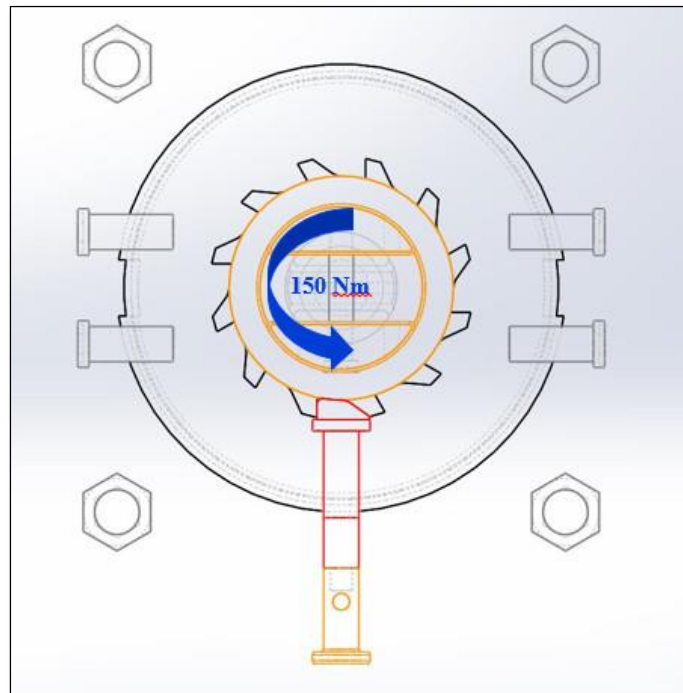


FIGURE 94: Torsion forces acting on the gear, seen from above

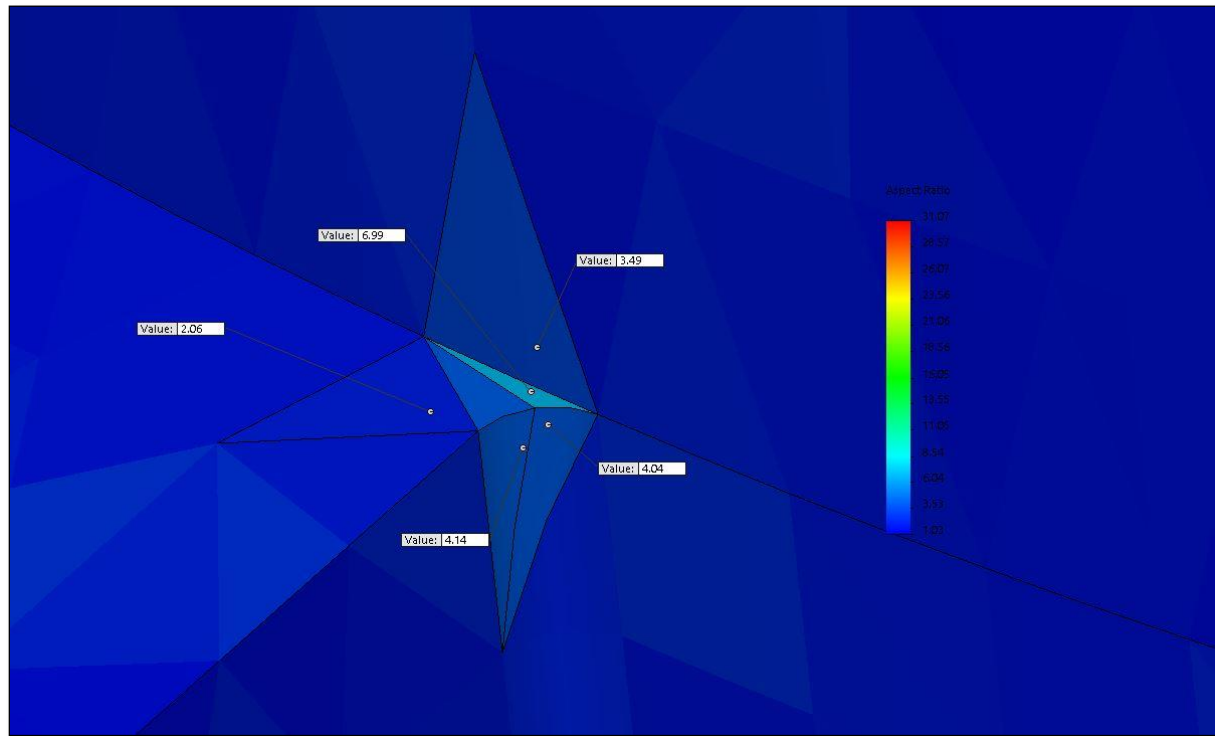


FIGURE 95: Aspect Ratio values on the edge of the gear

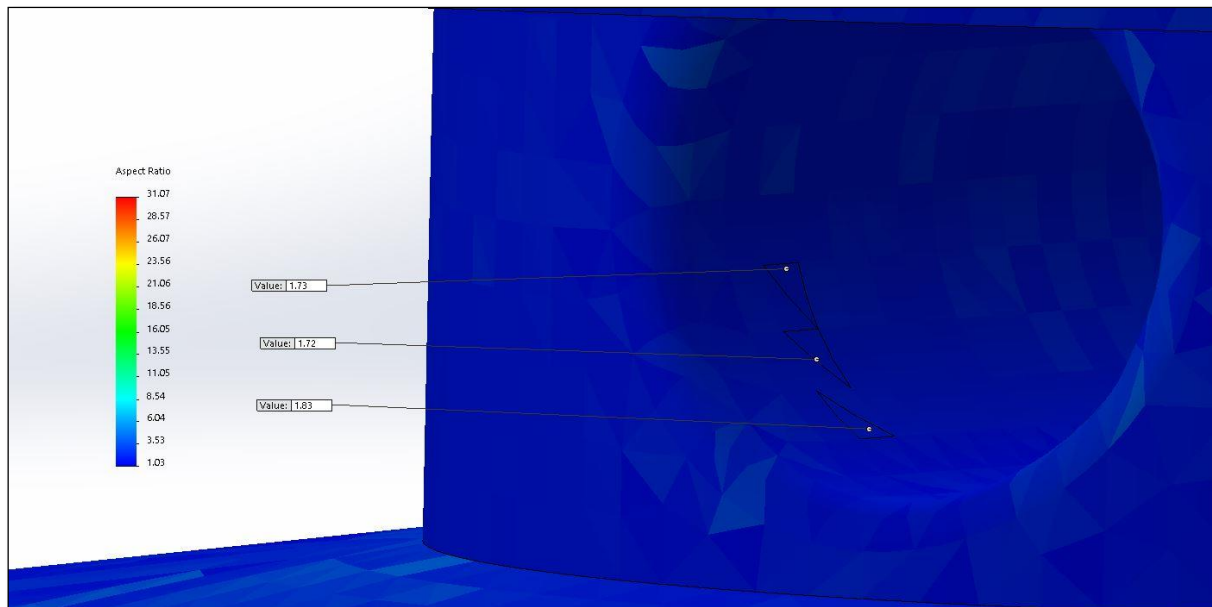


FIGURE 96: Aspect Ratio values inside the top wire-hole of the shaft

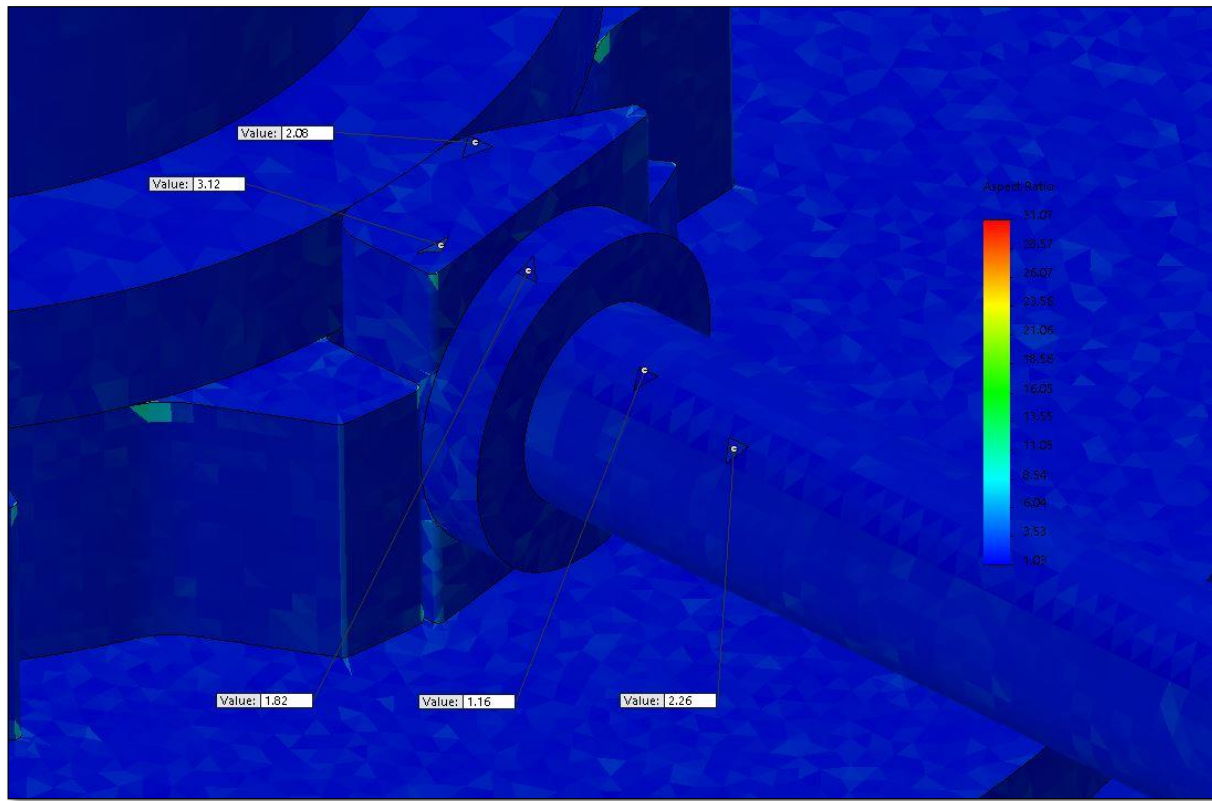


FIGURE 97: Aspect Ratio values on the locking bolt

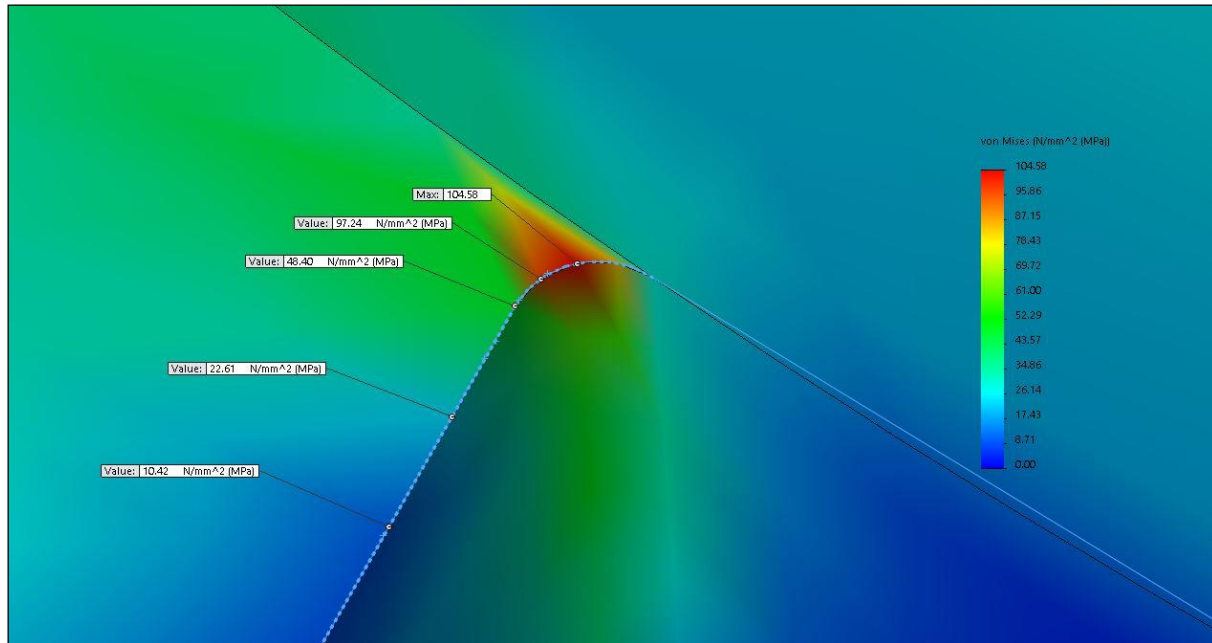


FIGURE 99: Von Mises values of the highest stresses occurring at the edge of the gear

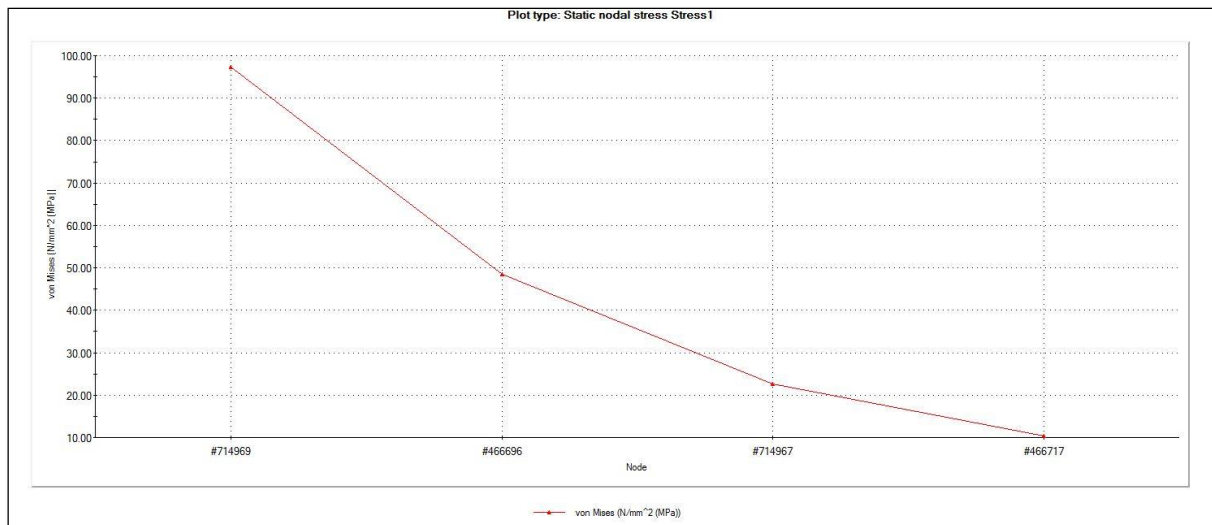


FIGURE 98: Von Mises values of the highest stresses occurring at the edge of the gear showed with a diagram of the plots.

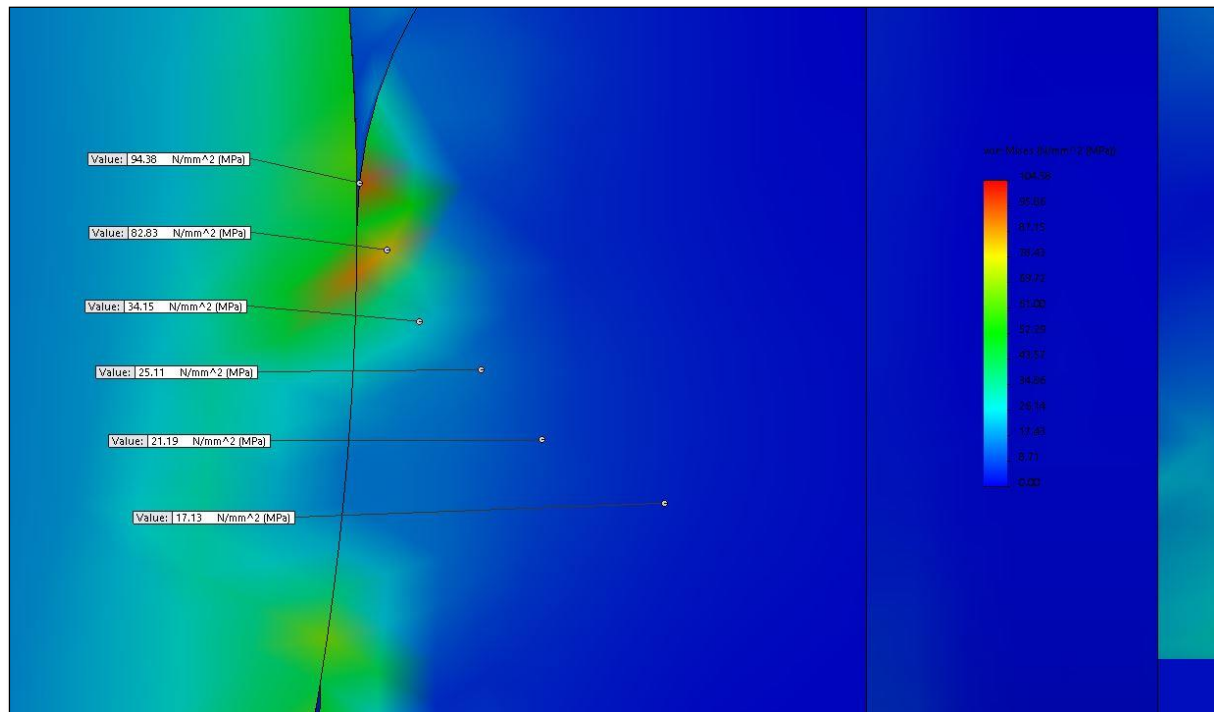


FIGURE 100: Von Mises values of the highest stresses occurring on the interlocking end of the locking bolt.

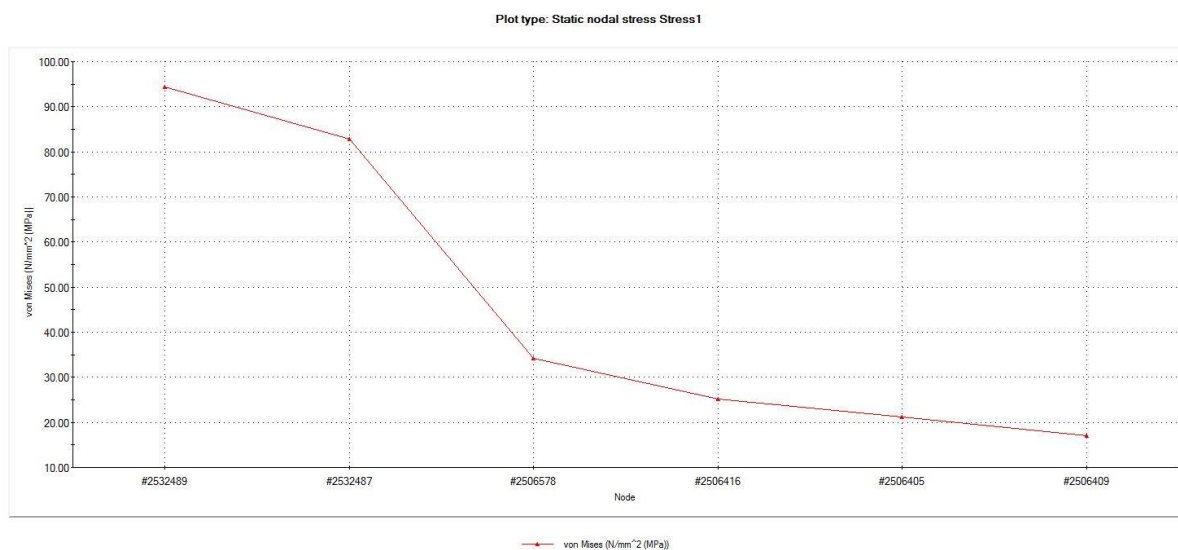


FIGURE 101: Von Mises values of the highest stresses occurring on the interlocking end of the locking bolt, showed with a diagram of the plots.

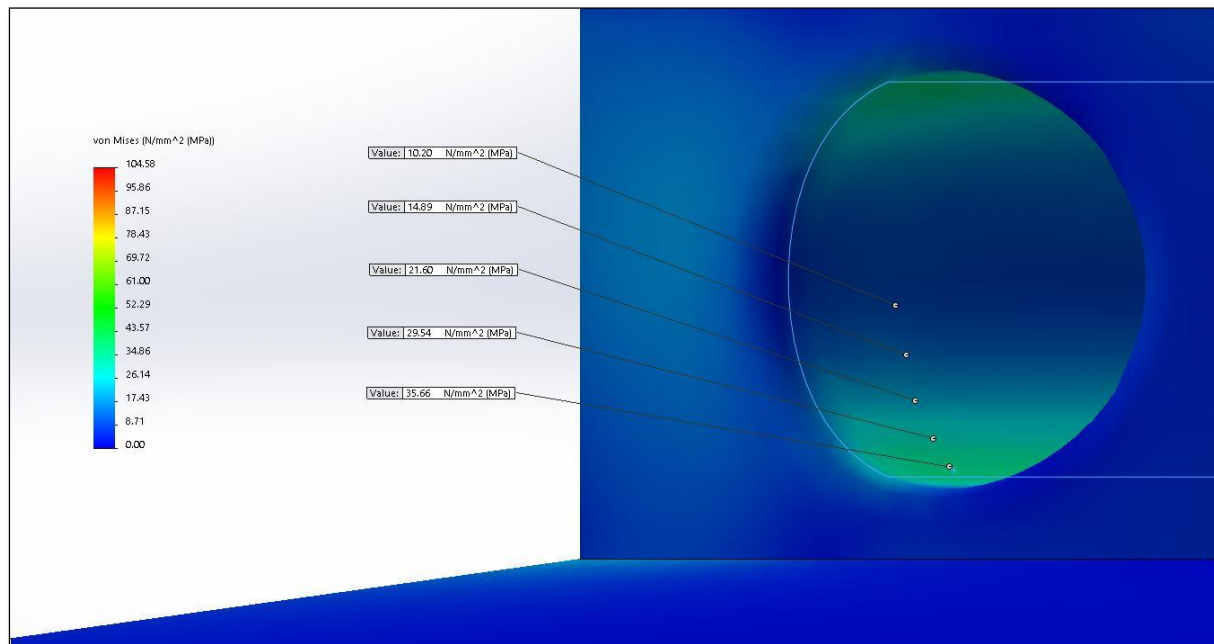


FIGURE 102: Von Mises values of the highest stresses occurring inside the top wire-hole of the shaft.

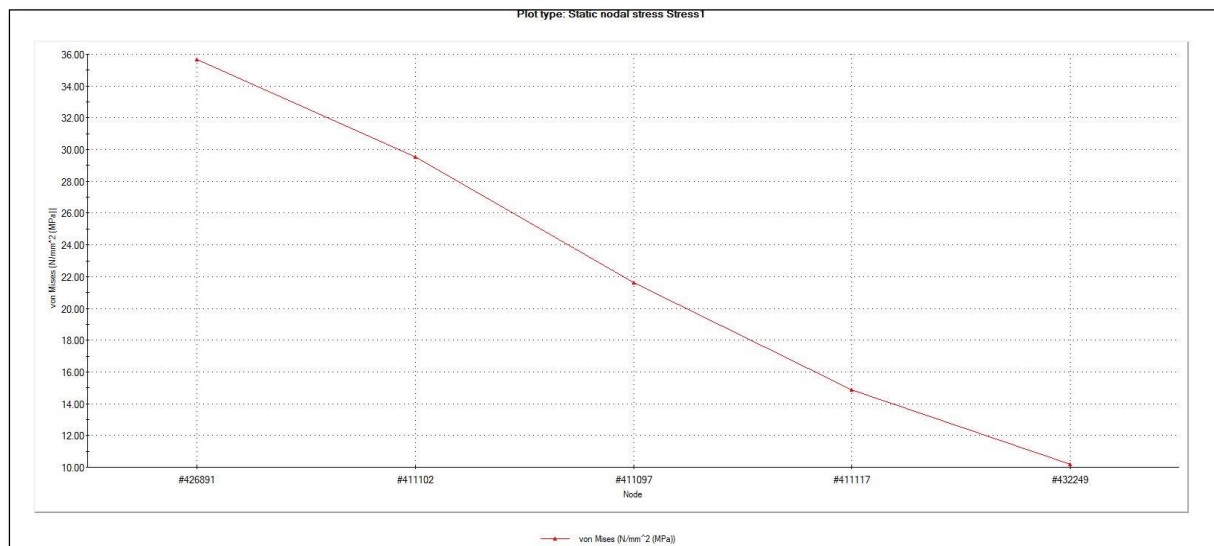


FIGURE 103: Von Mises values of the highest stresses occurring inside the top wire-hole of the shaft, showed with a diagram of the plots.

CHAIN HOOK ANALYSIS RESULTS

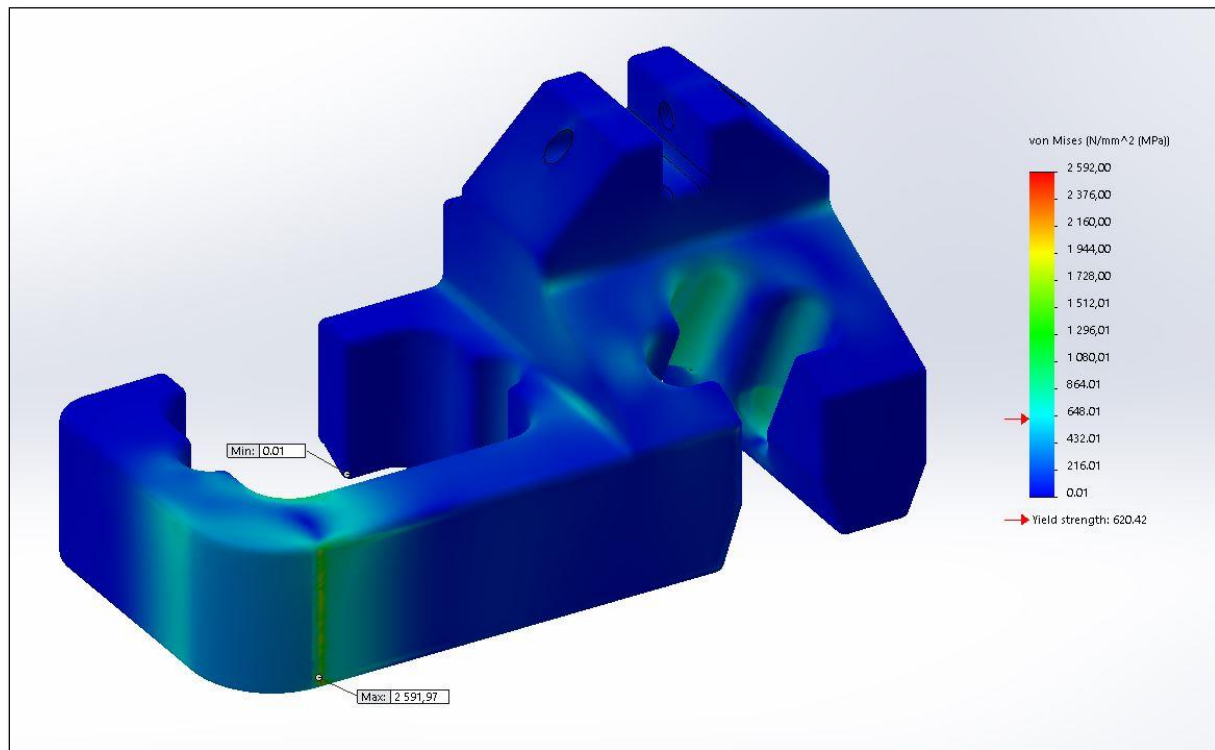


FIGURE 104: Von Mises values in the strain scenario.

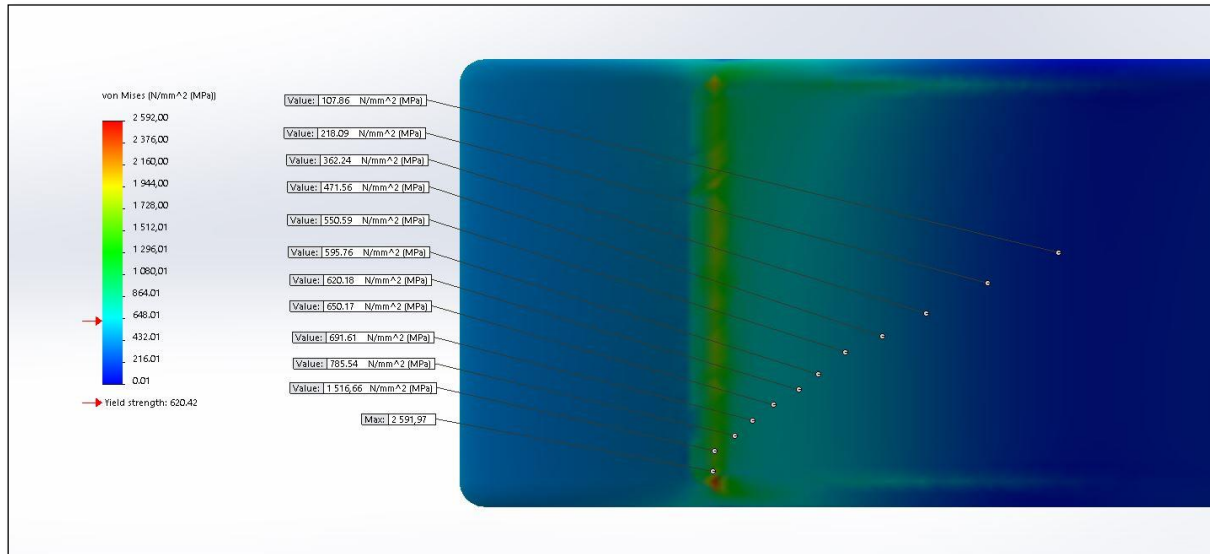


FIGURE 105: Von Mises values in the outer wall of the claw in the strain scenario

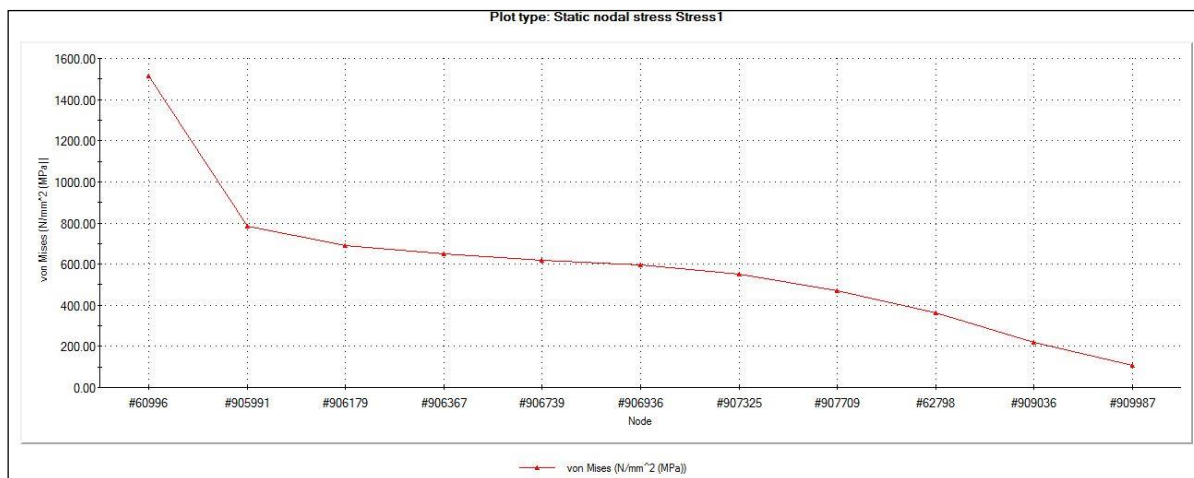


FIGURE 106: Von Mises values in the outer wall of the claw in the strain scenario, showed with a diagram of the plots.

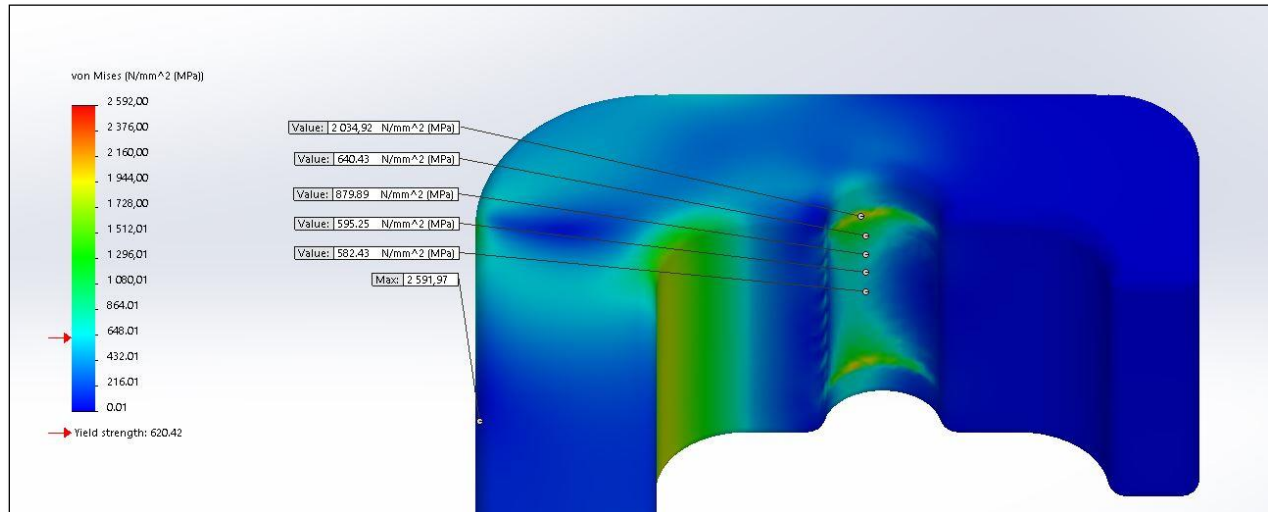


FIGURE 108: Von Mises values in the track on the inside of the claw. (Strain scenario)

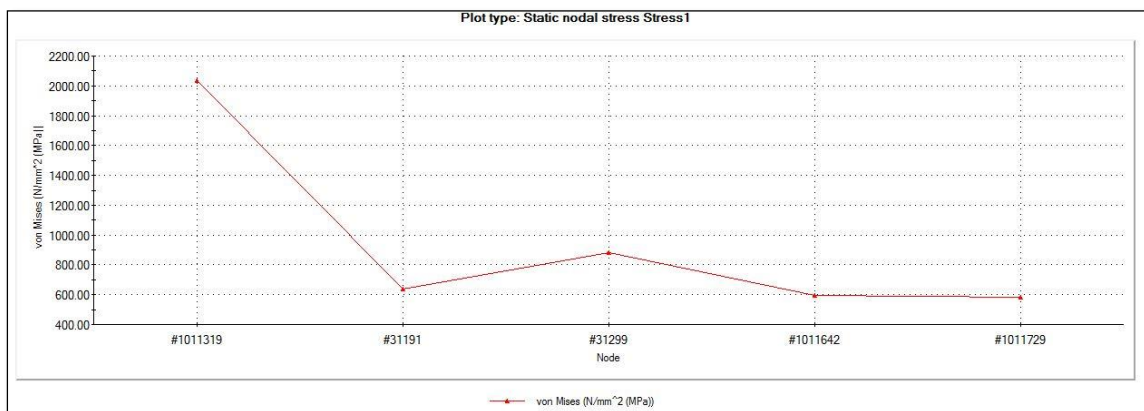


FIGURE 107: Von Mises values in the track on the inside of the claw in the strain scenario, showed with a diagram of the plots

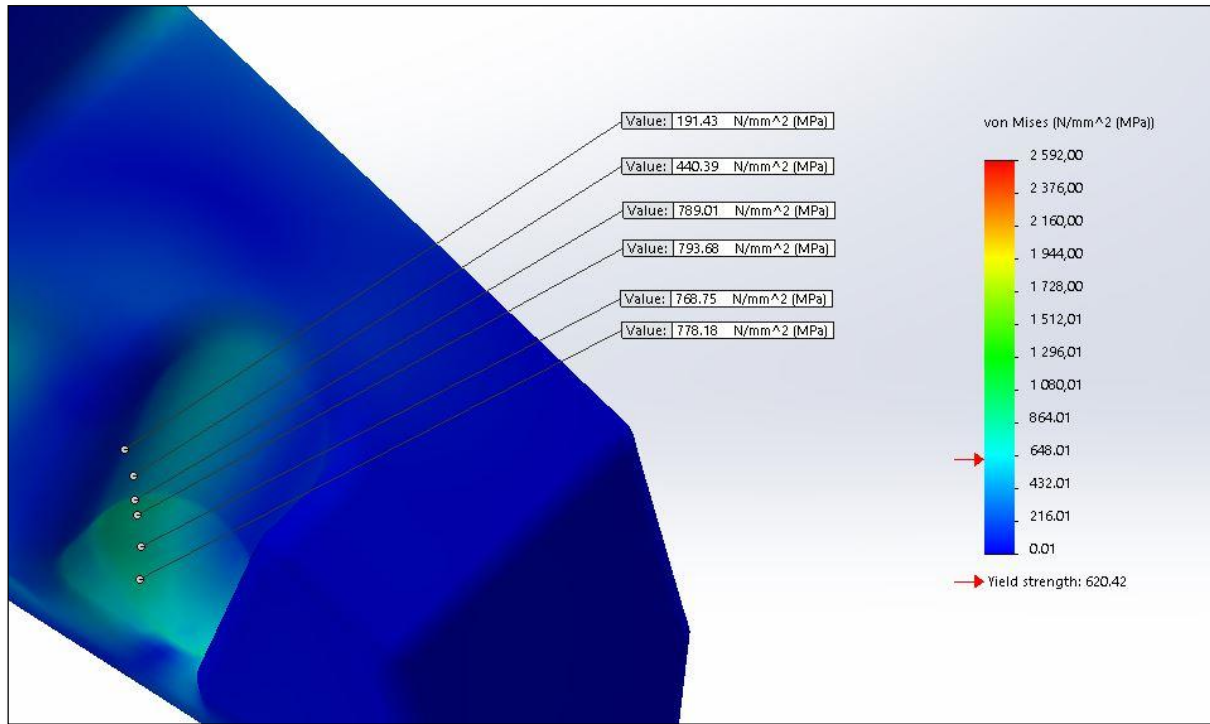


FIGURE 109: Von Mises values in the right groove where the chain is hooked on, strain scenario.

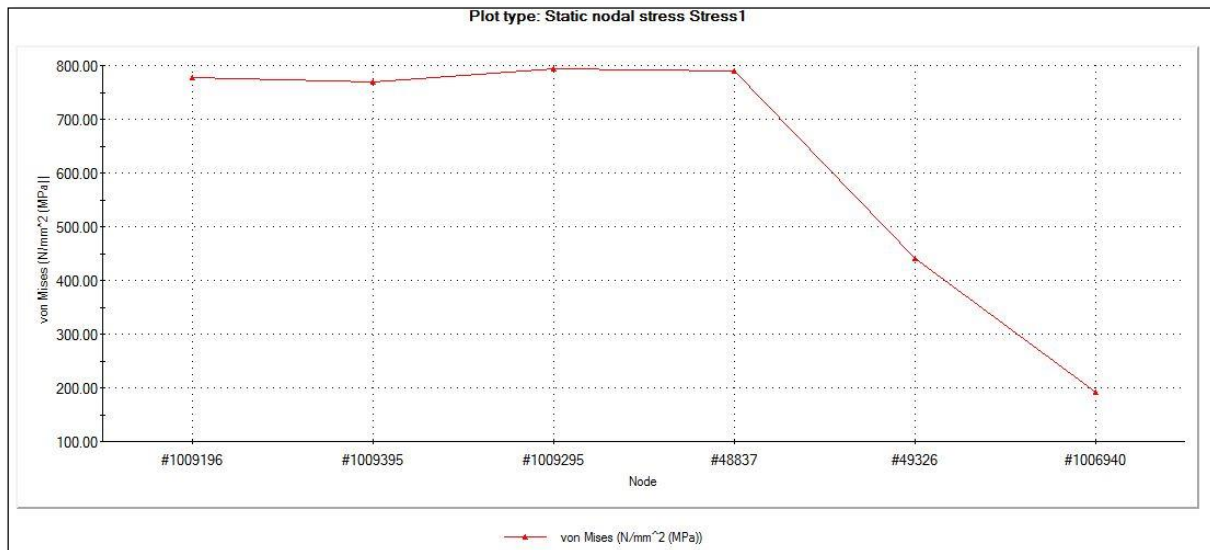


FIGURE 110: Von Mises values in the right groove where the chain is hooked on. (Strain scenario) Shown with a diagram of the plots.

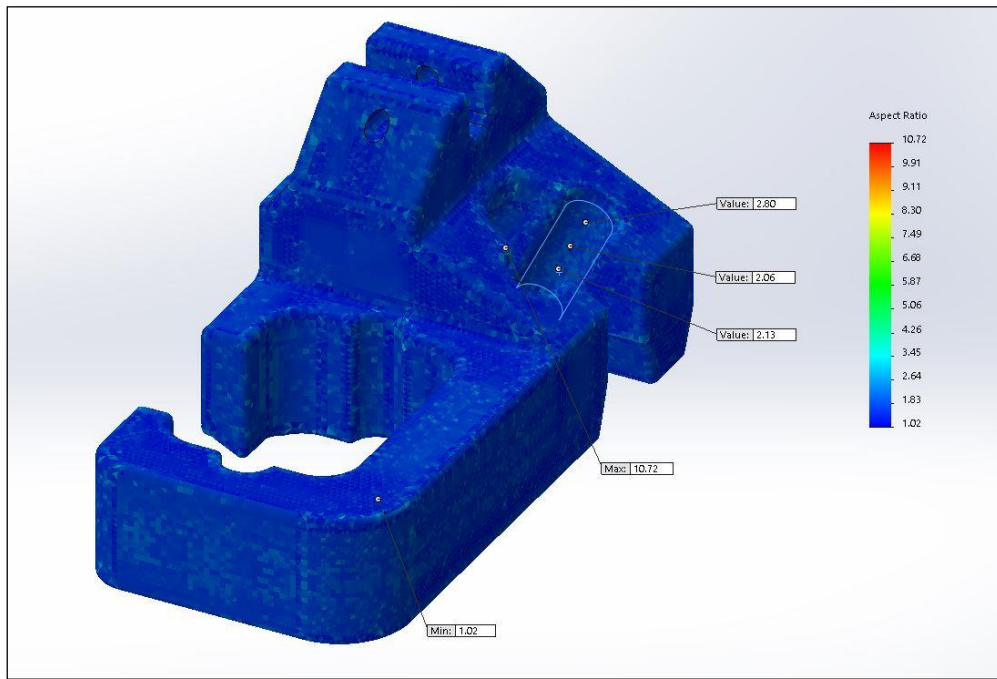


FIGURE 111: Aspect Ratio values in the right groove. (Strain scenario)

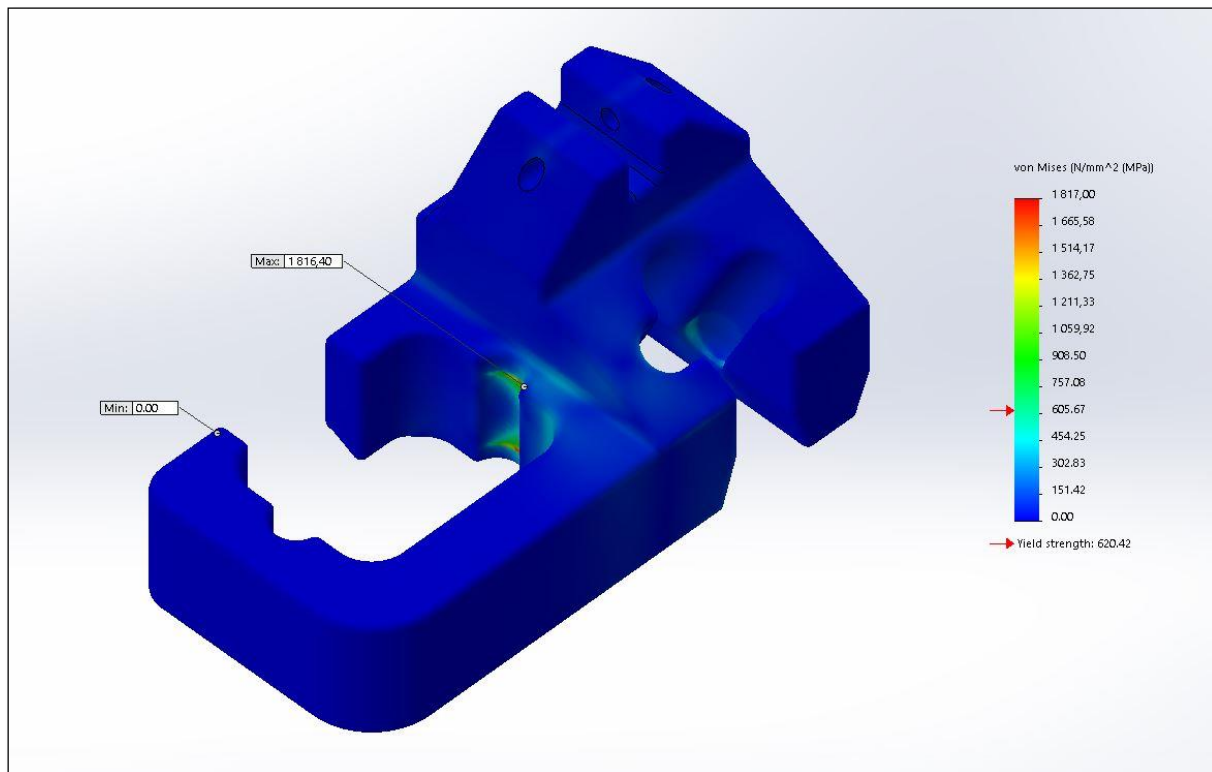


FIGURE 112: Von Mises values in the inner track in the pressure scenario.

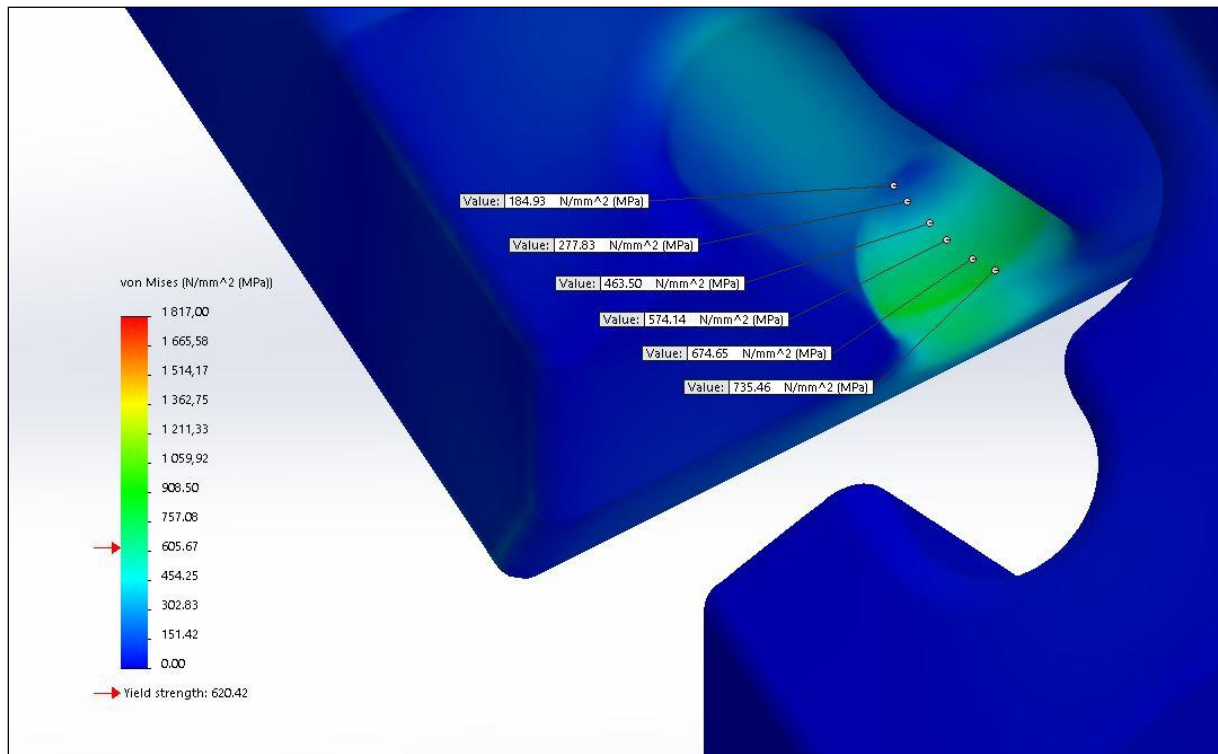


FIGURE 113: Von Mises values inside the left groove of where the chain is hooked on

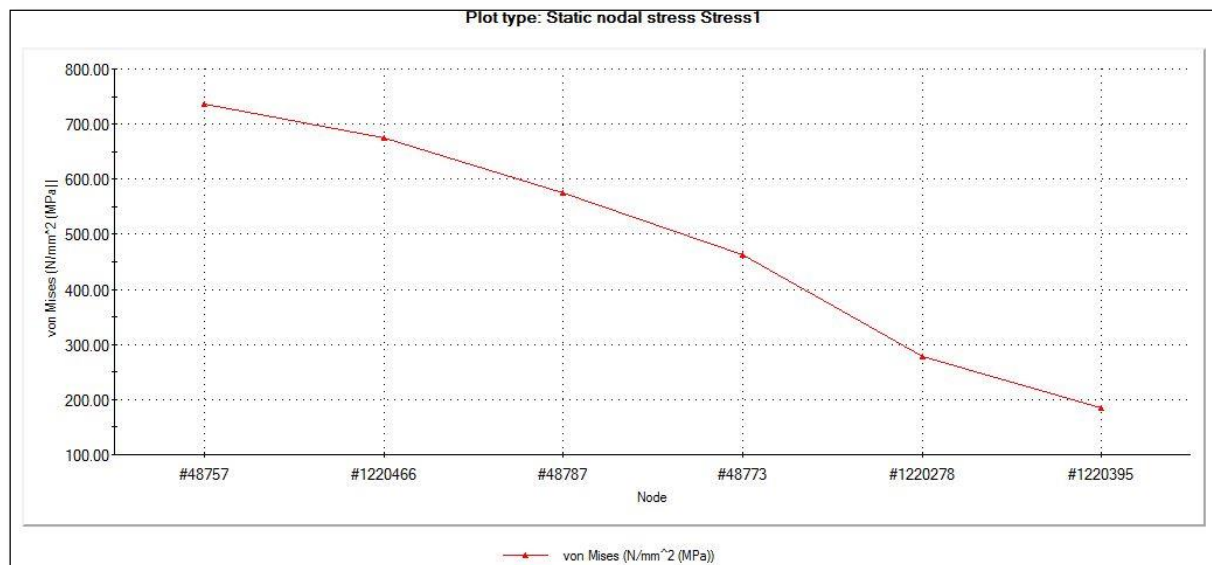


FIGURE 114: Von Mises values inside the left groove of where the chain is hooked on. (Pressure scenario). Shown with a diagram of the plots.

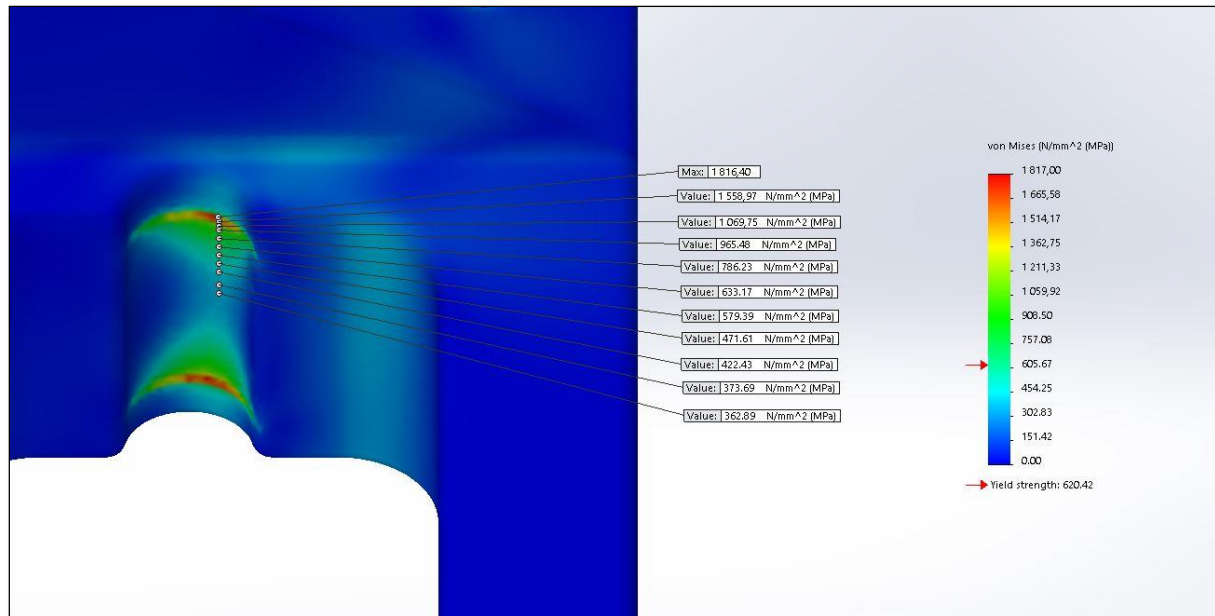


FIGURE 115: Von Mises values in the right track on the inside of the claw. (Pressure scenario)

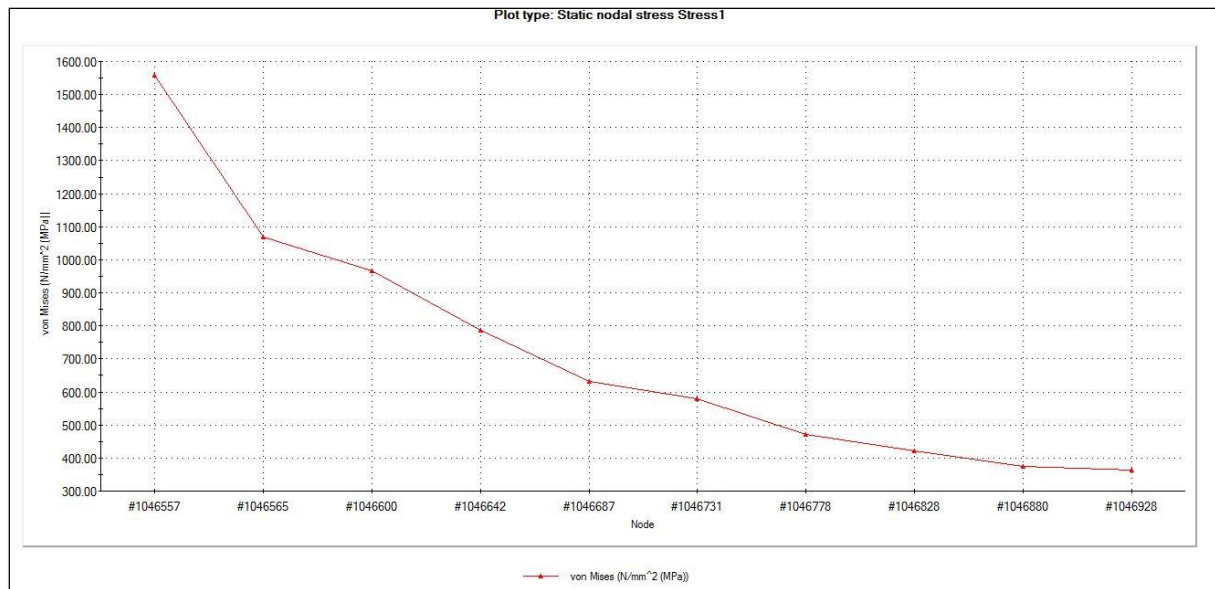


FIGURE 116: Von Mises values in the right track on the inside of the claw. (Pressure scenario). Shown with a diagram of the plots.

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OFFSHORE LIFTING CLAMP ENGINEERING
VERSION 5.0

REQUIREMENT SPECIFICATION

20.05.16

ABSTRACT

The requirement specification document describes the main requirements that is fundamental for the project, in addition to requirements from the DNV 2.7-3 standard and the DNV 2.22 standard. This document also includes a situation analysis, which defines the situation offshore. The purpose with this document is to define what the active and passive stakeholders require from OLC. Reading this document will give the ability to understand what the requirements are, and how they have to be fulfilled to ensure that the product has an optimal design.

CHANGES

The changes will be listed here:

Version	Date	Description
5.0	20.05.2016	Added: Column to table; requirements and requirements DNV Updated: List of contents, list of figures and list of tables
4.2	20.05.2016	Updated the requirement specification DNV to v4.1
4.1	18.05.2016	Updated the requirement specification table
4.0	14.05.2016	Changed the name of the source list to reference list Updated the reference list Removed: Colum from tables; requirements and requirements DNV
3.0	09.05.2016	Updated Requirement specification to v5.0 Updated Requirement specification DNV to v4.0 Updated Situation analysis to v3.0 Updated 1.4.1 DNV 2.7-3. Updated source list. Made list of figures and tables.
2.0	07.03.2016	Changed 1.4.1 DNV. Changed the situation analysis. Updated 1.1 Situation analysis to v2.0. Updated 2.1 Requirements to v3.0. Updated 2.2 Requirements DNV to v3.0. Changed colors. Updated the source list.

In addition to the above:

There may be spelling mistakes that are corrected. It is possible that these changes are not listed.

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INTRODUCTION

The purpose of the OLC Engineering requirement specification is to document all the requirements that needs to be followed throughout the project. These requirements are the foundation of the entire design process. It is therefore of great importance that all the main requirements are in place as early as possible. Most of these requirements are given by OLC's employee; FMC. In addition, OLC have made some requirements by themselves. There are also quite a lot of requirements given from standards and laws which the group need to take into account. In order to make it easier to define requirements the group have also made a situation analysis that describes typical scenarios the lifting clamp will face. When it comes to the stakeholders in the project OLC have divided these into active and passive stakeholders.

1. REQUIREMENT SPECIFICATION

1.1 SITUATION ANALYSIS

Handling lifting equipment offshore involves taking into account several important factors. One of the key factors is to fulfill various requirements when it comes to performing lifts, storage and checking, and maintenance of the lifting equipment by the usage of standards. In today's lifting operations there are different requirements for different environments. In offshore operations, the requirements are stricter than it is onshore. Lifting operations offshore is heavily reliant on DNV standards. The standards ensures that the lifting equipment in lifting operations is used in a safe and reliable way. The standard leads to limitation of lifting operations because of the need to adhere to strict rules, but this is still an important measure that needs to be done in offshore lifting operations.

(DNV provides that the lifting equipment is correctly dimensioned and is certified for its use, while NORSOK ensures that the lifting equipment in lifting operations is used in a safe and reliable way.)

Lifting operations are processes where the risks are high and the possibility for injuries increase. In addition to personal injury, an accident can cause heavy costs if something should go wrong. There are therefore performed risk assessments in the form of an analysis. The risk assessment analysis makes it easier to handle a lifting operation because personnel are then aware of the degree of risk. It is important to stop the operation as quickly as possible, if there are observed or discovered any aberrations or changes during the lifting operation.^[5] One of the most important parts of the process is to plan the lifting operation before the operation is performed. The planning is done to ensure that the execution takes place in a precise way.

By planning, it assures that:

- People who are involved in the lifting operation are informed about practical things like weight of the cargo, what different lifting equipment that are going to be used, what is going to be lifted and how the plan of action is going to be.^[5]
- The safety barriers is considered. ^[5]
- Clarification of path, and removing things that can prevent the lift, in addition to lock down of the area so it is not possible to stand under the suspended loads. ^[5]

→ Various frequencies between two ships or a ship and platform are registered and compensated for. [5]

→ Personnel agrees to type of communication to be used during the lifting operation and that there are sufficient personnel during the entire operation. The personnel should also have sufficient expertise and knowledge of the rules and various standards that are fundamental for the lifting operation. [5]

→ Lifting appliances and lifting devices shall be used in accordance with manufacturer's instructions. [5]

→ The area where the cargo will land is dimensioned in terms of weight and size of the load. [5]

Wind and weather may be restrictions offshore because it is important to have good wind and weather conditions when the various operations and installations are performed offshore. Meaning that the waves should be low and that there are not too much wind.

The main parameters that must be measured thoroughly before performing operations or installations are wind, pressure and wave data. The air and sea temperature, humidity, pressure, wind, wavelength and visibility are usually measured on offshore boats and ships. Other limitations may also be movements and blind spots during the operation, which is difficult to control, and can be a problem during the lifting operation. [7], [5]

Storage of lifting equipment is done to protect it against the weather and other harmful effects when it is not in use. Before any lift, it is important to perform a prior and post-usage check to be certain that it is safe to use the selected lifting gear. The lifting equipment that are damaged or worn are marked and then later collected for disposal or repair. For practical reasons the storage location for the lifting equipment is close to where the lifting operation is taking place. By storing the lifting equipment properly, the lifetime is increased.

When it comes to the lifting clamp, a typical scenario is internal lifting, lifting a pipe from A to B on the deck of a ship. For every lifting operation, the different phases for the lift are reviewed in beforehand.

The main areas for lifting are:

- Onshore
- Offshore

Onshore lift is a type of lift that takes place on land, however, the offshore lift is performed out at sea.

Both onshore and offshore lifting can be further divided into different types of lift. One type of offshore lifting is offboard lift. An offboard lift is executed offshore, where you lift something from a vessel and onto another vessel.^[8] For example, from a boat and over to a platform. Offboard lifting does not include internal lifts on vessels.

There is higher and more rigorous safety requirements for performing an offboard lift. The reason for the rigorous requirements for an offboard lift is involvement of higher risks and greater consequences, and thus the strict requirements contribute to preventing accidents and incidents. As showed in the following picture, lifts can have many different lifting areas. ^{[4],[5]}

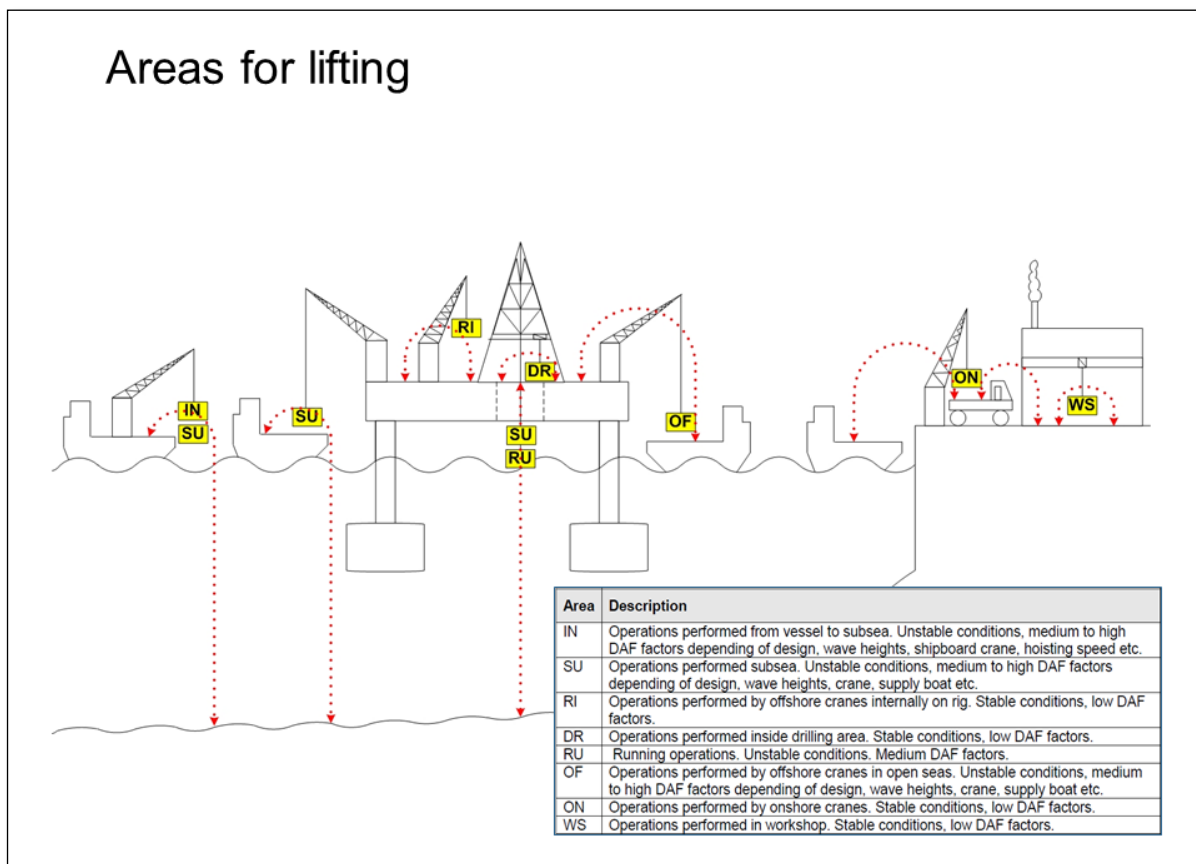


FIGURE 1: Different lifting scenarios for different areas ^[6]

When it comes to OLC's lift, it is important to follow the regulations and standards in order to do the procedure. The standards OLC are using are the DNV 2.22 and DNV 2.7-3.

Since the operation is most likely to happen offshore, OLC need to be aware that the weather conditions may be harsh. There are limits when it comes to how high the waves are, and if the lifting operation can be performed or not.

1.2 STAKEHOLDERS

Stakeholders are persons or groups who are interested in the project. The stakeholders for the OLC Engineering project are divided into active and passive, and the aim is to succeed in completing the requirements given by them. The active stakeholders are those who are directly affected by the project. The passive stakeholders are those who are influenced indirectly by the project. [1], [2]

1.2.1 ACTIVE STAKEHOLDERS

The active stakeholders for the project are OLC, DNV- Det norske veritas, HSN – University College of Southeast Norway, and the group's customer and employer FMC Technologies. The stakeholders will lead the group to both perform the requirements in a satisfying way and to achieve the goals in the project. OLC Engineering will cooperate and get guidance from the external and the internal supervisors in addition to examiners from FMC Technologies and HSN. This will be achieved by communicating through e-mails, have meetings, and have their attendance at OLC's presentations.

1.2.2 PASSIVE STAKEHOLDERS

The passive stakeholders are those people who has an indirectly influence on the project, considering that they are the persons who will use the lifting clamp. For example: Persons who transport the lifting clamp, persons who perform the maintenance on the lifting clamp and persons who are certified to carry out lifting operations. It is important that OLC Engineering provide a lifting clamp that is easy to both handle and to use. By doing this, the group's passive stakeholders will get satisfied with the lifting clamp.

1.2.3 DETERMINE REQUIREMENTS

As mentioned in the introduction most of the requirements are given to the group from FMC. The group have already had several meetings with FMC, where FMC have told what OLC need to focus on when it comes to the product. FMC's main request is to focus on the reduction of:

- Weight
- Mounting time
- Production cost

The main reasons for FMC's request is that they want the lifting clamp to be less heavy so that it can be carried by hand. When using the lifting clamp the personnel first need to hoist the clamp into place before the real lift can take place. This is because of the high weight of the clamp (58 kg). By reducing the weight of the clamp, the performance of lifting operations will go easier. FMC also want the mounting of the clamp to be done as easy and quickly as possible. Besides, the longer the rigging time takes the more expensive the operation becomes. When it comes to the production cost, this is because the solutions FMC have today are quite expensive.

The group have also made some requirements by themselves. These requirements are requirements that personalize the end product and make it one of a kind.

In addition to the requirements given by FMC, OLC also learned that there was several standards that needed to be followed when designing a new lifting gear. FMC told the group that the main standards they needed to focus on were the DNV 2.22 and the DNV 2.7-3.

1.3 DNV

Det Norske Veritas (DNV) is a Norwegian foundation that owns enterprises within ships classification, certification, consulting, testing, inspection and research through the group DNV GL. [3]

After receiving more information from FMC about the given task, OLC understood that in order to get a good result it was crucial for the group to follow the previously mentioned DNV standards 2.22 and 2.7-3.

1.3.1 DNV 2.7-3

Contains information about portable offshore units (PO-Units) including lifting arrangements with a maximum gross weight (MGW) which is less or equal to 100 tons. PO Units are different types of tools that perform lifting. PO Units are divided into five groups A, B, C, D and E. [9]

To find out which requirements that applied for OLC's PO Unit, the group used a table from DNV 2.7-3

Selection of Operational Classes			
<i>Type</i>	<i>Risk</i>	<i>MGW</i>	<i>Class</i>
A	Low	$MGW \leq 25 \text{ t}$	R60
A	Low	$MGW > 25 \text{ t}$	R45
A	High	$MGW \leq 25 \text{ t}$	R45
A	High	$MGW > 25 \text{ t}$	R30
B	Low	$MGW \leq 15 \text{ t}$	R60
B	Low	$MGW > 15 \text{ t}$	R45
B	High	$MGW \leq 15 \text{ t}$	R45
B	High	$MGW > 15 \text{ t}$	R30
C	High	$MGW \leq 15 \text{ t}$	R45
C	High	$MGW > 15 \text{ t}$	R30
D	High/Low	$MGW \leq 10 \text{ t}$	R45
D	High/Low	$MGW > 10 \text{ t}$	R30
E	Low	$MGW \leq 15 \text{ t}$	R60
E	Low	$MGW > 15 \text{ t}$	R45
E	High	$MGW \leq 15 \text{ t}$	R45
E	High	$MGW > 15 \text{ t}$	R30

Tabell 1: Selection of Operational Classes [9]

OLC's clamp is a PO Unit of type E, this because it is a customized lifting tool, which connects to a load. [9]

The group concluded that the PO unit has a high risk according to the risk evaluation in DNV 2.7-3. [9]

The maximum gross weight – MGW is less than 15 ton.

The operational class of OLC's portable offshore unit is R45, meaning that the waves can be at a maximum of 4,5 meters high during lifting operations. [9]

OLC's PO unit is going to be used in an off board lift in addition to normal offshore lifts, and must therefore be dimensioned according to R60, even if it only should be used in R45.[8]

1.3.2 DNV 2.22

Contains information about lifting appliances and cranes onboard ships and offshore installations.

Because of the need to follow the DNV standards and since there are so many requirements within the standards, OLC have made a separately requirement specification list for the DNV requirements only.

OLC have received some information about an existing lifting clamp from FMC including drawings. This information makes it easier to find out what is important in the DNV standards. For instance, when it comes to minimum material thickness OLC know that it has to be between 4 mm and 6 mm. [9]

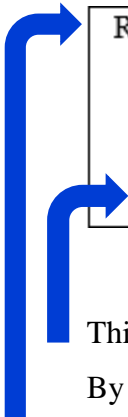
1.4 PRIORITIES

The requirements are divided into priorities of high, medium and low importance. The letters A, B and C. indicate this. Here the A requirement means that the requirement shall be achieved. The B requirement means that it should be achieved. While the C requirement is a requirement that can or may be achieved. When OLC are going to refer to a priority by its ID the group have decided to use the numbers 1, 2 and 3 instead of the letters A, B and C.

1.5 TRACEABILITY

In order to keep track of all the requirements OLC have given each requirement its own unique ID. By doing this, the group are able to trace back every single requirement and find

out things such as who made it. The group do also have a list of all the changes that have been done with the requirements and can easily find previous versions of the requirements.



R3.2.0	Different diameters The lifting clamp should have the option to lift pipes with different diameters. <i>Given by FMC</i>	B		
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FIGURE 2: Example of requirement

This particular requirement is given to OLC by FMC as seen on the bottom line.

By looking at the identification number, it is seen that it has an R, this stands for requirement. The number 3 indicates that it belongs to a certain class. This requirement belongs within the design requirements. The next number, the number 2 indicates the priority of the requirement. As mentioned earlier if it is a 1 the requirement has an A priority, if it is a 2 it has a B priority and if it is a 3 it has a C priority. In this case the requirement has a priority of B meaning that the requirement should be accomplished. The last number of the ID tells what the number of the requirement it is within its class. Since the number here is 0 this means that it is the first requirement that has been made within its class.

Every requirement will be linked to the activity specification list and the test specification. In this way, OLC can trace each requirement to the corresponding activity and test.

1.6 RESULT

The color-coded table found below shows by color if the requirements in the requirements specification and the requirements specification DNV are approved or not.

The requirement is approved
The requirement is not approved
The requirement is not tested, or partially tested.
The requirement is no longer applicable for OLC's solution.

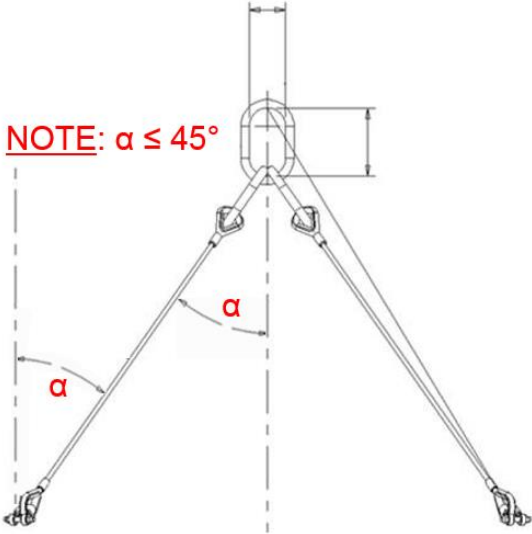
Tabell 2: Color codes

2 REQUIREMENT SPECIFICATION LISTS

2.1 REQUIREMENTS

Project name	Offshore Lifting Clamp Engineering	Version number	6.0	
Group name	Group 5	Date	18.05.2016	
Requirement specification				
ID	Requirements	PRI	Result	Test
Main requirement				
R1	DNV 2.7-3 Shall follow the DNV 2.7-3. <i>Public requirement</i>	A		T1
R2	DNV 2.22 Shall follow the DNV 2.22. <i>Public requirement</i>	A		T2
Design requirement				
R3.1.0	Weight The lifting clamp shall weigh less than 58kg. <i>Given by FMC</i>	A		T3.1.0.1 T3.1.0.2
R3.1.1	Locking mechanism The locking mechanism of the lifting clamp shall have double barriers. <i>Given by FMC</i>	A		T3.1.1.0
R3.1.2	SWL The lifting clamp shall have a SWL (Safe working load) of minimum 4100kg. <i>Given by FMC</i>	A		T3.1.2.0
R3.1.3	Standardized parts The lifting clamp shall fit with existing standardized slings, shackles, forerunners and other lifting products relative to DNV. <i>Given by FMC</i>	A		T3.1.3.0 T3.1.3.1

R3.1.4	Width of the lifting clamp The width of the clamp shall not exceed 300 mm. <i>Given by FMC</i>	A		T3.1.4.0 T3.1.4.1
R3.2.0	Different diameters The lifting clamp should have the option to lift pipes with different diameters. <i>Given by FMC</i>	B		T3.2.0.0 T3.2.0.1
R3.2.1	Standardization The lifting clamp should be standardized in such a way that the clamp will fit several types of pipes. <i>Given by FMC</i>	B		T3.2.1.0
R3.3.0	Automatic closing The lifting clamp can have an automatic closing feature, which is accomplished without the need of human force. <i>Given by the project group</i>	C		T3.3.0.1 T3.3.0.2
R3.3.1	Taken subsea The lifting clamp can be taken subsea. <i>Given by the project group</i>	C		T3.3.1.0
R3.3.2	Submerged in the ocean The lifting clamp can be made out of a material that can withstand being taken subsea. <i>Given by the project group</i>	C		T3.3.2.0
Documentation				
R4.1.0	THI The lifting clamp shall include THI (Transport and handling instruction). <i>Given by FMC and DNV 2.7-3_[9]</i>	A		T4.1.0.0
R4.1.2	CE The lifting clamp shall be CE marked. <i>Given by FMC</i>	A		T4.1.2.0
Performing lifting operations				

R5.1.0	Offboard lift The lifting clamp shall be designed to perform offboard lifts. <i>Given by FMC</i>	A		T5.1.0.1 T5.1.0.2
R5.1.1	Lifting The lifting clamp shall be fastened in such a way that there is no danger of the clamp to slide, during the lifting operation. <i>Given by FMC</i>	A		T5.1.1.0
R5.1.2	Sling angle The angle of the sling during a lift shall not exceed 45°  FIGURE 3: Sling Angle [6] <i>Given by FMC</i>	A		T5.1.2.0
R5.1.3	Temperature The lifting clamp shall tolerate being used at temperatures between -40°C and 50°C. <i>Given by FMC</i>	A		T5.1.3.0
R5.1.4	Tightened to pipe The lifting clamp shall be tightened in such a way that	A		T5.1.4.0

	there is no danger of the clamp to slide or move out of position after it has been mounted on the pipe. <i>Given by FMC</i>			
R5.1.5	Force on tightening mechanism If a tightening mechanism is chosen to tighten an existing lifting gear, the tightening mechanism must withstand an increase of applied force during lifting. <i>Given by FMC</i>	A		T5.1.5.0
R5.1.6	Hands off The lifting equipment must be “hands off”, meaning after it has been installed it shall perform the lift with no human contact or interference. <i>Given by FMC</i>	A		T5.1.6.0
R5.3.0	Working hours Mounting the lifting clamp can take maximum 1 hour. <i>Given by FMC</i>	C		T5.3.0.0
R5.3.1	Carried by person The lifting clamp can be carried by one person. Weight limit is 25kg. <i>Given by FMC and NORSOK R-002_[8]</i>	C		T5.3.1.1 T5.3.2.1
R5.3.2	Center of gravity The lifting clamp can compensate for changing center of gravity during lifting operations. <i>Given by FMC</i>	C		T5.3.2.1 T5.3.2.2
Production				
R6.1.0	Production cost 1 The production cost shall be reduced by 10%. <i>Given by FMC</i>	A		T6.1.0.0
R6.2.0	Production cost 2 The production cost should be reduced by 50%. <i>Given by FMC</i>	B		T.6.2.0.0
R6.3.0	Production cost 3 The production cost can be reduced by 80%.	C		T6.3.0.0

	Given by FMC			
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Tabell 3: Main requirement specification list

ID: Identification number

PRI: Prioritized requirements: A, B or C.

2.2 REQUIREMENTS DNV

Project name	Offshore Lifting Clamp Engineering				Version number	5.0																										
Group name	Group 5				Date	20.05.2016																										
Requirement specification																																
ID	Requirements DNV				PRI	Results	Test																									
DNV 2.7-3																																
R1.1.0	Minimum material thickness The following minimum material thicknesses apply: <table><tr><th colspan="5">Minimum Thicknesses</th></tr><tr><th>MGW</th><th colspan="2">Single events</th><th colspan="2">Multiple events</th></tr><tr><td>0-1t</td><td>3 mm</td><td>3 mm</td><td>4 mm</td><td>4 mm</td></tr><tr><td>1-25t</td><td>5 mm</td><td>4 mm</td><td>6 mm</td><td>4 mm</td></tr><tr><td>>25t</td><td>6 mm</td><td>5 mm</td><td>8 mm</td><td>6 mm</td></tr></table> <p>TABLE 5: Minimum material thickness [9]</p> The thickness may be decreased below these values after special consideration. [9]				Minimum Thicknesses					MGW	Single events		Multiple events		0-1t	3 mm	3 mm	4 mm	4 mm	1-25t	5 mm	4 mm	6 mm	4 mm	>25t	6 mm	5 mm	8 mm	6 mm	A		T1.1.0.0 T1.1.0.1
Minimum Thicknesses																																
MGW	Single events		Multiple events																													
0-1t	3 mm	3 mm	4 mm	4 mm																												
1-25t	5 mm	4 mm	6 mm	4 mm																												
>25t	6 mm	5 mm	8 mm	6 mm																												
R1.1.1	Steel bolts, nuts and pins Bolts and pins considered essential for structural integrity and operating safety shall conform to a recognized code or standard. [9]				A		T1.1.1.0 T1.1.1.1																									
R1.1.3	Allowable stresses Design loads shall not produce Von Mises equivalent stresses, σ _e exceeding: σ _e = 0.85 x R _e (yield				A		T1.1.3																									

	stress).[9]																		
R1.1.6	<p>Design loads basis</p> <p>The design loading on all elements in a lift with lifting slings shall be calculated based on F (in kN) where F is the greater of F_{Air} and F_{Sub} (if applicable). The following definitions apply: For all PO Units:</p> <p>F_{air} = DF x MGW x g</p> <p>Where the design factor, DF, is defined according to the Operational Class and MGW in the table:</p> <table><tr><th colspan="3">Design Factors – DF</th></tr><tr><th>Operational class</th><th>MGW < 50 tonnes</th><th>MGW ≥ 50 tonnes</th></tr><tr><td>R60</td><td>1.4+0.8x $\sqrt{50/MGW}$</td><td>2.2</td></tr><tr><td>R45</td><td>1.4+0.6x $\sqrt{50/MGW}$</td><td>2.0</td></tr><tr><td>R30</td><td>1.4+0.4x $\sqrt{50/MGW}$</td><td>1.8</td></tr></table> <p>TABLE 6: Design Factors - DF ([9])</p> <p>For subsea PO Units: F_{Sub} = 2.5 x MGW x g is normally adequate. [9]</p>	Design Factors – DF			Operational class	MGW < 50 tonnes	MGW ≥ 50 tonnes	R60	1.4+0.8x $\sqrt{50/MGW}$	2.2	R45	1.4+0.6x $\sqrt{50/MGW}$	2.0	R30	1.4+0.4x $\sqrt{50/MGW}$	1.8	A		T1.1.6
Design Factors – DF																			
Operational class	MGW < 50 tonnes	MGW ≥ 50 tonnes																	
R60	1.4+0.8x $\sqrt{50/MGW}$	2.2																	
R45	1.4+0.6x $\sqrt{50/MGW}$	2.0																	
R30	1.4+0.4x $\sqrt{50/MGW}$	1.8																	
R1.1.7	<p>Design load application</p> <p>For the normal lift condition the design loading for the PO UNIT global strength calculation/analysis shall be calculated based on F.[9]</p>	A		T1.1.7															

R1.1.8	Lifting Points Other alternative design than padeyes shall be used if better safety is documented. ^[9]	A		T1.1.8.0 T1.1.8.1
R1.1.10	Coating and corrosion protection PO Units shall be suitable for the offshore environment by means of construction, use of suitable material and/or corrosion and paint protection. ^[9]	A		T1.1.10
R1.1.11	Marking – General Marking shall be located in a prominent place. The location and elevation shall allow the marking plates and marking text to be easily read by a person standing beside the PO Unit. ^[9]	A		T1.1.11
R1.1.12	Information Plates PO Units shall be fitted with an information plate. ^[9]	A		T1.1.12
R1.1.13	Production documentation - Basis for certification The certification of each PO Unit shall be based on the documentation by the manufacturer. ^[9]	A		T1.1.13
R1.1.15	Manufacture – General Manufacture shall be performed according to approved drawings, production documents, identification of materials, specifications and procedures. ^[9]	A		T1.1.15
R1.1.16	Manufacture – Materials Metals utilized in primary structures shall as a minimum be supplied with a work certificate and be possible to identify. ^[9]	A		T1.1.16.0 T1.1.16.1
R1.1.18	Master link dimension The master link that is attached to the crane hook shall have minimum internal dimensions 270 x 140 mm. ^[9]	A		T1.1.18.0 T1.1.18.1

R1.1.19	Sling minimum dimensions The minimum dimensions of the sling shall follow the table for Minimum Sling Diameter (D), for R60. <div> <table> <tr> <th colspan="5">Minimum Sling Diameter (D)</th></tr> <tr> <th rowspan="2">Class</th><th colspan="2">Wire rope slings</th><th colspan="2">Chain slings</th></tr> <tr> <th>Single event</th><th>Multiple use</th><th>Single event</th><th>Multiple use</th></tr> <tr> <td>R30</td><td>$D \geq 10\text{mm}$</td><td>$D \geq 12\text{mm}$</td><td>$D \geq 7\text{mm}$</td><td>$D \geq 8\text{mm}$</td></tr> <tr> <td>R45</td><td>$D \geq 12\text{mm}$</td><td>$D \geq 15\text{mm}$</td><td>$D \geq 8\text{mm}$</td><td>$D \geq 10\text{mm}$</td></tr> <tr> <td>R60</td><td>$D \geq 14\text{mm}$</td><td>$D \geq 18\text{mm}$</td><td>$D \geq 8\text{mm}$</td><td>$D \geq 10\text{mm}$</td></tr> </table> <p>TABLE 7: Minimum Sling Diameter (D) [9]</p> </div>	Minimum Sling Diameter (D)					Class	Wire rope slings		Chain slings		Single event	Multiple use	Single event	Multiple use	R30	$D \geq 10\text{mm}$	$D \geq 12\text{mm}$	$D \geq 7\text{mm}$	$D \geq 8\text{mm}$	R45	$D \geq 12\text{mm}$	$D \geq 15\text{mm}$	$D \geq 8\text{mm}$	$D \geq 10\text{mm}$	R60	$D \geq 14\text{mm}$	$D \geq 18\text{mm}$	$D \geq 8\text{mm}$	$D \geq 10\text{mm}$	A		T1.1.19.0 T1.1.19.1
Minimum Sling Diameter (D)																																	
Class	Wire rope slings		Chain slings																														
	Single event	Multiple use	Single event	Multiple use																													
R30	$D \geq 10\text{mm}$	$D \geq 12\text{mm}$	$D \geq 7\text{mm}$	$D \geq 8\text{mm}$																													
R45	$D \geq 12\text{mm}$	$D \geq 15\text{mm}$	$D \geq 8\text{mm}$	$D \geq 10\text{mm}$																													
R60	$D \geq 14\text{mm}$	$D \geq 18\text{mm}$	$D \geq 8\text{mm}$	$D \geq 10\text{mm}$																													
DNV 2.22																																	
R2.1.5	Lifting gear strength Design and strength of lifting gear shall comply with recognized codes or standards.[10]	A		T.2.1.5																													

Tabell 4: DNV requirement specification list

ID: Identification number

PRI: Prioritized requirements: A, B or C.

All of the OLC's DNV requirements are found in DNV 2.7-3 and DNV 2.22. In some requirements OLC have changed or removed parts of the requirement in order for the requirement to apply to the group's PO-Unit. This has been done without affecting the requirement in any wrong way.

3 CONCLUSION

Requirement specification includes an analysis of the situation offshore. This analysis must be adhered to when working with lifting equipment and in lifting scenarios. By doing this the lifts will be more predictable and more safe to perform. OLC has determined both active and passive stakeholders who will be in focus during the entire project. Definition of the various requirements was made by OLC based on the information and requirements from the stakeholders; in addition, that OLC also defined some requirements by themselves.

The Requirements are divided into A, B and C priorities that indicates high, medium and low importance. The A priority must be fulfilled in order to satisfy requirements given by the customer and to achieve a good product with high quality. All requirements have an individual identification number, which leads to better traceability.

4 REFERENCES

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- [6] Lifting symposium 2015, Bjørn Michaelsen 18. November 2015
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- [9] DNV 2.7-3 May 2011
- [10] DNV 2.22 June 2013



OFFSHORE LIFTING CLAMP ENGINEERING
VERSION 1.0

TEST REPORT

20.05.16

ABSTRACT

The test report describes the test specifications, test plan, test method, test components, result description and test based on main requirements & DNV requirements. The purpose of the test report is to document that the product meets the requirements given by the stakeholders and OLC. This is done by performing tests and analyzing results. Reading this report will give a detailed understanding about the contents of test specification and the test plan.

CHANGES

The changes will be listed here:

Version	Date	Description
		•

In addition to the above.

There may be spelling mistakes that are corrected. It is possible that these changes are not listed.

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INTRODUCTION

The document consists of test specification which describes all the tests that needs to be done in order to approve the requirements given in the requirement specification, and a test plan which described the execution and results of the tests.

The goal is to have an optimal and improved design of the clamp, compared to the existing version of the clamp. Testing needs to be done repeatedly during the project period, because the whole purpose with the test specification and test plan is to check if the clamp works as expected, and if it meets the requirement specifications. By cross checking and testing the specifications by doing various tests, it is possible to see if the product is verified and validated, or if there is room for improvement.

1. TEST SPECIFICATION

Test specifications ensure that the product is built correct, and that the correct product is built. Based on the requirement specifications, OLC have developed a set of test specifications to verify and validate that the group is designing a product in correlation with the requirements given by the customer and by the regulations. Each requirement shall have a test connected to it, so that each requirement can be tested.

1.1 PRIORITIES

The goal of the tests is that the clamp shall work adequately based on the requirements of FMC Technologies. OLC have written requirements based on the DNV standard, situation analysis and the requests from FMC Technologies to achieve the goals. The requirements written are prioritized in A-, B- and C- demands, wherein:

- A- demands are requirements that *shall be* achieved.
- B- demands are requirements that *should be* achieved.
- C- demands are requirements that *can be* achieved.

OLCs test specifications are performed according to the priority of the requirement specifications. A- demands shall be tested and verified before performing the B- demands and so on.

1.2 TRACEABILITY

The test specification includes a lot of information in order to maintain a good traceability. It is important that it is easy to trace the test specifications back to the corresponding requirement. This in addition to things like who performed the test and when it was done. In the test specification document, OLC have ensured traceability by:

- ➔ ID-number: Connects each test to a specific ID number. All of the test specifications starts with the letter T. In all of our documents, ID-marks written in the form of: *T.x.x.x.x*, refer to the test specifications
- ➔ PRI: The column marked as PRI, determines the priority of the tests
- ➔ Results: Results includes results of the test (if the test is passed or not), the date of the test and the initials of the person initiating the test.
- ➔ Req.: Req refer to the corresponding requirement. This way OLC can always link the ongoing test of the product to the specific requirement for the desired outcome.

1.3 TEST SPECIFICATION CATEGORIES

This document includes two test specification documents: “Test specification” and “Test specification DNV”. The report is based upon the two requirement specification documents. The first document includes testing of the main requirements, and the second document consists of requirements from the DNV standards.

The two test specification documents have been categorized according to the corresponding categorization of the requirement specifications.

Test specification categories	
Categories	Description
Main test	Concerns the DNV requirements. Testing of these requirements is written in “ <i>Test specification DNV</i> ”.
Design Test	Testing of the requirements connected to the design specifications.
Documentations	Testing of requirements related to the documentation of the project.
Performing lifting operations	Testing the requirements connected to the lifting of the clamp and equipment.
Production	Testing of requirements corresponding to the production of the lifting clamp.
DNV 2.7-3	Defines the tests corresponding to the requirements connected to DNV 2.7-3.
DNV 2.22	Tests attached to the requirements connecting to DNV 2.22.
DNV 2.7-3 Testing	Defines the tests corresponding to requirement R1 that involves following DNV 2.7-3. Within the DNV 2.7-3 there are a number of requirements about how tests should be performed. It is important to perform these tests to satisfy requirement R1.

TABLE 1 : TEST SPECIFICATION CATEGORIES

2. TEST SPECIFICATION LIST

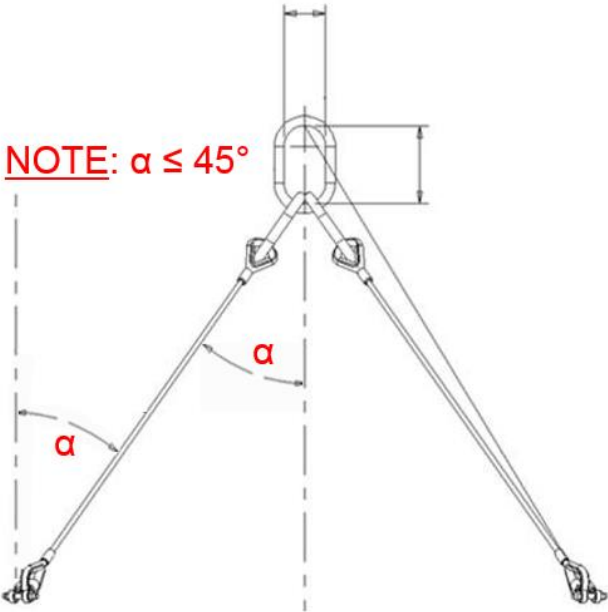
1	Project name	Offshore Lifting Clamp Engineering	Version number	5.0	
	Group name	Group 5	Date	18.05.2016	
Test specification					
ID	Test and description		PRI	Results	Req
Main Test					
T1	DNV 2.7-3 Complete the test specification for DNV 2.7-3		A	Described in the next table	R1
T2	DNV 2.22 Complete the test specifications for DNV 2.22		A	Described in the next table	R2
Design Test					
T3.1.0.1	3D Weight When working on design: Simulating weight of the clamp by acquiring suitable types of materials to the 3D-model. <i>The simulated weight shall be < 58kg.</i>		A	Passed 06.05.2016 HL, SK, HG	R3.1.0
T3.1.0.2	Model Weight Control the weight of a produced model of the clamp. <i>The measured weight shall be < 58kg.</i>		A	Passed 06.05.2016 HL, SK	R3.1.0
T3.1.1.0	3D Double barrier When working on design: Ensure that the 3D-model has two locking mechanisms that works individually. <i>The lifting clamp shall have double barrier on the locking mechanism.</i>		A	Not passed 06.05.2016 HL, SK, HG, MR, NL	R3.1.1

T3.1.2.0	Minimum SWL When working on design: To achieve SWL on 4100kg we need to test the design with the safety factor of 2.5. <i>The 3D-model shall withstand a simulated workload of > 10250 kg.</i>	A	Not tested	R3.1.2
T3.1.3.0	3D Standardized parts When working on the design: Assure that the diameters and lengths on the 3D-model are equal to the measurement given from known standards. <i>The lifting clamp shall fit with standardized slings, shackles, forerunners and other lifting products relative to DNV.</i>	A	Passed 06.05.2016 HL, SK, HG, MR, NL	R3.1.3
T3.1.3.1	Model Standardized parts Control the measurements of a produced model of the clamp. <i>The lifting clamp shall fit with standardized slings, shackles, forerunners and other lifting products relative to DNV.</i>	A	Passed 05.05.2016 HL, SK, HG, MR, NL	R3.1.3
T3.1.4.0	3D clamp width While working on design: Measure the width of the lifting clamp on the 3D-model and drawings. <i>The width of the lifting clamp shall not exceed 300 mm.</i>	A	Passed 19.05.2016 NL	R3.1.4
T3.1.4.1	Model clamp width Physical tests on a model: Ensure that the width of a physical model is	A	Passed 06.05.2016	R3.1.4

	<p>within the limits set for the width of the lifting clamp.</p> <p><i>The width of the lifting clamp shall not exceed 300 mm.</i></p>		HL, SK, HG, MR, NL	
T3.2.0.0	<p>3D Pipe diameter</p> <p>While working on the design:</p> <p>Control that the 3D-design includes implementation of options for lifting pipes of different diameters.</p> <p><i>The lifting clamp shall be able to lift pipes with different diameters.</i></p>	B	Not tested	R3.2.0
T3.2.0.1	<p>Model Pipe diameter</p> <p>Control that the produced prototype and model fits pipes of different diameters and that you can successfully perform lifts.</p> <p><i>The lifting clamp shall be able to lift pipes with different diameters.</i></p>	B	<p>Passed</p> <p>05.05.2016</p> <p>06.05.2016</p> <p>HL, SK, HG, MR, NL</p>	R3.2.0
T3.2.1.0	<p>Pipe ability</p> <p>Control if the prototype and model of the lifting clamp can fit different types of pipes, joints and risers, with small or no modifications.</p> <p><i>Does the lifting clamp fit different types of pipes?</i></p>	B	Not tested	R3.2.1
T3.3.0.1	<p>3D Closing Ability</p> <p>While working on the design:</p> <p>Control if the 3D design includes a mechanism for automatic closing.</p>	C	<p>Passed</p> <p>06.05.2016</p> <p>HL, SK</p>	R3.3.0

	<i>Does the design include a mechanism for automatic closing?</i>			
T3.3.0.2	Model Closing Ability Control on a physical model of the lifting clamp if it manages to close automatically. <i>Does the physical model have an automatic closing?</i>	C	Passed 06.05.2016 HL, SK	R3.3.0
T3.3.1.0	Subsea Control if the use of the lifting clamp includes being taken subsea. <i>Does the use of the physical model includes being taken subsea?</i>	C	Not tested	R3.3.1
T3.3.2.0	Submerged Control the materials of the physical model in a climate chamber or with a similar method for simulating subsea environment. <i>Does the physical model withstand being taken subsea?</i>	C	Not tested	R3.3.2
Documentation				
T4.1.0.0	THI Product Control if the final product includes THI. <i>The lifting clamp shall include THI.</i>	A	Not tested	R4.1.0
T4.1.2.0	CE Product Control if the product fulfills the requirements of CE-marking, and if it has a CE-certificate. <i>The product shall have a CE-certificate</i>	A	Not tested	R4.1.2
Performing lifting operations				

T5.1.0.1	Offboard lift Control if the produced lifting clamp has the required documentation in order to perform offboard lifts. <i>The lifting clamp shall be used when performing offboard lifts.</i>	A	Not tested	R5.1.0
T5.1.0.2	Offboard lift requirement While working on design: Control that the model implements the DNV requirements for offboard lifts. <i>The lifting clamp shall perform offboard lifts.</i>	A	Not tested	R5.1.0
T5.1.1.0	Non sliding Physical tests on a model: A mounted clamp shall be applied extensive forces without sliding. <i>The lifting clamp shall not slide during lifting operations.</i>	A	Passed 05.05.2016 HL, SK, HG, MR, NL	R5.1.1
T5.1.2.0	Lifting Angle Control that the sling during a lifting operation does not exceed 45° <i>The angle of the sling during a lift shall not exceed 45°</i>	A	Passed 05.05.2016 HL, SK, HG, MR, NL	R5.1.2

	 <p>NOTE: $\alpha \leq 45^\circ$</p> <p>FIGURE 1: LIFTING ANGLE [1]</p>			
T5.1.3.0	<p>Temperature range</p> <p>Physical tests on a model:</p> <p>The lifting clamp shall be exposed to minimum and maximum temperatures during a lift, without showing any signs of fatigue, deformations or defects in product and material.</p> <p><i>The lifting clamp shall tolerate being used at temperatures between -40°C and 50°C.</i></p>	A	Not tested	R5.1.3
T5.1.4.0	<p>Tight mounting</p> <p>Physical tests on a model:</p> <p>A mounted clamp shall be applied extensive forces without sliding.</p> <p><i>The lifting clamp shall not slide after it has been mounted on the pipe.</i></p>	A	<p>Passed</p> <p>05.05.2016</p> <p>HL, SK, HG, MR, NL</p>	R5.1.4
T5.1.5.0	<p>TM Force</p> <p>Physical test on model:</p> <p>Perform lifts with maximum SWL on the model, and control that the tightening</p>	A	Not tested	R5.1.5

	<p>mechanism does not show any sign of damage or wear after lift.</p> <p><i>The tightening mechanism must withstand an increase of applied force during lifting.</i></p>			
T5.1.6.0	<p>Hands off</p> <p>Physical test on model:</p> <p>Mount the lifting equipment on a pipe and control that the lifting procedure is performed hands off under different circumstances, simulating</p> <p><i>The lifting equipment must be “hands off”, meaning after it has been installed it shall perform the lift with no human contact or interference.</i></p>	A	Not tested	R5.1.6
T5.3.0.0	<p>Mounting hours</p> <p>Mount the prototype and model of the lifting clamp on a pipe to control if it takes ≤ 1 hour to mount it.</p> <p><i>The lifting clamp shall be mounted in ≤ 1 hour.</i></p>	C	<p>Passed</p> <p>05.05.2016</p> <p>HL, SK, HG, MR, NL</p>	R5.3.0
T5.3.1.1	<p>3D lift weight</p> <p>When working on design:</p> <p>Simulating weight of the clamp by acquiring suitable types of materials to the 3D-model.</p> <p><i>The simulated weight shall be ≤ 25kg.</i></p>	C	<p>Passed</p> <p>19.05.2016</p> <p>HL, SK, HG</p>	R5.3.1
T5.3.1.2	<p>Model lift weight</p> <p>Control the weight of a produced model of the clamp.</p>	C	<p>Passed</p> <p>06.05.2016</p> <p>HL, SK</p>	R5.3.1

	<i>The measured weight shall be $\leq 25\text{kg}$.</i>			
T5.3.2.1	3D Center of gravity Simulations on 3D-model: Control if the design handles a lift with different center of gravity. <i>The lifting clamp can compensate for changing center of gravity during lifting operations.</i>	C	Not tested	R5.3.2
T5.3.2.2	Model Center of gravity Physical test on model: Control if the design handles a lift with different center of gravity. <i>The lifting clamp can compensate for changing center of gravity during lifting operations.</i>	C	Not tested	R5.3.2
Production				
T6.1.0.0	Reduction 10% Create a budget for estimated production costs of the product and compare it to the production costs of an existing equivalent lifting clamp. Control that the production cost of the new product is reduced with 10%. <i>The production cost shall be reduced by 10%.</i>	A	Passed 19.05.2016 HL, SK, MR	R6.1.0
T6.2.0.1	Reduction 50% Create a budget for estimated production costs of the product and compare it to the production costs of an existing equivalent lifting clamp. Control that the production cost of the new product is reduced with 50%. <i>The production cost shall be reduced by 50%.</i>	B	Passed 19.05.2016 HL, SK, MR	R6.2.0

T6.3.0.2	Reduction 80% Create a budget for estimated production costs of the product and compare it to the production costs of an existing equivalent lifting clamp. Control that the production cost of the new product is reduced with 80%. <i>The production cost shall be reduced by 80%.</i>	C	Not passed 19.05.2016 HL, SK, MR	R6.3.0
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TABLE 2: TEST SPECIFICATION LIST

ID: Identification number

PRI: Prioritized requirements: A, B or C.

Results: The result of the test, including the date for test procedure and the initials of the persons initiating the test

Initials:

- Nelly Marie C. Larsen: **NL**

- Hasan Güven: **HG**

- Hanne Lode: **HL**

- Samrit Kaur: **SK**

- Magne Rasmussen: **MR**

3. TEST SPECIFICATION DNV LIST

2. Project name	Offshore Lifting Clamp Engineering	Version number	5.0	
Group name	Group 5	Date	20.05.2016	
Test specification				
ID	Test and description	PRI	Results	Req
DNV 2.7-3				
T1.1.0.0	3D Material When working on the design: Measure that the 3D-model has the minimum thickness required by DNV. <i>The simulated model shall have the minimum material thickness that are required.</i>	A	Passed 19.05.2016 HL, SK, HG	R1.1.0
T1.1.0.1	Model Material Measure the thickness of a produced model of the clamp. <i>The produced clamp shall have the minimum material thickness that are required.</i>	A	Passed 19.05.2016 HL, SK HG	R1.1.0
T1.1.1.0	3D Bolts and fasteners When working on the design: Assure that all bolts, nuts and pins on the 3D-model are listed in the part list and that they have a code or standard. <i>All bolts, nuts and pins shall be marked with a code or standard.</i>	A	Not tested	R1.1.1
T1.1.1.1	Model bolts and fasteners Check that all bolts, nuts and pins on the produced clamp are marked with a code or	A	Not tested	R1.1.1

	<p>standard.</p> <p><i>All bolts, nuts and pins shall be marked with a code or standard.</i></p>			
T1.1.3.0	<p>Stress test</p> <p>When working on the design: Perform FEM analyses on the 3D-model.</p> <p><i>Design loads shall not produce Von Mises equivalent stresses, σ_e exceeding $\sigma_e = 0.85 \times R_e$</i></p>	A	<p>Not Passed</p> <p>19.05.2016</p> <p>HL, SK, HG</p>	R1.1.3
T1.1.6.0	<p>Design Factor</p> <p>Check if the design factor is defined according to the operational class and MGW in table for Design Factors – DF.</p> <p><i>The design loading on all elements in a lift with lifting slings shall be calculated based on F.</i></p>	A	<p>Passed</p> <p>19.05.2016</p> <p>SK, HG</p>	R1.1.6
T1.1.7.0	<p>Design Loads</p> <p>When working on the design: Perform FEM-analysis with all the applied loads occurring during lifting operations.</p> <p><i>For the normal lift condition the design loading for the PO UNIT global strength calculation/analysis shall be calculated based on F.</i></p>		<p>Passed</p> <p>19.05.2016</p> <p>SK, HG</p>	R1.1.7
T1.1.8.0	<p>3D Sling Disconnect</p> <p>When working on the design: Make sure of that there are no possibilities for the sling to disconnect from the lifting point on the 3D-model.</p>	A	<p>Not relevant</p>	R1.1.8

	<i>The possibility of accidental disconnection of sling set shall be duly considered.</i>			
T1.1.8.1	Model Sling disconnect Ensure that there are no possibilities for the sling to disconnect from the lifting point on the produced clamp. <i>The possibility of accidental disconnection of sling set shall be duly considered.</i>	A	Not tested	R1.1.8
T1.1.10.0	Clamp protection Paint the produced clamp and check if it maintains its condition when tested in an offshore environment. This can be done in a climate chamber. <i>PO Units shall be suitable for the offshore environment by means of construction, use of suitable material and/or corrosion and paint protection.</i>	A	Not tested	R1.1.10
T1.1.11.0	Inspection Perform a visual inspection of the produced clamp, and check if all the marking plates and marking text are easily readable when standing next to it. <i>Marking shall be located in a prominent place.</i>	A	Not tested	R1.1.11
T1.1.12.0	Clamp Plate Check if the produced clamp has an information plate fitted onto it. <i>PO Units shall be fitted with an information</i>	A	Not tested	R1.1.12

	<i>plate.</i>			
T1.1.13.0	Production Documentation Check if the documentation the requirement refers to is completed. <i>The certification of each PO Unit shall be based on documentation.</i>	A	Not tested	R1.1.13
T1.1.15.0	Manufacture Approval Ensure that all drawings, specifications and procedures are fulfilled before starting manufacture. <i>Manufacture shall be performed according to approved drawings, specifications and procedures.</i>	A	Not tested	R1.1.15
T1.1.16.0	Identify Material When working on the design: Assure that all parts has been allocated a material. <i>Metals utilized in primary structures shall as a minimum be supplied with a works certificate and be possible to identify.</i>	A	Passed 20.05.2016 HL, SK, HG, MR, NL	R1.1.16
T1.1.16.1	Materials & Traceability Check if produced clamp has included all the materials and their traceability in the documentation. <i>Metals utilized in primary structures shall as a minimum be supplied with a works certificate and be possible to identify.</i>	A	Not tested	R1.1.16
T1.1.18.0	3D Master link	A	Not	R1.1.18

	<p>When working on the design:</p> <p>Assure that the size of the master link on the 3D-model has a dimension of 270 x 140 mm.</p> <p><i>The master link to be attached to the crane hook should have minimum internal dimensions</i></p> <p><i>270 x 140 mm.</i></p>		relevant	
T1.1.18.1	<p>Model Master link</p> <p>Assure that the size of the master link on the produced model has a dimension of 270 x 140 mm.</p> <p><i>The master link to be attached to the crane hook should have minimum internal dimensions</i></p> <p><i>270 x 140 mm.</i></p>	A	Not relevant	R1.1.18
T1.1.19.0	<p>3D Sling Diameter</p> <p>When working on the design:</p> <p>Assure that the minimum sling diameter has a dimension of $D \geq 10$ mm in the 3D model.</p> <p><i>The sling shall have the correct dimensions.</i></p>	A	Passed 20.05.2016 HG	R1.1.19
T1.1.19.1	<p>Model Sling Diameter</p> <p>Assure that the minimum sling diameter on the produced model has a dimension of $D \geq 10$ mm.</p> <p><i>The sling shall have the correct dimensions.</i></p>	A	Passed 20.05.2016 HG	R1.1.19
DNV 2.22				
T2.1.5.0	<p>3D Model Strength</p> <p>When working on the design:</p> <p>Assure that the 3D-model has the strength</p>	A	Passed 20.05.2016	R2.1.5

	that is required when following codes or standards. <i>Design and strength of lifting gear shall comply with recognized codes or standards.</i>		HG	
DNV 2.7-3 Testing				
T.7.1.1.0	Prototype Testing – Lifting The test load shall mimic the PO Unit mass (MGW) distribution as reasonably as possible. The Maximum Gross Weight shall be verified by weighing before a lift test is performed to avoid repeated load tests. ^[9]	A	Not tested	R1

TABLE 3: TEST SPECIFICATION DNV LIST

ID: Identification number

PRI: Prioritized requirements: A, B or C

Results: The result of the test, including the date for test procedure and the initials of the persons initiating the test

Initials:

- Nelly Marie C. Larsen: **NL**
- Hasan Güven: **HG**
- Hanne Lode: **HL**
- Samrit Kaur: **SK**
- Magne Rasmussen: **MR**

DNV 2.7-3 Testing:

Requirement R1 involves to follow DNV 2.7-3. Within the DNV 2.7-3 there are a number of requirements about how tests should be performed. To satisfy requirement R1 it is important that these tests are performed.

4. CONCLUSION TEST SPECIFICATION

The test specification includes an introduction to the testing, and describes all the tests that shall be performed. The tests are based on a requirement. A requirement can have several tests that needs to be approved in order to complete the requirement. The tests are divided into A, B and C priorities, accordingly to the priority of the requirement the test are based on. The test specifications are linked to the requirement specifications, giving it the same categories and type of ID-numbers. All numbers starting with the letter T throughout our project will refer to the test specifications.

The test specification is divided into two tables, corresponding to the requirement specifications; *Main requirement testing* and *DNV requirement testing*.

All the tests have been performed and analyzed in the test plan. The results from the test plan are placed in the test specification tables to give a good overview of the results.

5. TEST PLAN

Based on the test Specifications, OLC have developed a document that shows the progress and results of the tests to the product and its components in order to check whether they meet the requirements set in the specifications. The test plan is made to ensure that all tests in the test specification are performed in a systematic way.

The execution of the tests will provide OLC an insight on how the risk described in the risk assessment report will behave in practice. One of the objectives of testing is to detect any errors, omissions and weakest points of the product, so it is possible to improve the product if necessary. Tests will also give OLC an indication about the quality of the product. Another advantage is to get a better understanding of the practical application of the product.

6. TEST METHOD

OLC have divided the all the tests into four main groups. These four groups have been formed to have the opportunity to perform the same type of tests on the different groups.

6.1 SOLIDWORKS

The tests that are performed in SolidWorks are divided into two subgroups:

1. Design Phase

Design Phase tests are performed by using SolidWorks. The tests are performed on the 3D model of the product. The tests are performed to check whether the product meets design requirements. A design requirement goes partly on the structure, dimensions and weight of the product.

2. FEM

FEM tests are performed by using SolidWorks Simulation. The tests are performed on the 3D model to give an illustration on how the stresses will affect the product in reality.

6.2 PROTOTYPE

The test involves performing physical tests on the prototype, to get an indication of whether the prototype can meet the requirements. This will also give OLC for a visual depiction and the opportunity to see approximately how the final outcome may be.

6.3 MODEL

Tests if the final product will meet the requirement specification so that OLC can conclude whether the final product will be approved for off board lift or not, and if the quality of the final product will be good enough to satisfy the stake holders.

6.4 LIFTING

These tests examine how the product behaves before, during and after lifting. The execution of lifting tests will provide OLC feedback on whether the product meets the requirements and whether the product is suitable for off board lift.

7. TEST COMPONENTS

Relevant tests shall be performed on the components that compose the product as well as the entire system as a unit. These tests will provide OLC a feedback on how components behave individually and how the system interaction is. This will also give OLC information about the functionality of the components and the product as a whole.

7.1 THE MAT

The mat is not lifting equipment in itself, but only a protection for the pipe at that shall keep the sling in the correct position. Since the mat does not take the lift, it is not required to satisfy the various requirements to be approved as lifting equipment. The mat will therefore not need to satisfy all the tests for lifting equipment.

7.2 TIGHTENING MECHANISM

TM's task is to tighten the chain who takes the load of lift, meaning that the TM do not need to satisfy the requirements to be an approved lifting equipment. It will only be performed the appropriate tests on TM, which involves testing for lifting equipment will not be executed.

7.3 HOOK

The Hook attached to the chain will be a part of the lifting equipment and take a part of the lift. It must therefore be tested for all requirements to be approved as a lifting equipment. The tests will provide OLC feedback about if the Hook is suitable as an off board lifting equipment.

7.4 CHAIN

The chain is an already existing lifting product, should be included in several of the tests to get a more realistic result.

7.5 THE SYSTEM

The entire system must be tested as a unit, to check how the various components interact with each other. Testing of the system will show how the different function of the system interacts as a unit. Most components of the system do not need to be approved as lifting tool, since they do not take the load of the lift. The exception is the chain and TM, which must be designed to withstand the lift.

8. RESULT DESCRIPTION

8.1 COLOR CODES

To describe the test results OLC have split the result up into four categories. The four categories have its individual color that describes the results that are inserted into the test plan and test specification, to provide a simple overview and logical understanding of the results.

Test color	Description
Passed	The results satisfy the requirement. The test is performed properly.
Not passed	The results are not optimal, and the requirement is not achieved. Because of occurring faults or deficiencies before, during or/and after testing.
Not relevant	If the components OLC tests are not part of the lift, or for other reasons do not apply to the product.
Not tested	Did not get far enough in the process, lack of proper equipment, lack of test locations or by other obstacles did not have the opportunity to complete the tests at the moment.

TABLE 4: COLOR CODES

8.2 RESULTS TABLE

All tests are inserted into this table.

ID	Test name	Date	Performed by	Status
Test method				
Test	Description of the test.			
Execution	Explanation of the execution of tests.			
Results	Component Test			
	Describes how the test actually was performed and the results, on the testing of the components: Mat TM Hook Chain			
	System Test			
	Describes how the test actually was performed and results on the system test.			

TABLE 5: RESULTS TABLE

9. TEST PLAN TABLES

The tests are listed up in tables that describes all the relevant tests under different test methods, to make it easier to perform the test. The same test can be mentioned in several groups if is necessary to perform one test on several test methods. It is created two tables; one for tests related to the main requirements, and one for tests related to the DNV requirements. This simplifies the job for the person who is going to perform the tests. The person will not have to read through the whole test specification to perform a test.

For example, it will be performed FEM analysis tests in SolidWorks. The person can page up in the table and look at SolidWorks tests, under the FEM analysis tests, in both the tables. Here are the test ID and name of the test described to easily find the test in the test specification.

9.1 TEST PLAN TABLE FOR MAIN TESTS

SolidWorks	Prototype	Model	Lifting
Design Phase	T3.1.0.2 Model Weight	T3.1.0.2 Model Weight	T5.1.1.0 Non sliding
T3.1.0.1 3D Weight	T3.1.3.1 Model Standardized parts	T3.1.3.1 Model Standardized parts	T5.1.2.0 Lifting Angle
T3.1.1.0 3D Double Barrier	T3.1.4.1 Model clamp Width	T3.1.4.1 Model clamp Width	T5.1.6.0 Hands off
T3.1.3.0 3D Standardized parts	T3.2.0.1 Model Pipe diameter	T3.2.0.1 Model Pipe diameter	T5.3.2.2 Model Center of gravity
T3.1.4.0 3D clamp Width	T3.2.1.0 Pipe ability	T3.2.1.0 Pipe ability	
T3.2.0.0 3D Pipe diameter	T3.3.0.2 Model Closing Ability	T3.3.0.2 Model Closing Ability	
T3.3.1.1 3D Closing Ability	T3.3.1.0 Subsea	T3.3.1.0 Subsea	
T5.3.1.1 3D lift weight			

	T3.3.2.0 Submerged	T3.3.2.0 Submerged	
FEM			
T3.1.2.0 Minimum SWL	T5.1.3.0 Temperature range	T4.1.0.0 THI Product	
T5.3.2.1 3D Center of gravity	T5.1.4.0 Tight mounting	T4.1.2.0 CE Product	
	T5.1.5.0 TM Force	T5.1.0.1 Off board lift	
	T5.3.0.0 Mounting hours	T5.1.0.2 Off board lift requirement	
	T5.3.1.2 Model lift weight	T5.1.3.0 Temperature range	
		T5.1.4.0 Tight mounting	
		T 5.1.5.0 TM Force	
		T5.3.0.0 Mounting hours	
		T5.3.1.2 Model lift weight	
		T6.1.0.0 Reduction 10%	
		T6.2.0.0 Reduction 50%	
		T6.3.0.0 Reduction 80%	

TABLE 6: TEST PLAN TABLE FOR MAIN TESTS

9.2 TEST PLAN TABLE FOR DNV TESTS

SolidWorks	Prototype	Model	Lifting
Design Phase	T1.1.0.1 Model material	T1.1.0.1 Model material	
T1.1.0.0 3 D material			
T1.1.1.0 3D Bolts and fasteners	T1.1.1.1 Model Bolts and fasteners	T1.1.1.1 Model Bolts and fasteners	
T1.1.8.0 3D Sling Disconnect	T1.1.6.0 Design Factor	T1.1.6.0 Design Factor	
T1.1.16.0 Identify Material	T1.1.8.1 Model Sling Disconnect	T1.1.8.1 Model Sling Disconnect	
T1.1.18.0 3D Master link	T1.1.10.0 Clamp protection	T1.1.10.0 Clamp protection	
T1.1.19.0 3D Sling Diameter	T1.1.13.0 Product Documentation	T1.1.11.0 Inspection	
T2.1.5.0 3D Model Strength	T1.1.18.1 Model Master link	T1.1.12.0 Clamp Plate	
FEM	T1.1.19.1 Model Sling Diameter	T1.1.13.0 Product Documentation	
T1.1.3.0 Stress test		T1.1.15.0 Manufacture Approval	
T1.1.7.0 Design Loads	T7.1.1.0 Prototype Testing – Lifting	T1.1.16.1 Materials & Traceability	
		T1.1.18.1 Model Master link	
		T1.1.19.1 Model Sling Diameter	

		T7.1.1.0 Prototype Testing - Lifting	
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TABLE 7: TEST PLAN TABLE FOR DNV TESTS

10. THE PERFORMANCE AND THE STATUS OF THE TESTS

All the tests are filled in the result tables in this section. The status of all the tests of this section is also filled into the test specification, to get an overview over the status by reading the test specification. The section is divided into tests based on the main requirements and DNV requirements.

In this test plan all the physical tests that are possible to perform is tested on the prototype. All these tests have to be performed on the finished model as well. The status described in the tables and test specification is based on prototype testing and not testing of the finished product (described as model in this document).

10.1 TESTS BASED ON MAIN REQUIREMENTS

10.1.1 DESIGN TEST

T3.1.0.1	3D Weight	06.05.2016	HL, SK, HG	Passed
SolidWorks				
Test	Control the weight of the produced prototype of the clamp. Weight < 58 kg			
Execution	By weighing all the parts and the entire system. For example: Mat, hooks, TM and chain of 3.17 meters, in SolidWorks.			
Results	Component Test			
	Mat: Weight = 3,313 kg			
	TM: Weight = 1,857 kg			
	Hook: Weight = 3,124 kg			
	Chain: 3 m Chain weight = 3m			
	System Test			
	The entire system including chain.			
	Weight = 22.818			
	22.818 < 58 kg.			
	Incorrect parameters:			
	The weight of the materials chosen in SolidWorks may vary slightly from real materials.			

TABLE 8: TEST T3.1.0.1

T3.1.0.2	Model Weight	06.05.2016	HL, SK	Passed
Prototype				
Test	Control the weight of the produced prototype of the clamp. Weight < 58 kg			
Execution	By weighing the entire system, ie shackles, mat, hooks, and TM. OLC performed two versions of this test, with chain and without chain, with a length of 3 meters.			
Results	Component Test			
	Each of the separate parts is not tested, when this is not relevant to the result of the test.			
	System Test			
	<p>Test 1: The entire system without chain.</p> <p>Weight = 3.26 kg</p> <p>3.26 kg < 58 kg</p> <p>Test 2: The entire system including chain.</p> <p>Weight = 14.18 kg</p> <p>14,18 < 58 kg</p> <p>Incorrect parameters:</p> <p>The hooks that was used when testing was very small, and had to low weight. The TM that was used in the test had unrealistic low weight.</p> <p>If the scale is not accurate enough.</p>			

TABLE 9: TEST T3.1.0.2

T3.1.1.0	3D Double barrier	06.05.2016	HL, SK, HG, MR, NL	Not Passed
SolidWorks				
Test	Determine if the locking mechanism of the lifting clamp has double barriers.			
Execution	Visual inspection of locking mechanism of the clamp.			
Results	Component Test			
	Mat: Passed			
	Hook: Not passed. This must be fixed in future work.			
	TM: Passed			
	Chain: Not relevant			
	System Test			
	If all components contain double barriers, the whole system will also contain double barriers.			

TABLE 10: TEST T3.1.1.0

T3.1.2.0	Minimum SWL	06.05.2016	HG	Not tested
SolidWorks				
Test	The 3D-model shall withstand a simulated workload of > 10250 kg.			
Execution	By performing FEM analysis.			
Results	Component Test			
	Mat: Not relevant			
	Hook: Not tested			
	TM: Not relevant			
	Chain: Not relevant			
	System Test			
	Not tested, because OLC did not get far enough in the process.			

TABLE 11: TEST T3.1.2.0

T3.1.3.0	3D Standardized parts	06.05.2016	HL, SK, HG, MR, NL	Passed
SolidWorks				
Test	Does the clamp fit with standardized lifting equipment?			
Execution	Perform a simulating test on the model to see if it fits with standardized parts.			
Results	Component Test			
	Mat: Not relevant			
	Hook: Passed			
	TM: Passed			
	Chain: Not relevant, already standardized.			
	System Test			
	Passed, since all the relevant components have passed.			

TABLE 12: TEST T3.1.3.0

T3.1.3.1	Model Standardized parts	05.05.2016	HL, SK, HG, MR, NL	Passed
Prototype				
Test	Does the clamp fit with standardized lifting equipment?			
Execution	Perform physical tests where the product is tested with standardized parts.			
Results	Component Test			
	Not relevant for each component, as this should be tested in the entire system as a unit.			
	System Test			
	The system fits with standardized slings, shackles and forerunners.			

TABLE 13: TEST T3.1.3.1

T3.1.4.0	3D clamp width	19.05.2016	NL	Passed
SolidWorks				
Test	The width of the lifting clamp shall not exceed 300 mm.			
Execution	Measuring the total width of the clamp in SolidWorks with measuring tool. The width ≤ 300 mm			
Results	Component Test			
	Mat: Width of the mat = 300 mm			
	TM: Not relevant			
	Hook: Not relevant			
	Chain: Not relevant			
	System Test			
	Width of the clamp = 300 mm $300\text{mm} \leq 300\text{mm}$			

TABLE 14: TEST T3.1.4.0

T3.1.4.1	Model clamp width	06.05.2016	HL, SK, HG, MR, NL	Passed
Prototype				
Test	Measure the width of the clamp. The width ≤ 300 mm.			
Execution	Measure the width of the clamp, with a tape measure or other measuring tools.			
Results	Component Test			
	Mat: Width of the mat = 300 mm			
	TM: Not relevant			
	Hook: Not relevant			
	Chain: Not relevant			
	System Test			
	Width of the clamp = 300 mm $300\text{mm} \leq 300\text{mm}$ Incorrect parameters: The measuring equipment is not accurate enough, or that the test person reads incorrect values.			

TABLE 15: TEST T3.1.4.1

T3.2.0.0	3D Pipe diameter			Not tested
SolidWorks				
Test	Test if the lifting clamp is able to lift pipes with different diameters.			
Execution	Control that the 3D-design includes implementation of options for lifting pipes of different diameters, by testing the clamp on pipes with different diameters.			
Results	Component Test			
	Mat: Not tested			
	TM: Not tested			
	Hook: Not relevant			
	Chain: Not tested			
	System Test			
	Not tested, because OLC did not get far enough in the process.			

TABLE 16: TEST T3.2.0.0

T3.2.0.1	Model Pipe diameter	05.05.2016 06.05.2016	HL, SK, HG, MR, NL	Passed
Prototype				
Test	Test if the lifting clamp is able to lift pipes with different diameters.			
Execution	Try the prototype on pipes with different diameters. The test is executed on a 13" and 16" pipe. The mat that is going to be tested is supposed to take diameters from 12" to 16". The length of the tested mat is 1275 mm.			
Results	Component Test			
	Not relevant			
	System Test			
	<p>Test on 16" pipe:</p> <p>Testing at 16 " pipe was successful. The clamp fits perfect.</p> <p>The mounted mat is shown in Figure 2</p>			
	<p>Test on 13" pipe:</p> <p>On the 13" pipe, the mat has an overlap of one third of the length of the mat.</p> <p>The mounting went well, but was a little more challenging than the mounting on the 16 " pipe. The test made it clear that it is a challenge if the overlap is too big. On the basis of this test, the varying diameter a mat can take is needed to be reduced. In this case, the varying diameter of the mat was</p> <p>Reduced from 12 " to 16 " to 13 " to 16 ".</p> <p>Figure 3 shows the overlap on a 13 " pipe.</p>			

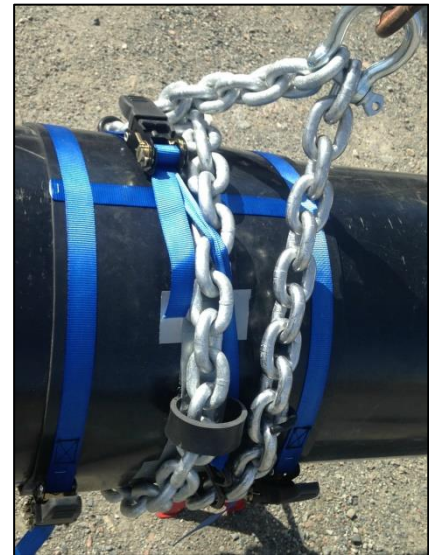


FIGURE 2: MAT ON 16 " PIPE.



FIGURE 3: OVERLAP ON 13 " PIPE.

TABLE 17: TEST T3.2.0.1

T3.2.1.0	Pipe ability			Not tested
Prototype				
Test	Control if the prototype of the lifting clamp can fit different types of pipes, joints and risers, with small or no modifications.			
Execution	Mount the clam on different types of pipes, joints and risers.			
Results	Component Test			
	Not relevant, because this must be tested on the whole system.			
	System Test			
	Not tested. It is needed various equipment that was not available during the test period.			

TABLE 18: TEST T3.2.1.0

T3.3.0.1	3D Closing Ability	06.05.2016	HL, SK	Not passed
SolidWorks				
Test	Check if the lifting clamp provides automatic closing.			
Execution	Visual inspection of the lifting clamp in SolidWorks.			
Results	Component Test			
	Not relevant			
	System Test			
	The clamp does not contain a mechanism for automatic closure.			

TABLE 19: TEST T3.3.0.1

T3.3.0.2	Model Closing Ability	06.05.2016	HL, SK	Not passed
Prototype				
Test	Check if the lifting clamp provides automatic closing.			
Execution	Visual inspection of the lifting clamp.			
Results	Component Test			
	Not relevant			
	System Test			
	The clamp does not contain a mechanism for automatic closure.			

TABLE 20: TEST T3.3.0.2

T3.3.1.0	Subsea			Not tested
Prototype				
Test	Does the use of the physical model includes being taken subsea?			
Execution	Test whether the prototype can be used subsea, by lowering the clamp in the water and look if it is working properly.			
Results	Component Test			
	Not relevant, because this must be tested on the whole system.			
	System Test			
	Not tested due to lack of equipment and test locations.			

TABLE 21: TEST T3.3.1.0

T3.3.2.0	Submerged			Not tested
Prototype				
Test	Check if the physical prototype withstand being taken subsea.			
Execution	Put the materials used in the product in a climate chamber to simulate the subsea environment.			
Results	Component Test			
	Mat: Not tested			
	TM: Not tested			
	Hook: Not tested			
	Chain: Not tested			
	System Test			
	Not tested due to lack of equipment and OLC did not get far enough in the process.			
	Incorrect parameters: A climate chamber is not the same as the real environment the clamp shall be used in. It will only give an indication of how the materials will behave.			

TABLE 22: TEST T3.3.2.0

10.1.2 DOCUMENTATION TESTS

T4.1.0.0	THI Product			Not tested
Model				
Test	Control if the final product includes THI.			
Execution	Read the THI			
Results	Component Test			
	Not relevant			
	System Test			
	Not tested, because OLC did not get far enough in the process to produce a model to test.			

TABLE 23: TABLE T4.1.0.0

T4.1.2.0	CE Product			Not tested
Model				
Test	Control if the final product have a CE-certificate.			
Execution	Read the CE marking on the product.			
Results	Component Test			
	Not relevant			
	System Test			
	Not tested, because OLC did not get far enough in the process to produce a model to test.			

TABLE 24: TEST T4.1.2.0

10.1.3 PERFORMING LIFTING OPERATIONS

T5.1.0.1	Off board lift			Not tested
T5.1.0.2	Offboard lift requirement			
Model				
Test	Control if the produced lifting clamp has the required documentation in order to perform off board lifts.			
Execution	Read the documentation.			
Results	Component Test			
	Not relevant			
	System Test			
	Not tested, because OLC did not get far enough in the process to produce a model to test.			

TABLE 25: TEST T5.1.0.1, T5.1.0.2

T5.1.1.0	Non sliding	05.05.2016	HL, SK, HG, MR, NL	Passed
Prototype				
Test	A mounted clamp shall be applied extensive forces without sliding.			
Execution	To perform this test, it was used an untreated but cleaned steel pipe. The mat used in the test had a hardness grade 70 sh A.			
	The mat was attached to the pipe with two straps. Furthermore, it was drilled two holes in the mat so the chain could be threaded through the mat. As shown in Figure 4. The reason for this solution was because the pipe had a very small size, it is 265 mm long, have a diameter of 190 mm, and have a protrusion part on one end.			
	The lift was made vertically to create a worst possible situation for the mat.			



FIGURE 4: VERTICAL FRICTION TEST


The test was conducted in three ways:

Test 1:

The lift shall be performed on a clean, dry pipe. The pipe shall be kept in the air for a specific time period. The crane operator shall move the pipe with exaggerated movements.

Test 2:

The lift shall be performed on a surface covered with water. It is important that the clamp does not slip on the wet surface, since it most likely will be sea water in the air or raining when the clamp is mounted. The pipe shall be kept in the air for a specific time period. The crane operator shall move the pipe with exaggerated movements.

	<p>Test 3:</p> <p>The lift shall be performed on a surface covered in oil. It is a chance that the pipe gets greasy when mounting. The pipe shall be kept in the air for a specific time period. The crane operator shall move the pipe with exaggerated movements.</p>
Results	<p>Component Test</p>
	<p>Mat:</p> <p>Test 1:</p> <p>The pipe was lifted in the air and jerked hard in to try to get the mat to slip. The lift went on for about a minute. After the lift the mat did not show any signs of sliding. The distance between the bottom of the pipe up to the mat was measured before and after the lift. Shown in figure 5</p> <div></div> <p>FIGURE 5: DISTANCE BETWEEN THE BOTTOM OF THE PIPE AND THE TOP</p>

	<p>Test2:</p> <p>This test was performed in the same way as Test 1, only with a wet contact surface against the pipe. The result was the same as in test 1, no signs of slippage.</p> <p>Test 3:</p> <p>This test was performed in the same way as Test 1 and 2, only with an oily contact surface against the pipe. The result was the same as in test 1 and 2, no signs of slippage.</p> <p>Result:</p> <p>These tests gave an unexpected result, it was expected that the tube which was greased in oil would glide. This confirms the theory that the friction between the pipe and the mat are high, so the mat will not slip against the pipe.</p> <p>Incorrect parameters:</p> <p>A lift where this clamp is used will never lift vertically in reality.</p> <p>The mat which the test was performed on does not have the correct hardness; the final mat design will have an even higher coefficient of friction, which will provide even better results.</p> <p>TM: Not relevant</p> <p>Hook: Not relevant</p> <p>Chain: Not relevant</p>
	System Test
	Use the results from the Mat tests.

TABLE 26: TEST T5.1.1.0

T5.1.2.0	Lifting Angle	05.05.2016	HL, SK, HG, MR, NL	Passed
Prototype				
Test	Control that the sling during a lifting operation does not exceed 45°.			
Execution	Before all lifts, the length of the forerunner must be calculated to ensure that the angle of the chain does not exceed 45°.			
Results	Component Test			
	Not relevant			
	System Test			
	<p>Testing of a lift in 45°:</p> <p>In this test it was used a 3m long chain on a 16 " pipe. This means that the chain goes up from the tube with a height of 7.7 cm, which must be subtracted from the length of the forerunner. Shown in Figure 6.</p> <p>The chain is placed 30 cm from the end of the tube. Shown in Figure 7. If the lift shall be performed in a 45° lift the length of the forerunner is calculated to 84.85 cm.</p>			
	<p>Height of chain on pipe in cm:</p> $h^2 = 34.2^2 - 20^2 \rightarrow h = 27.7 - 20$ <p>(radius of the pipe) = 7,7 cm</p> <p>Length of forerunner in cm:</p> $L^2 = 60^2 + 60^2 \rightarrow 84.85 \text{ cm}$ <p>Total length of forerunner:</p> $84.85 - 7.7 = 77.15 \text{ cm}$			

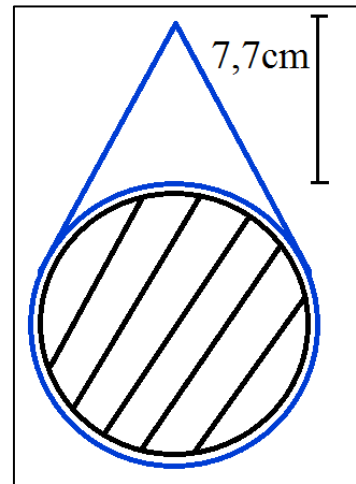


FIGURE 6: Chain around the pipe

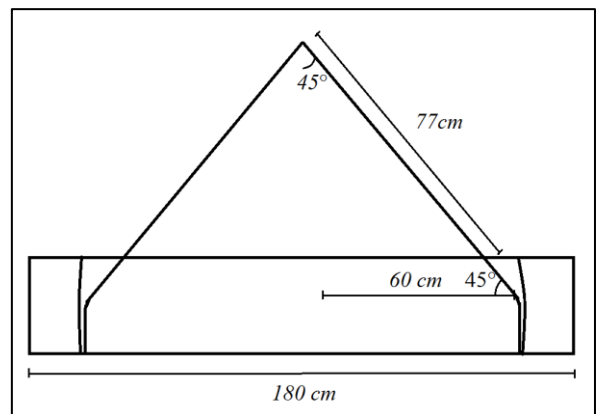


FIGURE 7: Chain mounted on the pipe in a 45° lift

In this test the clamp shall lift in a 45° angle. This is the maximum angle of what it can lift. The calculations shall be made to make sure that the angle does not exceed 45° . The angle does not exceed 45° as long as the length of the forerunner is correct.

Figure 8 shows the physical performed test.



FIGURE 8: Test T5.1.2.0

Incorrect parameters:

Calculations may be performed incorrectly.

The length of the forerunner can be measured incorrectly.

TABLE 27: TEST T5.1.2.0

T5.1.3.0	Temperature range			Not tested
Prototype				
Test	The lifting clamp shall be exposed to minimum and maximum temperatures during a lift, without showing any signs of fatigue, deformations or defects in product and material.			
Execution	Preform lifts in -40°C and in 50°C.			
Results	Component Test			
	Not relevant			
	System Test			
	Not tested, due to lack of proper equipment, and test locations.			

TABLE 28: TEST T5.1.3.0

T5.1.4.0	Tight mounting	05.05.2016	HL,SK,H G,MR,NL	Passed
Prototype				
Test	Control if the clamp slides after it has been mounted on the pipe.			
Execution	<p>Mounted the clamp on the pipe in different conditions:</p> <p>Test 1: Clean pipe</p> <p>Test 2: Pipe with water</p> <p>Test 3: Pipe with oil</p>			
Results	Component Test			
	Not relevant			
	System Test			
	<p>Test 1: Do not slide after mounting.</p> <p>Test 2: Do not slide after mounting.</p> <p>Test 3: Do not slide after mounting.</p>			

TABLE 29: TEST T5.1.4.0

T5.1.5.0	TM Force			Not tested
Prototype				
Test	The tightening mechanism must withstand an increase of applied force during lifting.			
Execution	Perform lifts with maximum SWL on the model, and control that the tightening mechanism does not show any sign of damage or wear after lift.			
Results	Component Test			
	Mat: Not tested			
	TM: Not tested			
	Hook: Not tested			
	Chain: Not relevant, already standardized and certified for the intended use.			
	System Test			
	Not tested due to lack of equipment, when it is needed a pipe that weighs 8200kg.			

TABLE 30: TEST T5.1.5.0

T5.1.6.0	Hands off			Not tested
Prototype				
Test	Test if the product does not need human contact after installation.			
Execution	Mount the lifting equipment on a pipe and control that the lifting procedure is performed hands off under different circumstances, simulating.			
Results	Component Test			
	Not relevant			
	System Test			
	Not tested, because OLC did not get far enough in the process.			

TABLE 31: TEST T5.1.6.0

T5.3.0.0	Mounting hours	05.05.2016	HL, SK, HG,MR, NL	Passed
Prototype				
Test	Check if it takes less than an hour to mount a clamp.			
Execution	Measure the time it takes to mount the lifting clamp. One person mounted two clamps, one after another. (Since it will be used two clamps in a lift.)			
Results	Component Test			
	Not relevant			
	System Test			
	<p>It took 15 minutes and 14 seconds for a person to mount two clamps.</p> <p>This means it takes 7 minutes and 37 seconds to mount a clamp.</p> <p>7 minutes and 37 seconds < 60 minutes.</p>			

TABLE 32: TEST T5.3.0.0

T5.3.1.1	3D lift weight	19.05.2016	HL, SK, HG	Passed
SolidWorks				
Test	Test the weight of the clamp; it shall weigh less than 25 kg, so that it can be carried by hand.			
Execution	Simulating weight of the clamp by acquiring suitable types of materials to the 3D-model, in SolidWorks.			
Results	Component Test			
	The weight of the various components:			
	Mat: Weight = 3,313 kg			
	TM: Weight = 1,857 kg			
	Hook: Weight = 3,124 kg			
	Chain: 3 m Chain weight = 3m			
	System Test			
	The weight of the whole system 22.818kg.			
	22.818 kg < 25 kg.			
	Incorrect parameters:			
	The weight of the materials chosen in SolidWorks may vary slightly from real materials.			

TABLE 33: TEST T5.3.1.1

T5.3.1.2	Model lift weight	06.05.2016	HL, SK	Passed
Prototype				
Test	Test the weight of the clamp; it shall weigh less than 25 kg, so that it can be carried by hand.			
Execution	Measure the weight of the physical system.			
Results	Component Test			
	Each of the separate parts is not tested, when this is not relevant to the result of the test.			
	System Test			
	The weight of the whole system 14.18 kg. 14.18 kg < 25 kg.			
	<p>Incorrect parameters:</p> <p>The hooks that was used when testing was very small, and had to low weight. The TM that was used in the test had unrealistic low weight.</p> <p>If the scale is not accurate enough.</p>			

TABLE 34: TEST T5.3.1.2

T5.3.2.1	3D Center of gravity			Not tested
SolidWorks				
Test	Test if the lifting clamp can compensate for changing center of gravity during lifting operations.			
Execution	Test by simulating a lift of pipes with different center of gravity in a FEM analysis in SolidWorks.			
Results	Component Test			
	Not relevant			
	System Test			
	Not tested, because OLC did not get far enough in the process.			

TABLE 35: TEST T5.3.2.1

T5.3.2.2	Model Center of gravity			Not tested
Prototype				
Test	Test if the lifting clamp can compensate for changing center of gravity during lifting operations.			
Execution	Test by lifting pipes with different center of gravity.			
Results	Component Test			
	Not relevant			
	System Test			
	Not tested, because OLC did not get far enough in the process.			

TABLE 36: TEST T5.3.2.2

10.1.4 PRODUCTION

T6.1.0.0	Reduction 10%	19.05.2016	HL, SK, MR	Passed
Prototype				
Test	Test if production costs are reduced by at least 10%			
Execution	Create an estimated budget of what the product will cost. Compare the budget with the price of an existing clamp.			
Results	Component Test			
	Not relevant			
	System Test			
	<p>In the test it is assumed that an existing lifting clamp costs 75,000 kr. Since prices can be between 50-100 000 kr.</p> <p>The reason for this assumption is that the 16" clamp is a medium sized clamp.</p> <p>Estimated price for produced clamp 19 138 kr.</p> $\frac{75\,000 - 19\,138}{75\,000} \cdot 100\% = 74,48\%$ <p>The cost is reduced by 74.48%</p> <p>74.48% > 10%</p> <p>Incorrect parameters:</p> <p>This is only an estimated price. The real price will vary.</p>			

TABLE 37: TEST T6.1.0.0

T6.1.0.1	Reduction 50%	19.05.2016	HL, SK, MR	Passed
Prototype				
Test	Test if production costs are reduced by at least 50%			
Execution	Create an estimated budget of what the product will cost. Compare the budget with the price of an existing clamp.			
Results	Component Test			
	Not relevant			
	System Test			
	In the test it is assumed that an existing lifting clamp costs 75,000 kr. Since prices can be between 50-100 000 kr.			
	The reason for this assumption is that the 16" clamp is a medium sized clamp.			
	Estimated price for produced clamp 19 138 kr.			
	$\frac{75\,000 - 19\,138}{75\,000} \cdot 100\% = 74,48\%$			
	The cost is reduced by 74.48%			
74.48% > 50%				
Incorrect parameters:				
This is only an estimated price. The real price will vary.				

TABLE 38: TEST T6.1.0.1

T6.1.0.2	Reduction 80%	19.05.2016	HL, SK, MR	Not passed
Prototype				
Test	Test if production costs are reduced by at least 80%			
Execution	Create an estimated budget of what the product will cost. Compare the budget with the price of an existing clamp.			
Results	Component Test			
	Not relevant			
	System Test			
	In the test it is assumed that an existing lifting clamp costs 75,000 kr. Since prices can be between 50-100 000 kr.			
	The reason for this assumption is that the 16" clamp is a medium sized clamp.			
	Estimated price for produced clamp 19 138 kr.			
	$\frac{75\,000 - 19\,138}{75\,000} \cdot 100\% = 74,48\%$			
	The cost is reduced by 74.48%			
	74.48% < 90%			
Incorrect parameters:				
This is only an estimated price. The real price will vary.				

TABLE 39: TEST T6.1.0.2

10.2 TESTS BASED ON DNV REQUIREMENTS

10.2.1 DNV 2.7-3

T1.1.0.0	3D Material	19.05.2016	HL, SK, HG	Passed
SolidWorks				
Test	Test if the material of the 3D model has the minimum thickness of 6mm that is required by the DNV Standard.			
Execution	Control that the 3D-design includes the minimum thickness that is required, by measuring the 3D-model on SolidWorks.			
Results	Component Test			
	Mat: Not relevant			
	TM: Not relevant			
	Hook: Passed. The fields that are a part of the lift has been measured with the thinnest surface of 8 mm.			
	Chain: Not relevant, because the chain is standardized lifting equipment.			
	System Test			
	If the components passed the test, the whole system will also pass the test.			

TABLE 40: TEST T1.1.0.0

T1.1.0.1	Model Material	19.05.2016	HL, SK, HG	Passed
Prototype				
Test	Test if the material of the model has the minimum thickness of 6mm that is required by the DNV Standard.			
Execution	Measure the thickness of the components in the system. Control that the model includes the minimum thickness that is required, by measuring the model with a caliper or other measuring equipment.			
Results	Component Test			
	Mat: Not relevant			
	TM: Not relevant			
	Hook: Passed. The fields that are a part of the lift have been measured with the thinnest surface of 8 mm.			
	Chain: Not relevant, because the chain is standardized lifting equipment.			
	System Test			
	If the components passed the test, the whole system will also pass the test.			
	Incorrect parameters:			
	The surfaces of the produced model may vary slightly from the prototype.			

TABLE 41: TEST T1.1.0.1

T1.1.1.0	3D Bolts and fasteners			Not tested
SolidWorks				
Test	Check if the bolts, nuts and pins on the 3D model are listed in the part list with a code or standard.			
Execution	By checking if the bolts, nuts and pins is marked with a code or standard in the 3D document.			
Results	Component Test			
	Not relevant			
	System Test			
	Not tested, because OLC did not get far enough in the process.			

TABLE 42: TEST T1.1.1.0

T1.1.1.1	Model Bolts and fasteners			Not tested
Model				
Test	Check if the bolts, nuts and pins on the produced model are listed in the part list with a code or standard.			
Execution	By checking if the produced model includes bolts, nuts and pins that is marked with a code or standard, and then tick on a check list.			
Results	Component Test			
	Not tested.			
	System Test			
	Not tested, because OLC did not get far enough in the process to produce a model to test.			

TABLE 43: TEST T1.1.1.1

T1.1.3.0	Stress test	19.05.2016	SK, HG	Not passed
SolidWorks				
Test	Make sure that the design loads not produce Von Mises equivalent stresses, σ_e exceeding $\sigma_e = 0.85 \times R_e$			
Execution	Tested by performing FEM analyses on the 3D-model and check if the FEM analysis results shows Von Mises equivalent stresses exceeds $\sigma_e = 0.85 \times R_e$.			
Results	Component Test			
	Mat: Not relevant, because it is not a part of the lift.			
	TM: The FEM analysis results shows max Von Mises stresses = 104,58MPa, which not exceeds Von Mises equivalent stresses $\sigma_e = 0.85 \times 620.42MPa = 527.357MPa$.			
	Hook: The FEM analysis results shows max Von Mises stresses = 2592,00 MPa, which exceeds Von Mises equivalent stresses $\sigma_e = 0.85 \times 620.42MPa = 527.357MPa$.			
	Chain: Not relevant, because the chain is standardized lifting equipment.			
	System Test			
	Not tested on the system.			

TABLE 44: TEST T1.1.3.0

T1.1.6.0	Design Factor	19.05.16	HG, SK	Passed
Prototype				
Test	Check if the design factor F is defined according to the operational class and MGW in the DNV standard.			
Execution	By studying the calculations and check if they are based on $F= 2.5 \times \text{MGW} \times g$			
Results	Component Test			
	Mat: Not relevant, because the mat is not a lifting equipment, but only used as a protection to the pipe.			
	TM: Not relevant, because the TM is not a part of the lift, but only used to tighten the mat to the pipe.			
	Hook:			
	Horizontal: The horizontal MGW for the hook is calculated to be 2050kg. The horizontal load on the Hook is calculated based on F, which proves that the design factor is defined according to the operational class and MGW in the DNV standard.			
	$F_{X1, \text{MGW}} = 2,5 \times 2050\text{kg} \times 9,81\text{m/s}^2 = 50276,25\text{N}$			
	Vertical:			
	The vertical MGW for the Hook is calculated to be 200kg. The vertical load on the hook is calculated based on F, which proves that the design factor is defined according to the operational class and MGW in the DNV standard.			
	$F_{\text{TM}, \text{MGW}} = 2,5 \times 200\text{kg} \times 9,81\text{m/s}^2 = 4905\text{N}$			
Chain: Not relevant, because the chain is standardized lifting equipment.				
System Test				
The system test is passed because the relevant tests on the components are passed.				

TABLE 45: TEST T1.1.6.0

T1.1.7.0	Design Loads	19.05.2016	SK, HG	Passed
SolidWorks				
Test	For the normal lift condition the design load F for the PO UNIT global strength calculation/analysis shall be calculated based on F.			
Execution	Tested by performing FEM analysis with all the applied loads occurring during lifting operations.			
Results	Component Test			
	Mat: Not relevant, because the mat is not a lifting equipment, but only used as a protection to the pipe. The mat does not get affected by forces during the lift.			
	TM: Performed FEM analysis on the TM by applying all the loads that occur during the lifting operation although the TM is not a part of the lift, it might be affected by forces. Results of the maximum Von Mises stress = 104,58MPa.			
	Hook: The FEM analysis has been executed by using the horizontal load on the Hook that is calculated to 50276,25N, in addition to the vertical load that is calculated to 4905N, in addition to a counterforce at the bottom of the grooves. Both of these calculations have been based on F. The results of the FEM analysis that is executed by applying all the loads occurring during lifting operations is the maximum Von Mises stress = 2592MPa.			
	Chain: Not relevant, because the chain is standardized lifting equipment.			
	System Test			
	The system test is passed because the relevant tests on the components are passed.			

TABLE 46: TEST T1.1.7.0

T1.1.8.0	3D Sling Disconnect			Not relevant
SolidWorks				
Test	Test if it is possible to disconnect the sling from the lifting point accidentally.			
Execution	Execute by study the 3D-model and check if it has possibilities for the sling to disconnect from the lifting point.			
Results	Component Test			
	Mat: Not relevant			
	TM: Not relevant			
	Hook: Not relevant			
	Chain: Not relevant			
	System Test			
	Not relevant. Explanation: The sling has no possibilities to disconnect from the lifting point on the 3D-model, because the chain is wrapped twice around the pipe, and both of the ends are attached to the forerunner. The only way to disconnect the sling from the lifting point might be if it is breaks during the lift.			

TABLE 47: TEST T1.1.8.0

T1.1.8.1	Model Sling Disconnect			Not tested
Model				
Test	Test if it is possible to disconnect the sling from the lifting point accidentally.			
Execution	Executed by performing lifts that test if the sling disconnects from the lifting point of the produced clamp.			
Results	Component Test			
	Mat: Not relevant			
	TM: Not relevant			
	Hook: Not tested			
	Chain: Not tested			
	System Test			
	Not tested, because OLC did not get far enough in the process to produce a model to test.			

TABLE 48: TEST T1.1.8.1

T1.1.10.0	Clamp protection			Not tested
Model				
Test	Check if the produced clamp maintains to withstand offshore climate.			
Execution	By having the produced clamp in a climate chamber.			
Results	Component Test			
	Mat: Not tested			
	TM: Not tested			
	Hook: Not tested			
	Chain: Not relevant, already standardized and certified for offshore use.			
	System Test			
	Not tested, because OLC did not get far enough in the process to produce a model to test.			

TABLE 49: TEST T1.1.10.0

T1.1.11.0	Inspection			Not tested
Model				
Test	Check if the produced clamp has marking plates and marking texts that are easily readable.			
Execution	By doing a visual inspection of the produced clamp.			
Results	Component Test			
	Mat: Not tested			
	TM: Not tested			
	Hook: Not tested			
	Chain: Not tested			
	System Test			
	Not tested, because OLC did not get far enough in the process to produce a model to test.			

TABLE 50: TEST T1.1.11.0

T1.1.12.0	Clamp Plate			Not tested
Model				
Test	Check if the produced clamp has an information plate fitted onto it.			
Execution	By doing a visual inspection of the produced clamp.			
Results	Component Test			
	Mat: Not tested			
	TM: Not tested			
	Hook: Not tested			
	Chain: Not tested			
	System Test			
	Not tested, because OLC did not get far enough in the process to produce a model to test.			

TABLE 51: TEST T1.1.12.0

T1.1.13.0	Product Documentation			Not tested
Model				
Test	Check if the produced clamp has a list of required documentation.			
Execution	By reading the required documentation.			
Results	Component Test			
	Mat: Not tested			
	TM: Not tested			
	Hook: Not tested			
	Chain: Not tested			
	System Test			
	Not tested, because OLC did not get far enough in the process to produce a model to test.			

TABLE 52: TEST T1.1.13.0

T1.1.15.0	Manufacture Approval			Not tested
Model				
Test	Check if the documentation is fulfilled before starting to manufacture.			
Execution	By checking if the documentation includes drawings, specifications and procedures that are fulfilled.			
Results	Component Test			
	Mat: Not tested			
	TM: Not tested			
	Hook: Not tested			
	Chain: Not tested			
	System Test			
	Not tested on the system, because OLC did not get far enough in the process to produce a model to test.			

TABLE 53: TEST T1.1.15.0

T1.1.16.0	Identify Material	20.05.16	HL, SK, HG, MR, NL	Passed
SolidWorks				
Test	Check if the 3D-models has got a specific material.			
Execution	By checking in the properties of the different parts in SolidWorks.			
Results	Component Test			
	Mat: Passed, Chloroprene, EPDM, UV stable Nylon & Steel.			
	TM: Passed, Alloy Steel.			
	Hook: Passed, Alloy Steel.			
	Chain: Not relevant, because the chain is standardized lifting equipment.			
	System Test			
	The test is passed on the system, since the test is passed on the components.			

TABLE 54: TEST T1.1.16.0

T1.1.16.1	Materials & Traceability			Not tested
Model				
Test	Check if the produced clamp has included all the materials and their traceability in the documentation.			
Execution	By reading the documentation and check if the marking is visible on the produced clamp.			
Results	Component Test			
	Mat: Not tested			
	TM: Not tested			
	Hook: Not tested			
	Chain: Not tested			
	System Test			
	Not tested, because OLC did not get far enough in the process to produce a model to test.			

TABLE 55: TEST T1.1.16.1

T1.1.18.0	3D Master link			Not relevant
SolidWorks				
Test	Check if the 3D-design includes a master link with a dimension of 270 ×140mm.			
Execution	Measuring the master link when working on the design.			
Results	Component Test			
	Not relevant to execute the test on any of the components.			
	System Test			
	Not relevant, because OLC has decided to not use a master link in the system.			

TABLE 56: TEST T1.1.18.0

T1.1.18.1	Model Master link			Not relevant
Model				
Test	Check if the produced model includes a master link with a dimension of 270 ×140mm.			
Execution	Measuring the master link on the produced model.			
Results	Component Test			
	Not relevant to execute the test on any of the components.			
	System Test			
	Not relevant, because OLC has decided to not use a master link in the system.			

TABLE 57: TEST T1.1.18.1

T1.1.19.0	3D Sling Diameter	20.05.16	HG	Passed
SolidWorks				
Test	Check if the 3D-model includes a sling with a dimension of $D \geq 10$ mm.			
Execution	Measuring the diameter of the sling when working on the design.			
Results	Component Test			
	Mat: Not relevant TM: Not relevant Hook: Not relevant Chain: Passed, because chain Diameter = 13mm. $D = 13\text{mm} > D = 10\text{mm}$.			
	System Test			
	The chain has a dimension of $D = 13\text{mm}$. $D = 13\text{mm} > D = 10\text{mm}$.			

TABLE 58: TEST T1.1.19.0

T1.1.19.1	Model Sling Diameter	20.05.16	HG	Passed
Prototype				
Test	Check if the produced model includes a sling with a dimension of $D \geq 10$ mm.			
Execution	Measuring the diameter of the sling on the produced model.			
Results	Component Test			
	Mat: Not relevant			
	TM: Not relevant			
	Hook: Not relevant			
	Chain: Passed, because chain Diameter = 13mm. $D = 13\text{mm} > D = 10\text{mm}.$			
	System Test			
	The chain has a dimension of $D = 13\text{mm}.$ $D = 13\text{mm} > D = 10\text{mm}.$			

TABLE 59: TEST T1.1.19.1

10.2.2 DNV 2.22

T2.1.5.0	3D Model Strength	20.05.16	HG	Passed
SolidWorks				
Test	Check if the 3D-model has the required strength.			
Execution	Test if the components withstands the stresses and forces they are exposed to.			
Results	Component Test			
	Mat: Not relevant, because the mat is not a lifting gear that needs to be approved by the DNV standards.			
	TM: Not relevant, because the TM is not a lifting gear that needs to be approved by the DNV standards.			
	Hook: Passed. The test is passed because OLC has included the safety factor while designing the Hook. The Hook shall lift a load of 2050kg. OLC has calculated with a safety factor of 2,5 to assure that the Hook can withstand the workload. The Hook has the capacity to withstand a load of: $2050\text{kg} \times 2,5 = 5125\text{kg}$.			
	Chain: Not relevant, because the chain is standardized lifting gear.			
	System Test			
	Passed, because the Hook withstands a load of 5125kg.			

TABLE 60: TEST T2.1.5.0

10.2.3 DNV 2.7-3 Testing

T7.1.1.0	Prototype Testing - Lifting			Not tested
Prototype				
Test	Perform lifts with realistic weight and weight distribution of the equipment.			
Execution	By lifting a pipe, and measuring the MGW before the test is performed.			
Results	Component Test			
	Not relevant			
	System Test			
	Not tested on the system, because OLC did not get far enough in the process to produce a model to test.			

TABLE 61: TEST T7.1.1.0

11. CONCLUSION TEST PLAN

Description of the different test methods and components helped OLC to achieve a good structure in the test results, in addition to dividing the test statuses into color codes. The color codes describes the approval of the requirements. One requirement can have many tests, but all the tests connected to the requirement must be passed to approve the requirement.

The purpose with the test plan tables is to give a good overview of the performance of all the different tests that shall be performed on the test method.

All the performed tests are put in tables that describe the full range of test. The status of the test is also filled into the test specification.

All the approved physical tests are performed on prototypes, but these tests should be performed on the finished model in the future, in addition to some more tests. This means that some of the tests that are approved on the prototype may not be approved on the finished product.

The risk assessment was considered to avoid damage during the performance of the tests. The tests also gave an indication of the dangers that can occur during a lifting operation. OLC gained more experience about the risks associated with the practical use of the product by performing the tests. These experiences were considered in the risk assessment.

12. CONCLUSION TEST REPORT

All tests defined in the test specification are analyzed in the test plan, where the status of the test is described. The purpose of this document is to certify that the requirements are met. The status of the tests is either passed, not passed, not relevant or not tested. The reason that some tests are not relevant may be because of design choice, where the described components are not included in the design. Some tests are not tested, they must be tested to approve the products for off board use. The summary of all the tests belonging to a specific requirement is inserted in the requirements specifications. A requirement may have several tests that need to be approved, to approve the requirement. If two out of three tests related to a requirement are approved and the third test is not approved, the requirement will not be approved.

13. RECOMANDATION FOR FUTURE WORK

Furthermore in the process it is recommended to perform all the remaining tests that can be tested on the physical prototype, 3D model of the product, and lifting tests. This is to ensure that all requirements are satisfied. When this is done the model can be produced and tested.

The remaining tests are:

- T3.1.2.0 - Minimum SWL
- T3.2.0.0 - 3D Pipe diameter
- T3.2.1.0 - Pipe ability
- T3.3.1.0 - Subsea
- T3.3.2.0 – Submerged
- T4.1.0.0 - THI Product
- T4.1.2.0 - CE Product
- T5.1.0.1 - Off board lift
- T5.1.0.2 - Off board lift requirement
- T5.1.3.0 - Temperature range
- T5.1.5.0 - TM Force
- T5.1.6.0 - Hands off
- T5.3.2.1 - 3D Center of gravity
- T5.3.2.2 - Model Center of gravity

It is important that all the tests described in Test Method - Model is performed on the produced model so that the product can be certified as a lifting tool approved for off board lifts.

14. REFERENCES

- | | | |
|-----|-------------------------------------|------|
| [1] | FMC Lifting symposium 2015 (edited) | 2015 |
| [2] | DNV 2.7-3 (DET NORSKE VERITAS) | 2011 |



OFFSHORE LIFTING CLAMP ENGINEERING

VERSION 3.0

RISK ASSESSMENT

20.05.2016

ABSTRACT

The risk assessment document describes the various risks that are associated with the project period, concepts and main concepts, in addition to the risks that are associated with the entire system as a unit. The risk assessment includes various tables that describes the risks and how the risk actions are implemented. The purpose with this document is to select a main concept with the highest quality and lowest grade of risk. Reading this document will give the opportunity to gain knowledge about the likelihood of risk occurrence and the consequence of the risks.

CHANGES

The changes will be listed here:

Version	Date	Description
3.0	21.05.16	<ul style="list-style-type: none">• Added description to 3. Risk assessment – Concepts• Added picture to 4. Risk assessment – Main Concept• Updated 4.1.1 Mat by updating a new picture
2.2	20.05.16	<ul style="list-style-type: none">• Added new:<ul style="list-style-type: none">- List of figures- List of tables
2.1	19.05.16	<ul style="list-style-type: none">• Added 5.1 & 5.2• Changed:<ul style="list-style-type: none">- 6: The name from “Risk associated with the entire system as a unit” to “Risk assessment – entire system”- 4: The name from “Main concept risk assessment” to “Risk assessment – Main concept”- 2: The name from “Project period risk assessment” to “Risk assessment – Project Period”- 3: The name from “Concepts risk assessment” to “Risk assessment – Concepts”• Updated:<ul style="list-style-type: none">- Table numbering- List of contents
2.1	18.05.16	<ul style="list-style-type: none">• Updated:<ul style="list-style-type: none">- The conclusion- 2 Project Period Risk Assessment• Added:<ul style="list-style-type: none">- Recommendation- Abstract• Edited:<ul style="list-style-type: none">- Description of 2.1.2 Group members- Description of 2.1.3 Design- 2.1.1 Project task- 3.1.4 Technical- 4 Main concept risk assessment- 4.1.1 Mat
2.0	17.05.16	<ul style="list-style-type: none">• Added <i>Risk Assessment Mat Concept v1.1</i> to Risk Assessment report v2.0
2.0	13.05.16	<ul style="list-style-type: none">• Edited the structure of the text by changing the options for distribution of the text evenly between the margins and customized the text by using advanced font and character options.• Updated:<ul style="list-style-type: none">- 2 Project period risk assessment- 2.1.1 Project task: Replaced the word «Source» with

		«references».
2.0	12.05.16	<ul style="list-style-type: none">• Updated the introduction.• Moved and changed the names and text on table 1.6.1 and 1.6.2.• Added <i>Risk Assessment</i> – General information about risk assessment.• Changed the name <i>main risk assessment</i> to <i>project period risk assessment</i>.•
1.0	07.03.16	<ul style="list-style-type: none">• Edited table numbering.• Edited text color.
0.1	07.03.16	<ul style="list-style-type: none">• Created: Introduction, list of contents, summary and source list.

In addition to the above:

There may be spelling mistakes that are corrected. It is possible that these changes are not listed.

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INTRODUCTION

The purpose of the risk assessment is to document all the possible risks associated to the project. OLC is following the spiral model, this means that the group are going to do a risk assessment in all the planned iterations. The frequent repetition gives OLC a good overview of the risks associated with the project and the lifting clamp.

The risks are given a likelihood and consequence, which together describe the degree of risk. The purpose with risk actions is to prevent and reduce the risk to an acceptable degree. Performance of risk actions occurs if the degree of risk is too high.

Risk assessment for the entire project period is accomplished in the first iteration. Risk assessment for the project period describes the risks connected to:

- Project tasks
- Group members
- The clamp design
- Tests
- Technical problems

Risk assessment for the different design concepts is performed in the second iteration. The purpose with the risk assessment for different design concepts is to be aware of the risks by having them in the mind while selecting the main concept. The risk assessment for the main concept was developed through the third, fourth and fifth iteration, in line with the development of the concept. Performance of the various risk assessments should lead to awareness and predictability, and will decrease the chances of things going wrong.

1. RISK ASSESSMENT

It is required to perform a risk assessment when developing a lifting tool for offshore use. The risk assessment should be performed according to the standard ISO 12100. This report is based upon the risk assessment explained in NORSOK R-002 standard, which describes an excerpt from ISO 12100. [2]

The first step in a risk assessment is to determine all the possible risks and collect all relevant information connected to design, production, installation, transport, mounting, demounting, maintenance, accidents, injuries, usage, misuse, testing, repair and other possible risks. [2]

A combination of likelihood and consequence will determine the degree of risk. The calculation of the likelihood is executed by taking the exposure hazard, occurrence of hazardous events and the ability to avoid damage into account. The consequences is estimated by taking environment, injury of people or other equipment into consideration. [1], [2]

Table 1.0[1] describes the likelihood of risk occurrence and the consequence of the risk. The likelihood starts with rare, having one point. Followed by unlikely, with two points, and so on. The consequences starting with insignificant, having one point. Followed by minor, with two points, and so on. Furthermore, the likelihood and consequences are multiplied together to provide the degree of risk.

Formula for degree of risk: $Likelihood \times Consequences = Degree\ of\ risk$

Consequences	Likelihood				
	Rare	Unlikely	Possible	Likely	Almost Certain
Insignificant	1	2	3	4	5
Minor	2	4	6	8	10
Moderate	3	6	9	12	15
Major	4	8	12	16	20
Catastrophic	5	10	15	20	25

TABLE 1: Overview of consequence and likelihood [1],[3]

The result of the data in Table 1.0 are divided into 4 degrees of risks by score, explained in table 1.1

Risk colors	Values	
Critical	19-25	The risk is extreme. The risk is not acceptable and must be avoided. The risk actions must be implemented immediately.
High	14-18	High risks is not accepted and the risk actions must be implemented as soon as possible.
Moderate	7-13	Generally not accepted. May be accepted under certain circumstances. The risk action should be used to avoid that the risk increases.
Low	1-6	The risk is acceptable, but in some cases the risk can be further reduced.

TABLE 2: The degree of risk [1]

The outcome of risk evaluation will show if reduction of the risk is necessary. The outcome is described as GOR (grade of risk) in table 1.2, which is the risk before a potential risk reduction.

Implementation of risk actions is mandatory if the grade of the risk is too high. The risk actions should be concrete actions that reduces risk to acceptable levels. Such as:

Redesign, design modifications, protection measures and information for the user. The results of the risk actions is described as GARA (Grade after risk actions). It is important to take into consideration that execution of risk action on a risk may affect other involved risk areas and increase risk elsewhere, which must be analyzed and assessed. [1],[2]

All the risks in this project will be placed in a table based on table 1.2. Describing the risk, GOR, risk action, GARA and all the different types of risk have been giving an individual ID number.

ID	RISK	GOR	RISK ACTIONS	GARA
TYPE OF RISK				

TABLE 3: Risk assessment template

2. RISK ASSESSMENT – PROJECT PERIOD

The first risk assessment describes the risk associated to the project period. The different types of categories the risks are divided into are:

- **Project task**
Describe the risks that OLC might face during the project task. Some of the risk associated with the project tasks is: Deadlines, bad traceability or cooperation.
- **Group members**
Describe the risks associated with each individual group member, such as: health problems or completion of individual assignments in the group due to different reasons.
- **Design**
Risk related to design problems. Such as: chosen concept does not work, or problems with the design program.
- **Test**
The risks related to execution of the planned test in the project period, as some of the planned test might not be feasible.
- **Technical**
Describes the technical risks that can occur during the project period. Such as: Corrupted PC or failing to have a backup.

2.1 RISKS ASSOCIATED WITH THE PROJECT PERIOD

2.1.1 PROJECT TASK

- **DEADLINES:**

The risk of not achieving deadlines may occur if the group for some reason is behind the schedule, or if FMC introduces the group to new requirements late in the process.

- **DEFINING REQUIREMENTS:**

Requirements are fundamental for the project; badly defined requirements might be risky because OLC may find it difficult to understand and follow the requirements. This can lead to bad quality of the product.

- **KNOWLEDGE CHALLENGE:**

Another risk in terms of requirements is if the group does not achieve the requirements due to challenges with knowledge.

- **BAD TRACEABILITY:**

Bad traceability in the documentation is a risk because it can lead to bad setup and be difficult to use. In the worst case, the group will lose all control of the documentation.

- **WRONG USAGE OF REFERENCES:**

Wrong usage of references in documents. For example: Usage of unreliable websites, as well as incorrect usage of references in different documents can be a factor of risk in the project.

- **COOPERATION STAKEHOLDERS:**

Bad collaboration and communication with the customers, both internal and external supervisors and examiners is a risk, because OLC will run the risk of not receiving good feedback and supervision throughout the project. Occurrence of this risk may result in failing to achieve good results.

- **COOPERATION OLC:**

The risk of poor cooperation and disagreement within OLC may cause OLC from performing the task within the estimated time, and that OLC does not satisfy the customer.

- **CONTRACT:**

There is a risk if the employer breaks the contract, due to bad economy or other reasons. This will cause OLC to be unable to complete the task, unless University College of Southeast Norway can find a solution.

2.1.2 GROUP MEMBERS

- **TIME ESTIMATION:**

The risk of time estimation can occur if the group members are not able to perform their work within a certain timeframe due to challenges related to illness or injury. This will be a big risk to the group, because it may be difficult for other team members to take over work tasks.

- **WELL-BEING:**

There is a risk if one or more group members do not thrive. This can lead to communication problems or bad atmosphere in the group.

- **STUCK IN INDIVIDUAL TASKS:**

It is a risk if the group members are stuck and finds it difficult to complete their tasks and do not ask for help.

2.1.3 DESIGN

- **DESIGN CONCEPT:**

It is a big risk if the design concept does not work and has to be changed late in the process. This can cause that the group must start the design concept again and submit an unfinished product.

- **FAIL TO FOLLOW THE A REQUIREMENTS:**

There is a risk if the group fails to follow all the A requirements, as the product will not be useable due to incomplete design. This means that the customer will be dissatisfied.

- **SOLIDWORKS:**

The group may have problems with SolidWorks if the executed work is deleted/lost or if the group have problems with the assembly of the design parts.

2.1.4 TEST

- **PLANNED TEST NOT FEASIBLE:**

Execution of the planned test are not feasible. The tests can be feasible if the group finds it difficult to perform tests because SolidWorks hangs up, or that the group are stuck in calculations.

2.1.5 TECHNICAL

- **BACKUP:**

There is a risk to lose documents and not have backup. For example, if Dropbox collapses.

- **CORRUPTED PC:**

A computer with important information is corrupted and lose important documents.

- **SAVING DOCUMENTS:**

One or more group members do not save the documents they have worked with, and lose their documents.

2.2 RISK ASSESSMENT TABLE: PROJECT PERIOD

Table 4 describes the degree of the risks that are associated with the project.

ID	RISK	GOR	RISK ACTIONS	GARA
PROJECT				
RI1.0	Deadlines	9 Moderate Possible	Avoid falling behind deadlines by following GANTT chart and work structured.	6 Moderate Unlikely
RI1.1	Defining requirements	8 Major Unlikely	Preventable by reviewing all the requirements repeatedly in each period, and get feedback from the customer.	4 Major Rare
RI1.2	Knowledge challenge	5 Catastrophic Rare	Seek out information and ask for help from supervisors and lecturers.	5 Catastrophic Rare
RI1.3	Bad traceability	20 Catastrophic Likely	Utilize a system of traceability by providing all documents an ID number.	10 Catastrophic Unlikely
RI1.4	Wrong usage of sources	4 Minor Unlikely	Use of reliable internet sites and other sources. By making source lists and good documentation.	2 Minor Rare
RI1.5	Cooperation stakeholders	15 Catastrophic Possible	Regular guidance meetings and good communication throughout the project.	10 Catastrophic Unlikely
RI1.6	Cooperation OLC	16 Major Likely	Democratic voting by disagreements. Team building and compromises can achieve good communication.	12 Major Possible
RI1.7	Contract	10 Catastrophic Unlikely	The group has no chance to prevent the risk of breach of contract in relation to the economy of FMC, the risk of bankruptcy or other causes.	10 Catastrophic Unlikely

GROUP MEMBERS				
RI2.0	Time estimation	12 Moderate Likely	Can be avoided if every group member have an overview of the various tasks the group members is going to do, so that the other group members can take over the tasks by illness or injuries.	12 Moderate Likely
RI2.1	Well-being	6 Minor Possible	Talk about the conflicts once they occur. Have a friendly behavior towards the other group members.	4 Minor Unlikely
RI2.2	Stuck in individual tasks	8 Major Unlikely	Preventable by having short deadlines for hand-ins and the obligation of updating ones work on Dropbox. Group members offer each other help.	4 Major Rare
DESIGN				
RI3.0	Design Concept	15 Catastrophic Possible	Preventable with good site preparation and understanding of the tasks and be solution oriented. Have several design concepts that is replaceable with the selected concept.	10 Catastrophic Unlikely
RI3.1	Fail to follow A requirements	5 Catastrophic Rare	Preventable by going through all requirements in each iteration. Frequent repetition will lead to less risk of ignoring any requirements.	5 Catastrophic Rare
RI3.2	SolidWorks	20 Catastrophic Likely	Save new versions and retain older versions when performing changes to the 3D model in SolidWorks, and upload this on Dropbox.	10 Catastrophic Unlikely
TEST				
RI4.0	Planned tests not feasible	15 Catastrophic	Seek guidance and assistance from lecturers who have knowledge of the	5 Catastrophic

		Possible	testing and calculations.	Rare
TECHNICAL				
RI5.0	Backup	15 Catastrophic Possible	Ensure to have backup of everything that is uploaded to Dropbox every week.	10 Catastrophic Unlikely
RI5.1	Corrupted PC	4 Major Rare	Transfer documents to Dropbox regularly.	4 Major Rare
RI5.2	Saving documents	8 Major Unlikely	Preventable by saving the documents on the group members' computer and Dropbox frequently.	4 Major Rare

TABLE 4: Risk assessment - project

GOR = Grade of risks

GARA= Grade after risk actions

2.3 RISK ASSESSMENT TABLE: PROJECT BY ID

Table 2.3.1 and 2.3.2 is a copy of the table 2.2 describing the likelihood of a risk occurring and the consequences of this risk.

Table 2.3.1 contains all the risks defined by ID numbers in the correct risk group, before risk action is implemented. Table 2.3.2 describes the risk after implementation of risk action.

2.3.1 TABLE: BEFORE RISK ACTION

Consequences	Likelihood				
	Rare	Unlikely	Possible	Likely	Almost Certain
Insignificant					
Minor		RI1.4	RI2.1		
Moderate			RI1.0	RI2.0	
Major	RI5.1	RI1.1 RI2.2 RI5.2		RI1.6	
Catastrophic	RI1.2 RI3.1	RI1.7	RI1.5 RI3.0 RI4.0 RI5.0	RI1.3 RI3.2	

TABLE 5: Risk before risk action

2.3.2 TABLE: AFTER RISK ACTION

	Likelihood				
Consequences	Rare	Unlikely	Possible	Likely	Almost Certain
Insignificant					
Minor	RI1.4	RI2.1	RI1.0		
Moderate				RI2.0	
Major	RI1.1 RI2.2 RI5.1		RI1.6		
Catastrophic	RI1.2 RI3.1 RI4.0 RI5.2	RI1.3 RI1.5 RI1.7 RI5.0	RI3.0 RI3.2		

TABLE 6: Risk after risk action

3. RISK ASSESSMENT - CONCEPTS

This section consists of a risk assessment for the four concepts OLC Engineering has decided to focus on. This risk assessment describes the risk that are associated with the:

- Wire Sling Clamp
- Chain Sling Clamp
- Adjustable Belt
- Sliding 2-part Clamp

3.1 RISKS ASSOCIATED WITH THE CONCEPTS

3.1.1 MOUNTING & LIFTING OPERATION

- **MOUNTING:**

There is a risk if installers do not understand the concept, or the manual, and finds it difficult to assemble the concept or fails to perform the installation.

- **INJURY:**

The staff being injured during the assembly. Such as: Being exposed to the risk of getting your limbs caught in between parts. In addition to occurrence of general accidents.

- **SLIDE:**

There is a risk if the lifting gear starts to slide during the lift.

- **PORTABLE:**

Risky to carry portable lifting devices when there is high waves or bad weather during the assembly of the lifting gear. This applies to lifting accessories that is possible to carry by hand.

- **WRONG MOUNTING:**

Wrong mounting is a risk that can cause rotation of the lifting accessories around the pipe. The lifting accessories can also fall off during the lift or get damaged.

- **FAILURE WIRE:**

Wire Sling Clamp fails and breaks off during the lift.

- **FAILURE CHAIN:**

Chain Sling Clamp fails and breaks off during the lift.

- **FAILURE BELT:**

Adjustable Belt fails and breaks off during the lift.

- **FAILURE CLAMP:**

The danger that occurs if the sling that is linked to the clamp breaks during the lift.

3.1.2 DESIGN

- **SELECTION OF CONCEPTS:**

The risk of selecting a concept that is difficult to design compared to other concepts.

- **LOOSE PARTS:**

The danger of having too many loose parts is that they can be lost during the assembly or during transportation.

- **PROTRUDING PARTS:**

The lifting gear is designed so it can get stuck or hooked onto other objects.

The lifting hook of the crane gets hooked into unwanted areas on the lifting gear.

- **A REQUIREMENTS:**

The risk that the lifting accessories does not satisfy the A requirement specifications.

- **SOLUTION:**

The customer does not accept the solution for the lifting gear.

3.1.3 TEST

- **MOTION:**

Difficult to test moving products or parts in FEM Analysis, which is actually moveable in reality. For example: Soft sling or a mat.

3.1.4 TECHNICAL

- **MAINTENANCE:**

The risk of meeting challenges due to maintenance.

- **REQUIREMENTS:**

Not following the requirements may cause that the lifting gear cannot be used offshore.

3.2 RISK ASSESSMENT TABLE: WIRE SLING CLAMP

RISK GARA	GOR	RISK ACTIONS	
MOUNTING & LIFTING OPERATION			
MOUNTING	10 Catastrophic Unlikely	This can be avoided by having a well written manual which is easy to understand. The staff will be trained to assemble the Wire Sling Clamp.	5 Catastrophic Rare
INJURY	10 Catastrophic Unlikely	Possible to avoid if the staff does not perform the lift or assembly at poor weather conditions or high waves.	5 Catastrophic Rare
SLIDE	20 Catastrophic Likely	Preventable by having a locking mechanism that tightens around the pipe and has a coating on the inside that increases the friction between the pipe and the coating.	5 Catastrophic Rare
PORTABLE	15 Catastrophic Possible	Avoidable by not lifting the Wire Sling Clamp at poor weather conditions or high waves.	5 Catastrophic Rare
WRONG MOUNTING	10 Catastrophic Unlikely	Preventable by thorough usage of the manual and adequate training of the installer. Can also be prevented by enabling the installer to perform the job structured.	5 Catastrophic Rare
FAILURE WIRE	10 Catastrophic Unlikely	Can be avoided by regular service and if the group ensures a sufficient safety factor of the Wire Sling Clamp.	5 Catastrophic Rare
DESIGN			
SELECTION OF CONCEPTS	9 Moderate Possible	Preventable by inventing several alternative solutions for design and test these.	6 Moderate Unlikely
LOOSE PARTS		Preventable by having a	

	10 Catastrophic Unlikely	rubberized sling instead of a matt, so that the Wire Sling Clamp only consist of one part instead of two.	5 Catastrophic Rare
PROTRUDING PARTS	2 Minor Rare	Preventable if the group avoids designing the Wire Sling Clamp with protruding parts.	2 Minor Rare
A REQUIREMENTS	10 Catastrophic Unlikely	Preventable by reviewing requirement specifications at each iteration.	5 Catastrophic Rare
SOLUTION	12 Major Possible	Preventable by regular meetings and contact with the customer to get feedback during the solution process.	8 Major Unlikely
TEST			
MOTION	10 Minor Almost - Certain	This is a risk that the Wire Sling Clamp will have, because this concept consists of a wire sling which is moveable in reality. This is preventable by choosing correct moveable materials in SolidWorks.	10 Minor Almost - Certain
TECHNICAL			
MAINTENANCE	6 Minor Possible	Possible to avoid by having regular routine checks and store the Wire Sling Clamp in a safe place.	4 Minor Unlikely
REQUIREMENTS	5 Catastrophic Rare	Repeat the requirement specifications in each iteration.	5 Catastrophic Rare

TABLE 7: Risk assessment table: wire sling clamp

GOR = Grade of risks

GARA= Grade after risk actions

3.3 RISK ASSESSMENT TABLE: CHAIN SLING CLAMP

RISK GARA	GOR	RISK ACTIONS	
MOUNTING & LIFTING OPERATION			
MOUNTING	10 Catastrophic Unlikely	This can be avoided by having a well written manual which is easy to understand. The staff will be trained to assemble the Chain Sling Clamp.	5 Catastrophic Rare
INJURY	15 Catastrophic Possible	Possible to avoid if the staff does not perform the lift or assembly at poor weather conditions or high waves.	10 Catastrophic Unlikely
SLIDE	20 Catastrophic Likely	Preventable by having a locking mechanism that tightens around the pipe and has a coating on the inside that increases the friction between the pipe and the coating.	5 Catastrophic Rare
PORTABLE	15 Catastrophic Possible	Avoidable by not lifting the Chain Sling Clamp at poor weather conditions or high waves.	5 Catastrophic Rare
WRONG MOUNTING	10 Catastrophic Unlikely	Preventable by thorough usage of the manual and adequate training of the installer. Can also be prevented by enabling the installer to perform the job structured.	5 Catastrophic Rare
FAILURE CHAIN	10 Catastrophic Unlikely	Can be avoided by regular service and if the group ensures a sufficient safety factor of the Chain Sling Clamp.	5 Catastrophic Rare
DESIGN			
SELECTION OF CONCEPTS	9 Moderate Possible	Preventable by inventing several alternative solutions for design and test these.	6 Moderate Unlikely
LOOSE PARTS	10 Catastrophic	Preventable by having rubberized sling instead of a matt, so that the Chain Sling	5 Catastrophic

	Unlikely	Clamp only consist of one part instead of two.	Rare
PROTRUDING PARTS	6 Minor Possible	Preventable if the group avoids designing the Chain Sling Clamp with protruding parts.	6 Minor Possible
A REQUIREMENTS	10 Catastrophic Unlikely	Preventable by reviewing requirement specifications at each iteration.	5 Catastrophic Rare
SOLUTION	12 Major Possible	Preventable by regular meetings and contact with the customer to get feedback during the solution process.	8 Major Unlikely
TEST			
MOTION	4 Minor Unlikely	The Chain Sling Wire is composed of moveable parts, which causes that the FEM Analysis is less difficult to perform.	4 Minor Unlikely
TECHNICAL			
MAINTENANCE	6 Minor Possible	Possible to avoid by having regular routine checks and store the Chain Sling Clamp in a safe place.	4 Minor Unlikely
REQUIREMENTS	5 Catastrophic Rare	Repeat the requirement specifications in each iteration.	5 Catastrophic Rare

TABLE 8: Risk assessment table: chain sling clamp

GOR = Grade of risks

GARA= Grade after risk actions

3.4 RISK ASSESSMENT TABLE: ADJUSTABLE BELT

RISK GARA	GOR	RISK ACTIONS	
MOUNTING & LIFTING OPERATION			
MOUNTING	10 Catastrophic Unlikely	This can be avoided by having a well written manual which is easy to understand. The staff will be trained to assemble the Adjustable Belt.	5 Catastrophic Rare
INJURY	10 Catastrophic Unlikely	Possible to avoid if the staff does not perform the lift or assembly at poor weather conditions or high waves.	5 Catastrophic Rare
SLIDE	15 Catastrophic Possible	Preventable by having a locking mechanism that tightens around the pipe and has a coating on the inside that increases the friction between the pipe and the coating.	5 Catastrophic Rare
PORTABLE	6 Minor Possible	Avoidable by not lifting the Adjustable Belt at poor weather conditions or high waves.	2 Minor Rare
WRONG MOUNTING	10 Catastrophic Unlikely	Preventable by thorough usage of the manual and adequate training of the installer. Can also be prevented by enabling the installer to perform the job structured.	5 Catastrophic Rare
FAILURE BELT	10 Catastrophic Unlikely	Can be avoided by regular service and if the group ensures that the Adjustable Belt is designed with a sling that has a sufficient safety factor.	5 Catastrophic Rare
DESIGN			
SELECTION OF CONCEPTS	9 Moderate Possible	Preventable by inventing several alternative solutions for design and test these.	6 Moderate Unlikely
LOOSE PARTS	5	The Adjustable Belt consists only of one part, which means	5

	Catastrophic Rare	that the only risk is if the Adjustable Belt is lost during transportation.	Catastrophic Rare
PROTRUDING PARTS	4 Minor Unlikely	Preventable if the group avoids designing the Adjustable Belt with protruding parts.	2 Minor Rare
A REQUIREMENTS	10 Catastrophic Unlikely	Preventable by reviewing requirement specifications at each iteration.	5 Catastrophic Rare
SOLUTION	12 Major Possible	Preventable by regular meetings and contact with the customer to get feedback during the solution process.	8 Major Unlikely
TEST			
MOTION	10 Minor Almost-Certain	This is a risk that the Adjustable Belt will have, because this concept consists of a belt which is moveable in reality. This is preventable by choosing correct moveable materials in SolidWorks.	10 Minor Almost-Certain
TECHNICAL			
MAINTENANCE	6 Minor Possible	Possible to avoid by having regular routine checks and store the Adjustable Belt in a safe place.	4 Minor Unlikely
REQUIREMENTS	5 Catastrophic Rare	Repeat the requirement specifications in each iteration.	5 Catastrophic Rare

TABLE 9: Risk assessment table: adjustable belt

GOR = Grade of risks

GARA= Grade after risk actions

3.5 RISK ASSESSMENT TABLE: SLIDING 2-PART CLAMP

RISK GARA	GOR	RISK ACTIONS	
MOUNTING & LIFTING OPERATION			
MOUNTING	10 Catastrophic Unlikely	This can be avoided by having a well written manual which is easy to understand. The staff will be trained to assemble the Clamp.	5 Catastrophic Rare
INJURY	15 Catastrophic Possible	Possible to avoid if the staff does not perform the lift or assembly at poor weather conditions or high waves.	10 Catastrophic Unlikely
SLIDE	10 Catastrophic Unlikely	Preventable if the Clamp is screwed onto the pipe with a set of preloading bolts.	5 Catastrophic Rare
PORTABLE	15 Catastrophic Possible	Avoidable by not lifting the Sliding 2-part Clamp at poor weather conditions or high waves.	10 Catastrophic Unlikely
WRONG MOUNTING	15 Catastrophic Possible	Preventable by thorough usage of the manual and adequate training of the installer. Also preventable by enabling the installer to perform the job structured.	5 Catastrophic Rare
FAILURE CLAMP	10 Catastrophic Unlikely	Can be avoided by regular service and if the group ensures that the Sliding 2-part Clamp is designed with a sling that has a sufficient safety factor.	5 Catastrophic Rare
DESIGN			
SELECTION OF CONCEPTS	9 Moderate Possible	Preventable by inventing several alternative solutions for design and test these.	6 Moderate Unlikely
LOOSE PARTS	10 Catastrophic Unlikely	The lifting gear consists of two parts, and might consist of more parts, which means that it is a possibility that parts	10 Catastrophic Unlikely

		may be lost during the assembly or shipping.	
PROTRUDING PARTS	6 Minor Possible	Preventable if the group avoids designing the Clamp with protruding parts.	4 Minor Unlikely
A REQUIREMENTS	10 Catastrophic Unlikely	Preventable by reviewing requirement specifications at each iteration.	5 Catastrophic Rare
SOLUTION	12 Major Possible	Preventable by regular meetings and contact with the customer to get feedback during the solution process.	8 Major Unlikely
TEST			
MOTION	2 Minor Rare	This is a risk which Sliding 2 part Clamp most likely won't be exposed to, as this concept is not composed of components which are movable in reality.	2 Minor Rare
TECHNICAL			
MAINTENANCE	6 Minor Possible	Possible to avoid by having regular routine checks and store the Sliding 2-part Clamp in a safe place.	4 Minor Unlikely
REQUIREMENTS	5 Catastrophic Rare	Repeat the requirement specifications in each iteration.	5 Catastrophic Rare

TABLE 10: Risk assessment table: sliding 2-part clamp

GOR = Grade of risks

GARA= Grade after risk actions

4. RISK ASSESSMENT – MAIN CONCEPT

This risk assessment describes the main concept in this project. The main concept consists of a rubber mat fastened to the pipe with two straps, a standardized chain, a tightening mechanism for the chain and two hooks that holds the chain in the correct position.



FIGURE 1: FINAL DESIGN

This risk assessment describes each part of the system, as well as the entire system as a unit. It is carried out a risk assessment for each part of the system, to get an overview of the risks, as well as to compare the various parts with each other. The results of the risk assessment are placed in two tables, one before risk action and one after. These tables will give an indication of which parts should be further developed in relation to the risk assessment in later work. The risk assessment for the entire system is performed in the same way as previous risk assessments.

OLC has gone through relevant risks parallel with the development of the product during the third, fourth and fifth iteration in the project model. The purpose is to develop a safe product that satisfies the requirements. Such as:

R5.1.0 Off board lift - The clamp must be safe to use in an off board lift.

R5.3.1 Carried by person - It must be safe for a person to carry the clamp without danger for injuries or losing parts of the clamp.

4.1 RISK ASSOCIATED WITH PARTS OF THE SYSTEM

4.1.1 MAT

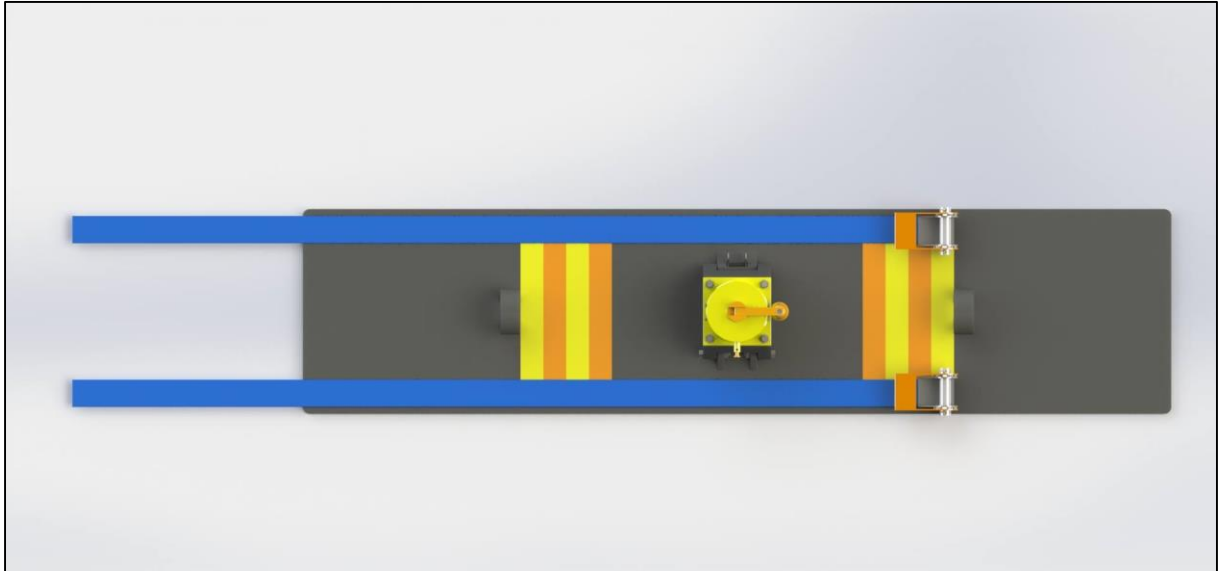


FIGURE 2: MAT

DESIGN

RISK:

One risk is that the mat does not get an optimal design. Using a mat with largest possible varying diameter can cause too large or too small overlap. This can lead to bad assembly as shown in Figure 3 or that the chain comes in direct contact with the pipe surface. The straps on the sides of the mat must be correctly positioned to make room for the chain in the middle. The width of the mat is only 30cm. The width of the mat might lead to a risk that the chain might slip off the edge on the mat in a 45° lift.



FIGURE 3: OVERLAP

The pockets of the mat has to be placed correctly to keep the chain in the right position. The chain might get a large space for movement on the bottom of the tube if the pockets are placed too far up. The pockets can get in the way of the overlap if they are placed too far down.

RISK ACTION:

Incorrect overlapping of the mat can be prevented by designing several mats to the various diameters. To get a correct size and placement of the straps on the sides it must be carried out calculations and tests, to achieve desired qualifications for the straps, and at same time make space for the chain in the middle of the mat. OLC has designed a hook to get the right angle on the chain. This hook will avoid that the chain slides off during a 45° lift. To ensure proper positioning of the pockets it must be performed calculations and tests.

GOR:	20 Catastrophic Likely	GARA:	5 Catastrophic Rare
-------------	-------------------------------	--------------	----------------------------

MOUNTING

RISK:

There is a risk that the staff who is responsible to install the mat does not understand the instructions. On the other hand, that the mat is incorrectly mounted. The mat must be positioned at the center of the tube in order to perform a correct lifting.

RISK ACTION:

This can be prevented if only qualified personnel takes responsibility of the assembly and that the operating instructions are read carefully.

GOR:	20 Catastrophic Likely	GARA:	10 Catastrophic Unlikely
-------------	-------------------------------	--------------	---------------------------------

INJURY

RISK:

The possibility of getting hurt on the rubber mat is small. The greatest danger must be risk of crushing using tensioning straps. It can also occur a minor injury by losing the mat while carrying it.

RISK ACTION:

This can be prevented by reading the manual, be careful and be predictable.

GOR:	6 Minor Possible	GARA:	2 Minor Rare
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NOT WORKING

RISK:

There is a risk that the mat does not work as expected.

RISK ACTION:

This can be prevented by routine checks and good maintenance of the mat.

GOR:	12 Major Possible	GARA:	4 Major Rare
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FAILURE PART

RISK:

One risk is that the mat or permanently installed components loosen or breaks. The tightening straps for attaching the mat, pockets that keeps the chain in place or top pocket that holds TM and chain in the right position can loosen or break.

RISK ACTION:

These risks can be prevented by good maintenance and routine checks.

GOR:	15 Catastrophic Possible	GARA:	5 Catastrophic Rare
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PROTRUDING PARTS

RISK:

The risk of protruding parts is big if other objects are caught up in these. On the mat, this applies to all the pockets and buckles on the straps.

RISK ACTION:

This can be prevented by deliberate design and testing.

GOR:	9 Moderate Possible	GARA:	3 Moderate Rare
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WRONG USE

RISK:

There is a risk if the mat is used to perform tasks that the mat not is suited for. Such as: used on pipes with incorrect diameter, tightening straps are similar to regular tightening equipment and there is a risk that they are being ripped off for other uses.

RISK ACTION:

Usage of the mat on pipes with wrong diameter is prevented by clearly marking on the pipe and describing how it can be used. The straps should be attached so well that they cannot be removed.

GOR:	15 Catastrophic Possible	GARA:	5 Catastrophic Rare
-------------	--------------------------	--------------	---------------------

REQUIREMENTS

RISK:

There is a risk that the mat does not meet all the requirements that applies both design and installation on pipe.

RISK ACTION:

The requirements for the design and installation must be approved through strict testing, and documentation.

GOR:	20 Catastrophic Likely	GARA:	5 Catastrophic Rare
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4.1.2 CHAIN

DESIGN

The chain is already standardized and certified. The chain design is decided by the fabrication.

MOUNTING

RISK:

The risk of installing the chain wrong. The middle of the chain must be placed on the middle of the mat in order to perform a correct lift. The chain must be placed inside the pockets on the mat.

RISK ACTION:

Prevented by reading the user manual, and that the middle link of the chain is marked in a visible and logical way, so that the middle of the chain is placed on the center of the mat. Or that the chain is permanently mounted on the mat.

GOR:	20 Catastrophic Likely	GARA:	5 Catastrophic Rare
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INJURY

RISK:

There is a danger of injury by squeezing fingers in links of the chain during assembly.

RISK ACTION:

The risk is prevented by being careful when mounting.

GOR:	4 Minor Unlikely	GARA:	2 Minor Rare
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NOT WORKING

The chain is already standardized and certified. The chain shall function as specified by the manufacturer.

FAILURE PART

RISK:

There is a risk that the chain will break.

RISK ACTION:

This can be prevented by following the manufacturer's instructions for routine checks and maintenance, in addition to not use the chain to perform lifts that exceeds the break load of the chain.

GOR:	5 Catastrophic Rare	GARA:	5 Catastrophic Rare
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PROTRUDING PARTS

RISK:

The chain does not consist of protruding parts, but there is a risk associated with the links to the chain because these can get stuck in other objects.

RISK ACTION:

The risk can be prevented by avoiding the usage of parts that can hook up in the chain, in the entire system.

GOR:	4 Major Rare	GARA:	4 Major Rare
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WRONG USE

RISK:

Misusage of the chain is a big risk. As such: if it is used for heavier lift than it is suited for.

RISK ACTION:

Readable marking on the chain that describes the maximum load can prevent this.

GOR:	15 Catastrophic Possible	GARA:	10 Catastrophic Unlikely
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REQUIREMENTS

The chain is already standardized and certified for off board lifting. So the chain meets all the requirements.

4.1.3 TIGHTENING MECHANISM



FIGURE 4: TIGHTENING MECHANISM

DESIGN

RISK:

The risk associated with the design of the TM is sideways turned lifts. It is primarily that the TM must be designed in such a way that it can tighten the ends of the chain parallel to avoid a sideways turned elevator. TM will also be exposed to torsional stresses and must be designed to withstand these stresses.

RISK ACTION:

To avoid the risk of uneven tension in the TM, it needs to be tested that it tightens evenly. The design must also be tested for the loads it must endure.

GOR:	6 Moderate Unlikely	GARA:	3 Moderate Rare
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MOUNTING

RISK:

There is a risk if the TM are incorrectly installed, which can cause that the chain is not tighten enough, or that the TM does not tight equally on both sides of the mat.

RISK ACTION:

This can be avoided with reading the manual and good marking on pocket on the mat describing where TM should be placed. Or that the TM is permanently mounted on the mat.

GOR:	16 Major Likely	GARA:	4 Major Rare
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INJURY

RISK:

Risk associated with potential injury on TM consists of a squeeze danger, usually by misplacement of fingers under the wire when tightening the TM. On the other hand, the danger of losing the TM while carrying it.

RISK ACTION:

By building a protective body around the TM to prevent risk of crushing fingers, and that user manuals are read carefully.

GOR:	9 Moderate Possible	GARA:	6 Moderate Unlikely
-------------	---------------------	--------------	---------------------

NOT WORKING

RISK:

There is a risk if the TM is not properly tightened so the mechanism locks up, or if it does not tightened parallel.

RISK ACTION:

This can be prevented by good maintenance and regular routine check.

GOR:	12 Major Possible	GARA:	4 Major Rare
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FAILURE PART

RISK:

There is a danger that TM is broken. The weakest parts this particularly applies to is the gear, locking pin and wire.

RISK ACTION:

This can be prevented by good maintenance and regular routine check.

GOR: 8 Major Unlikely

GARA: 4 Major Rare

PROTRUDING PARTS

RISK:

Protruding parts on this mechanism that can attach themselves to other objects are the locking pin, crank handle and wire.

RISK ACTION :

To avoid the protruding parts from attaching to other objects, it is important to take this into account in the design process.

GOR: 9 Moderate Possible

GARA: 6 Moderate Unlikely

WRONG USE

RISK:

Wrong usage of the tightening mechanism is a risk if the wire is not tightened enough. The TM will not perform its expected task, which is to tighten the chain sufficient. There is also a risk if the tightening handle is not locked in position and can move freely.

RISK ACTION:

Preventable by locking the pin into the tightening handle, to lock it in a specified position. Moreover, by marking the wire with how much it should be tightened on the different diameters of pipes. Such as by marking an area of wire with yellow or green to mark how much the wire should be tightened on a 14" and 16 " pipe.

GOR: 15 Moderate Almost certain

GARA: 6 Moderate Unlikely

REQUIREMENTS

RISK:

There is a risk that the TM does not meet all the requirements that applies both design and installation on pipe.

RISK ACTION:

The requirements for the design and installation must be approved through strict testing, and documentation.

GOR:	8 Major Unlikely	GARA:	4 Major Rare
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4.1.4 HOOKS

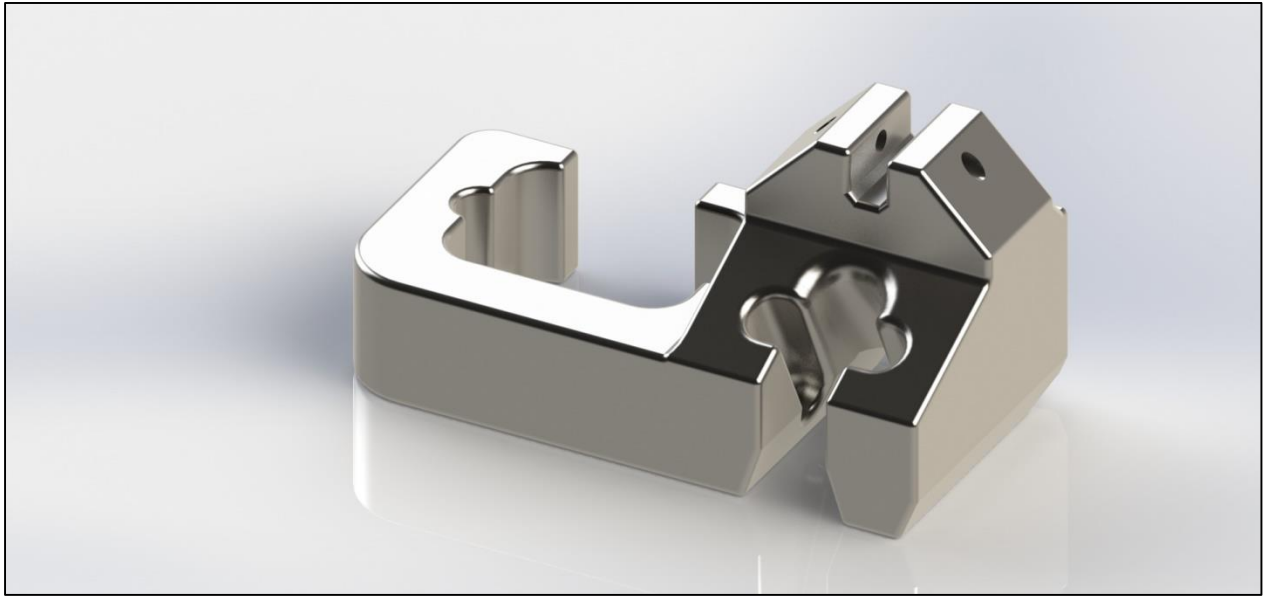


FIGURE 5: CHAIN HOOK

DESIGN

RISK:

There is a risk if the hooks does not meet the design requirements. There is designed two different hooks, as they will have different features on each side of the chain. The most dangerous risk can occur if the hooks are designed wrong. Wrong design of the hooks may have major consequences. Some of the consequences can occur if the hooks are not able to hold the chain in the right position so that the hooks disengage from the chain, if the hooks cannot withstand the expected load or if the 'free' chain cannot slide into the hook.

RISK ACTION:

To avoid these challenges, it is used design optimization in Solidworks by using FEM analysis. It is made several versions of the hook that is tested carefully.

GOR:	25 Catastrophic Almost Certain	GARA:	10 Catastrophic Unlikely
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MOUNTING

RISK:

Since it is designed two different hooks there is a risk that they will be mounted on the wrong side. There is a risk that they may be mounted in the wrong part of the chain or into the wrong chain.

RISK ACTION:

This can be prevented if qualified personnel takes the responsibility to execute the mounting, and that the instructions are read carefully. It is also important to mark the different hooks to describe which side it shall be used on.

GOR:	25 Catastrophic Almost Certain	GARA:	10 Catastrophic Unlikely
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INJURY

RISK:

Each hook weighs 3124.30 grams therefore there is a risk to lose it during installation, as this may cause damage.

RISK ACTION:

Careful handling of the hooks can prevent this.

GOR:	9 Moderate Possible	GARA:	3 Moderate Rare
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NOT WORKING

RISK:

There is a risk that the hooks does not work as expected.

RISK ACTION:

This can be prevented by good maintenance and regular routine check.

GOR:	10 Catastrophic Unlikely	GARA:	5 Catastrophic Rare
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FAILURE PART

RISK:

A risk might occur if the hooks cannot withstand the expected stress or if they are used longer than the expected lifetime.

RISK ACTION:

This can be prevented by marking the max load on the hooks, good maintenance and regular routine check.

GOR:	15 Catastrophic Possible	GARA:	5 Catastrophic Rare
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PROTRUDING PARTS

RISK:

There is a risk that the hooks are protruding parts and can attach itself to other objects.

RISK ACTION:

This can be prevented by an optimal design and testing of hooks.

GOR:	8 Major Unlikely	GARA:	4 Major Rare
-------------	------------------	--------------	--------------

WRONG USE

RISK:

Wrong usage of the hooks is a big risk if the hooks are mounted on the wrong side of the mat, the hooks are not attached properly to the chain or misused on another product.

RISK ACTION:

This can be prevented if qualified personnel will take the responsibility of mounting the hooks. Operating instructions are read carefully, and that the hooks are marked to show where it is supposed to be used.

GOR:	20 Catastrophic Likely	GARA:	10 Catastrophic Unlikely
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REQUIREMENTS

RISK:

The hooks are a part of the lifting scenario and have to be classified as a lifting tool. All the requirements given by the clients and the standards must be fulfilled to approve the hooks as lifting tools. There is a risk that they do not meet all of these strict requirements.

RISK ACTION:

Frequent review of all requirements in each iteration and frequent testing of the requirements prevents this.

GOR:	25 Catastrophic Almost Certain	GARA:	5 Catastrophic Rare
------	--------------------------------	-------	---------------------

4.2 RISK ASSESSMENT TABLES: RISK ACTION OF PARTS

The tables shows the documented risks associated with the different parts of the system. This overview makes it easy to observe the parts that are associated with the greatest risk, and makes it easier to see what should be most focused on and worked forward with.

4.2.1 TABLE: BEFORE RISK ACTION

Table 4.2.1 describes the risks before risk action. As shown in the table the greatest risk is associated with the hooks. Because these are supposed to be a lifting tool that needs to be approved. There is least risk relating to the chain because this is already a standardized and approved lifting tool.

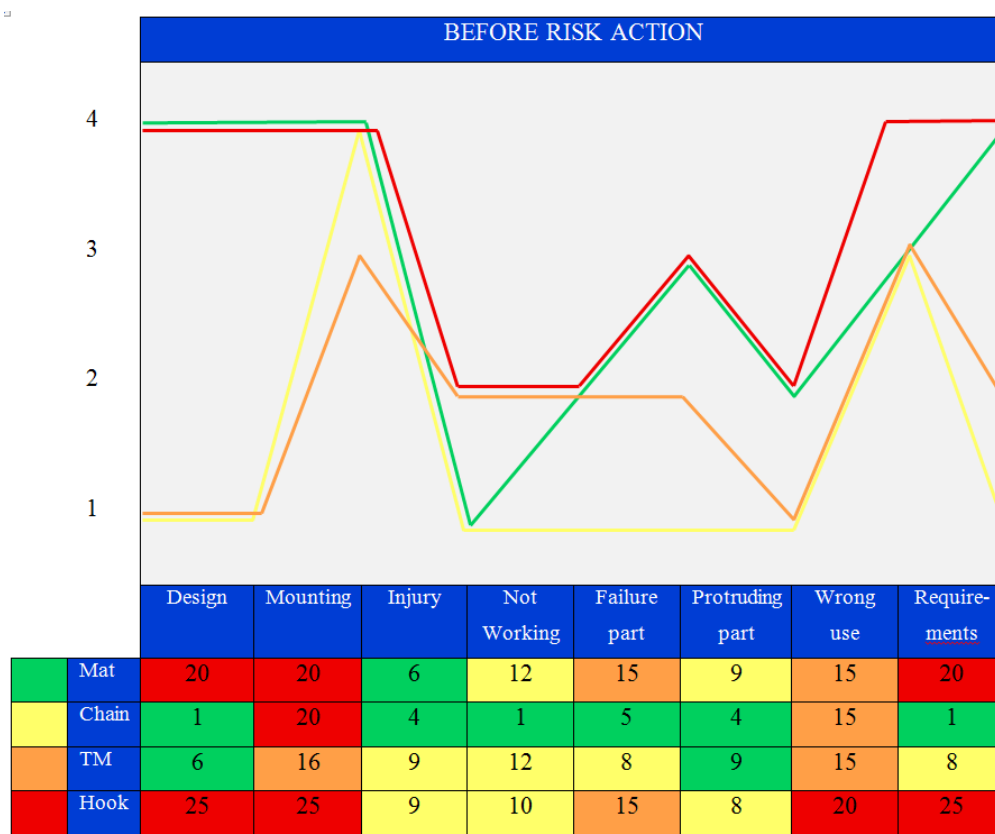


TABLE 11: Before risk action of parts

4.2.2 TABLE: AFTER RISK ACTION

Table 4.2.2 describes risk after risk action. The results gives the ability to compare the table 4.2.1 and 4.2.2, and study the difference before and after the risk action is implemented. Most of the risks with a high grade of risk is now reduced by implementing the risk action. Most of the risks are now acceptable. Except the yellow results that are generally not accepted, but may be accepted under certain circumstances, because the grade of risks is not too high.

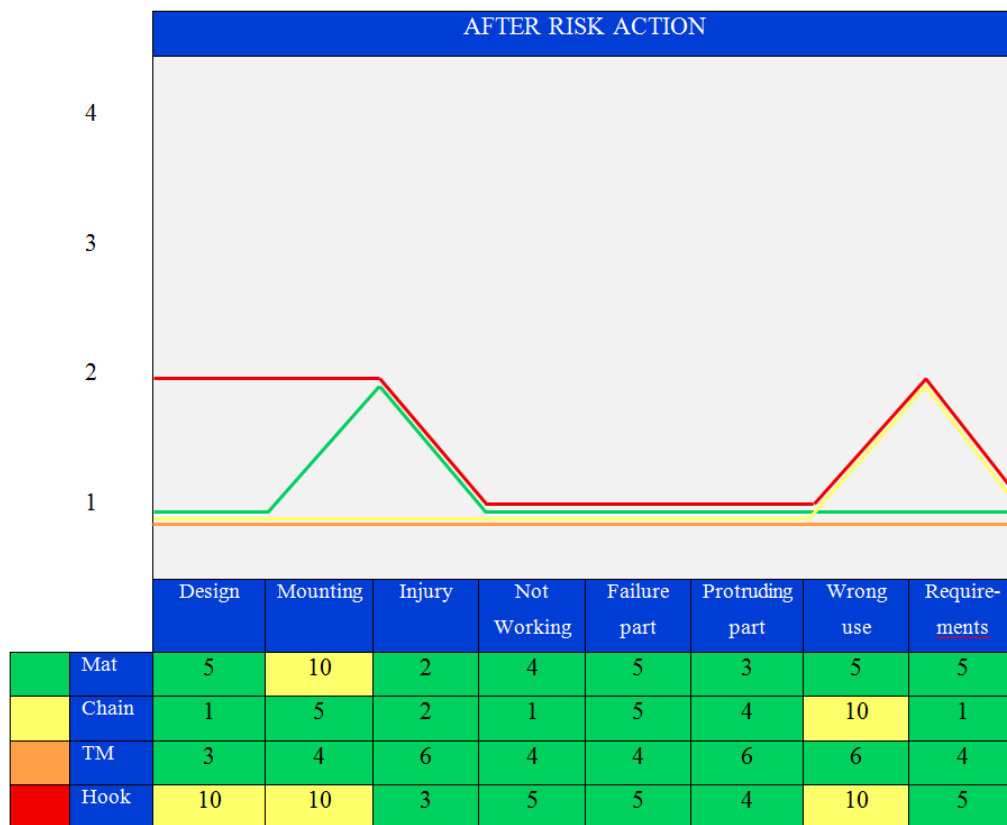


TABLE 12: After risk action of parts

4.3 RISK ASSOCIATED WITH THE ENTIRE SYSTEM

4.3.1 MOUNTING & LIFTING OPERATION

- **MOUNTING:**

There is a risk if installers do not understand the concept, or the manual, and finds it difficult to assemble the mat concept or fails to perform the installation.

- **INJURY:**

The staff being injured during the assembly. Such as: Being exposed to the risk of getting your limbs caught in between parts. In addition to occurrence of unexpected accidents.

- **SLIDE:**

There is a risk if the mat concept starts to slide during the lift.

- **PORTABLE:**

Risky to carry portable system devices when there is high waves or bad weather during the assembly of the system. This applies to lifting accessories that is possible to carry by hand.

- **WRONG MOUNTING:**

Incorrect installation of the system can lead to excessive risk. Wrong assembling of the mat can cause that the mat are rotating or sliding on the pipe. Incorrect assembly of the hooks can cause that the chain goes out of the correct position. Incomplete tension of the chain can cause the chain to move.

4.3.2 DESIGN

- **LOOSE PARTS:**

The danger of having too many loose parts is that they can be lost during the assembly or during transportation.

- **PROTRUDING PARTS:**

A risk can occur if the system is designed so it can get stuck or hooked onto other objects. The lifting hook of the crane gets hooked into unwanted areas on the system.

- **SOLUTION:**

The customer does not accept the solution for the system.

4.3.3 TEST

- **MOTION:**

The system contains moving parts that are difficult to test in FEM Analysis, which is actually moveable in reality.

- **RESULTS:**

The risk if the results from the physical tests does not conform with the simulation tests.

- **PHYSICAL TESTS:**

Not be able to perform physical tests.

4.3.4 TECHNICAL

- **MAINTENANCE:**

The risk of meeting maintenance challenges.

- **REQUIREMENTS:**

Not following the requirements may cause that the mat cannot be used off board or offshore.

4.4 RISK ASSESSMENT TABLE: ENTIRE SYSTEM AS A UNIT

RISK	GOR	RISK ACTIONS	GARA
MOUNTING & LIFTING OPERATION			
MOUNTING	20 Catastrophic Likely	This can be avoided by having a well written manual which is easy to understand. The staff will be trained to assemble the Mat concept.	5 Catastrophic Rare
INJURY	6 Moderate Unlikely	Possible to avoid if the staff does not perform the lift or assembly at poor weather conditions or high waves.	3 Moderate Rare
SLIDE	20 Catastrophic Likely	Preventable by having a locking mechanism that tightens around the pipe and using a material with high friction coefficient.	5 Catastrophic Rare
PORTABLE	12 Major Possible	Avoidable by not lifting the mat at poor weather conditions or high waves.	4 Major Rare
WRONG MOUNTING	15 Catastrophic Possible	Preventable by thorough usage of the manual and adequate training of the installer. Can also be prevented by enabling the installer to perform the job structured.	5 Catastrophic Rare
DESIGN			
LOOSE PARTS	4 Minor Unlikely	Prevented by making the entire system as a unit. Alternatively, that it consists of two big major parts that are difficult to lose.	2 Minor Rare
PROTRUDING PARTS	6 Minor Possible	Preventable if the group avoids designing the system with protruding parts.	2 Minor Rare
SOLUTION	12 Major Possible	Preventable by regular meetings and contact with the customer to get feedback during the solution process.	8 Major Unlikely
TEST			

MOTION	8 Minor Likely	This is a risk that the mat will have, because this concept consists of a rubber mat and non-metallic materials that is moveable in reality. This is preventable by choosing correct moveable materials in SolidWorks.	6 Minor Possible
RESULTS	9 Moderate Possible	Preventable by using most realistic values in Solidworks. For example: Realistic value for the load or elasticity or rigidity of the materials.	6 Moderate Unlikely
PHYSICAL TESTS	15 Moderate Almost Certain	Good planning and purchase or borrow necessary equipment or materials.	6 Moderate Unlikely
TECHNICAL			
MAINTENANCE	6 Minor Possible	Possible to avoid by having regular routine checks and store the mat in a safe place.	4 Minor Unlikely
REQUIREMENTS	12 Catastrophic Likely	Repeat the requirement specifications in each iteration, and have regular meetings with the customer.	5 Catastrophic Rare

TABLE 13: System

GOR = Grade of risks

GARA= Grade after risk actions

5. CONCLUSION

By keeping these risks and risk actions in mind, OLC believe that OLC will have a greater chance of success with the project. Since OLC have been writing risk assessments repeatedly for each iteration, this have had a good influence on the group when while working with the project. Execution of various risk assessments during the project has lead to gaining a better understanding of the risks that are associated with the different parts and the whole system as a unit.

OLC found it beneficial to execute the risk assessment, because it gave the group the opportunity to reflect on the various situations that can incur, in addition to that the group have reflected on how situations with high risks should be handled. The risks are reduced a lot by implementing the GARA to the risks. This has been a helping hand for the group during the entire project, as these risk assessments with the implementation of GARA has helped the group by choosing a main concept with high quality and a low degree of risk.

6. RECOMMENDATION

There are some products and concepts that have slightly higher risk than others, but this can be changed by doing some necessary changes with the product, or by finding a better GARA to the risk. OLC believes that those slightly higher risks might be reduced without encountering too many challenges. OLC recommends to improve the risk assessment of the Hooks because it has some challenges with the design, mounting and wrong usage. The Mat needs to improve the risk of mounting. The Chain also needs to be improved due to the risk of wrong usage. These risks can be improved by doing some small adjustments and having a stricter GARA that includes having stricter and more disciplined rules and requirements.

7. REFERENCES

- | | | |
|-----|---|------------|
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OFFSHORE LIFTING CLAMP ENGINEERING
VERSION 2.0

ITERATION EVALUATION

22.05.16

ABSTRACT

The iteration evaluation report describes the activities, meetings, project evaluations and planning of the next iterations. The iteration report includes five iteration evaluations, in addition to the evaluation of the startup-phase, the system test and the project completion. The purpose with the iteration evaluation report is to evaluate what OLC have been working with in each iteration to give an overview of the process of the project. This report will give the opportunity to obtain a brief, but detailed description of what the various iterations of the project contains.

CHANGES

The changes in the document are listed here:

Version	Date	Description
2.0	22.05.16	<ul style="list-style-type: none">• Implemented the last situation evaluation for the last period
1.0	20.05.16	<ul style="list-style-type: none">• Added: Abstract, introduction and conclusion
0.3	20.05.16	<ul style="list-style-type: none">• Updated: List of contents• Added: List of figures• Created: Figure name
0.2	19.05.16	<ul style="list-style-type: none">• Added “Evaluation after fourth iteration”• Updated “Evaluation after fifth iteration”

In addition to the above:

There may be spelling mistakes that are corrected. It is possible that these changes are not listed.

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INTRODUCTION

In order for OLC to evaluate their work, the group decided to write iteration evaluation documents after each completed iteration. By doing this, the group could find out what activities and task that were completed and which activities that still had to be done.

To maintain a good communication, there have been several meetings with the both the internal and the external supervisor. The meeting minutes have been evaluated so that all the important information have been documented.

The status of the project have been defined by summarizing the performed work, and finding out what comes next. This kept all the group members updated after each iteration.

1. EVALUATION OF THE STARTUP PHASE

The purpose of the startup phase of the project period was to create a project plan. Here OLC decided the project model, created a task list and a schedule. OLC also defined all the system requirements and created a test plan for all the requirements.

OLC have set the startup period from the project start in week 2, until the first presentation in Week 5. The estimated time schedule for the period is 550 hours in total for the whole group.

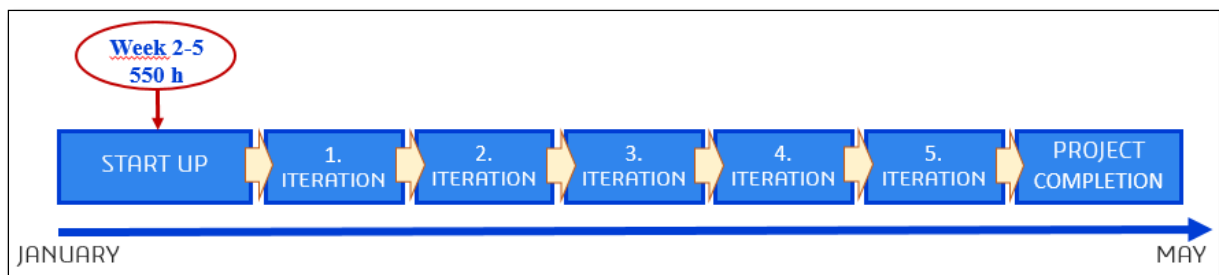


FIGURE 1: Project timeline (START UP)

1.1 ACTIVITIES DURING STARTUP PHASE

The activities OLC completed in week 2, 2016:

Activity	Description of task done
A1.1 Kick off	All group members attended at group meetings and preparations for the project. OLC gathered information about other previous bachelor projects, for inspiration.
A1.3 Group contract	OLC worked on, and completed a group contract concerning some ground rules for the group work in the group.
A1.4 Templates	OLC started developing a template to use in all the written documentations.

The activities OLC completed in week 3, 2016:

Activity	Description of task done
A1.6 Project model	OLC started to do research and discussed different kinds of project-models in week 2. OLC decided to go for the spiral-model, with several iterations planned. OLC have been working on the project model, and the first version of the spiral-model document was finished.
A1.7 Time schedule	OLC started to design a time schedule for the project throughout the project lifetime, in week 2. This was completed in week 3.
A1.8 Activity specifications	The activity-list describes the different activities throughout the project period. OLC started working on developing the activity-list to be used in the Gantt chart.
A1.4 Time-tracking	OLC finished the time tracking template. So that OLC all can use the same time tracking system to track the working hours in the project.

The activities OLC completed in week 4, 2016:

Activity	Description of task done
A1.5 Logo	Decided on a logo for the project.
A1.9 Gantt chart	The Gantt chart is based on the time schedule and action plan. Some of the group members have been learning how to use the Gantter-software in week 2. OLC finished the first version of our Gantt chart in week 4.
A2.2 Situation Analysis	OLC started working on the situation analysis in week 2. The purpose of the situation analysis is to get an overview of the surroundings and risks associated with lifting.
A4.1.1 Project plan report	OLC started working on the project plan report in week 3. The group finished the first version in week 4.
A2.2.2 Requirements	OLC started writing the system and DNV requirements in week 3. The group finished the first version of the system requirement

Specification 1	specification in week 4. The DNV requirements were very deficient and OLC did not deliver a full-featured version.
A2.2.3 Requirements Specification Document	OLC completed the first version of the requirements specification document.
A2.3.2 Test Specification Document	OLC completed the first version of the test specification document, although with a deficient test specification.

The activities OLC completed in week 5, 2016:

Activity	Description of task done
A1.10 First project report	OLC finished and handed in the first report of the project. Consisting of a project plan, a requirements specification and a test specification.
A.4.2.2 First Presentation	OLC started making the presentation template in week 3. In week 4 The group started working on the first presentation. OLC held the first presentation of the project on Thursday 04/02/16.

The activities OLC did not finish in the startup phase:

Activity	Description of task done
A1.11 Web site	OLC were supposed to create a website with information about the group. The reason that the group did not finish this task was because the school did not have the website address ready.
A2.1 DNV	OLC have been reading DNV 2.7-3 and 2.22. the group did not finish reading these documents because they were really comprehensive.
A2.3.1 Test specification 1	OLC started writing the test specification in week 3. The group was not able to write the test specification, due to the need of a first version of the requirement specification. The first version of the test specification was not completed, and the group handed in an incomplete version on the first presentation.

1.2 MEETINGS

OLC had several meetings with the customer, internal and external supervisor in the startup phase. This in order to get information, guidance and feedback for the choices.

1.2.1 MEETINGS WITH INTERNAL SUPERVISOR

- 19/01/2016 - OLC introduced the project to the internal supervisor Amin Hossein Zavieh. Explained to him the use of the spiral model, and the time schedule for the project.
- 27/01/2016 - Amin gave the group some advice about the first presentation. This was about what OLC should include in the presentation. He also recommended the group to send the requirements the group had made to FMC, to get a feedback before the first presentation.
- 03/02/2016 - In this meeting OLC held a pre presentation for Amin. He gave the group feedback and some advice for the main presentation.

1.2.2 MEETINGS WITH EXTERNAL SUPERVISOR

- 21/01/16 - OLC had a meeting with Einar Totland and Bjørn Michaelsen at FMC. Here the group received more information about the clamp, the situation analysis, the requirement specifications and the test specifications.
At the end of the meeting, the external supervisor Per Øystein Hansson came by to say hello.

1.3 PROJECT EVALUATION

1.3.1 ACTIVITIES

According to the activity list for the period, the group finished many of the activities at the estimated time.

The biggest mistake was that OLC didn't start writing the requirement- and test specifications before week 3, which was too late. The group should have started writing them at the same time as the project plan in week 2. Because these tasks were too big and time-consuming. OLC also planned to start the requirements specification and test specifications at the same time, which is not possible since the test specification is based on the requirements specification.

OLC did not managed to read throughout DNV 2.22 and 2.7.-3, because they were large and extensive. This led to a delay of several activities in the startup phase and the group will get a lot of extra work in the next period. OLC must continue to write requirements from DNV and create tests for them, so that a full version of the requirements- and test specification can be achieved.

There were also some long days and late nights before the deadline for submission of documents. OLC started on writing the reports too late. The group should try to avoid that before the next presentation.

OLC did not create their own website. This was not the groups fault, because the school did not have the web-address ready. OLC can not do anything about it before the web-address is ready.

1.3.2 TIME SCHEDULE

Time used in the startup phase:

Week 1 Total hours: 18 h

Week 2 Total hours: 126 h

Week 3 Total hours: 137,5 h

Week 4 Total hours: 182,5 h

Week 5 Total hours: 164,5 h

Total = 628,5 h

OLC spent a total of 628,5 hours during this period which is 78,5 hours more than the time estimate of 550 hours for the period. The reason for why the group spent several hours more is because OLC calculated the time estimation per activity wrong.

1.3.3 COOPERATION WITHIN THE GROUP

The cooperation in the group is good, and everyone contributes in the project work.

It is OLC's scheduling and misplaced priorities which is the reason for the delay in the process.

1.4 PLANNING THE NEXT ITERATION

After this phase OLC are starting the first iteration of the spiral model, with a duration of two weeks. The group have to finish the uncompleted tasks from the startup period in addition to the planned activities for the first iteration.

The planned activities for the first iteration are:

- **Requirement Specification**
Review of requirements specification.
- **Test Specification**
Review of test specification.
- **Risk Assessment 1**
Main risk assessment for the entire project period.
- **Evaluate Design Concepts 1**
Come up with several design concepts.
- **Evaluation and Analysis 1**

Evaluate the design concepts.

2. EVALUATION AFTER FIRST ITERATION

OLC are using the spiral model in the project. Here the group have that each iteration last for two weeks. The first iteration is from Week 6 through Week 7, 2016. The estimated time for the first iteration is 250 hours for the whole group.

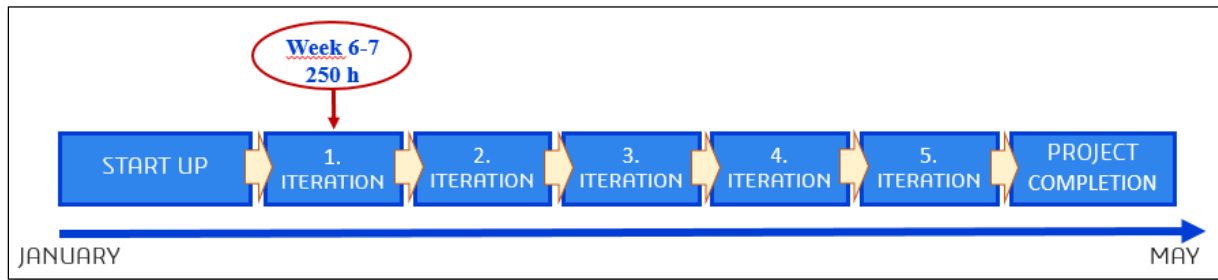


FIGURE 2: Project timeline (1. ITERATION)

2.1 ACTIVITIES DURING FIRST ITERATION

Activity	Description of task done
A2.2.2 Requirement Specification 1	OLC completed the second version of the requirement specification both for the main requirements and the DNV requirements.
A2.3.1 Test Specification 1	OLC completed the first version of the test specification both for the main test and the DNV tests.
A2.4.1 Risk Assessment 1	In the first iteration, OLC wrote a general risk assessment for the entire project period. Here the group summarized and analyzed the possible risks in the project. After having assigned all the risks to a category, OLC looked at how the group could reduce the risks to acceptable levels. OLC completed the first version of the main risk assessment.
A3.1.2 Evaluate Design Concepts 1	OLC came up with many design concepts, and started writing the "Clamp concepts" document.

A3.3.1 Evaluation and Analysis 1	To evaluate and analyze the work the group had done in the iteration OLC had a group meeting. Here the group did a brief summary and planned the next iteration.
A1.11 Website	OLC are waiting to create the website until the second iteration.

2.2 MEETINGS

OLC did not meet with the customer / external supervisor during this period. Due to the large workload at the end of the previous period The group decided to allow some extra time for working with the additional subject: Mechatronics. This because this was not a priority at the end of the previous period.

OLC actually planned having two meetings with the internal supervisor Amin, but one was cancelled.

2.2.1 MEETINGS WITH INTERNAL SUPERVISOR

- 10/02/2016 - Amin had to cancel the meeting because he also is an internal supervisor for other groups, and one of his groups had their first presentation at the same time as the planned meeting.
- 17/02/2016 - Amin gave the group feedback on the first presentation. He was very pleased with the presentation and the submitted documentation. OLC also received answers to what was expected of the group on the second presentation.

2.2.2 MEETINGS WITH EXTERNAL SUPERVISOR

- No meetings with customer / external supervisor in the first iteration.

2.2 PROJECT EVALUATION

2.3.1 ACTIVITIES

The plan for this iteration was originally to review requirements to discover errors, omissions, change of poorly described requirements and optionally remove or add new requirements. This if OLC had gaps or if the group had described a claim two times.

Because of the incomplete requirement specification in the startup phase OLC spent a lot of time finding relevant requirements from DNV 2.22 and 2.7-3. OLC did not have time to review that many of the previous documents.

OLC also planned to review a complete test specification to discover errors, omissions, change of poor-described tests and possibly removing or adding new tests. Because of the large delay with requirements and test in the startup phase, it was a huge task to write all the tests instead of reviewing them.

The test specification still had to wait for the requirements specification to be finished, something that resulted the group to wait until week 7 in the iteration to finish the test specification.

A large part of this iteration was to come up with possible design concepts. OLC put the selected concepts into a concept matrix to compare them and find the best possible solution.

The group are planning to bring these solutions to the meeting with FMC 23/02/2016 in the next iteration, for feedback.

2.3.2 TIME SCHEDULE

Time used in the first iteration:

Week 6 Total hours: 50,5 h

Week 7 Total hours: 110 h

Total = 160,5 h

OLC spent 160.5 hours in total in this iteration, which is 89.5 hours less than the time estimated during this period. Considering that the group were 78,5 hours in advance after the startup phase OLC are only 11 hours behind the estimated time frame. The problem with this period was not wrong estimated time commitment, but OLC just placed too few hours into the project.

2.3.3 COOPERATION WITHIN THE GROUP

The cooperation in the group has been good. The reason for the low number of working hours in week 6 is because OLC had to prioritize the subject the group had next to the project, as this was not a priority during the end of the previous period.

In Week 7 OLC had really few working hours. This is because two group members was ill and one group member was away on vacation.

2.4 PLANNING THE ITERATION

After this iteration the second iteration in the spiral model starts, with a duration of two weeks. In this iteration, OLC must make up for lost workload due to illness and holidays, to get back on track.

The planned activities for the second iteration are:

- **Requirement Specifications**
Review of requirement specifications.
- **Test Specifications**
Review of test Specifications.
- **Risk Assessment 2**
Risk assessment for the four design concepts OLC decided to go forward with.
- **Evaluate Design Concepts**
Come up with more solutions for the four design concepts.
- **First Design**
Starting on the first main design.
- **Website**
Finalize the website
- **Evaluation and Analysis 2**
Evaluate the design concepts.

3. EVALUATION AFTER SECOND ITERATION

OLC are using the spiral model in the project, where OLC have each iteration lasting for two weeks. The second iteration are from Week 8 through Week 9, 2016. The estimated time for the second iteration is 250 hours for the whole group.

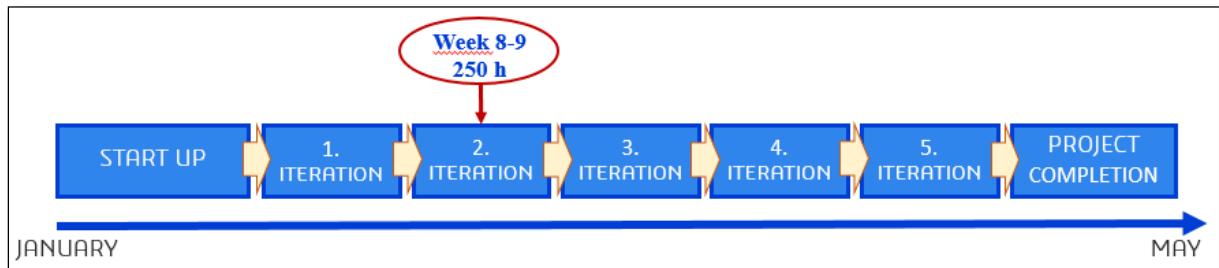


FIGURE 3: Project timeline (2. ITERATION)

3.1 ACTIVITIES DURING SECOND ITERATION

Activity	Description of task done
A2.24 Review Requirement Specifications 1	OLC made small changes in the requirements specification, and got a new requirement on the meeting with FMC 02/23/2016. OLC created version 1.1 of the requirement specification.
A2.3.3 Review Test Specifications 1	OLC made some small changes in the test specification, and made new tests on the new requirements from FMC. OLC created version 1.1 of the test specification.
A2.4.2 Risk Assessment 2	OLC created a new risk assessment for the four concepts OLC chose to move forward with. So that OLC can take the risk in consideration when deciding on a design concept. Completed the first version of: Risk assessment several design concepts.

A3.2.2 Evaluate Design Concepts 2	After the meeting with FMC 04/03/2016 OLC created a new concept matrix. After a new evaluation of the concepts OLC decided on a concept to work more with. OLC are going to present this concept on the second presentation.
A3.2.1 First Design	First design of the main concept.
A3.3.2 Evaluation and Analysis 2	To evaluate and analyze the work OLC had done in the iteration the group had a group meeting. Here OLC did a brief summary and planned the next iteration
A1.11 Website	The website is now ready. The only thing that needs to be done with the website in the future is to post regular updates on where OLC are in the process.

3.2 MEETINGS

In this period OLC planned 2 meetings with the customer/external supervisor, and 2 meetings with the internal supervisor.

3.2.1 MEETINGS WITH INTERNAL SUPERVISOR

- 24/02/2016 – OLC explained the concepts, presented sketches and the concept matrix. OLC informed the internal supervisor about the new requirements OLC received at the meeting with FMC.
- 02/03/2016 – OLC discussed the design concepts with Amin, because of the challenges regarding the task. OLC planned the topics for the meeting with FMC 04.03.16

3.2.2 MEETING WITH EXTERNAL SUPERVISOR

- 23/02/2016 – Einar gave the group feedback regarding the first presentation, the requirement specification and the test specification. OLC went through the design concepts and the concept matrix. Einar gave his suggestions on how to move forward in the choosing of design concept.
- 04/03/2016 – OLC showed drawings of the four concepts that the group agreed on moving on with. Einar wants OLC to bring up a recommended concept, after further evaluation of presentation 2.

3.3 PROJECT EVALUATION

3.3.1 ACTIVITIES

At the meeting with FMC 23/02/2016, OLC received a new requirement. Many of the concepts did not satisfy this requirement. This meant that OLC had to rethink and modify several of the concepts.

The evaluation process of the design concepts have been long and challenging. It proved to be very difficult to come up with a concept that satisfies all the requirements.

The website is finally up and running. It proved to be more challenging than assumed because no group members had the knowledge OLC needed to create a website.

A group member therefore had to acquire the required knowledge to create the website, which took more time than OLC had estimated.

3.3.2 TIME SCHEDULE

Time used in the second iteration:

Week 8 Total hours: 133 h

Week 9 Total hours: 247,5 h

Total = 380,5 h

OLC spent 380.5 hours in this iteration which is 130,5 hours more than the estimated time during this period. Considering that OLC were 11 hours behind schedule after the first iteration, OLC are now 119,5 hours in advance of the time schedule.

3.3.3 COOPERATION WITHIN THE GROUP

The cooperation in the group has been good.

Despite the fact that one group member have been away on vacation, and some group members have been ill, OLC have placed more than enough working hours in the project.

3.4 PLANNING THE NEXT ITERATION

After this iteration the third iteration in the spiral model starts, with a duration of two weeks. In this iteration, OLC need to work a lot with the main design concept. The process of choosing a design concept has taken much longer time than assumed. The costumer is pleased that OLC have spent good time on choosing a concept.

The planned activities for the third iteration are:

- **Documentation**
Deliver all the necessary documentation before the second presentation.
- **Second presentation**
Prepare, and hold the second presentation on the 10th of March at 11:30 AM.
- **Requirement Specifications**
Review of requirement specifications.
- **Test Specifications**
Review of Test Specifications.
- **Risk Assessment 3**
Make a risk assessment for the main concept.
- **Second Design**
Creating different solutions on the main concept.
- **Evaluation and Analysis 3**
Evaluate the design concept.

4. EVALUATION AFTER THIRD ITERATION

OLC are using the spiral model in the project, where OLC have an iteration to last for two weeks. The third iteration are lasting from week 10 through week 11, 2016. The estimated time for the third iteration is 300 hours for the whole group.

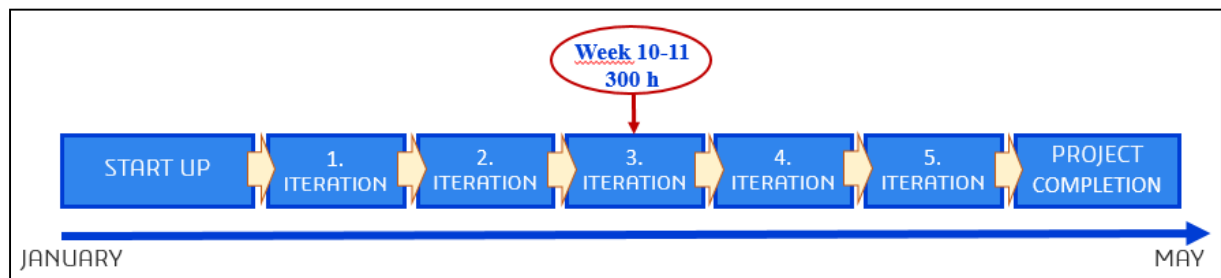


FIGURE 4: Project timeline (3. ITERATION)

4.1 ACTIVITIES DURING THIRD ITERATION

Activity	Description of task done
A2.2.5 Review Requirement Specifications 2	The requirement Specifications are updated with small changes. OLC have added a new C-requirement based on the proposed design, where this requirement must apply to the product if the product shall be used subsea.
A2.3.4 Review Test Specifications 2	The Test Specifications are updated with small changes. OLC have added a new test, to verify the added requirement.
A2.4.3 Risk Assessment 3	A first version of the risk assessment of the proposed design concept is done. This risk assessment will be updated further on, as OLC get more details of the designed product.

A3.2.2 Second Design	OLC are now working on the second design of the product. The focus in this phase is on calculating and finding information on existing lifting accessories and on material characteristics for the proposed design concept.
A3.3.3 Evaluation and Analysis 3	The evaluation and analysis in this iteration has been done throughout the iteration, and been based on discussions.
A4.2.3 Design Second Presentation	The first part of this iteration has been focusing on designing the second presentation, including going through the material so far in the project, designing the power point presentation and preparing for the presentation.
A4.2.4 Second Presentation	OLC had the second presentation on Thursday 10 th of March. OLC felt that the presentation went well, and OLC got some feedback for the further process of developing a detailed design of product.
A5.10 Document update	OLC have updated different documents in the project, including documents in the project plan and activity time tracking tables.

4.2 MEETINGS

During the third iteration, OLC did not plan any meetings with the external supervisor. This is because OLC had the second presentation in week 10, and the external supervisor was away for week 11. The next meeting with external supervisor will be after the exam in the subject “Mechatronics” after the Easter vacations.

OLC had only one meeting with the internal supervisor during this iteration, because the internal supervisor was away for week 11.

4.2.1 MEETINGS WITH INTERNAL SUPERVISOR

Meetings with internal supervisor

- 09/03/2016 – OLC explained the proposed design concept of the product, and went through the plan for the second presentation.

4.3 PROJECT EVALUATION

4.3.1 ACTIVITIES

The design of and the actual second presentation went well. OLC used a lot more hours on these activities than first planned, and the group have to modify the estimated hours in the activity plan for the third and last presentation.

The requirement and test specification and the risk assessment are all a quick done and has gone smoothly in this third iteration. OLC assume that these activities will go quickly in the next iterations.

The second design activity in this iteration is proven to be a bit more challenging than expected, and it will be the main focus for the project further on. OLC have been working on gathering information about materials and lifting accessories, and trying to find an acceptable

solution for making sure the mat will hold the lifting accessories in place before and during a lift offshore.

4.3.2 TIME SCHEDULE

Time used in the third iteration:

Week 10 Total hours: 211,5 h

Week 11 Total hours: 88 h

Total = 299.5 h

OLC spent 299,5 hours in this iteration which is 0,5 hour less than the estimated time during this period. This means that the group in total has been exactly on track considering estimated working hours for this iteration.

Estimated working hours in the project until the end of this third iteration was 1350 hours for the group in total. The actual working hour for the group has been 1469 hours in total. This means the group has 119 hours extra put into the project at this point.

4.3.3 COOPERATION WITHIN THE GROUP

The cooperation in the group has been good.

4.4 PLANNING THE NEXT ITERATION

After this iteration the fourth iteration in the spiral model starts, with a duration of two weeks starting after the Easter vacation – week 13 and 14.

In this iteration, OLC need to work on the design of the product, focusing on the material characteristics of the mat, and a solution for making sure the equipment is fit before and under an offshore lift. There is a challenge in this iteration that the exam of the subject “Mechatronics” is placed on Wednesday in the second week of this iteration (week 14). The group members need to focus and put a lot of hours in studying and preparing for this exam. Still, OLC need to make sure that the group are working on the design of the product, so that the group can present a result for the external supervisor and customer in a meeting, either at the end of the fourth iteration or in the beginning of the fifth iteration.

The planned activities for the fourth iteration are:

- **Review Requirement Specification 3**
Review and update the requirements.
- **Review Test Specifications 3**
Review and update the test specifications.
- **Risk Assessment 4**
Update the risk assessment.
- **Evaluate and Analysis 4**
Evaluate the design of the product.
- **Third design**

Continue working on the design of the product from the third iteration, focusing on materials of the product, calculations of the lifting accessories and designing a solution for making sure the equipment is fastened and fit before and under an offshore lift.

5. EVALUATION AFTER FOURTH ITERATION

OLC are using the spiral model in the project, where each iteration last for two weeks, except for the start up and ending phase. The fourth iteration are lasting from week 13 through week 15, 2016. The estimated time for the fourth iteration is 250 hours for the whole group in total.

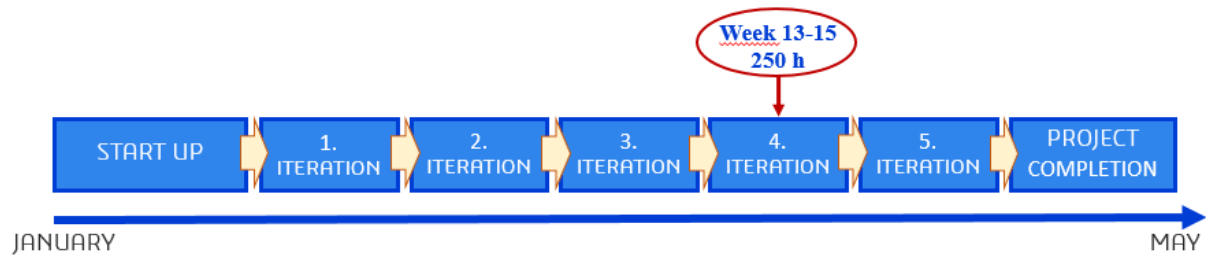


FIGURE 5: Project timeline (4. ITERATION)

5.1 ACTIVITIES DURING FOURTH ITERATION

Activity	Description of task done
A2.2.6 Review Requirement Specifications 3	The group has reviewed and updated the requirement specification and the requirement document by doing small modifications like changing descriptions of requirements and having an overall review of the document to check if it needs more modifications.
A2.3.5 Review Test Specifications 3	The test specification is reviewed by reading through it and by doing minor adjustments. The test specification do not need major changes because the group has done good and disciplined work from the start.
A2.4.5 Risk Assessment 4	The group has done small modifications of the risk assessment of the mat concept. The modifications has been done by changing risk names.

A3.2.3 Third Design	OLC have been working further with finding different solutions throughout the fourth iteration. The group has worked on concepts of various math solutions. OLC have worked with the materials, different wire, chain and soft sling, in addition to finding solutions for the tightening mechanism so OLC can succeed achieving the new requirement OLC got from FMC.
A3.3.4 Evaluation and Analysis 4	The evaluation and analysis for this iteration has been done by doing selections through meetings and conversations with FMC. The group has bought different equipment for visualization. OLC have evaluated and constricted the solutions by determining that OLC should use the chain sling in the concept. OLC have not done any simulations, but have made an assembly for illustration by trying two different locking mechanisms (Spring and strap), in addition to fit/mount the mat with ratchet straps.
A5.10 Document update	The group has moved the iteration one week forward because of the Mechatronic exam. The group has updated the activity list, specification list and time schedule related to the iteration. OLC have started to write the design document, to write about further development of the math concept.
A5.8 Web site update	The group has updated the information and progress of the project on the OLC web site.

5.2 MEETINGS

During the fifth iteration, OLC had planned two external meetings:

- Meeting with external supervisor at FMC
- Two weakly meetings with internal supervisor

5.2.1 MEETINGS WITH INTERNAL SUPERVISOR

- **Wednesday 31st of March:**

The group got feedback from the second presentation, and discussed the presentation.

OLC went thru the follow-up document and gave a summary of what the group have been working and focusing on. The group also decided to cancel the meeting for week 14 due to Mechatronics exam, and decided to have the next meeting 13.04.16.

- **Wednesday 13th of April:**

The group told the internal supervisor about the meeting with Trelleborg and got some ideas and suggestions from the supervisor. The group updated the supervisor by showing the different tightening mechanism concepts.

5.2.2 MEETINGS WITH EXTERNAL SUPERVISOR

- **Meeting with external supervisor at FMC, Thursday 14th of April:**

OLC introduced the different concepts to Bjørn Michaelsen and got feedback on all the concepts, and got confirmed that several of the concepts would not be approved in off board lift.

OLC was given some new standards to use in the project:

NORSOK R-002-2012

NORSOK R-003-2004

STD10031634

5.3 PROJECT EVALUATION

5.3.1 ACTIVITIES

The group had planned to go further in the process than OLC are now. OLC have few 3D drawings in SolidWorks. The reason of having few 3D drawings is that the group has met challenges when it comes to the solution because it includes flexible materials such as fabric and polymers that makes it difficult to draw 3D drawings, something that would be easier if OLC used steel materials.

The group does its utmost to get optimal 3D drawings despite the materials. The prototype that the group has made helps to see how it can be and how it is possible to mount this to get better insight and overview.

5.3.2 TIME SCHEDULE

Time used in the fourth iteration:

Week 13 Total hours: 7 h

Week 14 Total hours: 68 h

Week 15 Total hours: 211,5 h

Total = 286,5 h

OLC spent 286,5 hours in this iteration which is 36,5 hour more than the 250 hours estimated for this period. The group in total is on track considering the estimated working hours.

Estimated working hours in the project until the end of this fourth iteration was 1600 hours for the group in total. The actual working hour for the group has been 1755,5 hours in total. This means the group has 155,5 hours extra put into the project at this point.

5.3.3 COOPERATION WITHIN THE GROUP

The cooperation in the group has been good throughout the iteration. The group have had some challenges with the 3D drawings, but OLC are hoping to solve this challenge by drawing some optimal and creative 3D drawings that illustrates the materials. The group is working eagerly and everyone is contributing in the project work.

5.4 PLANNING THE NEXT ITERATION

After this iteration, the fifth iteration in the spiral model begins. The fifth iteration will last from week 16-17.

5.4.1 FINISHING

The group are planning to complete the risk analysis, test specification and requirements specification 100%, in addition to continuing to write the design report. The group also plans to find a final solution that OLC can go for. Finding a final solution is incredibly important to the further process in the project and final evaluation analysis of the design. Finalizing the ultimate 3D drawings is important so the design is ready for performing FEM analysis, in addition to do the material selection.

5.4.2 SYSTEM TESTING

The plan is also to find out how the group can perform test by having a test plan. In addition to the test plan, it is important to get everything ready for the project completion, which is the project's latest iteration. For testing, it is important that the group has a completed test plan, everything ready for system testing plan and a developed prototype.

5.4.3 MEETINGS

The group has planned the following meetings:

- Meeting with Trelleborg
 - *To discuss the use of materials*
- Meeting with FMC
 - *Update and get feedback if they are satisfied*
- 2 Meetings with Amin
 - *Weekly meetings for guidance*

The planned activities for the fifth iteration are:

- **Complete Requirement Specifications**
Finish and complete the requirement specification document
- **Complete Test Specifications**
Finish and complete the test specification document
- **Final Risk Assessment**
Perform a final risk analysis of the designed product, in cooperation with FMC
- **Final evaluation and analysis**
Perform evaluations, FEM analysis` and calculations based on the final design
- **Finalize Design**
Finalize the design of the product, based on the results from the fourth design
- **Project clamp production**
Produce a model of the clamp for physical testing
- **Iteration evaluation 6**
Evaluation of the progress and work done in the Fifth Iteration.
Preparations for the next iteration.
Documentation in an Iteration Evaluation Document.

6. EVALUATION AFTER FIFTH ITERATION

OLC are using the spiral model in the project, where each iteration last for two weeks, except for the start up and ending phase. The fifth iteration are lasting from week 16 through week 17, 2016. The estimated time for the fifth iteration is 450 hours for the whole group in total.

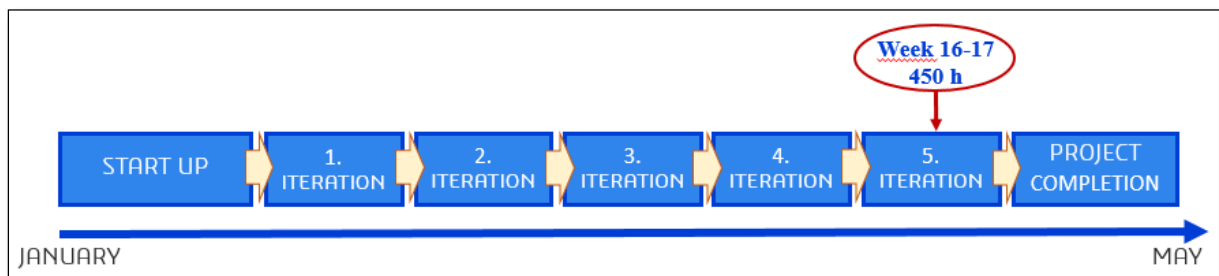


FIGURE 6: Project timeline (5. ITERATION)

6.1 ACTIVITIES DURING FIFTH ITERATION

Activity	Description of task done
A2.2.7 Complete Requirement Specifications	The requirement specifications are updated and completed. OLC have added two new requirement given to the group by the customer in this last iteration. OLC now consider the requirement specifications as completed. Any further changes will only be for minor adjustments or corrections.
A2.3.6 Complete Test Specifications	The test specifications are updated and completed. OLC have added some new tests, because of the new requirements given to the group by the customer in this last iteration. OLC now consider the test specifications as completed. Any further changes will only be for minor adjustments or corrections.
A2.4.4 Final Risk Assessment	The final risk assessment is subjected to the next iteration. OLC have chosen to do this, as OLC are not completely finished with the final design and evaluation of the product.

A3.2.5 Finalize Design	OLC have been working on the design throughout the whole iteration. In the beginning of the iteration OLC focused on different solutions for a tightening mechanism and hook. At the end of the iteration OLC narrowed the designs down to one design, and have been working on completing this. OLC will continue finalizing this design in the beginning of the next iteration.
A3.3.5 Final Evaluation and Analysis	The evaluation and analysis in this iteration, has been focused on evaluating the different solutions and selecting one design to go for. OLC are not finished with this activity, and will continue it into the next iteration. This is because OLC need to do some more analysis on the chosen solution until the design is completed and ready for production and testing.
A3.1.3 Project clamp production	The project clamp to production is an ongoing activity. OLC have made some prototypes of the lifting mechanism, but OLC need to continue this in the next iteration, in accordance with the completion of the design and the execution of the tests.
A4.1.3 Third and Final Report	OLC have started on this document, working on all of the components in the final report.
A5.10 Document update	OLC have updated different documents in the project.

6.2 MEETINGS

During the fifth iteration, OLC had planned two external meetings:

- Meeting with external supervisor at FMC
- Meeting with Trelleborg Offshore Norway, in Krokstadelva

In addition to this, OLC have had two weekly meetings with the internal supervisor.

6.2.1 MEETING WITH INTERNAL SUPERVISOR

- **Wednesday 20th of April:**

OLC went through the last meetings with FMC and Trelleborg Offshore Norway, and OLC discussed and got feedback on materials of the mat, tightening mechanism and the structure and layout of the final report.

- **Wednesday 27th of April:**

OLC went through the different design solutions for presentation on the following meeting with FMC, and got comments and feedback on these. OLC also discussed and got input for preparations of the final report and presentation.

6.2.2 EXTERNAL MEETINGS

- **Meeting with Trelleborg Offshore Norway, Monday 18th of April:**

The meeting was held at Trelleborg in Krokstadelva, with Svein Gabrielsen, design and engineering manager. OLC got a presentation of the Trelleborg Offshore Norway company and their products, and OLC presented the project. OLC discussed different solutions to the problem, and the likelihood that the proposed solution would work in real life. Svein Gabrielsen gave his permission for the group to use the information in the reports.

- **Meeting with external supervisor at FMC, Thursday 28th of April:**

OLC gave the external supervisor a status update of the project and presented the different solutions for tightening mechanism of the product. In this meeting, the external supervisor also gave the group two new requirements:

- *Width of the lifting clamp*

The width of the clamp shall not exceed 300 mm

- *Force on tightening mechanism*

If a tightening mechanism is chosen to tighten an existing lifting gear, the tightening mechanism must withstand an increase of applied force during lifting.

6.3 PROJECT EVALUATION

6.3.1 ACTIVITIES

The finalize design and evaluation and analysis for this iteration has proven to be quite challenging, and OLC have spent many more hours on this than first expected. Though the proposed solution for lifting cylindrical tubes by using rubber mats are both weight reducing and cost effective – finding an effective, reliable and easy-handling tightening mechanism for the lifting equipment has proven to be tough. The first period of the iteration has gone to developing, discussing and evaluating different solutions for tightening the lifting equipment to the mat.

The introduction of two new requirements late in the project period made it even more challenging. Still, OLC have landed on one design of a tightening mechanism, the wire drum tensioner, and hook for further developing and finalizing in the beginning of the next and last iteration. **The risk assessment** will be written in the next iteration as well, based on the developed design.

The requirement and test specification are now finished. OLC have added the two new requirements with their respective tests. Any further changes will be of minor adjustments and corrections.

The making of a prototype of the project clamp is ongoing. OLC have made a prototype of the mat for testing and visualizing the concept and handling of the product. OLC have also brought in materials and components to be used to make two additional prototypes for testing.

OLC have started working on the third and final report. This includes writing on the design report and updating existing documents in the project. The project period is getting closer to the deadline, and it is important to work on getting all the documents ready in time.

6.3.2 TIME SCHEDULE

Time used in the second iteration:

Week 16 Total hours: 239 h

Week 17 Total hours: 244,5 h

Total = 483,5 h

OLC spent 483,5 hours in this iteration which is 33,5 hour more than the 450 hours estimated for this period. The group in total is on track considering the estimated working hours.

Estimated working hours in the project until the end of this fifth iteration was 2050 hours for the group in total. The actual working hour for the group has been 2239 hours in total. This means the group has 189 hours extra put into the project at this point.

6.3.3 COOPERATION WITHIN THE GROUP

The cooperation in the group has been good. OLC have felt the pressure, anxiety and uncertainty in relation to achieving a solution to the problem in time. Both the old requirements in the project and the two new requirements OLC received, has been challenging. But the group members have all contributed to finding a solutions that can work. Now that OLC are done with the extra course this semester, the bachelor project is fully prioritized with normal working hours starting at 09:00 every day.

6.4 PLANNING THE NEXT ITERATION

After this iteration the last iteration in the spiral model begins, which is the “system test and project completion” phase. This iteration will last from week 18 until the project ends in week 21.

6.4.1 SYSTEM TEST

The last iteration will be focusing on testing of the product and completing the project. Since OLC were not able to completely finish the design, evaluation, analysis and risk assessment of the product, OLC need to spend some time in the beginning of the iteration to focus on these activities. At the same time OLC need to work on the test documentation, test plan and getting the prototype made of the product, so that OLC can do some testing on the design. OLC need to finish all of these planned activities by the middle of the week 19, so that OLC can ready the documents before deadline.

6.4.2 PROJECT COMPLETION

After the middle of week 19, all focus will be on getting the documents ready for the report. OLC want to have all the documents ready by Friday 13th of May. The next week will then be of detail reading, corrections and putting together the whole report.

The deadline for handing in the report is on Monday 23th of May, at 09:00.

The report shall be handed in in three versions:

1. Digital – all documents from the project shall be delivered digitally on a CD
2. Printed out in paper – the presented report shall be printed out and delivered in a red binder
3. Hardcover report – the presented report shall be delivered in a hardcover version

Since the report needs to be delivered in a hardcover version, the deadline for the report to be completely finished is on Friday morning 20th of May.

In addition to completing the report, the focus in the last part of the next phase, will be on preparing for the last presentation of the project.

The third and final presentation will be on Wednesday 25th of May, at 11:30.

6.4.3 SYSTEM TEST

The planned activities for the system test and project completion phase are:

- **Finalize design (from iteration 5)**
Complete the 3D modelling, drawings and design specifications of the product
- **Final Evaluation and Analysis (from iteration 5)**
Complete the final evaluation and analysis
- **Final Risk Assessment (from iteration 5)**
Complete the final risk assessment
- **Review Test Documentation**
Go through the test specifications and make a test plan for the product
- **Testing of produced clamp**
Perform tests on the produced prototype of the clamp, based on the test specifications and test plan.
- **Test Documentation**
Write and complete the documentation of the testing of the produced clamp

Project completion:

- **Third and final report**
Complete all of the documents in the project and put together the final report
- **Deliver final Project Report and product**
The deadline for handing in the final report is on Monday 23th of May, at 09:00
- **Iteration Evaluation 7**
Write the last iteration evaluation, with a sum up and conclusion of the project
- **Design Third Presentation**
Prepare and design the third and final presentation of the project
- **Final presentation**

The final presentation is set to Wednesday 25th of May, at 11:30

7. EVALUATION AFTER FIFTH ITERATION

We are using the spiral model in our project, where each iteration last for two weeks, except for the start up and ending phase. Our last phase – system test and project completion - are lasting from week 18 until the final presentation on Wednesday 25th of May in week 21, 2016. The estimated time for the last phase is 675 hours for the whole group in total.

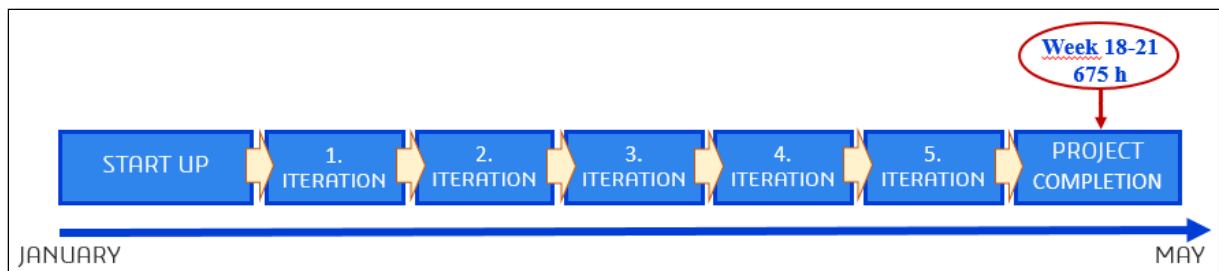


Figure 7 Project timeline (SYSTEM TEST AND PROJECT COMPLETION)

This evaluation of the system test and project evaluation phase is written on Sunday 22th of May – three days before the end of the project. This means that there are still some ongoing activities in this iteration while writing the evaluation, and that the iteration is not completely finished. Still, the final report for the whole project is to be delivered on Monday 23th of May before 09:00 AM, and we wanted to do an evaluation of the last period and the project in total before this.

7.1 ACTIVITIES DURING THIRD ITERATION

Activity	Description of task done
A2.4.4 Final Risk Assessment <i>From last iteration</i>	The final risk assessments and report is now completed. <ul style="list-style-type: none">- Concept risk assessment is updated- New risk assessment was made on the final concept, one each on the mat, tightening mechanism, chain and hook.
A3.2.5 Finalize Design <i>From last iteration</i>	This activity has been taken a lot of hours in this last phase, consisting on: <ul style="list-style-type: none">- 3D modelling of the tightening mechanism- 3D modelling on the chain hook- 3D modelling of lifting mat- Dimensions and layout of mat- Material selection for mat
A3.3.5 Final Evaluation and Analysis <i>From last iteration</i>	FEM analysis was done on the tightening mechanism and chain hook. Evaluations of the product and project has been done throughout the period by internal discussions.
A3.1.3 Project clamp production <i>From last iteration</i>	We have produced several prototypes during the last phase: <ul style="list-style-type: none">- Rubber mat with pockets and tie-downs- Duplex ratchet tie-down- Wire tensioner- 3D printed wire tensioner and hook
A2.3.8 Review Test Documentation	The test specifications and all associated documents has been reviewed and controlled, and are now finished.

A2.3.7 Testing of produced prototype	Testing of produced prototype has been done this last period. The tests have consisted of lifting tests, friction tests, dimensions and weight tests and mounting tests.
A2.3.9 Test Documentation	A test plan and test report has been written. Several tests was performed and documented in the test plan. These have been traced back to the test specifications and requirement specifications.
A4.1.3 Third and Final Report	We have been working on the third and final report throughout the whole period. By Sunday 22th of May, the report was completed and printed.
A4.1.4 Deliver final Project Report and product	The final project report shall be handed in before Monday 23th of May at 09:00 AM
A4.2.5 Design Third Presentation	This is an ongoing process. We have begun working on the power-point presentation and manuscript for the final presentation of our project. This will be continued working on for the last days of the period, in addition to making a project poster and description.
A4.2.6 Final Presentation	The final presentation is set to Wednesday 25 th of May, Room: Hegstad, at 11:30 AM.
A5.10 Document update	All older documents has been updated and finished.
A5.10 Web site update	The web site has been updated with information under the “project status” bar.

7.2 MEETINGS

During the system test and project completion phase, we did not plan any meetings with our external supervisor. We have only had three weakly meetings with our internal supervisor.

7.2.1 MEETING WITH INTERNAL SUPERVISOR

- **Wednesday 4th of May:**

An update of the work done and last meeting with FMC was given. Information about the two new requirements given by FMC was discussed, and feedback and input about the third and final report was given.

- **Wednesday 11th of May:**

We discussed and gave information about the physical tests done the week before, and about prototypes made. More input and feedback about how to structure the final report was given.

- **Wednesday 18th of May:**

We gave an update of the last week work on the design and final report. Feedback and input on references in the document was discussed.

7.3 PROJECT EVALUATION

7.3.1 ACTIVITIES

There has been a lot of work done in the **Finalize design** activity. This was originally intended to be completed in the previous iteration. But due to new requirements given and challenges experienced considering the chosen solution, we had to continue working on the design in the last iteration.

The tightening mechanism was completed in SolidWorks based on the chosen concept. A chain hook for tightening the chain was also developed. The chain hook proved to be extra challenging. While working on the mat concept and tightening mechanism, we were not working on a specialized lifting equipment. This means that the requirements relating to offshore lifting equipment did not apply to these components. The chain hook designed is supposed to carry some of the weight during lifting, meaning that this actually is considered as a lifting equipment, and must be designed and developed in relation to the requirements set for offshore lifting equipment. Starting working on this type of equipment this late in the project was extra difficult, and a lot of hours was out into this.

The design of the mat solution has been focused on dimensions, layout, structure and materials. This has been much a material technological task which has been challenging because of the lack of necessary equipment and laboratory to conduct needed research. But it has been an interesting work which we have been able to come up with a recommendation.

In the **Final evaluation and analysis** the work has mostly consisted of FEM analysis of the tightening mechanism and chain hook. The analyzes of the tightening mechanism went seemingly good. When applied force of 200 kg in each direction, simulating the force the wire will pull with, it has endured the stress very well. This has made us a little unsure whether we can trust the results, but it seems pretty good.

Considering the analyzes of the hook, we have spent a lot of hours and frustration on this. It has been tricky to design the hook so that it can withstand the forces it will be exposed to in relation to the requirements set by the regulations, and we have not managed to get it to work at we want.

We have also done a lot of evaluations through discussions in the group, helping us to proceed further with the design and project. When it comes to the design of the hook, we recommend

FMC to have a closer look at this, to get the dimensions and design correct in order to manage the expected forces applied to it.

Project clamp to production and testing of prototype has been very interesting and fun. We have managed to produce several prototypes of the mat, and also prototypes of two different tightening mechanisms. Being able to visually have a look at the product, touching it, mounting it and testing it, has been informative and exciting. We were able to use a crane for performing lifting tests, and we have had different pipes and diameters for testing the mounting of the system.

The test documentation has been a big priority during the last period. We have a lot of tests to perform according to the test specifications, which has been a bit challenging. We have not been able to perform all of the tests due to the lack of equipment, location and tools, or the fact that we are not far enough in the project to be able to perform the test.

In the test plan there are a lot of test which is intended to be tested on both the prototype and model of product. Since we do not have a realistic model of the product, we have approved several of the tests based on the results of the prototype testing. The final approval of the tests are depending on the results of tests on realistic models.

In the requirement specifications, it must be noticed that even if the requirement is not approved, it does not necessary mean that the tests are not approved. A requirement can be depending on several tests. If one of these tests fail or is not tested, the requirement will not be approved.

Working on the test documentation has been a lot of work and challenging, but we are satisfied with the documentation.

The final report has been the most important result of the last period, since the due date of the project is now. The group has worked many hours and late nights to finish it. We have got feedback and guidance from our supervisor, which has been informative and helpful in relation to complete the document. And we have managed to finish the report in time, including all the work and documentation needed.

The final presentation is the last activity needed in the project period, and is an ongoing task. Since our project is the first of the bachelor projects to be presented, only two days after the report is supposed to be handed in, we feel a bit pressure and stress to finish it. But we are

confident that we shall manage to design and hold a good presentation, and this will be our focus for the next days.

7.3.2 TIME SCHEDULE

Time used in the last iteration:

Week 18 Total hours: 211,5 h

Week 19 Total hours: 289 h

Week 20 Total hours: 308 h

Total = 808,5 h

We have spent 808,5 hours so far in this iteration, which is 133,5 hours more than the 675 hours estimated for this period. The group in total is on track considering the estimated working hours.

The total working hours for the project in total is 2725 hours for the whole group. Up to this point, having three more days left until the final presentation, we have put in a total of 3097,5 hours in the project. This is 372,5 hours more in the project than estimated at project start. This is completely in line with what is planned, since the original estimated workload was anticipated workload without the addition of any extra hours and overtime.

7.3.3 COOPERATION WITHIN THE GROUP

The group has been working well together throughout the whole project period, and we are very satisfied with that. This last period, consisting of three weeks in May with days off and holidays, has nevertheless been a little challenging. Knowing that there is much work to be done and a deadline approaching has put stress on the group. The members of the group are in different life situation having different responsibilities outside the project, that has affected the possibility to prioritize the project in small periods of the last phase. This has been a stress factor in the group, but it is sorted out and the project is on track. All team members has acted to complete the project with the best quality and all have done the tasks they are set to do.

And we are all over satisfied with the work done by each member and the project to be delivered.

7.4 PLANNING THE REST OF THE PROJECT COMPLETION PHASE

By the end of Sunday 22th of May, there is only three days left of the project period. The final report is finished and ready to be delivered.

The rest of the project completion phase will be focusing on preparing for the last and final presentation. We will be working on the power point presentation, posters for advertisement of our project and a description of our project for an information

CONCLUSION

The iteration evaluation has provided the group with valuable evaluations throughout the project. This has been done by listing all the performed activities both the ones that were completed and the ones that were not. The amount of time used per week and in the different iterations helped the group a lot to understand what activities they needed to put aside more time to. This also gave information about which activities that did not need as much time to complete as originally thought. The group has by time become more aware of how important it is to have a good project plan. This especially since the iteration evaluation reflects back to the plan. The group now know that activities have the tendency to take longer time than planned, and the iteration evaluation is proof of this.

