

BACHELOR THESIS

BACHELOROPPGAVERNS TITTEL Improvements of Bend Stiffener Connector release mechanism	DATE 25.05.2023
---	--------------------

	NUMBER OF PAGES
--	-----------------

AUTHORS Marius André Øverli Haugstad, Mahdi Hosseini, Tarakan Sathiyanthan, Manzi Axel Bjørnstad Rwabizambuga	INTERNAL SUPERVISOR Sam Woodford
---	-------------------------------------

PROJECT PARTNER Aker Solutions	EKSTERNAL SUPERVISORS Phuong Hoang Bernard Håland Tiril Øyvik
-----------------------------------	--

ABSTRACT:

3 KEYWORDS

OSLOMET

 **Aker**Solutions

Preface and acknowledgements

This bachelor thesis is the result of a collaboration between Oslo Metropolitan University and Aker Solutions. This project can only be described as the perfect end to our enlightening and exciting times at the university and reaffirmed our passion for both the subjects and field of mechanical engineering.

We would like to acknowledge the guidance and inspiration given by our supervisor Phuong Hoang at Aker Solutions. We are immensely grateful for the opportunity you presented to us. This gratitude extends to Bernard Håland and Tiril B. Øyvik. The insight gained from meeting and working with such experienced and highly competent professionals was inspiring. We also would not have been able to complete this project without the generous offer of materials you supplied us with.

We would like to express our deep gratitude to Sam Woodford for the guidance, structure and support he's given throughout our project. The confidence he instilled in us helped us meet our expectations and work purposefully. In addition, we would like to thank Rune Ordeløkken, whose help and insight in the manufacturing of our prototype was vital to our project.

Lastly, we'd like to acknowledge the late Prof. Chi Huu Luong. We benefited greatly from your fun and motivating lectures. They've helped us a lot during this project as they surely will continue to help us in the future.

Marius André Øverli Haugstad

Tarakan Sathiyanthan

Manzi A. B. Rwabizambuga

Mahdi Hosseini

Table of Contents

Preface and acknowledgements.....	i
Table of Contents	ii
Table of Figures.....	iv
Abbreviations	v
1. Introduction	1
1.1 Background.....	2
Umbilical	2
Bend stiffener and Bend stiffener connector	3
Last year’s Project	4
1.2 Goals.....	6
1.3 Scope	7
In-Scope.....	7
Out Of Scope	7
1.4 Deliverables.....	8
2. Project management	9
2.1 Teamwork.....	9
2.2 Planning.....	9
Gantt Chart	9
Flow Chart.....	10
2.3 Time management	10
2.4 Resources.....	10
3. Research	10
3.1 Earlier projects	10
3.2 Competing products	13
4. Methodology	15
Design process.....	19
FE analysis	21
Prototyping	28
Scale model testing.....	28
5. Design.....	30
6. Results	38
Risk Analysis	40

7. Discussion	42
Bibliography	43
Appendix	44
Project Description	45
Flow Chart	50
Technical Drawings.....	67
Test Procedure and SJA	69
Prototype.....	72

Table of Figures

Figure 1 FPSO and Subsea Production System (Aker Solutions, 2017)	1
Figure 2 Cross-section of an umbilical (Aker Solutions, 2023)	Error! Bookmark not defined.
Figure 3 Male bend stiffener connector and bend stiffener (From Aker STEP file) Error! Bookmark not defined.	
Figure 4 AKSO's old BSC. During pull-in (left). Close up of Shear pin system (right) From AKSO's project description.	3
Figure 5 Cross-section of the split pin mechanism (Øyvik T. B., 2022).....	4
Figure 6 Point of concern. Topside pin could get caught on the rim of the fingerhook ring (Øyvik T. B., 2022).....	5

List of figures/tables

(AZO Materials, 2012) (AZO Materials, 2012)

Abbreviations

AKSO/Aker – Aker Solutions

OsloMet – Oslo Metropolitan University

BSC – Bend stiffener connector

DBSC – Diverless Bend stiffener connector

MBSC – Male Bend stiffener connector

FBSC – Female Bend stiffener connector

FPSO – Floating production, storage, and offloading vessel

Fler forkortelser

SYMBOLS?



Thesis structure – IRMRD



1. Introduction

Aker Solutions (AKSO) is a global energy company and a leading oil service provider. The subsea sector is a highly specialized field in the offshore oil and gas industry in which they offer a range of products and services. Among these products are subsea production systems that allow the production of hydrocarbons in deeper waters and other areas previously deemed too costly or complex to develop with the use of traditional offshore platforms (Aker Solutions, 2023).

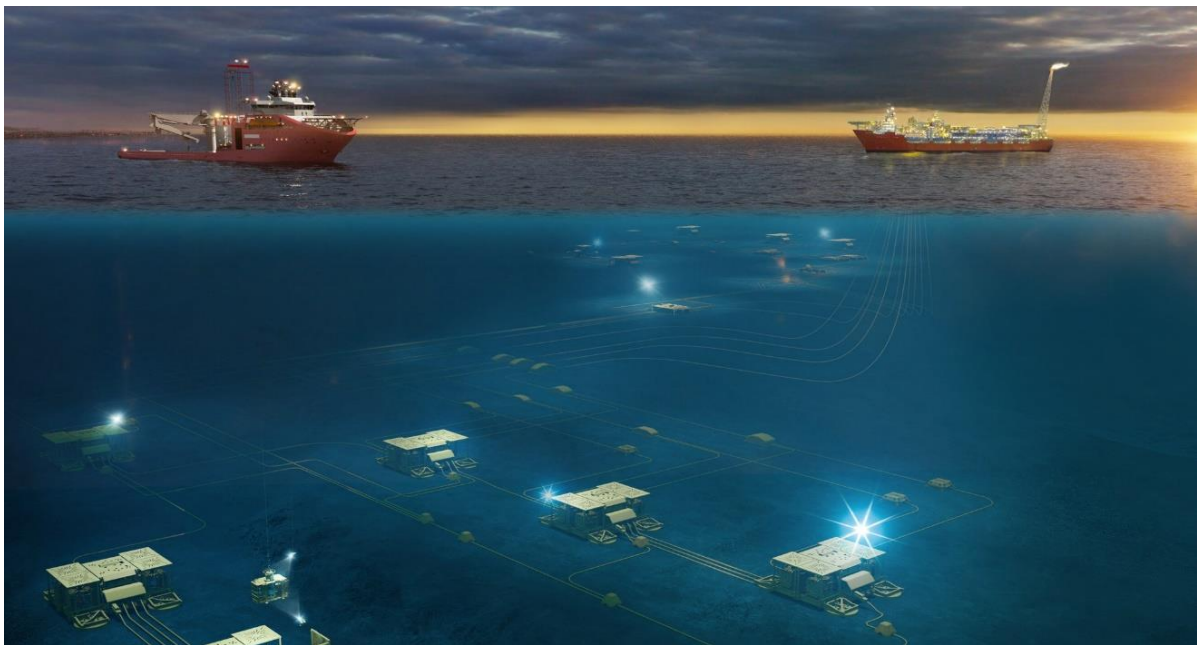


Figure 1 FPSO and Subsea Production System (Aker Solutions, 2017)

Subsea production systems are anchored to the seafloor and controlled from the surface. Umbilicals are the lifelines of these systems, essentially offering the power, heating, and signaling required for remote operation in a dynamic ocean environment. Bend stiffener connectors (BSC) couple umbilicals to topside facilities and are vital for ensuring safe and reliable production. The competitive nature of the oil and gas sector creates a need for constant renewal and development. Aker Solutions currently supplies BSCs that rely on the controlled mechanical failure of shear pins. Although these are proven, they wish to develop a diverless bend stiffener connector (DBSC) that is fully mechanical, automatic, and reusable.

A previous collaboration between Oslomet and Aker Solutions resulted in a concept they've tasked us to further develop. Our task is to analyze and improve upon the concept, further develop the release mechanism and to create a functional prototype.

1.1 Background

Umbilical



Figure 2 An AKSO created 3D-printed cross-section of an umbilical from one of their projects.

An umbilical is a cable that connects topside facilities to subsea systems. They can deliver power, heating, signaling or structural cables and can span thousands of meters. Each cable is unique to the needs of their respective project.

Bend stiffener and Bend stiffener connector

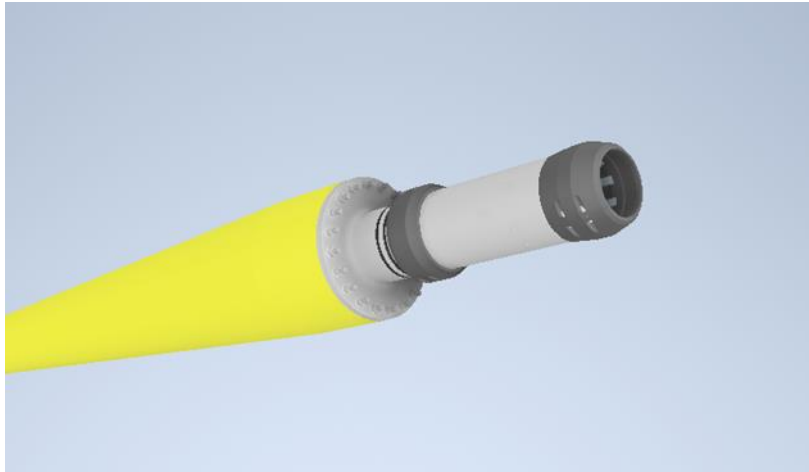


Figure 3 Male bend stiffener connector and bend stiffener (From Aker STEP file)

A bend stiffener is a large plastic cover that envelops the umbilical to ensure that it does not bend to an extent that would damage its internal components. The bend stiffener is fastened to the Male bend stiffener connector (MBSC).

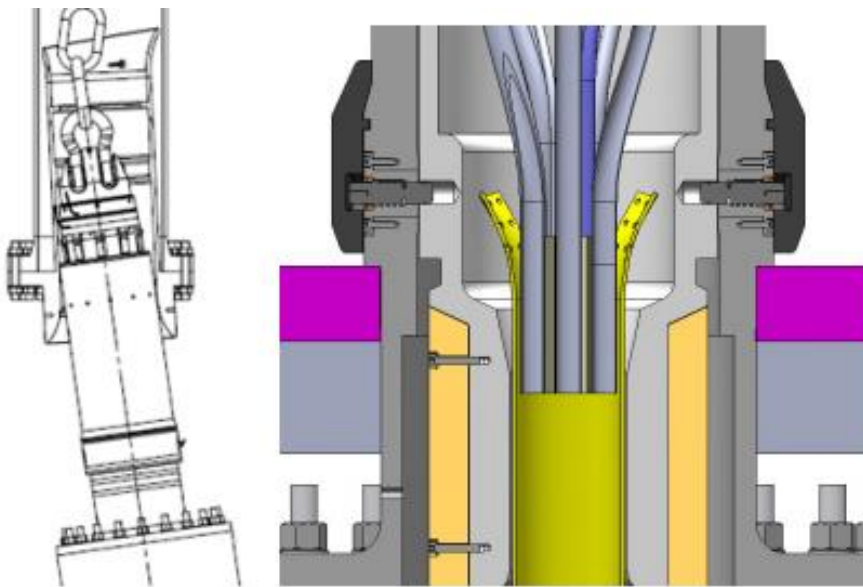


Figure 4 AKSO's old BSC. During pull-in (left). Close up of Shear pin system (right) From AKSO's project description.

A Bend stiffener connector (BSC) is a three-part system consisting of a Male and Female part, as well as a Pull-in head. The female bend stiffener connector (FBSC) is bolted on to a J-tube on the surface vessel. The male bend stiffener connector (MBSC) is connected to the pull-in

head via a shear pin release system. The purpose of the BSC is to ensure a stable and secure connection to subsea systems whilst also protecting the umbilical by providing an anchoring point for the bend stiffener.

Last year's Project

The students from last year's collaborative project between Aker Solutions and OsloMet were tasked with improving Aker's BSC. The system relied upon the mechanical failure of shear pins that facilitated the release of the pull-in head, thus allowing the umbilical to be raised topside.

The students had an iterative design process where they presented ideas and changed their concepts based on the feedback given by their project supervisors at Aker. They chose to pursue a two-part spring-loaded split pin mechanism housed on both the MBSC and the pull-in head.

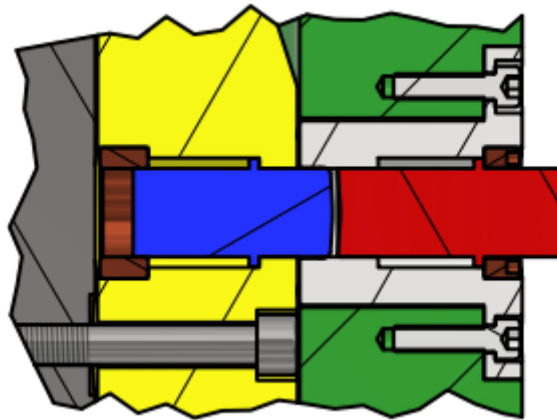


Figure 5 Cross-section of the split pin mechanism (Øyvik T. B., 2022)

As illustrated in the cross-section of the mechanism, the inner (blue) and outer (red) pins are aligned. During pull-in, the pins are actuated by the force applied by the walls of the FBSC as the MBSC and pull-in head are pulled through. When the inner pins are flush with the adapter (yellow), the pull-in head is free to be hoisted up as the MBSC stays connected to the FBSC via hooks on the male that grab onto a ledge inside the female.

The choice to keep the pins at the same diameter (35 mm) as the “strong mode” portion of the original shear pin design allowed the group to assume that calculations previously made about the strength of the pins would hold valid. The group later confirmed this by conducting strength analysis in inventor.

The outer pin system housed in the MBSC is modular and can easily be replaced if faulty. The students finished the project with a prototyping phase where they tested the functionality of the system. A simplified steel prototype of both the male- and topside pin systems was created, and they used clear acrylic panels to house them in. The outer pin stuck out of a hole in the acrylic panel and could be pushed to actuate the mechanism.

In their concluding remarks, the group made some general recommendations and mention points for improvement. One point was of particular concern.

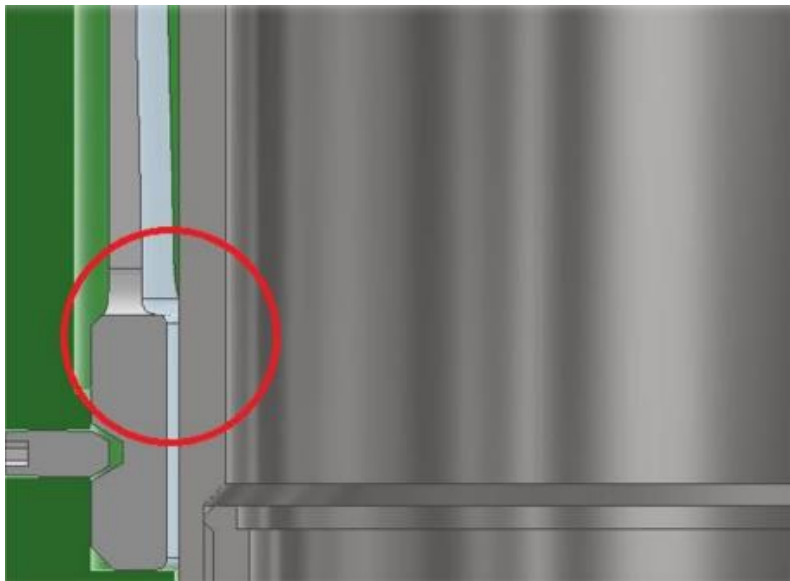


Figure 6 Point of concern. Topside pin could get caught on the rim of the fingerhook ring (Øyvik T. B., 2022)

The pins on the pull-in head will likely get caught on the rim of the fingerhook ring during the release sequence. This would result in the pull-in head not reattaching to the MBSC and the fingerhooks not being retracted thus release would be impossible unless the FBSC was removed from the J-tube.

Barring problems during the release sequence, the split-pin mechanism is a successful improvement on the existing shear pin system and serves as the basis for our project.

1.2 Goals

Our goal is to improve the bend stiffener connector by designing a fully mechanical system that can handle the installation load, ensuring that retrieval and release is automatic and independent. To achieve this, we will investigate and analyze earlier projects to determine what can be further improved upon. Based on this analysis, we will develop new or improved concepts for the design of the bend stiffener connectors coupling mechanism. The new system should meet these requirements, which have been set by in accordance with the guidelines given by Aker Solutions:

1. Release system between Male BSC (MBSC), Female BSC (FBSC), and Pull-in Head must be fully mechanical and automatic.
2. The system should be protected against any mechanical damage from any clash in the seabed or installation.
3. Strength performance should meet AKSOs required performance for installation loads and fatigue life of components for a 30-year lifecycle.
4. The mechanism should be as “simple” as possible. An excess of small, moving parts would increase the points of possible failure and increase the overall risk.

To ensure the success of the system we design, we will conduct a detailed risk analysis of potential problems that may occur and develop solutions to them.

We will manufacture a scaled down mock-up model of the entire system for presentation purposes. We will also manufacture a functional steel prototype that correctly represents the mechanical parameters of the final design and consequently conduct functionality and verification tests.

Our final goal will be to create a rendered animation of the system during assembly, pull-in, hang-off and release.

1.3 Scope

The scope of the project was detailed in the initial project description given to us by Aker and later specified as to ensure that the goals and limitations set would fulfill the expectations of our supervisors at both the university and our industry partner.

In-Scope

1. Design in accordance with the proper standards.
2. FEA analysis of isolated components.
3. Testing with high regard to health and safety.
4. Material costs for prototyping should stay below the budget limit at 5000 NOK.
5. Use well-established design methods for the design process.

Out Of Scope

6. Full-scale prototype.
7. Strict adherence to all standards.
8. The system must be protected against the marine environment (algae, seaweed, sand, etc.).
9. The release system must not be triggered due to wave, vessel, or winch motion.

Standards (1) are an important factor in ensuring that the design is in compliance with industry regulations. However, after taking into consideration the limited amount time we have to complete this project, we've decided to forgo strict adherence to the relevant standards (7). This decision was reached after discussion with project supervisors. The coupling mechanism is the heart of the project and as such, time will be better spent focusing on the design without having to double check each decision in lengthy standards.

We will investigate the strength of the design with finite element analysis (FEA) (2), but the components will be isolated and certain assumptions about load and conditions will be made. Assumptions made will be based on the work of earlier projects and relevant data from Aker.

Testing will be conducted with high regard to health and safety (3). The same regard will be given to the prototyping phase. This is to ensure the safety of each participant and to prevent damage of school property.

The budget (4) for the project is set at 5000 NOK. This limit is set by the faculty. We will source all materials needed while considering the budget.

A considerable amount of time and effort will be made to research design methodology (5). This is further detailed in the research and methodology sections.

Whilst the prototype of the mechanism will be full-scale, creating a full-scale prototype of the entire assembly is impossible (6), this is due to the immense size of the product and limited resources we possess.

The impact of environmental factors (8) on the system was originally a part of the project description, but after further consideration was removed from our list of goals. This decision was made by Aker. During these discussions the same decision was made about the need to protect the mechanism from preemptive release due to wave, vessel or winch motion (9). Although not our focus, we will strive to give recommendations on how best to achieve these initial goals.

1.4 Deliverables

As detailed in the project description given by Aker, the following work will be produced and delivered as the project draws to its end:

- A thesis documenting the project and the work done. This will include calculation reports and sheets from the strength analysis as well as other project documentation.
- A printed and bound copy of the thesis

- A project poster
- A 1 : 5 scale 3D-printed prototype for presentation purposes
- A 1 : 1 scale functional prototype of the mechanism
- STEP files of the final design.
- Videos and pictures detailing the prototyping phase.
- A rendered animation of the product during assembly, pull-in, hang-off, and release.

2. Project management

2.1 Teamwork

The team is comprised of 4 highly motivated students who through our time together at OsloMET have had the opportunity to work together on several projects. This previous experience helped us when resolving conflicts, managing expectations, and delegating tasks. The team is like minded and we've aspired to put forth our best efforts collectively.

Although Marius was chosen as the group leader and had the final say, decisions were generally made in consensus after giving each group member the opportunity to voice their opinion.

Weekly team meetings were held following our meetings with our university and industry supervisors to discuss the feedback that was given as well as to go over the tasks that needed to be completed.

2.2 Planning

Gantt Chart

Proper planning is a staple of any successful venture. To get a general overview of the work that would take place we created a Gantt chart detailing the different phases of the project and set deadlines as to when each phase should be completed. Next, we assigned areas of responsibility based on each group member's skills and wishes. Although all group members were responsible for different things, every member would contribute to all the work equally. This way, the responsible member would take charge of their area and delegate assignments based on what needed to be done.

Flow Chart

A flow chart based on the Gantt chart was created, detailing all the assignments that needed to be completed for each phase. To accompany the flow chart, we made a document that further detailed each assignment, the resources required to complete them and the time it would take.

2.3 Time management

The timeline set early on proved to be difficult to stick with as we discovered that several assignments were more time-consuming than we initially determined. As such, the deadlines for each phase were updated several times. We also allocated more time to assignments we knew would require a lot of learning before we could complete them. To combat further delays we made new plans at the end of each week, following our meetings with our project supervisors. The weekly plan detailed the work that needed to be completed each week.

2.4 Resources

A considerable number of resources were required, spending time identifying them helped us when it came to sourcing materials. The list has been edited throughout the project as more resources have been added or removed based on our use. The resources we used to complete the project are as follows:

Being edited

3. Research

3.1 Earlier projects

Will not be in bulletpoints, currently rewriting to fit thesis – this includes both the 2016 and 2018 summaries

2016

- Given 2 tasks, one was to do the same as us, create a fully mechanical, automatic and reusable release mechanism. The other task was to do an analysis of the finger hooks, and determine if there should be changes.
- Had a large background section on umbilicals and detailed several competing BSC products.
- Used a flow chart to explain how the connection and release process work. Also detailed the environmental conditions and details like the cost of each bend stiffener connector that Aker Sells.

- Chose to use a V – model to base their design approach. A model primarily used in software projects, but that still is applicable. In general their design was well documented. They included pictures showing a few of the design concepts they had, and after selecting one they detailed their development well, making it clear to understand what they did. In good documentation throughout the thesis.
- They used a quick-switch garden hose attachment as inspiration for their design. The clasp mechanism works by aligning the attachment to the exit of the garden hose and pushing them against each other.
- They also designed some protective parts that would shield vulnerable sections of the BSC when it's on the sea floor.
- After finalizing the design with guidance from Aker Solutions, they performed numerous FEA simulations. They included the results and put the set ups in the appendix. We will most likely be looking a lot at their set up, as this is one of the points, we need to spend a lot of time on.
- They used Abaqus to analyse both their design and the finger rings. The finger ring analysis ended up with them recommending the increase of fingers from 6 to eight.
- They made a scaled down 3D-model and an animation of the coupling and decoupling of the BSC which included their changes.

(Abbas H., 2016)

Being edited

2018

- Tasked with working on a specific BSC that was to be deployed on a project that AKSO was working on. Their task was to look at the shape of the groove of the shear pin, and look if they could improve it. They had to solve one of the possible issues of having the shear pins fallout after the pull-in sequence, possibly causing a jam on the ledge between the finger rings. They were to improve the release mechanism of the finger hook ring latching and look at the shape of the finger hooks. They also were to create protective coverings of vulnerable parts.

- The group didn't have any clear design model, but it also seems unnecessary since they were given very specific tasks. The shape of the groove on the shear pins was V-shaped, they changed this to a circular shape – explaining that this was more optimal with calculations.
- They changed the shape of the finger hooks and designed a cap that's mounted to the pull-in head which would rest on the top part of the hooks. When the pull-in head was released topside, the cap would follow along allowing the finger rings to spread out and rest on the ledge in the Female BSC.
- They also performed FEA analysis and determined that more than no less than six, but optimally 7 or 8 finger hooks should be used.
- They created a latching mechanism that would reconnect the Pull-in head to the male BSC upon release.
- The protective coverings were designed to be removed by a ROV prior to pull-in, and they received help from an ROV expert to make them optimal. The expert gave insight into how the ROV's operate and the clearances needed for the ROV to remove them. Designed a 3-part wrap around hard plastic cover that was held together by a shipping strap. The parts would have a 10 cm clearing that allowed the ROV to latch on to the part with one arm and cut it off with another.
- They performed FEA on all parts of the project but did not document it as well as the 2016 group did.
- They were asked to test the shear pin design using the hydraulic press in the machine lab. They were given Inconel by Aker solutions, and designer the pins from this. The housing was made using SJ355 steel. They created a test rig that would position a steel block that would shear off the pin using the pressure of the hydraulic press. They tested 6 pins, having gradually bigger indents whilst the two biggest had no indents. They measured the strain and stress rate and were able to get real data from testing the

pins until failure. They discovered that the hydraulic press was unable to test the 35 mm pins (no indent) as that press had a limit of less than the strength of the pins. They used a bigger press that is used to test concrete. This test was able to test the bigger pins further, but concrete press is designed to stop at the first sign of deformation, and they couldn't use this to test the pins until failure. The housing also broke whilst testing the thick pins, forcing them to fix weld this together.

- The group created a small prototype of the entire BSC with the help of resin and FDM 3D-printers. They also created an animation showing the coupling and decoupling processes, showcasing the internal workings of the system.

(Håland B., 2018)

Being edited

3.2 Competing products

List of 3-5 products?

Balltech BendLOK™ Diverless Bend Stiffener Connector



Beskrivelse (Balltec, n.d.)

FES International Diverless Bend Stiffener Connector



Beskrivelse (FES International, n.d.)

Design?

Pen and latch mechanisms.

Design research here or in

- **Research** (Include any relevant information on Umbilical structures, Ocean environment; include research into design methods, scale model testing, any relevant information on similar projects)
 - **Previous projects**
 - **Competing products?**
 - **Standards?**
 - **Books and research on mechanics of materials, FEA, fluid mechanics and subsea engineering**
 - **Delft design handbook**

4. Methodology

- **Methodology** (how you are going to achieve the MS and specifications: describe chosen design processes, describe what FE analysis will be done and decision making behind it, explain how scale model testing will be done. There should be lots of justifications in this section.

As mentioned earlier, a considerable amount of time was spent to create a good structure and a plan for progress. We created a flow chart, and a Ghant chart and used them for a deadline for each section. However, the flow chart was created later on, so we mainly used that to track our progress. The Ghant chart was used to show which person was in charge of each section of our work. Planning can be easy, the difficult part for us was to stick to the plan and maintain the deadline we set for ourselves. We did run into some issues on the way. Our solution for this was to create a new plan each week for things we were supposed to finish that week.

After doing thorough research on different design processes, we chose to approach the process by using the Basic Design Cycle. The Basic Design Cycle is a model that represents the trial-and-error process of design. By using the Trial-and-error method, we can explore numerous possibilities to find the best possible way to achieve our design goals. The design cycle has five stages. Gathering information and investigating the problem are the steps in the first stage, Analyze, which identifies the needs/requirements for the design. The second step, Synthesize, involves combining a number of thoughts and ideas in order to come up with numerous solutions to the design problem.

The third stage, Simulate, is about creating prototypes or models of the design to evaluate their functionality. The best design solution that meets the design criteria is chosen in the fourth stage, Evaluation, which involves assessing the models or prototypes. The decision stage is the last and final stage. The chosen design solution is refined to create the final model.

The Basic Design Cycle model allows us to ensure a complete and organized design approach that results in a successful outcome.

Moving forward, a thorough understanding of each stage of the design cycle will be presented.

Analyze:

In the basic design cycle, gathering information about the problem is the focus of the analyze phase. It involves defining the problem and gathering information as well as requirements. This stage makes sure that the problem and its requirements are completely understood.

Synthesize

This is the stage where creativity takes place. In this stage, creativity is used to generate ideas through a brainstorming session where you have to follow a strict set of rules.

1. It is important to postpone criticism.
2. Express any ideas you can think of. It is crucial to create an open environment where all the ideas are welcome. This involves encouraging the group to share even the most unconventional ideas. Who knows, sometimes the most unconventional ideas can spark new insights and even be combined with other ideas.
3. It is highly encouraged to combine and build upon other ideas.
4. Prioritize quantity over quality. By adopting this mindset, you can generate a high number of ideas, even if some are imperfect. This can lead to a solution that might not have been considered otherwise.

Once a significant number of ideas have been generated, they can be refined and developed further using the S.C.A.M.P.E.R method. S.C.A.M.P.E.R stands for substitute, combine, adapt, modify, put in other use, eliminate, and reverse. This method involves combining, substituting, adapting, modifying, putting to another use, eliminating, and reversing ideas, as part of the overall process of idea generation.

Substitute: Involves considering replacing an aspect of the idea with something else.

Combine: Involves merging ideas with another concept to create a new one.

Adapt: Involves modifying or adjusting the idea to make it more suitable.

Modify: Involves changing some features of the idea in order to create a new version of it.

Put to another use: Involves considering using the idea in a different context.

Eliminate: Involves removing the unnecessary features of the idea that may be hindering the process.

Reverse: Involves reversing the idea and considering the opposite by asking yourself how to achieve the opposite of your original goal. By doing so, you can potentially identify new ideas that you may not have considered otherwise. In addition, this method can help to reveal potential problems that can occur.

(Annemiek van Boeijin J. D., 2017)

The S.C.A.M.P.E.R method is used on the last stage of the idea generation after the initial ideas or concepts already have been established. This method is particularly useful when you “run out” of ideas and need to generate more creative solutions.

Simulate:

The creation of prototypes or models to test the functionality of the design happens at this important stage of the basic design cycle. This process involves gathering feedback, evaluating the prototypes, and making any changes that are required. Additionally, the design is tested using specialized software. This software allows designers to analyze different aspects of the design, such as how it reacts to different forces. These tests and simulations help the designers understand how the design will behave in reality and identify areas that need improvements or changes. This procedure helps in identifying potential problems so the design can be improved. For enhancing and improving the design, this stage is crucial.

Evaluation:

When exploring potential ideas, each of the ideas have their own unique weaknesses and strengths. To simplify our decision-making process, we narrow down our selection of ideas to the top three best ideas and then subject them to an evaluation process to analyze and compare their potential for success based on some variety of criteria.

After exploring numerous evaluation methods, we have determined that the Harris Profile method is the most suitable for our project.

The Harris Profile is a graphic representation of the weaknesses and strengths of the design concepts in relation to the design specifications or requirements. This method is used to compare and evaluate numerous concepts.

In order to use this evaluation method, you should follow these five steps:

Step 1: Create a list of the design specifications and rank them according to their importance.

Step 2: Create a matrix with a four-point scale assigned to each specification. Use the codes -2,-1,+1 and +2 to represent the different levels on the scale.

Step 3: Assess the performance of each design alternative in relation to the specifications, thereby creating a Harris Profile for each designs.

Step 4: Draw the profile by marking the scores on the matrix for each specifications.

Step 5: Compare the profiles and collaborate with the group to determine the design concept that has the highest overall score.

(Annemiek van Boeijin J. D., 2017)

The image below shows a visual representation of the anticipated outcome when creating a Harris Profile.

	--	-	+	++
Load bearing ability				
Mechanical simplicity				
Clash resistance				
Ease of testing				
Ease of operation				
Ease of manufacturing				
Wear resistance				

Decide:

The final phase of the design cycle involves the step of selecting the best design concept. In this stage, we use the Harris Profile method to evaluate the various concepts, allowing us to narrow down the concept options and focus on the top three best ones. To ensure a thorough decision-making process, the chosen concepts will be presented to Aker Solutions. This is done to get their expertise and insights on which concept we can move forward with. Their feedback will play a significant role in determining the most suitable design for our project.

Design process

To begin the Analyze phase of our design methodology, we began by clearly defining the project's scope and identifying its goals. This step lays the groundwork for the design process, ensuring that everyone in the group has a thorough understanding of the project.

Subsequently, we started to make a detailed list of requirements that the new improved model would have to meet. We formed a list based on our own research on the model and the definition document provided by Aker Solutions.

Here is our list of requirements:

Function and Performance:

- The attachment mechanism between the MBSC and FBSC should be fully mechanical and reversible.
- The attachment mechanism between the MBSC and Pull-in-Head should be fully mechanical and reversible.
- The mechanisms at work should not rely on a sequential procedure to work but rather a simple mechanism is desired.
- The load bearing parts in the mechanisms should not be fragile or prone to wear.
- Moving parts should be kept to a minimum.
- The mechanisms should be resistant to clashes to the seabed.
- The mechanisms should pass the hand calculated load tests.

Life in Service:

A 30-year lifecycle is expected of the final product.

Manufacturing:

The designed parts should not be overly complex so that their prototyping should be possible with the equipment at hand and manufacturing possibilities should be considered.

Testing:

The final mechanisms should not make testing it complicated to perform.

Next step involves gathering information. This step involves gathering relevant information about the problem we're trying to solve. In our particular case, we took an in-depth analysis of past bachelor theses, focusing on how they approached the problem. Additionally, we read their understanding of the Bend Stiffener Connectors as well as watching the animations they made of the Bend Stiffener Connectors system. This enabled us to generate innovative ideas and concept aimed at improving the current design which is the next phase.

Brainstorming

As previously stated, this is the phase where the creativity takes place. To generate a large number of ideas, we organized brainstorming sessions. Due to time limitations, we decided to have four brainstorming sessions in order to generate ideas.

To generate many ideas, we divided our brainstorming sessions into two parts. In the first part, rather than only focusing on improving the split pin mechanism, we put our effort to exploring different methods for connecting the Male Bend Stiffener Connector to the Female Bend Stiffener Connector. Our aim was to create alternative methods that could enhance the entire system and make it better.

During the second part of our brainstorming session, we focused on coming up with ideas for improving the split pin mechanism, which is the existing design. Our goal was to explore potential enhancements that could be accomplished using the split pin mechanism.

We generated ideas by sharing drawings and using play dough as creative tools.

[Sett bilder av det her:](#)

During our brainstorming sessions, we used a method called S.C.A.M.P.E.R to refine and develop our ideas. Instead of having separate sessions for this method, we used S.C.A.M.P.E.R directly into our brainstorming process. This approach saved us time, as we used the method after every part of the brainstorming sessions. Once everyone had a good grasp on how the concepts/ideas worked, applying S.C.A.M.P.E.R became easy. This allowed us to combine ideas, modify them to create a new version of it, eliminate unnecessary features and finally, explore where the ideas could potentially face difficulties in order to identify any problems that could occur.

FE analysis

Following our initial idea realization effort with the first prototype presentation to AKSO, the task of finding the friction forces acting inside of the bracket groove was given to us by our external supervisor Phuong. Abaqus CEA was the requested application by AKSO to be used for this task. After that we had finalized the 3D-models and produced a few more prototypes we tackled the challenge.

Our goal with the FEA was to analyze the interaction between the bracket groove and the pin knob when force is applied to the pin. The resultant rotation of the pin in the groove is then to be analyzed and the forces are to be determined. From these forces we were to find the friction force by calculating it from the results we got.

Abaqus steps

The first step starts outside of Abaqus which is to simplify the 3D-models to make the calculations run easier. Since our goal was the interaction of the forces on the inside surfaces of the bracket and the outside surfaces of the pin, the unnecessary features of the models for our intent were removed. These features include the hollow inside section of the pin, the fillet on the top edge of the pin, the bold holes on the bracket and the thread on the bracket. Since the models are symmetrical about one plane, we also cut them in half.

When importing the models into Abaqus we factor the models by 1/1000. Since the parts that we made in Inventor were in SI(mm) units and we want to use SI(m) in Abaqus we would want to this to make it easier when describing units later on. We then put a reference point on the axis of the rotation of the pin.

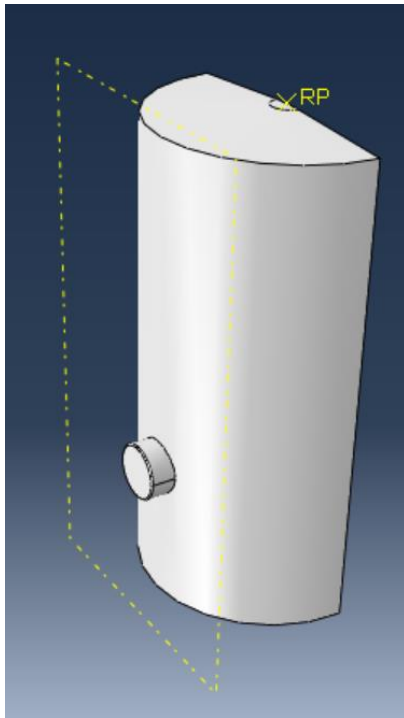


Figure 1 Simplified pin

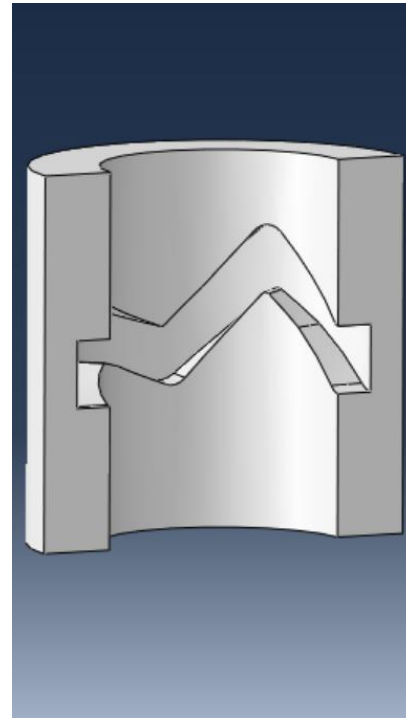


Figure 2 Simplified bracket

A solid homogenous section was created, and Inconel 625 was described and assigned to both parts. The material properties were retrieved from (AZO Materials, 2012).

Mass Density	
1	8440

Figure 3 Density of Inconel 625 in Abaqus

	Young's Modulus	Poisson's Ratio
1	208000000000	0.28

Figure 4 E and v of Inconel 625

In the step module of Abaqus we create a static general step and turn Nlgeom (nonlinear geometry) on. Nlgeom is usually turned on for large displacements, but because we want to see each instance of the analysis and we have many of surfaces that interact with each other we turn it on. In the incrementation tab we put a low minimum increment size and a relatively low initial increment size so that we don't come across any problems because of the increment size.

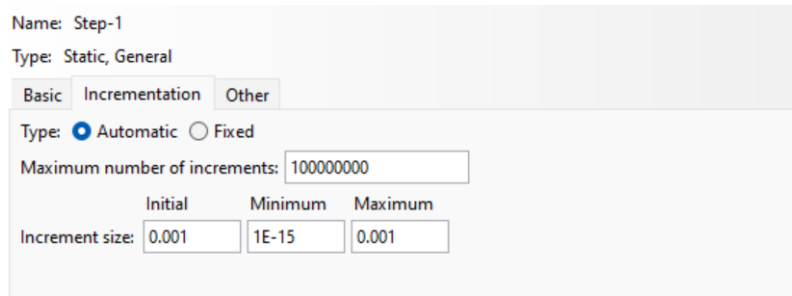


Figure 5 incrementation tab in the step section

In the interaction module of Abaqus we choose a “surface to surface contact (standard)” and select the inside surfaces of the bracket for the main surface, and the out facing surfaces of the pin as the secondary surface. We then create a contact interaction property and give it a friction coefficient. Normal behavior is added so that the parts don’t go into each other. The friction coefficient was given to us by AKSO in one of the meetings.

Coupling the surface of the pin to the reference points we made is necessary so that we can rotate the part about the y-axis.

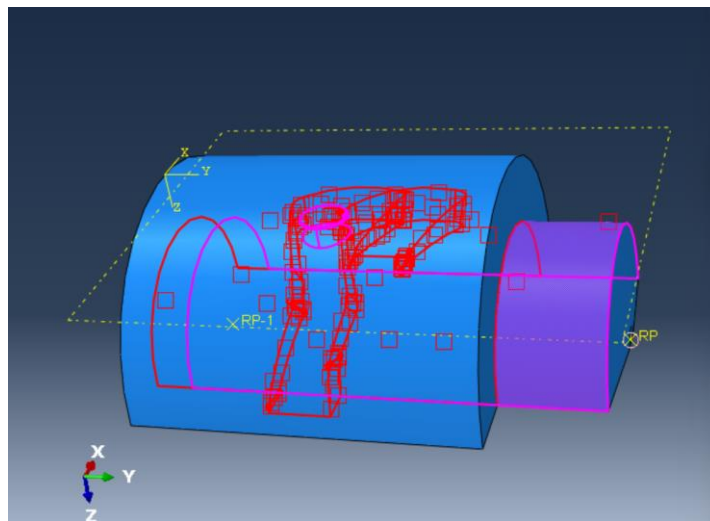


Figure 6 Main Surface in red and secondary surface in purple

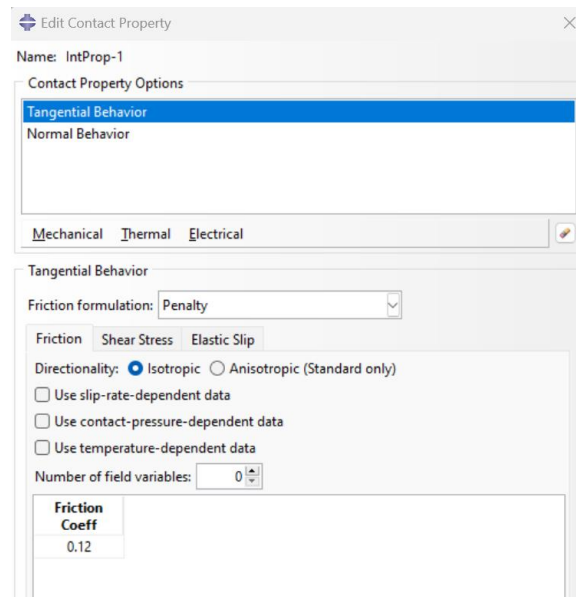


Figure 7 Friction coefficient of the interaction

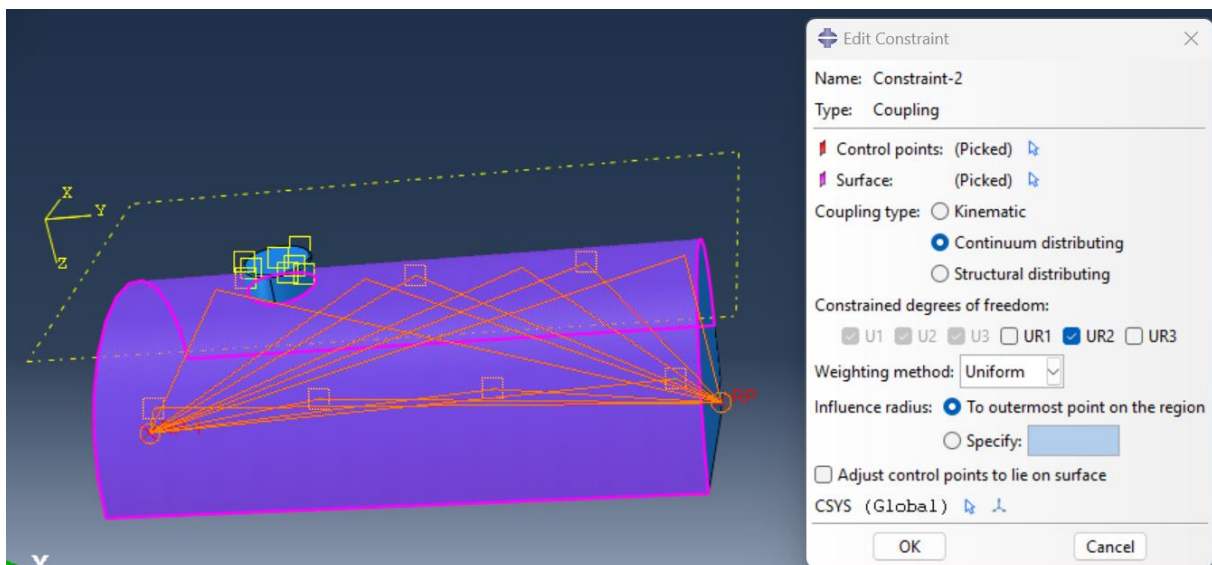


Figure 8 Coupling between the reference points and the pin surface.

When we are in the load module of Abaqus, we the sides and top and bottom of the bracket in an encastre constrain. This is supposedly representative of the real-world part since the real-world part cannot rotate in place and doesn't move.

The other boundary-conditions are put on the pin. We give the pin a 15mm displacement and let it have freedom rotational of movement about the y-axis. Then a rotational displacement is given to the reference point. This rotation is 1/8 of a circle or 0.785 radians. We choose the default (ramp) amplitude for the sake of simplicity for now even though another type of amplitude may be a more accurate model for the knob's movement. These displacements represent the out-direction push of the spring and the subsequent rotation that the groove does to the pin.

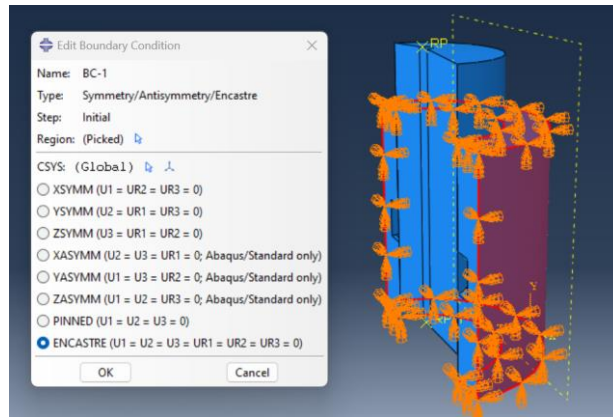


Figure 9 Bracket encatre

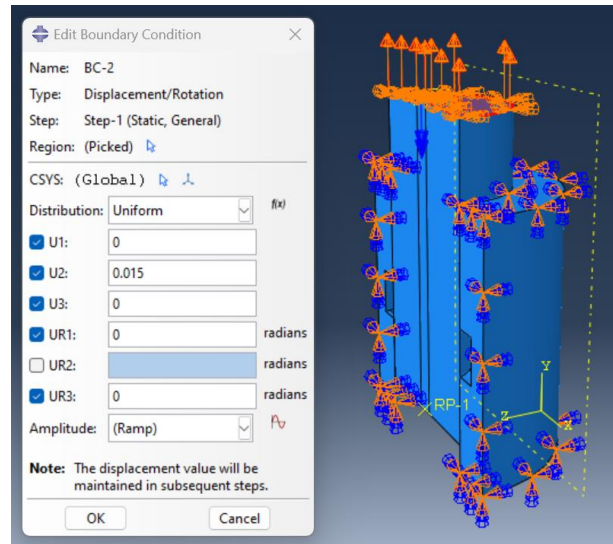


Figure 10 axial displacement of the pin

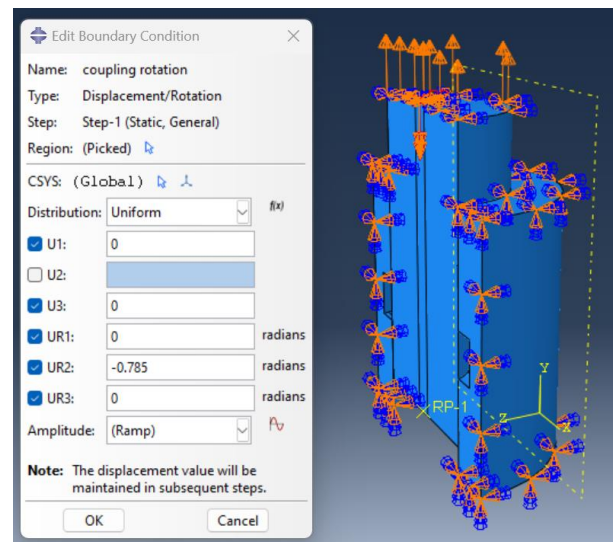
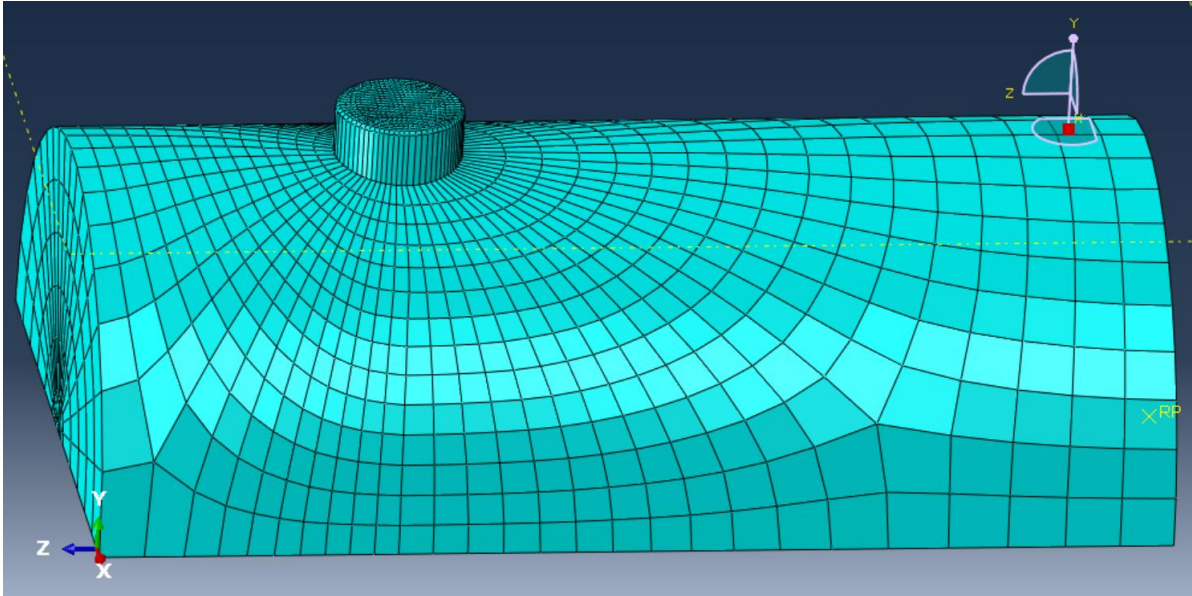


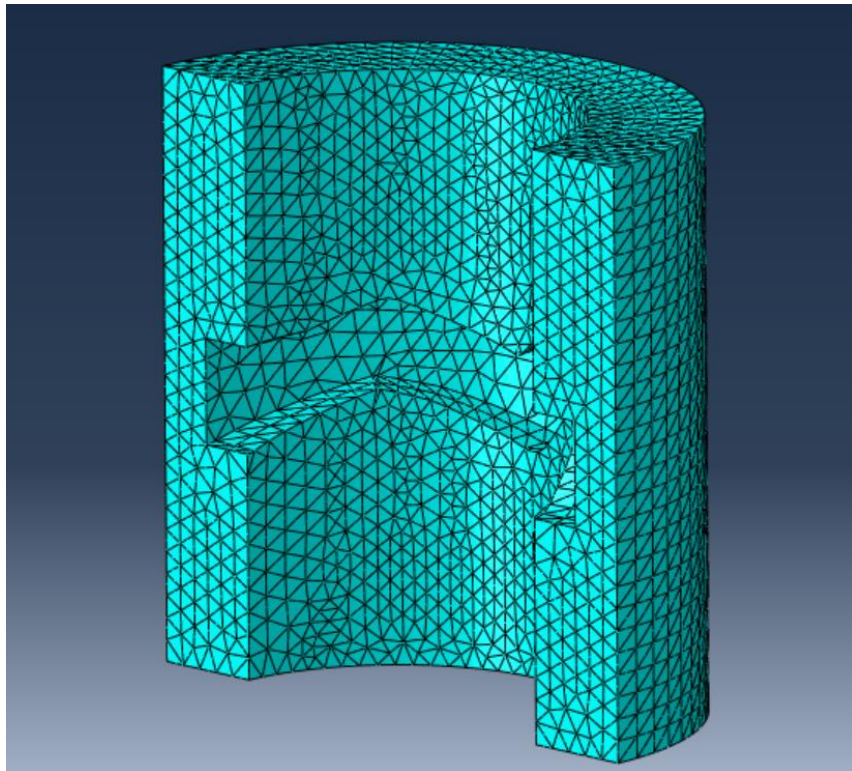
Figure 11 rotational displacement of the pin.

To mesh the pin we must first partition it first. We use datum plane and extend face by cell to partition the pin. We use the medial-axis algorithm and hex element type because these gives the best results for our case.



Figur 12 hex mesh on pin

Meshing the bracket with the hexahedra element shape type proved to be impossible, so we used the tetrahedra element shape type. Even though this type of mesh is not very optimized and won't give the most accurate results, we had to be content with it.



Figur 13 tet mesh on the bracket

The results we got from running the analysis were not realistic, so we proceeded with a trial-and-error procedure where we experimented with different settings in setting up the analysis. We first made the bracket rigid and only assigned material to the pin. Since we're only interested in the forces acting on the surfaces and not the deformation of the parts, doing this makes sense. And that doing this would make the calculations easier for Abaqus. The other setup we tried out was in the interaction module. Defining the interactions between the parts as general contact and not surface to surface. We experimented with this setting to find out which option gives the most accurate results and which option would calculate faster in Abaqus. Also, in the interaction module we experimented with the contact property as well, removing or changing the normal behavior a few times. Describing custom amplitude for the movement of the pin is something we also did. With a custom amplitude the movement of the pin in the groove would be more accurate to the real models.

Throughout this trial-and-error process we did not get any result that could be trusted. The reason for this, we think, is the tetrahedra mesh on the bracket. This type of mesh is not a very good choice for us, but any other type of mesh is not possible because of the complex geometry of the bracket.

After spending much time with Abaqus and seeing that there is only 4 weeks to the hand in deadline, we had to look at other options. From there we made the decision to switch to Solidworks. The main reason is that with the motion analysis module of Solidworks we could get friction force as a direct output of the analysis, something that was not possible in Abaqus.

Solidworks motion analysis does not use the fine element method for solving the problems but rather it uses a time-based approach for solving problems. The results we want can be solved from a kinematic analysis which is why the static and dynamic analyses we used in Abaqus were not needed.

Solidworks steps

We start by importing our step files of the pin and bracket into Solidworks, we then assemble them by giving them mates and move the assembly into motion analysis.

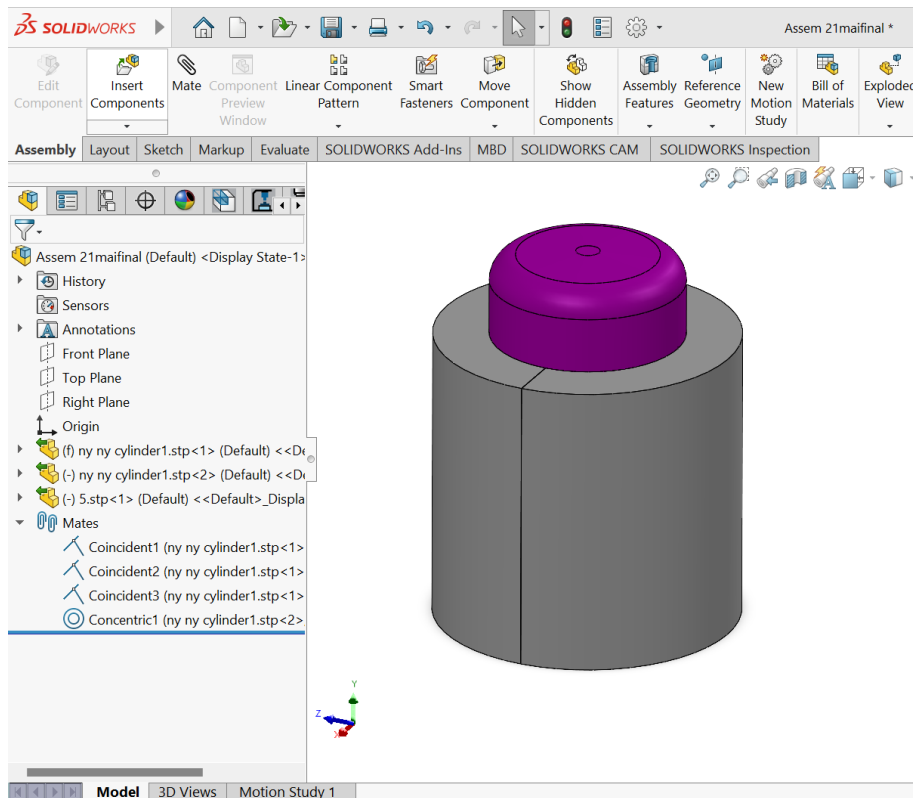


Figure 7 the assembly in the CAD environment.

In motion analysis we add a 225 N force equivalent of the spring force pushing the pin outward. and a force pushing the pin inward to simulate the pin being pushed in.

We describe the contact between the parts by giving them the friction coefficient values and the impact values. The impact values are not a general value for all parts with the same material but rather are dependent to a objects shape and

Prototyping

The purpose of our prototypes is to find errors and see the designs functionality. Our strategy is based on parallel prototyping. We created a few different designs based on our concept and compare them. We are going to divide this strategy into four steps. First, create a small scaled down prototype to see if the design concept works. Second, create a few designs based on our concept. Third, create a bigger scaled prototype with the different designs. Lastly, create a metal prototype.

Scale model testing

There is going to be three different scale model tests. Two 3D- printed, and one from the machine lab. The first 3D- printed test will be to see if the design works. This is a small scale

just to see some errors that can be corrected. The second prototype is a full-scale 3D- print. This model will have some corrections from the previous one. This is going to be a final test before a prototype in metal is ready to be produced. The final test will be a functionality test of the design.

- Discussing the first prototype. What went well, what went wrong.
- Discussing the second prototype, what changes did we make? Why did we make the changes that we did.
- Final prototype. Some processes and changes from the last one
- Find a place for test procedure and SJA stuff

5. Design

- Design concepts and evaluation

A Protecting lid for the finger hooks and modified pins

During the final design selection process, two main solutions were developed and presented to Aker Solutions. These solutions were developed based on the problem that the pins attached to the adapter getting stuck on the finger hooks during retrieval. This problem had been encountered by the bachelor group from last year. Our task this year was to improve the existing split pin design, so our focus was specifically on preventing the pins from becoming stuck on the finger hooks.

As mentioned earlier, we developed two solutions. The first solution consists of two parts. The first part involved modifying the pins to reduce the likelihood of them getting stuck on the finger hooks. This was done by rounding off the pins, enabling the pins to get pushed in smoother when they encounter the sloped part of the female bend stiffener connector.

The second part involves designing a new component that protects the finger hook ledge against impact from the pin. After a discussion between us in the group. We concluded that the best solution to prevent the pins from getting stuck on the finger hooks ledge was to create a new component which is a lid for the finger hooks. By creating a lid, the pins will experience smoother transition during retrieval. This minimizes the chance of the pins getting stuck on the finger hook ledge.

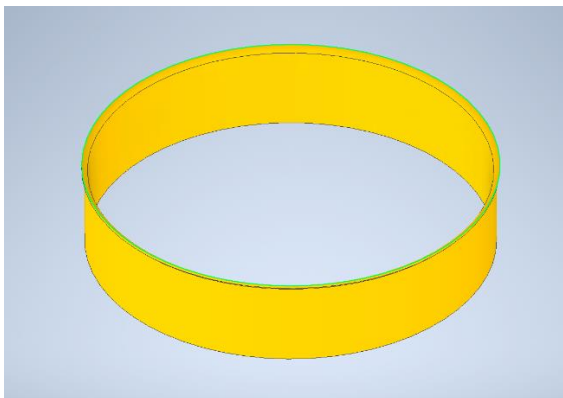


Figure 9: Protecting Lid for finger hooks

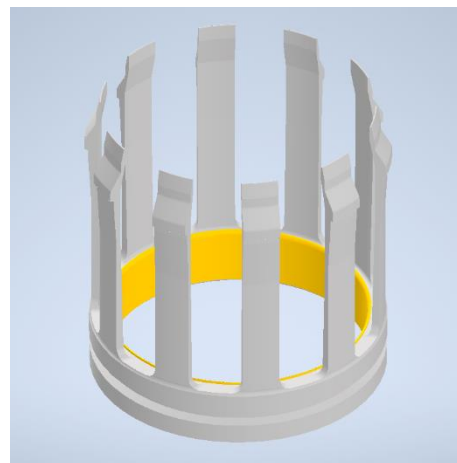


Figure 8: Assembly of protecting lid attached to the finger hooks

Pen mechanism

The other solution was based on the mechanism of pens. This solution came up on the first part of the brainstorming session where we generated ideas by ignoring the split pin mechanism.

The mechanism of pens is called the push pin mechanism and allows us to extend and retract the pin tip.

Pens operates as follows:

1. When not in use, the pin tip remains inside the barrel. The push button is in its resting position.
2. When you want to write something, you press the push button causing the spring inside it to be compressed and extend the pen tip out of the barrel.
3. When you are finished writing and want to retract the pen tip, press the push button again. This action releases the force on the spring causing the pin tip to pull back inside the barrel and simultaneously returning the push button to its resting position.

Using the pen mechanism, we discovered a solution that solves the problem of the pins getting stuck on the finger hooks ledge.

If you visualize it in our case during retrieval of topside, it will operate as follows:

1. The pins attached to the adapter on the topside have a spring mechanism.
2. As the topside is lowered, the pins will get pushed by the walls of the female bend stiffener connector. The force from the wall enables the pins to reach a notch where the pins will come to a halt.
3. While the topside continues getting lowered, the pins remains in halted position until they meet the sloped part of the female bend stiffener connector.
4. At this point, the pins will get pushed again, allowing them to extend fully to its resting position.

This means that when the topside is being lowered and the pins are in a halted position while passing through the finger hooks, it makes it less likely for the pins to get stuck on the finger hooks ledge which solves our problem.

With these two solutions being the ideas or concept we chose to go further with, we made a Harris-Profile for each solution.

Harris Profile of each concepts

	-2	-1	+1	+2
Mechanical Simplicity			+	
Load Bearing Ability				+
Easy to manufacture		-		
Clash Resistance			+	
Wear resistance		-		
Easy to test			+	

Figure 10 - Harris profile of Pen mechanism

	-2	-1	+1	+2
Mechanical Simplicity				+
Load Bearing Ability			+	
Easy to manufacture				+
Clash Resistance				+
Wear resistance				+
Easy to test				+

Figure 11 - Harris Profile of protecting lid

The Harris Profile has been done by group discussion. As a result, we have determined that the optimal solution in our case is the protective lid for the fingerhooks.

Presentation of the concepts:

After session of concept design evaluation, we had a meeting with Aker solutions to get their feedback on the designs and which concept design we should move forward with.

Aker solutions focused on improving the mechanism of the bend stiffener connectors. Due to that fact, they believed the pen mechanism was the best concept to move forward with. The reason is because the other solution, which involves the lid and rounding of the pins doesn't improve the overall mechanism.

Mechanism Redesign:

As mentioned, we are moving forward with the concept of using the pen mechanism.

This mechanism will be located in the adapter that is attached to the topside. So, the pins on the topside will have a pen mechanism.

During the redesign of the mechanism, we modified these following components from the current split pin mechanism:

1. MALE_BRACKET_POP (Backplate attached in the adapter)
- 2.
3. TOPSIDE_PIN_POP (Pins attached to the topside)
4. ADAPTER_WHOLE_BODY_POP (adapter attached to the topside)

Modifications on MALE_BRACKET_POP

For the mechanism to work, we had to make certain design modifications on the adapters backplate.

Previously, the backplate served as a protective plate to prevent the pin from detaching. With the redesign of the backplate, the pin will have its original function of protecting the pin from detaching, as well as securing the bracket in position and keep the spring in place.

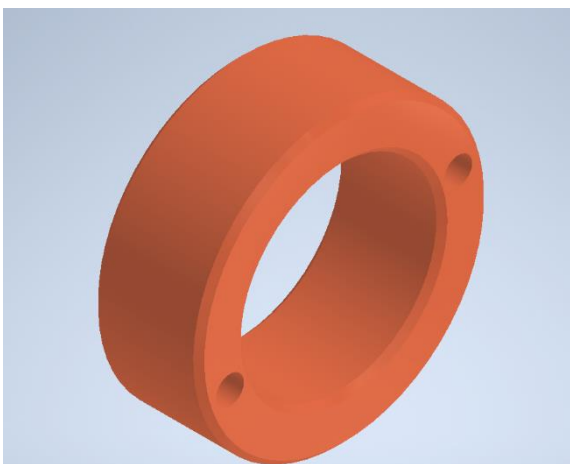


Figure 2: Retainer nut (From 2022 model) - Serves the purpose of securing the pin, preventing it from falling off.

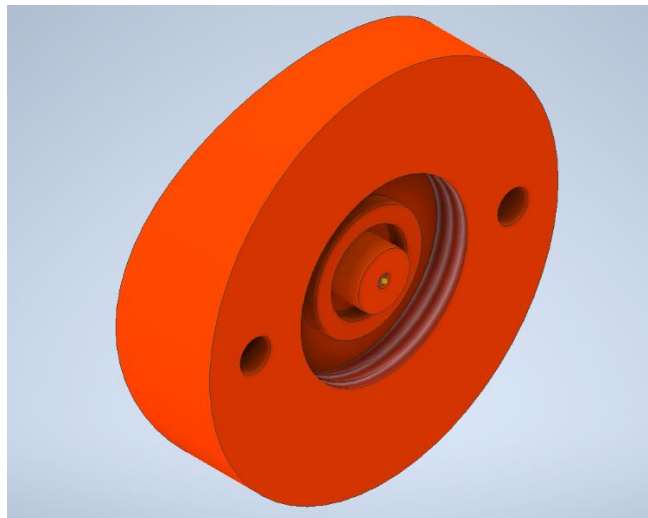


Figure 3: Back Plate (Redesigned) - serves the purpose of protecting the pin from falling off, keep the bracket in position and keep the spring in place.

Figure 2 shows the retainer nut that was used to secure the pin from falling off on the 2022 model which is also relevant in our case. Since we needed to fit the bracket inside the adapter, we had to create a redesigned retainer nut that serves purpose of securing both the bracket and pins. As a result, we replaced retainer nut with a backplate (Figure 3). The backplate serves the same function as the retainer nut in preventing the pin from falling off, it also keeps the bracket in place while also securing the spring.

Modifications on TOPSIDE_PIN_POP

In the process of exploring different solutions, a redesign of the already existing pins was necessary. The reason for this is that the pins must be able to fit inside the bracket, while the extrusion attached to the pins needs to fit the grooves inside the bracket.

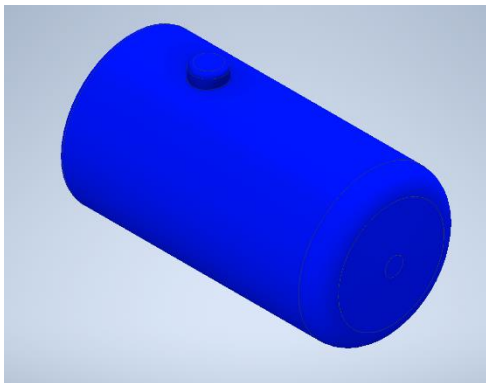


Figure 4 - Redesigned pin

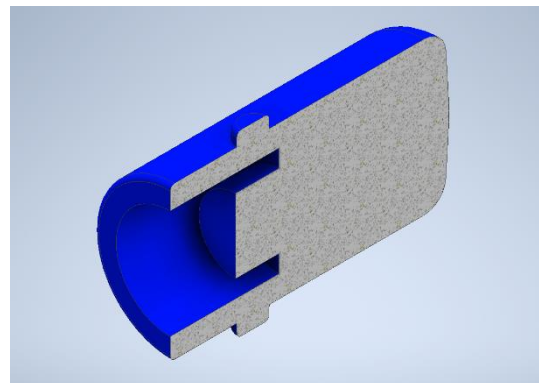


Figure 5 - Cross-section of redesigned pin

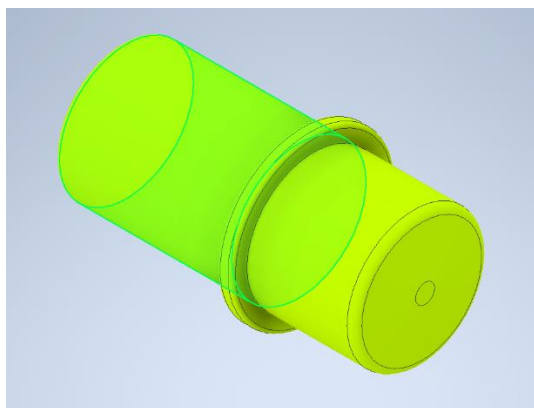


Figure 6 - Pins from 2022 (Split pin mechanism)

To make sure the mechanism works, a redesign of the pins from 2022 (Figure 6) was done. In figures 4 and 5, you can see the extrusions located on the sides of the pin. The extrusions are designed to fit into the grooves inside the bracket. Figure 5 also shows a hole located on the backside of the pin, where the spring will be placed. If there is a requirement to use a larger or smaller spring, the hole can be adjusted by modifying its size.

Modifications on ADAPTER_WHOLE_BODY_POP

In order to ensure that all the components fit in the adapter, we made necessary dimensional changes. This was because the bracket, which is a new part had to fit along with existing parts within the adapter. Additionally, the redesigned components had some dimension changes as well, so we had to make sure that all these part fit inside the adapter.

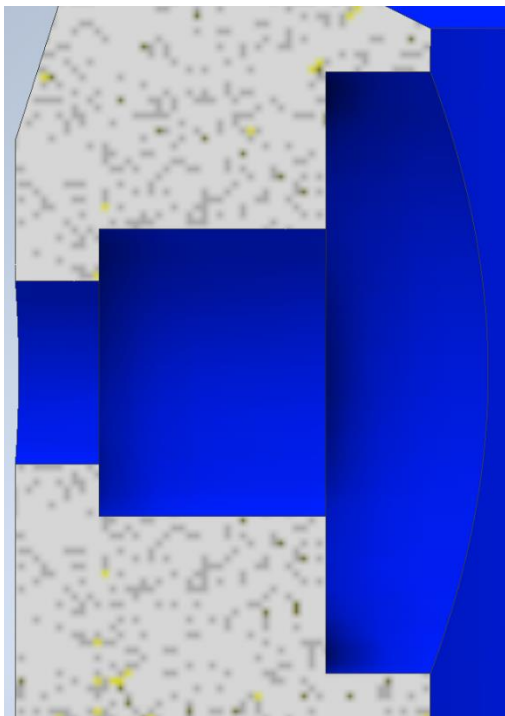


Figure 12 - Redesigned adapter (dimension wise)



Figure 8 - Adapter from 2022

New components:

To make sure the mechanism work, we had to create new components in addition to modifying existing parts

Bracket

A key component of the mechanism is the bracket, this new component allows the pin attached to the adapter to work like a push button on a pen. This component is a bracket with grooves inside it. These grooves are designed to direct the pins to two different positions. The first position is when the pins are at resting position. The second position is when the pins reach a notch and stop. When the pins are in second position, they can pass through the finger hooks without getting stuck on the finger hooks ledge.

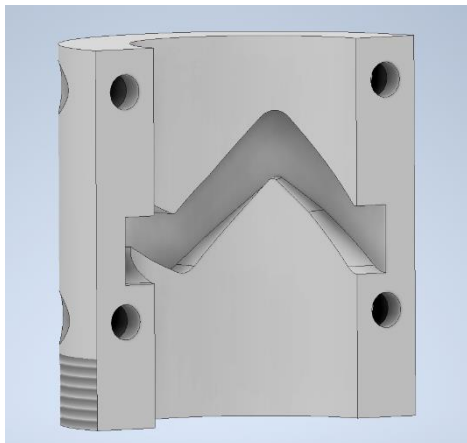


Figure 9: Bracket with grooves inside

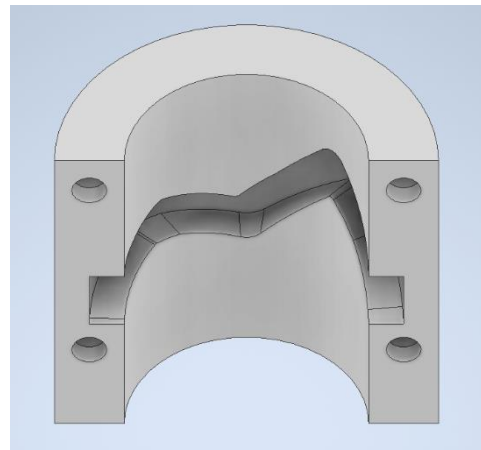


Figure 13: Bracket with grooves inside

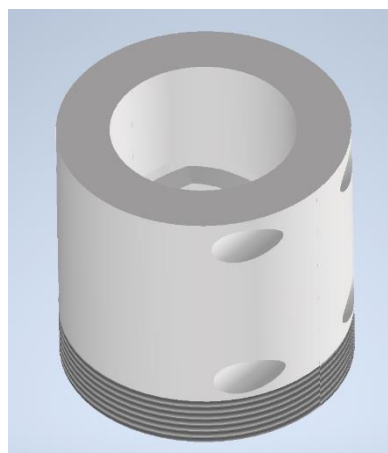


Figure 14 - Assembly of the bracket

Grease nipple

After a discussion with Aker Solutions, they requested us to make a grease nipple. The purpose of this request is to create a more efficient way of lubricating grease into the adapter through the backplate. By doing this, we ensured a simpler and more accessible way for inject grease.

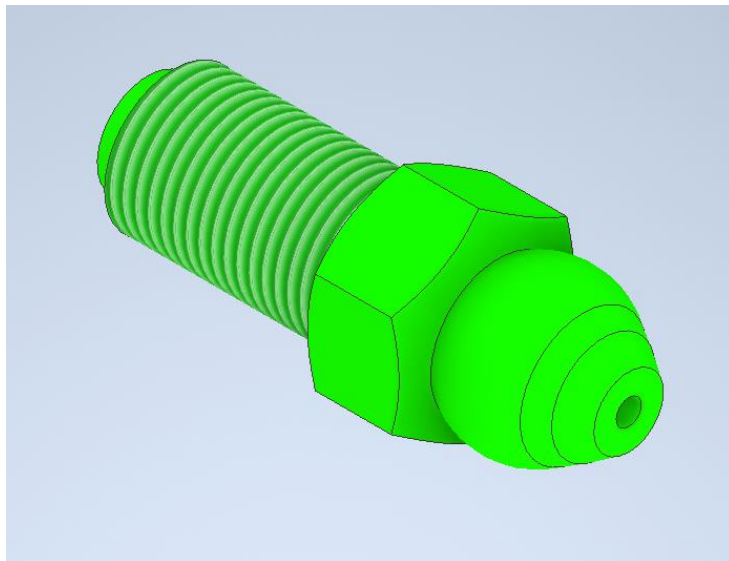


Figure 15 - Grease Nipple

6. Results

7. Results – show the results of FE and scale model testing

Functionality of final design:

The new redesigned solution with a pen mechanism solves the specific problem we wanted to solve regarding the pins getting stuck on the fingerhooks. We have reduced the chance of the pins attached to the adapter colliding and getting stuck on the finger hooks during both retrieval and release.

Mechanism springs:

Previous years` s project used Inconel 718 to their model. After a discussion among us, we chose to go for Inconel 625 instead. This is due to the fact that it is used in marine and offshore environments, making it corrosion resistant. Additionally, we had to adjust certain dimensions of the spring to ensure proper fit.

In the previous year`s project, the spring size had an unloaded length of 47,5 mm (L_0). In our case, we needed to increase the unloaded length to 50 mm (L_0) in order to ensure that the spring fits.

Calculations have been made to determine the amount of force needed to push the pins 15mm, releasing the topside from the Male BSC. To calculate the amount of force needed to push the pins, these equations have been used.

$$\text{Spring Force: } F_{Sp} = k * x$$

$$\text{Normal force (Redesigned Pin): } N_1 = \frac{m * g}{\sin(\theta)}$$

$$\text{Normal force (Pin attached to the male): } N_2 = m * g$$

$$F_F = \mu * N$$

$$F_{TOT} = F_{f1+2} + (2 * F_{Sp})$$

Forces	Values in N
Spring force	225 (Each pin)
Normal force 1	17.4471
Normal force 2	11.431
Friction force 1	2.09365
Friction force 2	1.372
Total Force	<u>453.46565</u>

In general, when analyzing an object's motion, it is important to take the forces into consideration. The inertia force is an example of such a force. However, if the object's acceleration is minimal, the inertia force can be neglected in calculations. When the forces acting on the object are minimal compared to its mass, the inertia force may not have an impact on the dynamics of the system. In our case, there is very little motion between the pins on the Male Bend Stiffener Connector and the Female Bend Stiffener Connector. Due to that, the inertia force can be neglected.

By calculating the forces required to push the pins 15 mm, we found out if it is possible for the wall on the Female Bend Stiffener to push the pins using the type of spring we selected and the redesigned pin. After a discussion with AKSO, we came to the conclusion that the wall on the female bend stiffener connector can push the pin by 15 mm as calculated.

- FEA
- Functional prototype
- Risk analysis

Risk analysis

This is an analysis of potential unwanted occurrences associated with the Bend Stiffener Connector. This assessment was done by group discussion. This assessment takes two key factors into account: the potential consequences and the likelihood of each event happening.

Unwanted Incidents

(1) Pins attached to the adapter will get stuck on the finger hooks ledge.

The redesigned model reduces the probability of pins getting stuck.

Consequence class: 3 Frequency class: 2

(2) Pin extrusions shear off.

The chances of the pin extrusions shearing off are minimal. However, if it does happen, it is easy to replace the pin.

Consequence class: 3 Frequency class: 3

(3) Grease nipple can be damaged or destroyed.

Consequence class: 2 Frequency class: 3

(4) Lubrication

Consequence class: 2 Frequency class: 2

(5) Fatigue Failure of the Spring

Over time, the constant pressure on the spring will cause it to weaken and eventually fail due to fatigue.

Consequence class: 4 Frequency class: 4

Risk Assessment Matrix

Consequence

		1 Insignificant	2 Minor	3 Moderate	4 Major	5 Severe
Probability	5 Very Likely					
	4 Likely				(5)	
	3 Possible		(3)	(2)		
	2 Unlikely		(4)	(1)		
	1 Very Unlikely					

(1) are an unwanted incident. By redesigning the mechanism, the probability of this incident to happen is reduced. The probabilities of (2) and (3) happening is minimal, although it is still possible. If that is the case, they can be replaced with a new one. The probability of (4) happening is minimal, but it can happen due to lack of maintenance. The probability of (5) to happening is high. This is because the pin experience constant pressure over time, leading to fatigue failure. To prevent this, you can release the pressure on the springs by simply pressing the pin once, allowing the spring to return to its normal resting position.

8. Discussion

- **Discussion** – evaluate the results, discuss any discrepancy between the results, discuss any possible sources of errors. Be critical of methods in this section, try to think of any ways that you could be wrong and how you might improve the reliability of your results (Further Work).

Bibliography

- Abbas H., J. A. (2016). *Improvement of diverless bend stiffener connector*. Oslo: Høgskolen i Oslo og Akershus.
- Aker Solutions. (den 5 December 2017). *Aker Solution Wins Johan Castberg Orders Totaling about NOK 4 Billion*. Hämtat från <https://www.akersolutions.com/news/news-archive/2017/akersolutions-wins-johan-castberg-orders-totaling-about-nok-4-billion/>
- Aker Solutions. (2023). *Subsea Production Systems*. Hämtat från WHAT WE DO: <https://www.akersolutions.com/what-we-do/subsea-production-systems-and-lifecycle-services/subsea-production-systems/>
- Aker Solutions. (2023). *Umbilicals*. Hämtat från Aker Solutions: <https://www.akersolutions.com/what-we-do/subsea-production-systems-and-lifecycle-services/umbilicals/>
- Annemiek van Boeijin, J. D. (2017). *Delft Design Guide*. BIS Publishers NBNI.
- Annemiek van Boeijin, J. D. (2017). Harris Profile. i *Delft Design Guide* (s. 139). BIS Publishers NBNI.
- Annemiek van Boeijin, J. D. (2017). SCAMPER. i *Delft Design Guide* (s. 123). BIS Publishers NBNI.
- Balltec. (u.d.). *Balltec BendLOK Diverless Bend Stiffener Connector*. Hämtat från Alliance Sealand Equipment Solutions: <https://asrental.sg/products/balltec/surf-solutions/balltec-bendlok-diverless-bend-stiffener-connector/>
- FES International. (u.d.). *Diverless Bend Stiffener Connector (DBSC)*. Hämtat från FES International: <https://www.fesinternational.com/fluid-transfer-products/diverless-bend-stiffener-connector-dbsc/>
- Håland B., E.-F. A. (2018). *Improvement of Bend Stiffener Connector*. Oslo: Oslo Metropolitan University.
- Øyvik T. B., R.-R. E. (2022). *Bend Stiffener Connector release mechanism improvements*. Oslo: Oslo Metropolitan University.

Appendix

- **Appendix**

Last Update: Friday 13. January 2023

Definition of Bachelor Thesis 2023

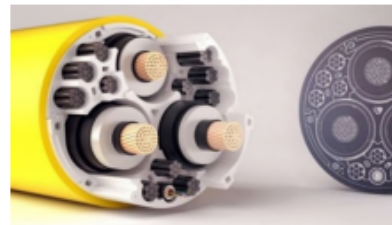
Improvement of BSC Release

PLEASE NOTE THAT FOLLOWING DOCUMENT IS AN 'IN-WORK' DRAFT EDITION AND IS SUBJECT TO FUTURE CHANGE.

General information:

The thesis and all files and documents from Aker Solutions are to be considered confidential. All partisans will be required to sign a confidentiality statement.

Language: English
 Communication: E-mail, meetings.
 Timeframe: January – May 2023
 Students: 4
 Product category: Subsea, Umbilical:
<https://www.akersolutions.com/what-we-do/products-and-services/umbilicals/>



Abbreviation/Term	Description	Explanation
AKSO / Aker	Aker Solutions	Aker Solutions
UMB	Umbilical	Umbilicals link surface and seafloor equipment. They provide electric and fiber-optic signals, electrical power and hydraulic and chemical fluids.
Topside		Any part of the system above the water line.
Subsea		Any part of the system below the water line and on the seabed.
(UMB) Termination		End unit of an umbilical. Where internal elements are branched out and prepared for interface.
Pull-in Head		Mechanical assembly containing the topside termination unit that is to be pulled up to the topside platform/vessel.
MBR	Minimum Bending Radius	
BS	Bend Stiffener	Large flexible component to prevent the umbilical from exceeding its MBR and to reduce the fatigue on the umbilical elements.
BSC	Bend Stiffener Connector	Mechanical assembly to attach BS the topside platform/vessel. Consist of Male and Female parts.
mBSC / fBSC	Male BSC / Female BSC	
Hang-off		When and where the Topside Pull-in head is attached to the topside vessel and secured for it's entire design life.
FEA	Finite Element Analysis	
ROV	Remotely operated (underwater) vehicle	
DNV	Det Norske Veritas	

Last Update: Friday 13. January 2023

Initial Tasks:

- General research into subsea and umbilical, get to know the different terms and abbreviations etc.
- Study drawings and documents provided by Aker.
- Read any thesis written by previous students in collaboration with AKSO.
- Make a progress plan for what to do and when to do it.
- Designate each team member a prioritized role: Modeling, drawing, calculations, writing, planning etc.
- Choose a group leader who is also to be the contact person and coordinator with Aker.

Thesis to include:

- Methodology
- Progress plan with dates and activities.
- Descriptions and illustrations documenting all concept design.
- Technical drawings: Detail drawings for any new/modified parts, GA (General Arrangement) and assembly drawings for the final assembly. Step-by-step drawings for the installation sequence.
- Test Documents: Test Procedure and Report that should contain Risk Assessment, Test Setup Drawings, assembly, and detail drawings as well as test data.
- Calculation and analysis: Detailed calculation reports (hand calculations and FEA) for relevant parts (to be specified further into the project).

Students to deliver to Aker at the end of the project:

- Printed and bound copy of final bachelor thesis, as well as PDF copy.
- STEP/Solidworks 3D files of final design.
- Rendered Animation video file showing installation and/or assembly.
- Videos and pictures from manufacturing and testing.
- Calculation reports, sheets and *Abaqus* files.
- 3D Printed models.

Aker to Provide

- Drawings, Solidworks/STEP files of current design, interface dimensions, relevant documents, general info on umbilical.
- Assistance and feedback through weekly meetings.
- If in doubt please ask, write down any questions you have during your work and ask them in our meetings.
- Feedback to thesis supervisor on perceived group performance and recommended grade.

Last Update: Friday 13. January 2023

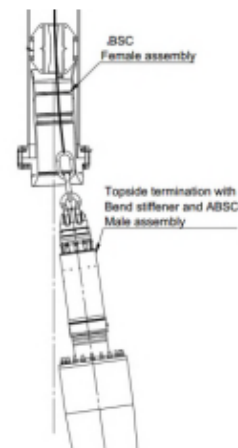
2023 Thesis task: Improvement of BSC Release

This year's bachelor task is to understand, improve, verify, and test the design of Aker Solutions' Umbilical BSC (Bend Stiffener Connector) design, with a focus on the attach and release mechanisms between the Male BSC, Female BSC and Termination Pull-in Head.

AKSO BSC

The BSC is a mechanical assembly to install and connect the BS in the designated location. The BSC is attached to the Pull-in head during installation and is to be disconnected and installed during the pull-in sequence. The installation of the BSC can be done manually by divers, crew on the vessel, ROVs or with an automatic mechanical solution. AKSOs BSC design is mechanical, automatic and diverless.

The BSC consist of two main components, the Male BSC and the Female BSC. The male part is attached to the Pull-in head, while the Female BSC is attached to the topside Platform or Vessel and will interface with the male BSC during installation.



Task

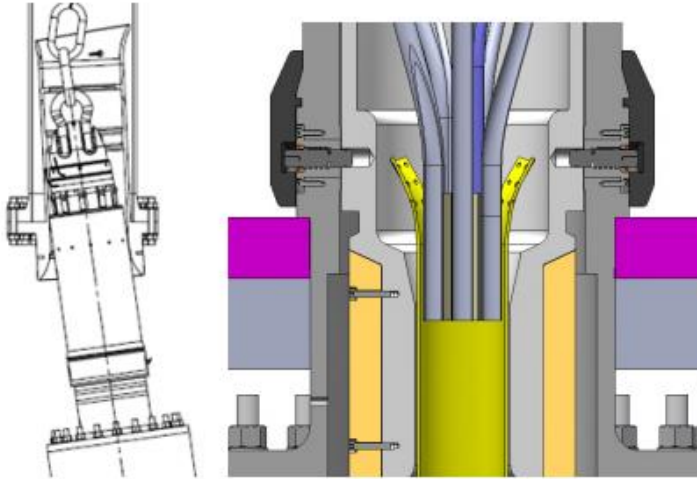
Improve the design of the release mechanism of the AKSO BSC and Pull-in head design. The older AKSO design made use of a shear pin design, the pin was designed to shear break during installation. The students from last year (2022) were tasked to create a breakless design to increase re-useability and risk. This year's task is to build on, improve, and test the solution developed by the 2022 Students.

System solutions requirements:

- Release system between mBSC, fBSC and Pull-in head must be fully mechanical and automatic.
- Develop and document concept designs, find the best solution in collaboration with AKSO.
- Create 3D Models and 2D drawings of the assembly with the new components in CAD software.
- Perform Strength Calculations by hand and by using FEA methods and make a Calculation Report.
- Check strength performance against installation loads provided by AKSO, check fatigue life of components for a 30-year design life. Estimated cycles/year can be provided by AKSO.
- Using DNV guidelines, calculate load cycles until failure.
- Choose applicable materials for the use, strength and environment for an actual use system and material for test use only.
- Create a rendered animation of the system during assembly, pull-in, installation, hang-off and release.
- Manufacture a functional scale prototype in the school lab. Design can be adapted for simplification but must correctly simulate the mechanical parameters.
- Plan and perform functional and verification test on the prototype and document the process with pictures, videos.
- Ensure the release system is not triggered prematurely due to wave, vessel, or winch motions.
- Perform detailed risk analysis of potential problems with design and develop potential solutions or measures to reduce risk or solve potential problems.

Last Update: Friday 13. January 2023

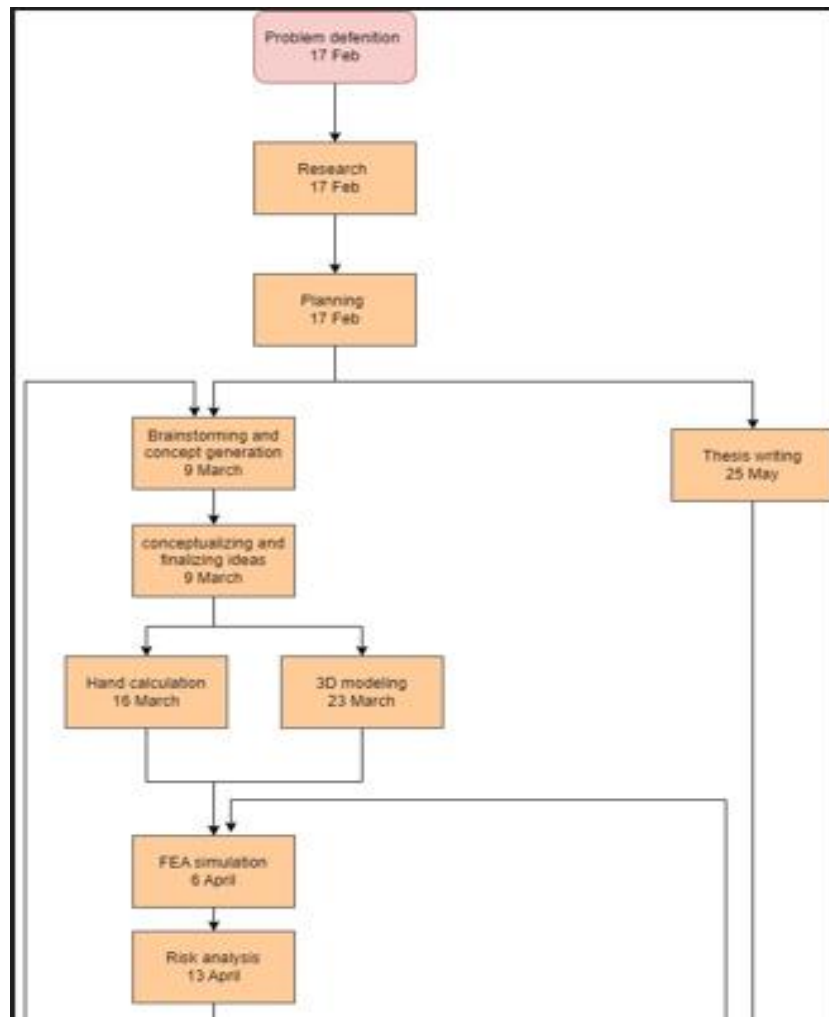
- Ensure the system is protected against the marine environment (Algae, seaweed, sand, etc.)
- Ensure system is protected against any mechanical damage from any clash on the seabed or installation.

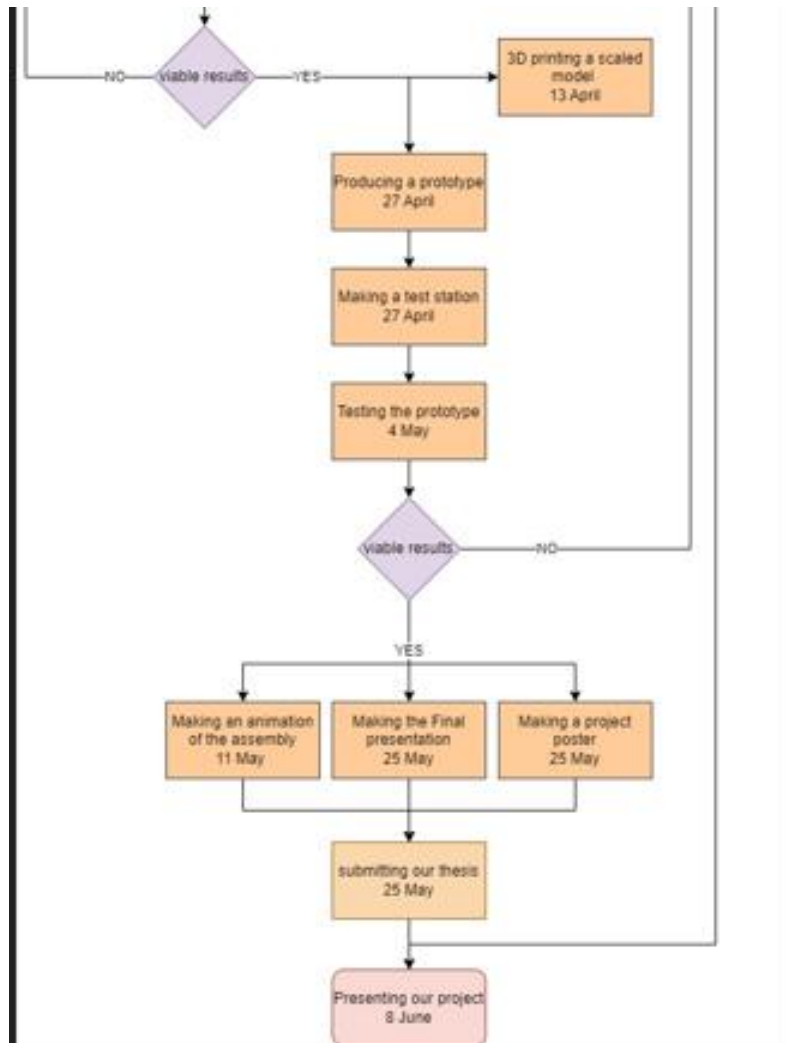


Old AKSO design for BSC and Pull-in Head release system

- Gantt chart

Flow Chart





Resources

List of resources used during the course of the project.

Will be tabled in final draft

Software:

- Inventor
- Abaqus
- Solidworks
- Microsoft office
- Cura
- Preform

Literatur:

- Ealier projects, specifications and materials given by AKSO
- Delft design handbook
- Noen bøker?

Standarder: Hvilke standarder trenger vi?

- ISO 13628-5 (Subsea umbilicals)
 - ISO 13628 Heter Petroleum and natural gas industries – Design and operation of subsea production systems. Kan det være flere relevante standarder tilknyttet denne?
- Hvilke andre?

Tilgang: Hvilke maskiner, kontorer eller datamaskiner trenger vi tilgang til?

- Maskinlabben
 - Hvilke maskiner trenger vi til å lage prototypen?
 - Hva slags testoppsett kan vi lage og hvilke maskiner/sensorer/måleinstrumenter trengs?
- 3D-printer – Makerspace?

Materialer: Har vi noen materielle utgifter til prototyping?

- Steel raw stock
- PLA
- Resin
- Steel Springs
-

Misc:

- Camera
- Poster

COMPARE

- Literature?
 - o ?
- Software:
 - o Microsoft Office Package (Word, PowerPoint, Excel, OneDrive, etc.)
 - o Autodesk Inventor
 - o Abaqus
 - o Solidworks
 - o Ultimaker Cura
 - o Formlabs Preform
 - o What else?
- Prototyping

- o Which machines are we using? – rune
- o Steel
- o Springs
- o PLA
- o Resin
- o 3D-printers
- Guidance?
- Budget
- o 5000 NOK
- Any more?
- Project Management Section – Gantt, Flow chart, how you communicate, delegate, manage resources, people skill, make sure your meetings are effective etc.
- o Gantt Chart
- o Flow Chart
- o Time management
- o Skills
- o Resources

Meeting summary

Meeting Date: 13.01.2023

Time: 09.00 – 10.00

Place: Teams Microsoft

Present: Atle Lagset, Hoang Pouong,

Tiril Øyvik, Bernard Håland,

Sam Woodford, Manzi Axel Bjørnstad Rwabizambuga,

Tarakan Sathiyanthan, Marius Haugstad and Mahdi Hosseini

Meeting Agenda:

- Introductions
- Short presentation from AKSO and Oslomet
- Questions

1: Presentation of Bachelor Team and External Supervisors

The meeting begins with everyone introducing themselves.

External Supervisors work in the Subsea department and are working with umbilicals.

2: Prep

The meetings will be done in Norwegian. The assignment should be written in English (documentation and work).

Aker Solutions will send documentation of last year's project once the bachelor group has submitted and signed a confidentiality agreement.

It is recommended to create a OneDrive folder that can be used as an interface for file sharing between the bachelor group and supervisors from Aker Solutions. Aker Solutions will upload the files needed for the bachelor group instead of sending large files via email.

Bachelor Group's Task and Expectations:

The focus of the bachelor group will be on the bend stiffener connector.

The objective of the bachelor thesis is to further develop the design from last year's bachelor group (Tiril) and see if it can be improved, do further analysis, produce a prototype, and test it in the school lab. The details are not yet clear, but general information has been provided to get the bachelor group started.

The bachelor group must study drawings and documents provided by the supervisors and try to understand them. They should look at the models, ask questions, and read relevant previous assignments.

It is desired that the group submits a printed copy of the assignment with drawings and a PDF version, as well as a STEP model of the design created by the group.

The group will receive an assembly file from the supervisors. Since it is an imported file, making changes to it will be difficult. The group is advised to recreate the design to make it easier to make changes and submit the assembly in the way the group has designed it.

The supervisors would like an animation showing how the assembly is put together and how it functions in practice.

When the group is in the lab, the supervisors would like to receive pictures and videos to track the progress.

Creating calculation reports and submitting any calculation files is required.

If time permits, 3D printing the design is wanted at the end.

General Information about the Task:

Bernard Håland has written a definition document that is not yet complete. This document shows what is expected from the bachelor group and what the bachelor group can expect from Aker Solutions.

The definition document includes a list of relevant abbreviations and explanations for each of them.

The group aims to have weekly meetings with external supervisors. During the meetings, the group will receive feedback and can ask questions to the supervisors. In the meantime, it is also possible to send emails with any questions to the supervisors.

Meetingsummary

Meeting: 27.01.2023

Time: 11.05 – 12.06

Present: Sam Woodford, Manzi Axel Bjørnstad Rwabizambuga,
Tarakan Sathiyananthan, Mahdi Hosseini and Marius Haugstad

- Weekly meeting suggested - Every Friday 11:00 - 12:00
- Choose group leader.
- Be as independent as possible.
- Send the meeting agenda before the meeting with Sam.
- Received 3 documents that need to be read.

Next week's homework:

- Problem statement – describe the situation which has created the need for this project.
- Project mission statement – what you want to achieve in a couple of lines.
- Include goals (SMART goals or can be like a design specification) and Scope (limitations for the project with justifications)
- Research how to test scale prototype – suggested.

Meeting summary

Date: 03.02.2023

Time: 11.00 - 12.00

Place: Pilestredet 35 (Oslomet)

Present: Sam Woodford, Manzi Axel Bjørnstad Rwabizambuga ,
Tarakan Sathiyanthan, Marius Haugstad og Mahdi Hosseini

Sam agrees with the group that the meeting is being held on Wednesday, February 8, 2023 since the group is meeting with Aker Solutions on Thursday, February 9, 2023.

It's good that the group has read previous AKSO project solutions (Aker Solutions). Sam recommends to be more analytic about it. He wants a little paragraph where the group evaluates earlier projects.

Next meeting with Sam after the visit to AKSO is on 17.02.2023. Read the bachelor solution from the previous year and provide a summary of how well you understand the project as homework for this meeting.

Sam wants the summary of the meeting with AKSO.

Feedback on Introduction:

Problem Statement: Very long intro about offshore etc.

Mission statement: Sam doesn't like the mission statement, expand mission statement. Acronyms should be defined.

Goals: Write the goals that applies for the project, not what you are going to achieve personally.

Scope: Too vague, be more specific.

Feedback flowchart:

Good flowchart

Recommended to go through it. Do we have knowledge to execute the stages.

Question and Answer:

Is it possible to the testing at Ocean Labs?

If the group take the initiative, Sam think they will say yes.

Homework for next Wednesday:

Write a good problem statement, mission statement, goals and scope before the meet with AKSO.

Meeting Summary

Meeting Date: 09.02.2023

Time: 12.20 – 13.45

Place: Pilestredet 35 (OsloMet)

Present: Manzi Axel Bjørnstad Rwabizambuga,

Tarakan Sathiyananthan and Mahdi Hosseini, Hoang Pouong, Tiril Øyvik and Bernard Håland

Agenda:

Go through:

Flowchart, Gantt chart, Problem statement, Mission statement and Scope and Goals

- After confirming the budget with OsloMet, write an email to Phuong about it because 3000 kr is way low for this project.
 - From the end of April to the end of May, Phuong will be away.
 - Clarify with Rune what the group is allowed to use in terms of lab equipment and machines
 - Students from both 2018 and 2022 created animations of the system using Inventor.
 - Tips: Make a section of the system to show the mechanism on Inventor.
 - Research scaled-down prototyping
 - The group must show a concept and present this to Aker Solutions by the end of the first week of march.
 - Develop a Test plan
-

Feedback on flowchart:

- Change “Presenting our thesis” to the end and “submitting the thesis” to second-to-last so it’s possible to have the presentation when Phuong is available.
- Each step in the flowchart should have an end date.

Introduction feedback:

Goals: “The system should be protected against any mechanical damage from any clash in the seabed or installation.” – The group can recommend how to meet this requirement with drawings (hand drawing etc.).

The group can ignore these goals: The system should be protected against the marine environment (Algae, Seaweed, Sand etc.), The release system should not be triggered due to wave, vessel, or winch motion.

Scope: Clarify how big the budget is.

Meeting summary

Meeting: 17.02.2023

Time: 11.01 – 11.30

Present: Sam Woodford (Intern Veileder), Manzi Axel Bjørnstad Rwabizambuga (Student), Tarakan Sathiyananthan (Student) and Mahdi Hosseini (Student)

Agenda: Go through work the group has done.

- Send Sam all the work that has been done, so the group can get feedback.
- Don't expect perfectly written work, as long as Sam gets our work .
- Next meeting on 3rd of March, no meeting next week.
- Don't send the files on PDF, send it on powerpoint or word.
- Ask AKSO, to postpone the conceptsharing to the week after the continuation exams because of time.

Meeting Summary

Meeting: 08.03.2023

Time: 12.00 – 13.30

Present: Atle Lagset, Tiril Øyvik (Ekstern Veileder), Bernard Håland (Ekstern Veileder), Manzi Axel Bjørnstad Rwabizambuga (Student), Tarakan Sathiyanthan (Student), Marius Haugstad (Student) og Mahdi Hosseini (Student)

Agenda:

Show the presentation to AKSO

- Continue with the model that was made in Inventor.
- Too many parts in that model. Possibly put the hooks on the male instead of the female.
- Satisfied with the pen mechanism. Atle said it was an idea they had before. He will look into it further and see why it either "failed" or why the idea was not used.
- Harris profile - Write specifications according to their importance.
- Make sure to divide the presentation so that everyone speaks equally.
- Male bracket pop - the holes are different. Don't know the reason for it, could be an error in the drawing.
- Aker wants us to focus on the mechanism part.
- Nice presentation.

Meeting Summary

Meeting: 10.03.2023

Time: 11.00 – 11.25

Present: Sam Woodford (Intern Veileder), Manzi Axel Bjørnstad Rwabizambuga (Student), Tarakan Sathiyathan (Student), Mahdi Hosseini (Student), Marius Haugstad (Student)

Agenda:

Show the presentation we presented for Aker Solutions on Wednesday 08.03.2023

Show the Concepts (Creative phase)

- Use the presentation we presented for Aker Solutions to the midterm presentation 29.03.2023
- No meeting next week.
- We will be holding a practice session and meeting for the midterm presentation on 24.03.2023 at 10:00 AM (lasting 2 hours).
- Book a room with a screen to do a proper presentation.

Meeting Summary

Meeting Date: 17.03.2023

Tid: 12.00 – 13.00

Sted: Teams Microsoft

Present: Hoang Pouong, Tiril Øyvik, Bernard Håland, Manzi Axel Bjørnstad Rwabizambuga, Tarakan Sathiyananthan (Student) and Mahdi Hosseini

Agenda:

Present our concepts

Quick recap from last meeting since Phoung was absent last meeting.

Very good concepts, supervisors are satisfied with all the concepts. With some advice from AKSO, they chose the pen mechanism concept that the group will work on with further.

Regarding the prototyping process, Phoung said that he can ask AKSO in Moss if they have some materials the groups can use since OsloMet has a low budget on project costs.

Its meeting next Thursday at AKSO.

Homework for that meeting is to make a model of the pen mechanism and make a rapid functional prototype to showcase the mechanism.

Questions:

If we buy something related to the project, can we buy it ourselves and send you the receipts.

We need spring and maybe some another components for the prototyping.

Meeting Summary

13.04.2023

Tid: 10.06 – 10.48

Place: Aker Solutions Fornebu

Present: Manzi Axel Bjørnstad Rwabizambuga,

Tarakan Sathiyananthan, Mahdi Hosseini, Marius Haugstad, Hoang Pouong , Tiril Øyvik and Bernard Håland

Agenda:

Show modified design

It would be better to be able to remove the whole part from the front, from the male part. Write it as an improvement potential, not change the current design.

Create a prototype of the female BSC as well, so that it is easier to see and understand the mechanism.

Make holes in the back plate so the space (where the spring sits) can be filled with grease.

Make the back plate thicker so we get more threads.

Wall thickness on the bracket needs to be increased.

Dreneringshull (Vannhull)

Inform Sam that one of the requirements from AKSO is to create a prototype. AKSO has provided the necessary materials for the group to create the prototype. It`s time to make it possible.

Meeting Summary

Meeting Date: 11.05.2023

Time: 14.00 – 14.50

Place: Teams

Present: Manzi Axel Bjørnstad Rwabizambuga,

Tarakan Sathiyathanan and Mahdi Hosseini, Bernard Håland and Marius Haugstad

- The requirement was to create a representative 3D print on a 1:5 scale. The group can make a model on a 1:10 or 1:8 scale. Refer to Bernard if Phuong asks.
- Tiril believes it will take longer than 2 days in the lab, so be prepared for it to take longer than expected.
- The calculations are not the most important thing; it's the mechanism that matters.

Mechanism springs:

Calculations have been made to determine the amount of force needed to push the pins 15mm, releasing the topside from the Male BSC.

Symbols	
F_{SP}	Spring Force
F_{TOT}	Total Force
N	Normal Force
F_f	Friction Force
k	Spring constant
Δx	Displacement

$$g = 9.81 \frac{m}{s^2}$$

$$\text{Inconel 625 Density} = 8440 \frac{kg}{m^3}$$

$$\text{Friction Coefficient } (\mu) = 0.12$$

$$\Delta x = 15mm$$

$$k = 15 \frac{N}{mm}$$

$$\text{Volume of improved pin design (VOID)} = 5.072955 * 10^{-5}$$

$$\text{Volume of Male BSC pin (VOMP)} = 8.732227 * 10^{-5}$$

Calculations to determine the weights of the pins:

$$m_1 = \text{VOID} * \text{Inconel 625 Density} = 0.42815 \text{ kg}$$

$$m_2 = \text{VOMP} * \text{Inconel 625 Density} = 0.7370 \text{ kg}$$

Calculations to determine Spring Force:

$$F_{SP} = k * x$$

Where F_{SP} is the force required to compress each spring.

$$F_{SP} = k * x = 15 \frac{N}{mm} * 15 \text{ mm} = 225 \text{ N (For each Spring)}$$

Calculations to determine normal force:

Where N is the Normal force acting on the pin.

$$N_1 = \frac{(0.42815 \text{ kg}) * 9.81 \frac{\text{m}}{\text{s}^2}}{\sin(13.93)} = 17.4471 \text{ N}$$

$$N_2 = (0.7370 \text{ kg}) * 9.81 \frac{\text{m}}{\text{s}^2} = 11.431 \text{ N}$$

Calculations to determine Friction Force:

$$F_F = \mu * N$$

Where F_F is the friction force acting on both pins.

$$F_{f1} = 0.12 * 17.4471 \text{ N} = 2.09365 \text{ N}$$

$$F_{f2} = 0.12 * 11.431 \text{ N} = 1.372 \text{ N}$$

Calculations to determine how much force is required to push the pin by 15 mm.

$$F_{TOT} = F_{f1+2} + (2 * F_{sp})$$

$$F_{TOT} = 2.09365 \text{ N} + 1.372 \text{ N} + (2 * 225 \text{ N}) = \underline{453.46565 \text{ N (For Each Pin)}}$$



Technical Drawings



Legg inn tekniske tegninger på denne siden

Test Procedure and SJA

Test Description: Three functionality tests will be performed. These tests will examine the ability of the mechanism in three different scenarios.

- Test 1 will verify the mechanism's functionality. If failed, tests 2 and 3 will not be held.
- Test 2 will test the mechanism whilst the pin is under load, simulating what will happen during the pull-in sequence. (SJA titled release)
- Test 3 will test if the mechanism can be actuated by an angled surface that will be attached to the test rig. (SJA titled reattach)

These tests will be held twice. One for each cylinder design.

Test participants:

Test location:

Test conditions:

Parameters:

Document: Test of release mechanism
 Version: 23.05.2023
 Issue date: 23.05.2023
 Page: 1 of 1

Vedlegg:

Jobb-beskrivelse: Test av release mekansime (spor 1)		Dato: 24.05.2023	
Original henges opp på arbeidssted		Verncombud (sign.):	
Områdeansvarlig (sign.):		HMS koordinator (sign.):	
Arbeidsleder (sign.):			
Andre (stilling, navn) sign.:			
Distribusjon: kopi til områdeansvarlig, arbeidsleder verneombud og HMS-koordinator.			
Arbeidsoperasjon (trinn)	Uønsket hendelse med konsekvenser for: personell, drift, materiell, ytre og miljø	Konsekvens*	Sannsynlighet
1. Oppsett – Sette huset og mekanismen i test rig, sikre at strikken sitter på	Strikk kan rives Person kan klemme fingrene	Lav Lav	Middels Lav
2. Release - Dytte inn pin, dra «topside» opp	Uriktig innsetting av mekanismen kan ødelegge test rigg At pin og mekanisme kiler seg med test rig Pin ikke blir dyttet langt nok inn	Høy Middels Lav	Middels Middels Middels
			Tiltak
			Kjøp nok med strikker slik at strikken kan erstattes
			Være to personer, ha god besyning og bruke riktig verktøy
			Følge test plan og tegninger, bruk god tid
			Bruke klemmer til å feste test rig sammen, slik at det enkelt kan tas fra hverandre
			Bruke test «dytter» til å dytte pinnen in
			Ansv.
			Tarakan
			Marius
			Marius
			Marius
			Mahdi

Test of reattachment

Document: 23.05.2023
Version: 1 of 1
Issue date:
Page:

Vedlegg:

Jobb-beskrivelse: Test av fange mekansime		Dato: 24.05.2023
Områdeansvarlig (sign.): <u>Arbeidssted</u>		Verneombud (sign.):
Arbeidsleder (sign.):		HMS koordinator (sign.):
Andre (stilling, navn) sign.:		
Distribusjon: kopi til områdeansvarlig, arbeidsleder verneombud og HMS-koordinator.		
Arbeidsoperasjon (trinn)	Konse-kvens*	Tiltak
1. Oppsett – Sette kantdel på testrigg	Høy	Sørge for riktig toleranser på deler slik at pasning ikke er et problem
	Lav	Følge test plan og tegninger, bruk god tid
2. Reattach – Senke «Topside» tilbake ned i test rig	Middels	Plassere test rigg godt inn på bord, bruke vernesko
	Lav	Følge test plan og tegninger, bruk god tid
	Middels	Bruke klammer til å feste testrigg veggene slik at den enkelt kan tas fra hverandre
		Ansv.
		Manzi
		Manzi
		Tarakan
		Marius
		Marius

Prototype

