# Sensur av hovedoppgaver

Høgskolen i Sørøst-Norge
Fakultet for teknologi og maritime fag

Prosjektnummer: **2017-03**
For studieåret: **2016/2017**
Emnekode: **SFHO3201**

**Subsea Connection system.**
Study on Speedloc on workover riser.
Studie av en Speedloc på workover riser.

**Utført i samarbeid med:** TechnipFMC, Kongsberg.

**Ekstern veileder:** Einar Totland.

**Sammendrag:**
TechnipFMC ønsket en studie på en Speedloc festet på Workover Riser. Overføring av krefter fra mutter, stud (gjengestag), segmenter og forspenning av kontaktflensene har flere uutforskede variabler som friksjon på mutter, friksjon (og konsistens) i studbeleggning (Xylan coating) etc.
Gruppe 3 har utført flere analyser. Både teoretiske og fysisk testing, hvor verdier fra det teoretiske ble testet ut i praksis.

**Stikkord:**
- Subsea
- Teoretisk studie
- Fysisk testing

Tilgjengelig: JA

## Prosjekt deltagere og karakter:

| Navn | Karakter |
|---|---|
| Bjørn Ledaal Rossavik | |
| Espen Hansen | |
| Erlend Berg-Olsen | |
| Asbjørn Antonsen | |

Dato: 29. mai 2017

| | | |
|---|---|---|
| Otto Waaraas | Karoline Moholth | Per Øystein Hansson |
| Intern Veileder | Intern Sensor | Ekstern Sensor |

# Gruppe 03-2017

## Speedloc connection on Workover Riser

Subsea Connection System

TechnipFMC

Høgskolen i Sørøst-Norge

# Summary

This thesis contains the documents for bachelor group 03-2017(Subsea Connection System), for solving the task given by TechnipFMC.

TechnipFMC wanted a study on speedloc connection on workover riser. Group 3 have done several analyses, theoretical and physical testing.

Published: 24.05.1017.

# The Inception phase

| | |
|---|---|
| **Version** | 2.0 |
| **Employer** | TechnipFMC |
| | |
| **SCS group members** | Asbjørn Antonsen,<br>Project leader and construction<br>Initial: AA |
| | Bjørn Ledaal Rossavik,<br>Qualification and specification<br>Initial: BR |
| | Erlend Berg-Olsen,<br>System Engineer and Project planner<br>Initial: EBO |
| | Espen Hansen,<br>Test and Verification<br>Initial: EH |
| | |

Høgskolen i Sørøst-Norge

# Summary

This document covers the project plan (inception phase) for bachelor group 03-2017(Subsea Connection System) and the task given by TechnipFMC.

It includes information about how SCS are going to control the project and description of the development of the project future.

The project plan is created by the group members, and is also a useful tool during the whole project.

# Document history

| Version | Pages | Date | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 31 | 24.01.2017 | AA | Made document and put together all documents into one document. |
| V.0.2 | 42 | 270.1.2017 | EH | Made document and put together all documents into one document. |
| V.0.3 | 40 | 30.01.2017 | BR | Changed FMC to TechnipFMC, spelling check and adding additional documents. |
| V.0.4 | 37 | 31.01.2017 | AA | Collected more files into document and fixed structure. |
| V.1.0 | 44 | 01.02.2017 | SCS | Final document for first hand-in. |
| V.1.1 | 47 | 17.02.2017 | EH | Front page. Updated Risk analyses. |
| V.1.2 | 48 | 19.03.2017 | BR | Added risk analyses for Elaboration phase. |
| V.1.3 | 48 | 02.05.2017 | BR | Orthography, updated document regarding to academic reading. |
| V.1.4 | 46 | 08.05.2017 | EH | Orthography, updated document regarding to academic reading. |
| V.1.5 | 46 | 17.05.2017 | AA | Updated all content |
| V.1.6 | 47 | 20.05.2017 | BR | Final report, content update and orthography. |
| V.2.0 | 47 | 24.05.2017 | SCS | Ready for last hand in. |

# Appendix list

[Apx.A]. Gantt chart.

[Apx.B]. Project specification.

[Apx.C]. Task and test specification.

# Abbreviations and technical words

| Abbreviation | Explanation |
|---|---|
| WOR | Workover Riser |
| SL | Speedloc |
| ISO | International Standardization organization |
| DNV | Det Norske Veritas |
| UP | Unified process |
| SCS | Subsea Connection System |
| HSN | Høgskolen i Sør-Øst Norge |

| Technical Words | Explanation |
|---|---|
| Friction | The force resisting the relative motion of solid surfaces, fluid layers and material elements sliding against each other. There are several types of friction. |
| Stud | Threaded rod similar to a bolt but it has no bolt head. |
| Nut | A nut is a fastener with a threaded hole. |

# Contents

# Figures



# Tables

# 1. Introduction

Subsea Connection System (SCS) are a group of four mechanical engineer students, studying in their last semester at HSN, Kongsberg. The group consist of four different technical backgrounds. Two are educated from the car industry, one as an automation mechanic and one has worked within the plumbing industry. SCS are going to write a bachelor's thesis for an international firm called TechnipFMC. TechnipFMC are global leader in oil and gas project, technologies, system and service.

In this bachelor's thesis, SCS are going to do a study on Speedloc (SL) connection on a workover riser. *(see fig.1, 2 and 3).*

To get a better understanding of this task, SCS must understand what a workover riser and Speedloc connector is.

Workover Riser (WOR) is used for installation, completion and intervention of Subsea Trees. WOR has a pressure range from 5000 psi to 15000 psi.

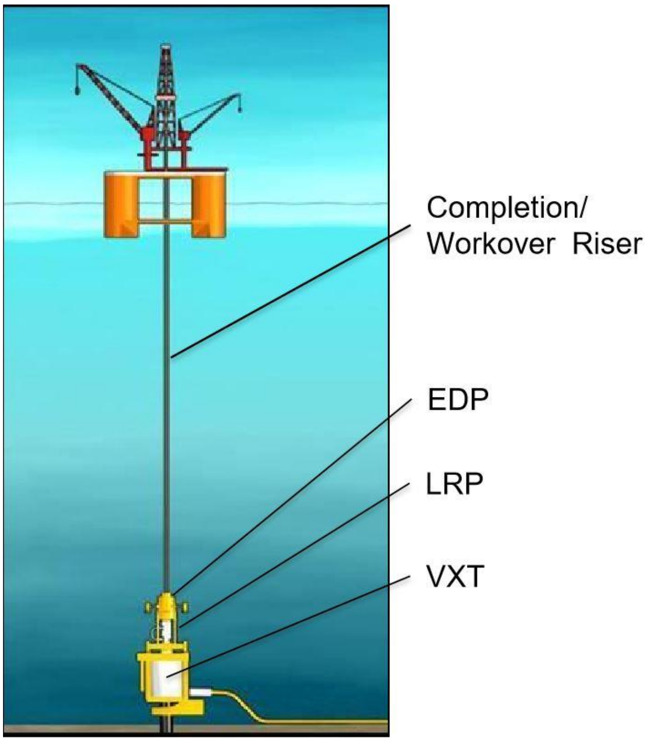



*Figure 1: Workover riser*

The riser is a piping connection between an offshore floating production structure or a Drilling rig and down to a subsea system. This is used either for production purposes such as drilling, production, injection, completion and workover purposes. Liquids and equipment can be transferred to the well inside this pipe, without any contact with the ocean around.

One of the most critical product in an offshore pipeline are the risers, consider sour service conditions and the dynamic loads they need to withstand.

Speedloc connector is used to connect the “pipes”, and the “equipment” together.

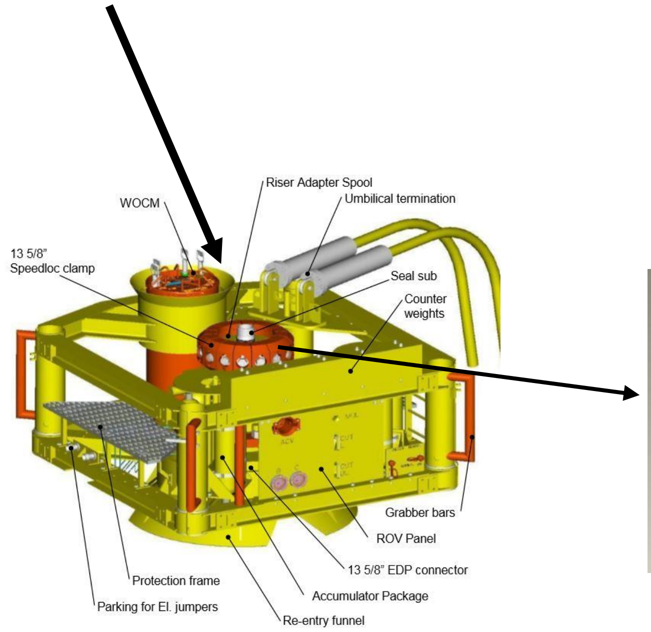



Figure 2: EDP with Speedloc connector

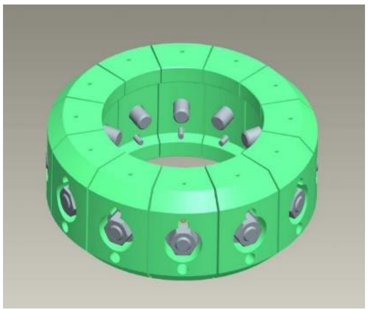


Figure 3: Speedloc Connector

As mentioned, SCS are going to take a deeper look into this Speedloc.

Many factors affect the force on the SL stud, such as nut, washer, friction and consistency in stud coating (Xylan). SCS must read and get into the testing and tables that TechnipFMC already has done. In this assignment SCS must investigate the torque that is being used, find out what torque is correct to use on this specific SL with these stud, what kind of forces the clamp generates and study the Xylan coating.

This final bachelor project is a big and time consuming task which requires that all the members in the group works together and pulls the load of the task in the same direction. SCS must work as a team in order to acquire the knowledge needed to solve challenges that may come along.

SCS have discussed and looked into many types of project models to use in the project.

SCS ended up with the Unified process model.

This model contains recurring and incremental aspects. The unified process model is divided into four main phases that reflects which part of the project SCS should work with.

This bachelor degree from HSN Kongsberg are divided into three phases, with one oral presentation in each phase.

Presentation 1:

This presentation is an introduction of the project, what it involves, how SCS are going to solve the tasks, what is done so far and what is going to happen further. Here is the project planning significantly important.

Presentation 2:

After this second phase, SCS are going to present the project status and what we have to work on further in the project.

Presentation 3:

This is the main presentation. This is where the final result is presented.

# 2. The task

## 2.1 Task description

TechnipFMC is looking for a study on Speedloc connector on Workover Riser *(see fig 4).* The transformation of forces from nut, through stud, segments and onto pretension of the connector hubs has several unexplored variables such as friction on nut washer, friction (and consistency) in stud coating (Xylan) etc.

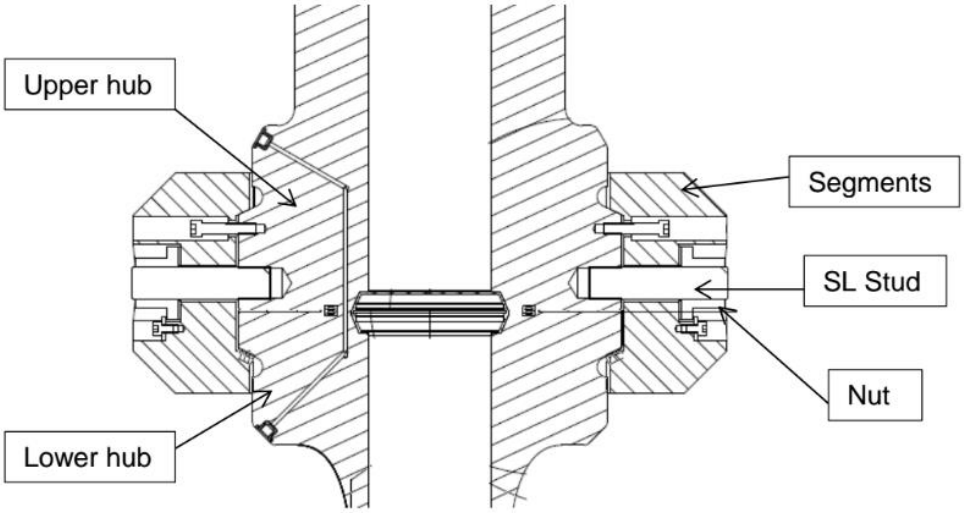



*Figure 4: Speedloc clamp with hubs*

Some analyzes has already been done from FMC, verifying the connector integrity, however the torque applied on nut is set from a standard table. The bachelor group should read and get into calculations and testing that has already been done.

## 2.1.1 Main task

- Investigate the torque that is being used today.

  Torque of 3434 N/m is used today, and has been taken out of a standard bolt-table. It is 67% of the yield strength on the material used on the bolt. This is based on a standard bolt connection, not necessarily ideal for the Speedloc clamp.

- FMC wants a specific study on these bolts that is used on the speedloc.

  What torque is correct to use, on this specific speedloc with this stud? What pretension is generated in the stud, connector flange and which key parameters affect this?

- The bachelor group also need to study and find out what forces the clamp itself generates.

- Study and analyze the Xylan coating that is been used on the bolt.

  The coating is used to help the bolt from getting stuck, prevent corrosion, etc. Is this coating necessary and can this influence the strength on the bolt negatively? Are the threads taking more damage with the coating on?

## 2.1.2 Additional task

If the main task is done and the time schedule allows us to do some extra work, an additional task is available.

- Make a test rig, so we can stretch and analyze what happens to the bolt under high torque. Any test shall be done to challenge calculation already performed, and verify consistency and effect of variables.

- If study proves inconsistencies between practice and results, connector design optimization might be proposed.

## 2.2 Understanding of the tasks

This project is not about creating a new product, but analyze a component that already exists. The task is relevant because it contains many different aspects of the education in mechanical engineering. Studies and analyses have already been done by TechnipFMC, and a big part of the job contains to read and understand all this information. Further SCS must do an individual study and try to solve the task after best effort based on their knowledge.

TechnipFMC is first of all looking for a study on a stud that is used to fasten the clamps on the Speedloc connection, and to see if it is good enough. They have already tested the overall integrity of the connection, and the product have been in operation subsea for some time.

There are some uncertainties that TechnipFMC want to be analyzed. What affect does the Xylan coating have on the stud, mechanical properties and how much do the mounting procedure affect the overall strength of the stud.

## 2.3 Main focus

Main focus in the task:

- Study the SL stud and define the pretension on the hubs.
- Better understanding of the forces in the connection.
- Test and verify the integrity of the SL stud.
- Make more predictable calculations on the SL stud.

Main focus in the group:

- Good communication.
- Good system engineering.
- Create a good learning process.
- Solve the main task after best effort.

## 2.4 Goal for this project

Main goal for this project is to perform a good study of the Speedloc connection on a workover riser. SCS have also set a goal to reach a good grade, to get a better understanding of project planning and project tools.

Goals:

- Better understanding of project planning and its tools.
- Problem solving.
- Analysing and testing.

### 2.4.1 Short term goals

- Good project documentation and work structure.
- Maintain good communication with internal and external employer.
- Every participant must learn and get a deeper understanding of the project-model and their role in the project.

### 2.4.2 Long term goals

- Deliver all documentation.
- Complete the project within the planned deadlines.
- Complete the project within the planned time budget.
- Complete the project with good quality at all levels in the process.
- Complete the project within the given guidelines and claims from the stakeholder.

# 3 Organization

## 3.1 Employer

SCS`s employer is TechnipFMC, Kongsberg.

TechnipFMC is a global market leader in subsea systems and a leading provider of technologies and services to the oil and gas industry.

### 3.1.1 Background information

From a continuous spray pump in California's orchards in the 1880s to some of the world's most sophisticated equipment for the oil and gas industry, FMC Technologies and its heritage companies have a long history of technical innovation.

In 1880 John bean invented a spray pump to battle diseases in his orchards.

But in the 1960s we started to see some of the FMC Technologies we recognize today. FMC developed an underwater wellhead equipment for offshore drilling. That was the start on the beautiful journey to build up a great and successful company in the oil business. In 1970s FMC trademark is created and launched.

In the 1990s FMC acquires Kongsberg Offshore, National Oilwell Fluid Control Systems, Smith Meter, and CBV Subsea, solidifying its position as industry leader.

June 14, 2001, FMC Technologies Inc. begins trading on the New York stock exchange.

December 31, 2001, FMC Technologies Inc. becomes an independent company.

FMC technologies headquarter is in northern Houston, Texas, USA. Globally FMC Technologies has around 18 900 employees, spread out on 30 locations in 16 different countries. There are around 3800 employees working for FMC Technologies in Norway.

May 19, 2016 FMC technologies announced that they are going to merge with the French company Technip. This merge happened in January 16, 2017.

Now they are called TechnipFMC.

## 3.2 Group members

| Personal information | Main responsibilities | Description |
|---|---|---|
| Asbjørn Antonsen<br><br>Mechanical Engineer<br>Telephone: 41358671<br>Mail:<br>antonsen.asbjorn@gmail.com | Project Leader<br>Construction | 29 years old and born in Hønefoss. Finished 2 years of high school as a car mechanic. 3 years in apprenticeship as an auto body refinish technician. Worked for two years in the same profession. 1 year in mandatory military service. 1 year in military service in Afghanistan as a car mechanic/top cover. |
| Bjørn Ledaal Rossavik<br><br>Mechanical Engineer<br>Telephone: 4192 2462<br>Mail:<br>bl_rossavik@hotmail.com | Qualification<br>Specification | 27 years old and born in Stavanger.<br>Finished 3 years on High-school as an Automation mechanic.<br>2 year as an Automation mechanic trainee at Tine Meieri, Kleppe.<br>Have worked for Weatherford Laboratories the last 5 years, as an Automation mechanic building laboratory equipment for testing of oil, gas and core samples. |

| | | |
|---|---|---|
| Erlend Berg-Olsen<br><br>Mechanical Engineer<br>Telephone: 97423214<br>Mail:<br>Berg.olsen.e@gmail.com | System Engineer<br>Project planner | 26 years old from a farm in Trøndelag.<br>Finished 2 years in High school, first year studied electromagnetics, and the second year studied car mechanical.<br>Then started as a car mechanical apprentice, and then worked as a licenced car mechanical. |
| Espen Hansen<br><br>Mechanical Engineer<br>Telephone: 40635627<br>Mail:<br>e.hansen@gk.no | Test and verification | 23 years old and born in Drammen.<br><br>Finished 3 years on Drammen High school with specialisation in economics and marketing.<br>Worked as a plumber in GK-Rør Drammen for 1 year.<br>5 years in Posten Norge AS. |

*Table 1: Group members*

## 3.3 Communication

Internal and external communication is very important for SCS and the project. With good communication, SCS will avoid misunderstanding and delays.

### 3.3.1 Internal communication

Good communication inside the group is important.

Every Monday to Friday all SCS group members meet at project group room from 08:00-16:00. SCS have a quick morning meeting every day and go through the task for the day. Then SCS usually work in the group room until 16:00. SCS see it as a positive and good thing that all are surrounded in the same room, and can help each other if necessary.

SCS will use Google drive to collect and save all documentation. SCS have secured the room and only group member have access to this room.

From the very beginning SCS made a list about templates and structure. In that way, SCS secure that everyone in the group are aware of how they shall do things and all documentation are done the correct way.

SCS also have a group chat on Facebook messenger, where we can discuss things when working from home.

### 3.3.2 External communication

Project leader will oversee communication with all the external and internal sensors as well as internal and external supervisors.

External communication with TechnipFMC will be done by mail, telephone and meetings.

To communicate with the internal personnel from HSN, SCS will use mail, telephone and meetings.

### 3.3.3 Follow-up

To keep good control on this project, SCS will have weekly meetings with our internal supervisor.

SCS have a document template that they will go through every week. In this document, SCS will discuss things such as what have been done this week and by who, what is important to do next week, what is the status is in the project etc.

With internal sensor, external supervisor and external sensor SCS will go through a similar document every 4th week.

It will also be 3 presentations during this bachelor project.

## 3.4 Stakeholders

SCS bachelor group have a lot of impacts to think about in this project. SCS have chosen to divide the stakeholders into two groups, active and passive stakeholders. Active stakeholders are stakeholders that have a direct impact to this project. Example of active stakeholders is TechnipFMC, HSN, etc. The other group is the passive stakeholders. This is stakeholders that have an indirect impact to this project. Example on this can be environment, law & regulations, users of the project, etc.

## 3.4.1 Active stakeholders

SCS have two active stakeholders in this project *(see fig 5).* The two active stakeholders are employer TechnipFMC and the school HSN, Kongsberg. TechnipFMC have given SCS a primary task, and an additional task to solve if there are time. TechnipFMC stated their needs and then SCS listed some concerns. From this SCS started to work with the requirements. HSN is also a stakeholder. HSN is the school this bachelor thesis are written for.

Here is a figure of active stakeholder and their concerns.

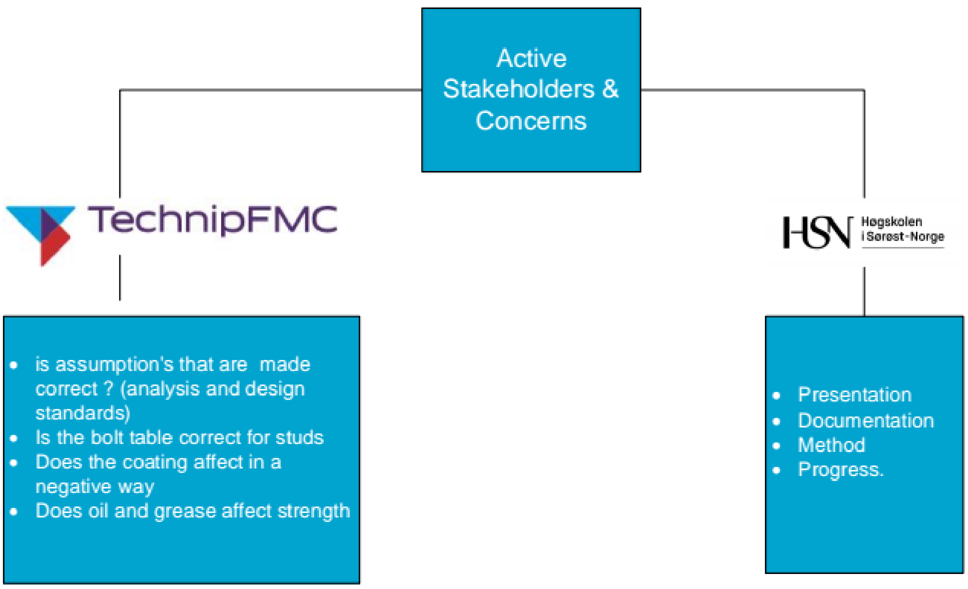



*Figure 5: Active Stakeholders*

## 3.4.2 Passive Stakeholders

Passive stakeholders are the indirect impact on this project *(see fig 6).*

SCS have divided passive stakeholders into five main categories.

External Forces, like the weather. This can`t be controlled, but something to be aware of.

Laws and regulations, like ISO and DNV standard. The project must be within the laws of ISO standards and DNV.

Users, the human factor. SCS can never know how a user will operate this equipment, but SCS must take this into account.

Environment. Production method is one example.

SCS does a job for TechnipFMC, but SCS are also thinking about the third-part, the company that buys this equipment/service from TechnipFMC.

Here is a figure of passive stakeholders and their concerns.

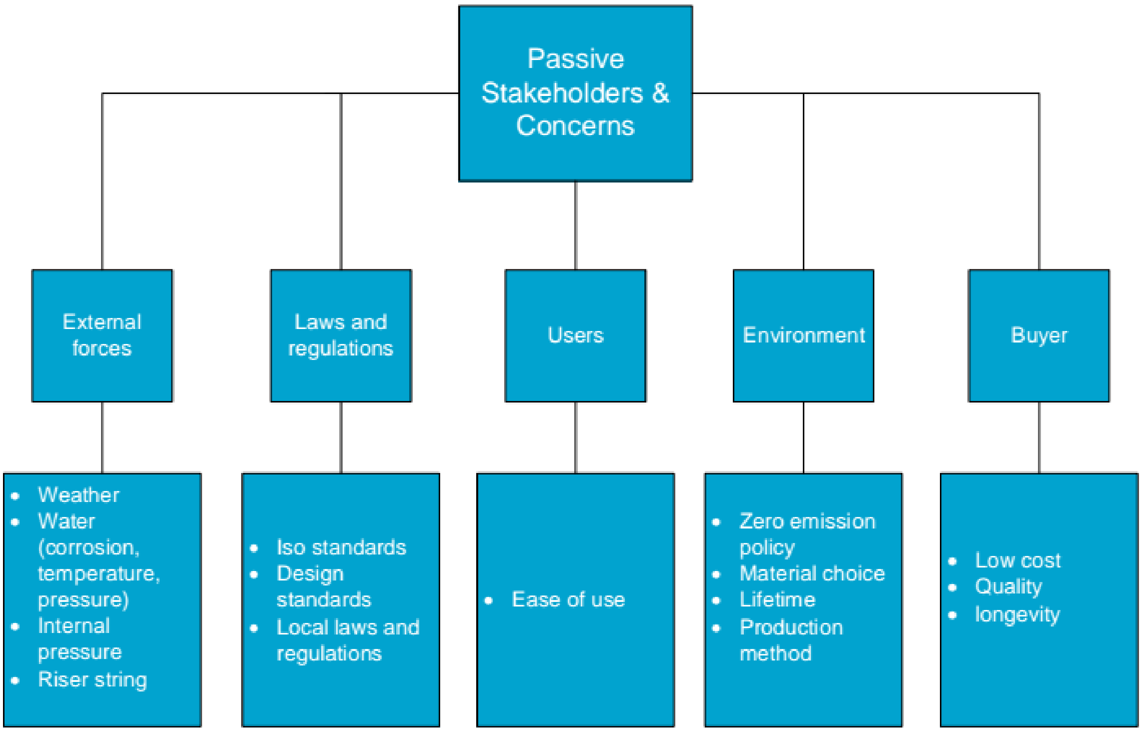



*Figure 6: Passive stakeholders*

# 4. Quality management

## 4.1 Document template

Templates and standards on documents are very important in a project. If group members use different template and standards, it will lead to confusion and the result will be messy.

Therefore, templates for meetings, timesheet, traceability have been made, and also a standard template to use on every document, this template must be used on every document. In this document, there are standard headings, standard text (with size and color) and standard layout on the whole document.

With templates and standards, SCS secure high quality and similarity in every document produced by Subsea Connection System.

### 4.1.1 Requirements

SCS got a project description from TechnipFMC, and from that document needs and concerns was developed.

Based on needs and concerns, requirements were written. After requirements were ready, a meeting with TechnipFMC and SCS was set up to discuss these requirements.

All the requirements are traceable and can be changed, if the customer or SCS find it necessary.

SCS have made a document where all the requirements are listed, with their own identification number. *(See appendix B project specification).* You can also read more about this discipline in chapter 7.2.2. Requirements.

Every requirement shall include:

- ID number.
- Where the requirement came from.
- Description.
- Priority.

## 4.1.2 Meetings

SCS have made templates for all the meeting documents.
This will secure the high quality and consistency on project documentation.

All meeting document shall include:

- Participants.
- Date and time.
- Location.
- Leader of the meeting.
- Agenda.

## 4.1.3 Follow-up

Every week SCS are obligated to have a follow-up document filled out and handed over to internal supervisor. After this is handed over to supervisor, there will be a meeting to discuss this document.

Follow-up document is a document that describe overall status report after the project week.

All follow-up document shall include:

- Timesheet for all group members for the current week.
- Task that has been done by all group members for the current week.
- Task to be done next week for all group members.
- Quick summary of project regarding to project plan.
- Summary of critical activities.

## 4.1.4 Daily meeting

SCS have a startup meeting every day, where all group members go through the activities that must be done that current day. At the end of the day, SCS have a quick brief on what is accomplished regarding to the morning plan.

This is an unofficial document that is for internal use only.

This is a helping document to remember hours spent on activities and a safety net if something is forgotten.

## 4.2 Plan for quality assurance

In this table, SCS can see different quality goals and action to meet them.

| Activity | Action |
|---|---|
| Main quality goals:<br>Identify the quality goals of the project | • Decide primary requirements with customer.<br>• The organizations quality goal or guidelines that the project must follow |
| Identify the customer | Customer is everyone who are going to have an effect on this analyze and study rapport. It can be many different firms in this category, but not everyone is equally important in this study. It is important to have focus on the active stakeholders. |
| Identify what the customer needs. | To ensure what the customer wants from this project are extremely important. To go through the requirement specification with the customer is important, to understand the customer needs.<br>Here it is important to identify the priority on requirements given. |
| Develop study properties | After identifying what the customer need, different analysis can start. It exists many different tools to best understand what the customer needs. Pugh matrix is one of many good alternatives to make sure that |

| | |
|---|---|
| | requirement specification meets the customers desire. Because SCS are running an analysis and not a product development, they could not use this method. |
| Develop processing properties | When identifying the properties of the product, SCS can start to find out how they can complete the project. Here it is important to make a good plan and find out what kind of tools to use, come up with good answers in the study and meet costumer's requirements. |
| Identify what kind of criteria the stakeholder's sets for the quality in the engineering, project and the study. | Identify the quality standards that are used to decide the quality of the study. TechnipFMC and HSN have different quality standards for the documents that SCS must follow.<br><br>• Documents on English.<br><br>Use of different System engineering tools. |
| Identify the stakeholder's expectation to the project process. | Identify what stakeholders expects beneath this bachelor thesis.<br><br>• Project status every month.<br>• Expects to get the opportunity to confirm before anything important goes online. |

*Table 2: Quality assurance*

# 5. Time Management

## 5.1 Time budget

Basing time budget on the size of the group, and then on how much time each member could put into this project. At the start, SCS based this budgeting on 30 hours a week from Monday to Saturday. Also, SCS need to consider different goals that are needed to be achieved during this project. SCS have three main goals regarding this bachelor project that need to be reached. These three goals are when SCS deliver documentation and have a presentation about the status to this project. This time frame is set by the school. SCS can only influence first and second presentation within a limited time. Third deadline for documentation is determined by the school, and is set to May 24, 2017.

Tracing the hours spent on given tasks are therefore important, so that SCS know what to do, when to do it and to see if SCS will meet the time budget. When SCS established hours per week, they can start to divide them into different tasks in the Gantt chart *(see fig 7)*.

## 5.2 Gantt

Gantt chart is a type of bar chart and illustrates a project schedule *(see fig 7)*. Gantt illustrate the start and finish dates of the task given in the project. It is used as a project tool to keep track of where you are, what to do, and when to do it in the project. SCS decided the unified process as a project model, so SCS put the four steps (phase) into the Gantt and then it's easier to see where SCS are in the development process of the project.

Here is a picture showing some of our Gantt model. SCS use MS Project to make the Gantt chart *(see appendix A for more information).*

| Task Name | Duration | Start | Finish | ID number |
|---|---|---|---|---|
| Unified process | 100,43 days | Mon 09.01.1 | Thu 08.06.17 | |
| Inseption | 17 days | Mon 09.01.1 | Wed 01.02.1 | A |
| Presentation 1 | 4,43 days | Wed 01.02.1 | Mon 06.02.1 | B |
| Elaboration | 20,43 days | Tue 07.02.17 | Wed 08.03.1 | C |
| Iteration 1 | 10,14 days | Tue 07.02.17 | Tue 21.02.17 | C.1 |
| Iteration 2 | 11,29 days | Tue 21.02.17 | Wed 08.03.1 | C.2 |
| Presentation 2 | 3,29 days | Wed 08.03.1 | Fri 10.03.17 | D |
| Execution | 42,14 days | Tue 14.03.17 | Mon 15.05.1 | E |
| Transition | 21,57 days | Fri 21.04.17 | Wed 24.05.1 | F |
| Presentation 3, final | 11,29 days | Wed 24.05.1 | Thu 08.06.17 | G |

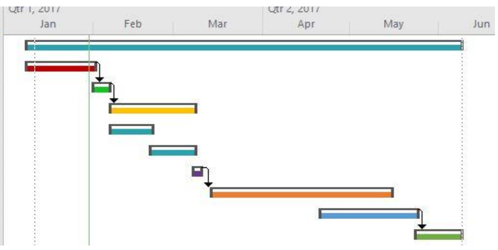



*Figure 7: Gantt chart*

# 5.3 Time tracing

## 5.3.1 Group Time Tracing

SCS time tracing is done in an excel sheet *(see table 3)*. All four group members update this sheet every week, with their total hours of work done this week. The reason why SCS have this, is to trace and have overall control over hours spent on the project.

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Dato: | Bjørn Rossavik | Erlend Berg-Olsen | Asjørn Antonsen | Espen Hansen | | | Navn: | Bjørn | Erlend | Asbjørn | Espen |
| 2 | Uke 2 | 20 | 19 | 18 | 17 | | | Total timer: | 50 | 50 | 50 | 50 |
| 3 | Uke 3 | 30 | 31 | 32 | 33 | | | | | | | |

*Table 3: Group time tracing*

## 5.3.2 Personal Time Tracing

For documentational purposes, SCS list up every hour in an excel document *(see table 4)*, which consist of week number, day, activity number, time spent each day and in what activity.

| Timeliste for: | Asbjørn Antonsen | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Uke nr: | 2 | | | | | | | |
| **Aktivitet** | **Mandag** | **Tirsdag** | **Onsdag** | **Torsdag** | **Fredag** | **Lørdag** | **Søndag** | **Sum.Total** |
| A | | 4 | | | | | | 4 |
| A.1 | 2 | | | | | | | 2 |
| A.1.1 | 0.5 | | | | | | | 0.5 |
| A.1.2 | 0.5 | | | | | | | 0.5 |
| A1.3 | 1 | | | | | | | 1 |
| A.1.4 | 1 | 1 | | | | | | 2 |
| A.2 | | | | | 7 | | | 7 |
| A.2.1 | | 2 | 5 | | | | | 7 |
| A2.2 | | | 2 | 7 | | | | 9 |
| Sum per dag | 5 | 7 | 7 | 7 | 7 | 0 | 0 | 33 |

*Table 4: Personal time tracing*

### 5.3.3 Activity number

A simple table that shows the different activities with associated activity number, that SCS will use to bill the hours spent during this project *(see table 5).*

Example of activity list:

| Task Name | ID number |
|---|---|
| **Inception** | **A** |
| Planning | A.1 |
| Project research | A.1.1 |
| Make standard documents and file structure | A.1.2 |
| Group structure | A.1.3 |
| Set up meeting with internal and external sensors | A.1.4 |
| Research former bachelor thesis | A.1.5 |
| Documentation | A.2 |
| Project model | A.2.1 |
| Project plan | A.2.2 |
| Quality management | A.2.3 |
| *Web page* | A.2.4 |

*Table 5: Example of activity and activity number*

# 6. Risk management

Risk management is an organized, systematic risk-informed decision-making discipline that proactively identifies, analyses, plans, tracks, controls, communicates, documents, and manages risk to increase the likelihood of achieving project goals.

## 6.1 Risk analysis

The risk analysis is important in the initial phase of the project. The analysis operates as a tool to increase the project's ability to reach specified goals.

Every project contains different forms of risks. To identify the risk at an early point, SCS have created a plan about how they shall handle the danger and how SCS can accept, control or avoid them totally. This is how SCS hope to deliver good service and achieve the project goals without any form of problems.

.

Risk Analysis:

- The process of identifying, assessing, and reducing risks to an acceptable level.
  - Defines and controls threats and vulnerabilities.
  - Implements risk reduction measures.

- An analytic discipline with three parts.
  - Risk assessment: determine what the risks are.
  - Risk management: evaluating alternatives for reducing the risk.
  - Risk communication: presenting this material in an understandable way to decision makers and/or the public.

# 6.2 Risk categories

## 6.2.1 Risk: Administration (1).

- Loss in communication between the group and stakeholder could lead to misunderstandings.
- Delays.
- External conflicts.
- Not following documentation templates.
- Poor time tracking.

*(See table 10).*

## 6.2.2 Risk: The Group (2).

- Diseases/sickness who lead to reducing in the work capacity.
- One of the members quit during the project.
- A member of the group gets too much work. This can have negative consequences related to estimated time and quality on the work.
- Internal conflicts lead to bad communication, discontent and can further on lead to bad productivity.
- Low knowledge about project planning.

*(See table 11).*

## 6.2.3 Risk: Technical and professional (3).

- Lower knowledge about the task and other expertise.
- Not meeting the requirements.
- Hardware and software problems.

*(See table 12).*

## 6.2.4 Risk: Theoretical tasks (4).

May include:

- Wrong formulas.
- Wrong calculations.
- Not finding correct values and answers.
- Did not identify all variables.
- Not finding correct formulas and information in ISO and DNV standards.
- Low knowledge about bolts, studs, nuts, washers, coatings etc.

  *(See table 13).*

## 6.2.5 Risk: Practical tests (5).

May Include:

- Calculations done in the theoretical part is not usable.
- Software complications in Solid Works and FEM.
- Low knowledge about Solid Works and FEM.
- 3-D drawings from TechnipFMC in ABACUS is not compatible in Solid Works.
- Analysis is not compatible.

  *(See table 14).*

## 6.2.6 Risk: Mechanical tests (6).

May include:

- Not finding a place to do tests (workshop).
- Wrong tools.
- Wrong size on studs, nuts, washers, material etc. Not relevant for use in small-scale testing.
- Not finding correct and relevant coating and grease.
- Theoretical calculations done is not usable for further mechanical testing.
- HSE (Health, safety and environment).

  *(See table 15).*

## 6.3 SCS risk analysis

To describe and calculate risks, SCS have systematically created a risk analysis. The analyse is a survey over non-expected causes and the following consequences this may occur. SCS consider risks as a possibility for something non-expected to happen and the consequences this has for (not only the project), but also for the crew and their values.

The analyse not only deal with big accidents, but also cooperation issues, technical problems, internal problems, etc.

In this risk analysis, SCS ask the group four questions and reflects about this when questions in the project emerge.

1. What can simply go wrong?
2. What is the probability for this to happen?
3. What is the consciences?
4. What can be done to reduce the consequences if something goes wrong or make sure this doesn't happen at all.

**PS!**

**Prioritize which risks who need to be addressed first, focus on the use of resources!**

**Use the numbers in the matrix to quantify the risk.**

The risk can be calculated out from this formula:

**Risk = Risk-Impact x Risk-Probability** *(see table 8).*

- Definition of Risk-Impact *(see table 6).*
- Definition of Risk-Probability *(see table 7).*

| Definition of Risk-impact | | |
|---|---|---|
| Impact-level | Frequency | Event interval |
| 1 | Negligible | Happens very rare. |
| 2 | Moderate | Happens rare. |
| 3 | Critical | Happens sometimes. |
| 4 | Catastrophic | Happens often. |

*Table 6: Definition of Risk-impact*

| Definition of Risk-probability | | | |
|---|---|---|---|
| Prob.-level | Value | Criteria | Outcome |
| 1 | Improbable | Not much chance this will become a problem. | The project goes on |
| 2 | Unlikely | Risks like this may turn into a problem once in a while. | The project goes on, but may be delayed. |
| 3 | Likely | There is an even chance this may turn into a problem. | The project stagnates. The group should do measurements. |
| 4 | Very likely | High chance of this becoming a problem. | The project stops. Critical solutions. |
| 5 | Near certainty | Everything points to this becoming a problem. | Catastrophic. Every measure to save the project. |

*Table 7: Definition of Risk-probability*

# 6.4 Risk: responsibility

For having a good plan about risk solving in our project, SCS are going to categorize them. This gives a systematic overview about different risks and how SCS should handle them correctly.

| Responsibility | |
|---|---|
| Accept | The group know the risk, but choose not to introduce measures. |
| Avoid | The group avoid the risk and choose to change the requirements specification, or impose more restrictions. |
| Control | The group control the risk to reduce the consequences. |
| Look over | The group know the risk and choose to have a constant look over. |

*Table 8: Responsibility*

| Risk = Risk-impact x Risk-Probability | | | | | | |
|---|---|---|---|---|---|---|
| Risk-impact | 4 | 4 | 8 | 12 | 16 | 20 |
| | 3 | 3 | 6 | 9 | 12 | 15 |
| | 2 | 2 | 4 | 6 | 8 | 10 |
| | 1 | 1 | 2 | 3 | 4 | 5 |
| | | 1 | 2 | 3 | 4 | 5 |
| | Risk-Probability | | | | | |

*Table 9: Risk-Impact x Risk-Probability*

This document contains a risk analysis, as well as a guide for how the risk can be solved.

| Risk (1) | Probability | Impact | Ranking | Measures |
|---|---|---|---|---|
| **Administration** | | | | |
| (1.1): Loss in communication between the bachelor group, the school and stakeholder. | 2 | 4 | 8 | Control: Regular meetings. |
| (1.2): External conflicts. | 2 | 3 | 6 | Control: Good communication and factual discussions. |
| (1.3): Delays(stakeholder/group). | 3 | 3 | 9 | Accept: Look over the time-schedule. Stocking the work plan or compute to work overtime. |
| (1.4): Not following documentation templates. | 2 | 2 | 4 | Control: Must be controlled before its uploaded by other members. |
| (1.5): Poor time tracking. | 3 | 3 | 9 | Control: Must be verified and uploaded every week. |

*Table 10: Risk: Administration*

| Risk (2) | Probability | Impact | Ranking | Measures |
|---|---|---|---|---|
| **Group** | | | | |
| (2.1): Diseases/sickness (short period). | 2 | 3 | 6 | Accept: |
| (2.2): One of the members quit the during the project. | 1 | 4 | 4 | Accept: The other group members must increase their work capacity. |
| (2.3): Internal problems and conflicts. | 3 | 3 | 9 | Avoid: Good communication. Act professional and substantive. Discuss and solve the problem at an early stage before it escalates. |
| (2.4): Poor work distribution. | 3 | 2 | 6 | Control: Daily meetings and work distribution. Every group member shall write their own time and task schedule. |
| (2.5): Low knowledge about project planning. | 4 | 4 | 16 | Look over: Have a plan to handle changes and challenges. Asking our supervisor if necessary. |

*Table 11: Risk: The Group*

| Risk (3) | Probability | Impact | Ranking | Measures |
|---|---|---|---|---|
| **Technical and professional** | | | | |
| (3.1): Lower knowledge about the task and other expertise. | 3 | 3 | 9 | Control: The group must use more time to understand the task and find information. |
| (3.2): Hardware and software problems. | 3 | 3 | 9 | Control: Find other alternatives, platforms. Always download files to external hard drive. |
| (3.3): Not meeting the requirement. | 2 | 3 | 6 | Avoid: Good communication with our stakeholder. A good requirement and test plan should have been created. |

*Table 12: Risk: Technical and Professional*

| Risk (4) | Probability | Impact | Ranking | Measures |
|---|---|---|---|---|
| **Theoretical tasks** | | | | |
| (4.1): Wrong formulas. | 2 | 4 | 8 | Control: Finding new sources. Ask teachers, TechnipFMC, others who may have more knowledge and information than us. |
| (4.2): Wrong calculations. | 2 | 4 | 8 | Control: Finding new sources. Ask teachers, TechnipFMC, others who may have more knowledge and information than us. |
| (4.3): Not finding the correct values and answers. | 3 | 4 | 12 | Control: Finding new sources. Ask teachers, TechnipFMC, others who may have more knowledge and information than us. |
| (4.4): Did not identify all variables on stud/nut/connection. | 3 | 3 | 9 | Look over: Do a new analyse. Use other sources. |
| (4.5): Not finding correct formulas and information in ISO and DNV standards. | 2 | 3 | 6 | Control: Finding new sources. Ask teachers, TechnipFMC, others who may have more knowledge and information than us. |

| | | | | |
|---|---|---|---|---|
| (4.6): Low knowledge about bolts, studs, nuts, washers, coatings etc. | 2 | 4 | 8 | Avoid: Each group member must ensure to update their skills. |

*Table 13: Theoretical tasks*

| Risk (5) | Probability | Impact | Ranking | Measures |
|---|---|---|---|---|
| **Practical tests** | | | | |
| (5.1): Calculations done in the theoretical part is not usable. | 2 | 4 | 8 | Look over: Go back to the relevant task. Checking formulas.<br>The group should do new calculations. |
| (5.2): Software complications in Solid Works and FEM. | 2 | 2 | 4 | Avoid: Use computers who have the newest updates and software. |
| (5.3): Low knowledge about SW and FEM. | 1 | 4 | 4 | Avoid: Each group member must ensure to update their skills. |
| (5.4): 3-D drawings from TechnipFMC in ABACUS is not compatible in Solid Works. | 2 | 4 | 8 | Control: This have to be controlled at an early stage in the testing phase.<br>SCS must make new drawings in Solid Works if the file transferring is not working.<br>This may take some time and shall be considered. |
| (5.5): Analysis done by SCS and TechnipFMC is not compatible. | 2 | 4 | 8 | Look over: Checking calculations. Do we have the same formulas? Are we doing the same calculations? Different mate? |

*Table 14: Practical tests*

| Risk (6) | Probability | Impact | Ranking | Measures |
|---|---|---|---|---|
| **Mechanical tests** | | | | |
| (6.1): Not finding a place to do tests (Workshop). | 1 | 4 | 4 | Avoid: Several alternatives. Backup.<br>- HSN.<br>- TechnipFMC. |
| (6.2): Wrong tools (Torque tools, vise, etc.) | 2 | 4 | 8 | Control: Using tools that fits the task. All torque tools shall be calibrated. |
| (6.3): Wrong size on studs, nuts, washers, etc. Not relevant for use in small-scale testing. | 4 | 4 | 16 | Control: Use materials that fits the test. Asking TechnipFMC for materials. |
| (6.4): Not finding correct and relevant coating and grease. | 3 | 4 | 12 | Control: Asking TechnipFMC. |
| (6.5): Theoretical calculations done is not usable for further mechanical testing. | 3 | 4 | 12 | Look over: Checking formulas.<br>The group should do new calculations. |
| (6.6): Not focus on safety during tests. HSE (Health, safety and environment). | 2 | 4 | 8 | Control: Using the SCS safety procedure for mechanical testing. |

*Table 15: Mechanical tests*

| Risk (7) | Probability | Impact | Ranking | Responsibility |
|---|---|---|---|---|
| **Elaboration Phase** | | | | |
| (7.1): Changes in tasks from TechnipFMC. | 3 | 5 | 15 | Control: Documents must be updated and extra time is to be sacrificed. |
| (7.2): Did not complete the iteration. | 3 | 3 | 9 | Control: The unsolved problem in the current iteration may be transferred over in the new iteration phase. The group may sacrifice some extra time. |
| (7.3): Did not finished the elaboration phase in estimated time. | 2 | 5 | 10 | Control: This is not optimal for the second hand in, but an explanation must be made and be a part of the elaboration phase document. |

*Table 16: Elaboration phase.*

# 7. Project management

To get a good work structure and organization for this project, SCS have chosen to use a project management tool known from systems engineering.

Unified process is a system engineering tool to clearly define a project. Unified process defines the project life-cycle, and uses an iterative and incremental method through four main phases in this project life-cycle. By using such a project management tool, SCS can develop the project from an idea to a finished study of this given task.

Focusing on the customer's needs, concerns and wanted functionality early in the development phase, SCS can write requirement specifications based on this knowledge. It is important to base evaluations on the overall aspect for this project, and this is controlled considering it shall reflect what the customer indeed want.

SCS will use this system engineering process through this project. This will help to evaluate each discipline as the complexity increases, assuring the quality of the project and the product.

## 7.1 Main four phases of the model

The model is divided into four phases, and in every phase SCS will go through and manage nine disciplines *(See fig 8).*

This is an estimate of time that SCS will use on each discipline in the different phases and iterations.

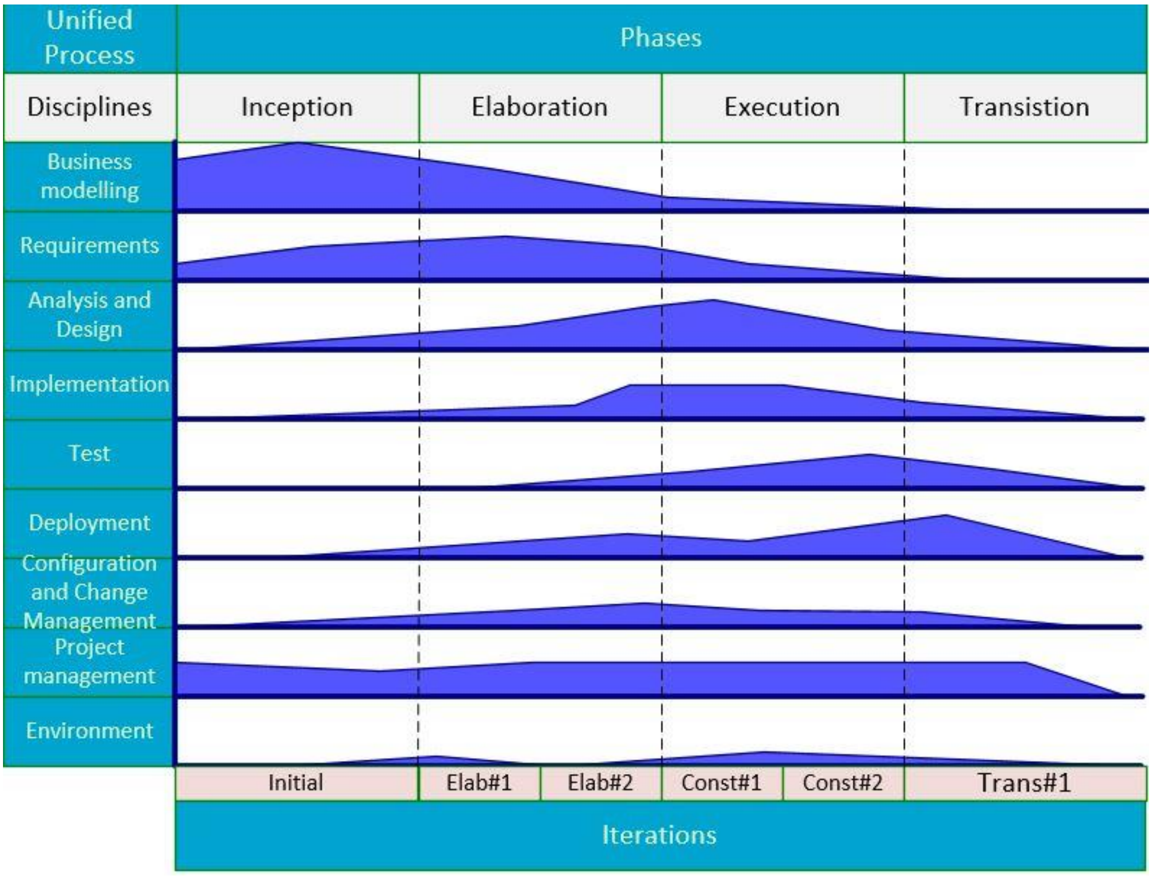



*Figure 8: Unified Process*

### 7.1.1 Inception phase

Inception is the first phase in this project model. This is where SCS will make a project plan for the whole project life-cycle, define the scope of the project, customer needs, requirements and expectation's. This is a quality measure to assure that SCS will deliver what the customer wants. Cost and risk are also defined in this phase.

This phase has an incremental approach. SCS will go from scope and planning phase to customer needs. This is to clearly define and understand what the customer want SCS to produce. By starting with the end in mind, it is easier to break it down into more specifics. This is the shortest phase, but the foundation in the project. This phase is only done once, but SCS will go through the nine disciplines as they start planning the iterations in the elaboration phase.

Understanding the customer is essential to reach the goals SCS set for this project. The more knowledge SCS get, the better chance they have to succeed.

### 7.1.2 Elaboration:

In Elaboration phase, SCS start to work more specific on the task, and this is done through iterations. SCS start by evaluating what they already have done with a critical eye to spot any problem. By using this method, SCS will eventually get a better understanding of the problems at hand, get into more detail about the problems and possible solutions.
In this phase, SCS will have two iterations, and SCS start this phase by planning the whole elaboration phase, before planning the first elaboration iteration. This phase is based on the information that SCS have obtained in the inception phase. Inception phase gives SCS a foundation, and now it is time to take a step further.

For SCS, this means to get deeper into the different requirements from TechnipFMC and test requirements from SCS. SCS do their best to get all requirement stated the best way, make sure their all relevant and described as detailed as possible.

One of the main goal for us at SCS in this elaboration phase has been to get control over different risks that can emerge. SCS must do their best to determine risks that can come up, and have a plan if they emerge. During these two iteration's they also need to plan the test's and analysis that need to be done in more specifics.

### 7.1.3 Execution

Through iterations in the elaboration phase, SCS have obtained more information and are prepared for execution. SCS have chosen to call this 3`th phase for execution (normally called Construction). Since this bachelor thesis is a study of an existing product, SCS feel that execution is more precise than construction.

Execution is the largest phase of all 4. This is where all the analyses and tests are being done. After inception phase and elaboration phase, SCS should be well prepared for Execution phase.

First SCS run an iteration with small scale analyses, and find the variables that are needed for larger analysis.

In the second iteration SCS will do more big scale analyses. Analyse example can be an analyse with stud and SL combined.

### 7.1.4 Transition

Now SCS are mostly done with the analyses and testing phase in this project and need to present them to our customer and HSN. SCS will publish a final document that contains all documents produced in the entire project, and SCS will have two final presentations, one at HSN and one at TechnipFMC.

This is where SCS publish their findings from this study, and come with recommendations regarding to changes in procedures and design that might need to be done.

# 7.2 Disciplines of this model

## 7.2.1 Business modelling

The understanding of the organization, process and tasks is important, and that is what this discipline focuses on. SCS need to get a good understanding of the customer's structure and practice to conduct this analysis within their standards, since SCS are conducting an analysis based on their need.

SCS also need to understand and have a structure on their own. Making templates, standards, how SCS are working as a group, etc.

## 7.2.2 Requirements

This is a very important and crucial discipline. A project depends on and always need to follow requirements. Requirements are agreed on between TechnipFMC and SCS.
SCS have made test requirements, to fulfil and complete requirements given from TechnipFMC.

This discipline keeps the group on track regarding to requirements, and leads the way.

## 7.2.3 Deployment

Final product in mind. SCS are focused on the final product and want to satisfy TechnipFMC. From the beginning SCS got the result in their mind and think about what the final result should contain. As the project goes on, this become more and more important.

In the transition phase, deployment take a lot of time. This keeps the main focus on the final result.

## 7.2.4 Configuration and change management

Challenges and problems will occur, and then SCS must be open for changes and configuration.

This is the discipline for surveillance regarding to if changes are needed. Also, if SCS need to do some configuration to keep the project on track.

## 7.2.5 Project management

Project management have focus on project structure and administration work.

For SCS this discipline will make sure that our group keeps on track with regarding to management inside and outside the group.

Project timeline and planning is up to speed.

Planning the different iteration and keeping this on track.

Administrate risk inside the project and project group.

## 7.2.6 Analyse & Design

This is the phase where SCS do the work needed in form of analysis and design studies such as:

- Product analysing.
- Theory (difference between bolt and stud).
- Analysing tests and results.
- Design analysing of bolt, stud, etc.
- Is there any reason for design changes?
- MATLAB.
- FEM-analysis.
- Solidworks.

## 7.2.7 Implementation

In this part, SCS are going to implement changes that have occurred through running tests and analysis. Implement any improvements in design, calculations, dimensions or material. The iteration phases will be a good help for SCS in this part. This shall also include new requirements / test requirements that may occur.

## 7.2.8 Testing

The testing discipline is where SCS test the requirement specification through different test-procedures. This is where they verify and identify different errors through testing, and find the correct values needed to complete the requirements.

- FEM-analysis.
- Calculations.
- Mechanical testing.
- Material testing.
- Lab.
- Workshop.

## 7.2.9 Environment

Here SCS will have focus on different activities which is important for our development.
To execute the analyse, SCS need to define where they can do testing and analysis.
Make an equipment list if the project needs new equipment for testing or analysing.

# 8. Final report

The inception phase was a successful phase. This phase lay down the foundation for the whole project. Templates, working structure, project model etc. has been established.

This was the first phase, and start up for SCS as a bachelor group. The group members worked good together, and came to an agreement on how this project shall be.

There have been meetings with TechnipFMC, regarding project requirements. These meetings went well, and both parts agreed. TechnipFMC is a solid and great employer, and SCS are really looking forward to work together with this company.

From the requirements, different tasks and tests were made. These tasks and tests are made to solve the requirements TechnipFMC have.

*For example*: TechnipFMC want to find the optimal torque value on stud. SCS have made a theoretical test where they calculate an answer. But do verify the answer, a mechanical test will be performed, with the calculated answer. This will give the best results.

Foundation for next phase is in place, and SCS are well prepared for the Elaboration phase.

# The Elaboration phase

| | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 2.0 |
| | |
| **SCS**<br>**Group members** | Asbjørn Antonsen,<br>Project leader and construction<br>Initial: AA |
| | Bjørn Ledaal Rossavik,<br>Qualification and specification<br>Initial: BR |
| | Erlend Berg-Olsen,<br>System Engineer and Project planner<br>Initial: EBO |
| | Espen Hansen,<br>Test and Verification<br>Initial: EH |
| | |

Høgskolen i Sørøst-Norge

# Summary


This document contains the second phase in SCS`s project. The elaboration phase.

This is a phase were SCS are going deeper into technical planning. Inception phase with planning of group structure, templates and overview of the project are now over.

In this phase, there will be more focus on technical procedures and how to complete tasks and tests from TechnipFMC. The elaboration phase has 4 iteration.

SCS have made 5 new documents in this phase:

- Project specification.
- Task and test specification.
- Theoretical task document.
- Practical test document.
- Mechanical test procedure document.

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 10.02.2017 | 5 | BR | Created document and filled in information regarding to elaboration etc. |
| V.0.2 | 21.02.2017 | 14 | SCS | Iteration 1 and Iteration 2. |
| V.0.3 | 22.02.2017 | 14 | EH | Updated information. |
| V.0.4 | 23.02.2017 | 16 | EBO | Updated information, added iteration 1 |
| V.0.5 | 08.03.2017 | 17 | AA | Updated abbreviation and technical words |
| V.0.6 | 17.03.2017 | 22 | AA, EH, BR, EBO. | Updated iteration 4. |
| V.0.7 | 18.03.2017 | 24 | AA, EH | Document review. |
| V.0.7.1 | 18.03.2017 | 26 | AA, BR, EBO. | Small changes in document template |
| V.0.7.2 | 18.03.2017 | 28 | AA, EBO, BR. | Updated info in iteration 1. Added summary and deviations in alliteration reports. |
| V.0.7.3 | 19.03.2017 | 29 | BR | Updated information in chapter 2 and 3. Updated and spellchecked iteration 1 and 2.<br>Added chapter 4 and sub chapters.<br>Added chapter 5 with information. |
| V.0.7.4 | 19.03.2017 | 31 | AA. | Updated summary and deviation in iteration 3 and 4. |
| V.0.8 | 20.03.2017 | 31 | AA | Added figure and table contents list. |
| V.0.9 | 20.03.2017 | 31 | BR | Spellcheck and small changes in iteration 3 and 4. |
| V.1.0 | 20.03.2017 | 32 | SCS | Final document. |
| V.1.1 | 04.05.2017 | 33 | BR | Added summary and orthography. |
| V.1.2 | 17.05.2017 | 33 | EH | Orthography. Changed name from TS to TT. |
| V.2.0 | 24.05.2017 | 34 | SCS | Ready for last hand in. |

# References

[Ref.1] **BS EN ISO 13628-7:2006** Petroleum and natural gas industries — Design and operation of subsea production systems — Part 7: Completion/workover riser systems.

[Ref.2] **DNV-RP-C203** FATIGUE DESIGN OF OFFSHORE STEEL STRUCTURES AUGUST 2005

[Ref.3] **DOC No: RPT60020900** REPORT, STRUCTURAL ANALYSIS, SPEEDLOC-II 222 CLAMP CONNECTOR

# Abbreviations and technical words

| Abbreviation | Explanation |
|---|---|
| WOR | Workover Riser |
| SL | Speedloc |
| ISO | International Standardization organization |
| DNV | Det Norske Veritas |
| UP | Unified process |
| SCS | Subsea Connection System |
| HSN | Høgskolen i Sør-Øst Norge |

| Technical Words | Explanation |
|---|---|
| Yield strength | Yield strength is the material property defined as the stress at which a material begins to deform plastically. Prior to yield point the material will deform elastically and return to its original shape when applied stress is removed. |
| Tensile strength | Measurement of the force required to pull the material to the point where it breaks, Tensile strength is the maximum amount of tensile stress it can take before it breaks. |
| Friction | The force resisting the relative motion of solid surfaces, fluid layers and material elements sliding against each other. There are several types of friction. |
| Stud | Threaded rod similar to a bolt but it has no bolt head. |
| Nut | Is fastener with a threaded hole. |
| STP | STP is a file extension for a 3-D graphic files. |

# Contents

# Tables



# Figures

# 1. Introduction

In this second phase of the project, SCS are going from the inception phase and into the elaboration phase.

From the Inception phase, SCS take the project a step further in the elaboration phase. Inception phase have given SCS a good and solid fundament for further project work, such as: templates, standards, project model, group structure, Gantt chart, task and test specification, etc.
Now it is time for more focus on the technical perspective regarding to SCS bachelor project.

In elaboration phase, SCS will have focus on analyses, tasks, tests and preparation for the execution phase.

# 2. Focus in elaboration phase

In this project, SCS considered several project models but ended up with Unified process. After some discussion, SCS decided that in this phase of the project it is important to have several iterations. This is because SCS want to have a good overview and control over the whole phase. Previously SCS had decided to have two iterations, but now the elaboration phase is divided into four different iteration phases. The iterations can be seen below:

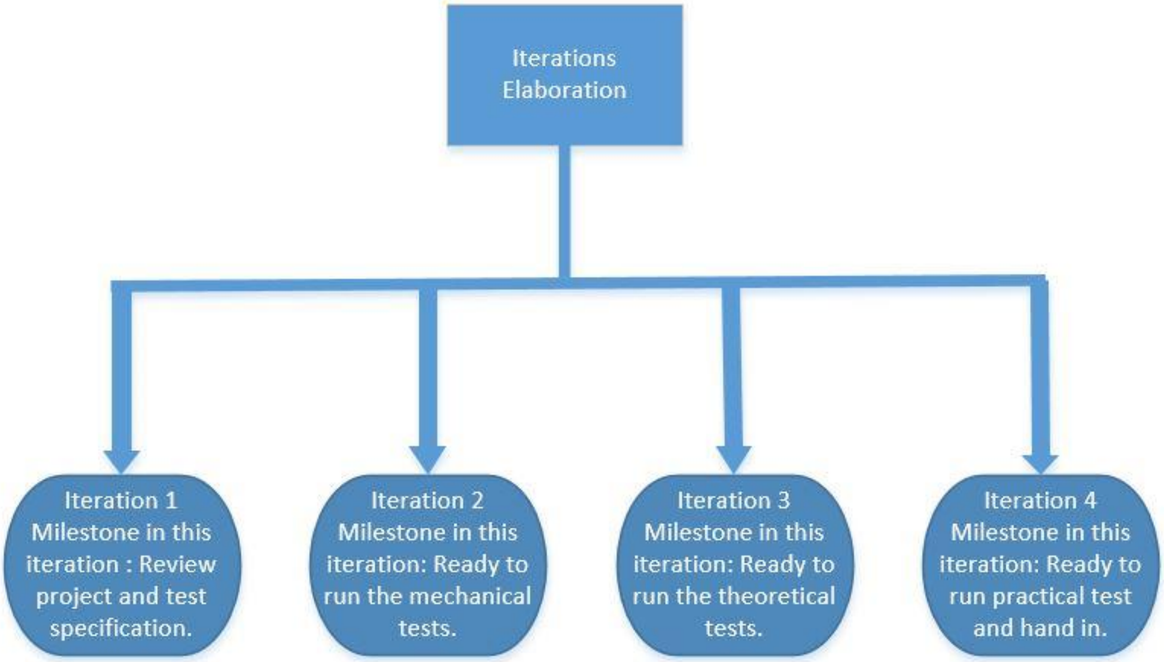



*Figure 1: Iteration Phases*

The elaboration phase has a high focus on the technical perspective in the project and is considered to be the foundation for the next phase, the execution phase.

As mentioned earlier in the introduction, SCS will have focus on different analyzes, tasks and tests preparation for the execution phase. SCS are building the foundation for the execution phase, and therefor risk analyzes are an important part. This is to prepare the project on things that can go wrong in the project. SCS are getting more technical information and are getting deeper into the main tasks given by TechnipFMC. Before SCS start the testing, a narrow risk investigation can help SCS to control the project in the best possible way.

# 3. Risk analyze for Elaboration Phase

## 3.1 Risk (7)

| Risk (7) | Probability | Impact | Ranking | Responsibility |
|---|---|---|---|---|
| **Elaboration Phase** | | | | |
| (7.1): Changes in tasks from TechnipFMC. | 3 | 5 | 15 | Control: Documents must be updated and extra time is to be sacrificed. |
| (7.2): Did not complete the iteration. | 3 | 3 | 9 | Control: The unsolved problem in the current iteration may be transferred over in the new iteration phase. The group may sacrifice some extra time. |
| (7.3): Did not finished the elaboration phase in estimated time. | 2 | 5 | 10 | Control: This is not optimal for the second hand in, but an explanation must be made and be a part of the elaboration phase document. |

*Table 1: Risk elaboration phase*

# 4. Main goals and iterations

Through the different iterations, SCS are working against a milestone for each iteration and trying to make the appropriate adjustments, so that SCS meet deadlines in time. When starting up a new iteration, SCS are going to make a specific plan for the iteration, and set an end milestone. In this way, all participant in SCS are working against the same end goal.

The Project specification document shall be as precise as possible. Tasks, analyses, test and other changes can come later in the project. SCS aim to get this as detailed and precise as possible. All tasks and tests shall be ready and well described.

SCS have 4 iterations in this phase:

**1 iteration:**

After SCS first presentation (1 of 3), there were some changes that needed to be done.

The tasks needed to be divided and some tasks needed to be changed.

Complete Project specification document. This document contains tasks, tests and analyses that need to be done in this project.

Complete test specification document.

**2 iteration:** Make a mechanical test procedure document. This includes finding a location, equipment needed for testing, materials to use in testing and the procedure for performance. SCS will also make a budget.

**3 iteration:** Make a theoretical task document, this include finding formulas to use under calculation.

**4 iteration:** Make a practical test document and completion of all documentation for elaboration phase.

# 5. Iterations

## 5.1 Iteration 1

First iteration goes from 07.02.2017 to 21.02.2017.

### 5.1.1 Iteration 1: Plan

**What:**

SCS main goal for this iteration is to go through project requirement and test requirement to change it into a more suitable matter.

Confirm and verify priority on requirements together with TechnipFMC.

**How:**

**Change the name of the project requirement to a more suitable matter**

In this bachelor thesis, SCS started to work out from a template given by HSN. This template is for a bachelor thesis that develops a product or equipment. Since SCS are going to make an analyze report and not develop a new product, this template is not suitable for this project.

**Go through the priority of our requirements**

Have a sit down with customer TechnipFMC, and go through every requirement.

This is a crucial phase in the project. This is where SCS are going to plan execution phase. They need to get as much as possible ready in this phase. Requirements is what SCS are working for, so this need to be as correct as possible. Requirements are given from TechnipFMC, and it is up to SCS to discuss if the requirement are achievable. SCS also need to have the priority correct. Which requirements are more important than others for TechnipFMC to finish. SCS are fully aware of that things can change, but their goal is to get it as correct and precise as possible.

**Change the name of the test requirements to a more suitable matter**

In first edition of the test requirement, SCS started to set up a template intended for a bachelor thesis which is going to develop a product or equipment. Since SCS are going to make an analyze report, this project and test requirements is more of a list of works demands, and not requirements. SCS must change the name of the test document to a more suitable matter.

**Review and correct the test document**

Read through the test document and review the content. Update document with more information. SCS completed the test document in inception phase as best as possible. In Elaboration phase, SCS have more information to make a better and more precise test document.

**Why**

SCS must make a good foundation for further project work. This will help to perform all tests for the analyze in the execution phase. With a good project and test specification, it will be easier to read, understand and perform.

### 5.1.2 Main goals

- Change the name on the project requirement document to a more suitable matter.
- Go through the priority of our requirements.
- Change the name of the test requirements to a more suitable matter.
- Divide tests into different suitable categories.

## 5.1.3 Iteration 1: Report

Changed the names “Project requirements” and “Test requirements”.

The new names are now “Project Specification” and “Task and Test Specification”.

**Project Specification document** has been updated according to name changes. Also, every task (task is the new name for requirements) was review together with TechnipFMC. Name changes of tasks was done, priority was reorganized and some task was removed. After this review, SCS are satisfied with the Project Specification and the tasks.

**Task and Test Specification document** has been updated according to name changes. SCS have now divided all tasks and tests into three different documents. In Task and Test Specification document, SCS explain all tasks and how they want to execute. Here is a list of every task and test that SCS want to complete in this bachelor thesis. It also includes a risk calculation on risk that may occur.

**Divided tests into different suitable categories**

SCS have divided tasks and tests into three different categories:

- Theoretical - The tasks that can be calculate by formulas on paper.
- Practical - The tests SCS can design and calculate by FEM – analysis in Solid works.
- Mechanical - Mechanical test in a workshop or laboratories, to check if the theoretical and/or practical calculations are correct in real life.

SCS feels that this gives a better overview over this project, and that the project is easier to control this way.

**Summary and Deviations:**

The challenge in this iteration was to divide and split tasks and tests into different categories.

SCS concluded that this project was not a standard bachelor thesis and some changes had to be done. The requirement document from the inception phase was not a good match for this project, so the group in cooperation with the customer decided to change requirements to tasks, and the new name of the requirement document is now Project Specification.

The focus in this bachelor project is to do analyze and run tests, so the work with creating a good task and test document is very important.

## 5.2 Iteration 2

This iteration goes from: 22.02.2017-03.03.2017.

### 5.2.1 Iteration 2: Plan

**What:**

Make a mechanical test procedure document. This include finding a location, equipment needed for testing and materials to use in testing. SCS must set up a budget.

**Create mechanical test procedure document.**

**Why:**

| **Mechanical tests** | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Date** |
| - TT-1-2A-M | Do a tensile strength test of the material used in stud. | A | TechnipFMC | 31/1 |
| - TT-1-2B-M | Test recommended pretension on nut including range. | A | TechnipFMC | 31/1 |
| - TT-2-1A-M | Investigate torque, fraction and elongation in bolt vs stud/nut. | C | TechnipFMC | 31/1 |
| - TT-2-1B-M | Investigate fraction in bolt vs stud/nut. | C | TechnipFMC | 31/1 |
| - TT-3-2-M | Do a mechanical test based on the variables affecting preload on stud and nut. | B | TechnipFMC | 31/1 |

*Table 2: Mechanical tests*

The mechanical test document shall be a guideline for mechanical testing. When SCS enters the execution phase and are going to perform mechanical testing, the test participants should use the test document as a guideline. This is where SCS can find necessary information about the test procedure.

Mechanical testing is a real-life test to verify calculations in the theoretical tasks and to see if assumptions that are made are correct. Real-life mechanical tests give another dimension to the results. Variables that may have been forgotten or left out will come up.

**How:**

Based on mechanical test list *(see table 2 Mechanical tests)* SCS will make a mechanical test procedure document. SCS may not use the real segment clamp connection, because this will be difficult to achieve, so a simulated hub may be created.

All mechanical tests shall have a good plan about how to perform them, and this will require research in material technology science and other subjects.

**Material selection.**

**Why:**

Material used is very important. If SCS fail at this point, it can end up with tests that gives wrong values to the analyses. Some questions need to be answered:

- What type of material shall be used?
- Is the material property important in the test?
- Can SCS get the material they need in the size required?
- How many nuts, studs and bolts are needed?

**How:**

Through material specification from TechnipFMC, SCS will find out what kind of material they use on their studs and nut. From the test procedure, SCS will get a better understanding of what they need.

To get a similar test environment, SCS may need to use the same material as they use in the SL connection. Some of the studs may be used more than once, but it all depends on what kind of tests SCS are going to run.

**Location.**

**Why:**

To perform mechanical tests, SCS need to use a workshop that have the tools and equipment they need:

- All the necessary tools and equipment to perform the test.
- Location close to Kongsberg.

**How:**

Location for mechanical testing shall be found. SCS have several opportunities of potential locations that can be used.

Such as:

- Workshop at HSN.
- Workshop at TechnipFMC.
- Workshop at TI Industrier Hønefoss.

To find the best location SCS need to check the availability and capacities. Eventually check other alternatives.

**Tools.**

**Why:**

From mechanical test procedure document, SCS need to find out what kind of tools that are needed to perform the mechanical tests. It is important that the equipment SCS use is calibrated, because of the traceability and the accuracy.

**How:**

Tools that SCS may need:

- Torque tool.
- Measuring device for elongation in studs/bolts.
- Measuring device for strain in bolt.
- Loadcell for measuring loads.
- Material property testing machine such as a UTS testing device.

**Budget.**

**Why:**

In the start-up of this bachelor project SCS asked TechnipFMC about how much they were willing to spend on this project. No clear answer was given, but they said that SCS needed to make a suggestion on how much it will cost to perform the main tasks.

**How:**

Based on the lists of necessary materials and tools, SCS need to create a budget to manage the finances. The budget shall include every material with specification, shop and prices.

The finished budget shall be delivered to TechnipFMC and must be approved by them. SCS will also perform theoretical tasks and practical tests, but these will not cost anything, since TechnipFMC already have what SCS need for this part of the analyses.

### 5.2.2 Main goals

- Make a mechanical test procedure document.
- Find location for performing tests.
- Find necessary tools, equipment and materials.
- Make a budget which is approved by TechnipFMC.

### 5.2.3 Iteration 2: Report

Main purpose in the second iteration was to complete a mechanical tests procedure document, and be ready to run these tests in the execution phase.

Iteration 2 was an important iteration for SCS. This is where they lay down the fundament for the mechanical tests for execution phase. The more SCS managed to get done in this iteration, the less they need to get prepared for mechanical tests in the next phase.

Main goals in iteration 2 was:

**Make a mechanical test procedure document**.

SCS have made a mechanical test procedure document based on project specifications and last draft of the task and test specification document. The mechanical test document has become a good tool to use when SCS will perform mechanical tests. Every test has been planned in detail and follows the same template.

**Find location for performing our tests.**

After some research, SCS found it best to do all off the mechanical tests in the workshop at HSN Kongsberg. If SCS are going to use the workshop at TechnipFMC, it would be difficulties with safety checks and with safety at their locations, this would only make it difficult for both parts.

SCS found out that HSN workshop have most of the equipment and tools that are needed, and everything that they don't have, can be borrowed from TechnipFMC.

At HSN Kongsberg, SCS can combine working with tasks and tests without any big movement between the locations (Computer-lab, group room, workshop, cafeteria and staff room).

**Find necessary tools and materials.**

**Tools.**

Tools to perform mechanical tests is important to have ready when SCS enter the execution phase, and start doing tests and analysis. The necessary tools needed is specified out from mechanical test procedure document.

Small-scale tests will not consist of advanced tools, and the tools will be available in several stores around Kongsberg, ex. Biltema.

**Material:**

A lot of research went into this category. SCS tried to find out if they could use other materials than was used in the original parts. They decided that in some of the tests they need to use the same material. In other tests, SCS can use different material, if the surface finish is the same.

**Scaling of the tests and parts list**

In every mechanical test, SCS have scaled down the size of the stud from original diameter of 47,625mm, down to 11,91mm. SCS would have a difficult time to do a full size scaled test. To get equipment strong enough for breaking a real size stud at diameter of 47,625 mm demands weary powerful equipment, so the simplest solution was to scale the stud down to a more suitable size.

A lot of research was done to scale down the materials. SCS also talked to a professor in material technology, Mehdi Gebreil Mousavi at HSN, about scaling down materials.

SCS has made a list over all the studs and nuts that are needed to perform the mechanical test *(see table 3 Part list).*

| Part list | | | | | | |
|---|---|---|---|---|---|---|
| Type | Total | With Xylan/PTFE coating | Without coating | Price | Material Spec. | Size |
| Stud | 20 | 8 | 12 | TBA | ASTM A453 GR660D | 1/2 "- 13 UNC L:150mm |
| Nut w.collar | 14 | 8 | 6 | TBA | ASTM A453 GR660D | 1/2"-13 UNC |
| Washer | 10 | 4 | 6 | TBA | ASTM A453 GR660D | di: 13mm do: 30mm t: 2mm |
| Bolt w.collar | 10 | 0 | 10 | TBA | Class 8.8 Medium carbon steel, quenched and tempered | 1/2 "- 13 UNC L:150mm |
| Stud | 10 | 0 | 10 | TBA | Class 8.8 Medium carbon steel, quenched and tempered | 1/2 "- 13 UNC L:150mm |
| Total price | | | | TBA | | |

*Table 3: Part list*

SCS have met some difficulties to order studs and nuts in scaled downed size with the correct coating. The total price is the question. SCS has send out request to different suppliers.

Tinius Olsen H10KL – tension machine:

In one of the mechanical tests, SCS are going to test the tensile strength of the material used in stud. With the machine showed below, SCS can find out where the studs yield strength is, and check if it is up to the standards.


*Figure 2: Tinius Olsen H10KL-Tension machine*

SCS Load Cell:

To simulate the clamp segment sliding on the hubs and making a resistance against the nut, SCS has come up with an idea to perform mechanical tests on a self-made rig system.

The friction that will arise between the clamp segment and the hub will not be included in this test rig, and must be included by the hand calculations.

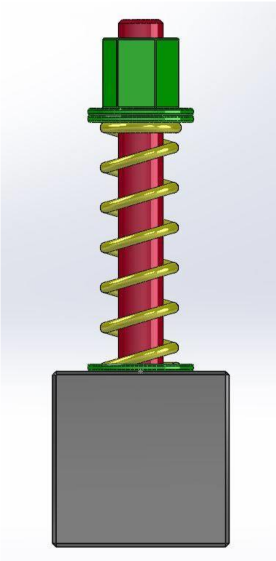


*Figure 3: SCS Load cell*

By calibrating how much the spring will be pressed down at a given pressure you can also use this test rig to control how much pressure that is given to the stud at all time, and it would be possible to measure with simple tools how much the stud will strain.

**Summary and Deviation:**

Currently SCS don't have a budget with prices ready. SCS have met some difficulties to find a supplier who can provide stud and nuts with coating to required specifications. But SCS have control over every part they need, to run all mechanical tests. TechnipFMC did not have what SCS needed in stock. In a worst-case scenario, TechnipFMC can order from their supplier, but this can take a long time and are very expensive.

## 5.3 Iteration 3

This iteration goes from: 06.03.2017-10.03.2017.

### 5.3.1 Iteration 3: Plan

**What:**

In this iteration, SCS need to make and specify a theoretical task document, with formulas and properties to use in the theoretical task document.

From iteration 2 SCS were not able to finish the budget and will continue work with that in this iteration also.

**Specify theoretical test procedure document.**

**Why:**

| **Theoretical tasks** | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Date** |
| - TT-1-1-T | Determine necessary force between hubs by calculation. | A | TechnipFMC | 31/1 |
| - TT-1-2-T | Provide recommended torque on nut including range. | A | TechnipFMC | 31/1 |
| - TT-3-1-T | Identify all variables affecting torque on nut and preload in stud. Make a list. | B | TechnipFMC | 31/1 |
| - TT-3-2-T | Investigate variables affecting torque on nut and preload in stud. | B | TechnipFMC | 31/1 |

*Table 4: Theoretical task list*

In the theoretical part of this study, calculations of different forces acting are a big part.

It is therefore important that the theoretical tasks are easy to follow for anyone with SCS`s level of education.

This is where SCS calculate the necessary forces between hubs, pretension on nut, etc. These results will be used as a reference of what to expect from mechanical and practical test. It will also show what impact the previous assumptions had on the analyze that is already done.

**How:**

SCS do not want to specify tasks to the degree that it is only to insert values and get the answer out of the equation. But more a guideline for what SCS want an answer to. Theoretical tasks will be specified by SCS from theoretical task list *(see table 4 Theoretical tasks).* To do that, they also need to research the analyze document from TechnipFMC (RPT60020900)[1]. Since this analyze follow ISO (13628-7)[2] and DNV (RP-C203)[3], SCS also need to research these documents. A big part of this iteration is to make sure SCS follows these guidelines.

**Find necessary formulas**

**Why:**

Each problem need an individual solution, and it is therefore important that SCS investigate how to solve these problems.

**How:**

From ISO and DNV, SCS must research the formulas and understand them, because they are guidelines for the theoretical tasks. SCS cannot find all formulas to calculate everything in ISO and DNV, so they need to research other places as well. This may include meetings with teachers, TechnipFMC or other people with knowledge about this subject.

## 5.3.2 Main goals

- Specify theoretical task document.
- Find necessary formulas.

[1] [Ref.3] **DOC No: RPT60020900**
[2] [Ref.1] **BS EN ISO 13628-7:2006**
[3] [Ref.2] **DNV-RP-C203**

## 5.3.3 Iteration 3: Report

**Specify theoretical task procedure document.**

As mentioned earlier, SCS do not want to specify the task procedure in detail. The reason for this is that research will be needed by each individual person performing the task.

Instead SCS have clarified what they want to get out of each task in the purpose topic. Each task includes the same template. If different people have worked one the same task, the contents and structure will be the same and easy to follow through the different tasks.

**Find necessary formulas.**

Formulas are different for each task. SCS list basic formulas and material properties needed, and then it is up to the participants to find out how to calculate each problem, and find formulas needed to solve each problem. SCS had a meeting with an analyze specialist from TechnipFMC, and this was very productive. SCS discussed methods they use/can use to calculate such tasks, and were given some good literature to review.

**Summary and deviation:**

Theoretical tasks are made and completed, and can be started on in the Execution phase.

SCS have also tried to get hold of a company that can give prices on parts, so that SCS can finish the budget that they were not able to finish in iteration 2. This has been unsuccessfully.

## 5.4 Iteration 4

Fourth iteration goes from 13.03.2017 to 20.03.2017.

### 5.4.1 Iteration 4: Plan

**What:**

Create a practical test document and finish/correct all documents for elaboration phase before second hand in.

**Create Practical Test Document.**

**Why:**

| **Practical tests** | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Date** |
| - TT-1-1-Pr | Find necessary force between hubs with FEM analysis. | A | TechnipFMC | 31/1 |
| - TT-2-1-Pr | Investigate values on bolt vs stud used from PRD-0000021662 will behave. | C | SCS | 1/3 |
| - TT-5-1-Pr | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | 31/1 |
| - TT-6-Pr | Reproduce analysis done by FMC in SW and compare results. | C | TechnipFMC | 31/1 |

*Table 5: Practical tests*

Practical testing is a part of the project and gives a clarity about the tasks by using 3D-tools on the computer. SCS shall use drawings drawn by TechnipFMC in ABAQUS, and transfer them into Solid works. By creating a practical test document, it should give a good overview about the practical tests and it is a tool for further work in the execution phase.

**How:**

From the Practical test table *(see table 5 Practical tests)*, SCS must create a practical test document, which includes a detailed specification of the tasks.

Use the same template as SCS used in the theoretical task document and mechanical test document.

Give every test a new ID, this gives the tests a good traceability. The test shall include topics as: Purpose, equipment, preparation, procedure, pictures, references and acceptance criteria.

**Finish and correct all documents created in the elaboration phase.**

**Why:**

After feedback from the sensor from the first hand in, SCS should use extra time on spell checking and proofreading documents.

**How:**

Documents that shall be created in the elaboration phase is: updated project specification, task and test specification, practical test document, theoretical task document, mechanical test document and elaboration plan document.

These documents should be finished as good as possible before second hand in. SCS should use some time to proofread the documents and do changes if it is necessary.

SCS should maybe use an extern corrector.

### 5.4.2 Main goals

- Create a practical test document.
- All document for the elaboration phase shall be finished.
- Preparing all documents for second hand in and orthography shall be done.

## 5.4.3 Iteration 4: Report

TechnipFMC handed over a STP file, with hubs, clamps, studs, etc. All SCS need to do, is to execute Practical Testing. SCS have done research in this file, and are ready for Practical Tests. A practical test document is now created.

SCS have created Practical test document, mechanical test document and theoretical task document. All these three documents are now ready for second hand in after correction.

The budget that was planned to be set up in iteration 2, have also been a small part of the fourth iteration. A suggestion over necessary materials have been created by SCS, and the budget have been discussed with Einar Totland (Supervisor from TechnipFMC). Materials SCS want to use under testing is not standard shelf item, and this can be difficult to obtain. The PTFE, Xylan coated bolt is quite expensive, and because of a low budget, SCS may have to look for other alternatives. SCS have contacted several bolt-shops around and tried to find something useful for testing.

SCS have in the last part of iteration four done corrections in every document who is created in the elaboration phase.

**Deviations:**

Friday 17.03.2017 TechnipFMC made a new demand, and because of this, changes needed to be done. TechnipFMC stated that they need SCS to do testing on a real size test cap *(See figure 4 test cap).* They will also give SCS one new stud, nut and washer to run tests on.

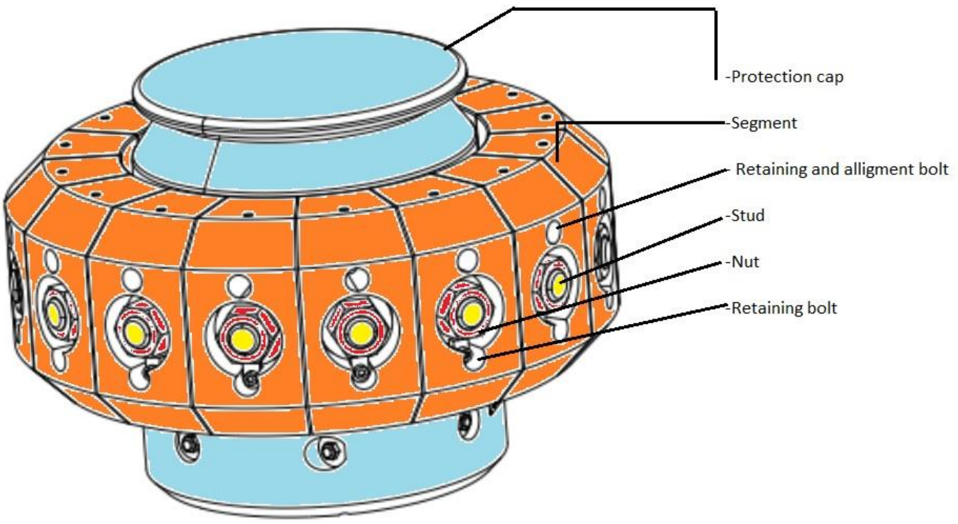



*Figure 4: Test cap.*

**Impact on the project:**

Early in the elaboration phase SCS, made a risk analyze *(see table 1 risk elaboration phase)*. SCS considered that changes in tasks from TechnipFMC was possible during this project.

Mechanical test document was specified in detail with scaled down tests, so that SCS could run tests at HSN Kongsberg. Now this means SCS need to do much of iteration 2 all over again, and that pretty much kills the time budget for the fourth iteration. In iteration 2 SCS decided upon testing equipment, material size, etc. and now all of this need new evaluation. SCS have been able to make a budget to TechnipFMC, with a proposal on what they need.

A change so late in the game is not negative, because SCS now have the opportunity to run full-scale tests, and all the other materials that are needed, SCS already know the price on. The test cap is very expensive, and TechnipFMC are not giving these parts to SCS.

TechnipFMC have specified how many studs that can be wrecked to perform tests. TechnipFMC need the rest of the test cap back afterwards, since it is a part they still can use in their testing on WOR. This means that SCS have the full responsibility if somethings happen to it.

**How we handled the changes.**

SCS went through most of iteration 2 one more time.

They planned the changes that needed to be done. The mechanical tests were most critical to finish, because of the budget, materials, procedure and tools needed. SCS have made the changes necessary to perform the tests. Some of the tests are still the same, with scale-downed material. (*See Mechanical test document for all the tests).*

A problem after getting the new task was to find a location. The test cap with hubs and all parts weigh 1400 kg. SCS decided to ask the people responsible for the workshop at HSN if it was possible to get the parts in the building, and they said yes. Next problem with size and weight are tools and equipment needed. This was one of the reasons SCS scaled down the size of the parts in the first place. SCS are still going to use the HSN workshop, since necessary equipment and tools could be borrowed to run the tests. TechnipFMC will borrow their torque tool for use in testing.

The changes needed was completed quickly. This was possible due to good work in iteration 2. This shows that a good work structure and planning is important for all projects.

# 6. Final Elaboration phase report

The elaboration phase has been an exciting challenge for SCS. They have gotten deeper into project tasks, and feel ready to start the next phase, the Execution phase.

Iteration 1 made a foundation for the next iterations. SCS have had several meetings with TechnipFMC and internal supervisor, Otto Waaraas. SCS had to get clarity in all tasks, and to decide if the tasks were achievable.

Looking at the final results in Project Specification document, SCS are satisfied with the result.

Iteration 2. Since all the members of the bachelor group have working experience, this was a very exciting iteration. This is where SCS could use some of their expertise and working experience, and complete this iteration with a very good result. SCS got a challenge in the last minute, with some changes from small scale tests, to full scale tests. This is more described in iteration 4, since they had to work with iteration 2 in iteration 4.

Iteration 3 was a though challenge. This was the iteration where SCS found formulas needed to solve the tasks. SCS had a meeting with an analyze expert (Toril Evenstad) from TechnipFMC, to help proceed. SCS have filled out the main formulas to solve every task. This means that SCS feel ready to execute and find the answers needed to complete the tasks.

Iteration 4 was a little setback. SCS did the things they had planned in the iteration, practical tests and finishing the elaboration document. But in the last minute SCS got a telephone from supervisor in TechnipFMC (Einar Totland), informing SCS that they can do a full-scale test on a test cap from TechnipFMC. In iteration 2, SCS decided to scale down materials, to complete the mechanical tests. But now SCS had to rewrite some of the mechanical tests, from scale down to full-size tests. The bachelor group worked hard through the weekend, and got a result they feel is acceptable.

All in all, SCS are satisfied with the results and work effort in the Elaboration phase, and are looking forward to the next phase, the Execution phase.

# The Execution phase

| | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 1.0 |
| | |
| **SCS Group members** | Asbjørn Antonsen, Project leader and construction Initial: AA |
| | Bjørn Ledaal Rossavik, Qualification and specification Initial: BR |
| | Erlend Berg-Olsen, System Engineer and Project planner Initial: EBO |
| | Espen Hansen, Test and Verification Initial: EH |
| | |



Høgskolen i Sørøst-Norge

# Summary

This document contains the third phase in SCS`s project, and is called the Execution phase.

As the name states, this is where we execute the tests and tasks we have made in this project so far.

In this document, you will find the plan for each iteration and the report from each iteration. There is a total of four iterations.

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 18.04.2017 | 6 | AA | Created document and filled in information regarding execution phase with iterations. |
| V.0.2 | 19.04.2017 | 10 | BR | Updated with frontpage, contents, document history, chapter. orthography and filled in information about iterations. |
| V.0.3 | 21.04.2017 | 13 | BR | Updated introduction, overview of execution phase, iteration 1 plan & report and iteration 2 plan. |
| V.0.4 | 27.04.2017 | 13 | EBO | Updated information, orthography |
| V.0.5 | 01.05.2017 | 15 | BR | Completed report for Iteration 2. |
| V.0.6 | 02.06.2017 | 16 | EBO | Iteration 3 plan. |
| V.0.7 | 03.06.2017 | 16 | EBO | Updated report iteration 2 with SolidWorks stp information. |
| V.0.8 | 08.05.2017 | 16 | AA | Updated contents and spell check |
| V.0.9 | 08.05.2017 | 22 | BR | Iteration 3 report and Iteration 4 plan. |
| V.0.9.1 | 11.05.2017 | 24 | BR | Iteration 4 report. |
| V.0.9.2 | 20.05.2017 | 24 | AA | Orthography. |
| V.0.9.3 | 21.05.2017 | 26 | BR | Updated iteration 4 report, contents, abbreviations list and added final report. |
| V.1.0 | 24.05.2017 | 27 | SCS | Ready for last hand in. |

# Abbreviations and technical words

| Abbreviation | Explanation |
|---|---|
| WOR | Workover Riser |
| SL | Speedloc |
| ISO | International Standardization organization |
| DNV | Det Norske Veritas |
| UP | Unified process |
| SCS | Subsea Connection System |
| HSN | Høgskolen i Sør-Øst Norge |

| Technical Words | Explanation |
|---|---|
| Friction | The force resisting the relative motion of solid surfaces, fluid layers and material elements sliding against each other. There are several types of friction. |
| Stud | Threaded rod similar to a bolt but it has no bolt head. |
| Nut | A nut is a fastener with a threaded hole. |

TechnipFMC

Subsea Connection System

# Contents

# Tables



# Figures

# 1. Introduction

The execution part of the Unified Process is the practical hands on part for this bachelor thesis. SCS are aware of what needs to be done from previous phases and iterations. This phase will as the name state, be to execute all tasks and test.
The execution phase is divided into iterations, this is done so it is possible to answer the most important questions first, and to have good control over the project phase.

# 2. The Execution Phase

## 2.1 Risk Analyze

| Risk (7) | Probability | Impact | Ranking | Responsibility |
|---|---|---|---|---|
| **Execution Phase** | | | | |
| (7.1): Changes in tasks from TechnipFMC. | 3 | 5 | 15 | Control: Documents must be updated and extra time is to be sacrificed. |
| (7.2): Did not complete the iteration. | 3 | 3 | 9 | Control: The unsolved problem in the current iteration may be transferred over in the new iteration phase. The group may sacrifice some extra time. |
| (7.3): Did not finished the execution phase in estimated time. | 2 | 5 | 10 | Control: This is not optimal for the second hand in, but an explanation must be made and be a part of the execution phase document. |

*Table 1: Risk execution phase*

# 2.2 Overview and iterations

## 2.2.1 Overview of the phase

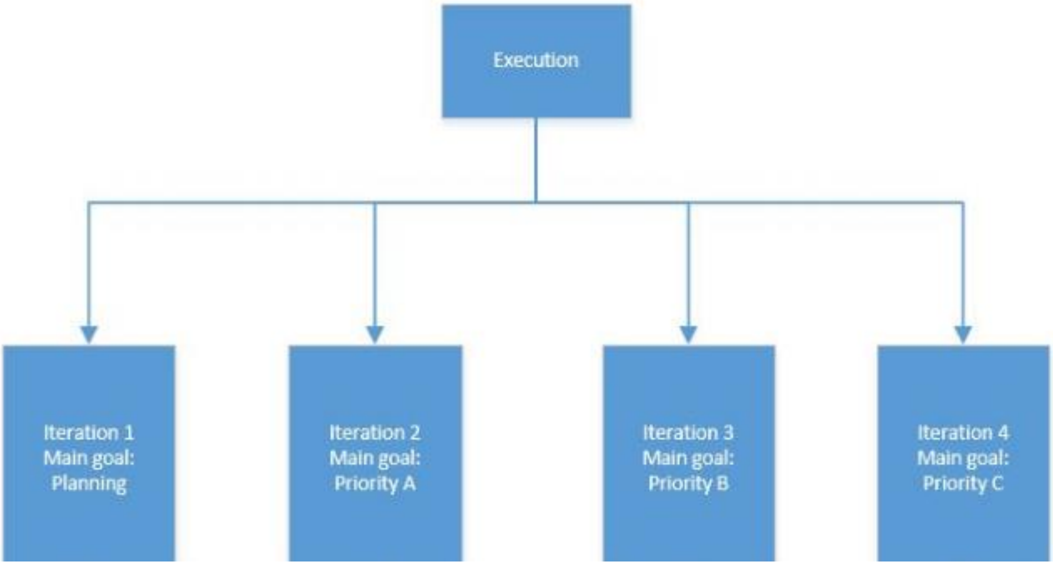



*Figure 1: Overview of the phase*

## 2.2.2 Iterations

In the execution phase, the main goal is to run tasks and tests that is created from the customer's needs.

This is the phase were the product is being developed, or in this project, were the research is to be carried out. The two earlier phases are the very foundation of this phase, and it is essential that good planning has been done in the past.

There are 4 iterations in this phase:

**1 iteration:**

- First a short iteration to establish some unknown factors before the task and tests can start.
- A detailed test plan of when the specific test shall start and end.
- Find all the strain gauge equipment used to test strain in bolts.
- Test cap location and transport.
- How to adapt stud for strain gauge.
- Checking software file, regarding to FEM analyses.
- Go through every theoretical task, and find standard values we need.

**2 iteration:**

Execute and finish all task and test with priority A. Good planning from iteration 1 will help the execution and do it more effective. SCS will use guidelines from TechnipFMC to verify the results.

**3 iteration:**

Iteration for task and test with priority B. Continue to execute task and tests, use values and data from Iteration 2 to complete all task and tests.

**4 iteration:**

This will be the final iteration in the execution phase.

This iteration will be used to complete all task and tests with priority C.

Use values and data from iteration 2 and iteration 3 to complete this iteration.

# 3. Iterations

## 3.1 Iteration 1

### 3.1.1 Planning

**What:**

This phase starts by administrate all the mechanical tests and verify that all equipment, workshop and tools needed are in place and reserved.

Need to make a detailed test plan of when each test shall be executed.

Find all the strain gauge equipment used to test strain in bolts.

Test cap location and transport.

How to adapt stud for strain gauge.

Checking software file, regarding to FEM analyses.

Go through every theoretical task, and find standard values we need

**How:**

To answer all these questions there will be meetings between the bachelor group and TechnipFMC.

Contact teachers at HSN, to find out more information.

SCS will also use literature, technical data sheet, go through all information received from TechnipFMC and HSN school materiel to find all information needed.

**Why:**

To plan the execution phase in the best possible way. This will ensure high efficiency and a good result.

## 3.1.2 Report

SCS have had meetings with TechnipFMC and teachers at HSN.

In meetings with TechnipFMC, a plan is made for the test cap. Strain gauge has also been discussed with TechnipFMC. They have employees that have long experience with the use of strain gauges. The issue regarding this, are that TechnipFMC have only accepted a budget with 2 employees (Einar Totland and Per Øystein Hansson) working with this bachelor thesis. A new budget must be made, if more employees from TechnipFMC are to be involved in this project. SCS are waiting for answer from TechnipFMC.

Formulas and theoretical task have been discussed. SCS will go more into the details of the theoretical tasks, and request a meeting with an analyze expert from TechnipFMC.

Practical test (FEM analyze) have been planned by SCS. SCS has received a STP file from TechnipFMC with 3D drawing of the equipment. SCS have analyzed and tried to convert the STP file into a suitable file that runs with SolidWorks FEM-analysis, but this has been unsuccessful. SCS will follow up on this, and contact teachers and TechnipFMC for help.

SCS have been in contact with teachers from HSN, Kongsberg. SCS discussed the use of strain gauges with mechatronic teacher Zoran. The school has all instrumental equipment required, SCS only need to provide strain gauges. SCS will discuss this more in detail with TechnipFMC.

Detailed test plan and updated Gantt chart is made. This will help SCS through this phase.

Website have been updated with Iteration 1.

## 3.2 Iteration 2

### 3.2.1 Planning

This iteration will contain execution of task and test with priority A.

There are 3 different type of tasks and tests in this iteration. These must be performed in one specific way.

1. Theoretical task has been analyzed in iteration 1. Formulas and values used need to be double checked.

2. Practical test, check that STP file are ready for use in SolidWorks, and investigate boundaries and forces used in FEA analyze from TechnipFMC. Do a FEA analyze in SolidWorks, but make sure that the test is as similar as possible as the FEA analyze from TechnipFMC. The new pre-tension on nut, found from TT-1-2-T will be used.

3. Mechanical test will be performed after theoretical tasks and practical test if this is required. This is because in TT-1-2B-M, values from TT-1-2T will be used. An SJA and HSE for mechanical testing have been made as a safety measure. The SJA and HSE must be read and understood, before testing is started.
   Mechanical test procedure document must be checked before start.

At the end of the iteration, after all tasks and test are finished, MT-1 will be done.
MT-1 is Main Task 1 which is the main priority that will provide new pre-tension on nut.

MT-1 will consist of a final report, where all the tasks and test values will be listed in. Finally, there will be a conclusion on recommended pre-tension for nut on SL-215.

## 3.2.2 Priority A tasks and tests

| ID | Description | Priority | Given by | Test date |
|---|---|---|---|---|
| MT-1 | Shall determine necessary pretension on nut from necessary force between hubs. (Compare the preload on hubs and the target preload on nut). | A | TechnipFMC | |
| - TT-1-1 | Determine necessary force between hubs. | A | TechnipFMC | |
| - TT-1-1-T | Determine necessary force between hubs by calculation. | A | TechnipFMC | |
| - TT-1-1-Pr | Find necessary force between hubs with FEM analysis. | A | TechnipFMC | |
| - TT-1-2 | Provide recommended pretension on nut including range. | A | TechnipFMC | |
| - TT-1-2-T | Provide recommended pretension on nut including range. | A | TechnipFMC | |
| - TT-1-2A-M | Do a tensile strength test of the material used in stud. | A | TechnipFMC | |
| - TT-1-2B-M | Test recommended pretension on nut including range. | A | TechnipFMC | |

*Table 2: Priority A tasks and tests*

## 3.2.3 Report

SCS started this iteration with TT-1-1-T and TT-1-2-T. SCS worked and solved these tasks as best as possible, but not all values were possible to find. SCS arranged a meeting with TechnipFMC, and got a meeting with an analyze expert, Toril Evenstad. After this meeting, SCS had all values that were needed to solve TT-1-1-T and TT-1-2-T.

TT-1-1-Pr could not be completed, due to a problem with the STP file from TechnipFMC. SCS consult a SolidWorks FEM teacher at HSN Kongsberg, but the teacher had the same problem as SCS. The STP file was an assembly part, and had to many fine elements into the drawing. This caused SolidWorks and our computer at HSN to fail when trying to mesh. Because SCS did not have the drawings of the under-parts, repairing of the issue then failed. TechnipFMC was aware that this could be a problem. They use ABAQUS, which is another program and they also have much better computers, so this was not an issue for them.

Two group members used a lot of time on this problem, with no result. Will continue to work hard next iteration on this issue.

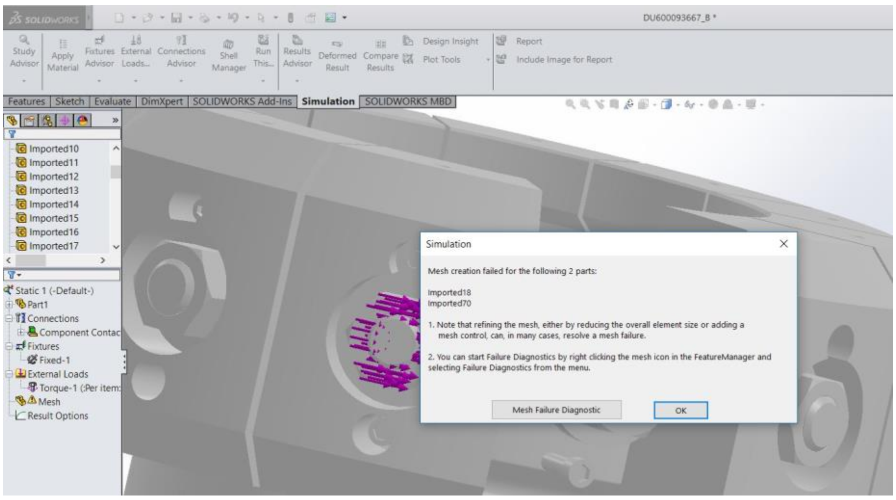



*Figure 2: Failure under FEM-analyses*

SCS have had meetings with TechnipFMC according to this. Analyze expert Toril Evenstad will assist SCS with this problem, and try to change the STP file or send a new file to SCS. This test will continue in Iteration 3.

The planning of executing TT-1-2A-M have started, but SCS must wait on TechnipFMC. To perform this test, SCS need more studs. A stud need to be machined downed and cut. TechnipFMC are working to get more studs for SCS.

TT-1-2B-M have been delayed. This was a very exiting test for SCS. Due to complications at TechnipFMC, the test cap needed to perform this test, did not arrived HSN workshop. TechnipFMC and SCS are working towards a solution, and will continue this in Iteration 3.

Since some task and test were delayed, SCS continued working on other Iterations.

TT-3-1-T and TT-3-2-T was completed in this Iterations. All worked as planned with these tasks.

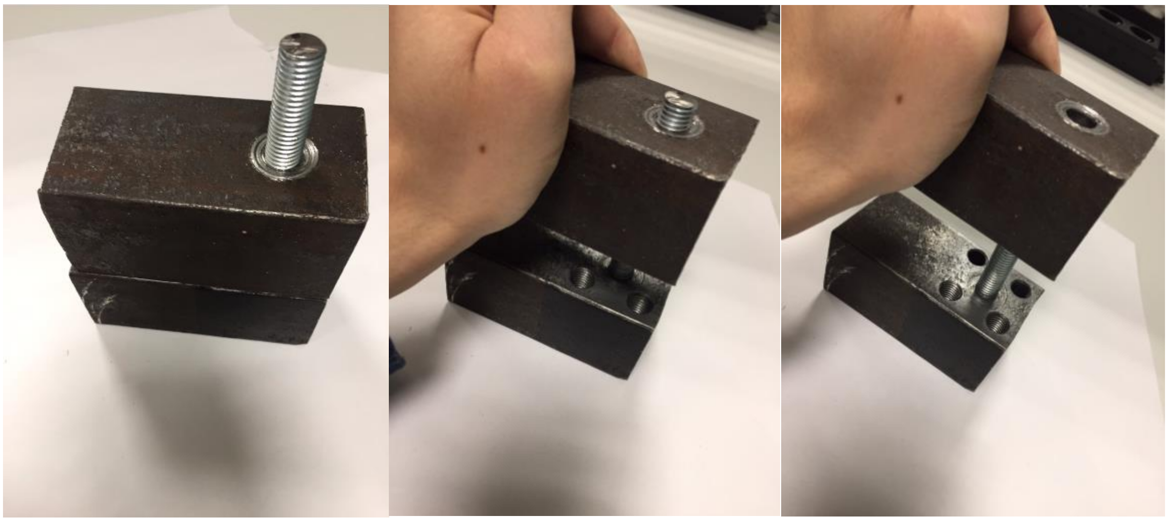
TT-2-1B-M have been started on. SCS started to make a test kit, a metal piece with threads. In the start of the test SCS had some fracture failures, and needed to optimize the metal piece. After some testing, SCS test kit is now ready to use. SCS has done 3 test on the new metal piece, with 2 bolts and 1 stud. 3 bolts and 4 stud remains to do. This will be done in Iteration 3. Test kit and equipment is on place, because of good work in this iteration.

Figure 3: SCS first test kit

This was SCS first test kit. SCS used a tube between bolt/stud and metal piece, to get a resistance upon fracture. In the beginning it worked well, but after breaking 4 bolts, the tube started to rotate and a high friction coefficient came. This caused that the bolt/stud did not got the same fracture point, and SCS need to do something with this problem.

SCS made a new resistance, and this time it worked perfectly afterwards!

Figure 4: SCS test kit



Website have been updated with Iteration 2.

# 3.3 Iteration 3

## 3.3.1 Planning

This iteration will contain testing that need to be performed to analyze the SL connector. In this iteration, all the B criteria tasks shall be performed. This test is not as important as they with A criteria, but still very important.

Due to a setback with the delivery of the speedloc, and some issues with the stp-file in SolidWorks, some of the tasks in iteration 2 must be performed this week.

This week will contain some meetings with TechnipFMC to discuss when the speedloc will arrive HSN. The tasks with A-priority from iteration 2 with the speedloc and SolidWorks must be performed on the side of all off the other tasks that have execution time in this iteration.

See the task documents for more explanations about each task.

## 3.3.2 Priority B tasks and tests

| | | | | |
|---|---|---|---|---|
| - TT-3-1 | Identify all variables affecting preload. | B | TechnipFMC | 31/01 |
| - TT-3-1-T | Identify all variables affecting preload. Make a list. | B | TechnipFMC | 31/1 |
| - TT-3-2 | Investigate variables in the stud & nut study. | B | TechnipFMC | 31/01 |
| - TT-3-2-T | Investigate variables in the stud/nut study. | B | TechnipFMC | 31/1 |
| - TT-3-2-M | Do a mechanical test based on the variables affecting preload on stud and nut. | B | TechnipFMC | 31/1 |

*Table 3: Priority B tasks and tests*

**How**

In this iteration, the tests will go both on the workshop with mechanical testing and with theoretical studies. It is important in this iteration to have good control over the time estimated to each test, to achieve that, Gantt cart must be followed.

In this iteration, it will be important for each member to work independent from the rest of the group, so all of the tasks will be covered.

The main focus must be on the tasks on iteration 2 that remains, they have priority A, so are therefore the most important ones.

**Why**

The tasks in iteration 3 have focus on variables around the stud and nut, such as friction. It is interesting for TechnipFMC to see how much they affect the stud and nut preload.

### 3.3.3 Report

TT-1-1 and TT-1-2 from iteration 2 was competed in this iteration. After meeting with TechnipFMC in iteration 2, SCS had all the data needed to complete these 2 tasks. In iteration 3 these two-theoretical tasks were completed. New torque for nut and hub face separation were found.

For SCS, this was the main goal to reach. TT-1-1 and TT-1-2 was priority A, and are most important for the customer, TechnipFMC.

TechnipFMC are holding back on the test-cap, because of safety reasons. There has been a meeting with Per Øystein Hansson from TechnipFMC, regarding the test cap. Issues with transport and safety of the test cap, have given a set-back. The new solution now is that the test cap is placed in a workshop at TechnipFMC Kongsberg, and SCS can do all the necessary testing there.

TechnipFMC will follow up this in the next iteration, and hopefully arrange the test. TechnipFMC are saying that they will do everything they can, to make it happened.

Meanwhile, the project goes on, and other tasks and tests have to be done.

TT-1-1-T and TT-1-2-T have been executed, test rapport is written and completed.

Results are accepted.

TT-1-2B-M have been executed, test rapport is written and completed.

Results are accepted.

Documentation from inception and elaboration phase have been read through and updated. They have been updated with new information, orthography and made alike the other documents.

Two group members have been working a lot with the new STP file, regarding FEM analyses in SolidWorks. But with no results so far. They will continue working with this in iteration 4.

Website have been updated.

Work on TT-1-2A-M has started.  A lathe was used and machined away all the threads from the stud. This was a start to get down to the material underneath coating and threads, and make a tensile sample. In iteration 4, work will continue on this task. First, SCS will use a saw to cut it up in correct pieces, then take a tensile test of the material in a tensile machine.

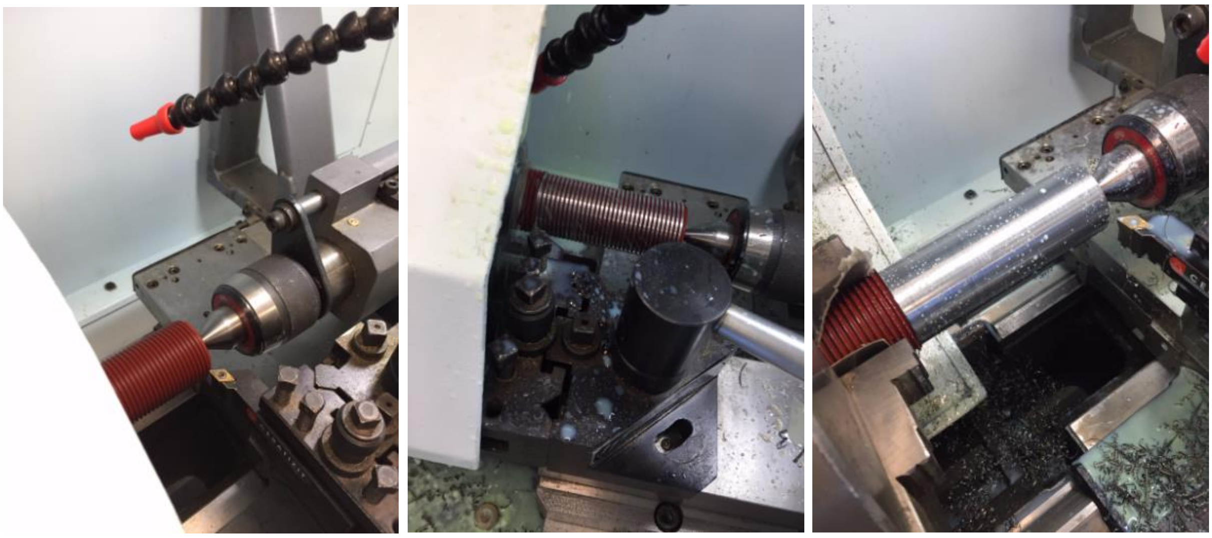
Here are some pictures of the machining part in this iteration.

*Figure 5: Lathe at HSN-Kongsberg*

Stud before machining:

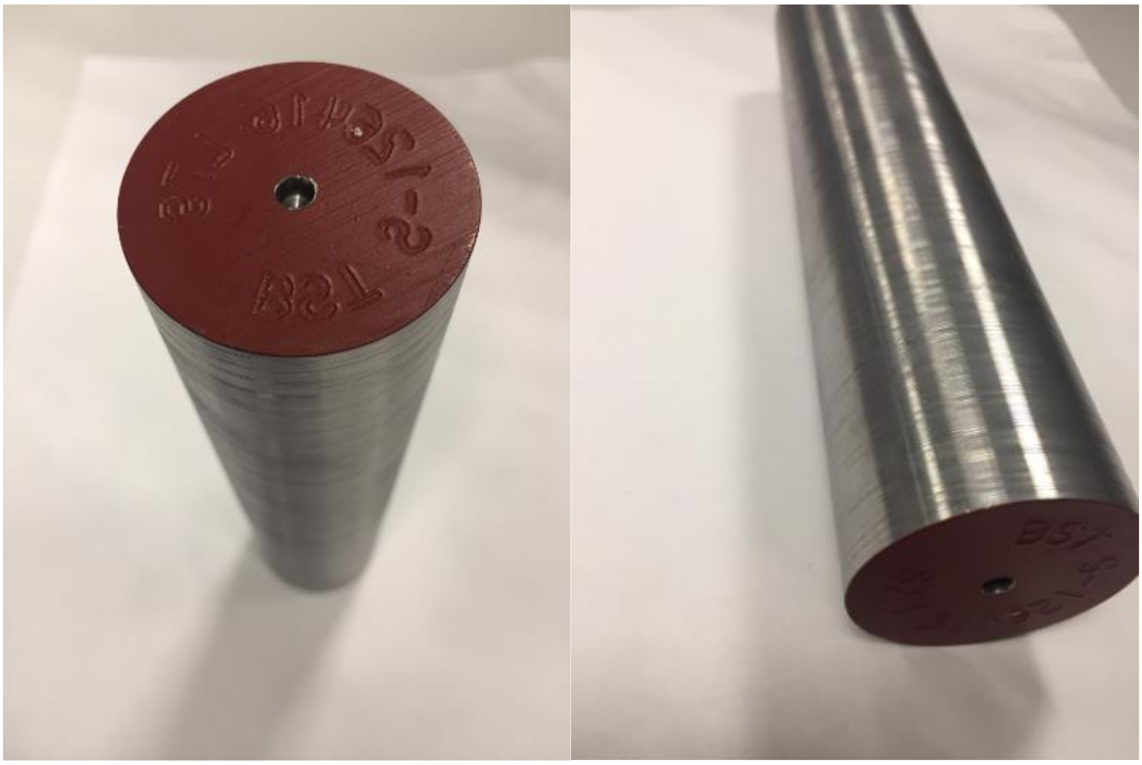
*Figure 6: Stud before machining*

*Figure 7: Stud in lathe*



Finished result:

*Figure 8: Stud after machining*



# 3.4 Iteration 4

## 3.4.1 Planning

Fourth and last iteration for the Execution phase.
In this iteration, all tasks and tests that is not completed, has to be done.

TT-1-2A-M, TT2-1A, TT-1-1-Pr and TT-3-2-M from earlier iteration has to be completed.

Tasks and tests in this iteration are priority C. Because they are priority C, the focus shall be on all the tasks and tests from the earlier iteration first. When those tasks and tests are completed, the focus will be on priority C tasks and tests.

TechnipFMC are working hard to make it possible for us in SCS to do a real size test on a test cap. Transport and safety issues has stopped this process. TechnipFMC are working on a solution, were SCS work 2 days in a workshop at TechnipFMC. Here they will be assisted by a verified workshop worker from TechnipFMC, and will complete test TT-1-2B-m and TT-3-2-M.
SCS have sent a procedure and SJA on the tests they will perform. Then, if all works out, TechnipFMC will be ready and prepared for testing.

If, worst-case scenario, this cannot be done, SCS will go back to the scale-down test.

In elaboration phase, SCS made a scale-down test of the stud and nut. At the last minute, TechnipFMC called and informed about a test cap that SCS can use. With this test cap, a real size test can be executed. SCS changed TT-1-2B-M and TT-3-2-M from scale-down test, to a full-scale test. SCS still have this scale downed test document saved, so in worst-case scenario, they will go back to this test.

## 3.4.2 Priority C tasks and tests

| | | | | |
|---|---|---|---|---|
| - TT-2-1 | Investigate values on bolt vs stud used from PRD-0000021662 will behave. | C | TechnipFMC | 31/01 |
| - TT-2-1-Pr | Investigate values on bolt vs stud used from PRD-0000021662 will behave. | C | SCS | 1/3 |
| - TT-2-1A-M | Investigate values on bolt used from PRD-0000021662. | C | TechnipFMC | 31/1 |
| - TT-2-1B-M | Investigate values on bolt vs stud fraction. | C | TechnipFMC | 31/1 |

| | | | | |
|---|---|---|---|---|
| MT-5 | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | 20/02 |
| - TT-5-1-Pr | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | 31/1 |
| MT-6 | Reproduce analysis in SW and compare results. | C | TechnipFMC | 31/01 |
| - TT-6-Pr | Reproduce analysis done by FMC in SW and compare results. | C | TechnipFMC | 31/1 |

*Table 4: Priority tasks and tests*

### 3.4.3 Report

Inception and elaboration document have been read through and spellchecked. Since SCS have had some "waiting-time" before starting on other tasks and tests, the most effective have been to read through documentation, and correct errors.

*10/5-2017*

SCS have been waiting for acceptance and start on full scale mechanical test.

May 10 SCS and Technip had a meeting from 08.40-14.00. 3 meetings were held this day.

One pre-meeting with Per Øystein Hansson, and 2 colleagues from his section. Torque values, testing procedure, safety hazard etc. were discussed.

Then there was a meeting between SCS, Per Øystein and his 2 colleagues, and 3 workshop workers at TechnipFMC. Safety hazards and procedure was narrowly discussed.

SCS was very impressed with the manpower and setup from TechnipFMC. It showed that TechnipFMC was taking this very seriously and are doing all they can to help perform this test. Hats off for TechnipFMC.

After 2 meetings, inspection off workshop and equipment were next. Safety hats, protective glasses and safety shoes are mandatory in TechnipFMC workshops.

Last meeting was held by Per Øystein and his 2 colleagues, together with SCS. Here a specific procedure for testing was discussed. All agreed on a procedure and how the test shall be performed. SCS have written a new procedure from this day, with feedback from TechnipFMC.

A SJA (Safe Job Analyze) was written and accepted, for testing to be done at TechnipFMC.

4 studs needed to be machined, such that strain gauges can be placed on the studs. After these was finished, the test could start.

A strain gauge is a gauge that measure strain in a material.

Strain gauge is a flexible bracket which support a metallic foil pattern. With the use of Wheatstone brigde method, a value can be read through the change of electrical resistance.

When the metal inside the foil are getting stretched or squeezed, the electrical resistance changes.

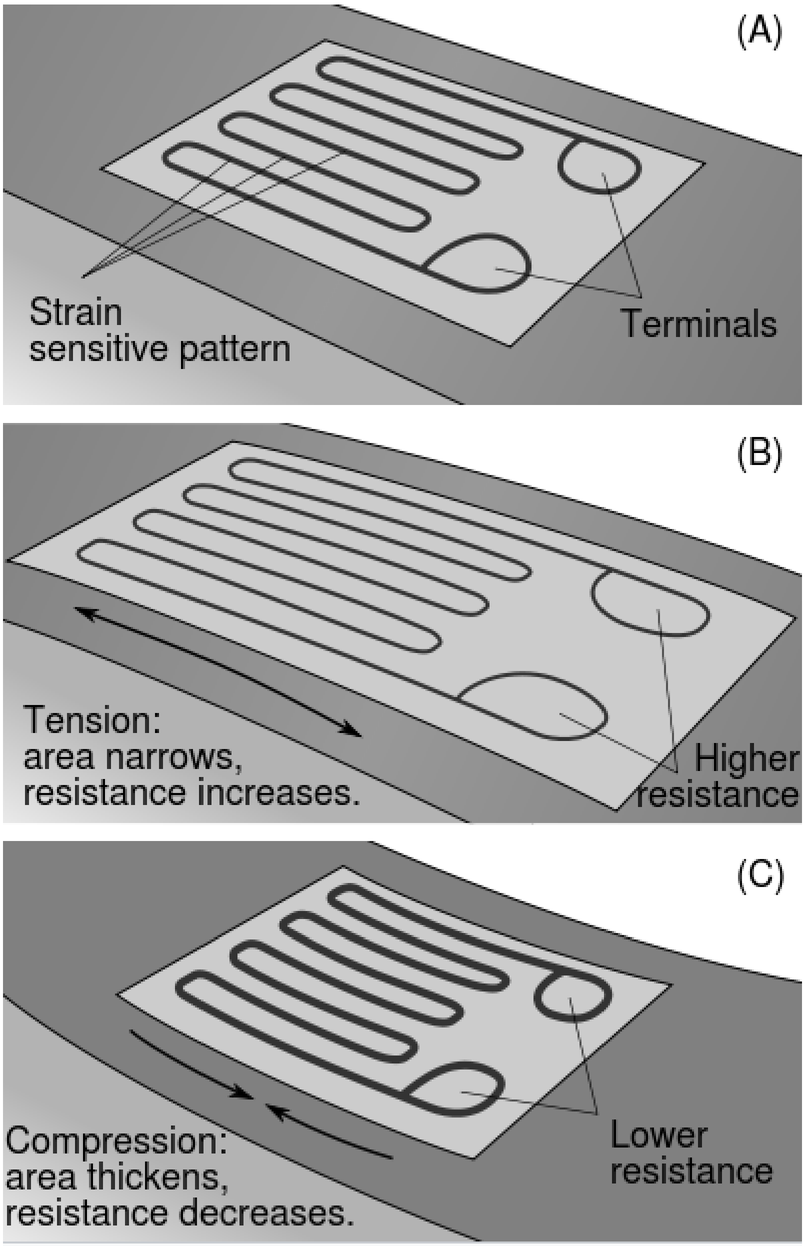



*Figure 9: Strain gauge scenarios*

Source: https://en.wikipedia.org/wiki/Strain_gauge

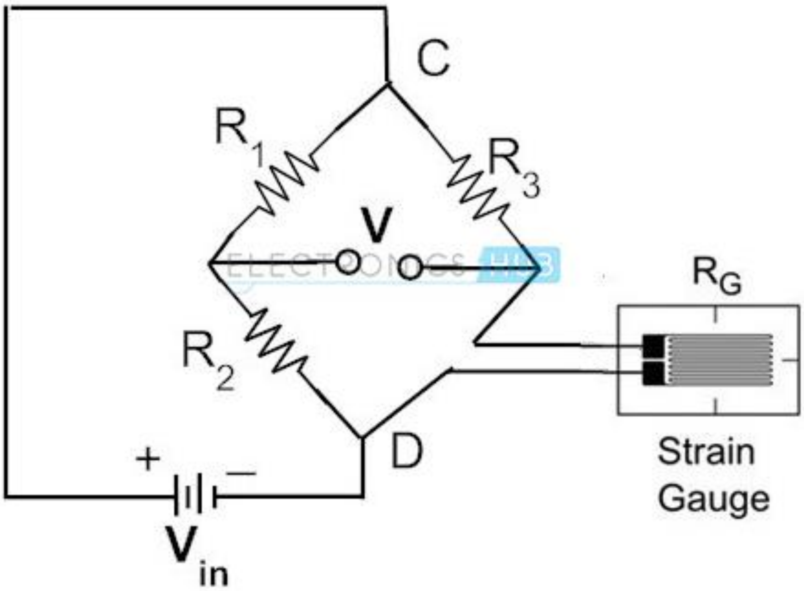


*Figure 10: Wheatstone bridge*

Source: http://www.electronicshub.org/wheatstone-bridge/

This shows a strain gauge Wheatstone bridge.

R1, R2 and R3 are references used as known values. With no strain, the system will be in balance. If a voltmeter is placed in to measure volt between point V, the value will be Zero. If there has been some strain on the gauge, the resistance in the circuit will change, and this will cause unbalancing of the bridge. This produces a voltage indication on voltmeter corresponds to the strain change. If the strain applied on a strain gauge is more, then the voltage difference across the meter terminals is more.

Main task (MT) have been updated with a report on each task. This includes a conclusion from all sub-task done. SCS aimed to verify each main task, that is the reason why theoretical task, practical and mechanical test have been performed on same main task.

All practical tests have been closed down. TechnipFMC delivered STP files, to be analyzed by SCS in SolidWorks FEM. SCS worked a long time trying to analyze the STP files, with no luck. Read more about this in the practical test document.

ST-1-2B-M have been completed and a final report is finished.

# 4. Final report

The execution phase has been challenging and exciting.

The phase started with planning and preparation. This is the phase were all the tasks and tests given are executed. It has been challenging to prepare and plan for all scenarios, but Gannt chart and risk analyses has been very helpful.

Iteration 2, 3 and 4 have been lapping each other. Iteration 2 was meant to be for all priority A tasks and tests. 3 of 5 tasks and tests with priority A was started on. Because of missing parts, priority B tasks and tests was also started on in this iteration.

This has been an unfortunately trend in this phase, because there have been missing parts, missing data etc. Unified Process project model is used, so this has not been a problem for the project progress. The project model chosen has been very good for this project so far!

The group have worked hard through it all, and handled the challenges in a good way.

At the end of the phase, there was a challenge with the time, because of the test cap testing at TechnipFMC. The group was very excited to do this test, and worked long hours with TechnipFMC to complete the test. Some days the work lasted more than 12 hours. SCS started working with this task in January, and haven't seen the Speedloc in real life. It was very impressive and excited to see it in real life, and do full scale testing.

Read more about the mechanical test on test-cap in document TT-1-2B-M.

All in all, SCS are satisfied of the work done in the Execution phase. Many long days and late nights have been done. The bachelor group have learned a lot and it has been a pleasure working close together with TechnipFMC at their workshop!

# Theoretical task Document

| | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 2.0 |
| | |
| **SCS**<br>**Group members** | Asbjørn Antonsen,<br>Project leader and construction<br>Initial: AA |
| | Bjørn Ledaal Rossavik,<br>Qualification and specification<br>Initial: BR |
| | Erlend Berg-Olsen,<br>System Engineer and Project planner<br>Initial: EBO |
| | Espen Hansen,<br>Test and Verification<br>Initial: EH |
| | |



Høgskolen i Sørøst-Norge

# Summary

This document contains the theoretical tasks and the layout for hove to solve them.

This document includes four tasks:

| Theoretical tasks | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Date** |
| - TT-1-1-T | Determine necessary force between hubs by calculation. | A | TechnipFMC | 31/1 |
| - TT-1-2-T | Provide recommended torque on nut including range. | A | TechnipFMC | 31/1 |
| - TT-3-1-T | Identify all variables affecting torque on nut and preload in stud. Make a list. | B | TechnipFMC | 31/1 |
| - TT-3-2-T | Investigate variables affecting torque on nut and preload in stud. | B | TechnipFMC | 31/1 |

*Table 1: Theoretical tasks*

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 28.02.2017 | 7 | BR | Created document, filled in information and made template for task. |
| V.0.2 | 03.03.2017 | 10 | BR | Updated introduction and TT-T-1 |
| V.0.3 | 07.03.2017 | 16 | EH | Updated TT-3-1-T and TT-3-2-T. |
| V.0.4 | 09.03.2017 | 15 | BR | Updated TT-1-1-T |
| V.0.5 | 09.03.2017 | 18 | AA | Updated TT-4-1-T, TT-4-2-T and TT-4-3-T |
| V.0.6 | 16.03.2017 | 21 | EH | Updated theoretical task list. Updated TT-3-1-T and TT-3-2-T. Inserted TT-1-2-T. |
| V.0.7 | 16.03.2017 | 22 | BR | Updated introduction. Updated TT-1-1-T. |
| V.0.8 | 20.03.2017 | 22 | AA | Added table contents list. Spell check |
| V.0.9 | 20.03.2017 | 24 | BR | Structure and spellcheck. |
| V.1.0 | 20.03.2017 | 24 | EH | Updated front page. Spell check and structure. |
| V.1.1 | 21.04.2017 | 23 | EBO | Updated references after APA standards. |
| V.1.2 | 11.05.2017 | 15 | EH | Removed Task 4. Changed name from ST to TT. Inserted table and figure list. Updated reference list. |
| V.2.0 | 24.05.2017 | 17 | SCS | Ready for last hand in. |

# References

[Ref.1] ASME. (2001). *ASME B1.1-2003.* The American Society Of Mechanical Engineers.

[Ref.2] DNV. (2005). *RP-C203.* Det Norske Veritas.

[Ref.3] FMC, Lasse Moldestad. (2007). *RPT60020900.* Kongsberg: FMC.

[Ref.4] Fonas. (1972). *Skrue håndbok.* Oslo: Elkem-Spigerverket A/S.

[Ref.5] ISO. (2006). *13628-7:2006.* British Standards.

[Ref.6] Statoil, Finn Kirkemo. (2010). *Stud and nut structural tension capacity matching.*

[Ref.7] Waløen, Å. Ø. (1976). *Maskindeler 2.* Tapir.

[Ref.8] John H. Bickford. *An introduction to the design and behavior of bolted joints. Second edition.*

Contact Einar Totland for information regarding references from TechnipFMC.

# Abbreviations and technical words

| Abbreviation | Explanation |
|---|---|
| WOR | Workover Riser |
| SL | Speedloc |
| ISO | International Standardization organization |
| DNV | Det Norske Veritas |
| SW | SolidWorks |
| SCS | Subsea Connection System |
| HSN | Høgskolen i Sør-Øst Norge |
| MT | Main Task |
| TT | Task Test |
| FEM | Finite Element Method |

| Technical Words | Explanation |
|---|---|
| Hubs | Flanged part of the SL connector. |
| Preload | Tension force in the stud/bolt after tightening. |
| Torque | Moment of force. |
| Scatter factor | Assessment of accuracy. |
| Stud | Threaded rod similar to a bolt but it has no bolt head. |
| Nut | Is fastener with a threaded hole. |
| Washer | Used to distribute the load. |

# Contents



# Tables



# Figures

# 1. Introduction

This document contains theoretical tasks for SCS.

**Every test includes an information table:**

**Main Task ID number** is direct linked to project specification document.

**Task Test ID** Unique ID number for each task. In that way, we can identify each task separately and have good traceability within the documents.

Task and test ID will be referred to on timesheet, analyze report, etc.

**TT-1** - Abbreviation for: Task Test 1.

**Priority** is categorized as showed here:

| | |
|---|---|
| A | Absolute |
| B | Important |
| C | Desirable |

**Description** gives a short explanation about the task.

**Result** is status quo after testing. SCS divide the results into 3 different categories.

| | |
|---|---|
| Accepted | Criteria and verification is accepted. |
| Uncertain, need more information | SCS are not sure about the result, and need to investigate and run more tests on this requirement. |
| Not accepted | Criteria and verification is **not** accepted. |

**Every test includes a list of topics:**

**Purpose:** Briefly describe the purpose of the task/test.

**Equipment:** Note any special equipment requirements.

**Formulas:** All formulas that is used to conclude this task.

**Precautions:** Document any precautions that need to be taken before, during, or after the task.

**Preparation:** List steps necessary to prepare for the task.

**Aids:** List technical papers, CTPL library tests and other information that might be useful as supporting information for the test team.

**Acceptance Criteria:** Document the acceptance criteria that will indicate if the task was passed.

# 2. Theoretical tasks

| Main Task ID | MT-1 |
|---|---|
| Task Test ID | TT-1-1-T |
| Priority | A |
| Description | Determine necessary force between hubs by calculation. |
| Result | Accepted |

**Purpose**

Calculate the minimum needed force between the hubs to get it leakproof.

Main purpose is to find the needed preload in stud, from the force needed to avoid hub separation.

**Equipment**

Pen and paper.

Advanced calculator.

Computer.

**Formulas**

Contact force (disregarding friction):

$$F_c = F_{bolt} \times n_{bolts} / (2 \times tan25°)$$ [1]

Where:

- $F_c$ = Total contact force.
- $F_{bolt}$ = Single bolt preload force.
- $n_{bolts}$ = number of bolts.

[1] [Ref.3] FMC, Lasse Moldestad, 2007, p.19

([2]) $T_{ec} = \frac{\pi}{4} \times (P_{int} - P_o) {D_s}^2$

Where:

- $T_{ec}$ = is the pressure end load.
- $P_o$ = is the external pressure.
- $P_{int}$ = is the internal pressure.
- $D_s$ = is the seal/gasket sealing diameter.

([3]) $T_s = T_e + T_{ec}$

Where:

- $T_s$ = is the total axial separation load tending to separate the connector.
- $T_e$ = is the effective tension (externally applied tension). Te is positive for loads which tend to part the connection.
- $T_{ec}$ = is the pressure end load.

Take friction into account

$\frac{Cfriction}{Cfrictionless} * 100\ \% = Factor\ to\ include\ friction$ ([4])

Use 25 degrees on segment to calculate friction.

[2] [Ref.3] (FMC, Lasse Moldestad, 2007, p. 10)
[3] [Ref.3] (FMC, Lasse Moldestad, 2007)
[4] [Ref.3] (FMC, Lasse Moldestad, 2007, p. 26)

Riser loads shall satisfy the following relationship:

$$\left(\frac{T_s}{T_c}+\frac{M_{bm}}{M_c}\right)\times\frac{1}{F_D}\leq 1$$

where

| | | |
|---|---|---|
| $T_s$ | is the total axial separation load tending to separate the connector | N (lb) |
| $T_c$ | is the axial load capacity (single load) for the applicable failure mode | N (lb) |
| $M_{bm}$ | is the absolute value of the externally applied bending moment | N-mm (lb-in) |
| $M_c$ | is the bending moment capacity (single load) for the applicable failure mode | N-mm (lb-in) |
| $F_D$ | is the design factor, see [1] | |
| $T_e$ | is the effective tension (externally applied tension). Te is positive for loads which tend to part the connection | N (lb) |
| $T_{ec}$ | is the pressure end load | N (lb) |
| $p_o$ | is the external pressure | N/mm2 (psi) |
| $p_{int}$ | is the internal pressure | N/mm2 (psi) |
| $D_s$ | is the seal/gasket sealing diameter | mm (in) |

Known values from ISO 13628-7 [5]:

Use a scatter factor of 10% = 0.10.

Wrench: measuring of turn of nut (nearly up to bolt yield, 67%) Stiffness, friction, calibration.

FD = Design factor, from ISO 13628-7. Extreme operation (0,80 Utilization) based on corroded wall thickness at design metal temperature.

From FMC analyses report RPT60020900 [6]:

Bolt root area = 1502 mm$^2$

**Procedure**

1. Collect all known numbers and values.
2. Start by finding minimum contact force between hubs. Based on internal and external loads.
3. Find the preload in each stud based on the hub face separation.

[5] [Ref.5] ISO. (2006). *13628-7:2006*. British Standards
[6] [Ref.3] FMC, Lasse Moldestad. (2007)

| Main Task ID | MT-1 |
|---|---|
| Task Test ID | TT-1-2-T |
| Priority | A |
| Description | Provide recommended torque on nut including range. |
| Result | Accepted |

**Purpose**

Find the recommended torque to apply on the nut. Ensure that the force on the clamp generates enough force between the hubs to give a leakproof connection.

**Equipment**

Pen and paper.

Advanced calculator.

Computer.

**Formulas**

The material used in the stud is essential for the preload applied:

Material used: ASTM A453/A453M.

Yield capacity: 724 MPa. (1100kN).

Tensile strength: 896 MPa. (1330kN).

## Stud tension capacities:[7]

The minimum yield capacity of a stud is calculated by:

$$T_{y\,min,s} = \sigma_{y\,min,s} \times A_r$$

where

$T_{y\,min,s}$ = minimum yield capacity of stud.

$\sigma_{y\,min,s}$ = minimum yield strength of stud material.

$A_r$ = root area of stud.

The minimum tensile capacity of a stud:

$$T_{u\,min,s} = \sigma_{u\,min,s} \times A_s$$

where

$T_{u\,min,s}$ = minimum ultimate tensile capacity of stud.

$\sigma_{u\,min,s}$ = minimum ultimate tensile strength of stud material.

$A_s$ = stress area of stud.

The maximum ultimate tensile capacity of stud is calculated as:

$$T_{u\,max,s} = \sigma_{u\,max,s} \times A_s$$

where

$T_{u\,max,s}$ = maximum ultimate tensile capacity of stud.

$\sigma_{u\,max,s}$ = maximum ultimate tensile strength of stud material.

$A_s$ = stress area of stud.

[7] [Ref.6] (Statoil, Finn Kirkemo, 2010, p. 13)

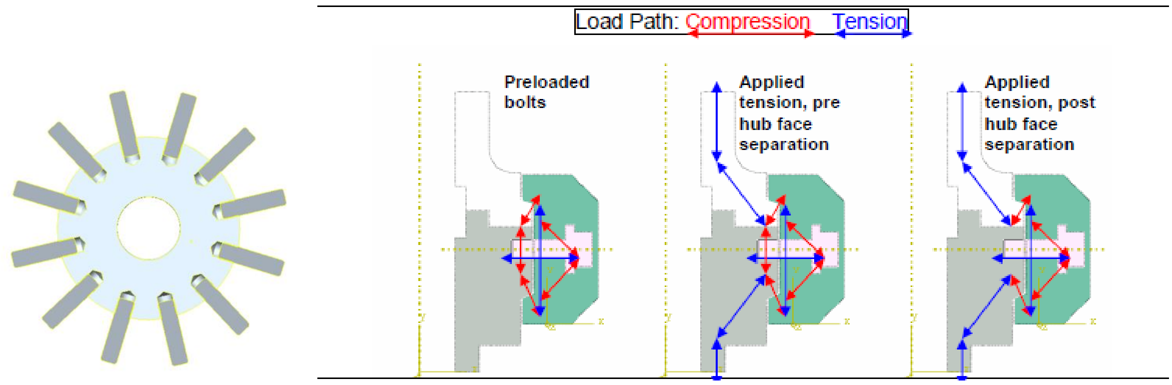



*Figure 1: Speedloc-II Segment Clamp*

The total clamp force is given by the number of studs(Left picture).

[8] Clamp force: $F_{tot} = \frac{Fboltx12stk}{(2 \times tan25°)}$

Tension capacity with respect to 0.1 scatter factor:

[9] $T_{scatter} = (1 - 0.1) \times T_{Yield}$

Preload-Torque applied:

- [10] See TNS/FONAS. Page: 10-12.

---

[8] [Ref.3] (FMC, Lasse Moldestad, 2007, p.19)
[9] [Ref.5] (ISO, 2006, p 226 (§G.1))
[10][Ref.4] Fonas. (1972)

## Procedure

1. Do necessary calculations on the stud geometry.

- Bolt root.
- Thread pitch.
- Minor and pitch diameter.

2. Find stud preload based on yield.

3. Calculate torque friction coefficient.

4. Find recommended torque.

5. Conclusion.

## Acceptance Criteria

The recommended torque is provided with upper and lower limits.

| Main Task ID | MT-3 |
|---|---|
| Task Test ID | TT-3-1-T |
| Priority | B |
| Description | Identify all variables affecting torque on nut and preload in stud. Make a list. |
| Result | Accepted |

**Purpose**

Identify all variables affecting preload on stud. Make a list.

**Equipment**

Computer.

**Aids**

- [11]Scatter factor: (ISO 13628-7, Annex G.1).
- [12]RPT60020900. (FMC, Lasse Moldestad, 2007)
- [13]TNS/FONAS. (Fonas, 1972)
- [14]Maskindeler 2. Åge Ø. Waløen. (Waløen, 1976)
- [15]ASME B1.1-2003 (Unified Inch Screw Threads).

[11] [Ref.5] ISO. (2006). *13628-7:2006.* British Standards.
[12] [Ref.3] FMC, Lasse Moldestad. (2007). *RPT60020900.* Kongsberg: FMC.
[13] [Ref.4] Fonas. (1972). *Skrue håndbok.* Oslo: Elkem-Spigerverket A/S.
[14] [Ref.7] Waløen, Å. Ø. (1976). *Maskindeler 2.* Tapir.
[15] [Ref.1] ASME. (2001). *ASME B1.1-2003.* The American Society Of Mechanical Engineers.

| Main Task ID | MT-3 |
|---|---|
| Task Test ID | TT-3-2-T |
| Priority | B |
| Description | Investigate variables affecting torque on nut and preload in stud. |
| Result | Accepted |

**Purpose**

Investigate variables affecting torque on nut and preload in stud.

**Equipment**

Pen and paper.

Advanced calculator.

Computer.

**Aids**

- [16]An Introduction to the design and behavior of bolted joints: Chapter 2
  D. Stress Areas-Metric Threads.
  E. Strength of the bolt under static loads.
- [17]TNS/FONAS. (Fonas, 1972)
- [18]Maskindeler 2. (Waløen, 1976)
- [19]ISO 13628-7 (Annex G). (ISO, 2006)
- [20]ASME B1.1-2003. (ASME, 2001)

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[16] [Ref.8] John H. Bickford. *An introduction to the design and behavior of bolted joints. Second edition.*
[17] [Ref.4] Fonas. (1972). *Skrue håndbok.* Oslo: Elkem-Spigerverket A/S.
[18] [Ref.7] Waløen, Å. Ø. (1976). *Maskindeler 2.* Tapir.
[19] [Ref.5] ISO. (2006). *13628-7:2006.* British Standards.
[20] [Ref.1] ASME. (2001). *ASME B1.1-2003.* The American Society Of Mechanical Engineers.

# Practical test Document

| | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 2.0 |
| | |
| **SCS Group members** | Asbjørn Antonsen,<br>Project leader and construction<br>Initial: AA |
| | Bjørn Ledaal Rossavik,<br>Qualification and specification<br>Initial: BR |
| | Erlend Berg-Olsen,<br>System Engineer and Project planner<br>Initial: EBO |
| | Espen Hansen,<br>Test and Verification<br>Initial: EH |
| | |

# Summary

This document contains all practical test that SCS shall preform in Solidworks with FEM analyzes. There are guidelines in every test on how to preform and execute it

TechnipFMC have done all their analyzes in ABACUS. They mean it can be interesting to see how it performs in other analyze tool, like Solidworks.

| **Practical tests** | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Date** |
| • TT-1-1-Pr | Find necessary force between hubs with FEM analysis. | A | TechnipFMC | 31/1 |
| • TT-2-1-Pr | Investigate values on bolt vs stud used from PRD-0000021662 will behave. | C | SCS | 1/3 |
| • TT-5-1-Pr | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | 31/1 |
| • TT-6-Pr | Reproduce analysis done by FMC in SW and compare results. | C | TechnipFMC | 31/1 |

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 03.03.2017 | 9 | BR | Created document, filled in information and made template for task. Filled in TT-1-1- pr. |
| V.0.2 | 08.03.2017 | 15 | BR | Updated TT-6-pr. |
| V.0.3 | 09.03.2017 | 15 | AA | Updated TT-1-1-Pr |
| V.0.4 | 09.03.2017 | 17 | EBO | Updated TT-2-1-Pr |
| V.0.5 | 15.03.2017 | 17 | BR | Updated every test with new structure, spellcheck and filled in more information about every test. |
| V.0.6 | 16.03.2017 | 17 | BR | Updated information in introduction chapter. Updated TT-1-1-Pr |
| V.07 | 20.03.2017 | 19 | BR | Added TT-5-1-Pr.<br>Spellcheck and structure update. |
| V.0.8 | 20.03.2017 | 20 | AA | Added figure and table contents list. Spell check. |
| V.1.0 | 20.03.2017 | 20 | AA, BR, EH, EBO | Spellcheck and structure check. |
| V.1.1 | 21.04.2017 | 20 | EBO | References updated after APA standards. |
| V.2.0 | 22.05.2017 | 21 | SCS | Ready for last hand in. |

# References


[ref.1] FMC, Lasse Moldestad. (2007). *RPT60020900.* Kongsberg: FMC.
[ref.2[ISO. (2006). *13628-7:2006.* British Standards.

# Abbreviations and technical words

| Abbreviation | Explanation |
| --- | --- |
| WOR | Workover Riser |
| SL | Speedloc |
| ISO | International Standardization organization |
| DNV | Det Norske Veritas |
| UP | Unified process |
| SCS | Subsea Connection System |
| HSN | Høgskolen i Sør-Øst Norge |

| Technical Words | Explanation |
| --- | --- |
| Friction | The force resisting the relative motion of solid surfaces, fluid layers and material elements sliding against each other. There are several types of friction. |
| Stud | Threaded rod similar to a bolt but it has no bolt head. |
| Nut | A nut is a fastener with a threaded hole. |

# Contents



## Tables



## Figures

# 1. Introduction

This document contains practical tests for SCS.

**Every test will include an information table:**

**Task Test ID** Unique ID number for each test. In that way, we can identify each task separately and have good traceability within the documents.
Task and test ID will be referred to on timesheet, analyze report etc.

TT-1 – Short for Task Test 1.

**Main Task ID number** is direct linked to project specification document, and is unique for every task. *See chapter 2.4 in Project specification V.1.0 for more information.*

**Description** gives a short explanation about the test.

**Priority** is categories as showed here:

| | |
|---|---|
| A | Absolute |
| B | Important |
| C | Desirable |

**Result**, what is status quo after testing. SCS divide the results into 3 different categories.

| | |
|---|---|
| Accepted | Criteria and verification is accepted |
| Uncertain, need more information | SCS are not sure about the result, and need to investigate and run more test on this requirement |
| Not accepted | Criteria and verification is **not** accepted |

**Date** is when the test is complete.

**Every test will include these topics:**

**Purpose**: Briefly describe the purpose of the task to be performed.

**Equipment**: Note any special equipment required.

**Preparation:** List steps necessary to prepare for the task.

**Procedure:** List actual steps in the procedure here, instructions.

**Pictures:** Pictures used to give a better understanding of the test.

**AIDS**: List aids like technical papers, documents used.

**Acceptance Criteria:** Document the acceptance criteria that will indicate that the test is passed.

# 2. Practical Test list

| Practical tests | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Date** |
| • TT-1-1-Pr | Find necessary force between hubs with FEM analysis. | A | TechnipFMC | 31/1 |
| • TT-2-1-Pr | Investigate values on bolt vs stud used from PRD-0000021662 will behave. | C | SCS | 1/3 |
| • TT-5-1-Pr | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | 31/1 |
| • TT-6-Pr | Reproduce analysis done by FMC in SW and compare results. | C | TechnipFMC | 31/1 |

*Table 1: Practical test list*

# 3. Practical Test

| Main Task ID | MT-1 |
| --- | --- |
| Task Test ID | TT-1-1-Pr |
| Priority | A |
| Description | Find necessary force between hubs with FEM analysis. |
| Result | TBA |
| Date | TBA |

**Purpose**

Determine force between hubs by practical testing.

**Equipment required**

- Computer.
- Solid works software
- Drawings of SL connector:

**Preparation**

- Make sure STP file and updated Solid works version are in place.
- Make sure the STP files are compatible with solid works.
- Read through TT-1-1-T, to get a better understanding on the internal and external forces.
- Find correct stud and nut in Solid works toolbox to use in analyze.

**Procedure**

1. Material data is set to 20 °C.
2. Use same mesh as in ref [1].
3. Use hexahedral, 8-noded elements (C3D8) were used.
4. Set friction coefficient to 0.15.
5. Scatter factor is set to 0.1.
6. Import and assemble all the parts in Solid works.
7. Assign proper material specifications to each part.
8. Use loads and forces from TT-1-1-T.
9. Fixtures and constraints as in TT-6-Pr.
10. Run FEM analyze.

N.B. Use practical test TT-6-Pr pictures to run this test.

**Pictures:**

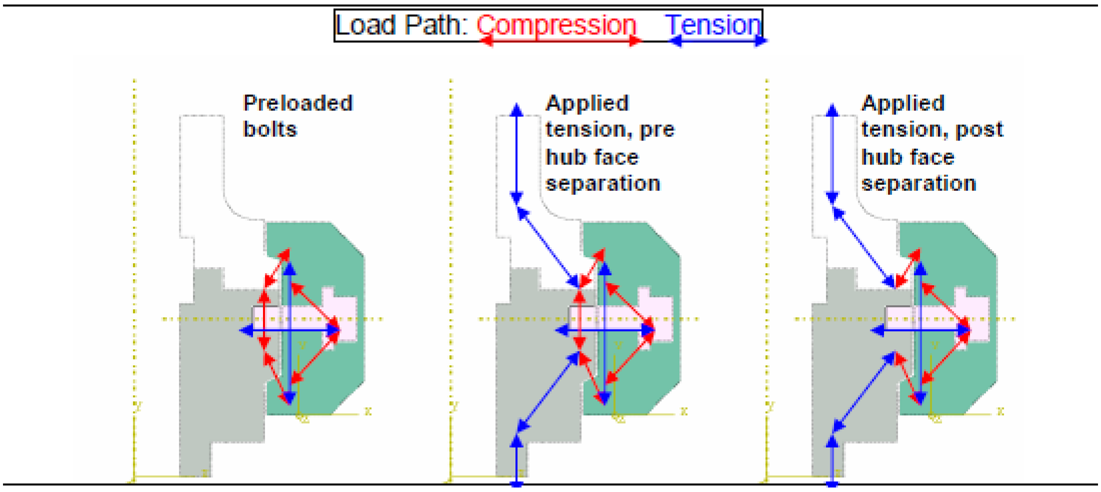



*Figure 1: Load path*

This picture shows the load path before and after face separation.

**Aids**

- TT-1-1-T (Theoretical task Document).

**Acceptance Criteria**

Force necessary between hubs are found.

| Test Team Members + roles |
|---|
| Name |
| |
| |
| |
| Test Completion Sign Off |
| *This test has been performed to the best of SCS ability per the requirements of the procedure. Deviations or problems encountered have been noted at the end of the test form.* |
| Signature, date and time |
| Comments and Notes |

| Main Task ID | MT-2 |
|---|---|
| Task Test ID | TT-2-1-Pr |
| Priority | C |
| Description | Investigate values from PRD-0000021662 on bolt vs stud. |
| Result | TBA |
| Date | TBA |

**Purpose**

In TechnipFMC report it is designed in ABAQUS with a bolt, and not a stud and nut.

Investigate the difference between stud with nut and bolt in Solid works. Take a closer look at where they will be ripped apart under pressure, and how they will influence the results on the speedloc.

**Equipment required**

- Computer.
- Solid works software.
- Drawings of the SL connector

**Procedure**

1. Material data is set to 20 °C.
2. Use same mesh as in TechnipFMC report RPT60020900.*see ref [1] (FMC, Lasse Moldestad, 2007)*
3. Use hexahedral, 8-noded elements (C3D8) were used.
4. Set friction coefficient to 0.15.
5. Scatter factor is set to 0.1.
6. Assign proper material specifications to each part.
7. Set correct calculated tension up against the nut.
8. Run individual FEM analysis, one with stud and one with bolt.

N.B. Use practical test TT-6-Pr pictures to run this test.

**Acceptance Criteria**

All values used in report RPT60020900 from TechnipFMC are found.

With FEM analysis, see where the forces will arise.

| Test Team Members + roles |
|---|
| Name |
| |
| |
| |
| Test Completion Sign Off |
| *This test has been performed to the best of SCS ability per the requirements of the procedure. Deviations or problems encountered have been noted at the end of the test form.* |
| Signature, date and time |
| Comments and Notes |

| Main Task ID | MT-5 |
|---|---|
| Task Test ID | TT-5-1-Pr |
| Priority | C |
| Description | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. |
| Result | TBA |
| Date | TBA |

**Purpose**

Find tension and bending moment capacity with FEM analyses, with friction included.

Use two different internal pressures, 10KSI and 20KSI. TechnipFMC want to know capacity with both pressures.

**Equipment required**

- Computer.
- Solid works software.
- Drawings of the SL connector

**Procedure**

1. Material data is set to 20 °C.
2. Use same mesh as in *ref [1].*
3. Use hexahedral, 8-noded elements (C3D8) were used.
4. Set friction coefficient to 0.15.
5. Scatter factor is set to 0.1.
6. Assign proper material specifications to each part.
7. Set correct calculated tension up against the nut.
8. Run FEM analysis.

N.B. Use practical test TT-6-Pr pictures to run this test.

## Acceptance Criteria

Tension and bending moment capacity are found, with an internal pressure on 10KSI and 20KSI.

| Test Team Members + roles |
| --- |
| Name |
| |
| |
| |
| Test Completion Sign Off |
| *This test has been performed to the best of SCS ability per the requirements of the procedure. Deviations or problems encountered have been noted at the end of the test form.* |
| Signature, date and time |
| Comments and Notes |

| Main Task ID | MT-6 |
|---|---|
| Task Test ID | TT-6-Pr |
| Priority | B |
| Description | Reproduce analysis done by FMC in SW and compare results. |
| Result | TBA |
| Date | TBA |

**Purpose**

In document RPT60020900 *(see ref [1])* from TechnipFMC, there has been done a FEM analyses in ABAQUS Ver.6.6.1.

SCS and TechnipFMC want to see if there is any difference when the same analyses are done in Solid works, with the exact same values, boundary, forces etc.

**Equipment required**

- Computer.
- Solid works software.
- Drawings of SL connector.

**Preparation**

1. Secure that STP file is in place, and can be analyzed in Solid works.
2. Make sure that the computer used under analyses, has good enough specifications to complete the analyses.
3. Check that Solid works has the settings needed to copy the analyze from ABAQUS.

**Procedure**

1. Material data is set to 20 °C
2. Use same mesh as in ABAQUS.
3. Use hexahedral, 8-noded elements (C3D8) were used.
4. Set friction coefficient to 0.15.
5. Scatter factor is set to 0.1.
6. Assign proper material specifications to each part.

Follow these 4 steps for analyzing.

- In the first step, extensive constraints are defined for the parts while a small bolt preload of 100N is applied in order to achieve stable contact on the mating surfaces.
- In the second step the preload is completed.
- In the third step the constraints are relaxed and the preload definition is fixed at the current displacement.
- In the fourth step the load is applied. Tensile force is applied for the tensile capacity analysis and bending moment for the bending moment capacity analysis.

**Picture:**

From TechnipFMC analyze runned in ABAQUS. (see ref [1])

Mesh:

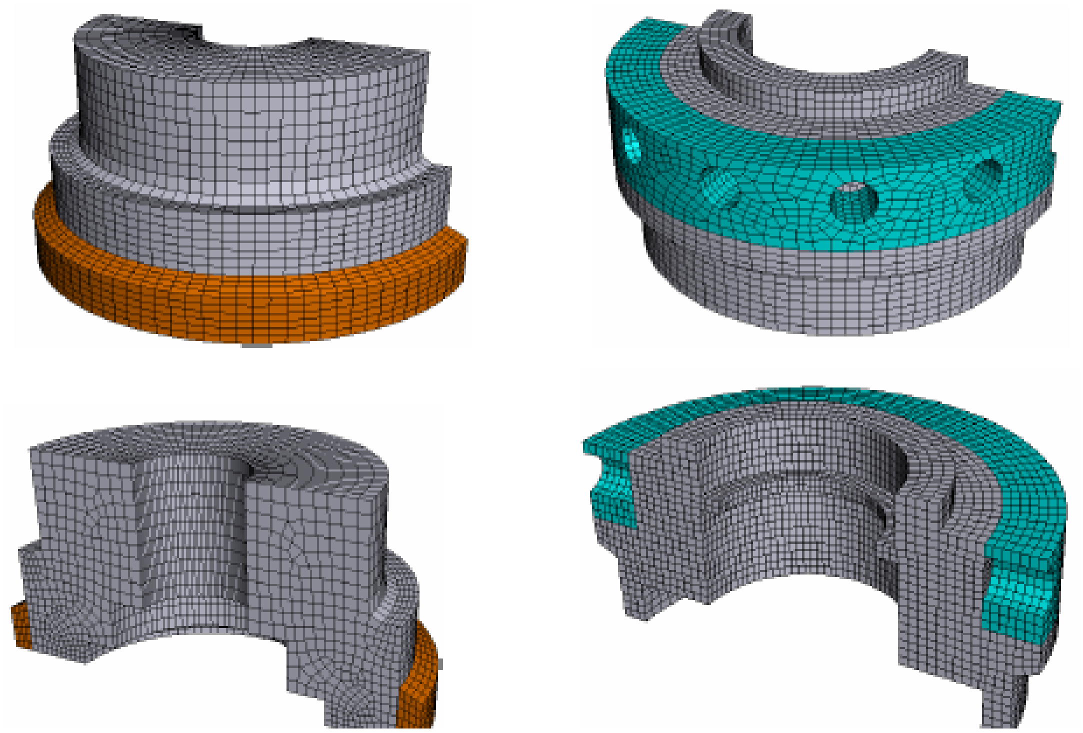


*Figure 2: Over all mesh quality needed*

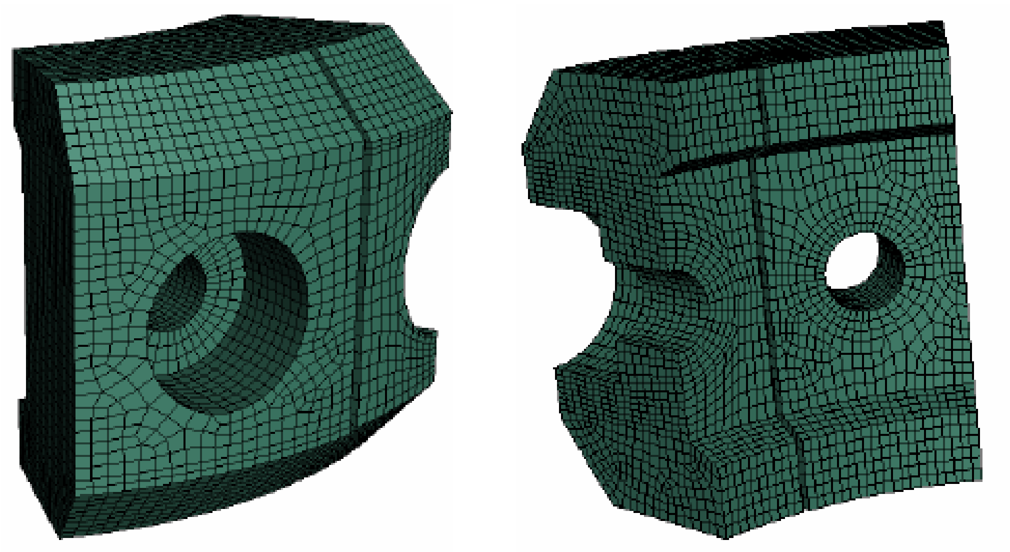


*Figure 3: Mesh quality circle and hole*

Boundary

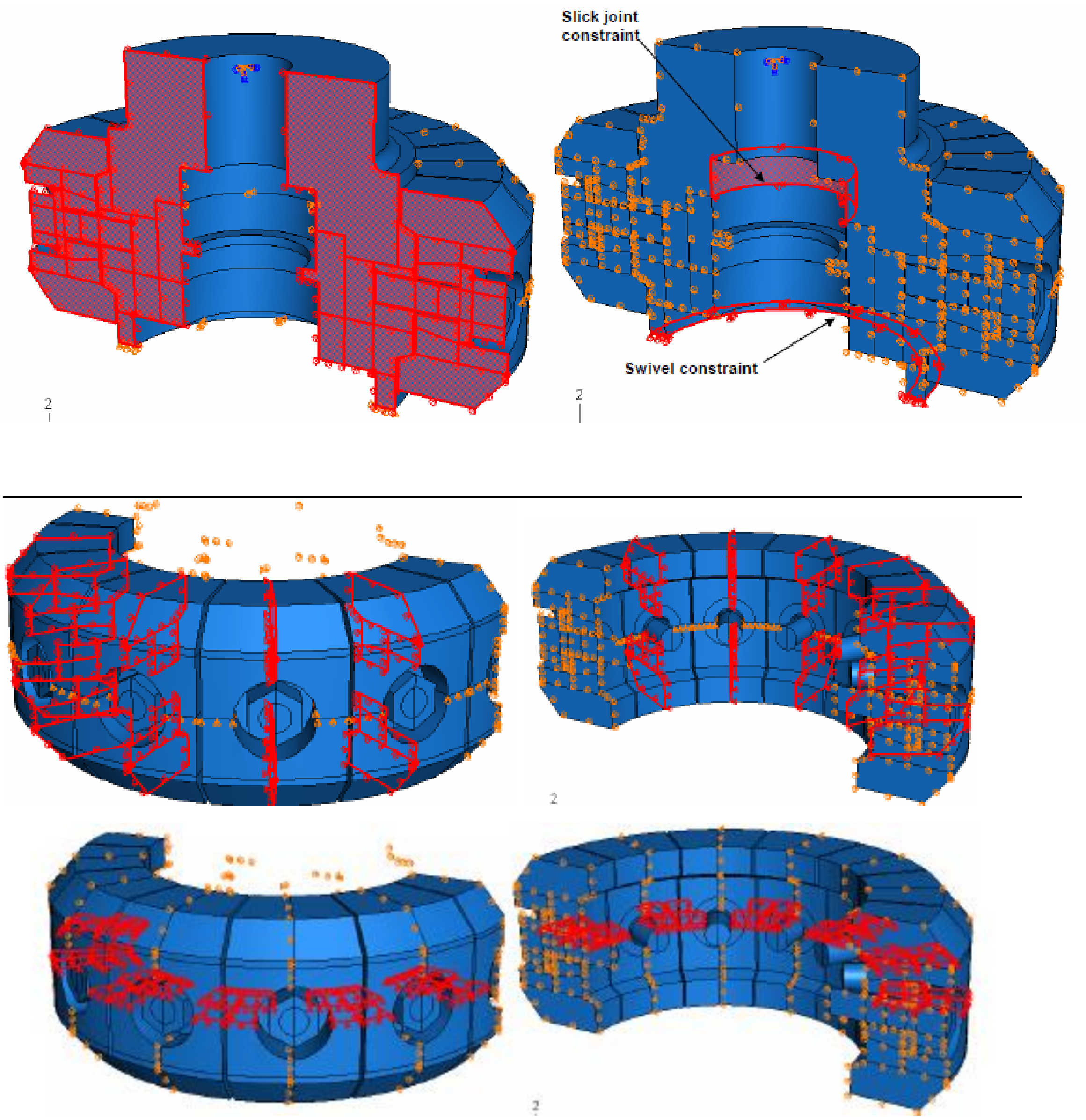



*Figure 4: Boundary conditions*

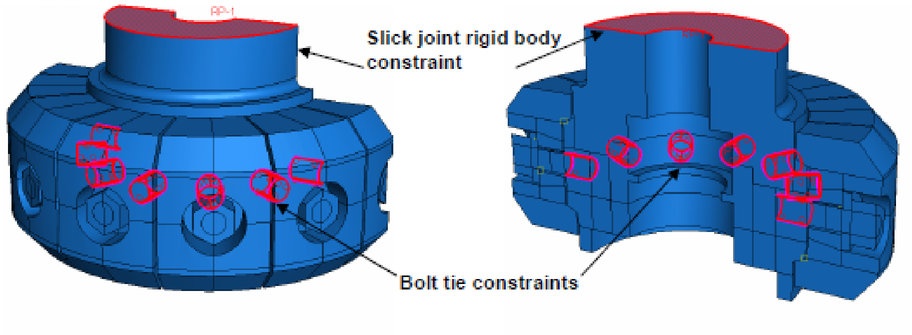



Figure 5: Rigid body constraints

## Interaction surface

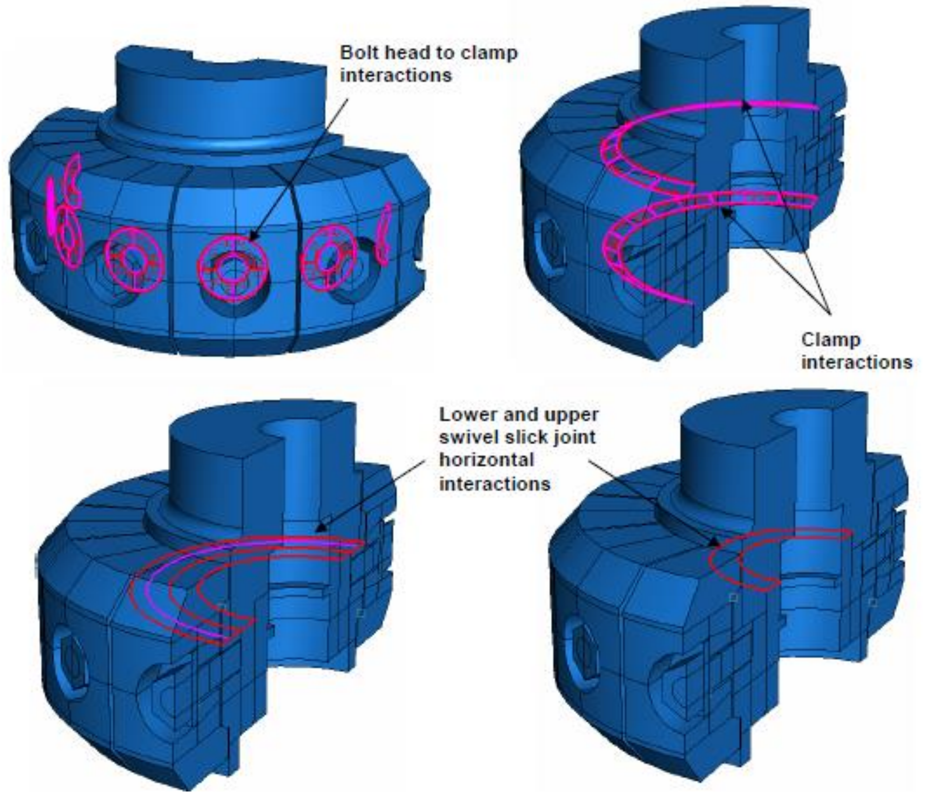



Figure 6: Surface interactions.

Loads applied

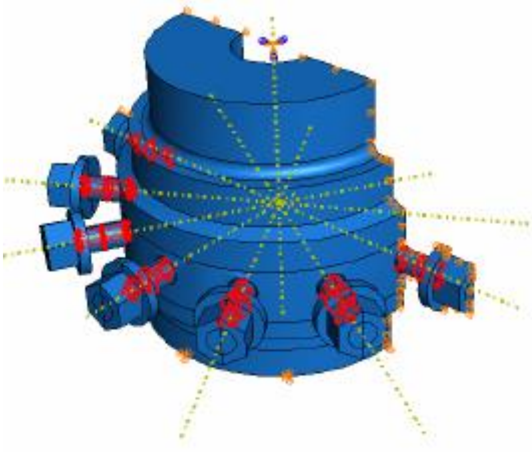


*Figure 7: Applied loads*

In the first step the bolts are applied a small preload force of 1kN each (0.5kN on the half bolts). The loads are applied as ABAQUS bolt loads and the cross-section areas of the bolts and the bolt axes to which they are applied can be seen in these pictures. In the second step the full preload is applied to each bolt.

**Acceptance Criteria**

When all boundaries, forces, nodes and mesh are analyzed the same way as in ABAQUS.

| Test Team Members + roles |
| --- |
| Name |
| |
| |
| |
| Test Completion Sign Off |
| *This test has been performed to the best of SCS ability per the requirements of the procedure. Deviations or problems encountered have been noted at the end of the test form.* |
| Signature, date and time |
| Comments and Notes |

# Mechanical Test Document

| | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 2.0 |
| | |
| **SCS<br>Group members** | Asbjørn Antonsen,<br>Project leader and construction<br>Initial: AA |
| | Bjørn Ledaal Rossavik,<br>Qualification and specification<br>Initial: BR |
| | Erlend Berg-Olsen,<br>System Engineer and Project planner<br>Initial: EBO |
| | Espen Hansen,<br>Test and Verification<br>Initial: EH |
| | |

# Summary

This document contains all the mechanical test and the procedures for performance.

| Mechanical tests | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Date** |
| - TT-1-2A-M | Do a tensile strength test of the material used in stud. | A | TechnipFMC | 31/1 |
| - TT-1-2B-M | Test recommended pretension on nut including range. | A | TechnipFMC | 31/1 |
| - TT-2-1A-M | Investigate torque, fraction and elongation in bolt vs stud. | C | TechnipFMC | 31/1 |
| - TT-2-1B-M | Investigate fraction in bolt vs stud. | C | TechnipFMC | 31/1 |

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 22.02.2017 | 5 | BR | Created document, filled in information and procedure template. |
| V.0.2 | 24.02.2017 | 13 | BR, AA & EBO | Updated document with TT-1-1-M, TT-2-M A & B and TT-4-1-M |
| V.0.3 | 01.03.2017 | 18 | EH, AA & BR | Updated document with TT-3-2-M, TT-2-1-M-A, TT-2-1-M-B and introduction. |
| V.0.4 | 02.03.2017 | 18 | BR | Updated document with TT-1-1-M and scale-down chapter. |
| V.0.5 | 07.03.2017 | 18 | EH | Updated TT-3-2-M. |
| V.0.6 | 08.03.2017 | 23 | EH | Updated TT-3-2-M. Inserted new test: TT-1-2A-M. Changed name on test TT-2-1-M-A to TT-2-1A-M. Inserted table and figure list. |
| V.0.7 | 09.03.2017 | 23 | AA | Updated TT-4-1-M |
| V.0.8 | 09.03.2017 | 23 | EBO | Updated TT-3-2-M, Orthography, pictures |
| V.0.9 | 09.03.2017 | 25 | BR | Updated Scale-down chapter. |
| V.0.9.1 | 14.03.2017 | | BR, AA and EH | Updated structure on all tests. Added temperature on TT-3-2-M. Added TT-2-1B-M. Removed TT-4-1-M |
| V.0.9.2 | 15.03.2017 | 26 | AA | Updated content and topics of each test. |
| V.0.9.3 | 16.03.2017 | 26 | AA | Updated test procedure and topics of each test |
| | | | | Spellcheck. Updated main chapter, topics, introduction, scale down. Added Chapter 5, SCS Load cell. |

| | | | | |
|---|---|---|---|---|
| V.0.9.4 | 16.03.2017 | 29 | BR | Updated every task with more information.<br>Filled in table for testing on TT-3-2-M. |
| V.0.9.5 | 17.03.2017 | 30 | BR & EBO | Updated document with full-size stud on TT-3-2-M. |
| V.0.9.6 | 20.03.2017 | 30 | EH | Updated TT-1-2A-M and TT-3-2-M after changes in requirements. Table and figure list. |
| V.1.0 | 20.03.2017 | 30 | AA, BR, EBO, EH | Structure and spellcheck. |
| V.1.1 | 21.04.2017 | 30 | EBO | Updated references after APA standards. |
| V.1.2 | 04.05.2017 | 32 | EH | Updated TT-1-1-M (test piece dimension), TT-1-2B-M and TT-3-2-M. |
| V.1.3 | 09.05.2017 | 33 | EH | Updated TT-1-2B-M, TT-2-1A-M, TT-2-1B-M and TT-3-2-M. |
| V.1.4 | 10.05.2017 | 35 | AA, EH | Updated test spec TT-1-2B-M<br>Updated task test ID |
| V.1.5 | 11.05.2017 | 31 | BR | Orthography. Updated TT-1-2B-M.<br>Removed TT-3-2-M. Updated figure list. |
| V.1.6 | 20.05.2017 | 32 | BR | Updated contents and introduction. |
| V.2.0 | 24.05.2017 | 36 | SCS | Ready for last hand in. |

# Abbreviations and technical words

| Abbreviation | Explanation |
|---|---|
| WOR | Workover Riser |
| SL | Speedloc |
| ISO | International Standardization organization |
| DNV | Det Norske Veritas |
| UP | Unified process |
| SCS | Subsea Connection System |
| HSN | Høgskolen i Sør-Øst Norge |

| Technical Words | Explanation |
|---|---|
| Friction | The force resisting the relative motion of solid surfaces, fluid layers and material elements sliding against each other. There are several types of friction. |
| Stud | Threaded rod similar to a bolt but it has no bolt head. |
| Nut | A nut is a fastener with a threaded hole. |

# Appendix list

[Apx.D] SCS torque table

[Apx.F] SJA-document for mechanical testing.

[Apx.E] HSE-document.

[Apx.H] Material certificate on stud and nut. Doc no: MTL01298 (Jørn Kleven, FMC)

Contact Einar Totland for information regarding references from TechnipFMC.

# References


[ref.1] Assembly procedure for Speedloc II Segment Clamp: ASY60067114.pdf (FMC, Sveinung Eriksrud, 2016).


Contact Einar Totland for information regarding references from TechnipFMC.

TechnipFMC

Subsea Connection System

# Contents



# Tables



# Figures

# 1. Introduction

This document contains mechanical tests for SCS.

**Every test will include their own information table:**

**Main Task ID** is direct linked to project specification document, and is unique for every task.

**Task Test ID** Unique ID number for each test. In that way, identifying each task separately and good traceability within the documents is possible.

Test ID will be referred to on timesheet and Gantt, analyses report etc.

TT-1: Short for Task Test -1.

**Priority** is categories as showed here:

| | |
|---|---|
| A | Absolute |
| B | Important |
| C | Desirable |

**Short description** gives a short explanation about the test.

**Result**, what is status quo after testing. SCS divide the results into 3 different categories:

| | |
|---|---|
| Accepted | Criteria and verification is accepted |
| Uncertain, need more information | SCS are not sure about the result, and need to investigate and run more test on this requirement |
| Not accepted | Criteria and verification is **not** accepted |

**Each test will include these topics:**

**Purpose:** Briefly describes the purpose of the test to be performed.

**Location**: Location where the test is executed.

**Equipment and tools required:** List off all equipment and tools required to perform the test.

**Preparations:** This is a list of preparations that need to be done before the test can start.

**Precautions:** Document any precautions that need to be taken before, during, or after the test.

**Procedure:** List actual steps in the procedure here, instructions.

**Pictures:** Pictures of tools, steps and procedures needed will be found here.

**Appendix**

Lists documents needed to perform the test.

**Aids:** List technical papers, CTPL library tests and other information that might be useful as supporting information for the test team.

**Acceptance Criteria:** Document the acceptance criteria that will indicate that the test was passed.

# 2. Scale-down for testing

Because of the forces, equipment and budget, SCS aim to scale down the tests where it is required. This is because full scale tests are expensive and may be difficult to perform at HSN workshop.

Scaling down the test and mechanical properties is a very important part, and SCS have had focus on this from the beginning. To get similar and comparable results to an original full-scale test, they have tried to use all the same calculations and assumption used if it was a full-scale test.

SCS has done a lot of research regarding to scale-down. There is one main formula to guide through this scale-down process. $\sigma_{YS} = \frac{\mathrm{F}}{\mathrm{A}}$

$\sigma_{YS}$ in this equation are representing yield point.

Yield point or Yield Strength, is where the material goes from an elastic deformation, to a plastic deformation.

Short explained: Elastic deformation is a deformation where the material goes back to the normal condition, with no permeant deformation. Plastic deformation is a permeant deformation.

Elastic deformation is acceptable over a short period of time, but plastic deformation is not acceptable.

This is all determined with a stress-strain curve.

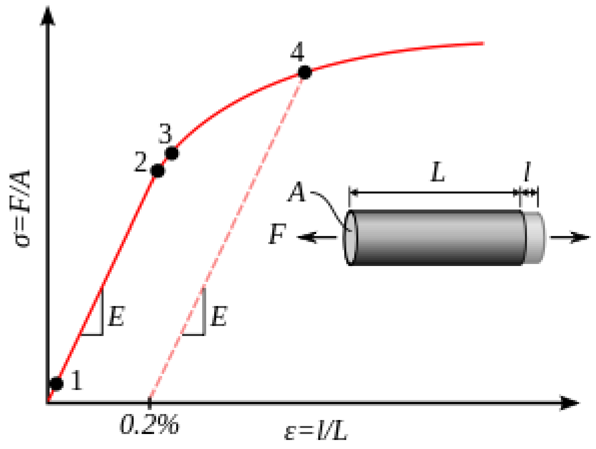



*Figure 1: Stress and strain curve*

**1.** True elastic limit. **2.** Proportionality limit. **3.** Yield point. **4.** Tensile point.

The stud from TechnipFMC have these specifications: Yield strength on 724 MPa and Tensile strength on 895 MPa.

SCS then go on and use the formula explained earlier. $\sigma_{YS} = \frac{\mathrm{F}}{\mathrm{A}}$

$\sigma_{YS}$ = 724 MPa. F= 1088950 N. A = 1485,24mm$^2$

$A = \frac{\pi}{4} x (D_b - 1{,}3xLpitch)^2$

All values in area formula will be the same as in full-scale. But, $D_b$ will be changed.

$D_b$ is the outer diameter on the bolt. In full-scale it is 1,875". To calculate it over to mm. $D_b$ = 1,875*25,4 mm. $D_b$ = 47,625 mm.

Scale down to a manageable size. Scale 1:4 is manageable. $\frac{Db}{4}$

Db 1:4 = 11,91 mm. Goes up to nearest standard inch, ½ inch bolt/stud.

$\sigma_{YS}$ must have the same value, 725 MPa. Because we use the exact same material.

We now get a new area. $A = \frac{\pi}{4} x \left(\frac{1}{2} x25{,}4 - 1{,}22687x25{,}4/13\right)^2$ = 83,37 mm$^2$

The new force will then be: $F = \sigma_{YS} xA$ => 724*83,37 = 60359,9 N.

SCS will use ½ inch stud/bolt and nut when doing a mechanical scaled downed test.

New force to simulate the original full-size force will be 60359,9 N.

$\sigma_{YS}$ are constant, 724MPa.

# 3. Mechanical tests

| Main Task ID | MT-1 |
|---|---|
| Task Test ID | TT-1-2A-M |
| Priority | A |
| Description | Do a tensile strength test of the material used in stud. |
| Result | Not accepted |

**Purpose**

Checking and verify the material behavior under a tensile strength test. This test cover the tension of metallic materials in any form at room temperature, specifically; the methods of determination of yield strength, yield point elongation, tensile strength and reduction of area.

**Location**

HSN-Kongsberg.

**Equipment and tools required**

- Material used in stud: ASTM A453/A453M.
- Cutting saw with cooling.
- Calibrated caliper.
- Tinius Olsen tension test machine.

**Preparation**

- Cut the metal into 10mm$^2$ or 30mm$^2$ pieces so it fits the tension machine.
- Cut the piece on both sides of the centerline in the vertical plane.

**Precaution**

- Test performers must have had training to use the tension tester and cutting saw.

**Procedure for mechanical test**

| **Procedure for tension test of stud material ASTM A453/A453M.** | | **Test no: 1** | **ID: TT-1-2A-M** |
|---|---|---|---|
| **Test procedure** | | | |
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **1** | Checking all equipment before use. | | |
| **1.1** | Mounting the metal piece in the tension tester. | | |
| **1.2** | Run the test with three samples. | | |
| **1.3** | Analyze the results. | | |

Material specification from TechnipFMC M36101 (FMC, Bent Orerød, 2016, p. 3)[1]: This test is to verify the mechanical properties in this table.

Table 2: Mechanical Properties. (All values are minimums unless otherwise noted.)

| | |
|---|---|
| Tensile Strength | 130,000 psi (895 MPa) |
| Yield Strength | 105,000 psi (725 MPa) |
| Elongation in 2", 4D or 5D | 15% |
| Reduction of Area | 18% |
| Rockwell Hardness | 24-35 HRC |
| Brinell Hardness | 248-321 HBW |
| NOTE: Stress rupture testing per ASTM A453/A453M is NOT required for fasteners that will be used in service temperatures of below 800°F | |

*Table 1: Mechanical Properties of stud material*

[1] [Apx.1]

Formulas for finding elongation, yield and tensile strength:

Elongation: $\varepsilon = \frac{\Delta L}{L_0}$ ( $\Delta L = change\ in\ gauge\ length, L_0 = initial\ gauge\ length$).

Tension: Yield/tensile: $\sigma = \frac{F}{A}$ ($F = tensile\ force, A = nominal\ cross\ section\ of\ the\ specimen$).

Tension tester capacity is 10,000N and 35,000N.

For the smallest tester, use a test piece on max $10mm^2$.

For the biggest tester, use a test piece on max $30mm^2$.

$$F_{10000N} = \sigma_T * A = 896MPa * 10mm^2 = 8960N$$

$$F_{35000N} = \sigma_T * A = 896MPa * 30mm^2 = 26880N$$

## Pictures

Figure 3: Cutting saw with cooling at HSN-Kongsberg

Figure 2: Tension machine at HSN-Kongsberg

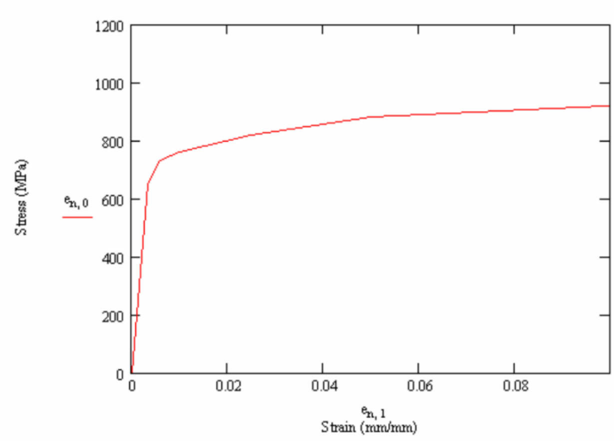



Figure 4: Stress and strain curve for stud material

.

**Acceptance criteria**

- A material behavior-curve shall be found under the tensile test. Maximum elongation, yield strength, ultimate tensile strength and reduction area.

| Test Team Members + roles |
|---|
| Name |
| |
| |
| |
| Test Completion Sign Off |
| *This test has been performed to the best of SCS ability per the requirements of the procedure. Deviations or problems encountered have been noted at the end of the test form.* |
| Signature, date and time |
| Comments and Notes<br>Did not finish this test because we didn't have the correct cutting tool. The Machined stud didn't fit the saw. The cutting was impossible. |

| Main Task ID | MT-1 |
|---|---|
| Task Test ID | TT-1-2B-M |
| Priority | A |
| Description | Test recommended pretension on nut including range. |
| Result | Accepted |

**Purpose**

Identify optimum pretension torque by applying increasingly higher torque until the optimum pre-load is measured in the stud.

**Location**

- Workshop at TechnipFMC.

**Equipment and tools required**

| Description | Part number / Batch | Check {X} |
|---|---|---|
| 4 pieces of machined studs 1.875", with Xylan coating. Machined to make place for strain gauges. | BST S-132186 L7S | X |
| 12 pieces of 1.875" studs, with Xylan coating. | BST S-132186 L7S | X |
| (Old) 15 pieces of 1.875" nut, with Xylan coating<br>(New) 1 piece of 1.875" nut, with Xylan coating | BST S-132176 7BL (Old)<br>BST S-126413 7BL (New) | X |
| (Old) 15 pieces of 1.875" washers, with Xylan coating<br>(New) 1 piece of 1.875" washer, with Xylan coating | BST S-132187 4130 (Old)<br>BST S-126397 4130 (New) | X |
| 16 SL 215 Clamps | PN P6000072423/E SN 5393-3 | X |
| Test-cap: Speedloc-II, 215-10K. | P6000120842/B | X |

| | | |
|---|---|---|
| Torque tool: HYTORC, AVANTI 3 M/ FIRKANTDREV | | X |
| Calibration certificate on torque tool. | | X |
| Rrosette. 4 pieces. | | X |
| Strain gauges. 8 pieces. | 812068728 | X |
| Molykote G-rapid plus. | | X |
| Jet-lube. Copper paste. | | X |
| Loctite SF 7063 | | X |
| Data logger for strain gauges | HBM | X |
| Computer program for logging | Catman V4.0.3 | X |
| Camera for documenting purposes | -------------------------------- | X |

**Preparation**

- Book time for testing at TechnipFMC.
- Prepare the workshop for mechanical testing.
- Collect and get all equipment and material required.
- Document serial numbers and material certificate.
- Inspect all hardware for signs of damage.
- Machine down 4 studs. Make ready for strain gauges and mark them with individual ID number.
- 4 studs shall have strain gauges and rosette mounted. Strain gauges shall be mounted in positon 12 and 6 o'clock. The rosette strain gauge shall be centered between two strain gauges.
- Check equipment and tools required list, and make sure all equipment and tools are in place.

**Precautions**

- Make sure the test participants know how to use the equipment (torque tool) and measurement tools (strain gauges).
- Before testing can begin, workshop safety training must be completed.
- The SJA *(see appendix F)* must be filed out and signed by all participants.

| Procedure for identifying optimum pretension torque, by applying increasingly higher torque until the optimum preload is measured in the stud. This value shall be used in test 2. | | Test no: 1<br>With PTFE and Molykote G-rapid plus on stud. | ID:<br>TT-1-2B-M1 |
|---|---|---|---|
| **Test procedure** | | | |
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **1** | Mount the stud into the hub. The stud will now be pointing outward from the hub. | | |
| **1.1** | Preload the stud into the hub, with torque 135Nm (Use two nuts to torque up stud). | | |
| **1.2** | Place the clamp segment around the stud, such that the angled contact surfaces face the hub and are parallel to the contact surfaces of the hub.<br>**Be careful not to damage strain gauges or wires!** | | |
| **1.3** | Once the clamp segment is in place, mount the shoulder screw into the threaded hole in the hub. Each clamp will be supported by the shoulder screw, preventing damage to the stud threads from the clamp segment. (See figure 5 and 6). | | |
| **1.4** | Mount back-out washer and socket screw on clamp segment. (See figure 5 and 6). | | |

| | | | |
|---|---|---|---|
| **1.5** | Apply Molykote G-rapid plus on stud threads, inside the nut and on the nut flange facing the washer. | | |
| **1.6** | Mount washer and nut on stud. Be careful not to damage the threads on the stud. | | |
| **1.7** | Thread the flange nut inwardly on the stud, until all the clamp segments are in contact with the hubs. Further tightening will pull the hubs together. | | |
| **1.8** | Make up the 12 segments without strain gauged studs, to torque as per ASY60067114(see ref [1]) (3434 Nm). | | |
| **1.9** | Torque up the nuts on the 4 studs with strain gauges assembled. Write down the values and torque according to SCS torque table *(see appendix D).* | | |
| **1.10** | Evaluate and record the applied torque value which gives correct and ideal average measured pre-tension in the studs. This value is to be used during test 2. | | |

| Procedure for 15 make-ups and brake outs of the four strain gauged studs using optimum torque found in test 1. | | Test no: 2 With PTFE and Molykote G-rapid plus. | ID: TT-1-2B-M2 |
|---|---|---|---|
| **Test procedure** | | | |
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **2** | Clean and inspect all parts then apply Molykote G-rapid plus on stud threads, inside the nut and on the nut flange facing the washer. | | |
| **2.1** | Make up the 12 segments without strain gauged studs, to the optimum torque obtained in test. | | |
| **2.2** | Apply torque found in test 1 in 3 steps 33%, 66% and 100% | | |
| **2.3** | Log data for the test with sequence number and stud ID number. | | |
| **2.4** | Repeat point 2.2 and 2.3 14 times. SEE POINT 2.5 BEFORE CONTINUING. | | |
| **2.5** | Visually inspect the stud after each new break out. Wipe off Molykote and take photos to document condition of stud and nut after every 5th make-and break. If galling or wear is observed document condition every make-and break out. | | |

| Procedure for identifying optimum pretension torque by applying increasingly higher torque until the optimum preload is measured in the stud. | | Test no: 3<br>With PTFE and copper paste. | ID:<br>TT-1-2B-M3 |
|---|---|---|---|
| **Test procedure** | | | |
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **3** | Dismount segments on the 4 studs with strain gauges, and clean all parts free of Molykote G-rapid plus.<br>Do not dismantle the rest of the SL connector that's already torqued up to spec. ASY60067114<br>(see ref [1]) (3434 Nm) | | |
| **3.1** | Place the clamp segment around the stud, such that the angled contact surfaces face the hub and are parallel to the contact surfaces of the hub.<br>**Be careful not to damage strain gauges or wires!** | | |
| **3.2** | Once the clamp segment is in place, mount the shoulder screw into the threaded hole in the hub. Each clamp will be supported by the shoulder screw, preventing damage to the stud threads from the clamp segment. (See figure 5 and 6). | | |
| **3.3** | Mount back-out washer and socket screw on clamp segment. (See figure 5 and 6). | | |

| | | | |
|---|---|---|---|
| **3.4** | Mount back-out washer and socket screw on clamp segment. (See figure 5 and 6). | | |
| **3.5** | Apply jet-lube kopr-kote on stud threads, inside the nut and on the nut flange facing the washer. | | |
| **3.6** | Mount washer and nut on stud. Be careful not to damage the threads on the stud. | | |
| **3.7** | Thread the flange nut inwardly on the stud, until all the clamp segments are in contact with the hubs. Further tightening will pull the hubs together. | | |
| **3.8** | Make up the 12 segments without strain gauged studs, to torque as per ASY60067114*(see ref [1])* | | |
| **3.9** | Torque up the nuts on the 4 studs with strain gauges assembled. Write down the values and torque according to SCS torque table *(see appendix D)* | | |
| **3.10** | Evaluate and record the applied torque value which gives correct and ideal average measured pre-tension in the studs. This value is to be used during test 4. | | |

| Procedure for 15 make-ups and brake outs of the four strain gauged studs using optimum torque found in test 3 | | Test no: 4 With PTFE and copper paste. | ID: TT-1-2B-M4 |
|---|---|---|---|
| **Test procedure** | | | |
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **4** | Clean and inspect all parts then apply jet-lube kopr-kote on stud threads, inside the nut and on the nut flange facing the washer. | | |
| **4.1** | Make up the 12 segments without strain gauged studs, to the optimum torque obtained in test. | | |
| **4.2** | Apply torque found in test 3 in 3 steps 33%, 66% and 100% | | |
| **4.3** | Log data for the test with sequence number and stud ID number | | |
| **4.4** | Repeat point 4.2 and 4.3 14 times. SEE POINT 4.5 BEFORE CONTINUING. | | |
| **4.5** | Visually inspect the studs after each new break out. Wipe off coating and take photos to document condition of stud and nut after every 5th make-and break. If galling or wear is observed document condition every make-and break out. | | |

| Procedure for identifying optimum pretension torque by applying increasingly higher torque until the optimum preload is measured in the stud. | | Test no: 5<br>With PTFE, dry stud. | ID:<br>TT-1-2B-M5 |
|---|---|---|---|
| **Test procedure** | | | |
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **5** | Dismount segments on the 4 studs with strain gauges, and clean all parts free of copper paste.<br>Do not dismantle the rest of the SL connector that's already torqued up to spec. ASY60067114<br>*(see ref [1])* | | |
| **5.1** | Place the clamp segment around the stud, such that the angled contact surfaces face the hub and are parallel to the contact surfaces of the hub.<br>**Be careful not to damage strain gauges or wires!** | | |
| **5.2** | Mount washer and nut on stud. Be careful not to damage the threads on the stud. | | |
| **5.3** | Once the clamp segment is in place, mount the shoulder screw into the threaded hole in the hub. Each clamp will be supported by the shoulder screw, preventing damage to the stud threads from the clamp segment. (See figure 5 and 6). | | |

| | | | |
|---|---|---|---|
| **5.4** | Mount back-out washer and socket screw on clamp segment. (See figure 5 and 6). | | |
| **5.5** | Make up the 12 segments without strain gauged studs, to torque as per ASY60067114 *(see ref [1])* (3434 Nm) | | |
| **5.6** | Torque up the nuts on the 4 studs with strain gauges assembled. Write down the values and torque according to SCS torque table *(see appendix D).* | | |
| **5.7** | Evaluate and record the applied torque value which gives correct and ideal average measured pre-tension in the studs. This value is to be used during test 6 | | |

| | | |
|---|---|---|
| | | |

| Test procedure | | | |
|---|---|---|---|
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **6** | Clean and inspect all parts and mount carefully back together. | | |
| **6.1** | Make up the 12 segments without strain gauged studs, to the optimum torque obtained in test. | | |
| **6.2** | Apply torque found in test 5 in 3 steps 33%, 66% and 100% | | |
| **6.3** | Log data for the test with sequence number and stud ID number | | |
| **6.4** | Repeat point 6.2 and 6.3 14 times. SEE POINT 6.5 BEFORE CONTINUING. | | |
| **6.5** | Visually inspect the studs after each new break out. Take photos to document condition of stud and nut after every 5$^{th}$ make-and break. If galling or wear is observed document condition every make-and break out. | | |

| Test procedure | | | |
|---|---|---|---|
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **7** | Clean all parts free of Molykote G-rapid plus. | | |
| **7.1** | Make up the 12 segments without strain gauged studs, to the optimum torque obtained in test. | | |
| **7.2** | Apply torque in steps until the stud fails. | | |
| **7.3** | Log data for the test with sequence number and stud ID number | | |
| **7.4** | Repeat point 7.2 and 7.3 until the stud fail. | | |

**Pictures**

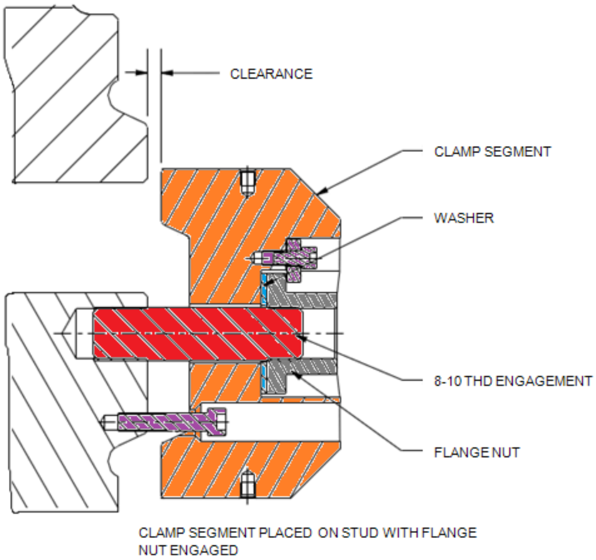



*Figure 5: Mounting picture 1*

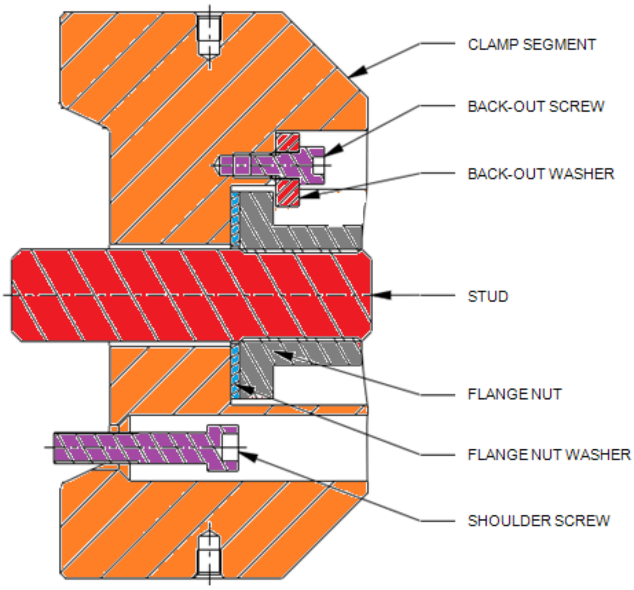



*Figure 6: Mounting picture 2*

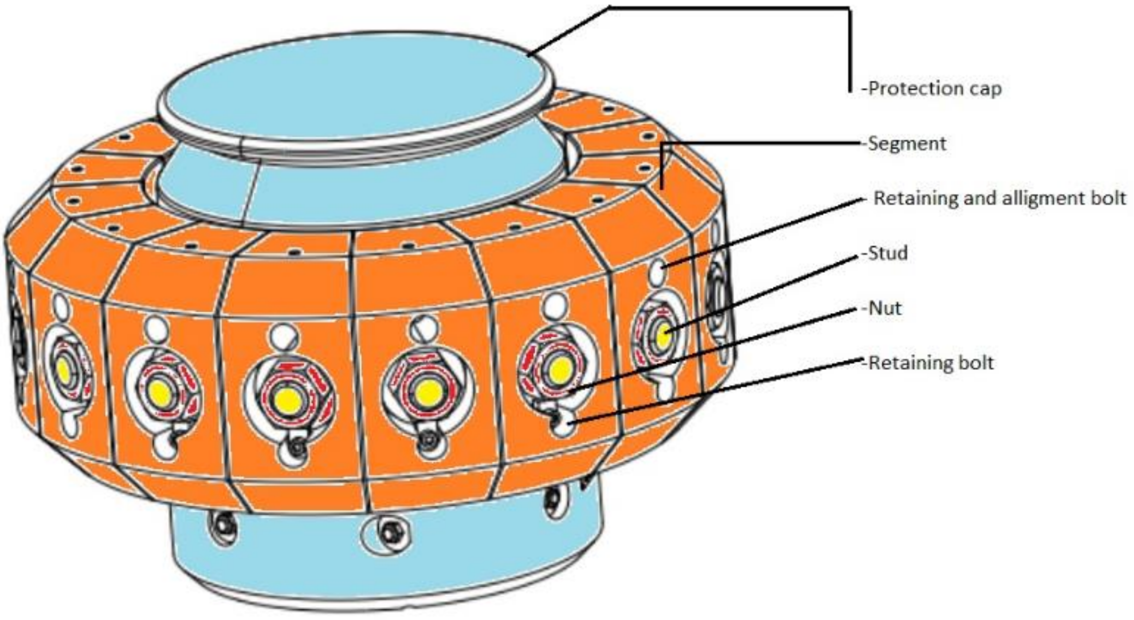



*Figure 7: Test Cap*

**Acceptance Criteria**

- Optimal pre-load of 67% of yield strength is reached (485Mpa) and an optimum pretension torque value is found.
- The test results are repeatable.
- Data collected are logged correctly to each test number and stud ID number

| Test Team Members + roles |
|---|
| Name |
| |
| |
| |
| |
| Test Completion Sign Off |
| *This test has been performed to the best of SCS ability per the requirements of the procedure. Deviations or problems encountered have been noted at the end of the test form.* |
| Signature, date and time |
| Comments and Notes |

| Main Task ID | MT-2 |
|---|---|
| Task Test ID | TT-2-1A-M |
| Priority | C |
| Description | Investigate torque, fraction and elongation in bolt vs stud. |
| Result | Accepted |

**Purpose**

Mechanical test of the stud and nut connection vs bolt connection used in the analyze. Check the fracture context between stud and bolt and measure the variables.

**Location**

- Workshop at HSN.

**Equipment and tools required**

- Vice.
- M12 stud 3 pieces. Grade 8.8.
- M12 bolt 3 pieces. Grade 8.8.
- M12 nut 3 pieces. Grade 8.8.
- SCS test kit.
- Calibrated torque tool.
- Calibrated caliper and puppitast. *(See figure 6).*
- Camera.

**Preparations**

- Book the workshop at HSN, Kongsberg.
- Collect and get all equipment, tools and material required for the test.
- Find details for M12 nut and M12 bolt. Do a tightening analysis for a M12 bolt.

## Precautions

- Control that stud and bolt have the same temperature and material.
- Control the test kit.
- Make sure the threaded holes in the kit are fine.

## Procedure for mechanical test

| **Procedure for small-scale testing of bolt vs stud.** | | **Test no:** | **ID:** |
|---|---|---|---|
| **Test procedure** | | | |
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **1** | Check equipment and tools required list, and make sure all equipment are in place. | | |
| **1.1** | Mount metal piece 1 with the threaded holes in the vice. | | |
| **1.2** | Mount metal piece 2 with the drilled hole on top of the other metal piece who is fastened in the vice. | | |
| **1.3.1** | **(Test 1)** Torque the bolt into piece 1, so the bolt head is touching piece 2. | Use 30Nm as pre-torque. | |
| **1.3.2** | **(Test 2)** Mount the nut on top of the stud who is pointing out from piece 2. | Use 30Nm as pre-torque. | |
| **1.4** | Mount the puppitast. | | |
| **1.5** | Apply torque until bolt/stud fractures and fail. | | |

| | | | |
|---|---|---|---|
| **1.6** | Measure the torque (load) applied on the nut and elongation in bolt/stud. | Torque used:<br>Step 1: 30Nm<br>Step 2: 84Nm<br>Step 3: 100Nm<br>Step 4: 110Nm<br>Step 5: 120Nm | |
| **1.7** | Repeat step 4-5 with a new bolt/stud three times. | | |
| **1.8** | Take picture to compare results for stud and bolt. | | |

**Pictures**


*Figure 8: Puppitast*

**Aids**

- PRD-0000021662 from TechnipFMC (FMC, Vidar Andersen, 2014)
  Not available for the public, contact TechnipFMC Kongsberg for more info.

**Acceptance Criteria**

- Repeat test 3 times, and get a comparable result, this test should give answers to how stud vs bolt behaves with torque up to tensile and yield strength.

| Test Team Members + roles |
| --- |
| Name |
| |
| |
| |
| Test Completion Sign Off |
| *This test has been performed to the best of SCS ability per the requirements of the procedure. Deviations or problems encountered have been noted at the end of the test form.* |
| Signature, date and time |
| Comments and Notes |

| | |
|---|---|
| Main Task ID | MT-2 |
| Task Test ID | TT-2-1B-M |
| Priority | C |
| Description | Investigate fraction in bolt vs stud. |
| Result | Accepted |

**Purpose**

This test is to investigate the fracture mechanism of the stud nut connection vs bolt connection. Difference between cracking and cutting point.

**Location**

- HSN Kongsberg Workshop.

**Equipment and tools required**

- Vice.
- M12 stud 3 pieces. Grade 8.8.
- M12 bolt 3 pieces. Grade 8.8.
- M12 nut 3 pieces. Grade 8.8.
- SCS test kit.
- Calibrated torque wrench.
- Camera.

**Preparations**

- Book the workshop at HSN, Kongsberg.
- Find details for M12 nut and M12 bolt. Do a tightening analysis for a M12 bolt.

## Precautions

- Control that stud and bolt have the same temperature and material.
- Control the test kit.
- Make sure the threaded holes in the kit are fine.

## Procedure for mechanical test

| **Procedure for small-scale testing of bolt vs stud.** | | **Test no:** | **ID:** |
|---|---|---|---|
| **Test procedure** | | | |
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **1** | Check equipment and tools required list, and make sure all equipment are in place. | | |
| **1.1** | Mount metal piece 1 with the threaded holes in the vice. | | |
| **1.2** | Mount metal piece 2 with the drilled hole on top of the other metal piece who is fastened in the vice. | | |
| **1.3.1** | **(Test 1)** Torque the bolt into piece 1, so the bolt head is touching piece 2. | Use 30Nm as pre-torque. | |
| **1.3.2** | **(Test 2)** Mount the nut on top of the stud who is pointing out from piece 2. | Use 30Nm as pre-torque. | |
| **1.4** | Apply torque until bolt/stud fractures and fail. | Apply 200Nm. | |
| **1.5** | Repeat step 4-5 with a new bolt/stud three times. | | |

| | | | |
|---|---|---|---|
| **1.6** | Take picture to compare results for stud and bolt. | | |

**Acceptance Criteria**

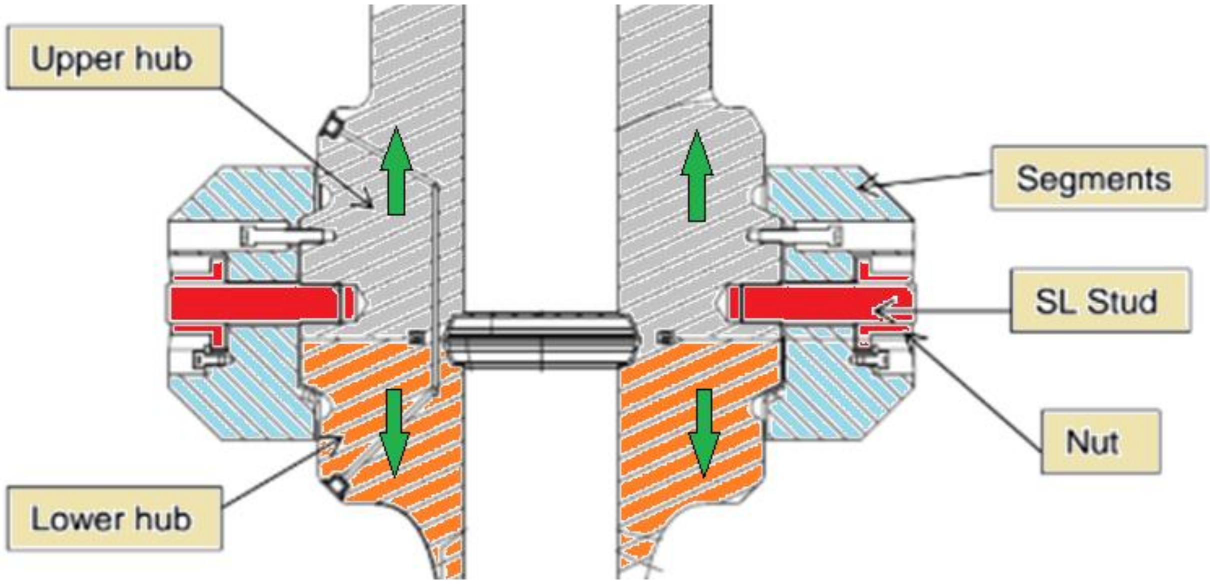
Test results shall be comparable.

| Test Team Members + roles |
|---|
| Name |
| |
| |
| |
| Test Completion Sign Off |
| *This test has been performed to the best of SCS ability per the requirements of the procedure. Deviations or problems encountered have been noted at the end of the test form.* |
| Signature, date and time |
| Comments and Notes |

| Main Task ID: MT-1 | Task Report |
|---|---|
| Task Test ID | TT-1-1-T |
| Priority | A |
| Description | Determine necessary force between hubs by calculation. |
| Result | Accepted |

**Purpose**

Calculate the minimum needed force between the hubs to avoid hub face separation.



# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 11.05.2017 | 6 | EH | Created document and filled inn calculations. |
| V.1.0 | 17.05.2017 | 7 | EH | Conclusion. |
| V.2.0 | 21.05.2017 | 7 | SCS | Ready for last hand in. |

# References

[Ref.1] Doc No: RPT60020900. REPORT, STRUCTURAL ANALYSIS, SPEEDLOC-II 222 CLAMP CONNECTOR. (Dag Andre Fjeldstad and Nils Pande-Rolfsen, from TechnipFMC).

[Ref.2] ISO 13628-7: 2006 Petroleum and natural gas industries – Design and operation of subsea production systems- Part 7: Completion/workover riser systems.

# Symbols

| | |
|---|---|
| $T_{ec}$ | pressure end load. |
| $P_0$ | external pressure. |
| $P_{int}$ | internal pressure. |
| $D_s$ | seal/gasket sealing diameter. |
| $T_s$ | total axial separation load tending to separate the connector. |
| $T_e$ | effective tension (externally applied tension). $T_e$ is positive for loads which tend to part the connection. |
| $F_{stud}$ | single bolt preload force. |
| $F_c$ | total contact force between hubs. |
| $n_{stud}$ | number of studs. |

# Contents

# 1. Introduction

The speedloc-II consist of 16 clamps distributed around the two hubs. There is one stud for each clamp connection. Due to the 25° inclining surfaces between the hubs and clamp, the preload forces applied to the stud force the hubs axially together. Optimal preload is achieved after threading the flange nut inwardly on the stud with correct moment.

In operation subsea, the riser and the speedloc connector is exposed for high bending and tension forces. The connector is the strongest part and will in worst case be the last component who will be destroyed.

Based on ISO 13628-7: 2006[1], connection pressure separation loads shall be based on worst-case sealing conditions.

Leak tightness is ensured by a seal stab located between the two hubs.

[1] [Ref.2] ISO 13628-7: 2006 Petroleum and natural gas industries.

# 2. Calculations

## 2.1 Minimum contact force between the hubs (Worst case)

Finding minimum contact force between the hubs based on internal pressure and applied tension:

$$T_{ec} = \frac{\pi}{4} * (P_{int} - P_o) * D_s{}^2$$

(ref [1] eq.3. page 10)[2]

Where:

- $T_{ec}$ = is the pressure end load.
- $P_o$ = is the external pressure.
- $P_{int}$ = is the internal pressure.
- $D_s$ = is the seal/gasket sealing diameter.

Calculating pressure end load maximum:

$P_{int}$ = 10ksi = 68,94 N/mm$^2$

$P_o$ = 0 (Worst case)

$D_s$ = 224mm

$$T_{ec} = \frac{\pi}{4} * (68{,}94 N/mm^2 - 0) \quad * 224^2\text{mm} = \mathbf{2,76 * 10^6 \mathit{N} = 2760 \mathit{kN}}$$

[2] [Ref.1] Doc No: RPT60020900.

## 2.2 Total axial separation load

$$T_s = T_e + T_{ec}$$ (ref [1] eq.2. page 10)[3]

Where:

- $T_s$ = is the total axial separation load tending to separate the connector.
- $T_e$ = is the effective tension (externally applied tension). Te is positive for loads which tend to part the connection.
- $T_{ec}$ = is the pressure end load.

$T_e$ = 350 000 kg = 3500kN. (Worst case).

Total axial separation load:

$$T_s = 2760\text{kN} + 3500\text{kN} = \mathbf{6260\ kN}$$

## 2.3 Necessary preload in each stud

Calculate the necessary preload in each stud based on tot axial separation load:

$F_c = T_s = 6260\text{kN}$

$$F_c = F_{stud} * n_{studs}/(2 * \tan 25°) \rightarrow F_{stud} = \frac{F_c}{n_{studs}} * (2 \times \tan 25°)$$ (ref [1] eq. page 19)[4]

Where:

- $F_c$ = is the total contact force between hubs.
- $F_{stud}$ = is the single stud preload force.
- $n_{stud}$ = number of studs.

$$F_{stud} = \frac{6260\ \text{kN}}{16} * (2 \times \tan 25°) = \mathbf{364,89kN}$$

[3] [Ref.1] Doc No: RPT60020900.
[4] [Ref.1] Doc No: RPT60020900.

# 3. Conclusion

As the tension, bending moment or internal pressure is increased, the contact forces between the two hubs will gradually be reduced. Consequently, the load will be transmitted through the clamps and the load on the studs will be increased. If a negative tensile force is applied (i.e. a compression force) the load will be transmitted directly through the contact between the hub faces, hence; no changes in the load on the clamps and bolts.

The internal pressure in the riser and connector on 10ksi is based on worst case scenario and is a value given by TechnipFMC.

The external applied tension on 350 000kg is worst case scenario and is a value given by TechnipFMC.

The preload on 364,89kN in each stud is under the yield strength on 485Mpa=720kN, and is therefore accepted.

This not conclude that the stud shall be preloaded with 364,89Kn, because the stud has to be preloaded to 67% of yield (720kn). This 67% is the recommended value for reaching the bests tightening(preload) effect on the stud.

| Main Task ID: MT-1 | Test report |
|---|---|
| Task Test ID | TT-1-2B-M |
| Priority | A |
| Description | Test recommended pretension on nut including range. |
| Result | Uncertain, need more information |

# Summary

This document contains the test report for the TT-1-2B-M mechanical test. Finding the optimal tightening torque on the nut, in the SL-215 clamp, in different scenarios with lubrication and without lubrication. The test values are based on the theoretical task TT-1-1 - T and TT-1-2-T.

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 22.05.2017 | 17 | AA | Created document and made the report |
| V.1.0 | 23.05.2017 | 20 | SCS | Ready for last hand in. |

# Appendix list

[Apx.F] SJA-document for mechanical testing.

# Reference

[Ref.1] Assembly procedure for Speedloc II Segment Clamp: ASY60067114.pdf (FMC, 2016).

Contact Einar Totland for more information regarding references from TechnipFMC.

# Abbreviations and technical words

| Abbreviation | Explanation |
|---|---|
| PTFE | Polytetrafluoroethylene |
| Mpa | Mega pascal |
| | |
| | |

| Technical Words | Explanation |
|---|---|
| Friction | The force resisting the relative motion of solid surfaces, fluid layers and material elements sliding against each other. There are several types of friction. |
| Stud | Threaded rod similar to a bolt but it has no bolt head. |
| Nut | A nut is a fastener with a threaded hole. |

# Contents

# Tables



# Figures

# 1. Pre-testing

Safety briefing are important so that the test participants know the safety rules at their workshop, without this briefing no test could start. Then the SJA (see appendix [2]) was filled in and agreed upon by all members of the test. Then a meeting between SCS and all participants from TechnipFMC were conducted. This was done so everyone knew what to expect from the test and what they could contribute with to help us. After this meeting some changes had to be made, based on the feedback from three experienced engineers at TechnipFMC.

# 2. Preparation

The test cap is not mounted together when it arrives and assembly is needed. The upper and lower hub need to be mounted together. This task is complex as there are strict procedures as how to mount it together *(SEE APPENDIX [1]).*
Preparations for the strain gauge and rosette sensors were made, because there had to be 5 wires coming out in between two segments and because it is a tight squeeze between the segments and the hub *(SEE FIG 1).* This step is not listed in the procedure because the wires used were thicker than anticipated. The relief groove is not hurting the overall integrity of the clamp. Figure 1 shows that the relief groove was made straight down and then out to one side in 90° degrees, as oppose to straight out from the hole who might lead to a lower strength capacity of the segment.

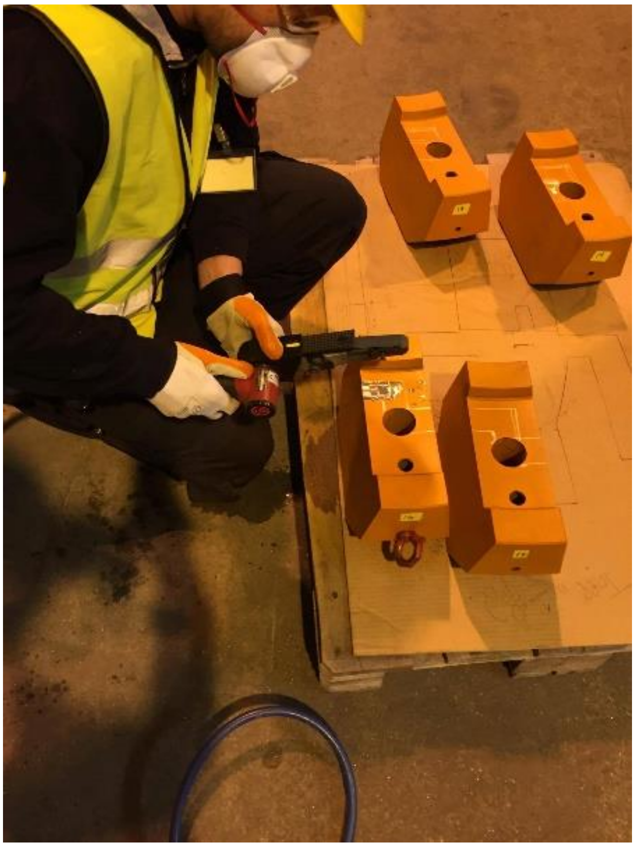


*Figure 1 Making room for wires*

Before the strain gauges and rosettes could be mounted, the 4 studs had to be machined down to the lowest diameter of the threads (43,1mm). *(SEE FIG 2).*

*Figure 2 Machined stud*

The stud got mounted back in the hub and torqued to spec with 135Nm, this is to mark the top at (0°). When the stud was tightened, and marked, the segment number and stud ID number were noted so that it couldn't be interchanged *(SEE FIG 3)*, and as a reference for the rest of the sensors. The strain gauges were mounted at 0°deg and 180° deg. The rosette was mounted in 90° deg between the two strain gauges. *(SEE FIG 4)*.

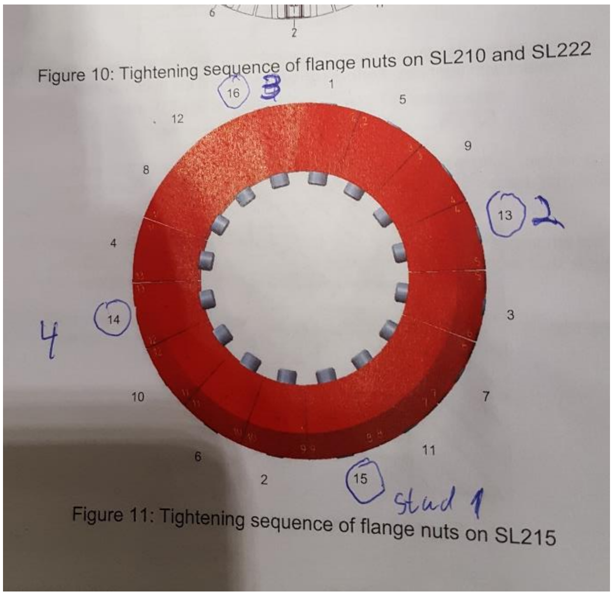



*Figure 3 Segment and stud id number*

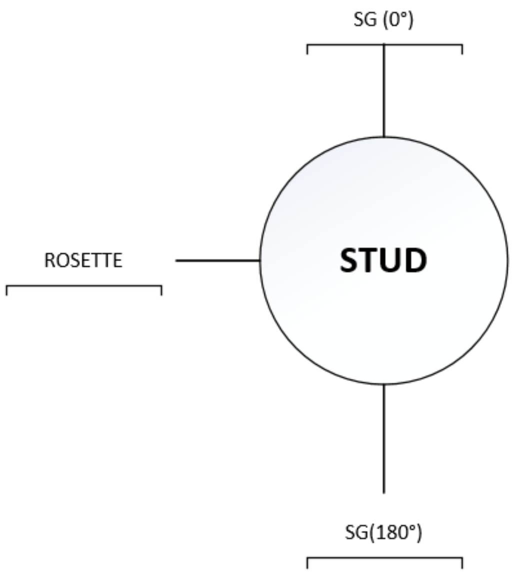



*Figure 4 sensor plasement*

The studs were then removed and prepped for the strain gauges and the rosette. Preparations before mounting the strain gauges and rosette are important. First the surface was prepped with 180 grain sand paper, this is done to get rid of any low or high spots left from the machining process. Next step was to make a grid so the strain gauge could be mounted straight in the axial direction of the stud *(SEE FIG 5).* Cleaning is done with Isopropanol and acetone in a 50% mix between every step to avoid contaminants such as grease and metal savings. If the surface is contaminated the strain gauge and rosette won't stick to the surface. When the surface is prepped take a piece of tape across the two poles on the strain gauge and mount it so that it lines up with the grid made in the steel (there is also a grid in the strain gauge *(SEE FIG 5).* Then the tape was peeled back one side and the surface cleaned again to make sure no contaminants were in between.
Since there are no wires on the strain gauges there are a lot of soldering to do to finish the installation. After the sensors were mounted wires were soldered on *(SEE FIG 6).*

*Figure 3 Grid and tape on strain gauge*

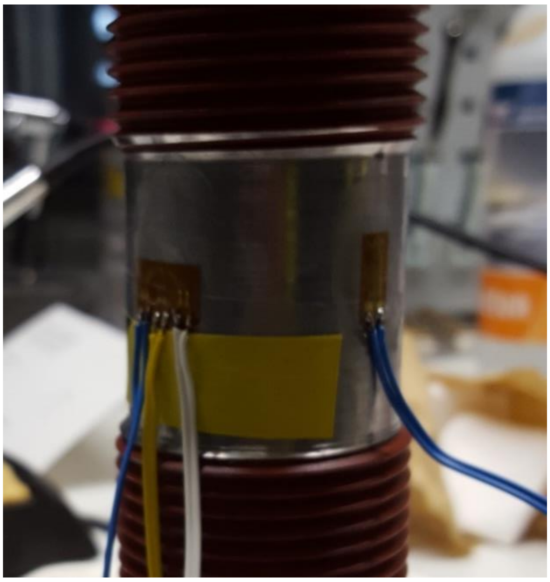


*Figure 4 Wires soldered on*

| Strain gauge name, stud number and Channel location | | |
|---|---|---|
| **Name** | **Channel** | **Stud number** |
| Ra | 1 | **1** |
| Rb | 2 | |
| Rc | 3 | |
| SG (0°) | 4 | |
| Sg (180°) | 5 | |
| Sg (0°) | 6 | **2** |
| Sg (0°) | 7 | |
| Rb | 8 | |
| Ra | 9 | **3** |
| Rb | 10 | |
| Rc | 11 | |
| Sg (0°) | 12 | |
| Sg (180°) | 13 | |
| Rb | 14 | **4** |
| Sg (0°) | 15 | |
| Sg (180°) | 16 | |

*Table 1: Strain gauge name, stud number and Channel location*

Due to the limitation of channels we could not use all strain gauges in the rosette in all the studs *(see table1)*. There are three separate strain gauges in the rosette, one in axial direction who can read axial strain in the stud and two in +/- 45° that can monitor torsional load. In stud 2 and 4 only the strain gauges were used.

# 3. Test no: 1 with PTFE and molykote

<u>Test id: TT-1-2B-M1:</u>

<u>Purpose of this test</u>**:**

This test is to identify the optimal torque on the nut with molykote as a lubricant between the PTFE coated nut and stud.

<u>Lubrication:</u>


<u>The test:</u>

The first step was carried out when all the studs were dressed up with sensors, they were ready to be mounted in the hub again *(SEE FIG 7).* Studs were mounted back in the hub with 135 Nm according to spec.

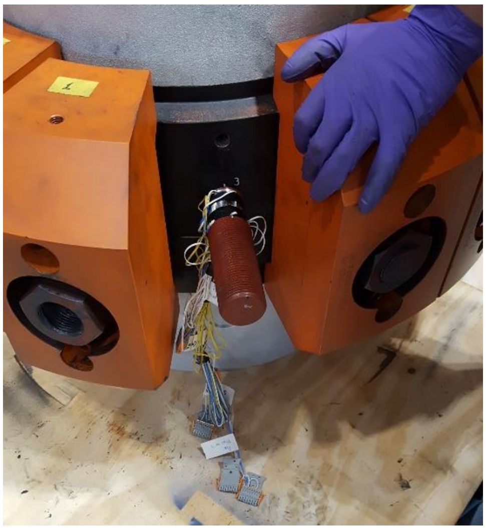


*Figure 5 Stud with sensors mounted in the hub*

When the studs are mounted in the hub, the segments are carefully mounted on the stud. Care must be taken not to damage wires or sensors *(SEE FIG 8).* Even with the reduction cut made in the segments it was a tight squeeze to mount the segments without damaging the wires.

Then the data logger and the computer got attached to control that the micro strain ($^{\mu m}/_{m}$) read on the computer is stable and not varying too much. Some trouble shooting had to be done to get stable values, it was found that the connection between the wires and the connector plug were loose on some sensors.

To get the values out in Mpa the e module of the steel was multiplied with the strain gauge value.

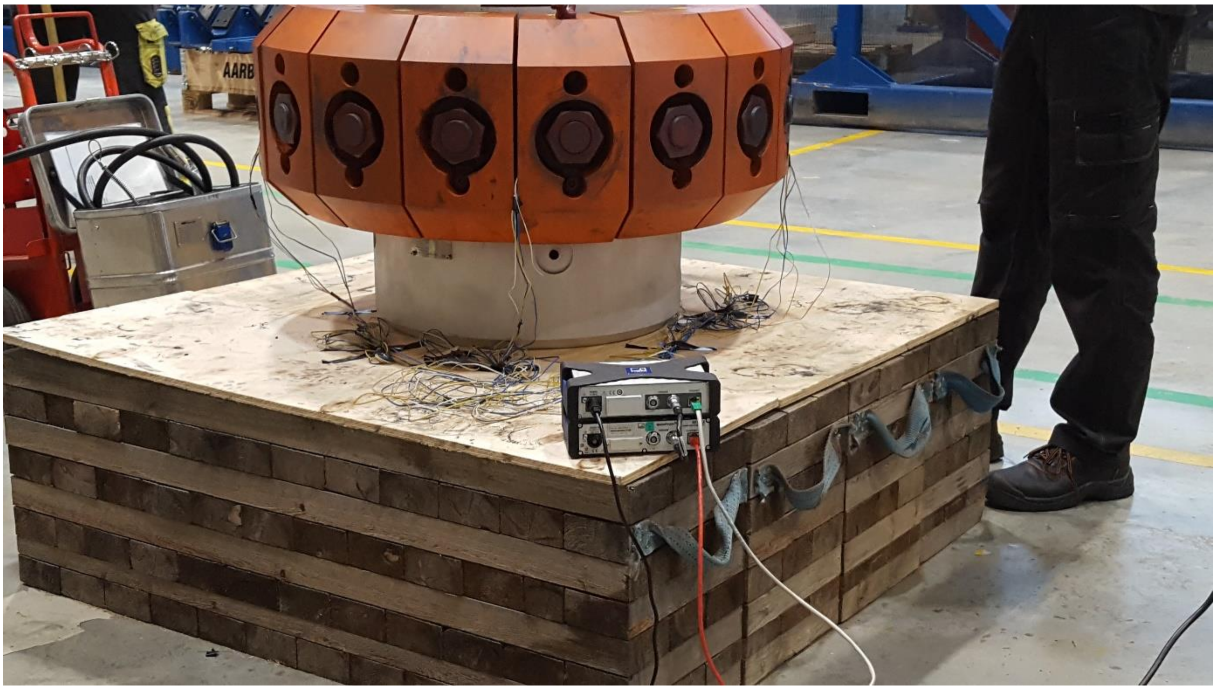



*Figure 6 Fully assembled SI-215 with sensors and data logger.*

All the 12 segments who has no sensors mounted were tightened to spec, then the sensors studs were torqued in three steps starting at max torque of 2500Nm with the j-gun. J-gun is an air operated tool that gives a torque value based on air pressure settings. The sequence was 33% and 66 %, before we could torque to 100% (2500NM) there were found that the average strain was too high already. Some trouble shooting started to find out if these results were accurate, we loosened off the nuts on the 4 studs and tried a different torque tool Hytorc Avanti 3 to see if the average strain developed were the same. This is a hydraulically operated tool and gives out a torque value based on the hydraulic pressure. With the Hytorc tool the average strain with molykote were found to be 517 Mpa at 1342Nm, so this is still way lower than the torque used today at 3434 Nm.

The torque of 1342 Nm will be used in test 2.

## 3.1 Conclusion

The average strain value of 485 MPa (target value) measured are occurring at significantly lower torque applied than what's expected. All the equipment has been examined for faults, but none is found, and before the test started the torque tool calibration were checked. This still doesn't mean that it can't be something wrong with the test set up, but that we can't find it.

Still some conclusion can come out of this test, as a conservative estimate it can be concluded that the friction values with molykote and PTFE is lower than each of them separated. Since molykote G-rapid plus is not listed in the mounting it should not be used before more testing has been done and friction values has been confirmed.

# 4. Test no: 2 PTFE and molykote

Test id: TT-1-2B-M2:

Purpose of this test:

This test was made to find out how the molykote behaves during 15 make and brakes, regarding to friction.

The test:

The test was carried out after the optimal torque of 1342Nm was found in test 1.

The procedure was carried out according to the test procedure for this test, although the three steps was skipped due to a limitation of time.

First the studs were torqued up and then they were torqued down, all this got logged on the computer to see if the strain gauges would reach zero when unloading the strain in the stud.

## 4.1 Conclusion:

With molykote the friction doesn't seem to be constant between make and break tests. It seems that it loses it lubricity between the different runs and the friction goes up in results in a lower strain in the studs. To be able to recommend molykote as a lubricant the friction should be more constant. To verify the use of molykote more testing must be done.

# 5. Test no: 3 With PTFE and copper paste

Test id: TT-1-2B-M3

Purpose of this test:

Test with Jet-lube kopr-kote is to find the effect of friction between copper paste and PTFE because this should have a much higher friction coefficient at 0,16, and is believed to maintain a more stable and constant friction value.

Lubrication:


The test:

Everything were disassembled and marked so that it was possible to mount the nut onto the stud it came off. The stud had turned out which had led to wires rapping around the stud in full revolution. If this has happened during disassembly or before is not known, but between every test we made sure to look that the strain values went down to zero again.

The marking was done so that it couldn't affect the test results if some nuts had worn itself to a specific bolt.

Everything was cleaned thoroughly to avoid contamination with molykote g-rapid plus. Loose parts like nuts and washer were put in the parts washer and studs were thoroughly cleaned with Loctite Sf 7063 super clean.

Before everything got assembled each part were visually inspected for damages that might had occurred and could affect the results, but nothing was found to be wrong.

The last step before assembly could continue was to inspect the strain gauges and wires for damage, no sign of damage was found here either.

Then the studs were lubricated with copper cote and everything was assembled according to the ASY60067114 procedure.

From the two tests, we could carry out with the copper paste, it was found that the friction was higher than with the molykote and a target torque of 1972 Nm was found.

## 5.1 Conclusion

Since the time left of testing was short, it was only possible to carry out two tests. From the data logged it was found that the friction between the PTFE and copper paste was higher than in the previous test, and the optimal torque value as found to be 1978Nm at the target strain value of 485Mpa. It also seemed that the friction was more consistent during the two tests than with molykote. If this is to be confirmed more testing must be done to verify.

# 6. Test no: 4 With PTFE and copper paste.

Test ID: TT-1-2B-M4

Purpose of this test:

This test is to see how the copper paste behaves under 15 make and break test regarding to friction.

This test was not conducted due to time left and other priorities was made.

# 7. Test no: 5 With PTFE and dry stud

Test id: TT-1-2B-M5

Purpose of this test:

This test is to see if the average stain value of 485 MPa is accruing at a torque of 3434Nm Used in the assembly procedure of the speedloc connector.

The test:

The same procedure was performed with cleaning and marking of the parts.

The same wrapping of the cables around the stud was found, it was also found that this happened when the nut was taken fully of the stud.

The torque procedure was carried out in steps to identify optimal torque related to 485 MPa strain in then studs on average. The target torque value was set to 2750Nm for the clean test, tried first at 2826Nm which was a bit too high since the average value was close to 73% of yield strength in the studs. With 2750Nm the average strain measured was still a bit high, but it was chosen since the value was still between 67% and 73% of Yield strength in the stud.

## 7.1 Conclusion

The torque value found is much higher than the other tests performed on the studs, but still significantly lower than the torque recommended in the assembly procedure.

# 8. Test no: 6 With PTFE and dry stud

Test id: TT-1-2B-M6

Purpose of this test:

This test is to see how the PTFE behaves without lubrication regarding to friction in 15 make and break.

The test:

Between test 2 and 3 with clean studs TechnipFMC wanted to verify that the values read from the strain gauge were correct and a test setup was made on stud three. The theory here was that if we pulled the stud straight out in the axial direction of the stud with a given load, it would be possible to calculate the values read from the strain gauge. The test set up was made and a load of 100kg pull was put on the stud, but this was too low to get an accurate reading. Then tried with 400 kg, but could not come up with an accurate value so the test was stopped. After this test, the strain gauges on stud three had been damaged somehow and the values that is seen from this stud in the next five test must be excluded as it is not correct.

## 8.1 Conclusion

From the clean test, it was found that the friction between the parts was much higher and a higher torque of 2750Nm could be used to obtain an average strain value of 485Mpa.

The interesting thing is that this test seems to have most stable and constant friction values of all the tests done.

# 9.Test no: 7 With PTFE and molykote. Breakage test.

Test id: TT-1-2B-M7

Purpose of this test:

It was in the interest of TechnipFMC that a breakage test was conducted. They wanted to see if it was possible to break the bolt at 3434Nm (which is the torque used today) with molykote g-rapid plus. This is because it is known that some do mount the speedloc with this lubrication and then since the friction seems to be very low with the use of this lubrication from the previous testing.

The test:

Stud one was chosen for this test and the torque was set to 3434 Nm.
We logged the values but the strain gauges soon failed to record and no useful data was recorded, but the stud would not fail in this test at that torque. Then the torque was turned up to 3900 Nm and after about 20 min the stud failed (See figure 9).

## 9.1 Conclusion

From this test, it is found that the stud will not break at 3434Nm. From the previous testing it migth be possible that the yield strength of the stud material was reached, causing the stud to plastically deform, however this is difficult to prove since the stud failed at a considerably higher torque. The stud failed after approximately 20 min at 3900Nm.

*Figure 7 Broken stud in hub*

*Figure 8 Broken stud with nut*

# 10. Total test conclusion:

From all these tests, it is difficult to conclude with a specific torque value because the test result might be inaccurate and therefore not valid. A trend though is possible to spot from this even though the results might be inaccurate, they are consistently inaccurate.

If a lubricant is to be used during assembly of the speedloc connection it seems that copper coat has a more stable and constant friction effect during testing than molykote. It must also be regarded that the friction in the PTFE coating is already low at 0,08, and that from the test results might seem to be even lower than that. With PTFE and with lubricant it is difficult to control and anticipate the effect of friction. This can also be seen in the breakage test. The stud broke at 3900Nm, which is not significantly higher than 3434Nm. Therefore, it is not recommended to use lubrication in any form during the assembly of the speedloc connection. More testing should therefore be performed if lubrication is to be used.

With dry stud, the values seem to be most stable and is therefore what must be used
In the torque procedure.

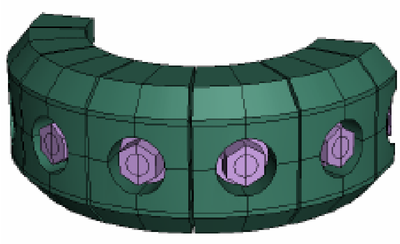
| Test Team Members + roles |
| --- |
| Name |
| Asbjørn Antonsen (Mechanical tester) |
| Erlend (Mechanical tester) |
| Espen Hansen (Mechanical tester) |
| Bjørn (Mechanical tester) |
| Test Completion Sign Off |
| *This test has been performed to the best of SCS ability per the requirements of the procedure. Deviations or problems encountered have been noted at the end of the test form.* |
| Signature, date and time |
| Comments and Notes |

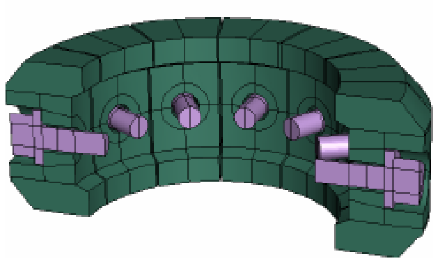
*Table 2 Test participants*

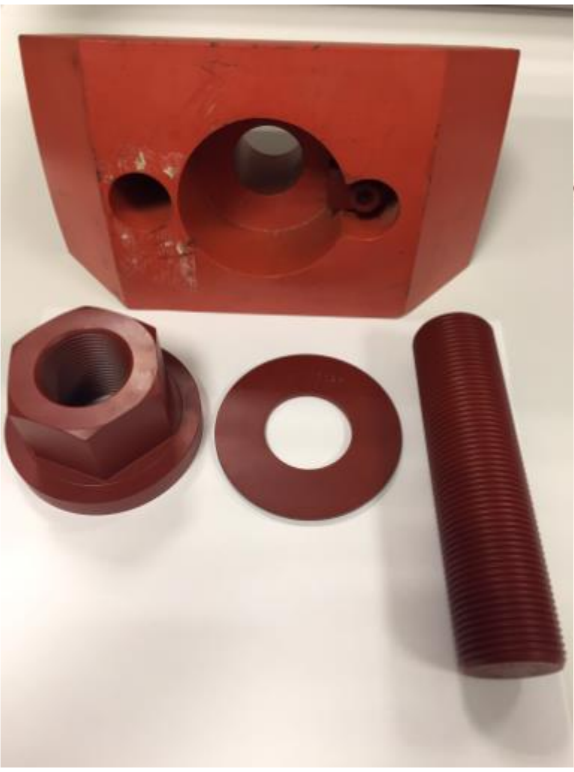
| Main Task ID: MT-1 | Task Report |
|---|---|
| Task Test ID | TT-1-2-T |
| Priority | A |
| Description | Provide recommended torque on nut including range. |
| Result | Accepted |

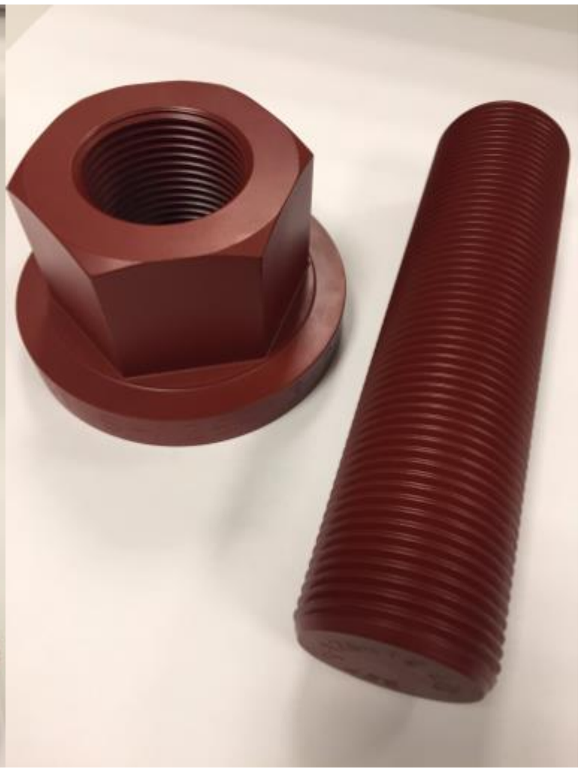
**Purpose**

Find the recommended torque to apply on the nut. Ensure that the force on the clamp generates enough force between the hubs to give a leakproof connection.









# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 11.05.2017 | 15 | EH | Created document and filled inn calculations. |
| V.1.0 | 17.05.2017 | 17 | EH | Conclusion. |
| V.2.0 | 21.05.2017 | 17 | SCS | Ready for last hand in. |

# References


[Ref.1] ISO 13628-7: Petroleum and natural gas industries – Design and operation of subsea production systems- Part 7: Completion/workover riser systems. Annex G.

[Ref.2] Fonas. (1972). *Skrue håndbok.* Oslo: Elkem-Spigerverket A/S.

[Ref.3] Mechanicalc. (2017, 23.05) https://mechanicalc.com/reference/bolted-joint-analysis

[Ref.4] Wikipedia. (2017, 23.05) https://en.wikipedia.org/wiki/Screw_thread#/media/File:ISO_and_UTS_Thread_Dimensions.svg

[Ref.5] ParkTool (Basic Thread Concept). (Aug 24, 2015) (2017, 23.05) http://www.parktool.com/blog/repair-help/basic-thread-concepts

[Ref.6] ME311 Machine Design. Lecture 9: Screws (Chapter 16). (2017, 23.05) http://slideplayer.com/slide/3449179/

# Symbols

| | |
|---|---|
| $A_{b,r}$ | bolt root area. |
| $d_b$ | nominal (basic major diameter) bolt diameter. |
| $d_n$ | effective contact diameter of nut-bearing surface. |
| $d_t$ | effective contact diameter of the threads. |
| $d_m$ | minor diameter of stud. |
| $l_{pitch}$ | pitch of the threads. |
| $M_{b,max}$ | maximum torque during make-up. |
| $M_{b,nom}$ | nominal torque during make-up. |
| $S_{ty}$ | yield strength. |
| $\%Yield$ | preload percent of yield. |
| $\varepsilon$ | scatter factor. |
| $M_T$ | applied torque. |
| $T_{b,nom}$ | nominal bolt preload (tension) during make-up. |
| $T_{b,max}$ | maximum bolt preload (tension) during make-up. |
| $T_{b,min}$ | minimum bolt preload (tension) during make-up. |
| $\mu_n$ | coefficient of friction between nut and bearing surface. |
| $\mu_t$ | coefficient of friction between nut and bolt threads. |
| $K_T$ | torque friction coefficient. |
| $R_T$ | mean thread radius. |
| $R_C$ | mean collar radius. |

## Contents



## Figures



## Tables

# 1. Stud Calculations

The root area $A_{br}$, expressed in square millimeters, of a standard inch series bolt with 60° thread angle:

$$A_{br} = \frac{\pi}{4} * (d_b - 1{,}3 * l_p)^2 = \frac{\pi}{4} * (47{,}625\text{mm} - 1{,}3 * 3{,}175\text{mm})^2 = \mathbf{1485{,}24mm^2}$$

([Ref.1] eq.G.7)[1]

<u>Stud diameter in mm</u>:

1.875”. Use a factor of 25,4 to calculate to mm.

$$\mathbf{d_b = 1{,}875" * 25{,}4 = 47{,}625mm}$$

is the nominal bolt (basic major) diameter, expressed in mm.

$$l_{pitch} = \frac{25{,}4}{8} = \mathbf{3{,}175mm}$$

is the thread pitch. Threads per inch are 8. SCS use a factor of 25,4 to calculate to mm.

<u>Minor diameter of stud:</u>

$$d_m = d_b - 1{,}3 * P = 47{,}625\text{mm} - 1{,}3 * 3{,}175 = \mathbf{43{,}497mm}$$ [Ref.1][2]

<u>Pitch diameter:</u> effective contact diameter on the threads. ([Ref.3] eq. pitch diameter)[3]

$$d_t = d_b - 0{,}64951905 * l_p = 47{,}625\text{mm} - 0{,}64951905 * 3{,}175 = \mathbf{45{,}56mm}$$

[1] [Ref.1] ISO 13628-7
[2] [Ref.1] ISO 13628-7
[3] [Ref.3]

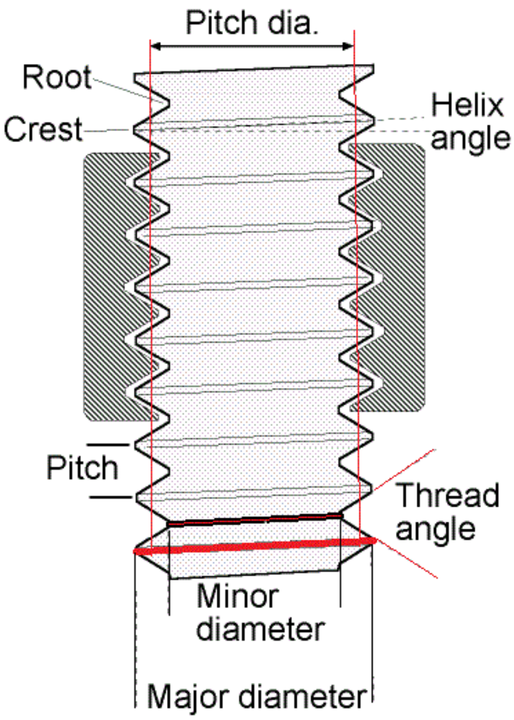



*Figure 1:Stud ([Ref.5])*[4]

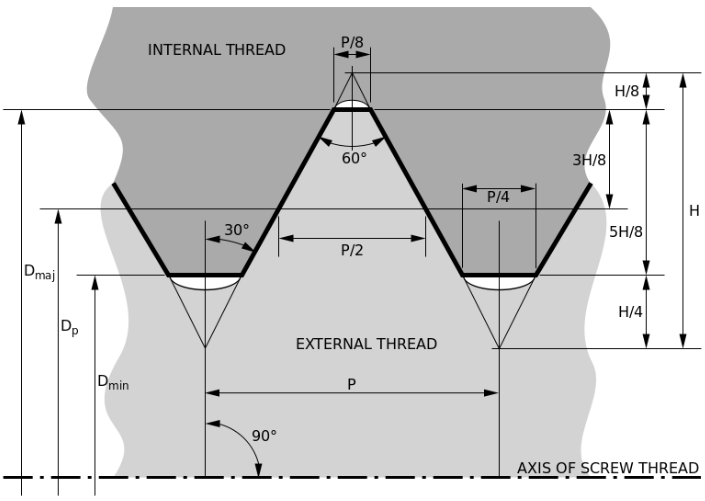



*Figure 2:Threads dimensions ([Ref.4])*[5]

[4] [Ref.5]

[5] [Ref.4]

## 2. Stud preload

The applied preload is commonly specified as a percentage of the stud material's tensile yield strength, $S_{ty}$.

A nominal preload of 67% bolt yield (485MPa) should be used for the Speedloc with an assumed scatter factor of 0.1 determined by qualification of the preload procedure.

$\mathbf{P_b}$ = (applied preload in stud)

$\mathbf{\%Yield}$ = (preload percent of yield) **0,67% (485MPa)**

$\mathbf{S_{ty}}$ = (yield strength) **724MPa**

$\mathbf{A_{br}}$ = (bolt root area) $\mathbf{1485,24mm^2}$

$\boldsymbol{\varepsilon}$ = (is the scatter in preload during make-up; see Table G.1 [Ref.1])

$$\mathbf{P_{b,nom}} = \mathbf{\%Yield} * \mathbf{S_{ty}} * \mathbf{A_{br}}$$

$$\mathbf{P_{b,min}} = \mathbf{\%Yield} * \mathbf{S_{ty}} * \mathbf{A_{br}} * (\mathbf{1} - \boldsymbol{\varepsilon})$$ ([Ref.1] eq.G.1)[6]

<u>The recommended preload force as a function of yield strength (0,67% and 0,73%) is:</u>

$$P_{b,nom} = 0{,}67\% * 724\text{MPa} * 1485{,}24\text{mm}^2 = 720500\text{N} = \mathbf{720,5kN}$$

With respect to **scatter factor on 0,10**: $P_{b,min} = 720{,}5 * (1 - 0.1) = \mathbf{648,5kN}$

$$P_{b,max} = 0{,}73\% * 724\text{MPa} * 1485{,}24\text{mm}^2 = 784979\text{N} = \mathbf{785kN}$$

With respect to **scatter factor on 0,10**: $P_{b,max} = 785 * (1 - 0.1) = \mathbf{706,5kN}$

[6] [Ref.1] ISO 13628-7

# 3. Torque to obtain preload

Many of the common tightening methods achieve the preload force by applying a torque to the nut or to the bolt head. When tightening a fastener with a torque wrench, which is one of the easiest and most common methods, the fastener is considered to be properly tightened once the specified torque is achieved. In this case, it is necessary to determine the torque value necessary to achieve the desired preload force in the bolt. This torque is calculated using:

$$M_T = \mathbf{K_T} * \mathbf{d_b} * \mathbf{P_b}$$ ([Ref.2] §4.3.2)[7]

$\mathbf{d_b}$ = nominal stud diameter

$\mathbf{P_b}$ = preload force

$\mathbf{K_T}$ = torque friction coefficient

When we tighten a bolt/stud,

(a) We apply torque to the nut,
(b) The nut turns,
(c) The stud stretches,
(d) Creating preload

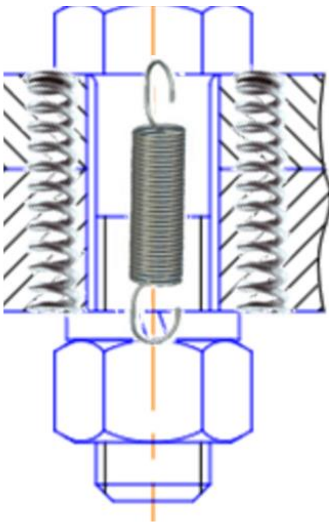


*Figure 3: Stud is really a spring. ([Ref.6]. Slide 19)*

So the stud is really a spring that strectes and creates preload on the joint.

[7] [Ref.2]

## 3.1 Torque friction coefficient

### 3.1.1 Equation from Mechanicalc:

$K_T = \left(\frac{R_T}{d_b}\right)\left(\frac{\tan\varphi + f_t * \sec\alpha}{1 - \tan\varphi * \sec\alpha}\right) + \left(\frac{f_c * R_c}{d_b}\right)$ ([Ref.3] eq.Torque to Obtain Preload)[8]

<u>Mean thread radius:</u> half of the mean bolt diameter, which is the average of the minor diameter and nominal diameter.

$R_T = \frac{d_b + d_m}{4} = \frac{47{,}625mm + 43{,}73mm}{4} = \mathbf{22,78mm}$

<u>Mean collar radius:</u> the area of the bearing face of the part being rotated during installation (either the nut or the bolt head).

$R_C = 0{,}625 * d_b = 0{,}625 * 47{,}625mm = \mathbf{29,76mm}$

<u>Friction coefficient between surfaces</u>:

$f_t = \mathbf{0,08}$ **or 0,06** (Xylan coating)

<u>Lead angle:</u>

$\tan\varphi = \frac{1}{2 * \pi * R_T * TPI} = \frac{1}{2 * \pi * 22{,}83 * 0{,}315} = 0{,}022 \rightarrow tan^{-1}(0{,}022) =$ **1,26°**

$TPI = \frac{1}{P} = 0{,}315$

Thread angle: $\alpha = \mathbf{30}°$

$\sec(\alpha) = \frac{1}{\cos(30°)} = \mathbf{1,154}$

[8] [Ref.3]

$$K_{T(0,08)} = \left(\frac{22{,}8mm}{47{,}625mm}\right)\left(\frac{0{,}022+0{,}08*1{,}154}{1-0{,}022*1{,}154}\right) + \left(\frac{0{,}08*29{,}76mm}{47{,}625mm}\right) = \mathbf{0{,}10}$$

$$K_{T(0,06)} = \left(\frac{22{,}8mm}{47{,}625mm}\right)\left(\frac{0{,}022+0{,}06*1{,}154}{1-0{,}022*1{,}154}\right) + \left(\frac{0{,}06*29{,}76mm}{47{,}625mm}\right) = \mathbf{0{,}08}$$

## 3.1.2 FONAS-equation:

$$K_T = \left(\mu_n \frac{d_n}{2*d}\right) + \left(\mu_t * \frac{d_t}{2*d} * \frac{1}{\cos 30°}\right) + \left(\frac{d_t}{2*d} * tgC\right)$$ ([Ref.2] §4.3.2)[9]

$d(\text{nominell diameter}) = 47{,}625mm$

$d_n(\text{effective contact diameter of nut} - \text{bearing surface}) = 60mm$

$d_t(\text{effective contact diameter of the threads}) = 45{,}56mm$

$tg\ C = \frac{P}{\pi * d} = \frac{3{,}175mm}{\pi * 47{,}625mm} = 0{,}021$

$C = \text{thread angle}$

$\mu_n = \mu_t = 0{,}06 \text{ or } 0{,}08$

**$d_n$ (nut-bearing surface = 60mm)**

$$K_{T(0,08)} = \left(\frac{0{,}08*60mm}{2*47{,}625mm}\right) + \left(0{,}08 * \frac{45{,}56mm}{2*47{,}625mm} * \frac{1}{\cos 30°}\right) + \left(\frac{45{,}56mm}{2*47{,}625mm} * 0{,}021\right)$$
$$= 0{,}050 + 0{,}044 + 0{,}010$$
$$= \mathbf{0{,}10}$$

$$K_{T(0,06)} = \left(\frac{0{,}06*60mm}{2*47{,}625mm}\right) + \left(0{,}06 * \frac{45{,}56mm}{2*47{,}625mm} * \frac{1}{\cos 30°}\right) + \left(\frac{45{,}56mm}{2*47{,}625mm} * 0{,}021\right)$$
$$= \mathbf{0{,}08}$$

[9] [Ref.2] Fonas. (1972). *Skrue håndbok.* Oslo: Elkem-Spigerverket A/S.

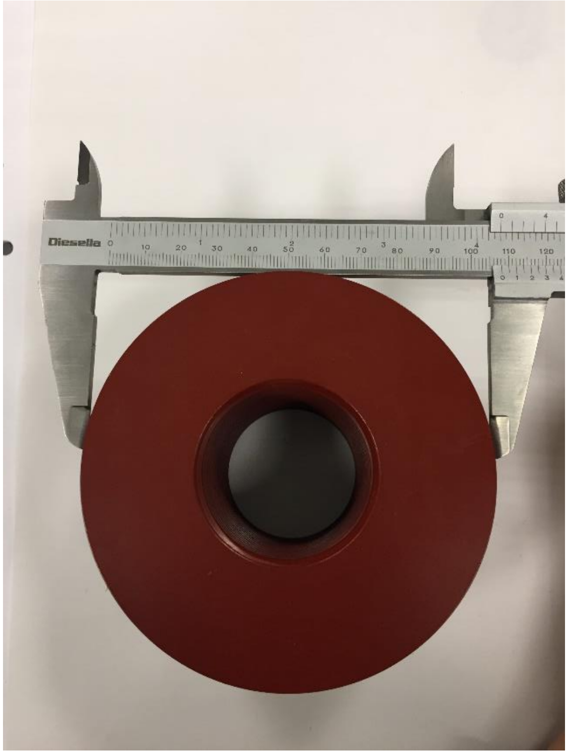



*Figure 4: Nut outer diameter – $d_n$=108mm*

*Figure 5: Nut inner diameter – $d_n$=48mm*

# 4. Torque calculations

$M_T = \mathbf{K_T * d_b * P_b}$ ([Ref.2] §4.3.2)[10]

$\mathbf{M_{T(0,06-0,08)}}$ = Xylan coating friction.

$\mathbf{M_{T(0,10)}}$ = nut-bearing surface friction.

Recommended torque with different K factor and without scatter factor:

0,67% of Yield:

$$\mathbf{M_{T,min(0,06)} = 0,06 * 47,625mm * 720,5kN = 2060Nm}$$

$$\mathbf{M_{T,min(0,08)} = 0,08 * 47,625mm * 720,5kN = 2745Nm}$$

$$\mathbf{M_{T,min(0,10)} = 0,10 * 47,625mm * 720,5kN = 3431Nm}$$

0,73% of Yield:

$$\mathbf{M_{T,max(0,06)} = 0,06 * 47,625mm * 785kN = 2243Nm}$$

$$\mathbf{M_{T,max(0,08)} = 0,08 * 47,625mm * 785kN = 2990Nm}$$

$$\mathbf{M_{T,max(0,10)} = 0,10 * 47,625mm * 785kN = 3738Nm}$$

With respect to a scatter factor of 0,10:

0,67% of Yield:

$$\mathbf{M_{T,min(0,06)} = 0,06 * 47,625mm * 648,5kN = 1853Nm}$$

$$\mathbf{M_{T,min(0,08)} = 0,08 * 47,625mm * 648,5kN = 2498Nm}$$

$$\mathbf{M_{T,min(0,10)} = 0,10 * 47,625mm * 648,5kN = 3088Nm}$$

0,73% of Yield:

$$\mathbf{M_{T,max(0,06)} = 0,06 * 47,625mm * 706,5kN = 2019Nm}$$

$$\mathbf{M_{T,max(0,08)} = 0,08 * 47,625mm * 706,5kN = 2692Nm}$$

$$\mathbf{M_{T,max(0,10)} = 0,10 * 47,625mm * 706,5kN = 3365Nm}$$

[10] [Ref.2] Fonas. (1972). *Skrue håndbok.* Oslo: Elkem-Spigerverket A/S.

**Torque on nut based on necessary preload in stud from hub face separation force:**

$$F_{stud} = \frac{6260\ kN}{16} * (2\times\tan 25°) = \mathbf{364,89kN}$$ ([Ref.1] eq. page 19)[11]

$$M_T = K_T * d_b * F_{stud} = 0{,}10 * 47{,}625mm * 364{,}89kN = \mathbf{1737,8Nm}$$

$$M_T = K_T * d_b * F_{stud} = 0{,}08 * 47{,}625mm * 364{,}89kN = \mathbf{1390Nm}$$

[11] [Ref.1] ISO 13628-7

| Friction | | 33 % of Torque | 66 % of Torque | 100 % of Torque |
|---|---|---|---|---|
| | | | | |
| | Min preload 0.67% | | | |
| K=0,06 | 2060Nm (0.67% of yield) | 680 Nm | 1360 Nm | 2060 Nm |
| K=0,08 | 2745Nm (0.67% of yield) | 906 Nm | 1812 Nm | 2745 Nm |
| K=0,10 | 3431Nm (0.67% of yield) | 1132 Nm | 2264 Nm | 3431 Nm |
| | | | | |
| | With respect to scatter | | | |
| K=0,06 | 1853Nm (0.67 W. scatter) | 611 Nm | 1223 Nm | 1853 Nm |
| K=0,08 | 2498Nm (0.67 W. scatter) | 824 Nm | 1649 Nm | 2498 Nm |
| K=0,10 | 3088Nm (0.67 W. scatter) | 1019 Nm | 2038 Nm | 3088 Nm |
| | | | | |
| | Max preload 0.73 % | | | |
| K=0,06 | 2243Nm (0.73% of yield) | 740 Nm | 1480 Nm | 2243 Nm |
| K=0,08 | 2990Nm (0.73% of yield) | 987 Nm | 1973 Nm | 2990 Nm |
| K=0,06 | 2019Nm (0.73 W. scatter) | 666 Nm | 1333 Nm | 2019 Nm |
| K=0,08 | 2692Nm (0.73 W. scatter) | 888 Nm | 1777 Nm | 2692 Nm |

*Table 1: Torque table*

Based on the results above, a mechanical test (TT-1-2-M) must be done. Use the following torque values and check the preload in stud by the mounted strain gauges.

| Torque (Nm) | 33% | 66% | 100% | ε, Strain in stud (MPa) | Test-ID |
|---|---|---|---|---|---|
| 2000 | 660 Nm | 1320 Nm | 2000 Nm | | |
| 2200 | 726 Nm | 1452 Nm | 2200 Nm | | |
| 2400 | 792 Nm | 1584 Nm | 2400 Nm | | |
| 2600 | 858 Nm | 1716 Nm | 2600 Nm | | |
| 2800 | 924 Nm | 1848 Nm | 2800 Nm | | |
| 3000 | 990 Nm | 1980 Nm | 3000 Nm | | |
| 3434 (Torque used today) | 1133 Nm | 2266 Nm | 3434 Nm | | |

*Table 2: Torque test table*

# 5. Conclusion

“The determination of the actual preload in a given bolt/stud-nut combination is difficult and all bolt preloading methods involve some degree of inaccuracy”. (ref [1] G.1.1).

“When the nut is turned by a torque, preload is introduced in the bolt due to the bolt pitch. Most of the torque applied is used to overcome thread friction and friction on the nut-bearing surface. Friction depends on the nature of the surface material as well as the applied lubrication”. ([Ref.1] G.1.3)[12].

“When making up and breaking out bolts, it is important to ensure that the desired preload is achieved. The tools used should be calibrated against a reference with a calibration traceable to a recognized standard. It is important that the whole preload system, consisting of tools and measuring devices, is calibrated as one unit. Bolt preload should be performed by qualified personnel.” ([Ref.1] G.1.1)[13].

The only way to confirm the calculated torque values, is through physically testing. The coefficient of friction is a compound value and depends on the material surface finish and contact surfaces. SCS will recommend connecting a strain-gauges on the stud. This will give a constant check on the strain and preload applied in stud. Lower friction coefficient will increase the preload in stud compared with a higher coefficient, if the torque value is the same.

The friction coefficients found in the two equations from Mechanicalc and FONAS is based on combining the friction in threads and between surfaces. We don’t know hove polite these equations are, and we cannot conclude with these values. The equations are normally used in bolt calculations and is maybe not right for stud/nut.

The difference in torque applied on a dry Xylan coated stud contra a Xylan coated stud with Molykote could be high. The Molykote combined with Xylan coating will give a very low

[12] [Ref.1] ISO 13628-7
[13] [Ref.1] ISO 13628-7

friction coefficient, maybe lover than 0,06. The Xylan itself is a low friction coating and maybe the applied Molykote is unnecessary.

We know that after some make and brakes, the Xylan coating will be worn away. The stud will then lose the low friction coefficient and maybe Molykote should be used to regain the low friction.

The mechanical test should include torque values based on the inaccuracy in friction, and friction values from 0.03 to 0.08 should be tested.

| Main Task ID: MT-2 | Test Report |
|---|---|
| Task Test ID | TT-2-1A-M |
| Priority | C |
| Description | Investigate torque, fraction and elongation in bolt vs stud. |
| Result | Accepted |

**Purpose**

Mechanical test of the stud and nut connection vs bolt connection used in the analyse. Check the fracture context between stud and bolt and measure the elongation.

| Procedure for small-scale testing of bolt vs stud. | | Test no: 1<br>Bolt + Molykote | ID:<br>TT-2-1A-M1 |
|---|---|---|---|
| **Test procedure** | | | |
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **1** | Check equipment and tools required list, and make sure all equipment are in place. | OK | EH |
| **1.1** | Mount metal piece 1 with the threaded holes in the vice. | OK | EH |
| **1.2** | Mount metal piece 2 with the drilled hole on top of the other metal piece who is fastened in the vice. | OK | EH |
| **1.3.1** | **(Test 1)** Torque the bolt into piece 1, so the bolt head is touching piece 2. | Used 30Nm as pre-torque. | EH |
| **1.3.2** | **(Test 2)** Mount the nut on top of the stud who is pointing out from piece 2. | Not relevant. | |
| **1.4** | Mount the puppitast. | OK | EH |
| **1.5** | Apply torque until bolt/stud fractures and fail. | Applied first 84Nm, then 100Nm and then 110-120Nm. The bolt started fracture around 120Nm. | EH |
| **1.6** | Measure the torque (load) applied on the nut and elongation in bolt/stud. | Torque used:<br>Step 1: 30Nm<br>Step 2: 84Nm<br>Step 3: 100Nm<br>Step 4: 110Nm | EH |

| | | | |
|---|---|---|---|
| | | Step 5: 120Nm | |
| **1.7** | Repeat step 4-5 with a new bolt/stud three times. | Repeated the test 3 times. | EH |
| **1.8** | Take picture to compare results for stud and bolt. | OK | EH |

**Bolt 1: M12 Bolt (Molykote).**

| | **Torque** | **Elongation** |
|---|---|---|
| Pre-torque | 30Nm | |
| Target torque 1 | 84Nm | 0,50mm |
| Target torque 2 | 100Nm | 0,685mm |
| Target torque 3 | 110Nm | 0,945mm |
| Target torque 4 | 120Nm | 9,3mm |
| Bolt head to fracture | | 13mm |

**Bolt 2: M12 Bolt (Molykote).**

| | **Torque** | **Elongation** |
|---|---|---|
| Pre-torque | 30Nm | |
| Target torque 1 | 84Nm | 0,275mm |
| Target torque 2 | 100Nm | 0,87mm |
| Target torque 3 | 110Nm | 1,66mm |
| Target torque 4 | 120Nm | 10mm |
| Bolt head to fracture | | 14,3mm |

**Bolt 3: M12 Bolt (Molykote).**

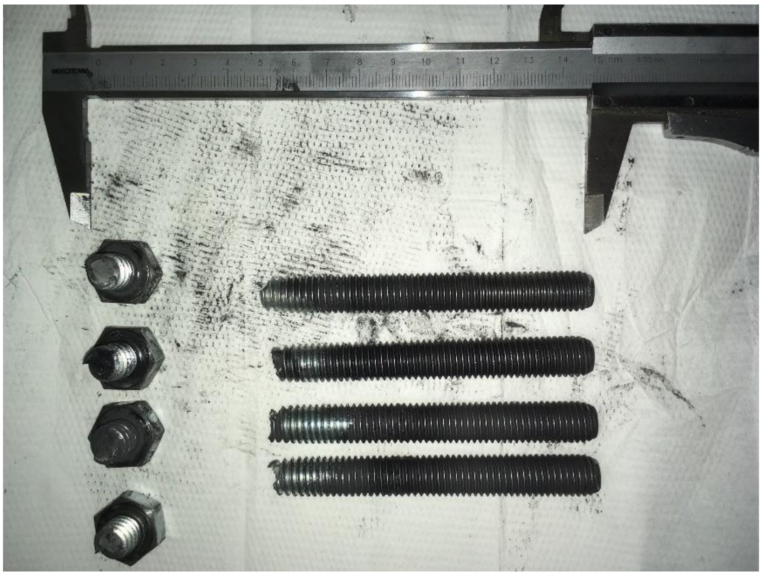
| | **Torque** | **Elongation** |
|---|---|---|
| Pre-torque | 30Nm | |
| Target torque 1 | 84Nm | 0,34mm |
| Target torque 2 | 100Nm | 1,21mm |
| Target torque 3 | 110Nm | |
| Target torque 4 | 120Nm | 9,8mm |
| Bolt head to fracture | | 12,5mm |

# Conclusion Bolt Test

Total bolt length was 107,5mm included the bolt head. Bolt head: h=7,5mm.

The torque was applied in steps, this was to have control over the moment who was necessary to brake the bolt. The maximum torque applied was 120Nm. The overall elongation for the three bolts is 9,7mm.

Overall length from bolt head to fracture point for the three bolts is 13,26mm, and the fracture happens approximately on the same place on every bolt.



| Procedure for small-scale testing of bolt vs stud. | | Test no: 2<br>Stud + Molykote | ID:<br>TT-2-1A-M2 |
|---|---|---|---|
| **Test procedure** | | | |
| **ACT NO** | **Procedure** | **Notes** | **Signature** |
| **1** | Check equipment and tools required list, and make sure all equipment are in place. | OK | EH |
| **1.1** | Mount metal piece 1 with the threaded holes in the vice. | OK | EH |
| **1.2** | Mount metal piece 2 with the drilled hole on top of the other metal piece who is fastened in the vice. | OK | EH |
| **1.3.1** | Torque the bolt into piece 1, so the bolt head is touching piece 2. | Not relevant. | EH |
| **1.3.2** | Mount the nut on top of the stud who is pointing out from piece 2. | Used 30Nm as pre-torque. | |
| **1.4** | Mount the puppitast. | OK | EH |
| **1.5** | Apply torque until bolt/stud fractures and fail. | OK | EH |
| **1.6** | Measure the torque (load) applied on the nut and elongation in bolt/stud. | Torque used:<br>Step 1: 100Nm<br>Step 2: 120Nm | EH |
| **1.7** | Repeat step 4-5 with a new bolt/stud three times. | Repeated the test 3 times. | EH |
| **1.8** | Take picture to compare results for stud and bolt. | OK | EH |

**Stud 1**

| | Torque | Elongation |
|---|---|---|
| Pre-torque | 100Nm | |
| Target torque 1 | 120Nm | 8,1mm |

**Stud 2**

| | Torque | Elongation |
|---|---|---|
| Pre-torque | 100Nm | |
| Target torque 1 | 120Nm | 8,9mm |

**Stud 3**

| | Torque | Elongation |
|---|---|---|
| Pre-torque | 100Nm | |
| Target torque 1 | 120Nm | 8,2mm |

# Conclusion Stud Test

SCS wanted to do a real-life test between stud and bolt, to see if there was any difference regarding fracture.

Stud length for the three was 95mm, 97mm and 95,4mm.

The torque was applied in steps, this was to have control over the moment that was necessary to brake the stud. The maximum torque applied was 120Nm. The overall elongation for the three studs is 8,4mm.

The fracture happens approximately at the same place, between the threaded engagement and the nut. This is similar to the bolt test and is also the expected fracture point because it is the weakest part.

Looking at the picture from the two different tests, you can see that the fracture happens at the same place on stud and bolt. So being conservative in the use of bolt vs stud in a FEM-analyze is ok based on the fracture point and the difference in elongation.

# M12 bolt.

Presented below are the results from TORQUE for a M12 Grade 8.8 bolt. The results are from http://www.boltscience.com/pages/torque2.htm

```
TORQUE TIGHTENING ANALYSIS RESULTS

Example calculation for a M12 bolt.

Torque tightening analysis for a M12 bolt.

FASTENER DETAILS
Fastener Diameter                           = 12.00 mm
Fastener Shank Diameter                     = 12.00 mm
Thread Pitch                                = 1.75 mm
Included angle between the thread flanks    = 60.00 degrees
Thread Pitch Diameter                       = 10.863 mm
Thread Root Diameter                        = 9.853 mm
Diameter related to the Thread Stress Area = 10.358 mm
Thread Stress Area                          = 84.264 mm�
Thread Root Area                            = 76.248 mm�
Bearing Area under Nut/Bolt Head            = 99.620 mm�
Fastener Outer Bearing Diameter             = 17.20 mm
Fastener Inner Bearing Diameter             = 13.00 mm
Fastener Clearance Hole Diameter            = 13.00 mm
Effective friction diameter of nut/bolt     = 15.20 mm
Fastener Yield Strength                     = 640.00 N/mm�

JOINT ASSEMBLY DETAILS
Black oxide steel external thread, no finish on steel
internal thread, no lubricant. Black oxide steel nut
or bolt, no oil, machined steel bearing surface. Prevailing
torque caused by a nylon/polyester patch on the threads.
Thread Friction Value                       = 0.120
Nut/Bolt Head Friction Value                = 0.120

TORQUE TIGHTENING ANALYSIS RESULTS
Yield Point Tightening Factor specified     = 0.90
Total Tightening Torque                     = 83.64 Nm
This torque is composed from:
Torque needed to extend the fastener        = 8.98 Nm
Torque needed to overcome thread friction   = 24.26 Nm
Torque needed to overcome nutface friction = 29.40 Nm
Prevailing Torque Value                     = 21.00 Nm

FORCE ANALYSIS RESULTS
Fastener Preload                            = 32239.37 N
Direct Force that would Yield the Fastener = 53928.91 N
Preload as a percentage of Yield Force      = 59.78 %

MAXIMUM STRESSES INDUCED INTO THE FASTENER
Percentage of the yield strength utilised   = 90.00 %
Von-Mises Equivalent Stress                 = 576.00 N/mm�
Tensile Stress due to Preload               = 382.60 N/mm�
Torsional Stress due to the applied torque = 248.59 N/mm�
Surface Pressure under the Nut Face         = 323.62 N/mm�
```

| Main task ID: MT-2 | Test Report |
|---|---|
| Task Test ID | TT-2-1B-M |
| Priority | C |
| Description | Investigate values on bolt vs stud fraction. |
| Result | Accepted |

**Purpose**

This test is to investigate the fracture mechanism of the stud nut connection vs bolt connection. Difference between cracking and cutting point.

**Location**

HSN Kongsberg Workshop.

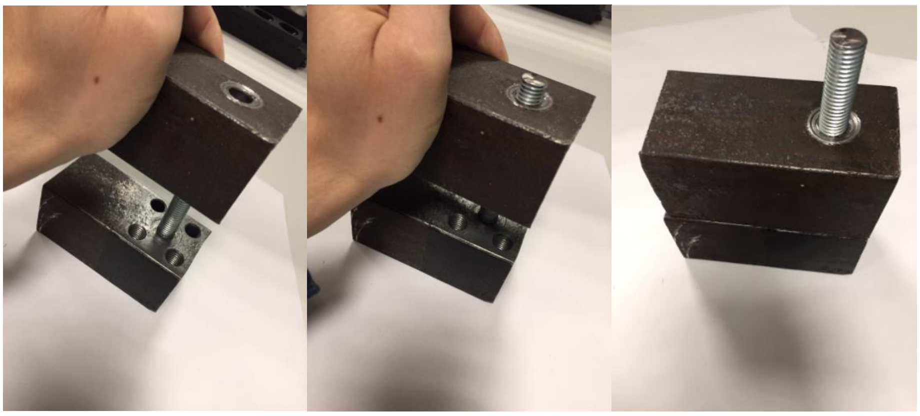
**Procedure of test**

SCS build a test kit to execute this test.

2 metal piece were machined to this kit.

1 metal piece with threads. SCS choose to drill and make 5 threads. This is because there are some high forces, and 5 holes are made to prevent damaging the same threads every time.

1 metal piece with a drilled hole were also made. This is to give a resistance on the bolt head/nut on stud. It also simulates the clamp that the real-life nut press against.



The metal piece with threads are mounted in a vice. Then the metal piece with a drilled hole are placed on top of this. These two metal pieces are mounted together with a small hand-vice. Test kit is now complete and ready.

SCS used a torque wrench to break the bolts and studs.

Torque was set to 200 Nm on both bolt and stud.

## Bolt test

# Stud test

# Conclusion

The reason this test was performed, was because FEA (Finite element analyse) are done with a bolt, instead of a stud. Stud are used in the real-life, but TechnipFMC used a bolt in their 3-D analyses tool, ABACUS. It is easier regarding to mesh, boundaries etc. to use a bolt, instead of a stud.

SCS wanted to do a real-life test between stud and bolt, to see if there was any difference regarding fracture.

**Conclusion:**

Using bolt instead of a stud, was a correct decision.

Looking at the picture from the two different tests, you can see that the fracture happens at the same place on both stud and bolt.

| Main Task ID: MT-3 | Task report |
|---|---|
| Task Test ID | TT-3-1-T |
| Priority | B |
| Description | Identify all variables affecting torque on nut and preload in stud. |
| Result | Accepted |

## List of variables

The following are some factors that affect the preload in stud and torque applied on nut.

1. Thread pitch, pitch diameter and thread form.
2. Surface finish of thread faces and nut-bearing surface area.
3. Temperature in material.
4. Environmental temperature.
5. Several types of lubricate between surfaces. (Ex: WD-40, Molykote and copper paste).
6. Coating. Nut/stud-bearing surface material. Xylan coating is used on nut, stud, washer and clamp.
7. Stud diameter. It takes more force to tighten a bigger stud because it is larger in diameter. Nominal diameter, minor diameter and pitch diameter.

8. Coefficient of friction. The value of this factor indicates that harder, smoother, and/or slicker nut/stud surfaces such as threads and bearing surfaces, requires less rotational force (torque) to stretch (tension) a stud. The friction coefficient is always an estimate. The commonly used coefficient is 0.20 for plain finished studs, 0.22 for zinc plated studs, and 0.10 for waxed or highly lubricated studs. The friction coefficient for Xylan coated studs is 0.08.

9. Tightening method and scatter factor. A scatter value of 0,2 is used as the studs will be preloaded with a hydraulic tensioner.

**Table G.1 — Indicative values of ε for bolts**

| Bolting-up (tightening) method<br>Measuring method | Factors affecting scatter | Scatter value<br>$\varepsilon$ |
|---|---|---|
| Wrench: operator feel or uncontrolled | Friction, stiffness, qualification of operator | 0,5 |
| Impact wrench | Friction, stiffness, calibration | 0,4 |
| Torque wrench equals wrench with measuring of torque (only) | Friction, stiffness, calibration | 0,3 |
| Hydraulic tensioner; measuring of hydraulic pressure | Stiffness, bolt length, calibration | 0,2 |
| Wrench or hydraulic tensioner; measuring of bolt elongation | Stiffness, bolt length, calibration | 0,15 |
| Wrench; measuring of turn of nut (nearly up to bolt yield) | Stiffness, friction, calibration | 0,10 |
| Wrench; measuring of torque and turn of nut (nearly up to bolt yield) | Calibration | 0,07 |

10. Friction against clamp and stud. 25 degrees. (Conservatively, no friction between the clamp segments and hubs has been assumed).

11. Material specification: Yield and tensile strength.

| Main Task ID: MT-3 | Task report |
| --- | --- |
| Task Test ID | TT-3-2-T |
| Priority | B |
| Description | Investigate variables affecting torque on nut and preload in stud. |
| Result | Accepted |

# Summary

This document contains a further investigation of the variables affecting preload in stud an applied torque on nut.

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 24.04.2017 | 9 | BR | Created document and filled inn information |
| V.0.2 | 02.05.2017 | 13 | EH | Updated information. |
| V.1.0 | 24.05.2017 | 14 | SCS | Ready for last hand in. |

# References

[Ref.1] Boulonplus. http://www.boulonsplus.net/basic-terminology/ (2017, 23.05)

[Ref.2] Wikipedia. (18.12, 2010) https://commons.wikimedia.org/wiki/File:Pure_iron_phase_diagram_(EN).png(2017, 23.05)

[Ref.3] Parla Tech. Industrial supply co, engineering tracing. http://www.parla-tech.com/molykote-tp-42-paste.php(2017, 23.05)

[Ref.4] Wilko. http://www.wilko.com/car-care-products/wd-40-dual-action-lubricant-spray-200ml/invt/0323229(2017, 23.05)

[Ref.5] CAVALIER, Industrial specialties. (http://www.gocav.com/MetricMfg/Metric.htm (2017, 23.05)

[Ref.6] Bolt science. http://www.boltscience.com/pages/casestdy.htm (2017, 23.05)

[Ref.7] Doc No: RPT60020900, from TechnipFMC

[Ref.8] Doc No: RPT60020900, from TechnipFMC

[Ref.9] (2017, 23.05) https://alliance.seas.upenn.edu/~medesign/wiki/index.php/Courses/MEAM247-11C-P2P1-background

Subsea Connection System

# Contents



## Figures

# 1. Investigate variables

From TT-3-1-T SCS have found different variables that have an effect on preload in stud and torque on nut:

## 1.1 Thread pitch, pitch diameter and thread form

Thread pitch used is 8 threads per inch.

Pitch diameter are: $dpi = \text{dnom} - 0{,}64951908 * 3{,}175$ => 45,56 mm.

Thread form used are Unified, ISO standard.

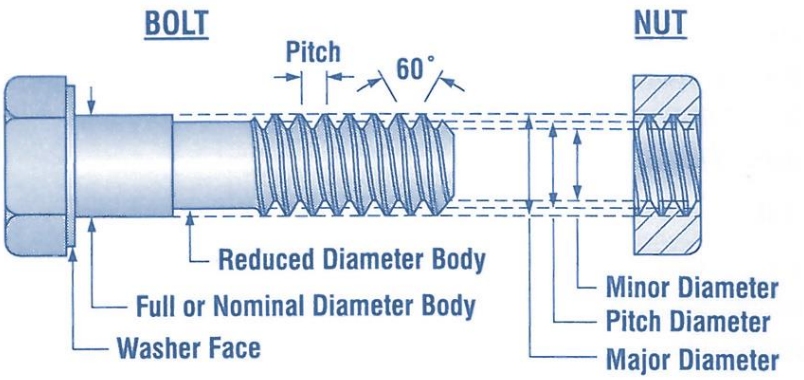



*Figure 1: Screw and nut ([Ref.1])*

Threads can be very easy, or very advanced. Form on threads, pitch, length etc. can all have a massive impact on forces effecting on the threads. That's why it is important to investigate threads and understand witch one to choose.

In this bachelor thesis, SCS have received an "Standard global make up, torque values", document number PRD-0000021662, from TechnipFMC. This document gives different types of standard bolt/nut values to use, with information as thread pitch, thread form etc. It also gives a recommended torque value to use.

We in SCS have investigated this document, and tried to use a little different approached.

## 1.2 Surface finish of thread faces and nut-bearing surface area

Surface finish on threads, nut bearing, washer and clamp are all the same.
The surface is coated with Xylan Coating, with a deep red colour. This coating is intended for components that require tight tolerances on assembly of mating surfaces; seal surfaces, coarse threaded connections and other sliding surfaces subjected to high loads, and where underwater visibility is required. This coating has excellent wear/corrosion resistance and is suitable for continuous operation at temperatures of -50 to 175°C.

Xylan coating have a friction factor of μ= 0,08. Ref PRD-0000021662, Chapter 7.5

*Figure 2: Nut, stud and washer with Xylan coating*

## 1.3 Temperature in material

Temperature in material is an important factor to use in calculations. Temperature can affect the structural strength in the metals. Metals are comprised of a symmetrical structure of atoms known as an allotrope. Heating the metal will displace atoms from their position and the displaced atoms form a new structure. This process is known as allotropic phase transformation. Allotropic phase transformation alters the hardness, strength and ductility of the metal. Temperature can also affect electrical and magnetic properties on a material. In other words, SCS needed to have control over the temperature.

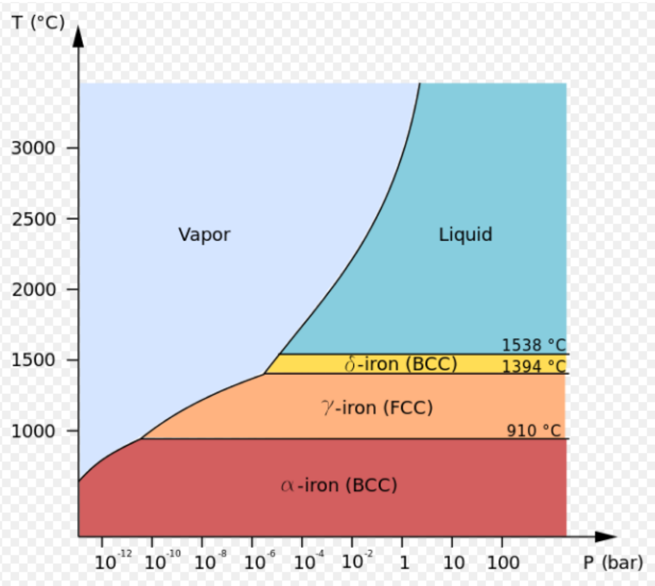



*Figure 3: Phase diagram of pure iron ([Ref.2])*

This curve shows a phase diagram of pure iron. This is an example on how the temperature can impact on metals.

FCC (Face centred cubic) and BCC (Body centred cubic) represent how atoms/sphere are arranged inside of it. This is highly effected by temperature and pressure, and will change the structural values on metals.

In SCS`s study, <u>20 °C have been used in all calculations.</u> This is a standard value used, to get comparable results and calculations.

## 1.4 Environmental temperature

SCS calculations are based on environmental temperature below 50 °C. At temperatures above 50 °C a derating must be made. This may be based on the yield stress derating at elevated temperatures above 50 °C specified in ISO 13628-7:2005(E)[1] for carbon manganese and low-alloy steels. Simply put: the capacities should be multiplied by the “Temperature reduction factor” in table 10 of ISO 13628-7:2005(E).

Environmental temperature below 50 °C are an “worst-case” scenario, where forces and bending capacity will be on the highest.

Fasteners for subsea installations will normally operate into deeper water and low temperatures, and the cost of fastener/joint failure are high. Ensuring their resistance to corrosion and the various forms of environmentally impact is important.

## 1.5 Several types of lubricate between surfaces

When installing studs, nuts, etc. lubricates are being used. This is a factor that can have a considerable impact on the torque. By using lubricate between surfaces, the friction will decrease and you need less torque force to achieve the necessary preload. Examples of lubricates is Molykote and WD-40.


*Figure 4: Molykote and WD-40 ([Ref.3 and 4])*

## 1.6 Stud diameter

It takes more force to tighten a bigger stud because it is larger in diameter and more surface areas who creates more friction.

Stud diameter is a variable to take into account. Normally, the best is to get as small diameter as possible, within the preferred values it shall operate in.

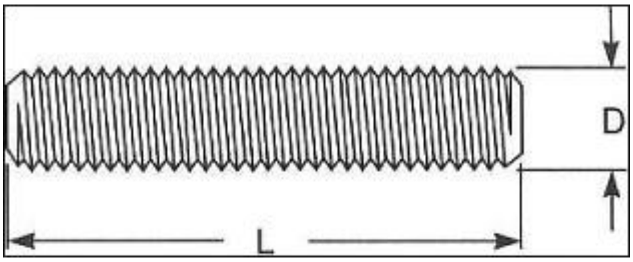



*Figure 5: Stud ([Ref.5])*

Larger diameter cost more money and are more difficult to handle.

An issue with a larger diameter is the tools that must be used. A working requirement is that if an equipment or tool are over 25 KG, a person cannot lift it. Then the company have to use a lifting crane or something similar to move it. With large diameter on stud/nuts/bolts, a heavy and big torque tool is required. The torque tool TechnipFMC have to use on today's studs and nuts, are over 25KG. This is acceptable, but it would be faster, easier and cheaper to use a tool under 25KG.

SCS are considering if it is possible to use a smaller diameter on stud and nut.

## 1.7 Coefficient of friction

The value of this factor indicates that harder, smoother, and/or slicker nut/stud surfaces such as threads and bearing surfaces, requires less rotational force (torque) to stretch (tension) a stud. The friction coefficient is always an estimate. The commonly used coefficient is 0.20 for plain finished studs, 0.22 for zinc plated studs, and 0.10 for waxed or highly lubricated studs. The friction coefficient for Xylan coated studs is 0.08.

Formula for friction: $\mu = \frac{frictional\ Force\ (F)}{normal\ force\ (N)}$

From tests, it is known that approximately 50% of the tightening torque is dissipated in overcoming friction under the bolt head or the nut face (whichever is the face that is rotated). Typically, only 10% to 15% of the overall torque is actually used to tighten the bolt, the rest is used to overcome friction in the threads and on the contact face that is being rotated (nut face or bolt head). This is illustrated in the pie chart shown. Relatively small changes in the nut face friction can have a significant effect on the bolt preload.

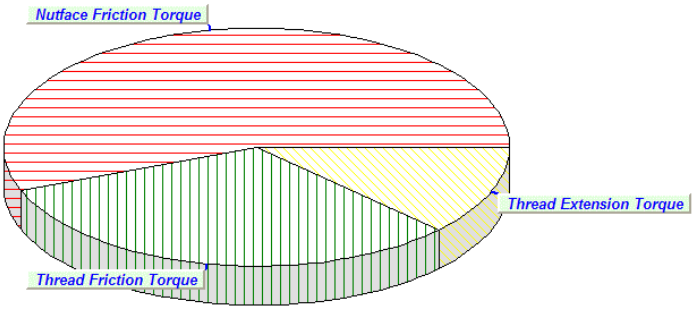



*Figure 6: Friction Pie chart ([Ref.6])*

## Example: Friction affecting preload

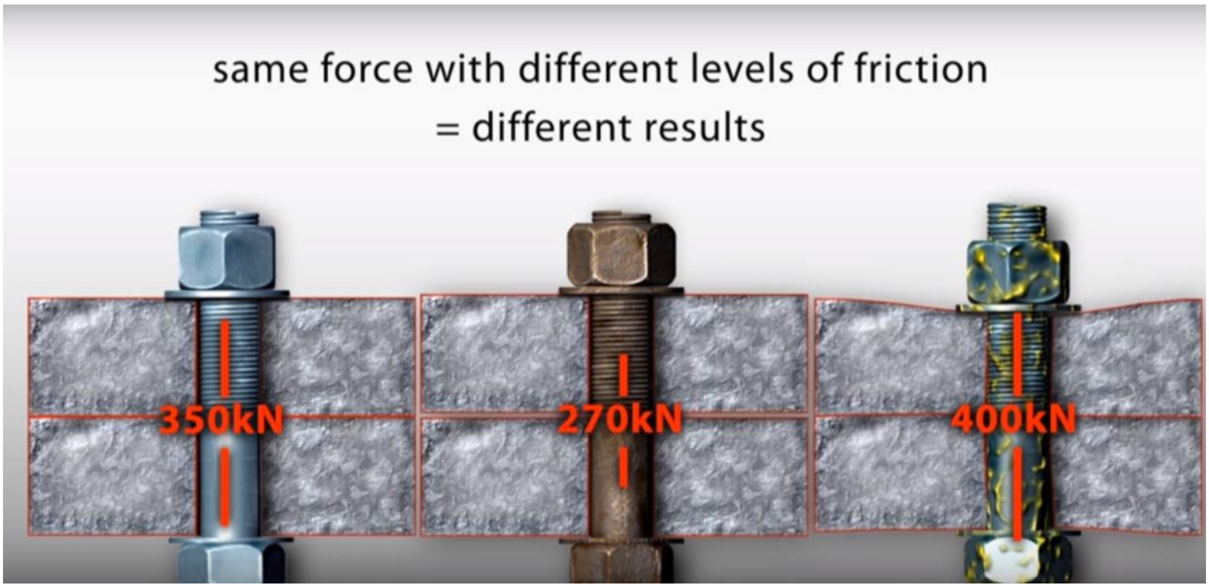



*Figure 7: Same torque with different friction.*

**Left bolt:**

Condition: A new, dry bolt. (Standard friction).

Torque: 2000Nm

Applied preload: 350kN

**Middle bolt:**

Condition: Old, rusted bolt. (High friction).

Torque: 2000Nm

Applied preload: 270kN

**Right bolt:**

Condition: A new, lubricated bolt. (Low friction).

Torque: 2000Nm

Applied preload: 400Kn

## 1.8 Tightening method and scatter factor

The determination of the actual preload in a given bolt-nut combination is difficult, and all bolt preloading methods involve some degree of inaccuracy. Scatter factor includes the inaccuracy in calculations.

**Table G.1 — Indicative values of ε for bolts**

| Bolting-up (tightening) method<br>Measuring method | Factors affecting scatter | Scatter value<br>$\varepsilon$ |
|---|---|---|
| Wrench: operator feel or uncontrolled | Friction, stiffness, qualification of operator | 0,5 |
| Impact wrench | Friction, stiffness, calibration | 0,4 |
| Torque wrench equals wrench with measuring of torque (only) | Friction, stiffness, calibration | 0,3 |
| Hydraulic tensioner; measuring of hydraulic pressure | Stiffness, bolt length, calibration | 0,2 |
| Wrench or hydraulic tensioner; measuring of bolt elongation | Stiffness, bolt length, calibration | 0,15 |
| Wrench; measuring of turn of nut (nearly up to bolt yield) | Stiffness, friction, calibration | 0,10 |
| Wrench; measuring of torque and turn of nut (nearly up to bolt yield) | Calibration | 0,07 |

Table G.1 is taken out of ISO 13628-7. In SCS`s study, a scatter factor of 0.10 are being used.

SCS have discussed this factor with TechnipFMC, and the conclusion was 0.10.

## 1.9 Friction against clamp and stud

A 25-degree angle. Conservatively, no friction between the clamp segments and hubs has been assumed.

In TechnipFMC analyse (Doc No: RPT60020900), they did not use any friction between clamp segments. SCS will use this as a factor in calculations.

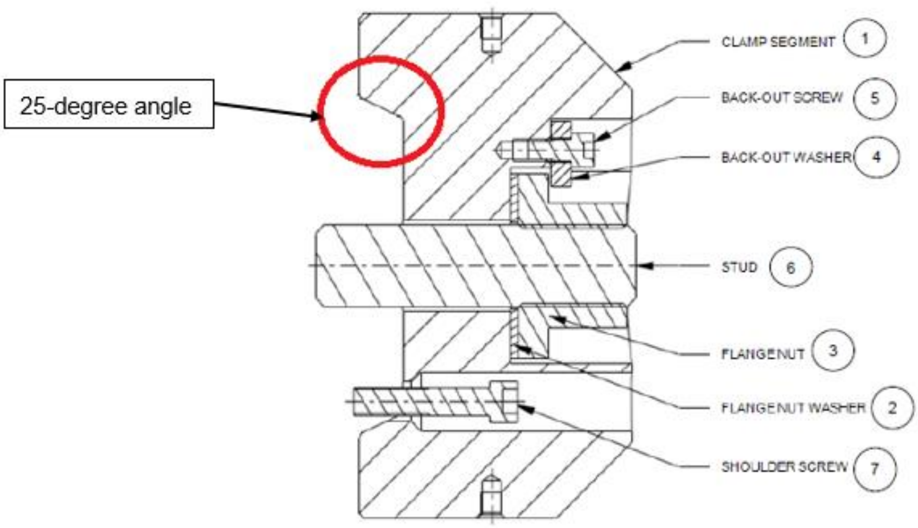



*Figure 8: Clamp segment ([Ref.7])*

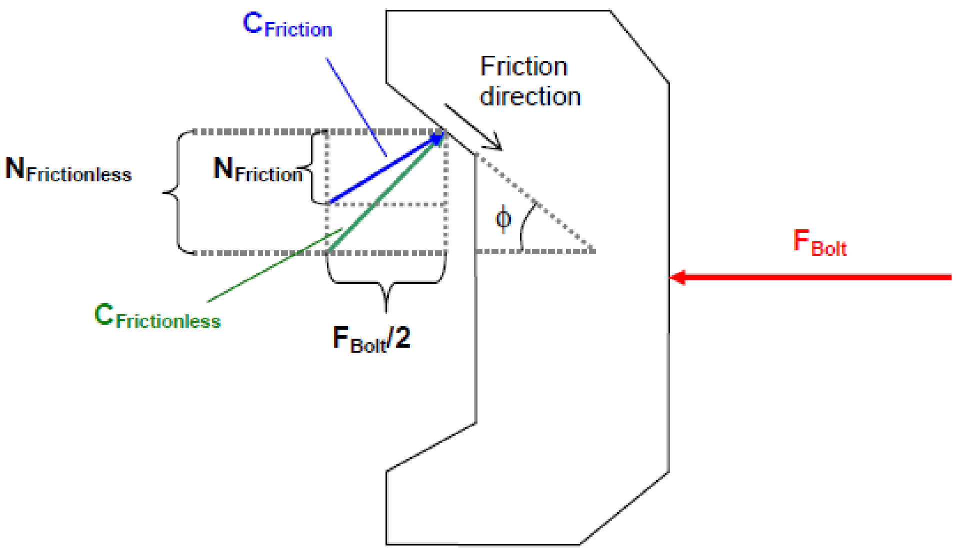



*Figure 9: Friction against clamp and stud ([Ref.8])*

## 1.10 Material specification: Yield and tensile strength

Yield point or Yield Strength, is where the material goes from an elastic deformation, to a plastic deformation.

Short explained: Elastic deformation is a deformation where the material goes back to the normal condition, with no permeant deformation. Plastic deformation is a permeant deformation.

So, when tightening the bolt in the elastic area, the bolt will operate like a spring and force the bolted connection together. A limit of 67% of yield strength is ISO standard and is also used in SCS analysis.

The term tensile strength refers to the amount of tensile (stretching) stress a material can withstand before breaking or failing. The ultimate tensile strength of a material is calculated by dividing the area of the material tested (the cross section) by the stress placed on the material.

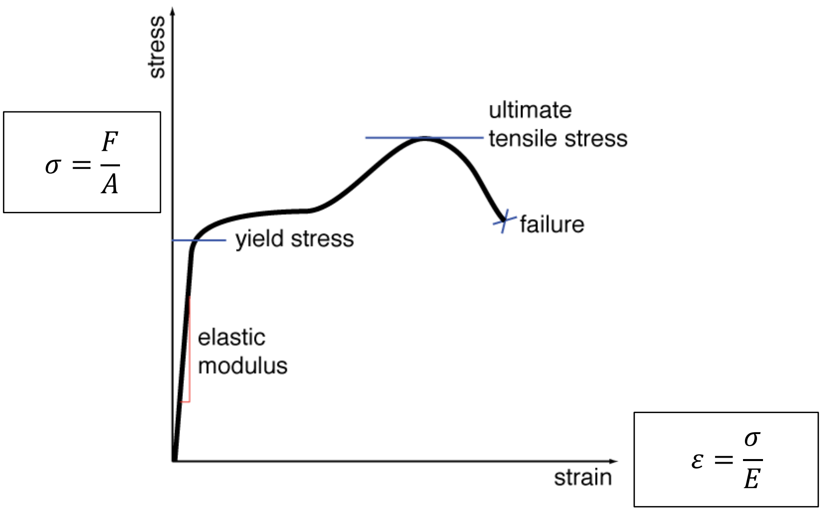



*Figure 10: Stress- strain curve ([Ref.9])*

E-modulus: 205 000MPa.

SCS use a Yields strength (sigma) on 725 MPa, and a Tensile strength on 895 MPa in this study.

TechnipFMC

Subsea Connection System

| Practical test report | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 1.0 |
| | |
| **SCS**<br>**Group members** | Asbjørn Antonsen,<br>Project leader and construction<br>Initial: AA |
| | Bjørn Ledaal Rossavik,<br>Qualification and specification<br>Initial: BR |
| | Erlend Berg-Olsen,<br>System Engineer and Project planner<br>Initial: EBO |
| | Espen Hansen,<br>Test and Verification<br>Initial: EH |
| | |



Høgskolen i Sørøst-Norge

# Summary

This document contains our attempt to run FEM-analyzes in Solidworks Simulation, recommended used mesh, and our stress and strain results.

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 22.05.2017 | 26 | EBO | Created document, filled in information and run FEM-analyze. |
| V.1.0 | 23.05.2017 | 26 | SCS | Ready for last hand inn. |

# Abbreviations and technical words

| Abbreviation | Explanation |
|---|---|
| WOR | Workover Riser |
| SCS | Subsea Connection System |
| HSN | Høgskolen i Sør-Øst Norge |
| FEM | Finite Element Method |

| Technical Words | Explanation |
|---|---|
| ABAQUS | Software for finite element analysis. |
| Hub | Flanged part of the SL connector. |
| Preload | Tension force in the stud/bolt after tightening. |
| Torque | Moment of force. |
| Stud | Threaded rod similar to a bolt but it has no bolt head. |
| Clamp | Speedloc without stud and nut |
| Nut | Is fastener with a threaded hole. |
| Washer | Used to distribute the load. |
| STP | STP is a file extension for a 3-D graphic files. |
| SLDPRT | File type for a 3-D graphic files that runs in Solidworks. |
| Mesh | Elements that approximates the geometry domain. |
| Tetrahedral | A triangular mesh type |
| Hexahedral | A rectangular mesh type |

Subsea Connection System

# Contents





Høgskolen i Sørøst-Norge

# Figure

# Table

# Report Solidworks simulation

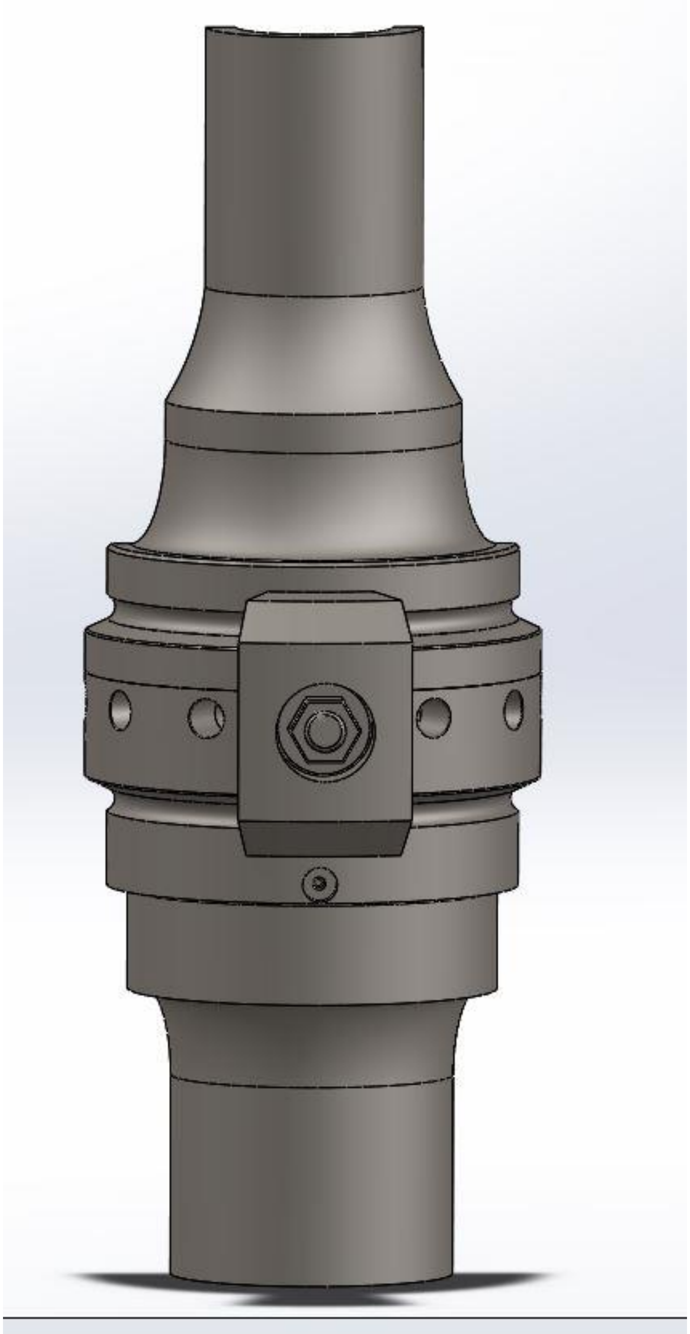


*Figure 1 Speedloc on hub*

# 1. Introduction

This document will contain our attempt to run analysis in SolidWorks simulation. In our bachelor thesis, we received some STP files from TechnipFMC where the parts we needed was drawn. This was weary large and memory demanding files that we had to convert from STP to SLDPRT files, to make it run in Solidworks simulation.

In our attempt to run the analysis that TechnipFMC already had run in ABACUS some difficulties occurred, our pc and the student version of Solidworks made it difficult to get believable results.

The computer used to run analyzes have a i7 processor with 3.1GHz, NVIDA Geforce 940M screen card, 8Gb DDR3 memory and 256 GB SSD hard drive.

This report contains how we made the analyses in Solidworks, and what went wrong.

# 2. Assumption

Because of errors and complications around modifying the parts to fit the Solidworks Simulation – student version, the test is run in the idea of the speedloc is in full engagement with the hub. This may cause not all off the stress in the 25º degrees area of the clamp. But the main part of this FEM-analyze was to see how the stress and strain appears around the nut and stud, and therefore the stress in the 25º of the clamp itself is not considered.

The washer that is being applied in the assembly in not included.

# 3. Parts

All the parts used in the analyze is given by TechnipFMC, they have created it for use in ABACUS – a different kind of 3D-drawing and simulation program. The parts where in SPT-file, you can open them and look at them, but you cannot change or run simulations on them in the student version of Solidworks, so to begin with it demands that the files are stored as SLDPRT-files, used by Solidworks.

The original file from TechnipFMC was weary large with many surfaces, and several imported bodies, the result was that we did break down the file and tried to run the analyze with just the stud, nut and the clamp to save memory space for Solidworks.

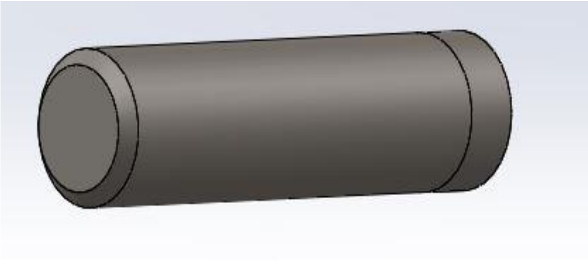


*Figure 2 Stud*

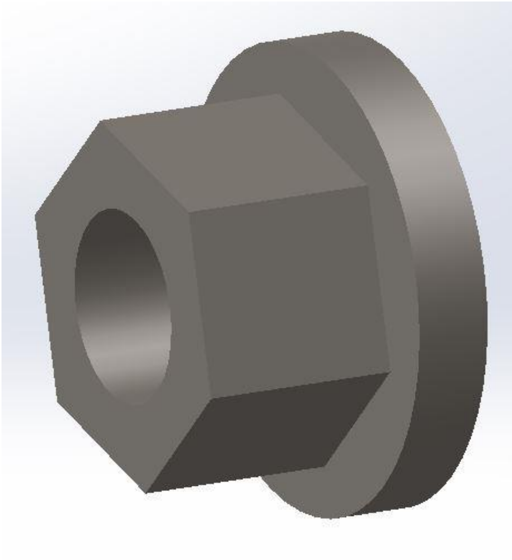


*Figure 3 Nut*

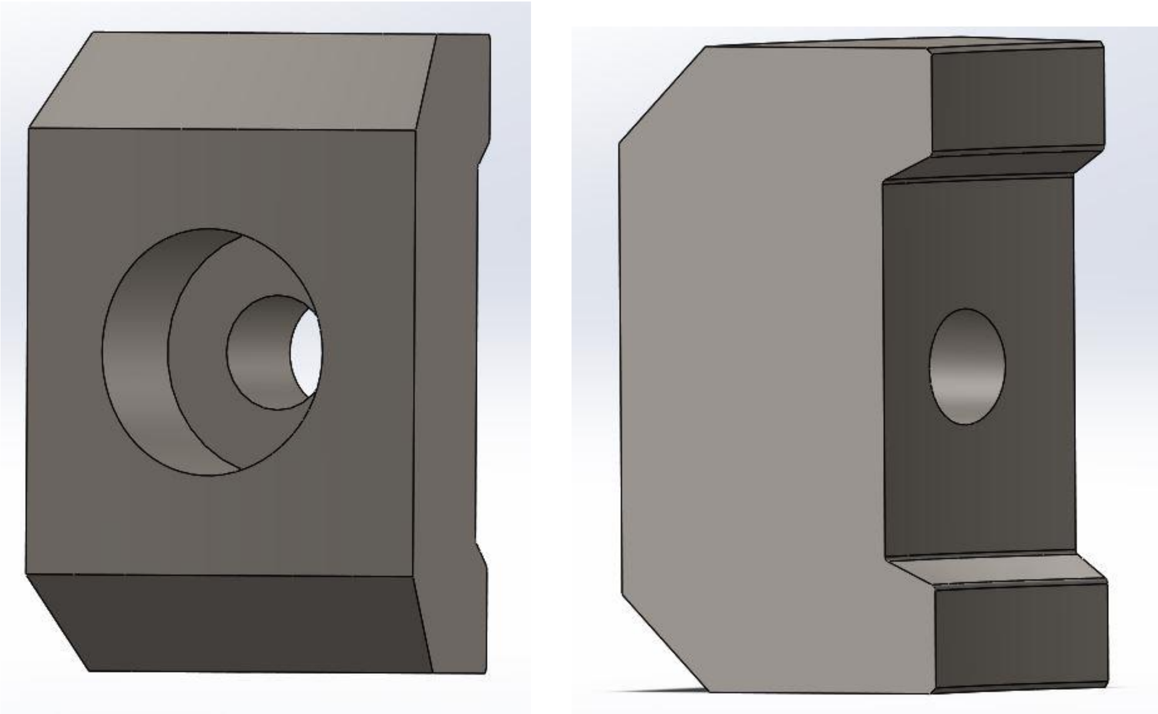


*Figure 4 Speedloc*

# 4. Fixtures and connection

## 4.1 Fixtures

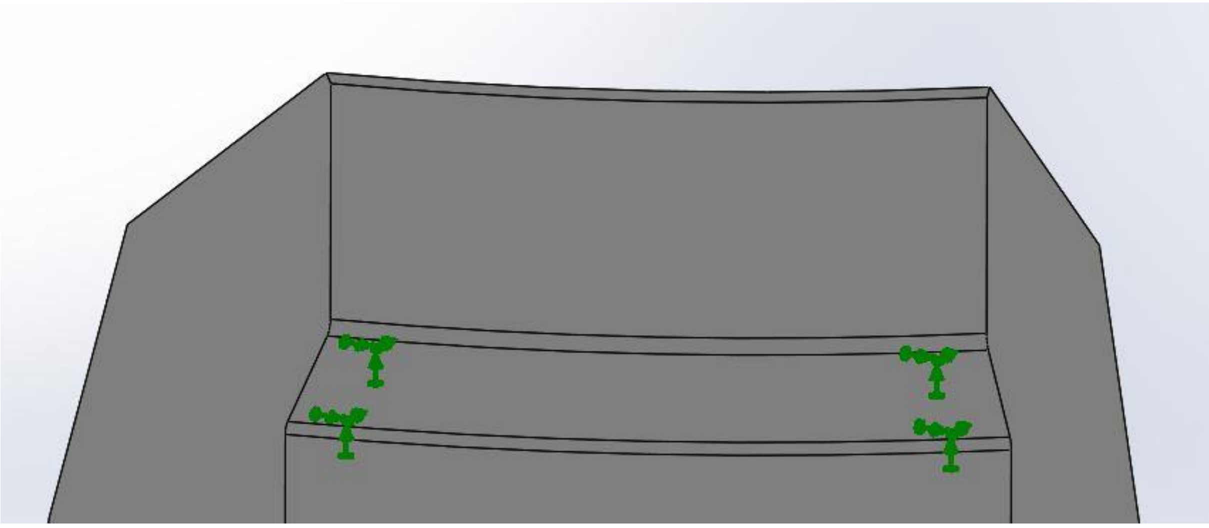


*Figure 5 Fixtures on Speedloc*

To simulate that the clamp is in full connection to the hub, “fixed geometry” was set on both 25º degrees sides on the speedloc. This helps the speedloc to think that it is in full contact with the hub.

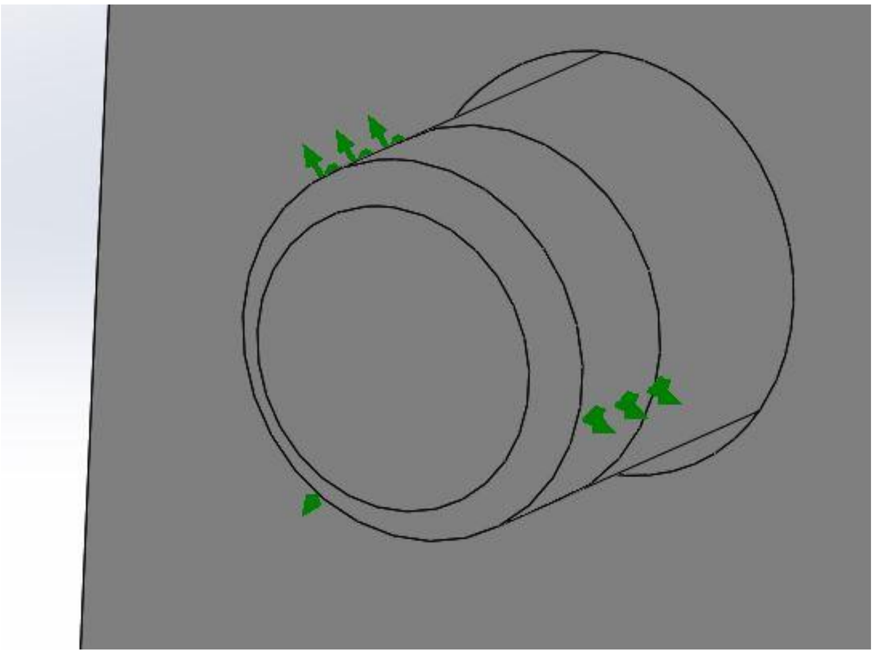


*Figure 6 Fixture on cylindrical faces*

To simulate that the stud is in connection to the hub, “advanced fixtures for cylindrical faces” was set. By drawing a split line for construction uses on the stud it is possible to choose the area you want to set your fixture on.

## 4.2 Connection

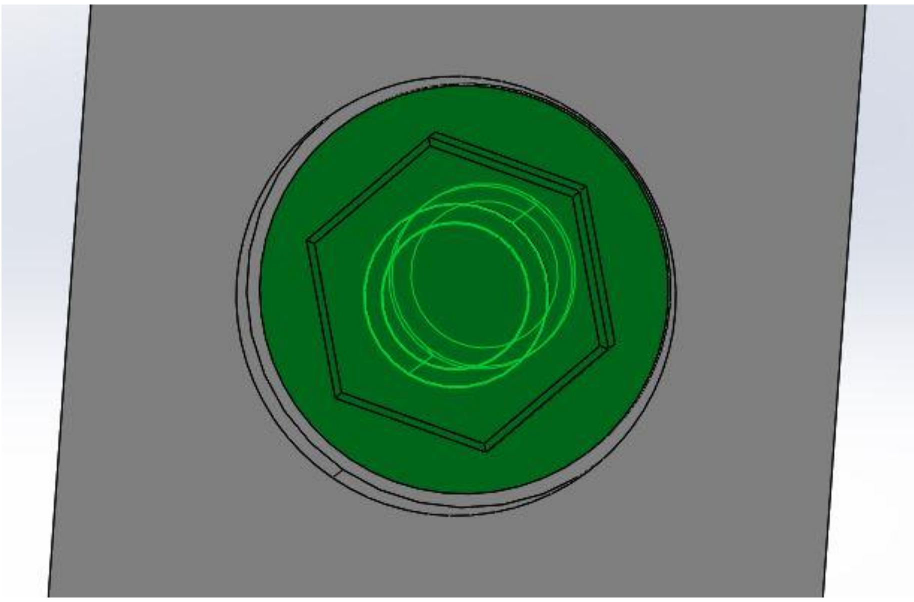


*Figure 7 Component contact*

Between stud/nut and nut/clamp a “no penetration” contact is set. By applying this the FEM analysis knows that it is going to transfer the forces in to the stud and clamp. The parts are free to move, but are connected as they would in real life.

## 4.3 Loads

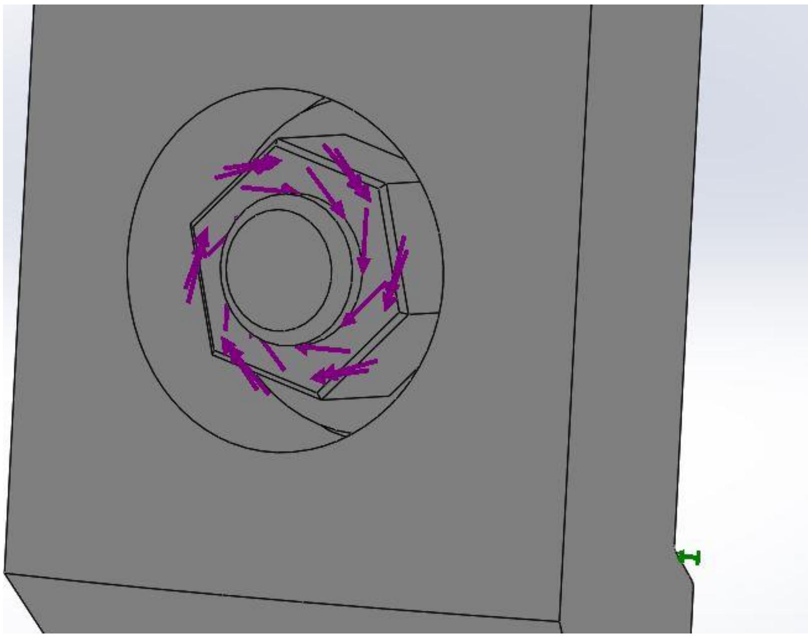


*Figure 8 Torque on nut*

A torque of 3434Nm was applied to the nut with a friction factor of 0.07.

3434Nm was applied because that is the currently applied torque of the stud and nut.

# 5. Mesh

A high-quality mesh is important to get a correct answer of your FEM-analyze. The more elements you get in transitions and edges, increases the quality of your mesh and the correctness of your FEM-analyze, but it demands much more of your computer.

In our analyze we tried to run our analyze with two different good quality meshes.

## 5.1 Used mesh

The first time was a run with a “draft quality mesh”, this mesh is a linear tetrahedral solid element.

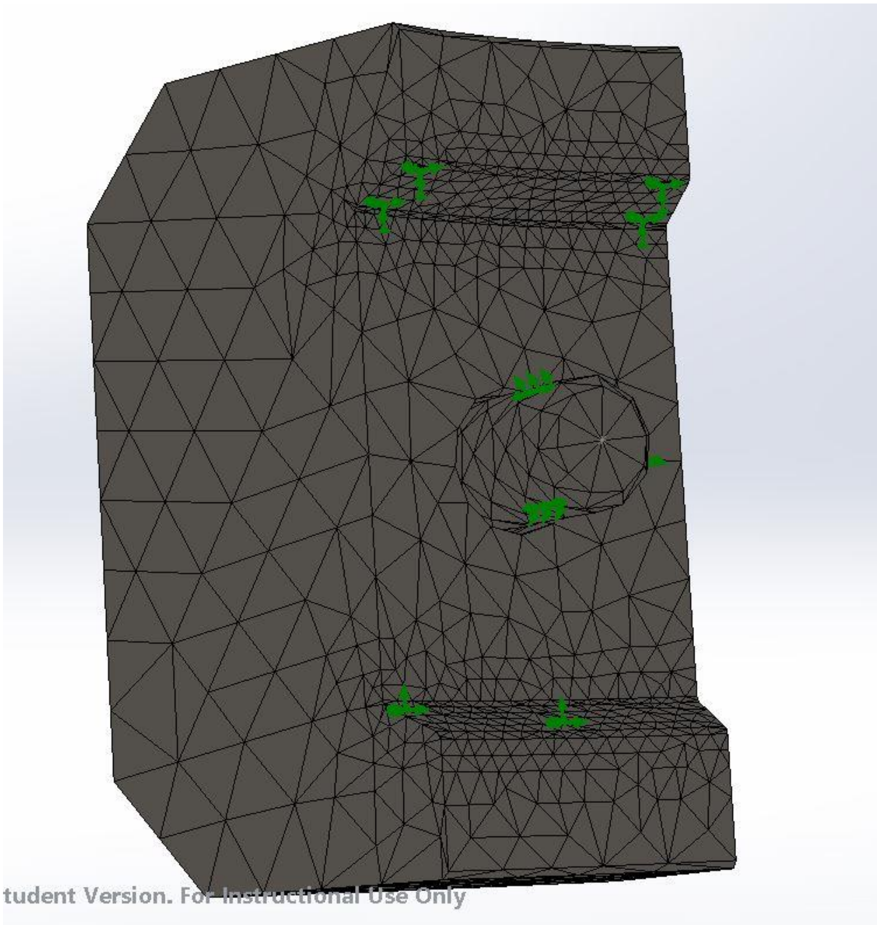



*Figure 9 Mesh on speedloc*

A curvature based mesh to create more elements in higher-curvature based areas with tetrahedral 10 elements in a circle. Draft quality mesh is recommended when you need to do a quick but high quality analyze, and is to prefer in the local features in your model.

*Table 1: Used Mesh*

| Mesh Details | |
|---|---|
| Study name | Static 1 (-Default-) |
| Mesh type | Solid Mesh |
| Mesher Used | Curvature based mesh |
| Jacobian points | 16 points |
| Max Element Size | 43.5436 mm |
| Min Element Size | 8.70871 mm |
| Mesh quality | Draft |
| Total nodes | 1552 |
| Total elements | 6132 |
| Maximum Aspect Ratio | 277.85 |
| Percentage of elements with Aspect Ratio < 3 | 91.1 |
| Percentage of elements with Aspect Ratio > 10 | 0.261 |
| Remesh failed parts with incompatible mesh | Off |
| Time to complete mesh(hh:mm:ss) | 00:00:01 |
| Computer name | |

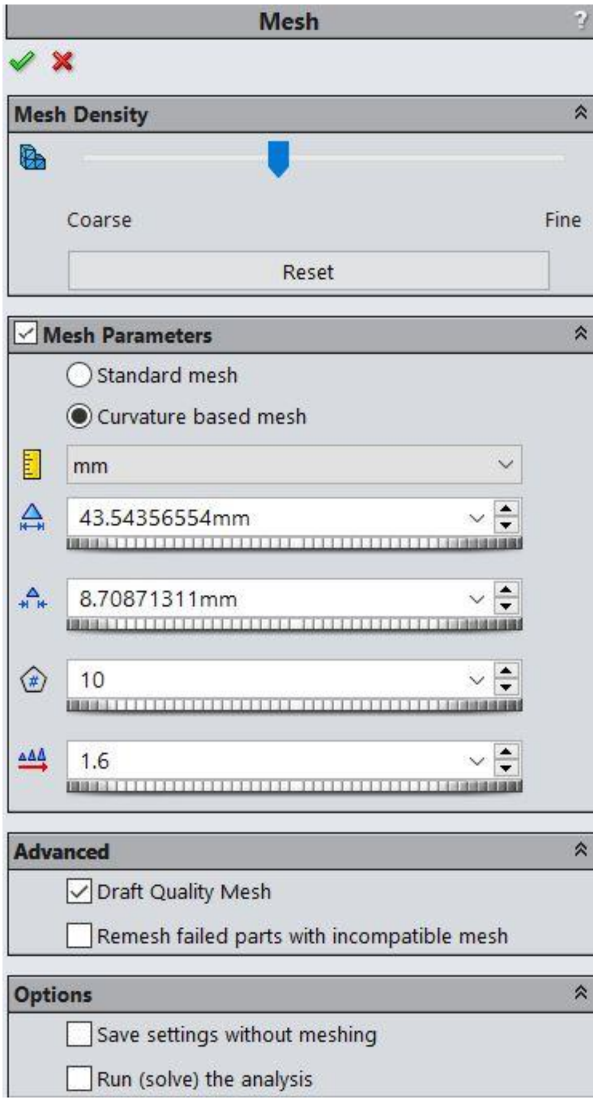


*Figure 10 Used mesh settings*

This meshing details will give you a good analyze to show where in the area the stress of the parts is located, but to get a 100% correct result that is trustworthy a "high quality mesh" is to recommend.

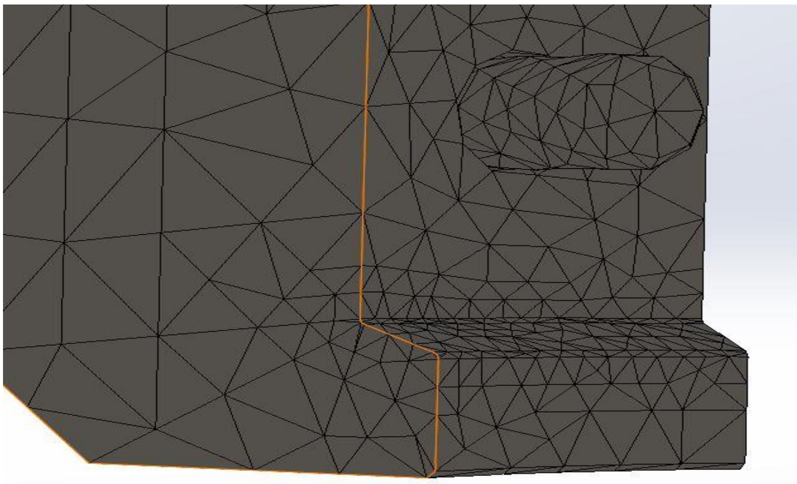


*Figure 11 Mesh on Speedloc*

## 5.2 Recommended mesh

A recommended mesh will contain a mesh with tetrahedral 10 elements or more, if you use to many elements you will see that a little or nothing changes the result of your FEM-analyze. From TechnipFMC it is desirable to run with Hexahedral with 10elements, but the student version of Solidworks don't have this kind of mesh.

In the student version of Solidworks you can choose "jacobian points 4, 16, 29 tetrahedral elements" to create your mesh, we tried to run with jacobian points 16.

Jacobian points are a high-quality mesh, that generates "parabolic" tetrahedral solid elements and creates finer mathematical overtures, but it demands a lot from the computer and will be harder to run.

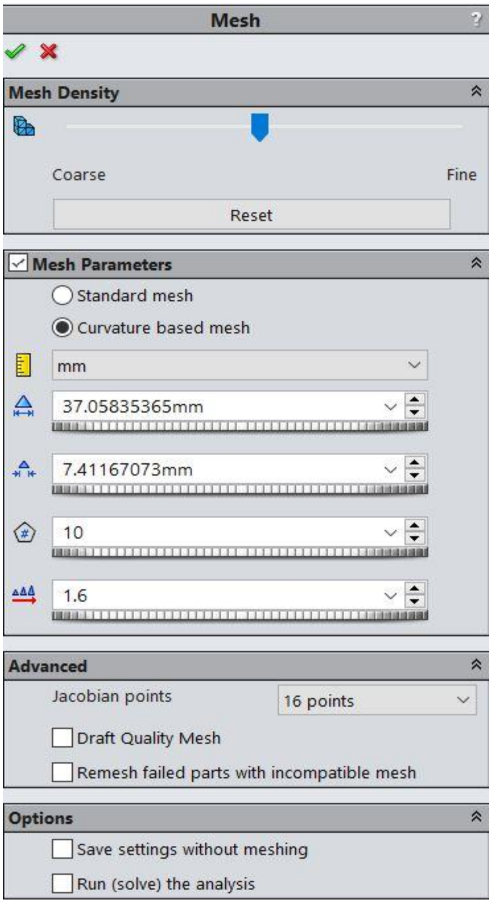



*Figure 12 Recommended mesh settings*

*Table 2 Recommended mesh*

| | |
|---|---|
| Mesher Used | Curvature based mesh |
| Jacobian points | 16 points |
| Max Element Size | 37.0584 mm |
| Min Element Size | 7.41167 mm |
| Mesh quality | High |
| Total nodes | 12200 |
| Total elements | 7450 |
| Maximum Aspect Ratio | 277.85 |
| Percentage of elements with Aspect Ratio < 3 | 92.6 |
| Percentage of elements with Aspect Ratio > 10 | 0.268 |
| % of distorted elements (Jacobian) | 0 |
| Remesh failed parts with incompatible mesh | Off |
| Time to complete mesh(hh:mm:ss) | 00:00:02 |
| Computer name | |

When FEM-analyze with this high-performance mesh is run, Solidworks refuse to complete the analyze. This may be because the use of fine elements is to many for our computer to run. The Solidworks simulation only want to run in “draft quality mesh”.

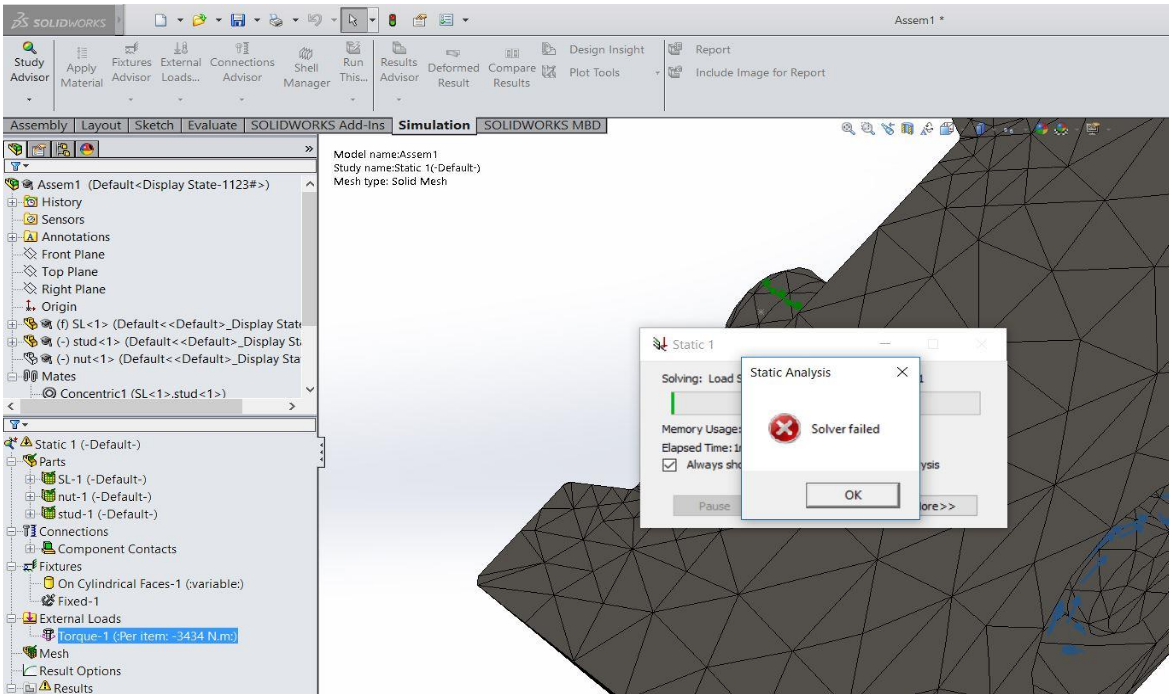



*Figure 13 Faild simulation*

The negativity of this high-quality mesh is that it is very demanding for files with many surfaces and harder to run around shapes with “dirty geometry” (short and sharp edges and V-shapes). This makes the jacobian point mesh to place the mid-node in a deformed way so the jacobian becomes a negative number, and the simulation solver fails.

# 6. Material

*Table 3 Material data*

| Property | Value | Units |
|---|---|---|
| Elastic Modulus | 207000 | N/mm^2 |
| Poisson's Ratio | 0.394 | N/A |
| Shear Modulus | 80000 | N/mm^2 |
| Mass Density | 7850 | kg/m^3 |
| Tensile Strength | 895 | N/mm^2 |
| Compressive Strength | | N/mm^2 |
| Yield Strength | 725 | N/mm^2 |
| Thermal Expansion Coefficient | | /K |
| Thermal Conductivity | 0.2256 | W/(m·K) |
| Specific Heat | 1386 | J/(kg·K) |
| Material Damping Ratio | | N/A |

Material data used in the FEM-analyze are of the type ASTM Stainless Steel Gr 660 D, used in the stud and nut.

# 7. Analyze

In the FEM-analyze a total stress of 472MPa is calculated, this shows that our mesh that is available for our student version of Solidworks, used in the FEM-analyze is not fine enough to get a 100% correct answer. But it gives you a good pointer of where in the stress area your heading.

The total strain in our FEM-analyze is 3,494e-003, and it shows that the stud most likely will have a microscopic torque deformation, something that is as expected will happen when a torque force of 3434Nm is applied.

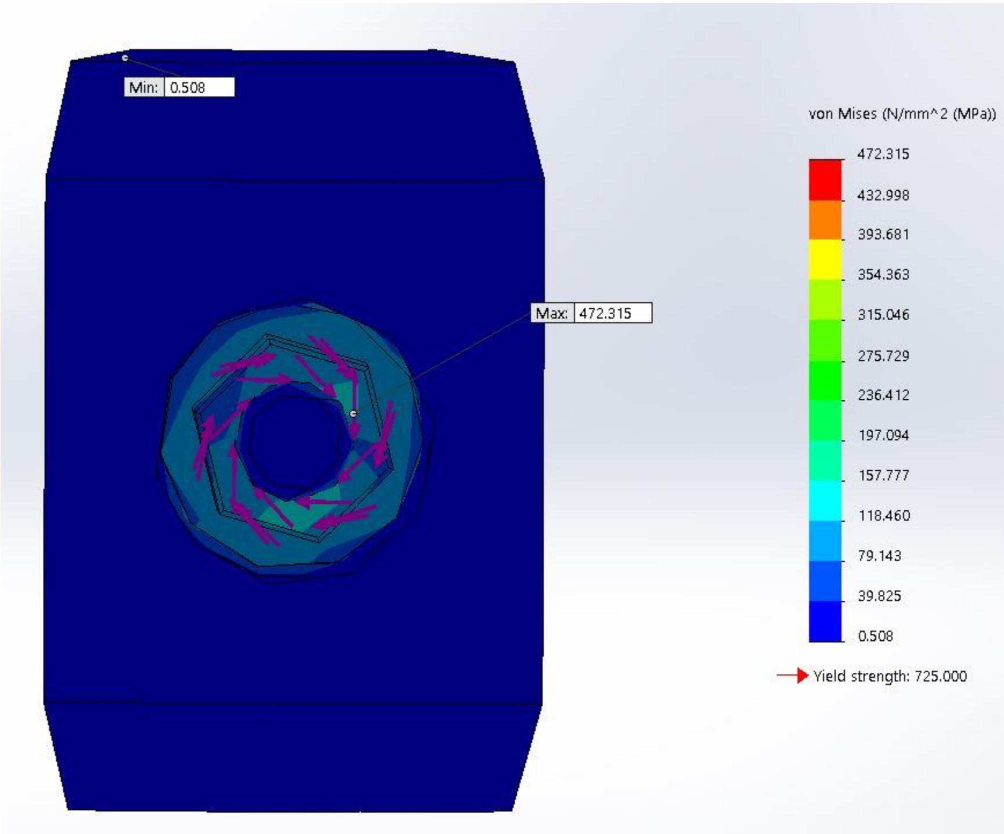
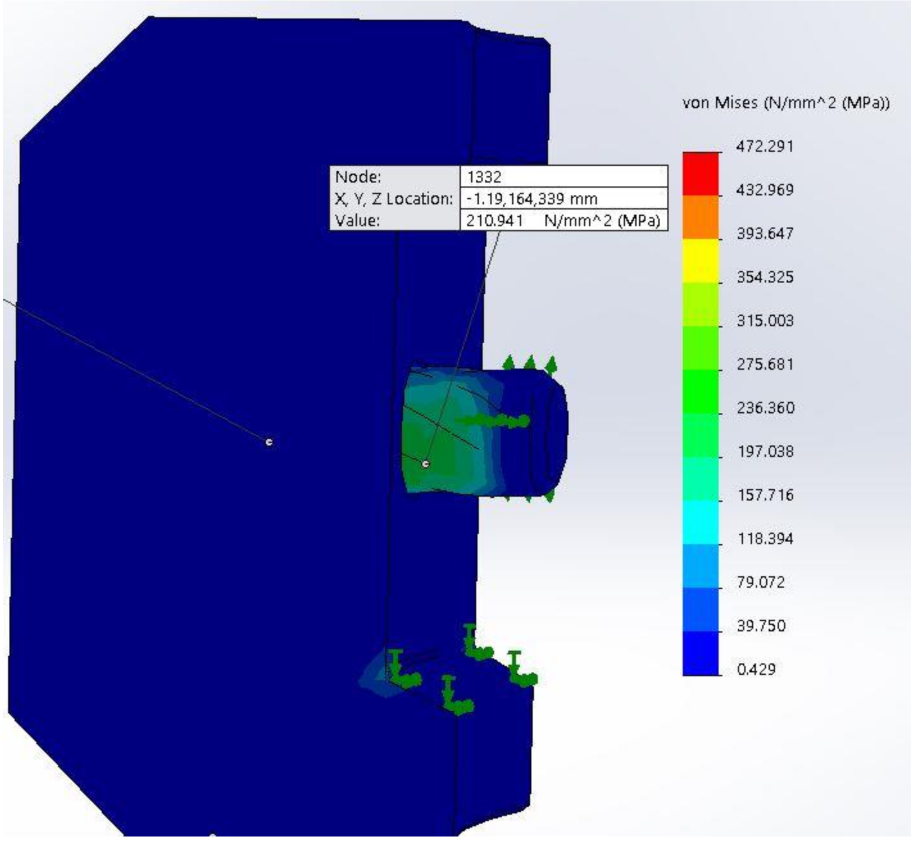



*Figure 14 Total stress on speedloc*




Most of the stress will apply between the inside of the clamp and the threaded portion in the hub. In count of this FEM-analyze a stress of 210Mpa will arise in the stud.

*Figure 15 Stress on speedloc and stud*

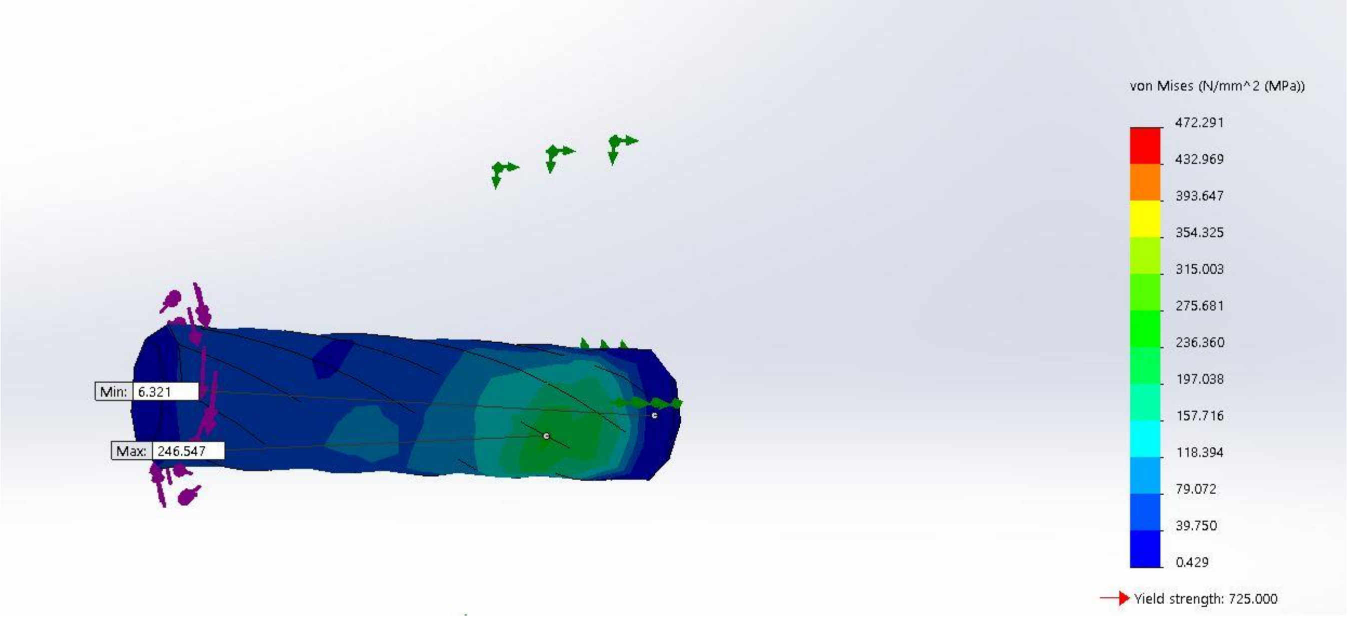



*Figure 16 Stress on stud*

Max stress in the stud appears to be 246,547 MPa something that is not enough as wanted preload in the stud.

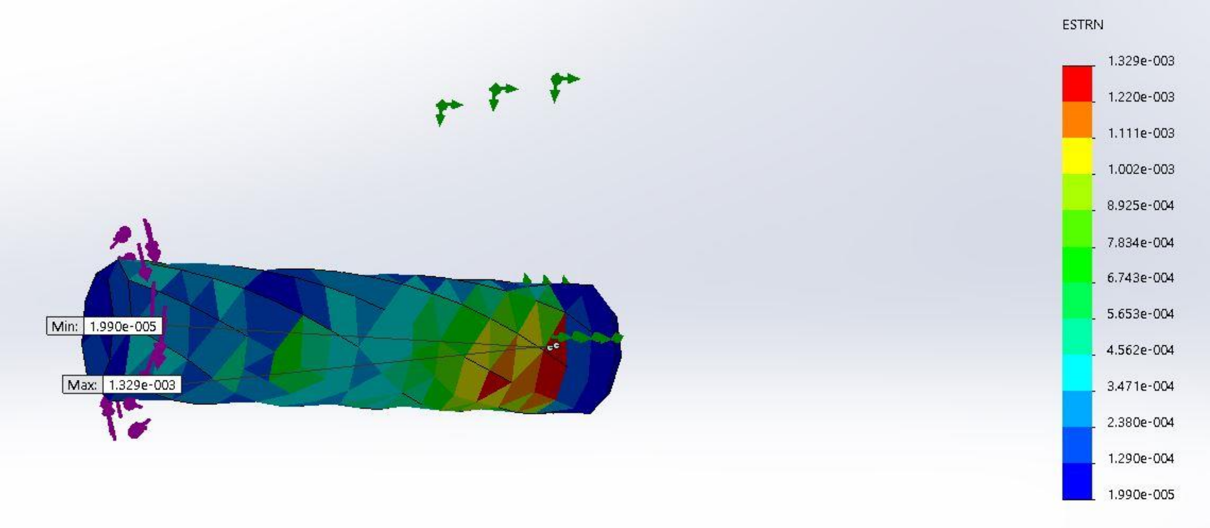



*Figure 17 Strain on stud*

Max strain in the stud appears to be 1.329e-003, something that is not acceptable, a desirable strain in the stud when a preload of 3434 is applied will be 2% of yield strength. '

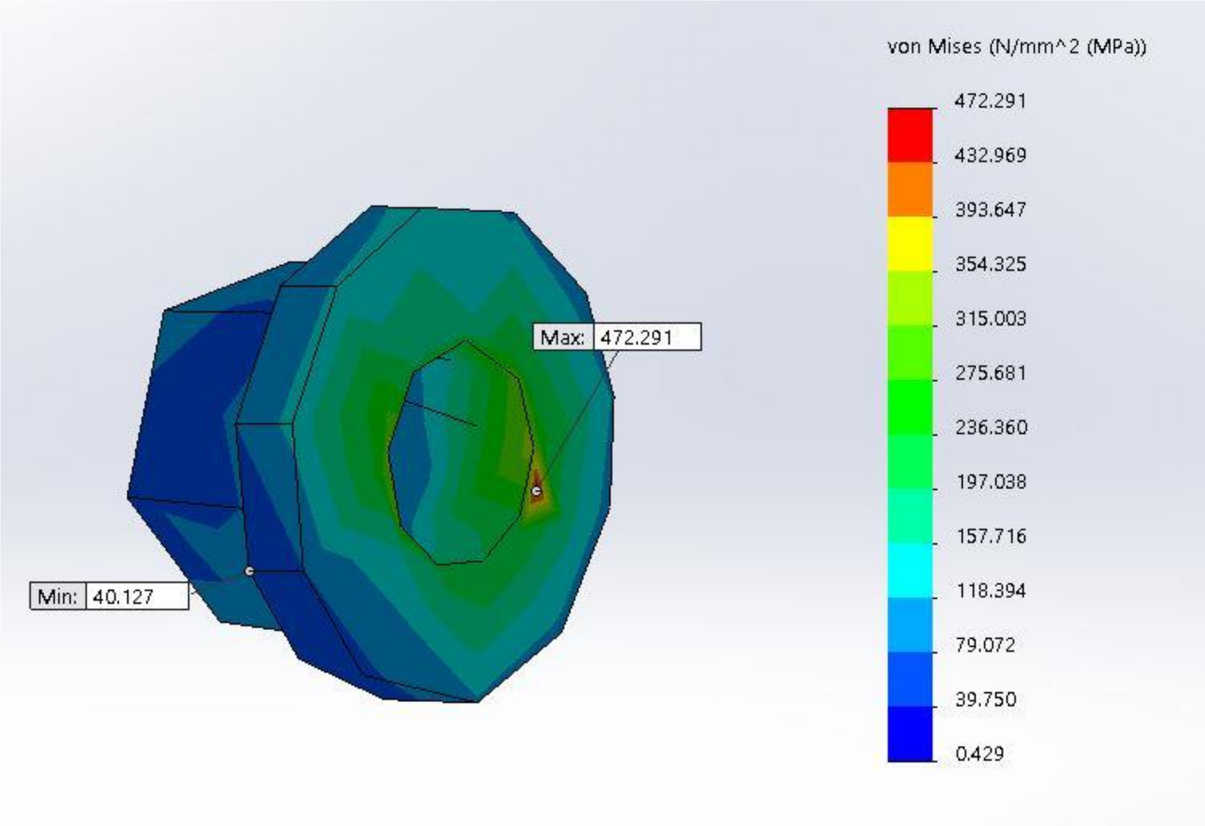



*Figure 18 Stress on nut*

Inside the nut a max stress of 472,291 MPa appears. A value between 67 % - 73% of the yield strength is recommended when full preload of the nut on stud is applied. A value of 472Mpa is therefore not far away from a desirable 485Mpa.

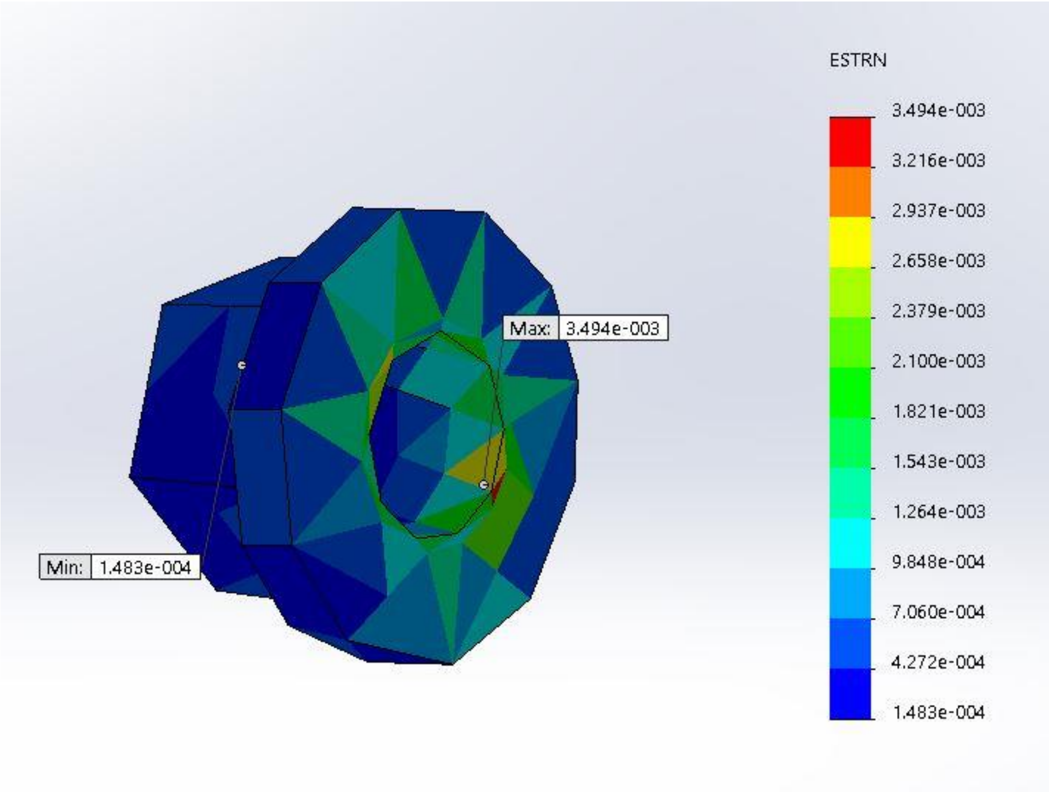



*Figure 19 Strain on nut*

Max strain in the nut gives us a value of 3.494e-003, this appears to be a little high.

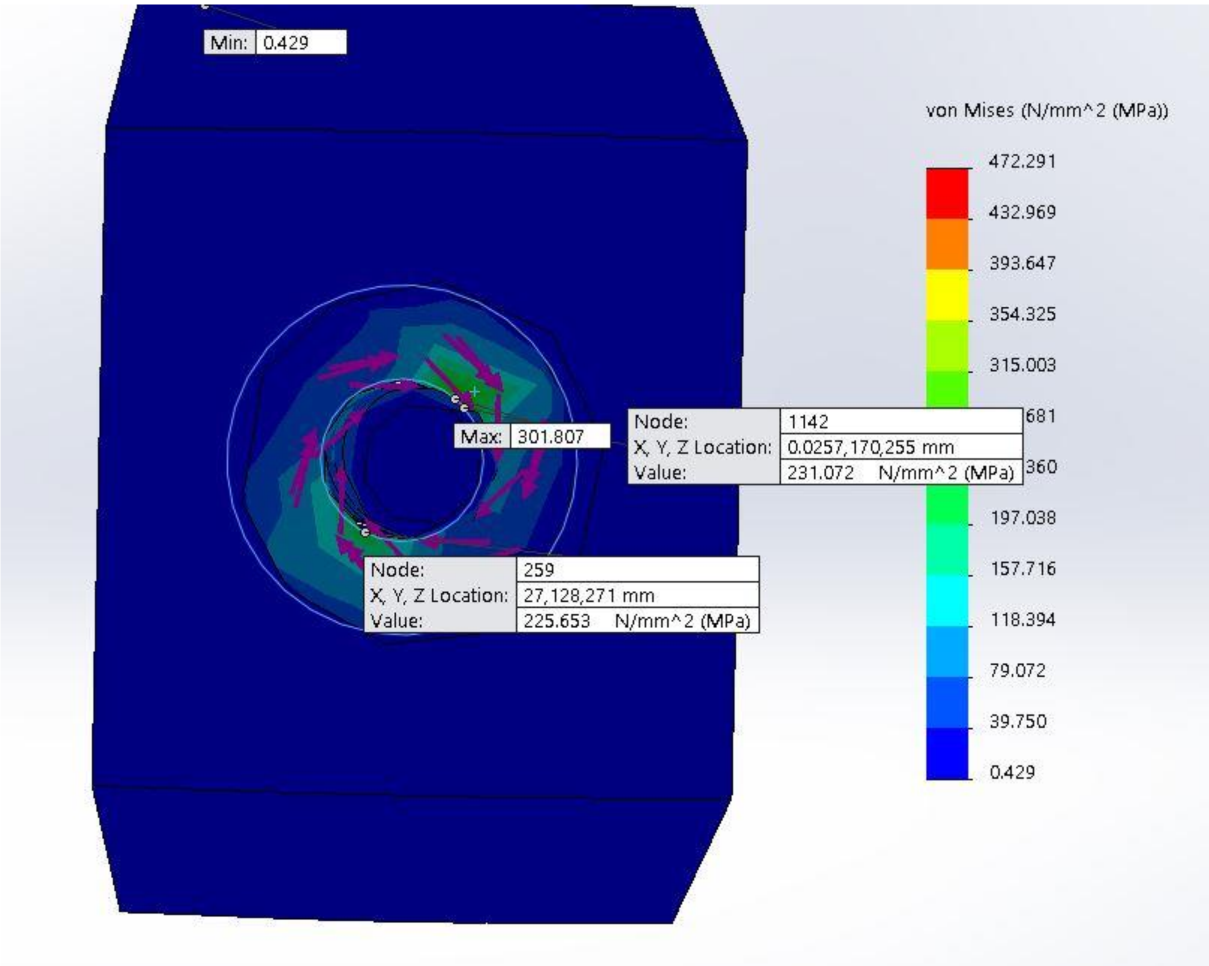



*Figure 20 Stress inside of clamp*

The Speedloc will have a max stress area of the clamp is 301.807MPa, something that seems trustworthy for an analyze of this qualification. In real life, a washer is applied between the nut and stud, but for this test it was not applied.

# 8. Conclusion

In the start SCS worked a lot to try and run the FEM-analyze with the whole file, stud-nut and hub, but SolidWorks had difficulties with the simulation of this parts together. Errors of interference between parts that nicely went together popped up, the files TechnipFMC wanted us to run tests on was locked from measurements and modifying and could not be run to fit well together. The result was that the FEM-analyze had to make some assumptions to go on with the testing.

The FEM-analyze shows well where the stress and strain will appear in the stud and nut, something that seems to be trustworthy after running our mechanical tesings. But the stress area in the stud seems to be too low, for high performance stress test parts designed in SLDPRT-files and with less fillets will be recommended to save the memory of the computer to run the analyze.

# Final project report

| | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 1.0 |
| | |
| **SCS Group members** | Asbjørn Antonsen,<br>Project leader and construction<br>Initial: AA |
| | Bjørn Ledaal Rossavik,<br>Qualification and specification<br>Initial: BR |
| | Erlend Berg-Olsen,<br>System Engineer and Project planner<br>Initial: EBO |
| | Espen Hansen,<br>Test and Verification<br>Initial: EH |
| | |

# Summary

This is a final report and project conclusion, after all tasks and tests are executed.

Every task and test executed have their own report. This document collect and use all this information to conclude with a recommendation.

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V0.1 | 21.05.2017 | 11 | BR | Created document, filled in information. Summary, introduction, main tasks, sub-task and sub task. |
| V.0.2 | 22.05.2017 | 16 | BR | Added all main task results and project future. |
| V.0.3 | 23.05.2017 | 16 | AA | Spellcheck and content update. |
| V.1.0 | 23.05.2017 | 16 | SCS | Ready for last hand inn. |

# References

[Ref.1] TT-1-2B-M report (SCS).

[Ref.2] Practical test report (SCS).

# Abbreviations and technical words

| Abbreviation | Explanation |
|---|---|
| WOR | Workover Riser |
| SL | Speedloc |
| ISO | International Standardization organization |
| DNV | Det Norske Veritas |
| UP | Unified process |
| SCS | Subsea Connection System |
| HSN | Høgskolen i Sør-Øst Norge |

| Technical Words | Explanation |
|---|---|
| Friction | The force resisting the relative motion of solid surfaces, fluid layers and material elements sliding against each other. There are several types of friction. |
| Stud | Threaded rod similar to a bolt but it has no bolt head. |
| Nut | A nut is a fastener with a threaded hole. |

# Contents



# 1. Introduction

This document will go through main tasks in the beginning. These main tasks are given from TechnipFMC, the employer for this project. A color code will indicate if the main tasks are completed. The same will be done on all sub-tasks and sub-tests.

| | |
|---|---|
| Accepted | Criteria and verification is accepted. |
| Uncertain, need more information | Need to investigate and run more tasks or tests. |
| Not accepted | Criteria and verification is **not** accepted. |

Collecting and using information gathered from tasks and tests completed, will give an end conclusion. This conclusion and a recommendation will be given in this document.

## 2. Main tasks

| ID | Description | Priority | Given by | Color code |
|---|---|---|---|---|
| MT-1 | Shall determine necessary pretension on nut from necessary force between hubs. (Compare the preload on studs and the target preload on nut). | A | TechnipFMC | |
| - TT-1-1 | Determine necessary force between hubs. | A | TechnipFMC | |
| - TT-1-2 | Provide recommended pretension on nut including range. | A | TechnipFMC | |
| MT-2 | Shall test if the values from the bolt table PRD-0000021662 is applicable for the stud and nut used in the SL connection. | C | TechnipFMC | |
| - TT-2-1 | Investigate values on bolt vs stud used from PRD-0000021662 will behave. | C | TechnipFMC | |
| MT-3 | Study relationship between stud preload and nut torque applied. Calculate contribution from each variable on preload. | B | TechnipFMC | |
| - TT-3-1 | Identify all variables affecting preload. | B | TechnipFMC | |
| - TT-3-2 | Investigate variables in the stud & nut study. | B | TechnipFMC | |
| MT-5 | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | |
| MT-6 | Reproduce analysis in SW and compare results. | C | TechnipFMC | |

# 3. Sub-tasks and sub-tests

| Theoretical tasks | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Color code** |
| - TT-1-1-T | Determine necessary force between hubs by calculation. | A | TechnipFMC | |
| - TT-1-2-T | Provide recommended torque on nut including range. | A | TechnipFMC | |
| - TT-3-1-T | Identify all variables affecting torque on nut and preload in stud. Make a list. | B | TechnipFMC | |
| - TT-3-2-T | Investigate variables affecting torque on nut and preload in stud. | B | TechnipFMC | |

| Practical tests | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Color code** |
| - TT-1-1-Pr | Find necessary force between hubs with FEM analysis. | A | TechnipFMC | |
| - TT-2-1-Pr | Investigate values on bolt vs stud used from PRD-0000021662 will behave. | C | SCS | |
| - TT-5-1-Pr | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | |
| - TT-6-1-Pr | Reproduce analysis done by FMC in SW and compare results. | C | TechnipFMC | |

| Mechanical tests | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Color Code** |
| - TT-1-2A-M | Do a tensile strength test of the material used in stud. | A | TechnipFMC | |
| - TT-1-2B-M | Test recommended pretension on nut including range. | A | TechnipFMC | |
| - TT-2-1A-M | Investigate torque, fraction and elongation in bolt vs stud. | C | TechnipFMC | |
| - TT-2-1B-M | Investigate fraction in bolt vs stud. | C | TechnipFMC | |

# 4. Results from Main tasks

## 4.1 Main Task 1

| ID | Description | Priority | Given by | Color code |
|---|---|---|---|---|
| MT-1 | Shall determine necessary pretension on nut from necessary force between hubs. (Compare the preload on studs and the target preload on nut). | A | TechnipFMC | |

SCS aimed to complete all main tasks, but to complete all Priority A main tasks was a minimum. Priority A tasks are most important for TechnipFMC. SCS have done theoretical calculations on MT-1, but did not manage to verify these results with a mechanical or practical test.

Practical test document explains more in detailed what happened with these tests.

SCS and TechnipFMC have done a mechanical test on a test cap, in the workshop at TechnipFMC. This test was done to verify the theoretical values from SCS, and to consider the friction coefficient. Read more about this in document TT-1-2B-M report *(see ref [1]).*

2 sub-tests with priority A was not completed. TT-1-2A-M are started on. Threads on stud are machined away, but the test stopped after this. Equipment to saw and split the stud into test sample were not found for SCS. TechnipFMC could assist in the end, but wanted to priority Mechanical testing on test-cap. This gives them a better result, so TechnipFMC and SCS together concluded that TT-1-2A-M could be dropped.

The second test with priority A that was not completed is TT-1-1-Pr. This was because of complication with FEM analyses. Please read Practical test document for more information, *(see ref [2]).*

2 theoretical tasks and 1 mechanical test was completed.

SCS set this Main task color code to be Yellow.

| | |
|---|---|
| Uncertain, need more information | Need to investigate and run more tasks or tests. |

Need to verify theoretical calculations in a 3-D FEA analyze or with mechanical testing.

## 4.2. Main task 2

| ID | Description | Priority | Given by | Color code |
|---|---|---|---|---|
| MT-2 | Shall test if the values from the bolt table PRD-0000021662 is applicable for the stud and nut used in the SL connection. | C | TechnipFMC | |

Main task 2 was set up with 2 mechanical tests and 1 practical test.

Due to complications with the practical test, this test was not completed.

The 2 mechanical tests were completed.

SCS are satisfied with the results from the mechanical tests.

Focus on this main task was to investigate if there was any difference between a stud and bolt when analyzing. Mechanical tests show that there are no differences with physical testing. Please read test report TT-2-1A- and TT-2-1B-M for more information.

SCS are satisfied with the results, but since it could not be verified with a practical test, this main task get color code Yellow.

| | |
|---|---|
| Uncertain, need more information | Need to investigate and run more tasks or tests. |

## 4.3 Main task 3

| ID | Description | Priority | Given by | Color code |
|---|---|---|---|---|
| MT-3 | Study relationship between stud preload and nut torque applied. Calculate contribution from each variable on preload. | B | TechnipFMC | |

This main task was completed and successful.

There was 2 theoretical task to complete in this main task. Those tasks were to study and find out variables that effect preload and torque value.
Please read TT-3-1-T report and TT-3-2-T report for more information.

This Main task get color code Green.

| | |
|---|---|
| Accepted | Criteria and verification is accepted. |

## 4.4 Main task 5 and 6

| ID | Description | Priority | Given by | Color code |
|---|---|---|---|---|
| MT-5 | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | |
| MT-6 | Reproduce analysis in SW and compare results. | C | TechnipFMC | |

First, Main task 4 was deleted in the Elaboration phase. Main task 4 are therefore gone.

Main task 5 and 6 was practical testing only.
Please read more about this in the Practical test document, *(see ref [2]).*

Since SCS could not preform the practical tests, none of these were completed.

Both Main task 5 and Main task 6 get color code red.

| | |
|---|---|
| Not accepted | Criteria and verification is **not** accepted. |

# 5. Project future

SCS have done both mechanical testing and theoretical calculations.

To come to an end conclusion regarding new torque value on nut, more tests must be done. After testing on the test cap, SCS conclude that molykote G rapid plus shall not be used. The friction coefficient changes to much, it is not trust worthy. Friction can go from 0,01 to 0,1.

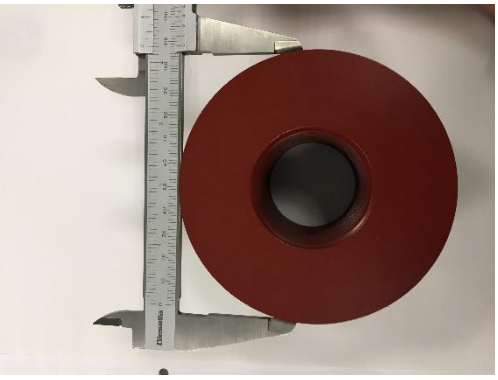
Copper paste was a more stable lubricant to use. 2 test run was done with Copper paste. Due to environment and HSE issues, TechnipFMC will not use Copper paste. A similar lubricant could be found, and tested.

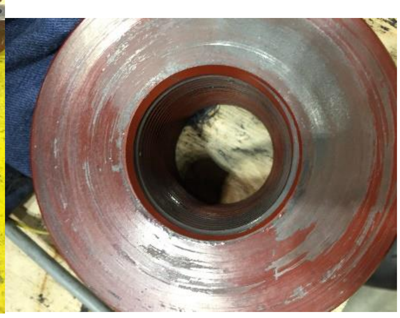
SCS recommend more testing with clean studs, only coated with Xylan.

Testing shall include optimal torque with make and break 15 times. New tensile value in stud will be measured, and it will show the strength of the Xylan coating.

Testing that was done this time with SCS, included first 15 test runs with molykote G rapid plus. Then 2 test runs with Copper paste.

After these 17 test runs, 10 test runs came up with only Xylan coating on threads. The testing done are not optimal for the Xylan coating, since 17 test runs was already done before. Lubricant was used on studs and nuts, but the Xylan coating began to fall off after these runs





Difference on Xylan coating on nut flange after 15 test runs, with lubricant used.

Therefore, a new test with freshly Xylan coating should be done.

Friction is a big contributor, and this factor must be under control.

Optimal solution can be to only use Xylan coating, and coat nuts, studs and washers after 10-15 make and brake. How many make and brake it takes before this is necessary, shall be tested.

SCS have done theoretical calculations on new torque value to use on nut, and SCS recommend testing this value. There are 3 different torque value, with different friction coefficient.

# Project evaluation

| | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 1.0 |
| | |
| **SCS**<br>**Group members** | Asbjørn Antonsen,<br>Project leader and construction<br>Initial: AA |
| | Bjørn Ledaal Rossavik,<br>Qualification and specification<br>Initial: BR |
| | Erlend Berg-Olsen,<br>System Engineer and Project planner<br>Initial: EBO |
| | Espen Hansen,<br>Test and Verification<br>Initial: EH |
| | |

# Summary

This document contains our thoughts throughout the project from inception phase of the unified process to the last workshop test. Here we discuss what went good and what could have been done differently throughout the project.

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 17.05.2017 | 10 | BR | Made document, introduction, project overview, time tracing, working platforms and presentation. |
| V.0.2 | 17.05.2017 | 17 | BR, EH, EBO | Added Risk, testing, responsibilities, Gannt chart, project model, the task and project work. |
| V.0.3 | 21.05.2017 | 18 | AA | Added summary and spellcheck. |
| V.0.4 | 22.05.2017 | 19 | BR | Structure update. |
| V.1.0 | 24.05.2017 | 19 | SCS | Ready for last hand in. |

# Contents

# 1. Introduction

This document contains evaluation about SCS bachelor thesis.

Choice and use of project model. Progress and working methods inside the project.
In every project there will be risks, and this was not an exception. SCS made a risk analyze, and updated this on the way in the project. Risk analyze helped this project going, and made it easier when challenges came up.

Main task from TechnipFMC will be described and discussed.

Tasks and tests was performed, to solve the main task and additional tasks. Changes needed to be done to complete it in the best way. The most exiting change made, was to go from small scale tests, to full scale test. TechnipFMC organized a full-scale test at their workshop. SCS worked side by side with TechnipFMC in one week, to complete full-scale tests. A lot of work was put into this test, and SCS was given a warm welcome at TechnipFMC.

Responsibilities and presentations have been evaluated, and project overview are discussed.
Future testing and recommendation from SCS is described

Summed up at the end with final thoughts on this bachelor thesis, from the members in SCS.

# 2. Risk management

Every project contains different forms of risks, so did our project. It is important to identify risks at an early stage and have a good plan over how it should be handled.

The risk management is important in the initial phase of the project and before every time the project is entering a new phase. The risk management operates as a tool to increase the projects ability to reach specified goals.

It is several risks who have occurred through our project period, some bigger than others. We have handled this as best as possible and the risk analyze have been a useful tool.

After first hand in we got feedback on our documents. Because our task is a bit different from a standard product development task, we had to rewrite some of our documents and fit the documentation after our task specification.

| | | | | |
|---|---|---|---|---|
| (7.1): Changes in tasks from TechnipFMC. | 3 | 5 | 15 | Control: Documents must be updated and extra time is to be sacrificed. |

In the last minute of the elaboration phase we got our first big risk challenge. From creating all our test based on scaled down models, we now got the opportunity to do mechanical tests on a real Speedloc connector. We had to do a big turn and start rethinking and rewrite many of our test procedures. The group was known about risks likes this could appear, and from our risk analyze we had created a plan about how we should handle. The whole bachelor group worked hard through the last weekend before second hand in and got an acceptable result.

| | | | | |
|---|---|---|---|---|
| (5.2): Software complications in Solid Works and FEM. | 4 | 3 | 12 | Avoid: Use computers who have the newest updates and software. |
| (5.3): Low knowledge about SW and FEM. | 1 | 4 | 4 | Avoid: Each group member must ensure to update their skills. |
| (5.4): 3-D drawings from TechnipFMC in ABAQUS is not compatible in Solid Works. | 3 | 4 | 12 | Control: This must be controlled at an early stage in the testing phase.<br>SCS must make new drawings in Solid Works if the file transferring is not working.<br>This may take some time and shall be considered. |

We had several problems with the stp files from TechnipFMC and getting this compatible in SolidWorks. The SolidWorks software is not responsible for solving the detailed 3D-drawings done in ABAQUS. We have done some new drawings, but solid works will not accept the mesh, boundary condition and the files were not reproducible. It was also a requirement from TechnipFMC that the drawing must have a special mesh element. Much time is spent on this problem and unfortunately, we could not get up with a conclusion.

| | | | | |
|---|---|---|---|---|
| (6.1): Not finding a place to do tests (Workshop). | 2 | 4 | 8 | Avoid: Several alternatives. Backup.<br>- HSN.<br>- TechnipFMC. |

It was planned to run the mechanical tests on speedloc test cap in our workshop at HSN-Kongsberg. The test cap was planned to be transported from TechnipFMC in the second week after Easter. Transport and safety issues stopped the process and as a last solution we got the opportunity to run the tests in the workshop at TechnipFMC. The testing was then delayed some weeks because of further planning and safety clearance at TechnipFMC, and a worst-case scenario the test couldn't be performed. May 10, SCS could finally start the testing at TechnipFMC. Thanks to Per Øystein Hansson and his crew for making this happen.

# 3.Testing

Instead of creating a product, our bachelor project was based on testing and further analysis. The results are based on some calculations and further mechanical testing. We have made tests that can investigate the preload problems and give us some polite results.

Through the testing, we have experienced that there is a difference between theoretical test procedures and the actual physical performance. The test procedure has gone through several remakes. Problems as the engineer think is easy to solve in the workshop, is not always the reality. The testing with the actual speedloc have taken much more time than expected and we have experienced that the test process is a comprehensive process. Consideration to HSE is very important and there is high focus on this through the performance.

## 4. Project model

Early in the bachelor thesis, the group decided to work out from a project model named Unified process. It was discussed several different models such as the V-model and the Waterfall model.

The V-model is like the waterfall model, they both are simple to use in a small project, but if problems or changes occurs during the project it is difficult to go back in time to do changes. The unified process model gave us these opportunity, and it was easy to have good control over the project with different disciplines and iterations in each phase.

The unified process has been a good system engineering-tool during our bachelor thesis. It has been easy to have good control over the project, where we are and future. After some feedback from our mentors at HSN, we decided in the inception phase to have more iterations in the next phases, and went from two iterations in each phase and up to four. During our elaboration phase some changes occurred to the tasks, when TechnipFMC wanted our testing to be done on real size equipment, big changes had to be done to our test documents. With unified process, it was possible to go back and change the document it mattered because we knew which iteration we had to do the necessary changes. The right project model for the bachelor thesis saved us for a lot of work.

# 5. Project work

The bachelor project has been an interesting part of our education. During this semester, all our educated school subjects has become handy to our performance. To make a study report of speedloc on workover riser for a large company as TechnipFMC, demands a lot of both theoretical and practical knowledge. In addition to the subjects the members has approached in the last years at HSN, we have gained a lot of new information around the subjects by taking it to a higher level.

A good group dynamic, and respect of others opinion is weary important when it comes to righting a group bachelor thesis. It cannot be avoided that in some decisions some discussions appear, it is then important for everyone to make good group decision. Everyone must respect each other, and let the group members have their right to express their opinion, before a decision are going to be taken.

In our bachelor thesis, the group dynamics has been good, decisions have been taken as a group, and everyone could express their opinion. No external sources have been contacted to make any group related decisions.

Our mentor at HSN, Otto Waaraas, has been a good help to have and made sure that we stay in time to our deadlines, he has also been given us some helpful tips around the feedbacks we have been given after each presentation.

At TechnipFMC SCS was given two main contact sources. Our mentor Einar Totland has been a great guidance through our bachelor thesis. Through this semester, he has guided us through some difficulties with the tasks, and been the contact person on TechnipFMC until he was getting off with permission. In April, Per Øystein Hansson stepped in as our new contact person at TechnipFMC.

TechnipFMC have been an excellent employer and collaborator, SCS has felt welcome and been given all the information we need to solve our tasks from the very beginning.

Through our project, it has always been important for us maintaining professional to our employer and have tried as much as possible to stand on our own feet's. This have in some situations maybe prevented us to call and ask questions.

The school may have been better to informed about what kind of equipment that is available, and had more educated persons that can handle it.
Beside this the members of SCS feels that the project work has gone great.

# 6. The task

SCS was in November 2016 given from TechnipFMC a bachelor task a bit different from the standard. We were going to make a study report of an already existing product, and not create a new product.

The main problem TechnipFMC wanted us to investigate was the preload in the studs mounted in speedloc connector.

At the beginning our task mostly consisted of theoretical tasks, but if we had time they would like us to make a test rig to test the studs.
Later in the project we decided to make a scaled down test-rig and do mechanical tests of some of our theoretical answers, this idea did our mentor at TechnipFMC like.

Last week in our elaboration phase TechnipFMC wanted us to change our mechanical tests and do the testing on their test cap in full-scale. Now we could check our calculations on a real size connector and the group was excited over getting this opportunity. Since we had based al of our tests on small scale, this required that we had to rewrite many of our documents, but with a lot of hard work SCS finished in time.

We planned to run the tests at HSN, but we got some difficulties with the shipment of the equipment and it was high demands on safety. This problem moved the test several weeks. In the end of our bachelor thesis, SCS was invited to do the tests at their workshop at TechnipFMC.

We could maybe have a better shipment plan of the equipment earlier in the project, but the total load of the test cap and the budget from TechnipFMC made this difficult.

SCS was also going to do some FEM-analysis in SolidWorks, but met some difficulties with the program. We could begin with the FEM-analysis earlier, but the problem was not in the drawings, but in the SW-software. SolidWorks was not able to run analysis at this level.

SCS had a very interesting bachelor thesis that was very realistic up to our main school subject. It has been heavy theoretical and practical for a group of four students to solve. We are grateful that TechnipFMC gave us this opportunity.

# 7. Responsibilities

The four group members have covered the following responsibilities:

- Project leader and construction
- Qualification and specification
- System Engineer and project planner
- Test and verification

Since the Unified model is based on a relatively flat administrative structure, nobody really sits higher than others. The group have had one group manager, but there has not been any kind of a hierarchy. Every group member has had the achievement to take the leader role through the tasks.

Regardless of the responsibilities set, everyone in the group had to do work outside their specific field and all the group members have done useful experiences with subject areas along the way.

The group leader had the overall responsibility when it comes to meeting requests and dialog with the employer.

The group members have done tasks across their responsibility field, and the roles have changed through the project based on personal wishes and skills.

# 8. Presentations

SCS are having 3 presentations in this bachelor thesis.

Presentations are the only chance SCS have to show their project and progress to the audience. In the presentations, SCS aimed to give a good knowledgeable presentation, with a little bit of show. It is important to have a little bit of show to keep the audience interested and to get their attention.

## 8.1. First presentation

First presentation was held February 6, 2017.

This was the first opportunity to show of the group and project task.

Presentation went well, and SCS was satisfied with the final results.

SCS got good feedback from the sensor, but also some point that should be changed.

From the beginning of the project, SCS made a requirement document. This document contained tasks and tests that TechnipFMC wanted SCS to execute. School template regarding bachelor thesis require a requirement document. But in this case, with a different type of bachelor thesis, that was not relevant. The school template is made for developing and building a physical product. This bachelor thesis is an analyze of a SL clamp, so it is different from the standard bachelor thesis.

SCS agreed with the sensor, and made the change. “Requirements” was transformed to “Project specification”. Project specification contains different tasks and tests TechnipFMC want to see executed.

There were also some issues with the language. SCS got feedback that spellcheck and the language in the document could be better

SCS are satisfied with the results, but understand that they should make the change on their own, regarding to the requirements. It`s the first time the members in the group are writing a bachelor thesis, so it was natural to follow the template. But, SCS should think more specific about their bachelor thesis, and only use the material that was relevant from the template.

Welcoming screen used in presentation.

## 8.2. Second presentation

Second presentation was held March 23, 2017.

The presentation itself went as expected, and SCS was satisfied with the result.

Presentation went deeper into the project tasks and tests, and was more technical than the first one. It was a fine line between explaining it in detail, but still make the audience understand. It is important to not get to detailed in the technical, because it can be difficult to understand for people not working with the project.

The feedback after the second presentation was good, but there was some point that could be better. After the first presentation, SCS got feedback that spellcheck and the language in the document could be better. SCS agreed with that. It is a challenge for the group to write all in English, but since TechnipFMC requires that, it must be done.

SCS got feedback that it was less spell mistakes, but the document should be more academic. References was left out, and still some of the language could be better.

SCS took this feedback, and went through all documents made. Here spellcheck, orthography and references was added. This is a point that SCS should have done much better from the start. With Norwegian language, this would be easier. But SCS should read more bachelor thesis in English.

# 9. Project overview

## 9.1 Time tracing

In week 1, SCS made an excel sheet to keep track on hours spent in the project.

Gannt chart was also made, to divide the time on activities.

*See appendix 1 for Gannt chart.*

Unified process has been used as a project model. This contains 4 phases, and hours spent in every phase has been documented.

Total hours planned for each group member was, 600 working hours, without presentations.

Since it was hard to plan time used regarding to presentations, this was not included in the working hours SCS planned to use in this project.

Time spent on presentations was of course recorded, and an estimated hour spent on presentations was made.

In the first phase, Inception, Gantt chart showed a plan that included 140 working hours from each group member.

Here are the actual hours SCS spent on The Inception phase.

| Name: | Bjørn | Erlend | Asbjørn | Espen |
|---|---|---|---|---|
| **Total hours:** | 131.5 | 123 | 132 | 119 |

SCS are satisfied with the hours spent by the group in this phase. Since a lot of time went to self-studying and reading earlier bachelor thesis, the numbers are acceptable, because these hours was not recorded. It was time group members used on their own spare time, to get a better understanding on what is expected from a bachelor thesis.

In the second phase, Elaboration, hours planned was 200 working hours.

Here are the actual hours SCS spent on The Elaboration phase.

| Name: | Bjørn | Erlend | Asbjørn | Espen |
|---|---|---|---|---|
| **Total hours:** | 184 | 186.5 | 198 | 191.5 |

Hours spent are acceptable. SCS are doing a good job tracking hours spent on school, but forget to write up hours spent at home. The real number of hours spent on this phase, will be higher, due to late nights at home working. Less time was used in this phase, because it is expected to use more time in the Execution phase.

Third phase and fourth phase, Execution and Transition, planned working hours are 200.

| Name: | Bjørn | Erlend | Asbjørn | Espen |
|---|---|---|---|---|
| **Total hours:** | 231 | 214,5 | 237,5 | 236,5 |

Since SCS used a lot of time at TechnipFMC, the working hours went up more than planned. Week 20 some members worked 70 hours a week. This was to complete the mechanical test.

## 9.2 Working platforms

SCS decided the first week to use Google Drive as an electronic working platform.

There are a lot of opportunities, regarding electronic working platforms with storage up in the skies. Some members had good experience with Goggle drive and it had the most storage place available. 15 gigabytes per member, total of 60 gigabytes.

All in SCS are satisfied with Goggle drive as a working platform. It has worked perfectly, without any issues. Changing documents inside goggle drive could be better. Now the documents must be download, changed, and upload again.

Structure inside Google drive have been challenging. It has been 4 individual human beings working with it. People think differently, and storage documents differently.

Structure and template on how it should be on Goggle drive was made, and all members have done the best they could. SCS have had control over all documents, including old document, that are stored in a historical folder.

## 9.3 Gantt chart

Gantt chart was made in MS project. Gantt chart has been updated through the whole project period. At the begin, SCS made a Gantt chart for the whole project period from the project model. Gantt chart was divided into the 4 main phases, and added 3 presentations. Iteration was added in each phase. At the beginning, there was too few iterations. SCS understood this when the second phase started. The iterations become too big, and to be more effective, SCS felt that it would be better to have more iterations. Then there will be more milestones, and SCS can do an evaluation on the way. Instead of reaching the goal, and understanding that the task should be done separately.

Gantt charts contains the subject that can be seen here:

| Task Name | Duration | Start | Finish | ID number |
|---|---|---|---|---|
| Unified process | 125,57 days | Mon 09.01.17 | Fri 09.06.17 | |
| Inseption | 20,43 days | Mon 09.01.17 | Wed 01.02.17 | A |
| Planning | 15,86 days | Mon 09.01.17 | Thu 26.01.17 | A.1 |
| Project research | 1 day | | | A.1.1 |

Duration is for every group member, and show how long each activity shall take.

Start and finish date shows the timeline on the activity.

ID number is to identify each activity. This is to easier understand which activity a person is talking about. An activity list is made out from the Gantt chart, and used when SCS are time tracing hours spent on project.

All in all, SCS are satisfied with the use of Gantt chart. It is a great tool to be planning in, and gives an activity list to trace hours spent.

# 10. Our last thoughts

This last semester has been a fantastic travel through an exciting project. Every participant in the group is now a bit tired, but satisfied reaching the goals.

Through this project, we have developed us professionally and personally. The experience in cooperation is priceless, and working with a project over such a long time is good preparation for further working life.

We want to specially thank these persons for their contribution:

- Einar Totland, TechnipFMC
- Per Øystein Hansson, TechnipFMC
- Otto Waraas, HSN
- Erik Ranke, TechnipFMC
- Fredrik A.K. Lislien, TechnipFMC
- Dag Erik Molandsveen, TechnipFMC
- Toril Evenstad, TechnipFMC

# Gannt chart

| | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 2.0 |
| | |
| **SCS**<br>**Group members** | Asbjørn Antonsen,<br>Project leader and construction<br>Initial: AA |
| | Bjørn Ledaal Rossavik,<br>Qualification and specification<br>Initial: BR |
| | Erlend Berg-Olsen,<br>System Engineer and Project planner<br>Initial: EBO |
| | Espen Hansen,<br>Test and Verification<br>Initial: EH |
| | |



Høgskolen i Sørøst-Norge

# Document history

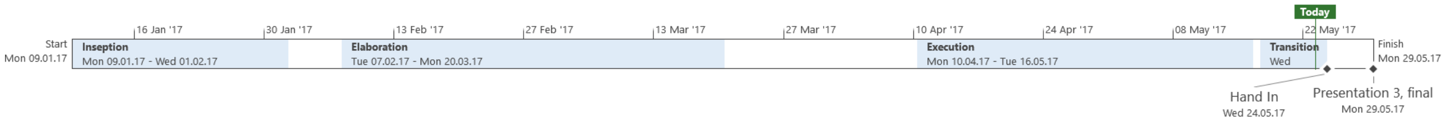
| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 10.01.2017 | 2 | BR | Made Gannt chart. |
| V.0.2 | 23.1.2017 | 3 | BR | Updated. |
| V.1.0 | 23.01.2017 | 3 | SCS | Ready for hand in 1. |
| V.1.2 | 23.05.2017 | 5 | EBO | Updated Gannt chart, time line. |
| V.2.0 | 23.05.2017 | 5 | SCS | Ready for hand in 2. |

# Gannt chart

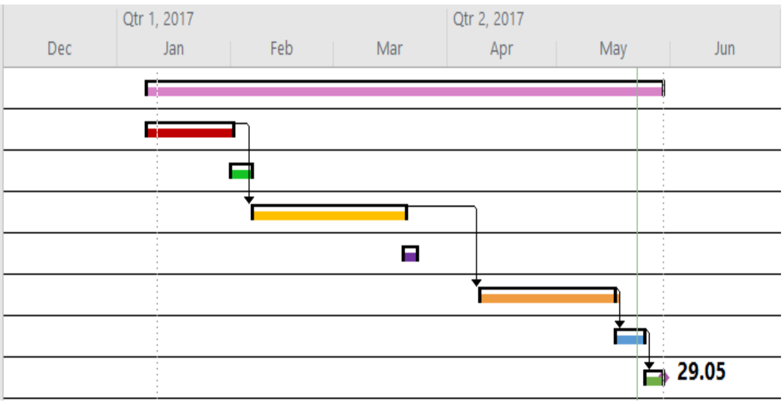
| Task Name | Duration | Start | Finish | ID number |
|---|---|---|---|---|
| | **115,29 days** | **Mon 09.01.17** | **Mon 29.05.17** | |
| **Inseption** | **20,43 days** | **Mon 09.01.17** | **Wed 01.02.17** | **A** |
| **Planning** | **15,86 days** | **Mon 09.01.17** | **Thu 26.01.17** | **A.1** |
| **Documentation** | **14,71 days** | **Mon 16.01.17** | **Wed 01.02.17** | **A.2** |
| Project model | | | | A.2.1 |
| **Project plan** | **13,57 days** | **Tue 17.01.17** | **Wed 01.02.17** | **A.2.2** |
| **Quality management** | **10,14 days** | **Fri 20.01.17** | **Wed 01.02.17** | **A.2.3** |
| Web page | 10 days | Fri 20.01.17 | **Wed 01.02.17** | A.2.4 |
| Gannt | 2 days | Fri 20.01.17 | Mon 23.01.17 | A.2.5 |
| **Presentation 1** | **4,43 days** | **Wed 01.02.17** | **Mon 06.02.17** | **B** |
| **Elaboration** | **34,14 days** | **Tue 07.02.17** | **Mon 20.03.17** | **C** |
| **Iteration 1** | **12,43 days** | **Tue 07.02.17** | **Tue 21.02.17** | **C.1** |
| Iteration 1 plan | 6,71 days | **Tue 07.02.17** | Tue 14.02.17 | C.1.1 |
| Project Spesification and testing | 6,71 days | **Tue 14.02.17** | Tue 21.02.17 | C.1.2 |
| Iteration 1 report | 1 day | Tue 21.02.17 | **Tue 21.02.17** | C.1.3 |
| **Iteration 2** | **9 days** | **Wed 22.02.17** | **Fri 03.03.17** | **C.2** |
| Iteration 2 plan | 4,43 days | **Wed 22.02.17** | Sat 25.02.17 | C.2.1 |
| Information regarind physical testing | 6,71 days | Sun 26.02.17 | **Fri 03.03.17** | C.2.2 |
| Iteration 2 report | 1 day | Fri 03.03.17 | Fri 03.03.17 | C.2.3 |
| **Iteration 3** | **5,57 days** | **Mon 06.03.17** | **Fri 10.03.17** | **C.3** |
| Iteration 3 plan | 3,29 days | Mon 06.03.17 | Wed 08.03.17 | C.3.1 |
| Formuels and calculation material | 2,14 days | Thu 09.03.17 | **Fri 10.03.17** | C.3.2 |
| Iteration 3 report | 1 day | Fri 10.03.17 | Fri 10.03.17 | C.3.3 |
| **Iteration 4** | **6,71 days** | **Mon 13.03.17** | **Mon 20.03.17** | **C.4** |
| Iteration 4 plan | 2,14 days | Mon 13.03.17 | Tue 14.03.17 | C.4.1 |
| Finish documentation | 3,29 days | Thu 16.03.17 | **Sun 19.03.17** | C.4.2 |
| Iteration 4 report | 1 day | Mon 20.03.17 | Mon 20.03.17 | C.4.3 |
| **Presentation 2** | **4,43 days** | **Mon 20.03.17** | **Thu 23.03.17** | **D** |
| **Execution** | **30,71 days** | **Mon 10.04.17** | **Tue 16.05.17** | **E** |
| **Iteration 1** | **11,29 days** | **Mon 10.04.17** | **Fri 21.04.17** | **E.1** |
| Iteration 1 plan | 1 day | Mon 10.04.17 | Mon 10.04.17 | E.1.1 |
| **Planning** | **11,29 days** | **Mon 10.04.17** | **Fri 21.04.17** | **E.1.2** |
| Iteration 1 report | 1 day | Fri 21.04.17 | Fri 21.04.17 | E.1.3 |
| **Iteration 2** | **7,86 days** | **Sat 22.04.17** | **Mon 01.05.17** | **E.2** |

| | | | | |
|---|---|---|---|---|
| Iteration 2 plan | 1 day | Sat 22.04.17 | Sat 22.04.17 | E.2.1 |
| **Theoretical tasks** | **7,86 days** | **Sat 22.04.17** | **Mon 01.05.17** | **E.2.2** |
| TT-1-1-T (Priority A) | | | | E.2.2.1 |
| TT-1-2-T (Priority A) | | | | E.2.2.2 |
| **Practical tests** | **7,86 days** | **Sat 22.04.17** | **Mon 01.05.17** | **E.2.3** |
| TT-1-1-Pr (Priority A) | | | | E.2.3.1 |
| **Mechanical testing** | **7,86 days** | **Sat 22.04.17** | **Mon 01.05.17** | **E.2.4** |
| TT-1-2A-M (Priority A) | | | | E.2.4.1 |
| TT-1-2B-M (Priority A) | | | | E.2.4.2 |
| Iteration 2 report | 1 day | Mon 01.05.17 | Mon 01.05.17 | E.2.5 |
| **Iteration 3** | **6,71 days** | **Tue 02.05.17** | **Tue 09.05.17** | **E.3** |
| Iteration 3 plan | 6,71 days | Tue 02.05.17 | Tue 09.05.17 | E.3.1 |
| **Theoretical tasks** | **6,71 days** | **Tue 02.05.17** | **Tue 09.05.17** | **E.3.2** |
| TT-3-1-T (Priority B) | | | | E.3.2.1 |
| TT-3-2-T (Priority B) | | | | E.3.2.2 |
| **Mechanical testing** | **6,71 days** | **Tue 02.05.17** | **Tue 09.05.17** | **E.3.3** |
| TT-3-2-M (Priority B) | | | | E.3.3.1 |
| Iteration 3 report | 2,14 days | Fri 05.05.17 | Sun 07.05.17 | E.3.4 |
| **Iteration 4** | **5 days** | **Wed 10.05.17** | **Tue 16.05.17** | **E.4** |
| Iteration 4 plan | 1 day | Mon 08.05.17 | Mon 08.05.17 | E.4.1 |
| **Practical tests** | **9 days** | **Mon 08.05.17** | **Wed 17.05.17** | **E.4.2** |
| TT-2-1-Pr (Priority C) | | | | E.4.2.1 |
| TT-5-1-Pr (Priority C) | | | | E.4.2.2 |
| TT-6-Pr (Priority C) | | | | E.4.2.3 |
| **Mechanical testing** | **9 days** | **Mon 08.05.17** | **Wed 17.05.17** | **E.4.3** |
| TT-2-1A-M (Priority C) | | | | E.4.3.1 |
| TT-2-1B-M (Priority C) | | | | E.4.3.2 |
| Iteration 4 report | 1 day | Wed 17.05.17 | Wed 17.05.17 | E.4.4 |
| **Transition** | **6,71 days** | **Wed 17.05.17** | **Wed 24.05.17** | **F** |
| **Iteration 1** | **4,43 days** | **Wed 17.05.17** | **Mon 22.05.17** | **F.1** |
| Collect and sort all documentation | 4 days | **Wed 17.05.17** | **Mon 22.05.17** | F.1.1 |
| **Iteration 2** | **2,14 days** | **Tue 23.05.17** | **Wed 24.05.17** | **F.2** |
| **Final project documentation** | **3,29 days** | **Mon 22.05.17** | **Wed 24.05.17** | **F.2.1** |
| Hand In | 2 days | Tue 23.05.17 | Wed 24.05.17 | |
| **Presentation 3, final** | **3,29 days** | **Thu 25.05.17** | **Mon 29.05.17** | **G** |

# Timeline




| Task Name | Duration |
|---|---|
| Unified process | 115,29 days |
| Inseption | 20,43 days |
| Presentation 1 | 4,43 days |
| Elaboration | 34,14 days |
| Presentation 2 | 4,43 days |
| Execution | 30,71 days |
| Transition | 6,71 days |
| Presentation 3, final | 3,29 days |



Subsea Connection System

# Project Specification

| | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 3.0 |
| | |
| **SCS Group members** | Asbjørn Antonsen, Project leader and construction Initial: AA |
| | Bjørn Ledaal Rossavik, Qualification and specification Initial: BR |
| | Erlend Berg-Olsen, System Engineer and Project planner Initial: EBO |
| | Espen Hansen, Test and Verification Initial: EH |
| | |



Høgskolen i Sørøst-Norge

# Summary

This document contains an overview over the tasks given from TechnipFMC and what they want SCS to investigate.

The tasks list table is based on the tasks given from TechnipFMC and is a layout created by SCS.

# Document history

| Version | Pages | Date | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 4 | 16.01.2017 | BR | Made document and chapters. |
| V.1.0 | 8 | 31.01.2017 | EH | Final document for 1. Presentation. |
| V.1.1 | 8 | 09.02.2017 | BR | Change from requirements to project specification, requirements task list. Updated information according to new changes. |
| V.1.2 | 8 | 21.02.2017 | BR & EH | Changed task ID from SR to ST. Updated name on task to match task and test specification. Updated priority after meeting with TechnipFMC 20/2-2017. Changed ST-5. |
| V.1.3 | 8 | 09.03.2017 | AA | Updated task list |
| V.1.4 | 8 | 10.03.2017 | SCS | Removed under-task ST-2-2 and ST-3-3. |
| V.1.5 | 7 | 16.03.2017 | EH | Removed main task 4. Updated task 2. |
| V.2.0 | 7 | 20.03.2017 | SCS | Spellcheck and structure check. |
| V.2.1 | 7 | 11.05.2017 | EH | Changed ID name on tasks from ST to MT. |
| V.2.2 | 7 | 17.05.2017 | AA | Updated contents in introduction |
| V.3.0 | 8 | 24.05.2017 | SCS | Ready for last hand in. |

# Contents

# 1. Introduction

Early in the project this document was referred to as requirements, due to feedback and tailoring of the model after first presentation it is now called project specification.

This is a document of project specifications for Subsea Connection System (SCS) during their bachelor thesis. Task list have been agreed on between SCS and TechnipFMC.

Every task shall include:

- An individual ID number, traceability is a high focus for us in SCS.
- Where do the task come from?
- Description about the task.
- Priority.

Each task will be described and explained what it demands to be successful.

After all tasks are in place and agreed on between SCS and TechnipFMC, the testing will start.

# 2. Tasks given from TechnipFMC

Customer (TechnipFMC) needs:

- Specific study of the forces acting on each component in the Speedloc connection.
  - Forces in the stud.
  - Forces in the clamp.
  - Is the preload and torque on the stud good enough, can it be higher/lower?
  - Pretension torque is set from a standard table for bolts, is this applicable for studs?
  - How strong is the connector?

- Review study that has already been done regarding the assumptions that has been made, are these assumptions correct?
- Study Xylan coating, regarding to material certificate. With or without coating? When should it be re-coated? Life time?
- Analyse the different between 3 scenarios regarding grease: Dry stud, light oil and Molykote.
- Check the difference between bolt and nut with washer. Table for bolt is used today, how does this affect the stud, nut and washer.

# 3. Priority

We have chosen to divide priority into 3 different categories:

| | |
|---|---|
| A | Absolute |
| B | Important |
| C | Desirable |

# 4. Task ID explanation

| | |
|---|---|
| MT-1 | ST (System Task), 1 for task number. |
| - TT-1-1 | 1-1 for derived task. (1 for task number - 1 for derived task). |

# 5. Task list

| ID | Description | Priority | Given by | Date |
|---|---|---|---|---|
| MT-1 | Shall determine necessary pretension on nut from necessary force between hubs. (Compare the preload on studs and the target preload on nut). | A | TechnipFMC | 31/01 |
| - TT-1-1 | Determine necessary force between hubs. | A | TechnipFMC | 31/01 |
| - TT-1-2 | Provide recommended pretension on nut including range. | A | TechnipFMC | 31/01 |
| MT-2 | Shall test if the values from the bolt table PRD-0000021662 is applicable for the stud and nut used in the SL connection. | C | TechnipFMC | 31/01 |
| - TT-2-1 | Investigate values on bolt vs stud used from PRD-0000021662 will behave. | C | TechnipFMC | 31/01 |
| MT-3 | Study relationship between stud preload and nut torque applied. Calculate contribution from each variable on preload. | B | TechnipFMC | 31/01 |
| - TT-3-1 | Identify all variables affecting preload. | B | TechnipFMC | 31/01 |
| - TT-3-2 | Investigate variables in the stud & nut study. | B | TechnipFMC | 31/01 |
| MT-5 | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | 20/02 |
| MT-6 | Reproduce analysis in SW and compare results. | C | TechnipFMC | 31/01 |

# Task and Test specification

| | |
|---|---|
| **Employer** | TechnipFMC |
| **Version** | 3.0 |
| | |
| **SCS**<br>**Group members** | Asbjørn Antonsen,<br>Project leader and construction<br>Initial: AA |
| | Bjørn Ledaal Rossavik,<br>Qualification and specification<br>Initial: BR |
| | Erlend Berg-Olsen,<br>System Engineer and Project planner<br>Initial: EBO |
| | Espen Hansen,<br>Test and Verification<br>Initial: EH |
| | |

# Summary

This document contains the man task list and a guideline for hove to solve each task.

The main task list is the tasks given from TechnipFMC. From the main tasks, it is made three sub task lists: theoretical, practical and mechanical.

This document also includes a risk analyze for the three sub task lists.

TechnipFMC

Subsea Connection System

# Document history

| Version | Date | Pages | Approved by | Description |
|---|---|---|---|---|
| V.0.1 | 16.01.2017 | 6 | BR | Made document and chapters with information. Made a template of test requirement that shall be used on every test. |
| V.0.2 | 24.01.2017 | 25 | AA | Made test template for every test |
| V.1.0 | 31.01.2017 | 25 | EH & EBO | Final document for 1. Presentation, filled in every test requirement. |
| V.1.1 | 15.02.2017 | 28 | BR & EH | Updated introduction. Changed name from Test specification to Task and Test specification.<br>Divided all tests into 3 groups. Theoretical, Practical or mechanical. Changed all information regarding this. |
| V.1.2 | 16.02.2017 | 31 | AA | Updated task and test specification. |
| V.1.3 | 16.02.2017 | 33 | BR | Updated information, made all main task and divided derived task and test. |
| V.1.4 | 21.02.2017 | 33 | EH & BR | Changed ID from TR to TT, and SR to ST. Color ID. Updated priority after meeting with TechnipFMC 20/2-2017. Updated Mechanical task list, ST-4-1-M. |
| V.1.5 | 08.03.2017 | 33 | AA | Updated task names, theoretical, mechanical and practical. Spellcheck. |
| V.1.6 | 09.03.2017 | 17 | AA | Removed content 5.1 and 5.2 |
| V.1.7 | 15.03.2017 | 17 | BR | Updated all task list with name and priority.<br>Removed ST-2-1-T and ST-2-2-T. Added ST-2-1-Pr. |
| V.1.8 | 16.03.2017 | 17 | EH | Updated all tasks. Removed ST-4. Table list. |
| V.1.9 | 18.03.2017 | 17 | EH | Updated Mechanical test deviation ST-3-2-M. Updated MT-3. |
| V.2.0 | 20.03.2017 | 18 | AA, EBO, BR, EH. | Structure and spellcheck. |
| V.2.1 | 10.05.2017 | 19 | EH | Updated all main tasks. Inserted Main Task 5.<br>Moved the risk analysis to the bottom. |
| V.2.2 | 17.05.2017 | 19 | BR | Orthography. |
| V.3.0 | 24.05.2017 | 22 | SCS | Ready for last hand in. |

# References

[Ref.1] **DOC No: RPT60020900.** REPORT, STRUCTURAL ANALYSIS, SPEEDLOC-II 222 CLAMP CONNECTOR, TechnipFMC.

[Ref.2] **BS EN ISO 13628-7:2006** Petroleum and natural gas industries — Design and operation of subsea production systems — Part 7: Completion/workover riser systems.

[Ref.3] **Doc No: PRD-0000021662, Rev: H.** STANDARD GLOBAL BOLT MAKE UP, TORQUE VALUES, TechnipFMC.

Contact Einar Totland for information regarding references from TechnipFMC.

# Abbreviations and technical words

| Abbreviation | Explanation |
|---|---|
| WOR | Workover Riser |
| SL | Speedloc |
| ISO | International Standardization organization |
| DNV | Det Norske Veritas |
| SW | Solid Works |
| SCS | Subsea Connection System |
| HSN | Høgskolen i Sør-Øst Norge |
| MT | Main Task |
| TT | Task Test |
| FEM | Finite Element Method |

| Technical Words | Explanation |
|---|---|
| ABAQUS | Software for finite element analysis. |
| Hubs | Flanged part of the SL connector. |
| Preload | Tension force in the stud/bolt after tightening. |
| Torque | Moment of force. |
| Scatter factor | Assessment of accuracy. |
| Stud | Threaded rod similar to a bolt but it has no bolt head. |
| Nut | Is fastener with a threaded hole. |
| Washer | Used to distribute the load. |
| STP | STP is a file extension for a 3-D graphic files. |

# Contents



# Tables

# 1. Introduction

Task and test specification document is a document based on the project specification document. This document will describe and plan how to execute and solve the main tasks and tests from employer.

SCS refer to documents and analyses from TechnipFMC. These documents are confidential, please contact Einar Totland or Per Øystein Hansson in TechnipFMC for more information.

# 2. Main tasks

| ID | Description | Priority | Given by | Date |
|---|---|---|---|---|
| MT-1 | Shall determine necessary pretension on nut from necessary force between hubs. (Compare the preload on hubs and the target torque on nut). | A | TechnipFMC | 31/01 |
| MT-2 | Shall test if the values from the bolt table ISO 13628-7 is applicable for the stud (1.875-8UN-2A) and nut. | C | TechnipFMC | 31/01 |
| MT-3 | Study relationship between stud preload and nut torque applied. Calculate contribution from each variable on preload. | B | TechnipFMC | 31/01 |
| MT-5 | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | 31/01 |
| MT-6 | Reproduce analysis in SW and compare results. | B | TechnipFMC | 31/01 |

*Table 1: Main tasks*

This is SCS main task list, given from TechnipFMC.

From these main tasks, SCS have divided sub tasks into 3 groups.
*(See Chapter 4 for more information).*

After finishing all sub tasks and tests to a main task, a main task report will be made.

## 2.1 Table guidance for main tasks

**Main task ID:** Unique ID number for each task. In that way, SCS can identify each task separately and have good traceability within the documents.

Main Task ID will be referred to on timesheet, analyze report, etc.

MT-1 – Short for Main Task 1.

**Priority:** The tasks is divided in three priority categories.

| | |
|---|---|
| A | Absolute |
| B | Important |
| C | Desirable |

**Task description:** Gives a short explanation about the task.

**Verification:** States all the theoretical tasks, practical and mechanical test that is necessary to solve the main task.

**Result**: The status quo after testing. SCS divide the results into 3 different categories.

| | |
|---|---|
| Accepted | Criteria and verification is accepted |
| Uncertain, need more information | Need to investigate and run more tasks or tests. |
| Not accepted | Criteria and verification is **not** accepted |

**Date:** When the main task is complete.

## 2.2 List of Main tasks

| Main task ID | MT-1 |
|---|---|
| Priority | A |
| Task description | Shall determine necessary pretension on nut/stud from necessary force between hubs. (Compare the preload on studs and the target torque on nut). |
| Verification | TT-1-1-T, TT-1-2-T, TT-1-1-Pr, TT-1-2A-M, TT-1-2B-M |
| Result | TBA |
| Date | TBA |

**Purpose**

Test the material behavior of the stud.

Calculate hub face separation and find necessary contact force between the hubs.

Find recommended torque on nut and preload in stud.

**Equipment**

- Formulas.
- Computer.
- Solid Works (FEM).
- Drawings.
- Material specifications and values.
- Different tools to perform mechanical testing.
- Tension tester.

## Preparation

- Make sure all STP drawing files are in place.
- Location for mechanical testing.
- Make sure all the necessary studs, bolts, nuts and washers are in place.
- Make a test procedure for mechanical testing.

## Acceptance Criteria

The hubs must be seal proof. The stud shall have the right preload force based on the material in stud/nut and the calculated hub force.

| Main task ID | MT-2 |
|---|---|
| Priority | C |
| Task description | Shall test if the values from the bolt table PRD-0000021662[1] is applicable for the stud and nut used in the SL connector. |
| Verification | TT-2-1-Pr, TT-2-1A-M, TT-2-1B-M, |
| Result | TBA |
| Date | TBA |

**Purpose**

In report RPT60020900[2] from TechnipFMC, they have used values based on a bolt, not as a stud and nut.

In real life, the speedloc clamp is fastened with a stud and a nut. In this task, SCS are going to test the differences in mechanical behavior and strength of stud vs bolt.

**Equipment**

- Work shop for mechanical testing.
- Necessary tools.
- SCS-Test bench.
- Computer.
- Solid Works (FEM).

**Preparation**

- Make sure all STP drawing files are in place.
- Location for mechanical testing.
- Make sure all the necessary studs, bolts, nuts and washers are in place.
- Make a test procedure for mechanical testing.

**Acceptance Criteria**

A mechanical test shall be done and give repeatable results. A FEM-analysis shall be done.

[1] [Ref.3] **Doc No: PRD-0000021662, Rev: H**
[2] [Ref.1] **DOC No: RPT60020900.**

| Main task ID | MT-3 |
|---|---|
| Priority | B |
| Task description | Study relationship between stud preload and nut torque applied.<br>Calculate contribution from each variable on preload. |
| Verification | TT-3-1-T, TT-3-2-T, TT-3-2-M |
| Result | TBA |
| Date | TBA |

**Purpose**

Identify all variables affecting torque on nut and preload in stud, and investigate the variables by calculations and testing.

**Equipment**

- Computer.
- Pen and paper.
- Advanced calculator.
- Tools and materials to perform mechanical testing.

**Preparation**

- Location for mechanical testing and tools required.
- Make sure all the necessary studs, bolts, nuts and washers are in place.
- Make a test procedure for mechanical testing.

**Acceptance criteria**

All variables affecting preload in stud and torque on stud shall be listed and investigated.

A mechanical test of the variables shall be done.

| Main Task ID | MT-5 |
|---|---|
| Priority | C |
| Description | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. |
| Verification | TT-5-1-Pr |
| Result | TBA |
| Date | TBA |

**Purpose**

Find tension and bending moment capacity with FEM analyses, with friction included.

Use two different internal pressures, 10KSI and 20KSI. TechnipFMC want to know capacity with both pressures.

**Equipment required**

- Computer.
- Solid works software.
- Drawings of the SL connector. STP file from TechnipFMC, with the same drawing used in ABAQUS.
  (Filename: DU600093667_B.stp).

**Procedure**

1. Material data is set to 20 °C.
2. Use same mesh as in TechnipFMC report RPT60020900. (FMC, Lasse Moldestad, 2007)[3]
3. Use hexahedral, 8-noded elements (C3D8) were used.
4. Set friction coefficient to 0.15.
5. Scatter factor is set to 0.1.
6. Assign proper material specifications to each part.
7. Set correct calculated tension up against the nut.
8. Run FEM analysis.

[3] [Ref.1] **DOC No: RPT60020900.**

## Aids

- RPT60020900[4] from TechnipFMC. (FMC, Lasse Moldestad, 2007)

## Acceptance Criteria

Tension and bending moment capacity are found, with an internal pressure on 10KSI and 20KSI.

[4] [Ref.1] **DOC No: RPT60020900.**

| Main task ID | MT-6 |
|---|---|
| Priority | B |
| Task description | Reproduce analysis done by FMC in SW and compare results. |
| Verification | TT-6-1-Pr |
| Result | TBA |
| Date | TBA |

**Purpose**

Reproducing FEM analysis done by TechnipFMC from report RPT60020900[5] in Solid works, and compare the results.

TechnipFMC have done an analysis on exact same equipment in ABAQUS ver.6.6.1. program. SCS are going to use solid works.

**Equipment**

- Computer.
- Solid Works, FEM-analysis.
- STP file from TechnipFMC, with the same drawing used in ABAQUS. (Filename: DU600093667_B.stp).

**Preparation**

- Make sure all the files from TechnipFMC is usable in Solid works.

**Acceptance Criteria**

When all boundaries, forces, nodes and mesh are analyzed the same way is in ABAQUS. Differences must be documented and reported.

[5] [Ref.1] **DOC No: RPT60020900.**

# 3. Derived task and test division

**Theoretical task**

Color code:

First, there are “Theoretical task”. This is a theoretical part, where SCS investigates different values and analysis. SCS will also do calculations in this part.

For example: Calculate with an advanced calculator on what force the seal attached to the hubs needs, to keep it leakproof.

**Practical test**

Color code:

Practical test for SCS, is a test done in Solid works. SCS will use FEM (Finite element mesh) to analyze the speedloc.

**Mechanical test**

Color code:

Mechanical test is where SCS physically test different parts.

For example, SCS will run an interval test (100 times) on a small-scale stud, to see how this affects the stud.

Each task or test is set up with a table. This table contains necessary information about every requirement. It gives information about requirement ID number, short summary of the requirement, priority, who is responsible for the test, how to verify it, acceptance criteria, result and date.

Each test undergoes a more detailed transformation after this.

In this document, there will be a list of every task or test SCS have, with their own personal ID.

In the theoretical task document, SCS have taken a deeper look into how they can specific solve each task or test. Formulas, tools to use etc. are found.

| Theoretical tasks | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Date** |
| - TT-1-1-T | Determine necessary force between hubs by calculation. | A | TechnipFMC | 31/1 |
| - TT-1-2-T | Provide recommended torque on nut including range. | A | TechnipFMC | 31/1 |
| - TT-3-1-T | Identify all variables affecting torque on nut and preload in stud. Make a list. | B | TechnipFMC | 31/1 |
| - TT-3-2-T | Investigate variables affecting torque on nut and preload in stud. | B | TechnipFMC | 31/1 |

*Table 2: Theoretical tasks*

| Practical tests | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Date** |
| - TT-1-1-Pr | Find necessary force between hubs with FEM analysis. | A | TechnipFMC | 31/1 |
| - TT-2-1-Pr | Investigate values on bolt vs stud used from PRD-0000021662 will behave. | C | SCS | 1/3 |
| - TT-5-1-Pr | Shall find Tension and bending moment capacity with friction as a factor at [10KSI] and [20 KSI] internal pressure on Speedloc. | C | TechnipFMC | 31/1 |
| - TT-6-1-Pr | Reproduce analysis done by FMC in SW and compare results. | C | TechnipFMC | 31/1 |

*Table 3: Practical test*

| Mechanical tests | | | | |
|---|---|---|---|---|
| **ID** | **Description** | **Priority** | **Given by** | **Date** |
| - TT-1-2A-M | Do a tensile strength test of the material used in stud. | A | TechnipFMC | 31/1 |
| - TT-1-2B-M | Test recommended pretension on nut including range. | A | TechnipFMC | 31/1 |
| - TT-2-1A-M | Investigate torque, fraction and elongation in bolt vs stud. | C | TechnipFMC | 31/1 |
| - TT-2-1B-M | Investigate fraction in bolt vs stud. | C | TechnipFMC | 31/1 |
| - TT-3-2-M | Do a mechanical test based on the variables affecting preload on stud and nut. | B | TechnipFMC | 31/1 |

*Table 4: Mechanical tests*

# 4. Risk analysis

Risks and events may occur when working with tasks and tests. To ensure good control over different risks SCS use the risk-analyses tool described in the project plan. This gives a systematic overview about different risks and how to handle them correctly to ensure progress in the project. Risk analyzing is an important part of testing.

The risk is calculated from this formula: **Risk = Risk-Impact x Risk-Probability.**

As SCS did in the project plan they are going to categorize the different risks which may occur when working with theoretical tasks, practical tests and mechanical tests. *(See table 9: Risk-Impact x Risk-Probability in the Project plan).*

## 4.1 Risk: Theoretical tasks (4).

May include:

- Wrong formulas.
- Wrong calculations.
- Not finding correct values and answers.
- Did not identify all variables.
- Not finding correct formulas and information in ISO and DNV standards.
- Low knowledge about bolts, studs, nuts, washers, coatings etc.

## 4.2 Risk: Practical tests (5).

May Include:

- Calculations done in the theoretical part is not usable.
- Software complications in Solid Works and FEM.
- Low knowledge about Solid Works and FEM.
- 3-D drawings from TechnipFMC in ABACUS is not compatible in Solid Works.
- Analysis is not compatible.

## 4.3 Risk: Mechanical tests (6).

May include:

- Not finding a place to do tests (workshop).
- Wrong tools.
- Wrong size on studs, nuts, washers, material etc. Not relevant for use in small-scale testing.
- Not finding correct and relevant coating and grease.
- Theoretical calculations done is not usable for further mechanical testing.
- HSE (Health, safety and environment).

| Risk (4) | Probability | Impact | Ranking | Responsibility |
|---|---|---|---|---|
| **Theoretical tasks** | | | | |
| (4.1): Wrong formulas. | 2 | 4 | 8 | Control: Finding new sources. Ask teachers, TechnipFMC, others who may have more knowledge and information than us. |
| (4.2): Wrong calculations. | 2 | 4 | 8 | Control: Finding new sources. Ask teachers, TechnipFMC, others who may have more knowledge and information than us. |
| (4.3): Not finding the correct values and answers. | 3 | 4 | 12 | Control: Finding new sources. Ask teachers, TechnipFMC, others who may have more knowledge and information than us. |
| (4.4): Did not identify all variables on stud/nut/connection. | 3 | 3 | 9 | Look over: Do a new study. Use other sources. |
| (4.5): Not finding correct formulas and information in ISO and DNV standards. | 2 | 3 | 6 | Control: Finding new sources. Ask teachers, TechnipFMC, others who may have more knowledge and information than us. |
| (4.6): Low knowledge about bolts, studs, nuts, washers, coatings, etc. | 2 | 4 | 8 | Avoid: Each group member must ensure to update their skills. |

*Table 5: Risk (4) Theoretical tasks*

| Risk (5) | Probability | Impact | Ranking | Responsibility |
|---|---|---|---|---|
| **Practical tests** | | | | |
| (5.1): Calculations done in the theoretical part is not usable. | 2 | 4 | 8 | Look over: Go back to the relevant task. Checking formulas.<br>The group should do new calculations. |
| (5.2): Software complications in Solid Works and FEM. | 4 | 3 | 12 | Avoid: Use computers who have the newest updates and software. |
| (5.3): Low knowledge about SW and FEM. | 1 | 4 | 4 | Avoid: Each group member must ensure to update their skills. |
| (5.4): 3-D drawings from TechnipFMC in ABACUS is not compatible in Solid Works. | 3 | 4 | 12 | Control: This must be controlled at an early stage in the testing phase.<br>SCS must make new drawings in Solid Works if the file transferring is not working.<br>This may take some time and shall be considered. |
| (5.5): Analysis done by SCS and TechnipFMC is not compatible. | 3 | 4 | 12 | Look over: Checking calculations. Do we have the same formulas? Are we doing the same calculations? |

*Table 6: Risk (5) Practical tests*

| Risk (6) | Probability | Impact | Ranking | Responsibility |
|---|---|---|---|---|
| **Mechanical tests** | | | | |
| (6.1): Not finding a place to do tests (Workshop). | 1 | 4 | 4 | Avoid: Several alternatives. Backup.<br>- HSN.<br>- TechnipFMC. |
| (6.2): Wrong tools (Torque tools, etc.) | 2 | 3 | 6 | Control: Using tools that fits the task. All torque tools shall be calibrated. |
| (6.3): Wrong size on studs, nuts, washers, etc. Not relevant for use in small-scale testing. | 4 | 4 | 16 | Control: Use materials that fits the test. Asking TechnipFMC for materials. |
| (6.4): Not finding correct and relevant coating and grease. | 3 | 3 | 9 | Control: Asking TechnipFMC. |
| (6.5): Theoretical calculations done is not usable for further mechanical testing. | 3 | 4 | 12 | Look over: Checking formulas.<br>The group should do new calculations. |
| (6.6): Not focus on safety during tests. HSE (Health, safety and environment). | 2 | 4 | 8 | Control: Using the SCS safety procedure for mechanical testing. |

*Table 7: Risk (6) Mechanical tests*

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| | |
|---|---|
| **Test ID:** | |
| **Stud ID:** | |

# Torque/preload-test on SL II-222 stud

| Torque (Nm) | 33% | 66% | 100% | ε, Strain in stud (MPa) |
|---|---|---|---|---|
| 2000 | 660 Nm | 1320 Nm | 2000 Nm | |
| 2200 | 726 Nm | 1452 Nm | 2200 Nm | |
| 2400 | 792 Nm | 1584 Nm | 2400 Nm | |
| 2600 | 858 Nm | 1716 Nm | 2600 Nm | |
| 2800 | 924 Nm | 1848 Nm | 2800 Nm | |
| 3000 | 990 Nm | 1980 Nm | 3000 Nm | |
| 3434 (Torque used today) | 1133 Nm | 2266 Nm | 3434 Nm | |

SCS torque table.

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**Procedure for torque-test on SL stud:**

Step 1: Use the torque table above and start by torqueing to 33%. The correct torque is reached when the nut stops rotating + 3 seconds.

Step 2: Torque to 66%. The correct torque is reached when the nut stops rotating + 3 seconds.

Step 3: Torque to 100%. The correct torque is reached when the nut stops rotating + 3 seconds.

Step 4: Measure the preload in stud by the mounted strain gauges.
Minimum yield (67%) is 485MPa.  Maximum yield (73%) is 528 MPa.

Step 5: Need to un-torque fully between each test, to ensure correct preload and measurement for every case.

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| Test ID: | ID stud:<br><br>Max torque: 2000 Nm. | | | |
|---|---|---|---|---|
| Step | Torque (Nm) | Strain gauge, MPa | Remarks | Sign |
| 1 (33 %) | 660 | | | |
| 2 (66 %) | 1320 | | | |
| 3 (100 %) | 2000 | | | |

| Comments: |
|---|
| |

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| Test ID: 2 | ID stud:<br>Max torque: 2200 Nm. | | | |
| --- | --- | --- | --- | --- |
| Step | Torque (Nm) | Strain gauge, MPa | Remarks | Sign |
| 1 (33 %) | 726 | | | |
| 2 (66 %) | 1452 | | | |
| 3 (100 %) | 2200 | | | |

| Comments: |
| --- |
| |

TechnipFMC

Subsea Connection System

| Test ID: 3 | ID stud: Max torque: 2400 Nm. | | | |
|---|---|---|---|---|
| Step | Torque (Nm) | Strain gauge, MPa | Remarks | Sign |
| 1 (33 %) | 792 | | | |
| 2 (66 %) | 1584 | | | |
| 3 (100 %) | 2400 | | | |

| Comments: |
|---|
| |

TechnipFMC

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| Test ID: 4 | ID stud:<br><br>Max torque: 2600 Nm. | | | |
|---|---|---|---|---|
| Step | Torque (Nm) | Strain gauge, MPa | Remarks | Sign |
| 1 (33 %) | 858 | | | |
| 2 (66 %) | 1716 | | | |
| 3 (100 %) | 2600 | | | |

| Comments: |
|---|
| |

TechnipFMC

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| Test ID: 5 | ID stud: Max torque: 2800 Nm. | | | |
|---|---|---|---|---|
| Step | Torque (Nm) | Strain gauge, MPa | Remarks | Sign |
| 1 (33 %) | 924 | | | |
| 2 (66 %) | 1848 | | | |
| 3 (100 %) | 2800 | | | |

| Comments: |
|---|
| |

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| Test ID: 6 | ID stud:<br>Max torque: 3000 Nm. | | | |
|---|---|---|---|---|
| Step | Torque (Nm) | Strain gauge, MPa | Remarks | Sign |
| 1 (33 %) | 990 | | | |
| 2 (66 %) | 1980 | | | |
| 3 (100 %) | 3000 | | | |

| Comments: |
|---|
| |

| Test ID: 7 | ID stud:<br>Max torque: 3434 Nm. | | | |
| --- | --- | --- | --- | --- |
| Step | Torque (Nm) | Strain gauge, MPa | Remarks | Sign |
| 1 (33 %) | 1133 | | | |
| 2 (66 %) | 2266 | | | |
| 3 (100 %) | 3434 | | | |

| Comments: |
| --- |
| |

| Subsea Connection System | Safe Job Analysis (SJA) | | | |
|---|---|---|---|---|
| | Date: 11.05.2017 | Location: Konsberg Bygg 126E, FMC | Written by: AA and EH | SJA No: 1 |
| | Document: SJA-1.0 | Description of work: Mechanical test on speedloc connector. SL215 test cap. | | |

| No | Subtask | Safety risks | Possible consequence | Safety measure | Responsible for measures |
|---|---|---|---|---|---|
| 1 | Lifting of test cap with crane. | -Lifting equipment brakes.<br><br>-Crush injuries. | -Could be hit by falling object.<br><br>-Crushed between heavy objects. | Use of approved equipment. Secure the lifting area, keep distance when lifting.<br><br>Approved crane operator.<br><br>The participants must use helmet, accepted working clothes, safety glasses and safety shoes. | SCS |
| 2 | Mounting stud and segment on test cap. | Heavy objects. | Dropping segment our other heavy parts on someone or yourself. | Use of safety shoes. | SCS |
| 3 | Use of torque tool. | -Pressurized tool.<br><br>-Noisy.<br><br>-Crush injuries. | Pressurized hose or tools breaks. | -Safety glass, accepted working clothes and earing protection.<br><br>-Approved crane operator.<br><br>-Hose protection. | SCS |
| 4 | Applying chemicals. | Splash hazard. | Could lead to eye or skin damage. | -Read instructions for the applying chemical.<br><br>-Use of safety glasses and accepted gloves. | SCS |

| | | | | |
|---|---|---|---|---|
| Subsea Connection System | **Safe Job Analysis (SJA)** | | | |
| | Date: 11.05.2017 | Location: Konsberg Bygg 126E, FMC | Written by: AA and EH | SJA No: 1 |
| | Document: SJA-1.0 | Description of work: Mechanical test on speedloc connector. SL215 test cap. | | |

| | | | | |
|---|---|---|---|---|
| Activity leader: | Has SJA document been reviewed? | Yes | X | Signature: |
| | | No | | |
| Work leader: | Is the total risk acceptable? | Yes | X | Signature. |
| | | No | | |
| Experiences after work: | | | | |

| Signature list for everyone who have attended and performed Safety Job Analysis. | | | |
|---|---|---|---|
| **Name** | **Function/position** | **Signature** | **Attended the SJA meeting** |
| Asbjørn Antonsen (AA) | Tester | | Yes |
| Espen Hansen (EH) | Tester | | Yes |
| Bjørn Ledaal Rossavik (BR) | Tester | | Yes |
| Erlend Berg-Olsen (EBO) | Tester | | Yes |

| Subsea Connection System | # HSE manual for Mechanical Testing | | |
|---|---|---|---|
| | Document: RM-1.0 | Revision: 1.0 | Publication Date: April 2017 |

| **Theme:** | **General work instructions HSE** | | |
|---|---|---|---|
| Description: | This document provides basic safety guidelines for the safety of all personnel and the general public before, under and after mechanical testing operations. | | |
| Compiled by: | Espen Hansen | Revision date: | 23.5.2017 |
| Approved by: | Espen Hansen | Revision: | 1.0 |

**Purpose:** Shall inform SCS employees about the equipment and material they use and how this shall be handled.

**Scope:** The routine applies to all SCS employees and guests.

**Goals:** SCS shall not have any damage on personnel, materials or the environment. High level on HSE shall ensure a safe work environment.

| Theme | Review |
|---|---|
| **Tools:** | Every employee is responsible for their own tools, borrowed equipment and ensure good handling.<br>Damaged equipment shall be reported to the respective owner. |
| **Working clothes:** | Every employee is responsible for the clothes they are using under tests. |
| **First aid equipment:** | First aid equipment shall be available during work.<br>The employees are responsible for ensuring the first aid kit is complete. |
| **Use of phone:** | Always be in range and enough battery capacity under work. Shall be used with moderation. |
| **Confidentiality:** | The employees are not normally subject to any confidentiality agreement. It is expected that the given information regarding customers, projects, finance, prices, investments, etc. are not passed further to persons who is working for competing firms. |

| **Theme:** | **Personal safety instructions** | | |
|---|---|---|---|
| Description: | This document describes different precautions SCS employees shall be aware of during work. | | |
| Compiled by: | Espen Hansen | Revision date: | 7.4.2017 |
| Approved by: | Espen Hansen | Revision: | 0.1 |

**Purpose:** Reducing the risk of damages and accidents, by inform every employee about their responsibility. To understand and comply the HSE-routine.

**Scope:** The routine applies to all SCS employees.

**Goals:** SCS shall not have any accidents during work and damage on personnel, materiel or environment.

| **Claim for personal protection:** | |
|---|---|
| **Equipment** | **Shall be used in following environment and during following work:** |
| Helmet | Shall be used in areas where there is risk of falling objects. Shall always be used where this is mandatory. |
| Safety shoes | Shall be used within the test area and always in contact with heavy objects. |
| Safety vest (strong colour, reflex) | Always within the test area if this is mandatory. |
| Glasses/screen | Shall always be in use under work where there is a risk of splash or shavings. |
| Working clothes | Approved working clothes of a good standard. |
| Hearing protection | Shall be used within noise zones where the noise exceeds the norm and general noisy work. |
| Mask | Mandatory when needed. Ex during work where there is risk of inhalation dust or gas. |
| Fall protection | If needed. Scaffolding fittings, work in ladder or other installation work. |

| | |
|---|---|
| First Aid equipment | First aid equipment shall be available during work. |
| Special equipment | Special equipment as masks, coveralls, gloves, etc. may be applicable in some jobs. |

**Safe job analysis (SJA):** In operations who may occur risks, or where the risk is unknown, there must be carried a SJA. SJA must be reviewed with every test personnel. See Document: SJA-1.0.

**Certification:** Some work includes use of truck, cranes, lift, welding, hot work, etc. and this need special training. Jobs you are not compatible to do, shall not be done.

**HSE (Health, safety and environment)-deviation:** Accident, dangerous devices or damages shall be notified.

**Use of machinery and responsibility:** The user manual of the used machine must be followed.

**Clean workplace:** Clear and clean your workplace during work! The work is not completed before the workplace looks good. Infringement may lead to expulsion.

**This personal security information document is read, understood and I will ensure to live after the given decisions.*

Employee sign:

______________________________

Date/Place:

______________________________