Bachelor thesis: Raw material drawings

Rev	ECN No.	Date	Reviewed By	Approved By	Status
A	N/A	25.05.2014	Morten Mikalsen	Erlend Lindhartsen	Released

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1.0 The Project

The Bachelor thesis consists of mapping all elements in the process of making a raw material drawing, and meanwhile maintaining all stakeholders interests.

We have to map all the specific requirements linked to the raw material, so that sub-suppliers can conduct processes related to manufacturing in the most efficient way, without using unnecessary resources and time on changes along the way.

The result of the Thesis will most likely be procedure or a design guideline that manages the process of making raw material drawings. The thesis also has to maintain all of the stakeholders interests before the manufacturing process is started after the order.

2.0 About us

The project group consists of:
Morten Mikalsen (Project manager)

Tlf: +47 915 715 26
E-main: morten@buskerudva.no
Background: General admission, certified plumber, UIO – exam in specialized labor court, NKS: business administration, NKS: leadership, LO school, AOF top education in organization and leadership, 20 years as self-employed entrepreneur.

Nils Olav Huseby

Tlf: +47 9797 0490
E-mail: NilsOlav.Huseby@fmcti.com
Background: Certified machine worker with 8 years practical experience, and two years as project manager and purchasing agent in the same company. Started working for FMC Kongsberg 2. january 2013 as a Manufacturing Engineer. I'm working together with designers with quality insurance with a purpose of making production friendly design. I'm also lecturing in production technique internally in FMC.

Erlend Lindhartsen

Tlf: +47 9284 1340
E-mail: Erlend85@gmail.com
Background: Certified plumber and assistant teacher in math and physics at HBV.

3.0 Performance of the project

The start-up of the bachelor project was in the beginning of January. In the first month of the semester we mainly went to lectures in project administration, to get a better clue on what we were up against in the coming months. Going to the lectures was considered mandatory within the group to get better equipped in the process of working together as a group. The name of the thesis is Raw Material Drawings and is given to us by FMC, which is an oil based subsea organization.

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The Thesis mainly consists of us going in to the process of making raw material drawings across internal departments in FMC and external sub-suppliers in Norway and abroad.

Building a system and mapping all stakeholders interests in the manufacturing process were the goal of the Bachelor Thesis. With this system we're aiming to reduce delivery time and costs for raw materials. In this regard, doing interviews, mapping and systematizing information have been fundamental factors in the work around sewing together the documentation. All of our preliminary work in administration and technical research underlies our result, which is a design guideline for making raw material drawings. The design guideline is meant to standardize design methods in the planning phase, and limit any unnecessary bureaucracy related to delays and unnecessary costs.

We can say in a more detailed manner that the project group studied requirements from FMC carefully, and then came to an agreement with the project owner that the main goals for the project would be shorter delivery time and cost overruns related to delivery of raw materials in the oil industry. The steel is used in surface based service on existing oil-wells in subsea installation, where there are extensive requirements to pressure, tension, tightness and flexibility. All of these parameters are extremely important to maintain, since risk is a factor due to the extreme consequence if something goes wrong (i.e. oil leakage). Customers of FMC can be Statoil and BP, big companies and national states.

The work related to producing a solution has been focused on interviewing people internally in FMC and sub-suppliers of FMC. We have traveled to different places in europe to collect the necessary input for our project in making the best solution.

From the school's perspective, we needed to divide the work of the project into two main categories. The main categories were divided into an administrative and a technical role. The administrative work has mainly consisted of project planning and project management, while the technical work has been focused on research, reports and solutions.

We had to allocate the technical work into three main categories, in order to have the fairest possible distribution of work. Where the administrative work has been adjusted and worked with along the project. The group consists of only three group members, and it was natural for us to allocate the technical work into three parts to get the best possible responsibility and work distribution. The technical part consists of studies on forging, machining and testing of raw materials. We chose to develop exactly those documents, because they are most relevant to the manufacturing process of raw materials and raw material drawings. It then has naturally developed several technical documents (i.e. geometrical tolerances) because of what we have learned along the way about testing, forging and machining. As the foundation of all work from administrative and technical documents, we are confident that the result is satisfactory for FMC, and the way we used to assign work has shown to work well in practice. The distribution of the technical aspects around the processes associated with raw materials has proved to be a good working method to reach the goal.

The latest documentation that we have made has been based on administrative and technical documents, and feedback internally from FMC and FMC's suppliers. Making the system has been an iterative process, which consisted of analysis, construction and testing in iterative cycles. We are very satisfied with the result as it is today, where our solution has problem approaches for testing, machining and forging to meet project owner requirements.

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4.0 Conclusion of the Thesis

Straight away after we started testing our system, we found out that it would be very difficult to meet the requirements we had set together with our customer.

It turned out that FMC's suppliers want to have control of their own process, and don't really want to have too much detailed process control from FMC. Additionally, they always make their own Raw material/process drawings, and would still do so even if FMC made raw material drawings.

Since they still needed to make the same documentation, and they still used the same amount of time to make it, FMC would not save any money or lead time just by using raw material drawings.

The process of production would still take the same amount of time.

After a lot of discussions and research, we came to a conclusion;

- A raw material drawing alone will not help reduce the cost and lead time, but it opens up the possibility for enormous savings in the process, if used correctly.

This was very interesting to hear more about, but it was just on the edge of our bachelor thesis scope.

We did however, not change our requirement in the Requirement spec, since we saw that we needed to take these considerations into account for our thesis.

Parallel to our thesis, FMC has done a lot of investigation on the same matter. We have followed this process with interest, but still walked our own path, and taken our own decisions and considerations. Our guideline is quite different than what FMC concluded with.

The main benefit from having a raw material drawing comes from the way it can be used. It allows FMC to order the materials at an earlier stage in the process, even before the finished geometry is ready. However, this means that FMC needs to have a look at the way they handle the requirements for testing of materials, in particular the test speciment location.

Per now, at least for Statoil, this is defined by the finished geometry. The problem starts when we don't know the finished geometry at this stage of the process, then we need to specify the material testing in the most conservative way, and say that this covers all situations. This is one of the massive time thieves in prior projects, according to the suppliers we have interviewed.

Based on our concept evaluations for systems, we decided to make a Design guideline for the designer at FMC.

This document is considered as our system, and will help instruct the designers to make the best possible raw material drawings. The guideline is based on a lot of technical research, and input from FMC, and FMC's suppliers of forged raw materials, and machining suppliers.

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5.0 Potential improvements outside the scope

When we have talked to FMC's suppliers, and different people inside the FMC system, we have found out that there is a huge potential for improvement, not just on the aspect of raw material drawings, but in the whole process.

The thing that we got the most feedback on, that we were unsure how to put into the project was:

- FMC should specify testing, and test specimen location on the most conservative way, and that should cover the whole part. By doing so, the suppliers will save A LOT of time in discussions prior to pre-production meeting.

One of the reasons for this is that the test specimen locations are given by the final geometry, and once this is changed, the location for the test speciments gets changed, and all documentation needs to be updated. (Manufacturing plan and quality plan etc.)

- By using the raw material drawing correctly, with the above test requirements, FMC can put a purchase order on parts on a much earlier stage in the process, not having to change the test locations all the time. If FMC is unsure about the final dimensions of the product, they can specify extra stock material that might be subjected to change. However, this will have a cost impact.

This will result in a much earlier supplier involvement, and multiple processes can go at the same time independently.

- By using a raw material drawing, there will be much better drawings and information that gives the basis for a quotation from the suppliers.

This is very important. FMC will be able to quote on the same delivered geometry at multiple forging suppliers. The same goes for machining suppliers.

- A supplier mentioned that they do UT of the raw material upon arrival of raw material. This in despite that it has already been done prior to shipment at the raw material supplier.

This should not be necessary, as there already is an approved UT report present.

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Dokumentoversikt

Dokument nr	Versjon	Dokumentnavn	Sider	Beskrivelse	Eierskap
ADM0000	RevA	Bachelor thesis Raw Material drawings	6	Beskriver oppgaven med konklusjoner	Gruppe
ADM0001	RevA	Kravspek	8	Beskriver krav fra eier og andre stakeholders	N.O.H.
ADM0002	RevA	Testspek	16	Beskriver hvordan systemet testes etter en bestemt plan	N.O.H. / E.L.
ADM0003	RevA	Prosjektplan	22	Beskriver hvordan gruppa er satt sammen og hvordan den arbeider med prosjektet på alle plan.	M.M.
ADM0004	RevA	Consept def.	10	Beskriver oppgaven vi er satt til å løse.	N.O.H. / E.L.
TECH0001	RevB	Forging	16	Beskriver smiprosessen hos et utvalg av leverandører.	N.O.H.
TECH0002	RevB	Testing	16	Beskriver hvordan tester utføres på produktene under produksjon.	E.L.
TECH0003	RevA	Maskinering	16	Beskriver de krav som stilles for å begrense tid og kostnadsoverskrid.	M.M.
TECH0004	RevA	Guide line	14	Beskriver vårt forslag til prosedyre ved fremstilling av tegninger	N.O.H.
TECH0005	RevA	Geometr.tol.	12	Beskriver hvordan toleranser defineres.	N.O.H.
TECH0006	RevA	Questionaries	8	Beskriver hvordan vi gikk frem når vi intervjuet underleverandører i Italia, Sverige og Norge.	N.O.H.

Design Guideline for forged raw materials

Rev	ECN No.	Date	Reviewed By	Approved By	Status
A	N/A	25.05.2014	Erlend Lindhartsen	Nils Olav Huseby	Released

Summary:

This Guideline is meant to help designers design raw material drawings for forged components in the FMC riser system.

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List of Figures

List of tables

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Abbreviations and definitions

Abbreviation / definitions	Description
Manufacturing	Means the process of machining the part.
GPS	Geometrical Product Specifications
UT	Ultrasonic testing
WAS	Well Access Systems
PWHT	Post Weld Heat Treatment
COG	Center Of Gravity
DGL	Design Guideline
GPS	Geometrical Product Specification
HVOF	High Velocity Oxygen Fuel

Table 1, Abbreviations and definitions

Reference documents

Document name	Description
DGL10062519 – Rev B	Design Guideline, Materials, Prolongation Sizing, Production and qualification drawings and part report instructions (Not for external release)
TECH0001 – Rev B	Forging and Quenching requirements
TECH0002 – Rev B	Testing requirements
TECH0005 – Rev A	Geometrical tolerance requirements

Table 2, Reference documents

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1.0 Purpose

The purpose of this document is to clarify to the designers of WAS, how they are going to design the raw material drawings for the riser components.

2.0 Scope

This design guideline will focus on the process considerations that needs to be taken when making raw material drawings for forged riser components

The typical drawings needed to manufacture a riser joint would be:

Drawing type	**Responsible**
Finished geometry (with cladding sheets)	FMC
Semi-finished geometry	FMC
UT shape/Test locations	Supplier
Rough machining prior to quenching	Supplier
Forging drawing	Supplier

Table 3, Drawing types

Finished Geometry

Semi-finished geometry

UT shape

Quenching shape

Forging shape

<u>Geometry should be as similar as possible</u>

The drawing supplied to the raw material supplier should be made with 2 sheets:

1. The semi-finished geometry, showing “as delivered” from forging supplier geometry. In this sheet the final geometry (If available) should be illustrated as a dotted line inside the raw material geometry. Sheet 1 should also include Center of gravity for ease of handling.

2. Geometry with a suggestion to prolongation, and a defined critical section if applicable.

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3.0 Evaluate finished geometry

	Checklist	Yes	No
3.1	Are there any non-concentric features on this product?		
3.2	Is there any welding on this part?		
3.3	Is the thickest material section thicker than 500mm?		
3.4	Can the flanges be further apart than the biggest diameter of the part?		
3.5	Is the inner bore bigger than 400mm?		
3.6	Is the material a ring?		
3.7	Is the forged material a round bar?		
3.8	Is there any HVOF or Nickel Plating on the finished geometry?		

Table 4, Checklist for evaluation

If you get yes, on any of the above points, you need to go to section 4.1 before you go through the general design considerations.

4.0 Design considerations

4.1 Special Design considerations

Nr.	Requirement	Reference
3.1	Non-concentric features are very costly. Most of these will be forged as barstock, and machined to the desired geometry by milling. Milling is generally a more expensive machining process than Turning. However, on longer components the supplier might forge the flanges eccentric. Involving the forging supplier will be very beneficial. These features generate challenges both in the forging process, as well as in the inspection process, as the suppliers need to do UT of this. The variation in material thickness of the finished geometry, gives different acceptance criteria's for the UT. Another way to make these flanges is to forge a concentric flange around the center bore, and machine away the excess material. This is however, quite costly.	TECH0001, Section 4.1 TECH0002, Section 3.8

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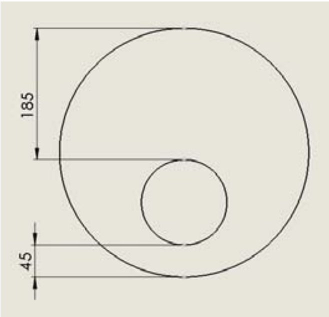

Figure 1, Eccentric flange

3.2	Components with welding could generate challenges for the welding supplier if this is not taken in consideration from the forging supplier. All welded surfaces needs to have a minimum material thickness of 20mm on the Pre weld- geometry. If finished dimensions have less than 20mm material thickness, the shape delivered to the welding supplier needs to have a more material on the other side of the welded geometry, which will be machined away after welding. We recommend to even add 5mm extra, which adds up to 25mm. The 30ºangle is to accommodate for easier turning operations. All cladded / welded components need's PWHT. This will generate distortion in the material, and it will generate scaling on the outside of the material due to precipitation. Therefore, it is required with extra stock material or much bigger tolerances on all areas affected by the welding.	

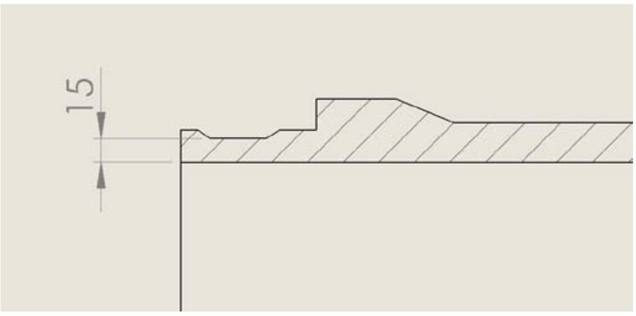

Figure 2, Pre-weld geometry

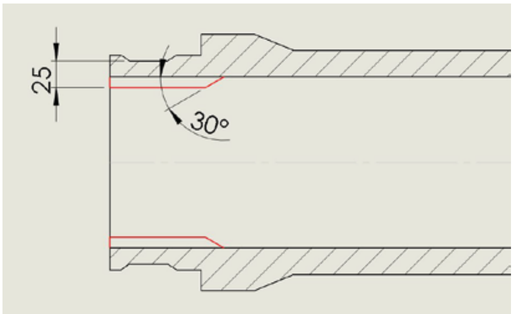

Figure 3, Pre-weld geometry required material

3.3	For materials with a thickness of 500mm and above as the quenched geometry, it might be challenging to achieve good mechanical properties in the center. This means it must be specified as “pre-bored”, or with a lower strength requirement. Typically test caps, cannot be specified as one big piece. We need a geometry that accommodates maximum 500mm material thickness. Maximum material thickness is equal to a maximum inscribed sphere of ø500mm into any crossection of the material.	
3.4	It is a lot cheaper to forge something to shape, than to machine a component to the desired geometry. This means, as long as we can take the forging process in consideration, we will save money. Flanges close to each	TECH0001, Section 4.1

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	other will most likely be forged as a bar, and machined in between. The tools used for the forging process are selected based on size and geometry. However, the suppliers want to use as big tools as possible, but generally never smaller tools than the radius of the finished diameter. Additionally they need space on each side of the tool. This means that the distance between the flanges needs to be at least as big as the biggest diameter of the biggest flange.	

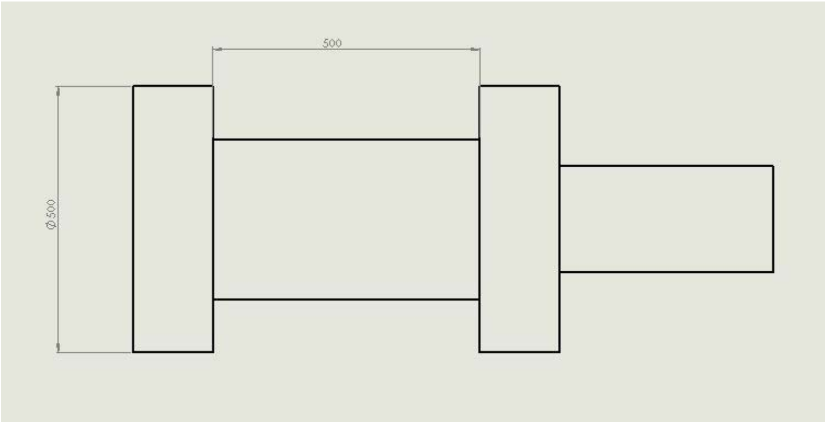

Figure 4, "As forged" requirement

3.5	Is the inner bore bigger than ø400mm? If this is the case, the supplier can punch a hole in the part, and forge out on a mandrel. This is called Sleeve forging. This becomes more difficult on longer parts, but it is still possible. This can be a way of achieving the desired material properties on materials with a big center hole, and thick walls. For example, some of the parts for FMC swivel use this process.	
3.6	For materials that have the shape of a ring, it will not be a good solution to use a prolongation for testing. In this case, the forging supplier will typically make an extra ring, and this will be a sacrificial part. Therefore, do not design a suggestion for prolongation on ring forgings.	
3.7	For smaller components with a raw material that will most likely be a round bar. These will most likely not be forged as individual components, but rather as a long barstock. Especially if there is a quantity of more than 1. This means that 1 prolongation should cover the whole batch of the barstock. Therefore, we should design a proposal for this. However, the suppliers should be involved in this process, because of batch length limitations etc.	
3.8	If there are any HVOF or Nickel Plated coatings, these might need special considerations. This should be clarified with a supplier.	

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4.2 General design considerations

The following considerations should be considered in the given sequence:

Nr.	Requirement	Reference
4.2.1	Add 7mm to all surfaces. This can be done by using a 7mm offset on existing geometry.	TECH0002, Section 3.4
4.2.2	Now all surfaces needs to be made straight. Both tapers and radiuses need to be removed.	TECH0002, Section 3.4
4.2.3	Bore should be specified to the finished dimension and tolerances on all components longer than 1500mm or 10 x ID.	TECH0001, Section 4.2
4.2.4	Balance geometry to accommodate heat treatment and UT	TECH0001, Section 4.1
4.2.5	Apply geometrical tolerances according to recommendations	TECH0005, Section 5
4.2.6	Apply [3D] requirements on critical dimensions.	TECH0005, Section 4.2
4.2.7	Add Sheet 2 with a suggestion to length of prolongation. The geometry shown here should not be a section.	TECH0002, Section 3.6
4.2.8	Add critical section or highest utilized section on Sheet 2 if applicable	
4.2.9	Add the COG on Sheet 1 for ease of handling	
4.2.10	If available, add finished geometry as a stapled line on sheet 1	

Table 5, Design guide for Semi-finished geometry

This page is made to be printed out as a desk reference guide

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5.0 Description of design criteria's

Ref.	Description
4.2.1	First thing to do is to add 7mm of stock material on all surfaces. This is because of the limitations in the ultrasonic testing equipment. The ultrasonic equipment has a "blind zone" of about 4-5mm. By adding 7mm stock, we should have enough margins for the general tolerances, and eccentricity.

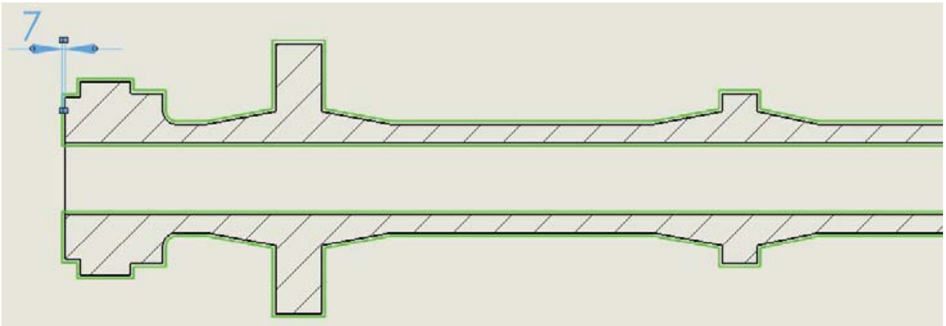

Figure 5, 7mm added stock material

Ref.	Description
4.2.2	Remove all tapers and radiuses. This is necessary because of the Ultrasonic testing equipment capabilities, as tapers will create "blind zones".

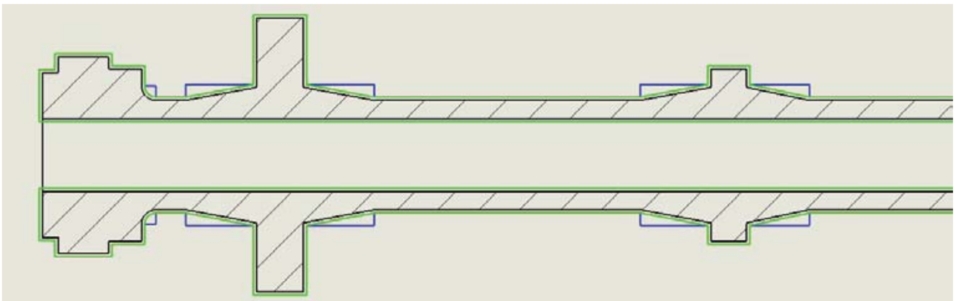

Figure 6, UT geometry

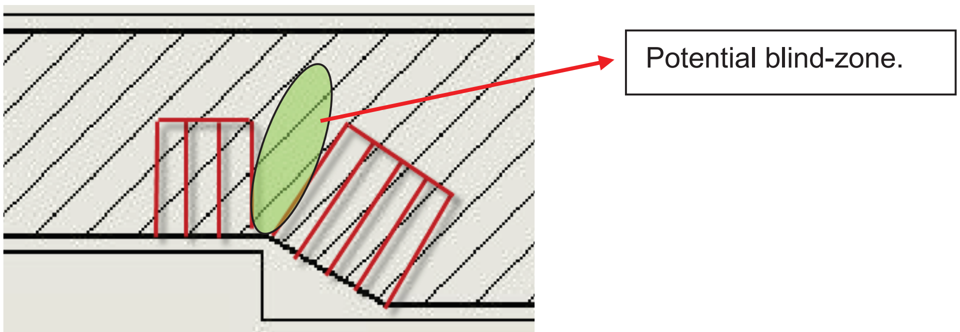

Figure 7, UT taper blind-zone

Ref.	Description
4.2.3	If the Depth / diameter ratio on the inner bore is higher than 10, the inner bore should be specified with the finished dimension and geometrical requirements

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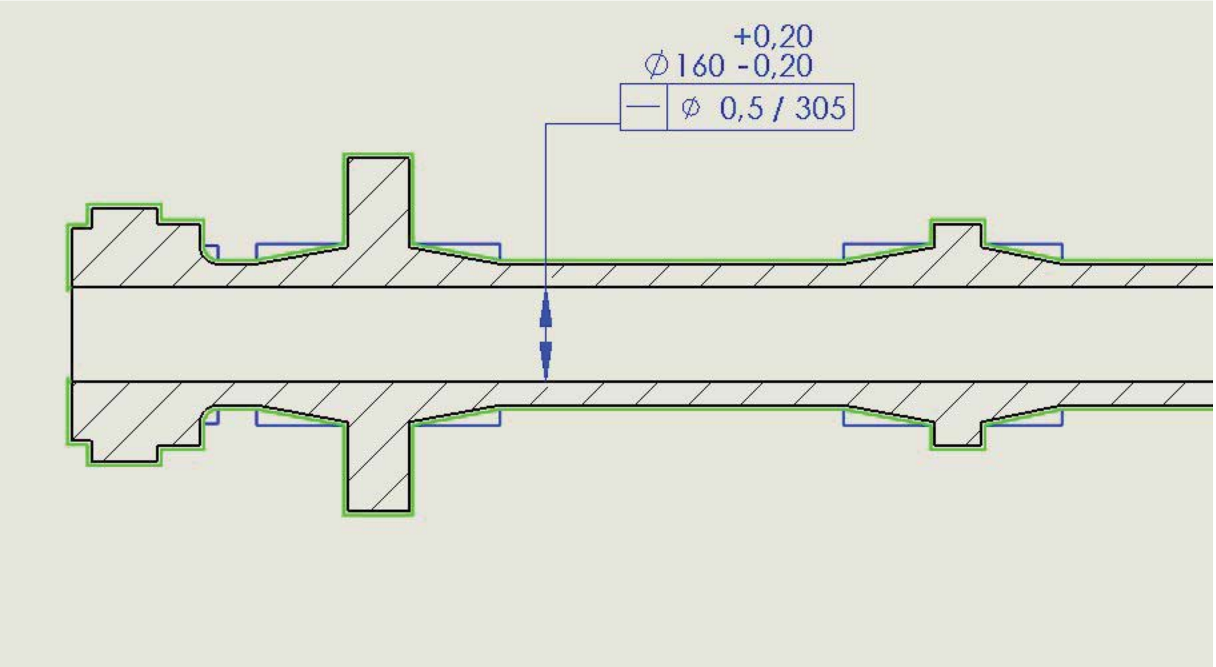

Figure 8, Inner bore specification

4.2.4	Balance geometry to accommodate heat treatment geometry and Ultrasonic testing. By having very big differences in material thicknesses, there might be challenges in the heat treatment after quenching. If needed, add extra stock material for additional design freedom on the finished geometry. This will have a cost impact. Rule of thumb: 75kg/h in additional machining time. Additionally, different material thicknesses require different calibration blocks for the Ultrasonic testing. One block covers typically +-10% in material thickness and radius.

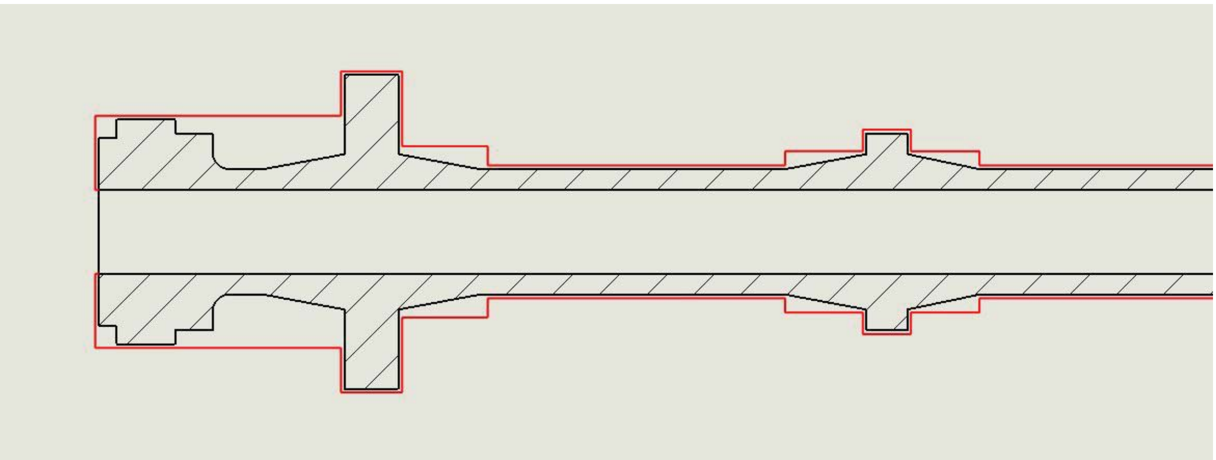

Figure 9, Balanced geometry

4.2.5	Apply geometrical tolerances according to recommendations. You should find these in the geometrical tolerance document. Below is an example. Some reminders:

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	If the bore is in finished geometry, this should be the reference for all other dimensions and geometries. Do not specify one datum on a long internal feature, as this will be very difficult to use as a reference. Do not use the face of a long part as a datum since just a small deviation will have a big impact on several maters of length. Make sure that you secure enough stock material for all operations.

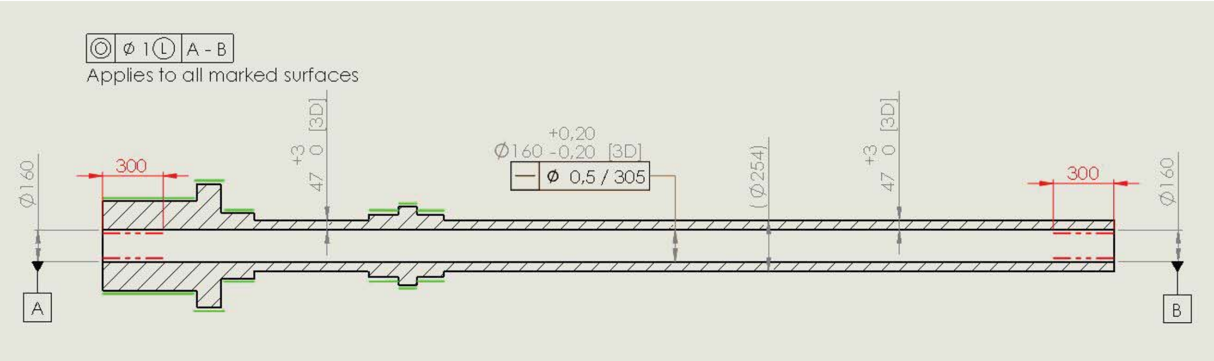

Figure 10, Applied GPS

4.2.6	Apply [3D] requirements on critical dimensions; this will make sure that the suppliers need to make a measuring report on all dimensions with 3D requirements. Should be applied to inner bore if it is a final geometry. Material thickness is also a typical 3D requirement.

See figure 10

4.2.7	Add sheet 2 with a suggestion to prolongation geometry. As illustrated in figure 12, the prolongation view should NOT be a section, but rather shown as a massive bolt. This is because we do not know the geometry the supplier will quench in, and it is the quenched geometry that is relevant for the prolongation. Additional information regarding prolongation can be found in DGL10062519

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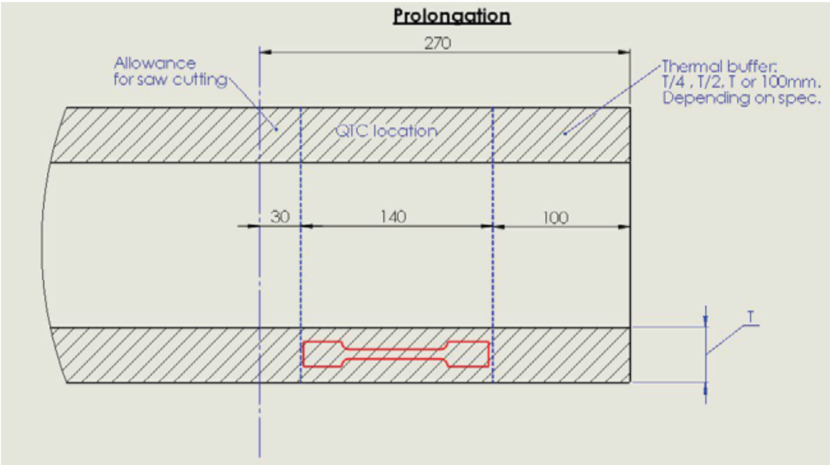
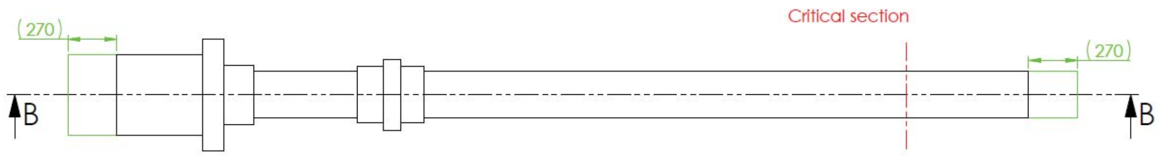
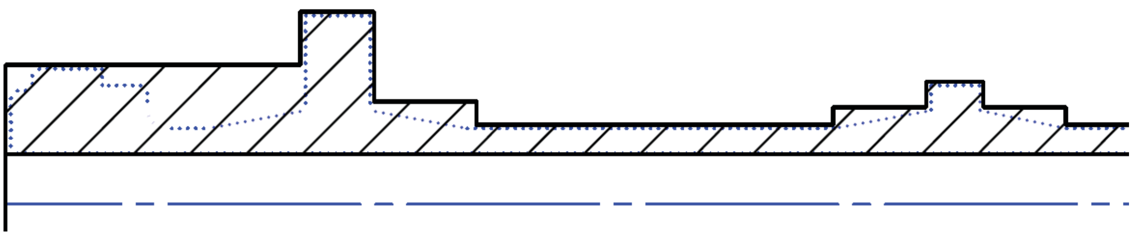
 Figure 11, How to determine length of prolongation  Figure 12, How to show prolongation	
4.2.8	Add critical section or highest utilization on sheet 2.
See Figure 12	
4.2.9	Add center of gravity on sheet 1.
 Figure 13, Center of gravity	
4.2.10	If available and possible, add finished geometry as a stapled line in sheet 1
 Figure 14, Finished geometry	

Table 6, Explanation of design criteria's

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Forging and Quenching requirements

Rev	ECN No.	Date	Reviewed By	Approved By	Status
B	N/A	25.05.2014	Erlend Lindhardtsen	Nils Olav Huseby	Released

Summary:

This document will give a basic understanding about the theoretical and technical background of Forgings, and why this implicates the design of raw material drawings.

This document will also cover the process of quenching.

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Abbreviations and definitions

Abbreviation / definitions	Description
Manufacturing	Means the process of machining the part.
ISO	International Organization for Standardization
QN	Quality Notification
VOR	Variation Order Request

Table 1, Abbreviations and definitions

Reference documents

Document name	Description
SPC60089863 – Rev C	Specification , Material – Forging, for 2-1/4 CR 1 MO (ASTM A182-F22) Modified material, 85 KSI Yield, for non-welded and welded workover riser joints, H2S service
ISO 13628-7:2007	Petroleum and natural gas industries – Design and operation of subsea production systems – Part 7: Completion/workover riser systems
TR 2382-version 2: 2013	Material and fabrication requirements for subsea XT, WH, TH and WOS
ASTM A668:2013	Standard specification for steel forgings, carbon and alloy, for general industrial use
Web References	**Description**
https://www.forging.org/system/files/field_document/OpenDieArticles.pdf	Forging solutions, Articles on open die forging. Written by Forging Industry Association, 2007
http://www.forging.org/Design/page1.html	Product design guide for Forging. Written by Forging Industry Association
Books	
S. Kalpakjian and S. Schmid, “Manufacturing Engineering & Technology”, (6th Edition), Prentice Hall, (April 6, 2009)	

Table 2, Reference documents

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Basics of Forging/Quenching

1.0 Scope

This document will give an understanding to why we need to consider the Forging process to make the best possible Raw material drawings.

2.0 Document History

Revision	Description	Date	Sign
00	Created document	04.04.14	NOH
A	Released document	09.04.14	NOH
02	Updated document with new information and pictures collected from interviews of suppliers and FMC.	22.04.14	NOH
B	Released document	25.05.14	NOH

Table 3, Document History

3.0 Theoretical approach to the forging and quenching process

3.1 General about forging

Forging is a very old method of steel shaping, and can be traced back to the time when blacksmith's where hammering on the steel on an anvil, to achieve the best possible material properties.

In modern times, there are generally two major classes of forging.

1. Open die forging

2. Closed die forging (also often referred to as Impression die forging)

The main difference in these two classes is:

In the closed die forging process, the workpiece is deformed between two die halves, which carry the impression of the final shape.

Open die forging is carried out between an anvil and a flat, or simple shaped die. There are of course different types of dies, and different ways of doing this.

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The shaping of the material is done by a big hydraulic press, and materials are often heated up (to between 850 – 1150ºC), to allow for easier deformation.

The starting point of most forgings is an Ingot. This can be in many different shapes, but it is almost always a taper, because it has to be removed from the ingot mold.

Figure 1, Ingot Mold

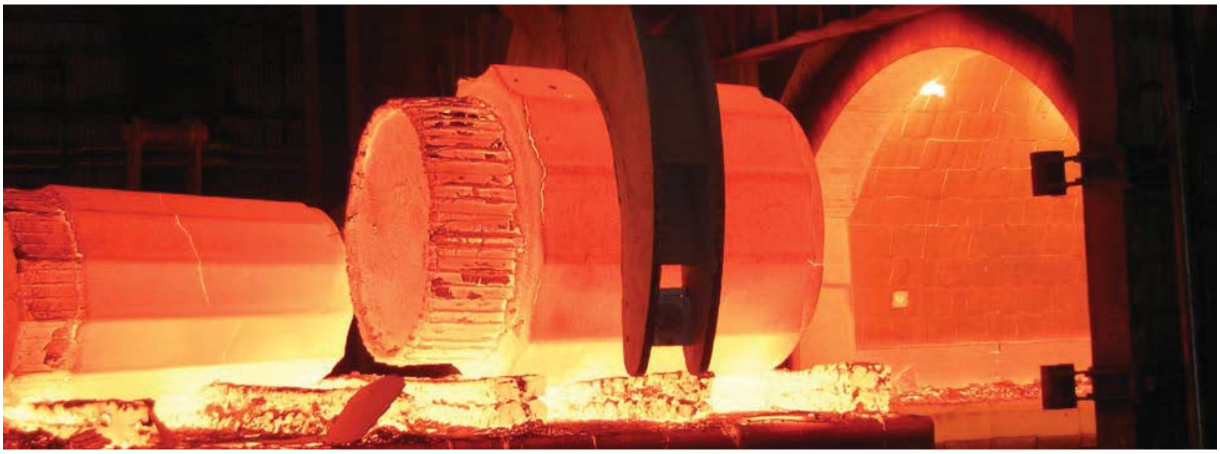

Figure 2, Ingot just out of furnace

There are three general temperature categories, cold, warm and hot. Hot forging is used in FMC's material specifications relevant to this project.

Note, you also have a forging method called "Hammer forging", which also gives better properties to materials, however, this does not give as good properties as the common "open die forging". FMC mainly uses open die forging, and we will therefore focus on that. Additionally you have Ring rolling, and other alternative forging methods, but we will not look into these in this bachelor thesis.

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A couple of examples to open die forging:

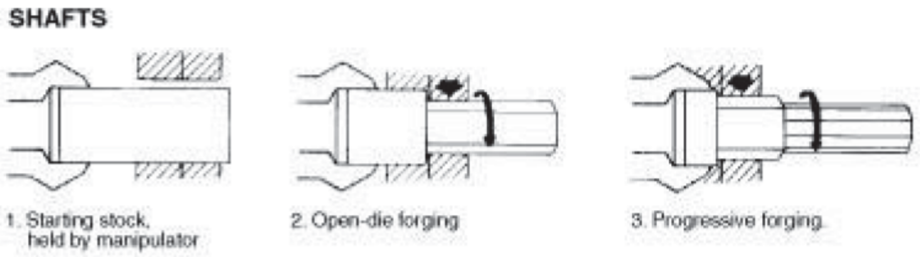

Figure 3, Open die shaft forging

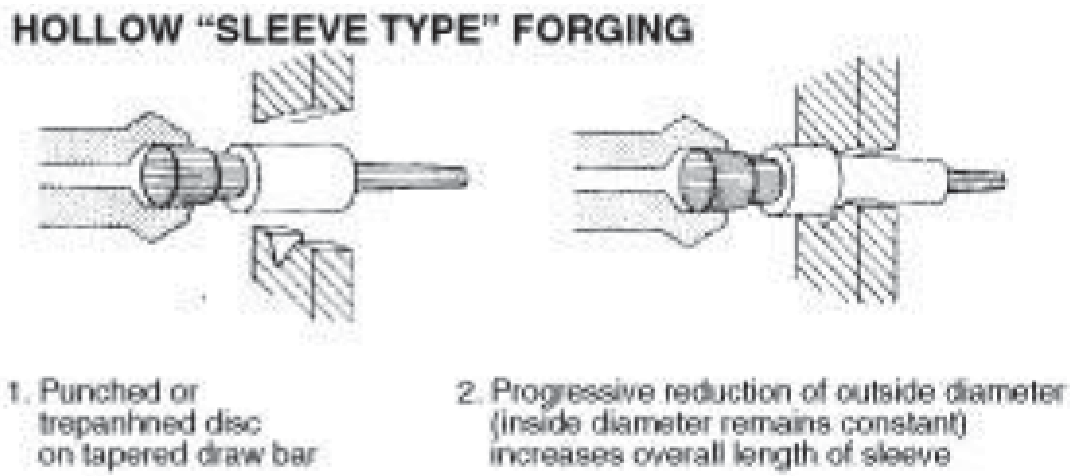

Figure 4, Open die hollow sleeve forging

Metallic materials are made from crystalline structures, and will have different properties in different directions, in regards to these crystalline structures. This is called "Grain flow", and we will get back to this in section 3.3

Forging is a way of controlling this "Grain flow", and more and more of FMC's customers are requiring this on critical components, with high fatigue utilization.

To control and achieve the desired grain flow, the forges use different dies. These have different geometries, and will therefore make different "impressions" on the ingot.

A forged component will have quite a rough surface after forging. They are therefore very often machined before quenching. Another reason for machining the components before quenching is because of stress concentrations. You want to eliminate all sharp edges and corners.

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Figure 5, Part "as forged"

Figure 6, Part "as forged" - 2

All FMC Riser components are always machined prior to quenching, as this is a requirement in ISO 13628-7, Section 7.3.3.2

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3.2 General about Quenching

As forging gives the material the needed geometry, quenching gives the material the desired properties.

Quenching is the process of rapid cooling of a work-piece. The cool-down time is a big factor to what kind of properties your work-piece will end up with.

FMC's supplier's does quenching to achieve the desired strength. This requires strict process control to achieve a good result.

One of the reasons for the increase of strength when doing quenching is the phase transformations of the crystalline structures, and the introduction of martensite. Martensite is formed in carbon steels by cooling down at such a fast rate, that the carbon atoms do not have time to diffuse out of the crystal structure in large enough quantities to form cementite.

This tells us how important process control of quenching is. If the material is not cooled down fast enough, we will not have martensite, but cementite will occur instead, and cementite does not give the desired properties.

Some of the factors that control the cooling process are;

- Time from furnace to quench bath (Transfer time)
- Area exposed to water
- Temperature of work-piece when quenched

The only parameter relevant for this thesis will be the Area exposed to water. We can affect this. Especially on riser products, which are very similar to pipes, we can quench these with a hole in the center of the work-piece, to gain additional area exposed to the water.

However, it is preferred to quench the parts without having a hole in the center of the part. One important factor here is distortion due to the cool-down. This means, if we make a part with thinner wall thickness, it may distort more than a massive bolt.

Distortion comes from the different volumes of the different phases the material goes through.

Additionally, transferring a part that is heated up to 900ºC is a challenge, because with thin walls, it might bend or distort.

According to SPC60089863 FMC has a requirement of transfer time of maximum 90 seconds, this is a big challenge for the suppliers, as they need to use a crane to transfer the parts. This is something that creates a lot of QN's.

As you can see on figure 7, there are some handling issues on these big parts. 90 seconds with a crane will therefore become a challenge.

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Figure 7, Part ready for quenching

3.3 Why does FMC use forged components?

Forged components are known for having a high consistency in material quality and are therefore preferred to be used in critical components.

As mentioned earlier, the grain flow of a material is very important when it comes to the material properties.

For example, if you are going to tear a wooden plank into two pieces, this will always be stronger in the longitudinal direction of the fibers, compared to the strength across the fibers. The same thing applies for metallic materials.

Therefore, the grain flow of a rolled plate will go in one direction. The same applies for a rolled bar.

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Here you can see a cross section of a forged to shape flange;

Figure 8, Grain flow of forged flange

As you can see, the grain flow follows the geometry of the material. This will give better properties in the direction we want to have better properties.

Another example to how the process affects the grain flow.

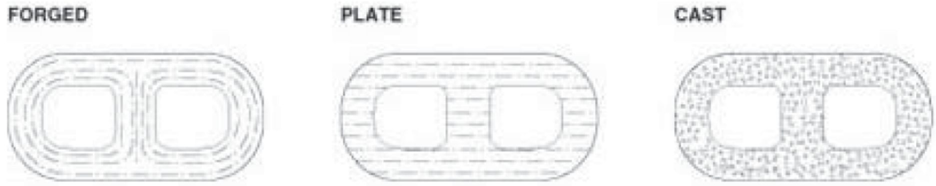

Figure 9, how the production method affects the grain flow

4.0 How the process affects the raw material drawings

This document will mainly focus on the already mentioned processes, forging and quenching. Both of these processes have limitations, and this will (probably) affect the raw material drawings.

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4.1 Challenges/limitations to the forging process

When we want to specify certain geometry as forged to shape, there are great limitations in regards to different dies and tools.

For example:
Designing two flanges to close to each other will not be possible to actually forge to shape, due to tooling capabilities and other technical metallurgical challenges.

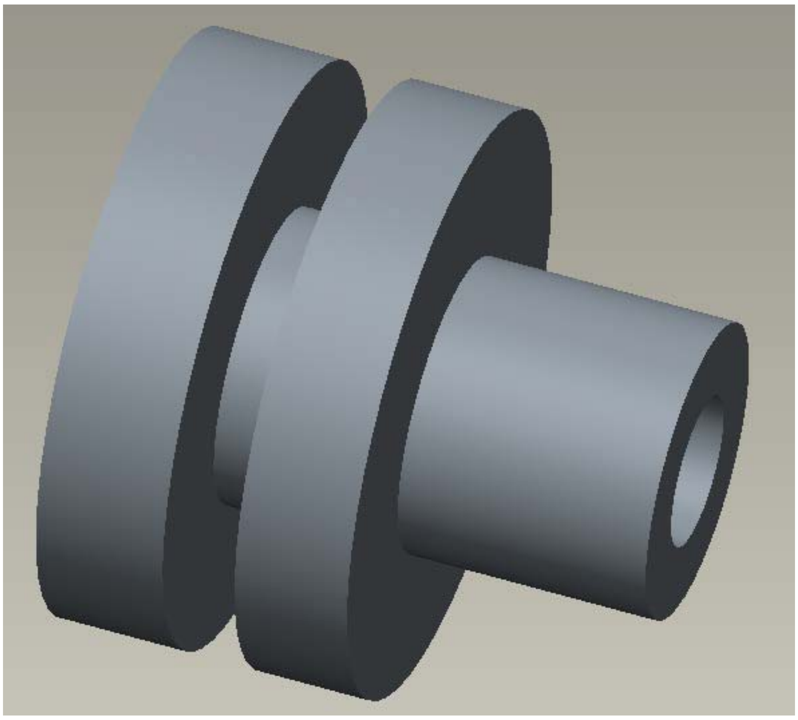

Figure 10, Example of forged flange connection

There are other challenges here as well. Sharp corners will also be impossible to achieve in the “as forged” state.

The typical “as forged” tolerance that can be achieved is typically +-5mm. There are multiple factors affecting this, such as Skill of the forgemaster, shrinkage of material, wear on dies etc. The shrinkage needs to be taken In consideration, and this depends a lot on experience, as the material will typically cool down from 1000ºC to 20ºC. The typical shrinkage for low alloy steel after forging is 4% from forging temp.

The width of the die used on typical riser components is about 400mm wide. It can be used smaller dies as well, but they need to be at least as wide as the radius of the material forged on. This is necessary to achieve good properties through the material.

This means; The distance between two flanges can be forged out directly “near net shape” if they have a distance of minimum 500mm, or for smaller components, they can be the radius of the material + 100mm of extra distance.

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Forging non-concentric parts is a challenge, and is therefore most often avoided. The part will most likely be forged as a bar that meets both geometrical requirements, and then machine out the eccentric flange or feature.

When machining a non-concentric feature, the suppliers very often need to mill this. This chip removal process is a lot slower than for example turning.

Figure 11, Forge and manipulator with workpiece

Figure 11 shows the forging tools (also referred to as dies), and you can easily see what kind of limitations these bring to the process.

4.2 Challenges and limitations to the quenching process

The distortion of the material is definitely a challenge, and might have a big impact to what kind of geometries the suppliers can deliver. We need to understand what kind of tolerances and dimensions that is achievable after quenching without machining.

If we are going to make a short riser component, it is no problem to drill a hole in it, which is smaller than the finished diameter. After quenching we can machine it from 2 sides, and still achieve the tolerances quite easy.

For the longer components, we want the hole to be as straight as possible when finished. It is most often preferred to do the drilling of the hole after quenching, because you only want to drill it once, and it is very challenging to machine a hole that has a depth to dia. ratio of more than 10.

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The difference is possible added machining time, and setups.

4.3 Why this should be considered during the design phase

If FMC designs a part with a finished geometry, and a raw material drawing level with a forging drawing, this could have a great impact on the price.

One of the reasons for this is that geometries that are not possible to forge to shape, needs to machined. And this is very often a very expensive way of forming materials. The closer the supplier can forge something to delivered geometry, the more time you will save in machining.

If we can find out what kind of tolerances the forging suppliers can achieve, and to what degree they machine them, and what kind of cost impact added stock might have at our machining suppliers, we might be able to find a good solution to how we design our raw materials.

5.0 Raw material drawing optimization

By taking the raw material process possibilities and limitations in consideration, we can save a considerable amount of cost on the raw material procurement price, and hopefully some on the lead time as well. (Ref. requirement specification)

5.1 Designing raw material drawings

First, we need to identify what information the designer needs to be able to design a **good** raw material drawing. This of course depends on the level of details the designer is going to make. If FMC makes these drawings, some of these levels might be challenging, if not impossible to make.

Assumed information needed:

- Finished geometry of the part after machining
- Material requirements
    - Forging ratio
    - Test speciment location
- How detailed the forging process should be specified
- Testing requirements
    - Sacrificial
    - Prolongation
- Machining consideration regarding geometry
- Forging limitations in regards to minimizing the amount of secondary operations

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5.2 Inspection of forged components

The components that are forged needs to comply with some sort of geometrical requirements. This means the geometry needs to be predictable from a manufacturer's point of view. Are the diameters concentric? Are the flanges perpendicular to the center line of the part? An angular misalignment might have a big impact on a component that is typically over 1200mm long.

Any non-compliance to the expected geometry will have an impact on the cost of the manufacturing. The additional cost will typically result in a VOR.

The reason for this could be many, a couple of examples:

- The amount of stock material might be more than expected, which means more machining time to achieve the finished geometry
- When taking concentricity and perpendicularity in consideration, the manufacturer might have too little stock, and will spend a lot of time fixing the part in the machine, to be able to achieve as close to finished geometry as possible.
- Additional tools might be needed because of the length / diameter ratio.

Per now we don't know how these things are secured in the process. FMC does approve the forging drawings from the supplier of the forged material. This is a requirement according to etc. SPC60089863 - section 8.1.

FMC does not have any good procedures to how they approve the raw material drawings from suppliers.

6.0 Approach to optimizing the raw material drawings

We need to define what the Pro's and Con's will be for FMC creating these drawings, in comparison with FMC's sub suppliers.

We need to define how much time FMC would spend on this compared to the suppliers.

How much time does the supplier spend to make these drawings, and how does it affect cost / lead time?

If FMC makes the raw material drawings for the suppliers, what information is needed, and what will the suppliers do with this information? If the raw material drawing has flaws in regards to the forging or manufacturing process, will this produce a lot of concession requests, which will increase cost in the long run?

To be able to answer some of these questions, we need to do thorough interviews of the suppliers, and relevant personnel within FMC. We then need to compare our findings with our theoretical findings/conclusions from literature and teachers within this subject.

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First of all, we need to confirm/check our assumptions regarding what information is needed in order to design good quality raw material drawings for forged components.

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Testing of raw materials

Rev	ECN No.	Date	Reviewed By	Approved By	Status
B	N/A	24.05.2014	Morten Mikalsen and Nils Olav huseby	Erlend Lindhartsen	Released

Summary:

This document contains information about applicable tests of raw materials for FMC technologies, such as nondestructive and destructive tests. The meaning of this document is to get a better understanding on how prolongations and sacrificial parts are tested, to determine mechanical and chemical properties. This document will address and discuss the processes related to each test of raw materials that are applicable for FMC, and potential problems related to testing.

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1.0 List of Figures

2.0 List of tables

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Abbreviations and definitions

Abbreviation / definitions	Description
NDT	None destructive testing
QTC	Qualification test coupon
DWG	Drawings – in example: technical drawing of a riser part or raw material drawing
CR	Concession request or change request in drawings
QN	Quality notifications in drawings
T	Thickness in material
ID	Inner diameter
OD	Outer diameter
PO	Order
MPI	Magnetic particle inspection
PO	Purchase order
MPI	Magnetic particle inspection
FBH	Flat bottom hole
KSI	Kilo pounds per square inch
UT	Ultrasonic testing
ISO	International Standards Organization
P	Load in Newton [N]
HB	Hardness
HR	Hardness number
L	Diagonal length of a diamond indenter

Table 1, Abbreviations and definitions

Reference documents

Document name	Description
Q01209 Rev M	Batch qualification testing
FMC 513-3: 2013-12-09	Scan plan for Pin End and Box End. Project: Wheatstone
TR2382-version 2 final: 2013-03-12	Requirement specification from Statoil
ISO13628-7:2006	Design and operation of subsea production systems
SPC60089663	Material specification for F22 steel
Q00360	Design Guideline for raw materials
Web References	**Description**
http://www.hardnesstesters.com/Applications/Rockwell-Hardness-Testing.aspx	Article on Rockwell hardness testing
http://www.ndt-ed.org/EducationResources/CommunityCollege/Materials/Mechanical/ImpactToughness.htm	Article on Impact Toughness
Books	
Serope Kalpakjan and Stephan R. Schmid, *“Manufacturing Engineering and Technology”, textbook for mechanical engineering students about engineering materials and manufacturing techniques, 2009*	

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Table 2, Reference documents

3.0 Document History

	Description	Date	Sign
00	Created document	19.03	EL
01	• Added item 2.7: Assumptions and theoretical approach to testing • Added item in 2.7: Sources	04.04	EL
A	Released document	04.04	EL
02	• Rewrote and improved text in Ultrasonic Testing • Added text in item 2.8: Challenges and limitations to testing • Added item in 2.9: Sources	10.04	EL
03	Improved content I item 2.8	15.04	EL
04	• Updated table of contents • Improved and rewrote most content in item 3.7: Challenges and limitations to testing • Added abbrivations in abbrivations and definitions	29.04	EL
05	• Added illustration of QTC with test specimens • Added illustration of prolongation • Improved content in item 3.5, 3.6 and 3.7 • Improved content in item 3.3 (ultrasonic testing) • Added figure in ultrasonic testing • Added book and web references • Added abbreviations	23.05	EL
B	Released Document	25.05	EL

Table 3, Document History

3.1 Theoretical approach to the testing process

3.2 Destructive testing

Destructive testing consists of testing a material and finding its limits. The part, which is tested such as sacrificial parts or any prolongations of a raw material, is tested until it breaks. Documentation of measurable parameters, such as Force and Energy is necessary for further analysis. Test methods regarded as destructive tests usually does not preserve material integrity, such as shape and surface characteristics. Destructive testing is considered as mechanical testing.

Tensile test

The tensile test is a common method for determining mechanical properties of materials, such as strength, ductility, toughness, elastic modulus and strain hardening capability. The test itself is dependent of prolongations- or sacrificial parts. Prolongations- and sacrificial parts are both abbreviated as QTC. The QTC's are stored or scraped after testing. Test probes are machined out of QTC's. A computer logs the

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necessary force needed for maintaining constant speed, and a machine pulls the test specimen to fracture. Elongation is thereby measured.

Figure 1, a typical stress-strain curve observed from a tension test:

$$\sigma = \frac{P}{A_0}$$

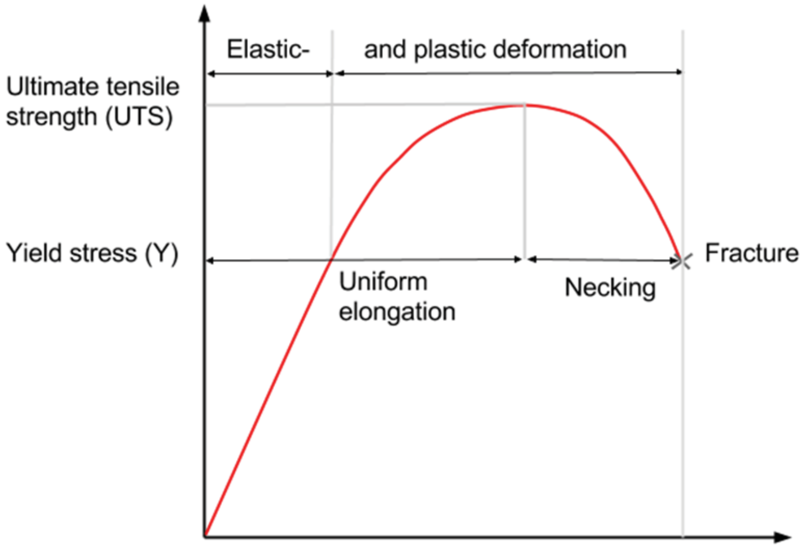

Figure 1

$$e = \frac{l - l_0}{l_0}$$

The definition of engineering stress, σ (nominal stress) is the ratio between force (P) and the cross-section(A_0).

CVN impact testing

Impact toughness is usually determined with a Charpy test. The Charpy test breaks the metal with a single blow with a pendulum. The impact toughness of the metal is determined by the energy absorbed by the test specimen. Dropping the pendulum from a fixed height, and measuring the height at the end of the pendulum-swing, makes it possible to determine the amount of energy absorbed in the test specimen. The energy absorbed is given by potential energy before subtracted with potential energy after.

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Figure 2, illustration of a Charpy test:

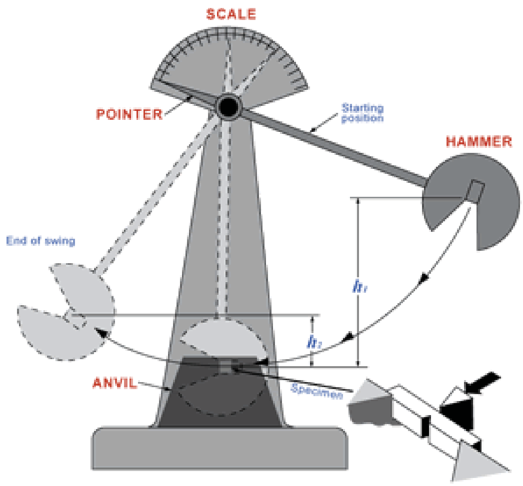

Figure 2

Metallographic sample (testing)

Metallographic testing is the study of materials. This test mainly involves examining a material with a microscope. Parameters such as grain size, grain flow and mechanical properties are measured with an operator using a microscope. Alloys can also be identified by observing the material with a microscope.

It's necessary to etch and polish the surfaces that require observing. Etching the top layer reveals the structure of the material.

3.3 Hardness testing

Hardness indicates general strength of the material and resistance to surface penetration. There are several ways to determine hardness in materials. The most commonly used are Brinell, Rockwell and Vickers.

Brinell test

The Brinell test uses a 10-mm steel or tungsten carbide ball under heavy load (P) against the part being tested. The load may vary from 500 kg to 3000 kg. The ball makes a measurable imprint in the material, and hardness (HB) is possible to determine. Testing hardness with Brinell is often not considered as a destructive test.

Rockwell test

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The Rockwell test is also used for testing hardness testing. The Rockwell method measures the permanent indentation produced by a load (P) with a diamond indenter. The test consists of two different sets of loads. The first load breaks any surface finishes and represents the zero or reference position that breaks through the surface of the material. After the preload, an additional load with higher load (P) is applied. This load is held for a predetermined amount of time (dwell time) to allow for elastic recovery. The major load is released, and final position of the indenter gives a position for measuring with the reference point from the initial load. The distance is converted to a hardness number (HR).

Vickers

The Vickers test loads a material with a pyramid shaped diamond indenter. The load typically ranges from 1kg –120kg and the diagonal (L) of the imprinter is usually less than 0.5 mm. This test is best suited for testing where mechanical properties in materials vary, in example welds. Essentially, the Vickers test gives the same hardness number independent of L, since a larger imprinter needs a higher load which results the same pressure.

Figure 3, illustration of the pyramid shaped diamond indenter:

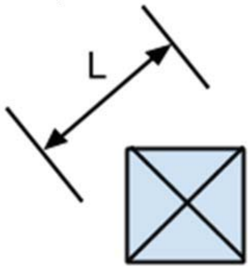

Figure 3

3.4 NDT – None destructive testing

NDT is a way of testing a material, without having to scrap it. All of the mechanical properties shall be intact after testing. NDT is usually not considered as mechanical testing.

MPI - Magnetic – particle Inspection

This technique is based on placing a magnetic metal powder on a surface of material. The test part becomes magnetic, and the magnetic powder gathers around any defects on the surface, because a bigger surface area attracts more powder, due to a larger magnetic field. The metal powder will find any small cracks, due to flux leakage and defects will become visible. According to ISO13628-7:

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- MPI shall be performed on the entire surface (inner, outer and ends/end bevels to the extent possible) on all accessible surfaces after final heat treatment and machining.

Ultrasonic testing

The idea of ultrasonic testing is based on sending out an ultrasonic beam on top of the test specimen surface, measuring wall thickness along the test path with acoustics. Volumetric irregularities are captured and visible for the operator. An additional machining Allowance of 7mm necessary to perform UT, since the first layer of the surface is not visible to the apparatus. All surfaces needs to be straight, and both tapers and radiuses need to be removed, in order to perform UT without blind zones.

Figure 4, Illustration of potential blind-zones:

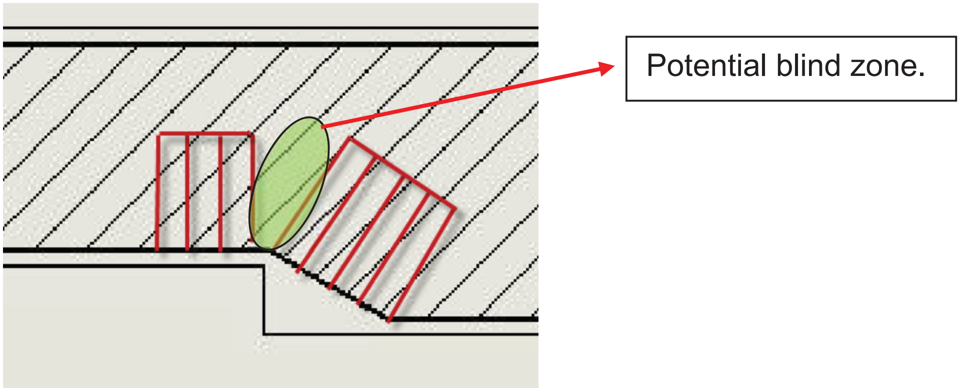

Figure 4

Any unnecessary machining allowance and UT-geometry is machined away later on, for final geometry. Any cracks or irregularities/defects interrupts the beam and reflect it back to its origin. The amplitude of the energy is reflected back, and the time required for the beam to return, indicates where flaws and defects may be located.

The forging shall be rough machined to a shape not limiting possibilities for ultrasonic examination. All of the surfaces have to be good enough to perform a reliable examination, and free for dirt etc. The final examination with ultrasonic testing shall be carried out after the test specimen is rough machined and heat treated, and surface finish shall be 6,3μm or better.

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Figure 5, Illustration of different surface finishes:

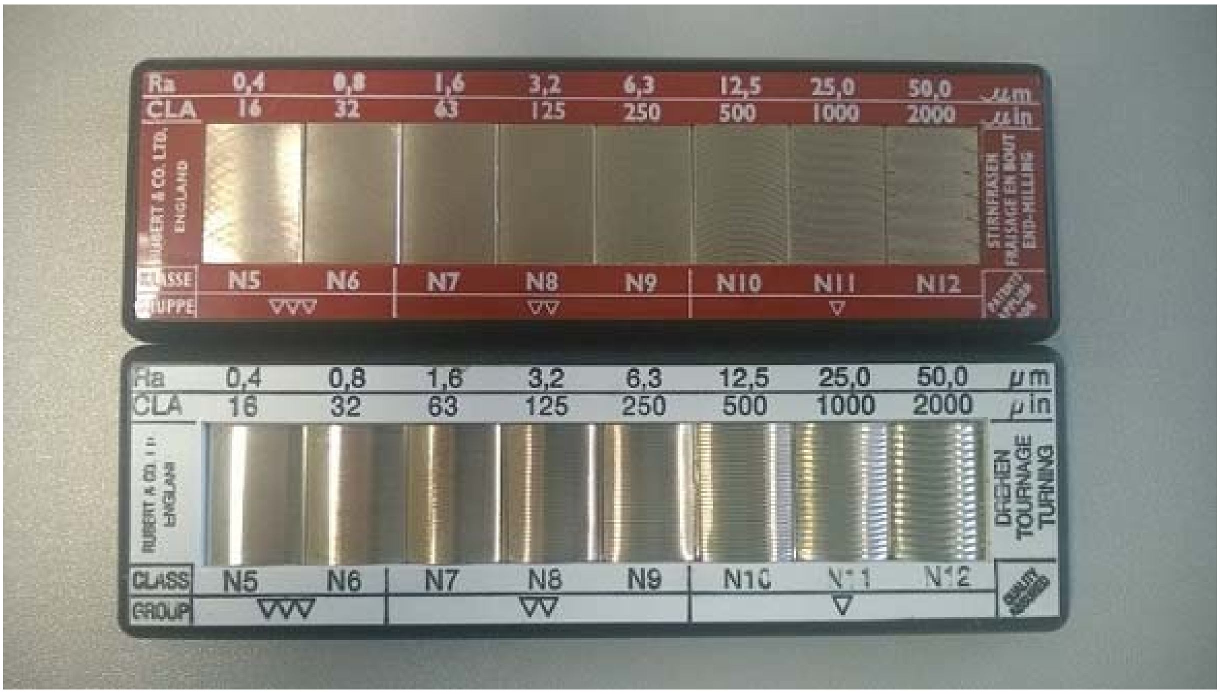

Figure 5

3.5 Qualification test coupon (QTC)

Qualification test coupon is a prolongation of a raw material or a sacrificial part which is being used for testing. The QTC shall be melted, forged and heat treated along with the material it qualifies and represents the thermal history and mechanical properties of the material. It's only necessary to have one QTC per heat.

Batch qualification testing

Tensile/tension and impact test specimens shall be removed from the raw material, so that the entire test specimen is T/4 (T=thickness) from any heat treated surface. This means that test specimens are machined out from QTC's or sacrificial parts.

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Figure 6, Examples of T/4 Specimen Removal from Simple Shapes for charpy- and tensile tests:

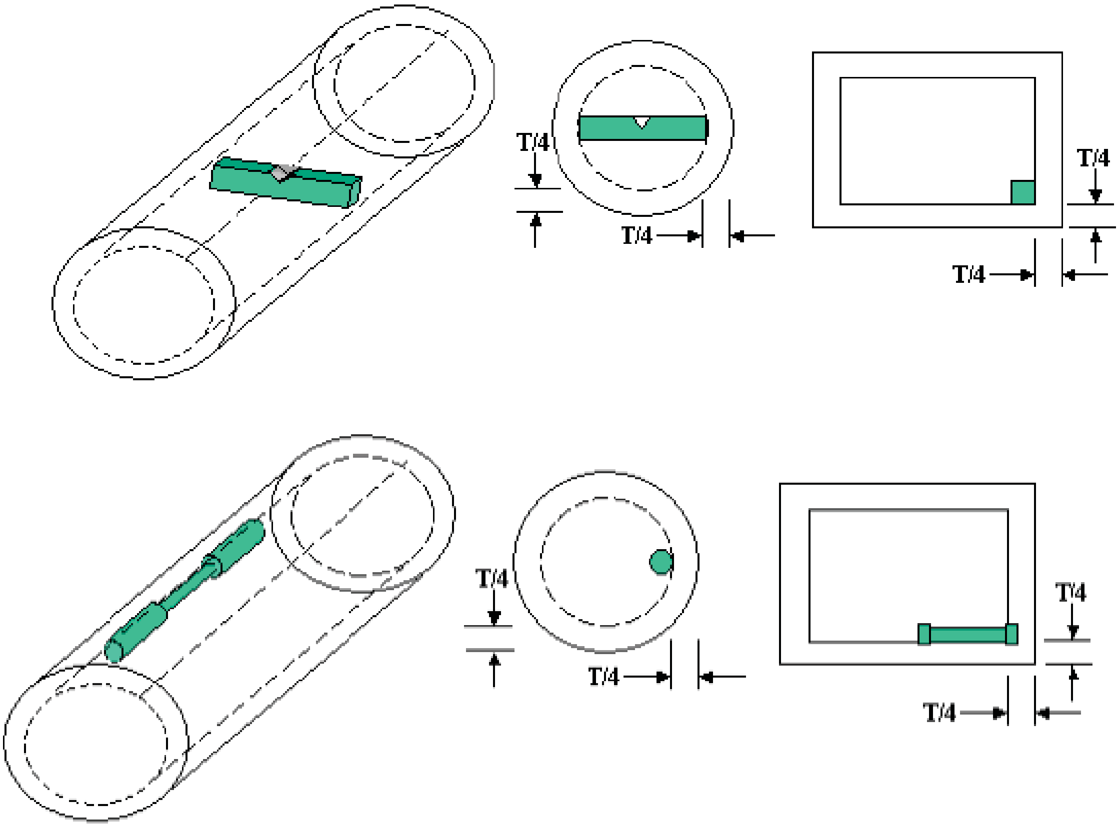

Figure 6

3.6 Why prolongations and sacrificial parts are being used (QTC)

It's necessary for the testing process to have a part for testing for each heat. This part is also known as a QTC and represent mechanical- and chemical properties for the rest of the batch. This part is usually a prolongation- or a sacrificial part made of a desired alloy which is the same as the rest of the batch. Prolongations are forged as an extension of the material, and sawed off after heat treatment for testing. Sacrificial parts are made independently of parts that are actually being used, but they will still needs to have the same form and shape, and represent mechanical and chemical properties. Sacrificial parts are only allowed to use if the test requires a size or geometry that is limited by a prolongation. This may be ring parts where it is not appropriate to use the prolongations, when the length ratio between prolongations and ring becomes too large. QTC is an efficient way to increase production, since this part is a representative of mechanical- and chemical properties for the whole batch. It's only necessary to have one prolongation and sacrificial part per heat treatment. The thickness of prolongations is

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defined as the largest inscribed sphere, or a representation of the heaviest load of the forged component. The length of the prolongation is defined as:

- Allowance for cutting + length of the test specimen + thermal Buffer.

The length of the thermal Buffer may vary between T/2, T/4 and 100mm depending on customer requirements and specifications.

Figure 7, illustration of prolongation:

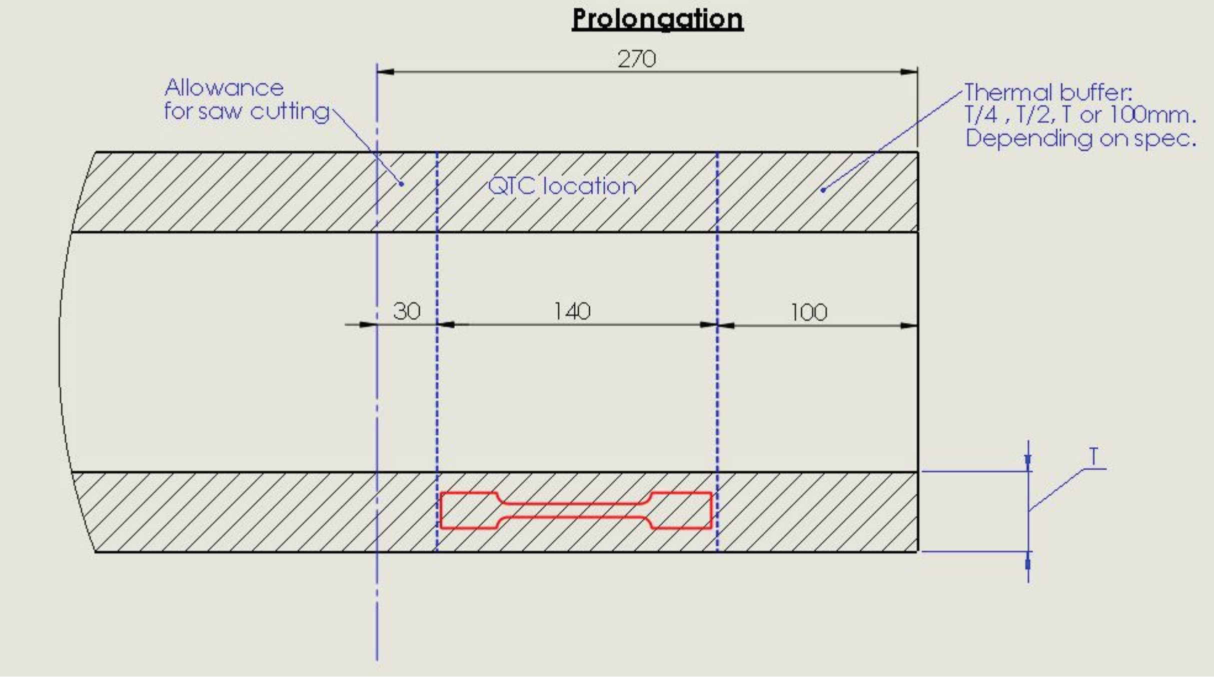

Figure 7

3.7 Assumptions and theoretical approach to testing

It's essential for prolongations in raw material drawings to have all of the necessary geometry and tolerances. Test specimens are machined out of prolongations in longitudinal- and transverse directions and have stringent requirements for placement. Test specimens acts as representatives for mechanical properties.

It's necessary to do a hardness test before the material can be qualified for further testing. The Brinell test is not considered as a destructive test, and is usually best suited for initial testing. The Brinell tests get taken where the material is thickest, along the prolongation surface. This is to cover the poorest mechanical properties of materials. Test points for testing are placed $8mm * 45^{\circ}$ apart. After the part is qualified for testing it's sawed off, for further testing.

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Figure 8, illustration Prolongation QTC:

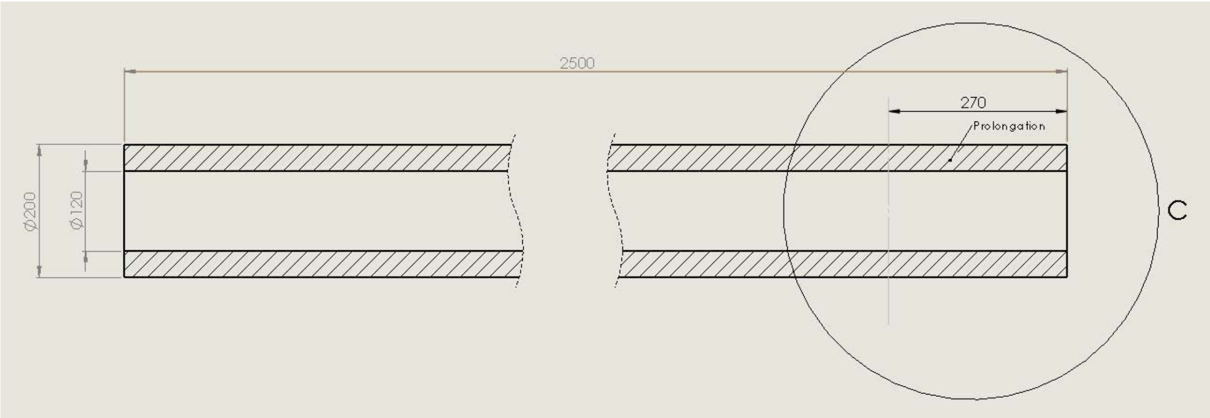

Figure 8

Next step in the process is to machine out test specimens for Vickers-, Charpy and Tensile testing in longitudinal- and transverse directions. It can vary if test specimens get taken out T/2 or T/4 from a heat treated surface, depending on customer requirements and thickness of final geometry. Test specimens represent material properties for the rest of the material, which means that the drawing has to be defined good enough to conserve geometry and tolerances.

3.8 Challenges and limitations to the testing process

Material testing shall be conducted after final heat treatment. The locations of test specimens varies if the raw material is heat treated as solid or pre-bored. All testing, both mechanical and NDT shall be made by a laboratory and in accordance to ASTMA370 and ISO 13628-7.

Figure 9, typical locations of test specimens are shown in figure 9:

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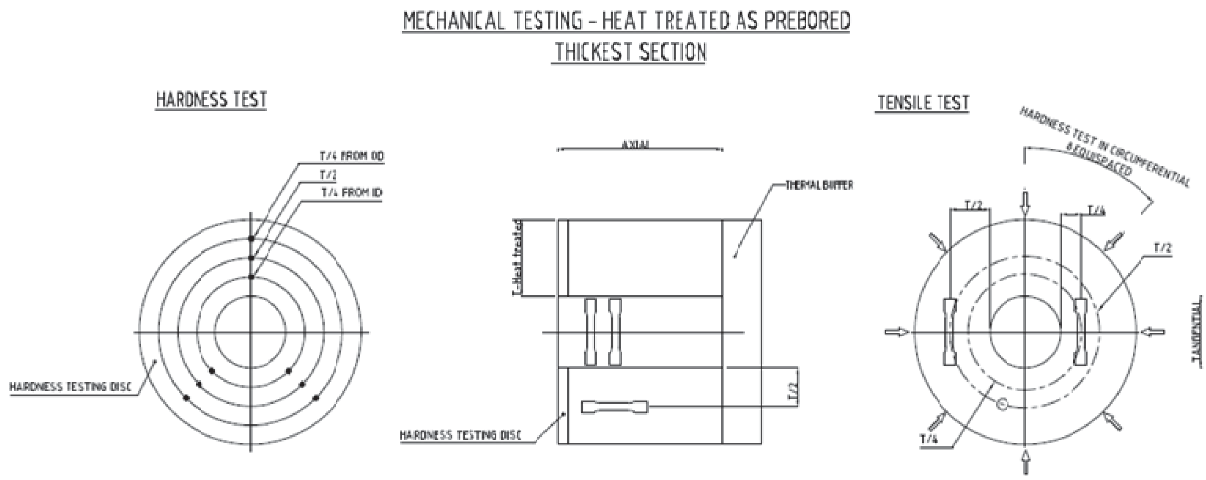

Figure 9

The Same principles shall be followed for extraction and location of test specimens in sacrificial forgings.

All mechanical testing shall be performed respectively in accordance to ISO1368-7:

- Hardness: T/4 from OD, T/2 and T/4 from ID if heat treated as pre bored
- Tensile: T/2 and T/4 from ID if heat treated as pre bored
- T/4 from OD, T/2, T/4 from ID and ID+2mm if heat treated as solid
- Tfinal/2 and ID+2mm if heat treated as solid

Problems represents them self when final geometry of the part is unknown, due to placement of test specimens. Extractions of test specimens are somewhat dependent of final geometry of the part, since thickness T has to be defined in order to extract test specimens from the right area. If specimens are off tolerances, a concession request has to be made. This cost money and delays the order. Inner diameter, ID and outer diameter, OD has to be known, before any material testing can be conducted. Sub-suppliers of FMC are dependent of this information to make process drawings for manufacturing. Other companies than FMC may have a more practical view on placement of test specimens.

We have found two different variations of placement of test specimens. Both variations are practical and conservative in regards of the testing process. According to sub-suppliers we've interviewed, placements of test specimens located T/2 (heat treated as pre-bored) or ID+2mm and T/2 (heat treated as solid) are more than enough to cover all of the necessary mechanical properties representing the material in the most conservative way. Both variations of placement might save a considerable amount of delivery time and money.

This means that QTC's have to have a lot of test locations, in order to fulfill all of the requirements in accordance to ISO1368-7. Multiple prolongations or sacrificial parts may be used to avoid overlapping of test specimens and cover what one prolongation can't, like geometry limitations etc. Prolongations may also not have enough material for

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all of the necessary test specimens within the batch, leading to sacrificial parts being used instead or both sacrificial and prolongations are used in the same batch

Some people in the business would say the requirements related to testing are not conservative and practical, especially considering the number of tests and locations. Testing in multiple areas may not be as considerate in the manufacturing process of raw materials.

Mechanical properties are genuinely poorest in:

- ID+2mm and T/2 if heat treated as solid
- 0.5T if heat treated as pre bored

Testing in ID+2mm and 0,5T should cover properties for the whole material, and at the same time be more conservative and less time consuming.

A problem is apparent when the part is drilled before quenching. Sub-suppliers manufacturing Riser components for FMC are using different methods to achieve the specified requirements from customers (i.e. Statoil and FMC). Transporting extremely hot parts from heat to quenching requires caution and time. Handling heavy parts with a bored center are a big challenge, since distortion is an increased risk. Bored center in pipes might also be necessary for large parts, to account for cooling in quenching tanks. This is necessary to get the desired mechanical properties after heat treatment. T and strength in the material are both decreased in this process, making transportation between furnace and quenching difficult.
According to SPC60089863:

- Transfer time between furnace and quenching shall not exceed 90 seconds, unless otherwise qualified by manufacturers.

A concession request has to be made every time because of this requirement, since the manufacturing process often fails to maintain the 90 second time limit. A solution would be to make the time limit on transferring from heat longer, or re-facilitate the steelworks to include better transfer time between furnace and quenching. The consequence of a longer transport time is often negligible, because the temperature in steel stays relatively unchanged in the extra short residence in air it takes to transfer. Supplier C claims that the change in mechanical properties doesn’t bear any practical meaning. With a typical transfer time from the furnace farthest away from quenching, gives a yield strength just under 80 KSI, where 80 KSI is the minimum yield strength in accordance to SPC60089863 for F22 steel.

Testing in accordance to ISO 13628-7 may require up to 24 different calibration blocks for UT for parts with a taper on finished geometry. The most expensive one may cost up to 50000 kr. to manufacture. The amount of calibration blocks can be reduced considerably, according to sub-suppliers we’ve interviewed.

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Reference standards shall be used for calibration and sensitivity settings. Flat bottom holes are used for adjusting how wide irregularities and flaws can be. In these standards, flat bottom holes in calibration blocks shall be:

- Ø1,6mm for T up 38mm
- Ø3,2mm for T from 38mm to 152mm
- Ø6,35mm for T exceeding 152mm

The smallest UT block (i.e. Ø1,6mm) will always have the highest requirement for irregularities and flaws, since this hole is smaller and will only tolerate tinier irregularities and flaws trough the material. Because of this it's natural to think that tapered parts can be tested with fewer calibration blocks, since calibrations blocks with smaller holes also cover irregularities for larger FBH. Using less calibration blocks will make testing of conic tension joints cheaper.

Figure 10, illustration of conic tension joint with UT geometry, and defined prolongation diameter with covered area for each calibration block:

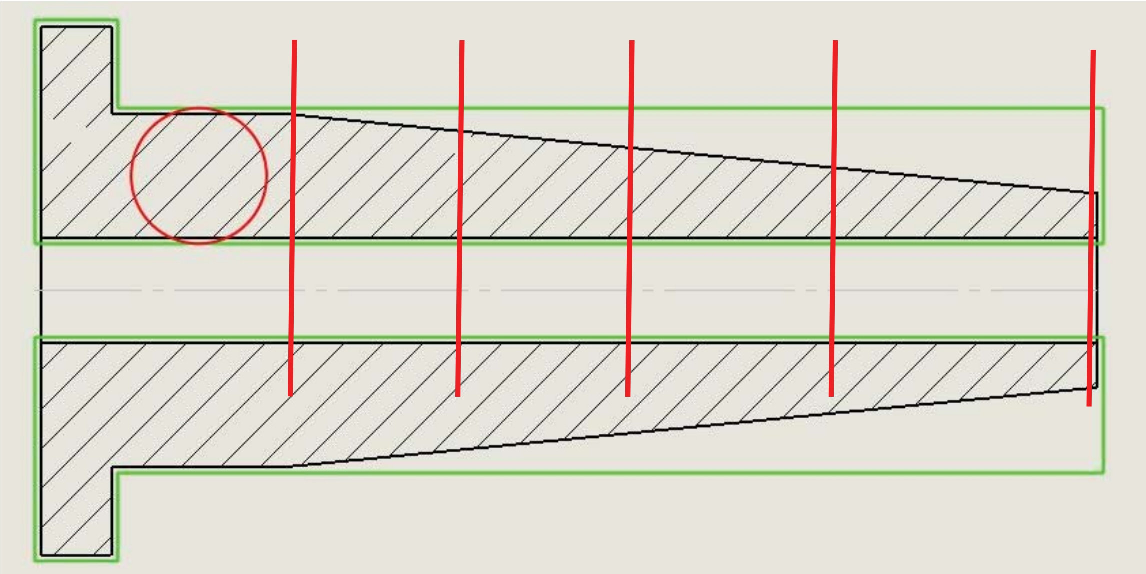

Figure 10

Same as with conical parts, eccentric parts is equally challenging to test. Eccentric parts may also require the same amount of calibration blocks to get an adequate test according to ISO1368-7. Since eccentric parts have variable thickness, calibration blocks may have to follow the same eccentric pattern to cover the difference in acceptance criteria. Therefore, same as with conic parts, smaller calibration blocks will have a larger coverage area for defects and less acceptance criteria. Therefore, smaller calibration blocks with smaller FBH will be more efficient and conservative towards the testing process.

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Mechanical processing of raw materials

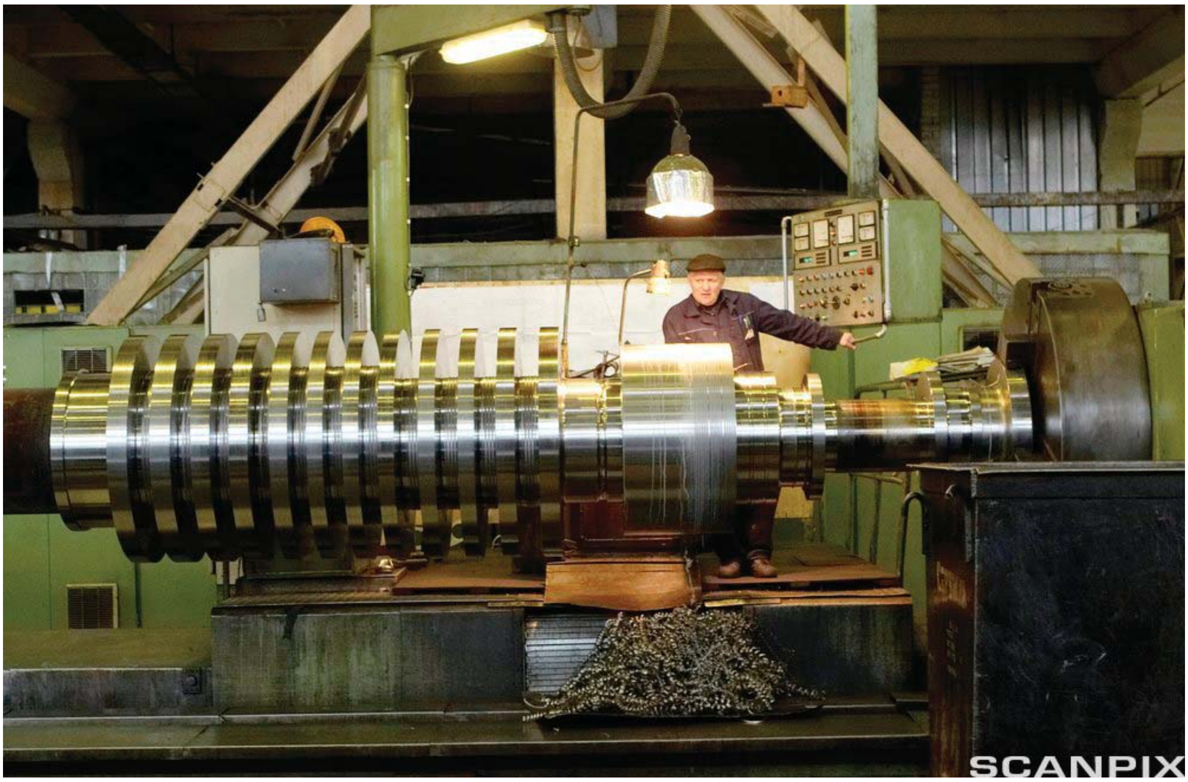

Figure 1 industrial turning

Rev	ECN No.	Date	Reviewed By	Approved By	Status
A	N/A	25.04.2014	Erlend Lindhartsen	Morten Mikalsen	Released

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Summary:

This document provides a description of the machining processes for raw materials when it is produced and tested. The scope is therefore outside the mandate of the group, and has been commissioned to an investigation.

Raw material drawings are dependent on finished geometry and all the processes related to raw materials, to avoid cost overruns and delays in the delivery of raw materials.

A central part of the investigation will describe how to safeguard the interests of all stakeholders, so that the goal of eliminating all quality notifications QN can be reached.

This document is meant to secure all of the machining interests in the process of raw material production. The descriptions will not describe cutting techniques, material composition, chemistry, or other specific metallurgy process details.

The aim is to bring out and highlight the needs in terms of material removal and material adding, and other grants material required for tensioning, testing and other physical requirements that can cause problems if they are not sufficiently taken into account during production of the raw materials drawings.

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1.0 List of Figures

2.0 List of tables

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Abbreviations and definitions

Abbreviation / definitions	Description
QN	Quality notification
UT	Ultrasonic testing
WAS	FMC department: Well Access Systems

Table 1, Abbreviations and definitions

Reference documents

Document name	Description
ISO13628-7:2006	Design and operation of subsea production systems
Books	
Serope Kalpakjan and Stephan R. Schmid, *“Manufacturing Engineering and Technology”, textbook for mechanical engineering students about engineering materials and manufacturing techniques, 2009*	

Table 2, Reference documents

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Basics of mechanical process

3.0 Scope

This document is developed to illuminate all of the processes from the early stages of raw material production, until the finished component has been tested and assembled into the main system, and ready for shipping.

4.0 Document History

Revision	Description	Date	Sign
00	Created document	20.04	MM
01	Revision 01	05.05	MM
02	Revision 02	10.05	MM
03	Revision 03	15.05	MM
A	Released document	25.05	MM

Table 3, Document History

4.1 Theoretical approach to the mechanical working process.

The Mechanical working process does essentially add or remove materials. Adding material can also change the geometry by extrusion, compression and bending. The most relevant processes in this thesis will essentially be adding and removal of material, and adding material consists of welding.

When it comes to adding material on components, a layer of filler material will be welded on to the structure of the raw material, which has excessive requirements, especially in the machining process to get satisfactory results. Powder metallurgy and welding is normally used if surface on base material doesn't have satisfactory quality.

The size of the material is essential when welding is considered, due to high generation of heat in the area around the weld. Considering the size of the material has to be taken into account when the raw material is made. Changes in geometry and partly deformation with subsequent need to align may be the consequence if sizing of material is not included in the planning process before drawing.

Welding machines are normally used in the process of adding material. In some cases, welding machines are not appropriate for mounting components, where serial production is considered difficult or not productive. In those cases, manually welds will be applied. Then it's sufficiently with a stable table and some solid lifting mechanisms to ensure a satisfactory result.

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Welding machines and the welded material, needs solid clamping, due to displacement of the welding machine so adding material in repetitions can be done without reprogramming the machines.

4.2 Why this should be considered during the design phase

Because of the different methods for machining, in this case the removal of material, a number of requirements has to be satisfied. Through a process to achieve the desired geometry, various forms of physical requirements will be needed. Tensioning will in most cases be done without making changes in base material, but in some case it’s needed. Where it is an obvious simplification in the raw material, changing simply geometry should be included in the process of making a raw material drawing.

Figure 2 **Mazak Integrex 200Y**

5.0 Raw material drawing optimization

An optimization of the drawings at this stage could result in significant cost savings. Delivery time, will not at this stage result in big delays, if the raw material is constructed in such a way that it not has to be scrapped.

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5.1 Designing raw material drawings

We can see for ourselves in the design phase, that an open dialogue between designers is beneficial to avoid unnecessary changes in drawings later. We know that an open dialogue works relatively well in other subject areas and in the same business. The communication between all of the stakeholders may not the best with sub suppliers from abroad. Not everyone master English in a satisfactory academic level. It will be important in this context to make clear procedures to ensure sub suppliers needs for communication. Our research and interviews will give input on this.

5.2 Inspection of mechanical working process

The machining companies we interviewed were clear in terms of the drawing policy. Raw material drawings from FMC are consistently re drawn, when they are presented to them.

Machining Industry designers are invited to participate throughout the planning and production process so that the finished drawings are optimized for all processes until finished geometry and testing. The biggest challenge they independently argue that gives the biggest challenges in terms of time, is bureaucracy. It takes in some cases up to six months and more before the publication of drawings may be approved and released. It means substantial delays before machining can be started, that’s not related to the suppliers. Sub suppliers claim that the processing time varies from who is responsible and that "normal" processing time should not exceed 12 to 14 weeks.

6.0 Approach to optimizing the raw material drawings

Our investigations so far have revealed different models on how to produce raw material drawings. These methods are based on how practice in this area has been, and in some case still is, and how we believe it can be implemented based on their own assumptions and information we have collected in all stages from forging to final product.

If the machining companies should do the job, it requires a considerable focus on the finished geometry before final drawings can be made. We talked with two suppliers of such services, and they are unanimous about the fact that they can make the most appropriate drawings in terms of delivery and cost.

7.0 What do we already know

After doing some internal research, we have gained the impression that it is a partially untapped potential in the use of internal dialogue between departments within the FMC to ensure top expertise in all project phases.

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There are differences in how each manufacturer solves the assigned tasks, resulting in varying challenges with the intention of checking that all suppliers meet the needs to move forward in the process towards the finished product.

We know that it usually is chosen suppliers that produce their own drawings regardless of FMC.

We have summarized the material we have received from a few suppliers of machining services, and on this basis, compared to what we found with similar studies from some raw material producers and FMC.

8.0 Supplier D

Supplier D will consistently produce drawings even on the basis of pre-geometry. They communicate even with raw material producers so that their demands are met. They do not want roughly shaped objects. It`s not possible for them to machine this. As we understand, they will have issues in semi-finished format, or at least in UT format and "as quenched". Heat-treated subjects should be blast clean before they are put into production.

Table 4, semi finished geometry

The drawings they make, where all processes added, based on a dotted version of finished geometry. This is something they do so they at any time could have control in all sub-processes to the finished product.

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A raw material ordering from this machining company will fulfill all their requirements in order to produce efficiently and without delay.

The biggest challenge is often "as quenched" parts in stock waiting for approved pre-geometry before machining can begin. In addition, there is a requirement to make UT shape for ultrasonic testing, despite raw material manufacturer has come with documentation of such testing.

Chip removal rates are not central to supplier D. They estimate machining time based on experience. Number of mechanical hours is their way of calculating the cost to remove excess material. This is a challenge as it often ordered cylindrical parts from forging manufacturers with relatively great need for machining.
We looked into the time spent on the number of kilograms material that must be removed

Turning:

Q	Chip removal rate
V_c	Cutting speed
A_p	Cut depth
F	Feed rate

Table 5, machining parameters

Example:

$$\mathrm{Q} = \frac{V_c \cdot A_p \cdot F \cdot 7{,}85}{1000} = \frac{200 \cdot 3 \cdot 0{,}3 \cdot 7{,}85}{1000} = 1{,}413\ \frac{\mathrm{Kg}}{\mathrm{min}}$$

Milling:

Q	Chip removal rate
V_c	Cutting speed
A_p	Cut depth
F_z	Feedrate per tooth
a_e	With of cut
Z_c	Number of teeths
D	Diameter of milling tool
n	Rev/min

Face milling

Table 6, machining parameters and figure of face milling

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$$Q = \frac{A_p \cdot a_e \cdot F_z \cdot (n = \frac{V_c \cdot 1000}{D\pi}) \cdot Z_c}{1000} = \frac{1 \cdot 40 \cdot 1 \cdot (\frac{200 \cdot 1000}{40 \cdot \pi}) \cdot 4}{1000} = 255 \frac{\mathrm{cm}^3}{\mathrm{min}}$$

$$\frac{255 \cdot 7{,}850}{1000} \approx 2 \frac{\mathrm{Kg}}{\mathrm{min}}$$

Based on this, one can calculate roughly what it will cost per kg to remove excess material. This is supplied to the machining operations to get an idea of the time consumption.

Figure 3 Finished geometry

9.0 Supplier C

There were fewer differences than what we expected after visiting both supplier C and supplier D in terms of what they thought were the biggest challenges in terms of process and production of drawings.

The main reason for time overruns is bureaucracy. They experience up to 36 weeks of waiting to get the latest version's drawing ready for manufacturing. They also have an estimated 12 to 14 weeks as reasonable and realistic time-consuming if standard routines could be implemented in a number of areas.

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Figure 4 Rough machining

Figure 5 “As Forged”

When it comes to roughing up the "semi finished" or "UT shape" is an in-house business. Rough machining will take place in very large machines where forgings are turned down to be preparation for heat treatment. Then it gets turned down to "UT shape" before going further to fine machining. Machining costs are calculated based on the time it takes to remove excess material. They operate with about 100 Kg/h which is the same numbers as supplier B in Italy. We (the bachelor group) are uncertain whether this is the number we can trust. To be conservative, we choose to believe this limit is rather 75 Kg/h.

.

Figure 6 Quenching

Riser component unit taken out of the oven before cooling. To avoid QN in this process, transfer time occur within a period of 90 seconds. Thermal process provides scaling. Many machining companies require sandblasting before machining.

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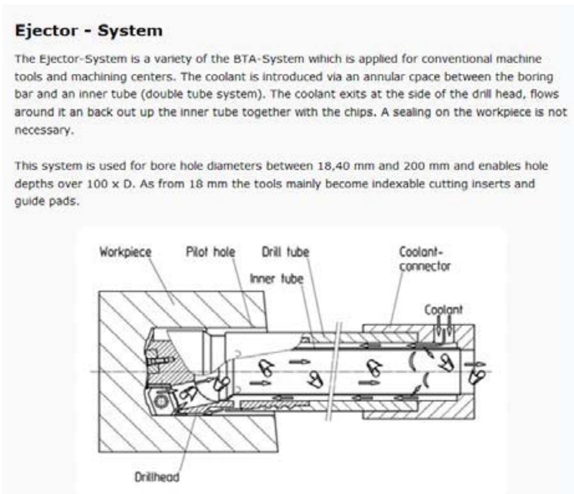
Figure 7 **UT shape**

Raw material in UT shape ready for machining.

Supplier C is an A to Z supplier of forged and machined components for the subsea industry. They have no capacity limitation in relation to the size of standard components. Supplier C has unlimited drilling capability from the standard requirements from FMC WAS and their needs.

Figure 8 Ejector drill



Ejector - System

The Ejector-System is a variety of the BTA-System which is applied for conventional machine tools and machining centers. The coolant is introduced via an annular cpace between the boring bar and an inner tube (double tube system). The coolant exits at the side of the drill head, flows around it an back out up the inner tube together with the chips. A sealing on the workpiece is not necessary.

This system is used for bore hole diameters between 18,40 mm and 200 mm and enables hole depths over 100 x D. As from 18 mm the tools mainly become indexable cutting inserts and guide pads.

Figure 9 Principle of ejector drill

10.0 FMC

Requirements from FMC in terms of raw material are used in the further processing work prior to finished product is governed by standards. These are mostly clear and unambiguous. It may be some areas where conclusions may seem somewhat "gray". A selected case is forging process where the term "forged two shape" is used. Standard ISO 13628-7 is so obscure in this area that the manufacturers is quit free to define what this means if the project owner is inaccurate in the description.

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There's no time to interview Statoil about this. They probably have many views on this subject.

We have learned that it usually is external designers who produce drawings. When finished geometry is not clear at this stage, the challenges to be solved gets more extensive. We got this information after a meeting with the project owner on April 30.

11.0 Summary

Conversations we have had with several people within the FMC tell us that there is no lack of technical expertise. What puzzles us is how obscure the process from raw material to finished plan drawing emerges when we see the whole process from the raw material to finished product in a total.

What we demand is perhaps a coordinating academic environment where FMC has a "hands on the wheel" during the whole manufacturing process from idea through to the finished component, tested and inserted into the main system. But without being controlled in such a way that the process becomes paralyzed.

Based on the material collected, it may look as if it is a set of common interests based on experiences among - and irrespective of raw material producers.

12.0 Preliminary conclusion

Machining companies we interviewed have relatively large differences in the way they approach the missions they are assigned. But they also have a number of common challenges. Our research shows that it may be possible to find solutions that work for everyone, if the client is on.

Machining technology will naturally be different in terms of the choice of method and type of equipment. It seems as if there is communication between the mechanical processes that provide the greatest challenges.

It also appears that most discrepancies applications due to ambiguity in how technology will solve a problem, when you know that there are alternative solutions that work well.

This demonstrates particularly well when we summarize real and expected time used in transition where machining companies take over the drawings for further processing.

In summary, one can say that there should be as few constraints as possible until semi finished geometry.

However, final geometry should be available as soon as possible if further delays will be avoided. It is primarily a question of time savings, as it turns out that the removal of excess material does not cause major cost increases.

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Our guideline has taken into account the information obtained and examined after we visited and interviewed some of FMC's suppliers.

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Geometrical tolerance requirements

Rev	ECN No.	Date	Reviewed By	Approved By	Status
A	N/A	20.05.2014	Erlend Lindhartsen	Nils Olav Huseby	Released

Summary:

This document will give a basic understanding about geometrical tolerances, and why this implicates the design of raw material drawings.

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Abbreviations and definitions

Abbreviation / definitions	Description
Manufacturing	Means the process of machining the part.
VOR	Variation order request
GPS	Geometrical Product Specifications
ID	Inner diameter
OD	Outer diameter
ISO	International Organization for Standardization

Table 1, Abbreviations and definitions

Reference documents

Document name	Description
ISO 8015:2011	Geometrical product specifications (GPS) – Fundamentals – Concept principles and rules
ISO 14405-1:2010	Geometrical product specifications (GPS – Dimensional tolerancing – Part 1: Linear sizes
ISO 2768-2:1989	General tolerances, Geometrical tolerances for features without individual tolerance indications
STD10086721 – Rev A	Classification of requirements on drawing
ISO 2692:2007	Geometrical Product Specification (GPS) – Geometrical tolerancing – Maximum material requirement (MMR), Least material requirement (LMR) and reciprocity requirement (RPR)
Books	
H. Nielsen, *"The ISO Geometrical Product Specification Handbook", ISO Danish Standards, 2012*	

Table 2, Reference documents

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Basics of Forging/Quenching

1.0 Scope

This document will give an understanding to why we need to consider Geometrical tolerances to secure enough stock material on forged raw materials.

The tolerances in this document are only for illustrational purposes, and are not meant as a guideline.

2.0 Document History

Revision	Description	Date	Sign
00	Created document	25.04.14	NOH
A	Document released	20.05.14	NOH

Table 3, Document History

3.0 Basic about dimensioning

There are 2 different ways of dimensioning parts.

1. You can use basic dimensions, and apply tolerances with GPS.

2. You can apply everything with linear dimensions, with tolerances

3.1 Geometrical tolerances

This is a way of describing the function of a part, with the tolerances. You describe the relationship between each and every feature with GPS.

It is in fact almost called a language, because of the way it describes the part.

Many people also believe that GPS will increase the cost of the part. This is not correct, as long as it is applied interpreted correctly. It does however, require a lot more competence from all the involved people.

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GPS contains a lot of principles. Such as: the independency principle, degrees of freedom etc. We will only go briefly into the principle of independency.

3.2 Principle of independency

ISO 8015 states that all dimensions needs to be fulfilled individually, and are not dependent on each other. This is called the principle of independency.

This means, if you just specify an ID and OD without any geometrical tolerances, they will not have any relation to each other at all, for example regarding coaxiality.

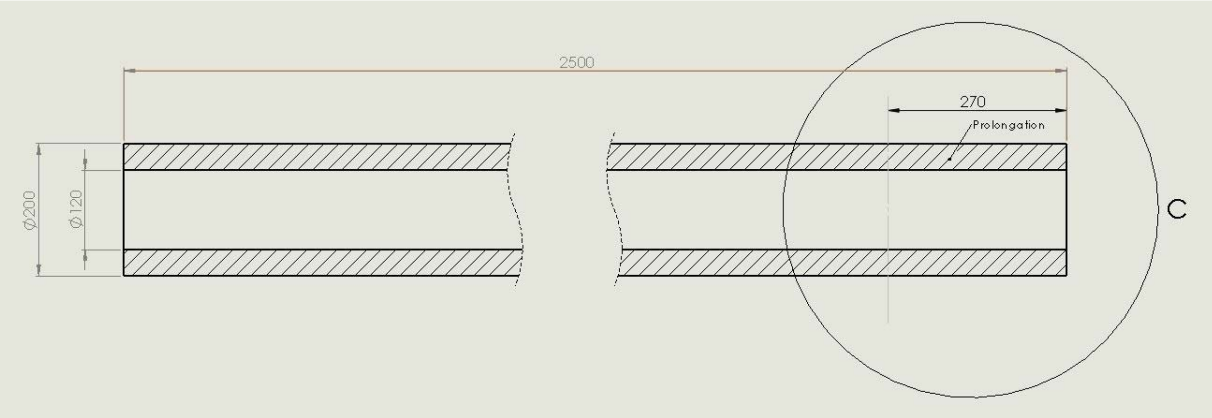

Figure 1, Plain pipe with OD / ID

This means, worst case scenario:

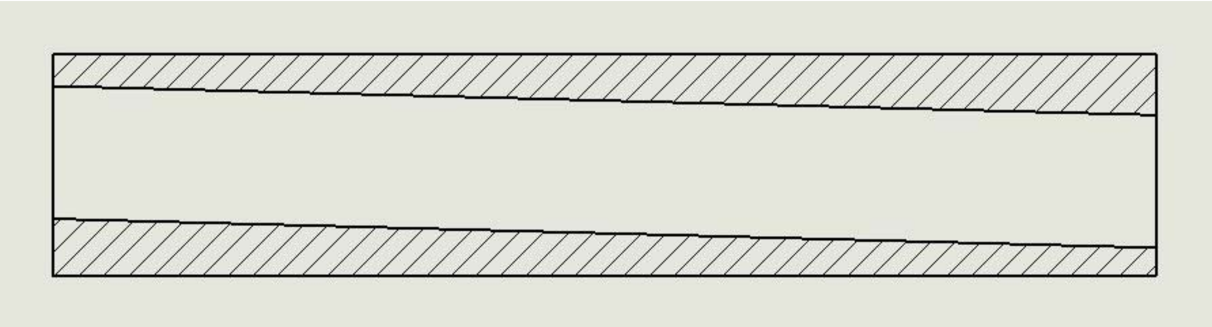

Figure 2, Pipe worst case scenario

3.3 Linear Dimensions

Dimensions given as just linear dimensions are considered as two point measurements.

ISO 14405 says that a linear dimension should fulfill the requirement in any given cross-section with a two point measurement.

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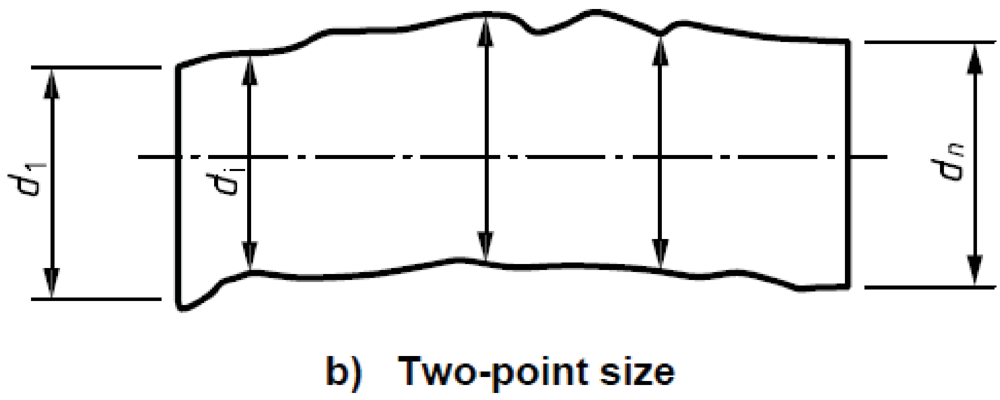

Figure 3, Two-point measurement

This means that a cylinder can be shaped like a banana, as long as we don't specify any geometrical requirements such as straightness or perpendicularity.

The two point measurements can also be an unclear specification in regards to how it should be measured.

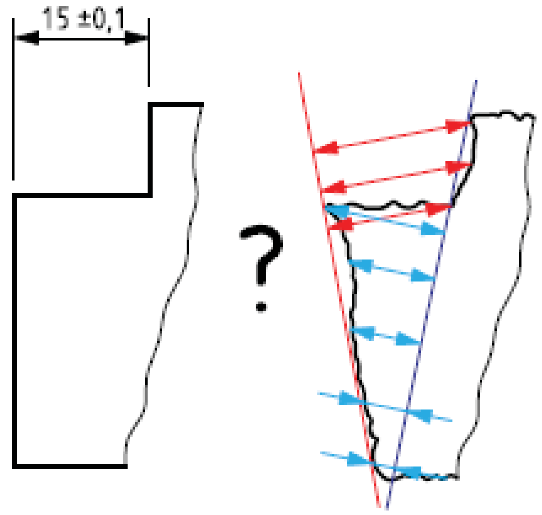

Figure 4, Measurement uncertainties

Figure 4 shows how linear dimensions have a big uncertainty to how they are measured.

4.0 Requirement criticality

This is something that should be considered, and used on all dimensions from the raw material drawing, that are identical on the finished part.

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Further information regarding these requirements can be found in FMC standard STD10086721. This is just a summary of this standard.

4.1 Classification of requirements

When FMC specifies requirements on the drawings, the suppliers also needs to measure them.

However, they are not required to send these results to FMC. This means that FMC needs to trust that our suppliers do the right thing.

By adding a requirement class to the dimension, the dimension now has a criticality definition.

There are 3 different classes:

Class 1: “Requirements shall be met in order to fulfill safety regulations; such as requirements concerning personal safety, statutory and official regulation.”

Class 2: “Requirement which means that deviation from the given requirements result in product non-function or renter further production impossible”

Class 3: “Requirement which means that deviation from the given requirements results in risk of disrupted product function or further production”

4.2 Documentation

When the classification is added to a dimension, we can now require documentation of it.

If we add a **D** to the classification, documentation is now compulsory. This means that the requirement verification record now needs to be supplied to FMC.

When we put both the classification and document requirement together, it will look like this on the drawing:

[3D]

By adding this to the finished dimensions that are on the raw material drawing, we can know for sure that the parts will not go from the raw material supplier with deviations that can be crucial to function.

On the surfaces that have 7mm extra stock material, this extra classification/documentations requirement should not be needed, unless it is critical. Etc. Material thickness on critical sections.

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5.0 Implementation of geometrical tolerances on raw material drawings

As described in previous sections, we can see that this is necessary, even though these are just raw materials, with bigger tolerances.

However, we have to be sure not to apply GPS the wrong way, as this will increase cost.

We can apply GPS in 2 different ways:

1. We can refer to ISO 2768-2, which is an ISO standard that covers general geometrical tolerances, that applies to all dimensions. This covers concentricity, perpendicularity, straightness etc., and it's all relative to the size of the dimensions. This means that the bigger the dimension is, the bigger the tolerance.

2. We can put individual GPS on each surface according to what we need. This requires more skill from the designer, but we will be able to specify the dimensions exactly according to what we need.

The challenge with geometrical tolerances is that they need to be measured. This means, if we apply a concentricity requirement between the inner and outer surface on a 10meter long part, it needs to measured according to the requirements. This can be a challenge.

This means that using method 1 (ISO 2768-2) on a long part can create implications. We should therefore avoid this, and use manual specifications on longer parts.

Method 1 is a very good solution on shorter parts. (Length < 1500mm)

On longer parts (Length > 1500mm), we should specify each requirement according to what we need.

In these cases, the bore is most likely specified as the finished dimension, with the finished tolerance. (Typically 5” or 7”, with a straightness of 0,5 / 300mm) This means that the bore should be the starting point for all other tolerances. (The main datum)

Does this mean we just put the main bore as datum A?

No, for longer components we should use the average of the ends as a fixing point, and let the straightness tolerance take care of the rest.

This means we use both datum A in one end, and datum B in the other end (in a limited length). See figure 5.

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To ensure the material thickness on this long pipe, we should specify this with a linear dimension, because this can be measured with Ultrasonic testing. This can be measured in a circumference on every meter for example.

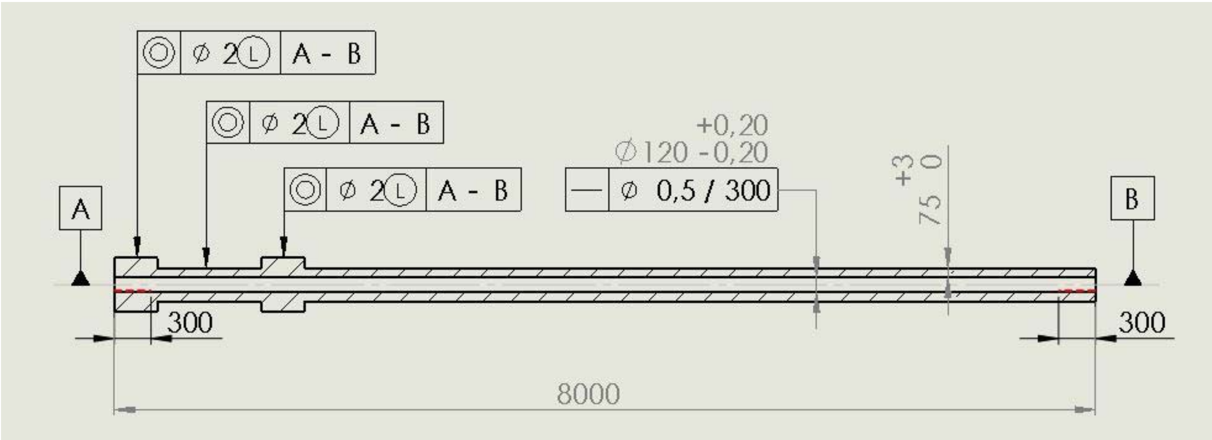

Figure 5, Example of GPS

On this example we have used two datums on one feature. Each of the datums are applied to a limited length of surface, to ease the measuring.

—	⌀ 0,5 / 300

This straightness tolerance secures the function of the main bore. This means that the center axis of the bore, needs to be within an imaginary cylinder of ø0,5mm, pr. 300mm.

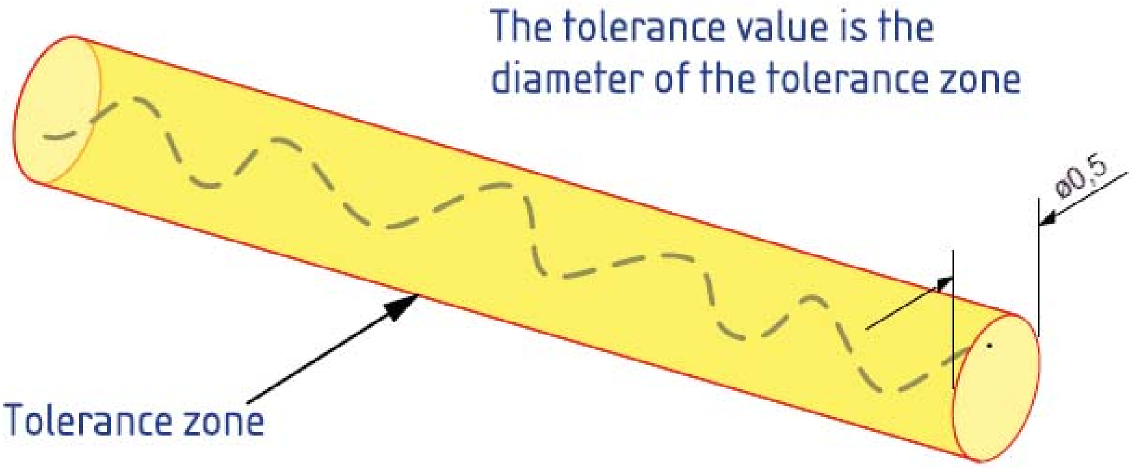

Figure 6, Tolerance zone for Concentricity

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◎	⌀ 2 Ⓛ	A - B

This concentricity tolerance secures that the features are concentric to each other, with a least material condition, according to the average axis of datum A and B.

The least material condition means:

The higher up in the basic tolerance you are, the more out of center the feature can be. Etc. If the basic dimension is 250+-1mm and you measure it to 251. You can add 2 more millimeters to the concentricity tolerance. This cylinder then has a tolerance of 4mm concentricity, which means it can be 2mm out of center.

In this way, we ensure that we have enough stock material for the finishing operations.

You can read more about Least material condition in **ISO 2692.**

The thickness of the rest of the material is ensured by a linear dimension, because it is close to impossible to measure the coaxiallity of an eight meter long part. This linear dimension can be measure by ultrasonic equipment. Furthermore, the straightness of the outer surface will be controlled by the straightness of the bore.

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Interview guide

Rev	ECN No.	Date	Reviewed By	Approved By	Status
A	N/A	04.04.2014	Erlend Lindhartsen	Nils Olav Huseby	Released

Summary:

This document will gather research regarding having an interview, and the actual interview guide.

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Abbreviations and definitions

Abbreviation / definitions	Description
Manufacturing	Means the process of machining the part.
VOR	Variation order request

Table 1, Abbreviations and definitions

Reference documents

Document name	Description

Table 2, Reference documents

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Basics of Interview's

1.0 Scope

This document will give an understanding to why we chose this interview model, and how we are going to perform the interview with the suppliers.

2.0 Document History

Revision	Description	Date	Sign
00	Created document	26.03.14	NOH
A	Released	04.04.14	NOH

Table 3, Document History

3.0 Research on interview method's

3.1 General about interview's methods

Interviews and research can be done in 2 general categories, one is qualitative research, and the other is quantitative research.

Qualitative means focus on numbers of interviews, and defining trends and statistics, while qualitative interviews focuses on in depth in specific subjects. We have decided to use qualitative research for our assignment.

Within qualitative research, there are two basic ways of having the interviews.

- The unstructured interview method
- The half structured interview method

After some research we found out that the unstructured method is very similar to a normal conversation, and will therefore not suit our needs.

Therefore we have chosen the half structured interview method.

3.2 Half structured interview method

With this method, the interview will follow an interview guide which is made prior to the interview. However, it opens up some loose conversations outside the guide, but it

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provides a red thread to how the interview will go, and works as a reminder if the interviews goes outside the scope.

To be able to perform a good in depth interview on the subjects we are going to talk about, we are very dependent on a good basic understanding of the processes we are going to talk about.

One thing to keep in mind, is that the information we get in this interview, is only based on how the supplier experiences the process, and will be a very subjective meaning. Interpetation and comparison of the different information we receive will be a very important task in this matter.

4.0 The buildup of the interview guide

4.1 The goal of the interview

At this point, we should already have done theoretical investigations regarding each process, and have a basic understanding of the processes. Additionally we should have made a set of assumptions to how the processes affect the raw material drawings.

The interview will be a way of verifying our assumptions, and getting deeper understanding to how the processes affect the drawings in “real life” situations.

Additionally we need to get input from the suppliers to how we can best improve the raw material drawings in relations to our requirements and goals.

4.2 Sequence of subjects in the interview

To be able to keep control of the interview, it is important for us to make a strict sequence in how the interview is performed.

Phase	Description	Est time	Who
1	Introduction and small talk	30 Min	
2	Presentation of bachelor thesis	30 Min	
3	Transition into the subject	30 min	
4	Guided tour of the workshop	1 Hour	
5	In depth detailed interview within the technical subject	2 Hours	
6	Improvement proposals regarding the raw material drawings	2 Hours	
7	Summary	30 min	

1. Introduction and small talk
2. Important with good foundation about what this project is, and how it can benefit their business. Talk about confidentiality. Inform that we will record the interview, and clarify allowance for the possibility of taking pictures.
3. Their experience with FMC and these kind of projects/processes

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4. Focus on the relevant subject.
5. Define limitations and possibilities with the process. How different ways of specifying the raw material drawings will affect their delivery process.
6. What can FMC do for you and what can you do for FMC to improve the project/process flow?

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Prosjektplan

Oppgavebeskrivelse

Oppgaven går I korthet ut på å kartlegge alle elementer I prosessen med å fremstille råmaterialtegninger I en produksjon hvor en rekke stakeholders er plassert rundt om i hele verden.

Vi må kartlegge alle spesifike krav knyttet til råmaterialet for at disse stakeholders/ underleverandører skal kunne gjennomføre sine prosesser mest mulig effektivt uten å bruke tid og resurser på endringer underveis.

Resultatet vil bli en prosedyre som kan styre fremstillingen av råmaterialtegninger på en slik måte at alle interesser ivaretas før man igangsetter støping av råemnet og velger verktøy/ metode for smiing.

Table of Contents

1 Mål og rammer

1.1 Bakgrunn

Denne bacheloroppgaven er et avsluttende prosjekt i et studiet innenfor «maskin» og «vann og miljø» Y-vei for årskullet 2010 – 2014 ved Høyskolen i Buskerud og Vestfold (HBV).

Oppgaven gjennomføres i samarbeid med FMC Technology og WAS (Wel Access Systems) som er en verdensomfattende virksomhet med spesialkompetanse innenfor subsee systemer generelt og fysiske kommunikasjonssystemer mellom brønn og overflatefartøyer for bl.a. service og vedlikeholdsarbeider.

Etter forespørsel fra FMC har HBV sammen med gruppa godkjent oppgaven som i korthet går ut på å se hvorvidt det er mulig å kvalitetssikre produksjonsprosessen av tekniske tegninger i forbindelse med råmaterialleveranser. Prosjektet har som oppgave å vurdere noen konkrete komponenter hvor smiing inngår som en sentral del av fremstillingen.

1.2 Rammer

Rammer for oppgaven er i utgangspunktet satt til planleggings og bestillingsprosessen, fram til produksjon av råemnet som derifra skal videre i en produksjonsprosess andre steder i verden.

1.3 Prosjektmål

1.3.1 For oppdragsgiver

1.3.1.1 Effektmål

Oppdragsgiver (FMC, WAS) har over tid brukt to fremgangsmåter i forhold til produksjon av råmaterialer. De to hyppigste metodene er hhv «Turn key» og «CPI». Forskjellen på disse modellene er i korte trekk at underleverandørene eller oppdragsgive (FMC) lager tegninger.

Det er ikke gjort noen studier tidligere om hvorvidt det er mest hensiktsmessig å bruke disse modellene. Derfor er det ønskelig at vi går dypere inn i dette med bl.a. spørreundersøkelser og intervjuer av alle parter i en fremstillingsprosess fra planstadiet og frem til ferdig maskinert produkt.

1.3.1.2 Resultatmål

Hovedmålet med dette er å avdekke elementer som kan medføre redusert behov for endringer underveis. Konsekvenser som følge av dette kan være betydelige besparelser i leveringstid og kostnader. Man har sagt at det kan ligge et innsparingspotensialer på leveringstid i størrelsesorden ca 10% og i kostnader ca 5%.

1.3.2 For studentene

1.3.2.1 Effektmål

Som studenter skl vi tilegne oss dypere forståelse av denne del av en omfattende og kostnadskrevende industri hvor leveringstid er et svært viktig element. Kostnader er, til en viss grad, underordnet leveringstiden da det er her de største overskridelsene skjer. Som studenter skal vi også tilegne oss en bedre forståelse og erfaring innen problemløsning i forbindelse med utviklingsprosjekter, prosess og samarbeid.

Emnebeskrivelsen i dette faget sier i korte trekk at vi skal:

- Arbeide selvstendig
- Planlegge
- Dokumentere
- Systematisere og vurdere
- Lære oss å samarbeide i team
- Lære og følge vedtatte styringsdokumenter og planer
- Forstå og tolke utordringer som dukker opp og finne adekvate løsninger
- Lære og presentere et prosjekt

1.3.2.2 Resultatmål

Prosjektet skal gi oppdragsgiver svar i henhold til prosjektplanens pkt 1.3

Prosjektet skal resultere i en sluttrapport og en presentasjon som skal gi en beskrivelse med målbare metoder for å få på plass en funksjonell fremstilling av råmaterialtegninger.

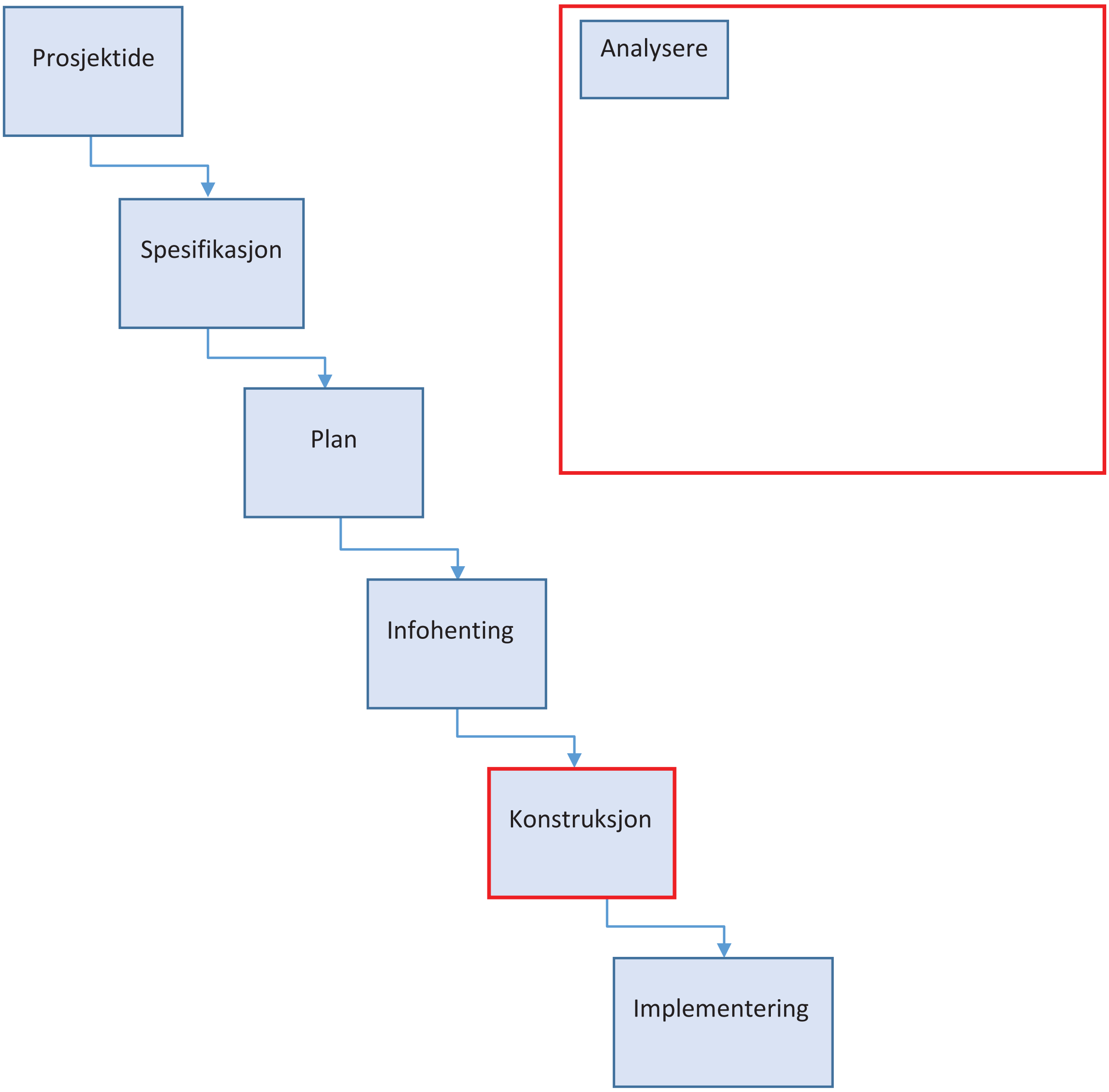
1.4 Prosjektmodell

Evolusjonær prosjektutvikling

Vi har valgt å utvikle vårt bachelorprosjekt i en evolusjonær utviklingsmodell. Modellen er en videreutviklet versjon av vannfallsmodellen. Målet med vår utviklingsmodell er å ferdigstille hvert element i prosjektet før vi starter på neste, for å få best mulig prosjektflyt.

Vår prosjektmodell skiller seg ut fra en klassisk vannfallsmodell, siden vi har valgt å ha iterative sykluser i utviklingsfasen av produktet, noe som gjør at vi får en evolusjonær prosjektmodell. Prosjektgruppa har planlagt å bygge/teste systemet i to ukers intervaller. I den forbindelse skal vi sende ut et fler alternativspørreskjema til underleverandører til FMC for å samle inn informasjon. I denne fasen av prosjektet er vi løsningsorienterte, og informasjonen som vi samler inn skal bidra til løsninger for å konstruere et produkt. Det er ønsket fra prosjekteier at resultatene vi får ut av prosjektet (output) implementeres i FMC sin prosjektsyklus, som skal forhindre forsinkelser og kostnadsoverskridelser i forbindelse med råvareleveranser.

Etter hver testrunde går vi tilbake til kravspesifikasjonen og vurdere hvorvidt vi har satt realistiske krav til systemet.



2 Omfang og avgrensning

2.1 Oppgavedefinisjon

2.1.1 Problemstilling

Hvordan forhindre forsinkelser og kostnadsoverskridelser i forbindelse med råvareleveranser?

2.1.2 Problemtilnærming

I forbindelse med systemutviklingsprogrammer innen subsea stilles det strenge og kostbare krav til materialer som brukes i alle installasjoner. WAS (Well access systems), en av divisjonene i selskapet FMC, har utformet denne bacheloroppgave som skal forsøkes løst som en prosess.

Det er pr i dag en del forskjellige modeller som har vært brukt ved utvikling av nye systemer. Dette gjelder også råvareleveranser.

Det viser seg at det foreløpig ikke er utviklet noen «konsistent» metode for å sikre leveranser uten overskridelser.

Vi skal i vår oppgave fokusere på alt som omhandler fremstilling av råmaterialtegninger, og hvorvidt dette kan redusere overskridelser i tid og kost.

2.1.3 Definisjoner

I denne sammenheng defineres råmaterialer som et støpt og utsmidd emne i stål som skal videreforedles i en produksjonskjede bestående av en rekke virksomheter verden over som ikke har kompatible kontrollsystemer som ivaretar alle de påfølgende produksjonsleddenes interesser.

Råvaretegning er en tegning basert på et helt eller delvis komplett tegningsett av det ferdige produkt. Modellene det henvises til over, dreier seg i hovedsak om fremstillingsprosessene av disse råmaterialtegningene.

Forsinkelsesproblemer i forhold til råmaterialer av denne type er ikke entydige. Det skiller hvor i prosessen forsinkelsen oppstår. De kritiske punktene er der hvor man ikke rekker å bli ferdig med grunnlagsmaterialet til tegningene slik at man mister produksjonsdato ved støperiene. Likeså der hvor det i tegningsprosessen ikke tas tilstrekkelig høyde for alle behov i hele produksjonslinjen som medfører at råvareemnet må (i verste fall) vrakes eller at det påløp ytterligere produksjonstid og kostnader.

Forsinkelsestid kan i verste fall om emner må vrakes og reproduseres bli over 20 uker. Det kan gå betydelig lenger tid en det om man ikke har kapasitet til å reprodusere umiddelbart. Om støperislott misses vil man kunne risikere forsinkelser opp mot det ekstreme 20 uker +.

Produksjonskjede er den totale aktivitetsmengde som skal til før komponenten er ferdigprodusert og klar for å monteres inn i det overordnede system.

Underleverandører er virksomheter som etter anbud har fått tildelt oppgaver i forbindelse med utvikling og produksjon av komponenter bestilt av FMC. Vi regner all produksjon av ingeniørtjenester, design, kontroll, støping, smiing, valsing, maskinering, alle kontrollprosesser underveis inkludert sluttkontroll, frakt, aktuelle offentlige institusjoner og evt andre nødvendige aktiviteter som underleverandører.

Oppdragsgiver er i hovedsak oljeselskaper og nasjonalstater hvor FMC er gitt i oppdrag å løse tekniske problemer i forbindelse med å få tilgang til oljeresurser på sokkel.

2.2 Avgrensning

Vi har etter samråd med oppdragsgiver besluttet å gi oppgaven en del begrensninger med tanke på at gruppa har begrenset med kapasitet og tid i forhold til siste presentasjonsdato 5. juni 2014. Innleveringsfrist er 26. mai.

I tillegg begrenses oppgaven naturlig fra råvaretegningene er ferdigproduserte og godkjent, til råvareproduksjonen er i gang. Det skal sies at hele prosesskjeden til en viss grad må analyseres for å få bedre innsikt som gjør oss i stand til å føre en fornuftig dialog med alle aktører.

3 Organisering

3.1 Ansvar

Det er inngått skriftlig avtale mellom partene i forbindelse med dette prosjekt. Ansvarsforhold fremkommer av disse. Alle avtaler er referert i rapportens pkt 8.

Oppfølging i prosjektet og godkjenninger underveis skal i utgangspunktet håndteres etter følgende ansvarsfordeling:

Ekstern sensor Ekstern veileder Økonomi	Børge Bjørnås FMC
Tekniske bistand Tekniske dokumenter Kontakt mot underleverandører	Anders Olsson FMC
Teknisk bistand Kravspesifikasjon Spørsmål til underleverandører	Per Inge Myran FMC
Internt veileder Administrative dokumenter	Jørn Breivoll HBV
Intern sensor	Karoline Moholt HBV

3.2 Samarbeid

Det er lagt opp til et tett samarbeid mellom studenter og høyskole. Interne møter med veileder foregår ukentlig. Oppdragsgiver har løpende innsyn i gruppas dokumenter og avholder oppdateringsmøter ca hver 2. uke. Hyppigere om det er behov.

3.3 Gruppesammensetning

Prosjektgruppa består av:

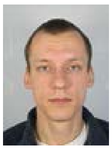
Morten Mikalsen (Prosjektleder)

Tlf: 915 715 26
E-post: morten@buskerudva.no
Bakgrunn: Generell studiekompetanse, fagbrev som rørlegger, UIO eksamen i spesialfag arbeidsrett, 20 vt bedriftsøkonomi NKS, 20 vt ledelse NKS, LO skolen, AOF topputdanning innen organisasjon og ledelse, 20 år som selvstendig næringsdrivende entreprenør.

Nils Olav Huseby

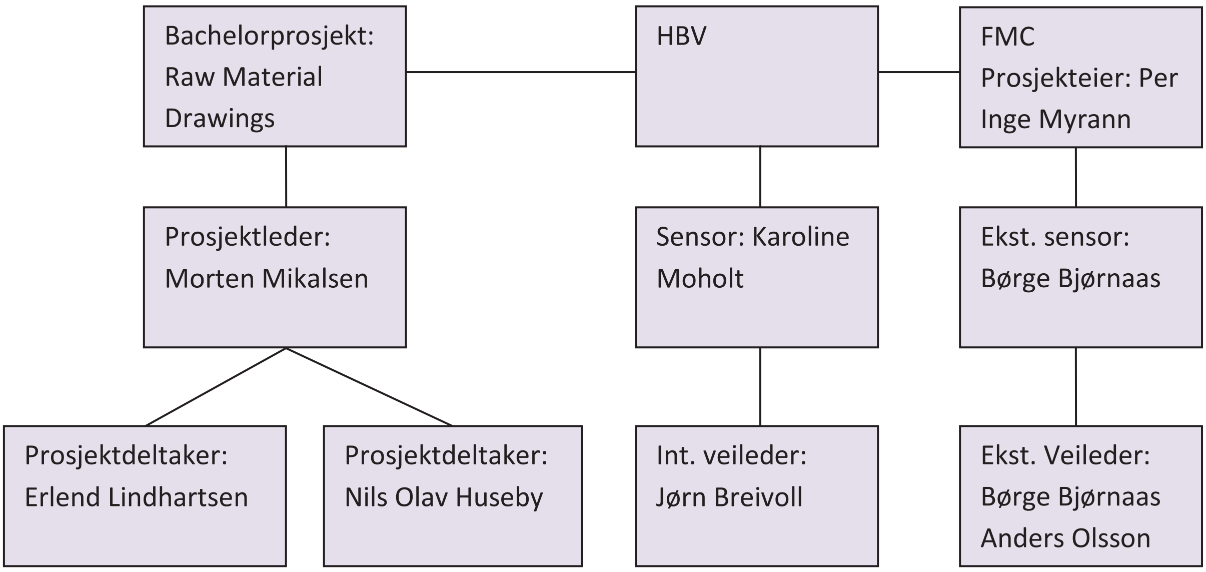
Tlf: 9797 0490
E-post: NilsOlav.Huseby@fmcti.com
Bakgrunn: Fagbrev som maskinarbeider, med ca 8 års praksis innen mekanisk bedrift, samt 2 år som prosjektleder og innkjøpsleder på samme bedrift. Startet å jobbe for FMC Kongsberg 2 januar 2013 som Manufacturing Engineer. Jobber nå med designere for å kvalitetssikre produksjonsvennlige design. Holder også jevnlige kurs i produksjonsteknikk internt i FMC.

Erlend Lindhartsen



Tlf: 9284 1340
E-post: Erlend85@gmail.com
Bakgrunn: Rørlegger med fagbrev og hjelpelærer innen matte og fysikk på HBV.

3.3.1 Organisasjonskart



3.3.2 Rollebeskrivelser

Prosjektleder (Morten Mikalsen)

Prosjektleder har overordnet ansvar for utførelse av prosjektet og kommunikasjon med prosjekteier. Han skal sørge for at aktiviteter blir ferdige og tidsfrister vedlikeholdes. Hovedoppgavene til en prosjektleder er å styre, kontrollere og følge med på alle deler av prosjektet.

Dokumentasjonsansvarlig (Erlend Lindhartsen)

Dokumentasjonsansvarlig skal sørge for at mappe- og filstruktur har en logisk og enkel struktur, som gruppemedlemmer og utaforstående forstår. Dokumentasjonsansavarlig skal også sørge for at alle dokumenter har korrekt format i henhold til dato, språk, revisjoner og fonter.

Budsjettansvarlig (Nils Olav Huseby)

Budsjettansvarlig har hovedansvaret for prosjektgruppas regnskap og booking av flyreiser.

3.4 Oppdragsgiver

FMC Kongsberg Subsea AS, WAS (Well Access Systems)
Kirkegårdsveien 45, 3601 Kongsberg

Kontaktpersoner:

Prosjekteier: Per Inge Myran

Tlf:
E-post: Peringe.myrann@fmcti.com

Ekstern sensor/Veileder: Børge Bjørnås

Tlf:
E-post: borge.bjornaas@fmcti.com

Teknisk support: Anders Olsson

Tlf:

E-post: anders.olsson@fmcti.com

3.5 Intern veileder HBV

Jørn Breivoll
Tlf: 32869573 eller 95242173
E-post: Jorn.Breivoll@hibu.no

3.6 Intern sensor

Karoline Moholt
Tlf: 32869547
E-post: Karoline.Moholth@hibu.no

4 Milepæler

4.1 Milepæler

Nr	Dato	Milepæl
1	Februar 18.	1. presentasjon
2	April 10.	2. presentasjon
3	Mai 26.	Innlevering presentasjon 3 kl 12.00.
4	Juni 4.	Generalprøve presentasjon 3
5	Juni 5.	3. presentasjon kl 0900

5 Risikoanalyse og kvalitetssikring

Grunnlag

Prosjektgruppen har tatt opp til vurdering og kommet fram til at det er hensiktsmessig å ha en ROS-analyse som en del av prosjektplanen. En risikovurdering vil gi et bedre overblikk for hva som kan gå galt i prosjektet, og da er det mulig for prosjektgruppa å gå analytisk gjennom det som er synliggjort som problemer og lage en aksjonsplan.

Grenser

Sannsynlighet ganger konsekvens gir risiko. Grenser for disse er det blitt tatt en faglig vurdering på i gruppa. Sannsynlighet og konsekvens er begrenset i intervallet [0,3]. Risiko som er i matrisen under er begrenset i intervallet [0,9].

Sannsynlighet			Konsekvens			Risiko		
2 <	Sannsynlig	≤ 3	2 <	Stor	≤ 3	6 <	Høy	≤ 9
1 <	Mulig	≤ 2	1 <	Moderat	≤ 2	3 <	Middels	≤ 6
0 ≤	Sjeldent	≤ 1	0 ≤	Liten	≤ 1	0 ≤	Lav	≤ 3

Punkt	Hva kan gå galt	Sannsynlighet	Konsekvens	Risiko
1	PC-problemer	Mulig (2)	Liten (1)	Lav (3)
2	Syk: 1-5 dager	Mulig (2)	Moderat (2)	Middels (4)
3	Syk: 5 dager eller mer	Sjeldent (1)	Stor (3)	Lav (3)
4	Uforutsett fravær: 1-5 dager	Mulig (2)	Moderat (2)	Middels (4)
5	Uforutsett fravær: 5 dager eller	Sjeldent (1)	Stor (3)	Lav (3)

	mer			
6	Priser på flyreiser og valuta kan variere	Mulig (2)	Liten (1)	Lav (2)
7	Filer i dropbox kan bli borte/slettet	Sjeldent (1)	Stor (3)	Lav (3)

Punkt	Aksjonsplan
1	Lever PC' n til Front Desk på FMC hvis noe skjer med FMC-Laptop. Søk profesjonell hjelp hos RH-data i Kongsberg hvis noe skjer med privat Laptop.
2	Tilkall lege og kontakt gruppemedlemmer hvis sykdom oppstår. Gruppen må tilpasse seg og modifisere prosjektplaner.
3	Tilkall lege og kontakt gruppemedlemmer hvis sykdom oppstår. Gruppen må tilpasse seg og modifisere prosjektplaner. Sykdom i lengere tid kan ha en negativ konsekvens på prosjektet, og da er det viktig at veiledere og sensor er klar over eventuell sykdom i gruppa.
4	Kontakt gruppen og gi en grunn for uforutsett fravær. Gruppen må tilpasse seg og modifisere prosjektplaner.
5	Kontakt gruppen og gi en grunn for uforutsett fravær. Gruppen må tilpasse seg og modifisere prosjektplaner. Fravær i lengere tid kan ha en negativ konsekvens på prosjektet, og da er det viktig at veiledere og sensor er klar over eventuelle fravær eller forfall i gruppa.
6	Lag et nytt reisebudsjett hvis flyreiser og eller valuta endrer seg med forholdsvis 10 %.
7	Det er viktig at alle gruppemedlemmer tar en «backup» av prosjektmappa en gang uka.

5.1 Risikofaktorer

5.2 Kvalitetssikring

5.3 Rapportering og kvalitetskontroll

5.3.1 Intern rapportering

Gruppa rapporterer ukentlig til skolen gjennom møter med intern veileder. I forbindelse med disse møtene er det i forkant produsert og levert et oppfølgingsdokument som beskriver ferdige og igangsatte elementer i prosjektet, samt nært fremstående elementer som skal igangsettes påfølgende uke. Dokumentet beskriver oppgaver samt forventet resursbruk. I tillegg har det i seg en avviksdel hvor endringer og feil, samt tiltak for å rette opp feil beskrives.

5.3.2 Ekstern rapportering

Etter behov og etter forespørsel fra prosjekteier eller ekstern veileder. Statusoppdateringer foregår ved at alle eksterne interesenter er gitt tilgang til gruppas interne dokumenter i sin helhet.

6 Gjennomføring

6.1 Aktivitetsplaner

Aktivitetsplaner med Gantdiagram ligger vedlagt dette dokument. ADM0004

6.2 Tids og resursplan

Prosjektgruppa har med bakgrunn i medlemmenes arbeidssituasjon utenfor prosjektet satt opp følgende tidsplan for felles samlinger basert på timer pr dag og uke. Det er enighet om å arbeide ca 40 timer pr uke med prosjektet fra 1.Mars. Grunnet få medlemmer og noe vanskeligheter med arbeidsformen innledningsvis i prosjektet, så gruppa seg nødt til å omstrukturere samt å stramme inn i forhold til arbeidsmetode og tid. 40 timer pr uke pr student er relativt mye med tanke på at Y-vei studenter har arbeid på dagtid ved siden av studiene. Allikevel anser vi dette som et nødvendig tiltak om vi skal kunne ferdigstille prosjektet, samt lage en kvalitativ god presentasjon nr 2.

Følgende tider er gruppa samlet:

	Mandag	Tirsdag	Onsdag	Torsdag	Fredag	Sum
Erlend	08 – 16 8 timer	08 – 16 8 timer	08 – 16 8 timer	08 – 16 8 timer	08 – 16 8 timer	40
Nils Olav	08 – 16 8 timer	08 – 16 8 timer	08 – 16 8 timer	08 – 16 8 timer	08 – 16 8 timer	40
Morten	08 – 16 8 timer	08 – 16 8 timer	08 – 16 8 timer	08 – 16 8 timer	08 – 16 8 timer	40

Som det fremkommer av oversikten, er antall timer gruppa kan arbeide sammen relativ lik. Dette krever en arbeidsstruktur som baserer seg på betydelig selvstudie og krav til løpende rapportering av status i de aktiviteter man har påtatt seg å arbeide med. Det er enighet om å arbeide så tett opp mot 40 timer pr uke som overhodet mulig, om prosjektet skal komme i mål. Det er i dag ca 3 uker igjen av prosjekttiden og siste evaluering viser at dette tiltaket er nødvendig ut fra en samlet gjennomgang.

6.3 Møteplan

Møteplanen beskriver de faste møter gruppen ser for seg å ha i prosjektperioden.

Kategori	Uke	Måned	Semester
Statusmøter	3	15	60
Interne møter HBV	1	4	16
Eksterne møter FMC		2	4

Statusmøter: Faste interne gruppemøter hver tirsdag, onsdag og torsdag. Rutinemessig agenda med oppsummering av pågående arbeider, omdisponering av resurser og avvikshåndtering.
Interne møter HBV: Ukentlige møter med intern sensor hver torsag fra kl 0900 til 1000. Gjennomgang av oppfølgingsdokument.
Eksterne møter FMC: Møter med ekstern sensor ca 2 ganger pr måned og ellers etter behov.

6.4 Definisjoner

Raw material drawings. Dette begrepet er brukt på det tidligste stadiet i fremstillingsprosesser hvor enkeltkomponenter skal produseres. Tegninger av et ferdig produkt vil utvikles samtidig som en råvaretegning.

Underleverandør. I oppgaven defineres dette som alle aktører som har oppgaver å utføre på komponenten fra planlegging til ferdig montert og testet i kombinasjon med hovedsystemet hvor komponenten har en driftsfunksjon.

Prosjekteier. Dette er FMC i forhold til bachelorprosjektets prosess og resultat.

Kunde. FMC i forhold til underleverandører.

Oppdragsgiver. I forbindelse med bacheloroppgaven er dette FMC. Ute i felt er dette begrepet knyttet til FMC`s oppdragsgiver, som kan være eks Statoil eller andre oljeselskaper og evt nasjonalstater direkte.

Råmateriale. I denne sammenheng er det komponenter i et bestemt system fremstilt av stål i en støpe/ smi operasjon. Dvs råemnet <u>før</u> maskinering, herding og funksjonstesting.

7 Prosjektøkonomi

7.1 Prosjektfinansiering

Alle aktiviteter som krever økonomi er HBV uvedkommende. Vi kan således ikke bestille, rekvirere eller på annen måte tilegne oss varer eller tjenester ut over det som finnes på skolen og som er forhåndsgodkjent av veileder.
Aktiviteter som nevnt over skal finansieres av oppdragsgiver eller gruppens medlemmer privat etter avtale.

7.1.1 Prosjektbudsjett

Godkjent totalbudsjett. Vedlagt i doc mappe ligger oppsplittet budsjett for alle aktiviteter.

Tog	1308
Fly	8000
Hotell	5250
Bil (km)	4200
Leiebil	2500
Diet	10341
Diverse	1500
Risiko (10%)	3309,9
Totalt	36408,9

7.1.2 Regnskap

Regnskap ligger vedlagt sammen med komplett budsjett. Dette regnskap leveres oppdragsgiver.

8 Kontrakter og avtaler

8.1 Bachelorprosjek arbeidstavtale (gruppe)

1. **Gruppeleder**
   a. Gruppens prosjektleder er Morten Mikalsen.
   b. Dersom det ikke oppstår enighet når beslutninger skal fattes, tar prosjektleder den endelige avgjørelsen.
   c. Prosjektleder har ikke anledning til å fatte beslutninger av betydning for prosjektet uten å først ha konferert med gruppens medlemmer.
   d. Gruppeleder har rett til å signere på vegne av gruppen.
2. **Arbeidstid**
   a. Det legges opp til fire dagers arbeidsuke mandag til og med torsdag frem til siste presentasjon primo juni 2014.
   b. Arbeidstiden er fra 0800 til 1600
   c. Ut over dette arbeider gruppens medlemmer på egenhånd.
   d. Arbeidstiden kan justeres for enkeltmedlemmer ut fra behov relatert til ekstern arbeidssituasjon. Det forventes at alle arbeider målrettet den tid de har forpliktet seg jfr denne avtale.
   e. Velferdspermisjon i prosjektperioden innvilges normalt ikke. Skriftlig søknad må leveres.
   f. Sykdom skal meldes inn så raskt det lar seg gjøre.

3. **Økonomi**
   a. Påløpte kostnader som det ikke finnes inndekning for i budsjettet skal være godkjent i gruppa og fordeles likt blant medlemmene.
   b. Regninger som presenteres i ettertid og som det ikke er gjort rede for, dekkes ikke.
4. **Ekskludering**
   a. Ingen kan ekskluderes fra gruppa uten saklig grunn.
   b. Om et medlem ikke utfører sine oppgaver slik gruppa forventer, og hvor medlemmet ikke er villig til å rette opp dette innen en gitt frist, kan ekskludering i verste fall vurderes.
   c. Betydelig fravær uten gyldig grunn og uten å varsle jfr pkt 2 f, kan medføre eksklusjon.
   d. Intern veileder er klageinstans.
5. **Arbeidsmiljø (HMS)**
   a. Det forventes at alle har en positiv og fremoverlent holdning til arbeidet som skal utføres.
   b. Det forventes og kreves at konflikter skal tas opp og løses så raskt som mulig.
   c. Alle er forpliktet til å være åpne om egen opplevelse av arbeidsmiljøet i prosjektperioden.
   d. Alle gruppens medlemmer er forpliktet til å ta like stort ansvar for prosjektarbeidet og arbeidsmiljøet.
   e. Ingen av gruppens medlemmer har eksklusive rettigheter ut over det ansvar man har tatt på seg i prosjektperioden.

8.2 Bachelorprosjektavtale intern (HBV)

STANDARDAVTALE FOR STUDENTENES ARBEID MED BACHELOROPPGAVEN MED EKSTERNE OPPDRAGSGIVERE VED HØGSKOLEN I BUSKERUD OG VESTFOLD – FAKULTET FOR TEKNOLOGI OG MARITIME FAG – KONGSBERG INSTIUTT FOR INGENIØRFAG.

Høgskolen i Buskerud og Vestfold

Fakultet for Teknologi og Maritime fag

Kongsberg Institutt for Ingeniørfag

1. BAKGRUNN

Formålet med denne kontrakten er å formalisere forholdet mellom ekstern oppdragsgiver, Høgskolen i Buskerud og Vestfold og studentene i arbeidet med hovedprosjektet for avgangstudentene ved Avdeling for Teknologi og Maritime fag – Kongsberg Institutt for Ingeniørfag ved Høgskolen i Buskerud og Vestfold.

Denne avtale definerer plikter og rettigheter for partene i forbindelse med dette arbeidet.

Oppdragsgiver er kjent med og aksepterer fullt ut at dette arbeidet er utført som et ledd i en høgskoleingeniørutdanning og at Høgskolen i Buskerud og Vestfold ikke kan garantere for arbeidets kvalitet eller påta seg noe økonomisk eller juridisk ansvar for det produktet som arbeidet fører til, eller bruken av produktet i noen sammenheng. Høgskolen kan heller ikke påta seg vedlikeholdsansvar for det produktet som utvikles i forbindelse med hovedprosjektet.

Studentene har ikke anledning til å motta lønn for arbeidet som utføres.

2. PARTER

Avtalen har tre parter:

- Avgangsstudentene i prosjektgruppen, nedenfor kallt Studentene.

- Ekstern oppdragsgiver, Firma FMC/ WAS v/ Per Inge Myrann
  nedenfor kalt oppdragsgiver.

- Høgskolen i Buskerud og Vestfold, nedenfor kalt Høgskolen.

3. OPPDRAGSGIVERS PLIKTER

Oppdragsgiver skal oppnevne en av sine ansatte som ekstern veileder for studentene. Det forutsettes at veilederen gir studentene den nødvendige hjelp med å definere oppgaven samt skaffe nødvendig underlag for arbeidet og at veilederen har myndighet til å opptre som ansvarlig representant for oppdragsgiver i spørsmål som omfattes av denne kontrakten.

Under arbeidet er det viktig at studentene får god anledning til regelmessige samtaler med veilederen i prosjektperioden.

Videre kreves det at oppdragsgiver stiller kvalifisert ekstern sensor(mastergrad / siv.ing eller tilsvarende innen fagområdet) til rådighet for prosjektet. Ekstern sensor skal medvirke ved evaluering av prosjektarbeidet. Ekstern sensor kan være den samme som veilederen.

Den eksterne veilederen skal godkjenne alle studentenes rapporter.

4. OPPDRAGSGIVERS RETTIGHETER

Oppdragsgiver har fulle rettigheter til å benytte resultatet av hovedprosjektet med mindre noe annet er angitt i vedlegget til denne kontrakten.

Ved bruk og eventuell publisering av resultatene av oppgaven skal det henvises til at arbeidet er et studentarbeid ved Høgskolen i Buskerud og Vestfold, Fakultet for Teknologi og Maritimefag samt studentenes og veiledernes navn.

5. HØGSKOLENS PLIKTER

Ved starten av avgangsåret skal studentene deles opp i prosjektgrupper på 4-6 personer som sammen skal gjennomføre en større oppgave, et hovedprosjekt. Omfanget er 20 studiepoeng. Dette tilsvarer ca. 600 timers arbeid pr. student.

Det er ønskelig at studentene innhentet en egnet prosjektoppgave fra oppdragsgiver og står for hoveddelen av kommunikasjonen med oppdragsgiver. Studentene skal i starten på prosjektet produsere en kravspesifikasjon og en prosjektplan i forbindelse med den foreslåtte prosjektoppgaven og rapportere disse skriftlig.

Hovedprosjektet skal evalueres med vanlige karakterer. Evalueringen vil bli gjort på grunnlag av det utførte arbeidet og av en rekke dokumenter og muntlige fremføringer/utspørringer samt regelmessige møter. Karakterene settes på individuelt grunnlag av intern veileder, intern sensor og ekstern sensor.

Høgskolen stiller intern veileder og intern sensor til rådighet i forbindelse med dette arbeidet.

6. HØGSKOLENS RETTIGHETER

Høgskolen har rett til vederlagsfritt å benytte resultatet av oppgaven i sin undervisning med mindre noe annet er angitt i vedlegget til denne kontrakten.

7. UTGIFTER

Det vil påløpe en del utgifter i forbindelse med arbeidet. Disse dekkes på følgende måte:

Lønn	Studentene skal ikke motta lønn for arbeidet med hovedoppgaven. Den eksterne veilederens og sensors lønn og utgifter dekkes fullt ut av oppdragsgiver. Den interne veilederens og sensors lønn og utgifter dekkes fullt ut av høgskolen.
Innkjøp av utstyr	Innkjøp av utstyr og bøker skal ordnes via oppdragsgiver. Innkjøp utstyr og bøker er oppdragsgiver sin eiendom etter prosjektperioden.
Andre utgifter inkludert reiser	Oppdragsgiver dekker studentenes direkte utgifter. Alle utgifter skal avtales og godkjennes på forhånd av oppdragsgiver.

8. UTSTYR OG KOMPONENTER

Høgskolen stiller sitt utstyr vederlagsfritt til disposisjon for studentene i den grad utstyret er egnet og tilgjengelig. Utstyr som lånes ut fra oppdragsgiver skal fortrinnsvis monteres i høgskolens lokaler. Utstyret skal holdes forsikret av oppdragsgiver. Utgifter til vedlikehold av utstyret dekkes av oppdragsgiver.

Komponenter til utstyr som konstrueres og bygges under arbeidet med hovedprosjektet betales av oppdragsgiver.

Utlånt utstyr og innkjøpte komponenter skal dokumenteres i eget vedlegg.

9. ENDRINGER

Alle endringer på denne standardavtalen skal dokumenteres i eget vedlegg.

10. VEDLEGGSLISTE

1. Endringer av standardavtale.
2. Utlånt utstyr og innkjøpte komponenter.

Dato:

For Oppdragsgiver **For Høgskolen**

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Studentene:

Nils Olav Huseby **Erlend Lindhartsen** **Morten Mikalsen**

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8.3 Bachelorprosjektavtale ekstern (FMC)
Vedlagt ligger avtale gjeldende for Nils Olav Huseby.
Tilsvarende avtale forefinnes for hver deltaker i gruppa, og disse er signert sammen med en avtale om etiske prinsipper. Disse avtaler legges frem på forlangende.

FMC Technologies

Nils Olav Huseby

FMC : 25.05.2014

AVTALE OM PROSJEKTOPPGAVE

Vi tilbyr deg herved samarbeid om prosjektoppgave, ved avdeling *WAS, Riser and rig interface product,* ved FMC Kongsberg Subsea AS.

Det vil ikke bli utbetalt lønn.

Start: *13.01.2014*
Varighet: *20.06.2014*

Oppgavens tema: Bachelor Thesis; Raw material drawing process

Kontaktperson: *Per Inge Myrann,*

Dersom du aksepterer denne avtalen, ber vi deg returnere en signert kopi til HR-avdelingen innen én uke.

Aksept av tilbud

Jeg aksepterer mine ansettelsesbetingelser. Jeg har også mottatt bedriftens taushetserklæring og etiske forpliktelser og aksepterer at disse inngår som en del av min skriftlige arbeidsavtale.

Med hilsen

FMC Kongsberg Subsea AS

HR Advisor

Signatur:__________________________________ Dato:_____________

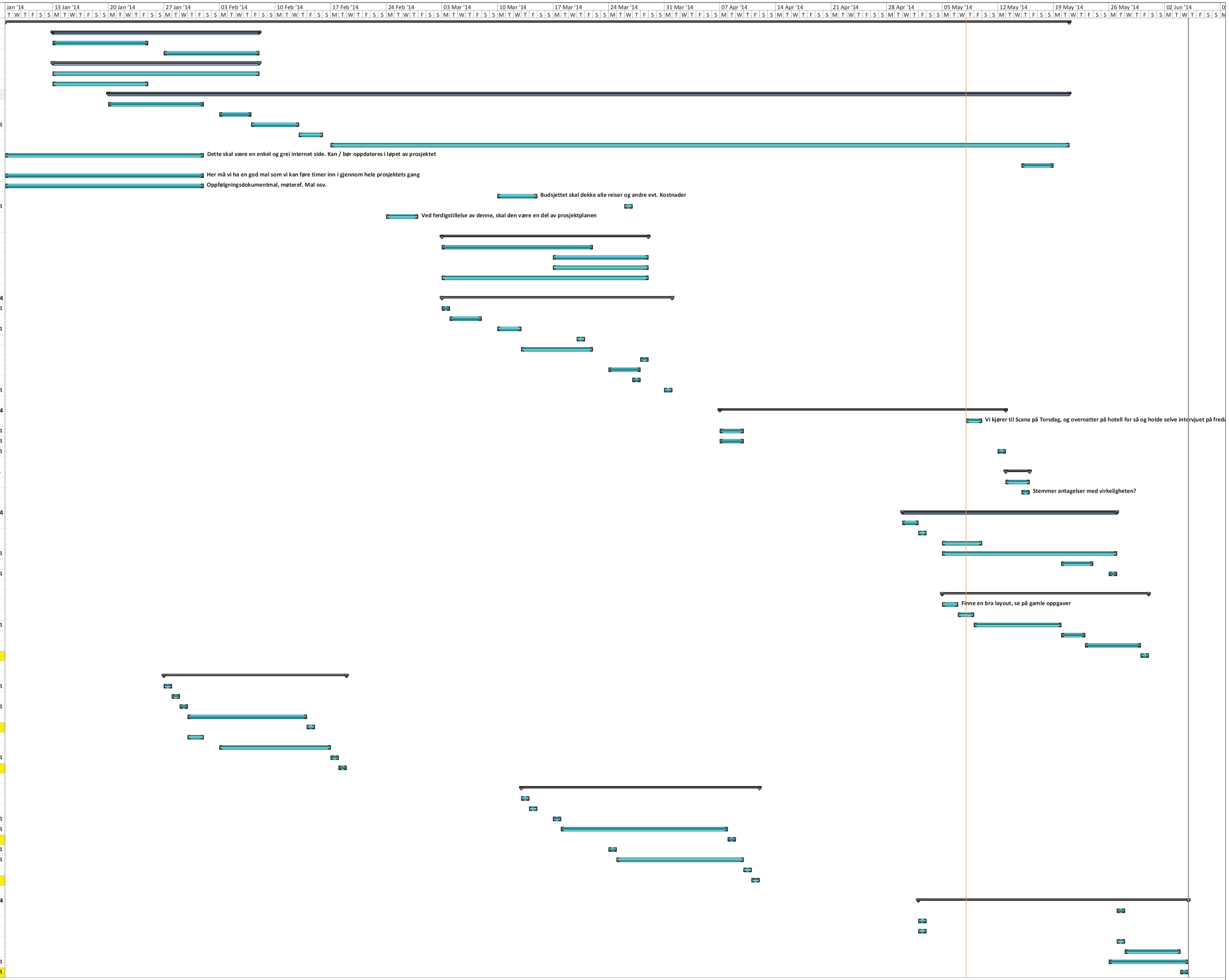
Tilbudet aksepteres:

Signatur:__________________________________ Dato:_____________

Task navn	Start	Slutt	Avhengigheter	Beskrivelse	Ressurs	Estimerte timer	Grunnlag for estimat av timer
Administrative ting							
Kravspesifikasjon	13.01.2014	07.02.2014		Krav fra FMC må tolkes og gjøres om tl en spesifikasjon, som skal være ihht. Prosjekthåndbok og veiledning fra HBV	FMC, Nils Olav	30	
Bestemme innhold og lage utkast	13.01.2014	24.01.2014					
Lage endelig versjon	27.01.2014	07.02.2014					
Testspesifikasjon	13.01.2014	07.02.2014		Testene skal være ihht. Krav spesifikasjonen	Gruppe	100	
Bestemme innhold og lage utkast	13.01.2014	07.02.2014					
Lage endelig versjon	13.01.2014	24.01.2014					
Prosjekt plan	20.01.2014	14.03.2014		Ref. Prosjekthåndbok for innhold	Gruppe	150	
Innhente informasjon	20.01.2014	31.01.2014					
Lage aktivitetsplan	03.02.2014	06.02.2014					
Lage utkast til prosjektplan	07.02.2014	12.02.2014					
Lage ferdig versjon	13.02.2014	15.02.2014					
Vedlikehold og justeringer	17.02.2014	20.05.2014					
Internettside	07.01.2014	31.05.2014		Dette skal være en enkel og grei internet side. Kan / bør oppdateres i løpet av prosjektet	Erlend	20	
Reklameplakat	15.05.2014	02.06.2014					
Timelister	07.01.2014	05.06.2014		Her må vi ha en god mal som vi kan føre timer inn i gjennom hele prosjektets gang	Nils Olav/ Erlend	50	
Maler og andre basisdokumenter	07.01.2014	31.01.2014		Oppfølgningsdokumentmal, møteref. Mal osv.	Nils Olav	50	
Lage budsjett	10.03.2014	14.03.2014		Budsjettet skal dekke alle reiser og andre evt. Kostnader	Nils Olav	10	
Godkjenning av budsjett av FMC	26.03.2014	26.03.2014			FMC	1	
Risikoanalyse	24.02.2014	27.02.2014		Ved ferdigstillelse av denne, skal den være en del av prosjektplanen	Erlend	10	
Informasjonsinnhenting							
Research Forging	03.03.2014	21.03.2014			Nils Olav	30	
Research Maskinering	17.03.2014	28.03.2014			Morten	30	
Research Testing Råmaterialer	17.03.2014	28.03.2014			Erlend	50	
Research Eksisterende system FMC	03.03.2014	28.03.2014			Gruppa	20	
Forberede intervjuer							
Definere bedrifter vi skal intervjue	03.03.2014	03.03.2014			Gruppe	10	
Lage en struktur for intervjuene	04.03.2014	07.03.2014			Gruppe	20	
Lage en forpresentasjon av gruppen	10.03.2014	12.03.2014			Nils Olav	25	
Få forpresentasjonen godkjent av FMC	20.03.2014	20.03.2014			FMC	10	
Lage intervjuguide	13.03.2014	21.03.2014			Gruppe	30	
Få intervjuguide godkjent av FMC	28.03.2014	28.03.2014			FMC	10	
Lage multiple choice spørsmål	24.03.2014	27.03.2014			Gruppe	30	
Få multiple choice spørsmål godkjent	27.03.2014	27.03.2014			FMC	10	
Bestille reiser	31.03.2014	31.03.2014			Nils Olav	10	
Gjennomføre intervjuer							
Reise til Scana	11.05.2014	12.05.2014		Vi kjører til Scana på Torsdag, og overnatter på hotell for så og holde selve intervjuet på fredagen. Vi forventere å bruke hele dagen	Gruppa	70	4 timers kjøring hver vei + 8 timers intervju * 3 personer
Reise til Ofar	07.04.2014	09.04.2014			Nils Olav/ Erlend	50	
Reise til Ringmill	07.04.2014	09.04.2014			Nils Olav/ Erlend	50	
Reise til Aarbakke	14.05.2014	14.05.2014			Morten	16	
Analysere Informasjon							
Strukturere og kategorisere informasjon fra intervjuer	13.05.2014	31.05.2014			Gruppe	100	
Sammenligne intervjuresultater med tidligere reserach	15.05.2014	15.05.2014		Stemmer antagelser med virkeligheten?	Gruppe	50	
Bygge et system	30.04.2014	26.05.2014					
Vurdere kravspesifikasjon	30.04.2014	01.05.2014			Gruppe	10	
Definere output sammen med FMC	02.05.2014	02.05.2014			Gruppe	10	
Lage en systembeskrivelse	05.05.2014	09.05.2014			Gruppe	30	
Bygge system	05.05.2014	26.05.2014			Gruppe	60	
Teste system	20.05.2014	23.05.2014			Gruppe	20	
Repetere	26.05.2014	26.05.2014			Gruppe	10	

Rapport					
Velge rapportmodell	05.05.2014	06.05.2014	Finne en bra layout, se på gamle oppgaver	Erlend	6
Fordele skriveoppgaver	07.05.2014	08.05.2014		Gruppe	6
Sammenfatte rapport	09.05.2014	26.05.2014		Gruppe	20
Konklusjon	20.05.2014	26.05.2014		Gruppe	25
Oppsummering	23.05.2014	26.05.2014		Gruppe	3
Innlevering	26.05.2014	26.05.2014			1
Presentasjon nummer 1					
Analysere krav fra sensor	27.01.2014	27.01.2014		Gruppe	3
Booke rom	28.01.2014	28.01.2014		Morten	1
Kalle inn alle relevante personer	29.01.2014	29.01.2014		Morten	2
Bygge innleveringsdokumentasjon	30.01.2014	13.02.2014		Gruppe	6
Levere dokumentasjon til sensor	14.02.2014	14.02.2014		Morten	1
Fordele presentasjonsfokus	30.01.2014	31.01.2014		Gruppe	6
Lage power point presentasjon	03.02.2014	16.02.2014		Nils Olav	10
Generalprøve	17.02.2014	17.02.2014		Gruppe	8
Presentasjon	18.02.2014	18.02.2014		Gruppe	3
Presentasjon nummer 2					
Analysere krav fra sensor	13.03.2014	13.03.2014		Gruppe	3
Booke rom	14.03.2014	14.03.2014		Morten	1
Kalle inn alle relevante personer	17.03.2014	17.03.2014		Morten	2
Bygge innleveringsdokumentasjon	18.03.2014	07.04.2014		Gruppe	25
Levere dokumentasjon til sensor	08.04.2014	08.04.2014		Morten	1
Fordele presentasjonstemaer	24.03.2014	24.03.2014		Gruppe	25
Lage power point presentasjon	25.03.2014	09.04.2014		Nils Olav	16
Generalprøve	10.04.2014	10.04.2014		Gruppe	25
Presentasjon	11.04.2014	11.04.2014		Gruppe	3
Presentasjon nummer 3					
Analysere krav fra sensor	20.05.2014	20.05.2014		Gruppe	3
Booke rom	02.05.2014	02.05.2014		Morten	1
Kalle inn alle relevante personer	02.05.2014	02.05.2014		Morten	2
Fordele presentasjonstemaer	27.05.2014	27.05.2014		Gruppe	35
Lage power point presentasjon	28.05.2014	03.06.2014		Nils Olav	40
Generalprøve	26.05.2014	04.06.2014		Gruppe	25
Presentasjon	05.06.2014	05.06.2014		Gruppe	3
Dokumentet tilhører ADM0003					1493 Antal timer pr gruppemedlem = 541

ID	Task Name	Start	Finish
1	**Administrative ting**	**Tue 07.01.14**	**Tue 20.05.14**
2	**Kravspesifikasjon**	**Mon 13.01.14**	**Fri 07.02.14**
3	Bestemme innhold og lage utkast	Mon 13.01.14	Fri 24.01.14
4	Lage endelig versjon	Mon 27.01.14	Fri 07.02.14
5	**Testspesifikasjon**	**Mon 13.01.14**	**Fri 07.02.14**
6	Bestemme innhold og lage utkast	Mon 13.01.14	Fri 07.02.14
7	Lage endelig versjon	Mon 13.01.14	Fri 24.01.14
8	**Prosjekt plan**	**Mon 20.01.14**	**Tue 20.05.14**
9	Innhente informasjon	Mon 20.01.14	Fri 31.01.14
10	Lage aktivitetsplan	Mon 03.02.14	Thu 06.02.14
11	Lage utkast til prosjektplan	Fri 07.02.14	Wed 12.02.14
12	Lage ferdig versjon	Thu 13.02.14	Sat 15.02.14
13	Vedlikehold og justeringer	Mon 17.02.14	Tue 20.05.14
14	Internettside	Tue 07.01.14	Fri 31.01.14
15	Prosjektplakat	Thu 15.05.14	Sun 18.05.14
16	Timelister	Tue 07.01.14	Fri 31.01.14
17	Maler og andre basisdokumenter	Tue 07.01.14	Fri 31.01.14
18	Lage budsjett	Mon 10.03.14	Fri 14.03.14
19	Godkjenning av budsjett av FMC	Wed 26.03.14	Wed 26.03.14
20	Risikoanalyse	Mon 24.02.14	Thu 27.02.14
21			
22	**Informasjonsinnhenting**	**Mon 03.03.14**	**Fri 28.03.14**
23	Research Forging	Mon 03.03.14	Fri 21.03.14
24	Research Maskinering	Mon 17.03.14	Fri 28.03.14
25	Research Testing Råmaterialer	Mon 17.03.14	Fri 28.03.14
26	Research Eksisterende system FMC	Mon 03.03.14	Fri 28.03.14
27			
28	**Forberede intervjuer**	**Mon 03.03.14**	**Mon 31.03.14**
29	Definere bedrifter vi skal intervjue	Mon 03.03.14	Mon 03.03.14
30	Lage en struktur for intervjuene	Tue 04.03.14	Fri 07.03.14
31	Lage en forpresentasjon av gruppen	Mon 10.03.14	Wed 12.03.14
32	Få forpresentasjonen godkjent av FMC	Thu 20.03.14	Thu 20.03.14
33	Lage intervjuguide	Thu 13.03.14	Fri 21.03.14
34	Få intervjuguide godkjent av FMC	Fri 28.03.14	Fri 28.03.14
35	Lage multiple choice spørsmål	Mon 24.03.14	Thu 27.03.14
36	Få multiple choice spørsmål godkjent	Thu 27.03.14	Thu 27.03.14
37	Bestille reiser	Mon 31.03.14	Mon 31.03.14
38			
39	**Gjennomføre intervjuer**	**Mon 07.04.14**	**Mon 12.05.14**
40	Reise til Scana	Thu 08.05.14	Fri 09.05.14
41	Reise til Ofar	Mon 07.04.14	Wed 09.04.14
42	Reise til Ringmill	Mon 07.04.14	Wed 09.04.14
43	Reise til Aarbakke	Mon 12.05.14	Mon 12.05.14
44			
45	**Analysere Informasjon**	**Tue 13.05.14**	**Thu 15.05.14**
46	Strukturere og kategorisere informasjon fra in	Tue 13.05.14	Thu 15.05.14
47	Sammenligne intervjuresultater med tidligere	Thu 15.05.14	Thu 15.05.14
48			
49	**Bygge et system**	**Wed 30.04.14**	**Mon 26.05.14**
50	Vurdere kravspesifikasjon	Wed 30.04.14	Thu 01.05.14
51	Definere output sammen med FMC	Fri 02.05.14	Fri 02.05.14
52	Lage en systembeskrivelse	Mon 05.05.14	Fri 09.05.14
53	Bygge system	Mon 05.05.14	Mon 26.05.14
54	Teste system	Tue 20.05.14	Fri 23.05.14
55	Repetere	Mon 26.05.14	Mon 26.05.14
56			
57	**Rapport**	**Mon 05.05.14**	**Fri 30.05.14**
58	Velge rapportmodell	Mon 05.05.14	Tue 06.05.14
59	Fordele skriveoppgaver	Wed 07.05.14	Thu 08.05.14
60	Sammenfatte rapport	Fri 09.05.14	Mon 19.05.14
61	Konklusjon	Tue 20.05.14	Thu 22.05.14
62	Oppsummering	Fri 23.05.14	Thu 29.05.14
63	Innlevering	Fri 30.05.14	Fri 30.05.14
64			
65	**Presentasjon nummer 1**	**Mon 27.01.14**	**Tue 18.02.14**
66	Analysere krav fra sensor	Mon 27.01.14	Mon 27.01.14
67	Booke rom	Tue 28.01.14	Tue 28.01.14
68	Kalle inn alle relevante personer	Wed 29.01.14	Wed 29.01.14
69	Bygge innleveringsdokumentasjon	Thu 30.01.14	Thu 13.02.14
70	Levere dokumentasjon til sensor	Fri 14.02.14	Fri 14.02.14
71	Fordele presentasjonsfokus	Thu 30.01.14	Fri 31.01.14
72	Lage power point presentasjon	Mon 03.02.14	Sun 16.02.14
73	Generalprøve	Mon 17.02.14	Mon 17.02.14
74	Presentasjon	Tue 18.02.14	Tue 18.02.14
75			
76	**Presentasjon nummer 2**	**Thu 13.03.14**	**Fri 11.04.14**
77	Analysere krav fra sensor	Thu 13.03.14	Thu 13.03.14
78	Booke rom	Fri 14.03.14	Fri 14.03.14
79	Kalle inn alle relevante personer	Mon 17.03.14	Mon 17.03.14
80	Bygge innleveringsdokumentasjon	Tue 18.03.14	Mon 07.04.14
81	Levere dokumentasjon til sensor	Tue 08.04.14	Tue 08.04.14
82	Fordele presentasjonstemaer	Mon 24.03.14	Mon 24.03.14
83	Lage power point presentasjon	Tue 25.03.14	Wed 09.04.14
84	Generalprøve	Thu 10.04.14	Thu 10.04.14
85	Presentasjon	Fri 11.04.14	Fri 11.04.14
86			
87	**Presentasjon nummer 3**	**Fri 02.05.14**	**Wed 04.06.14**
88	Analysere krav fra sensor	Tue 27.05.14	Tue 27.05.14
89	Booke rom	Fri 02.05.14	Fri 02.05.14
90	Kalle inn alle relevante personer	Fri 02.05.14	Fri 02.05.14
91	Fordele presentasjonstemaer	Tue 27.05.14	Tue 27.05.14
92	Lage power point presentasjon	Wed 28.05.14	Tue 03.06.14
93	Generalprøve	Mon 26.05.14	Wed 04.06.14
94	Presentasjon	Wed 04.06.14	Wed 04.06.14



Project: Gant diagram
Date: Thu 08.05.14

Task | Milestone | Project Summary | External Milestone | Inactive Milestone | Manual Task | Manual Summary Rollup | Start-only | Deadline
Split | Summary | External Tasks | Inactive Task | Inactive Summary | Duration-only | Manual Summary | Finish-only | Progress

Requirement Specification

Rev	ECN No.	Date	Reviewed By	Approved By	Status
B	N/A	25.05.2014	Nils Olav Huseby	Erlend Lindhartsen	Released

Summary:

This requirement specification will cover the *Requirements* to our system. These are defined with a specific measurable, owner, and priority.

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Abbreviations and definitions

Abbreviation / definitions	Description
DWG	**Drawing**
N/A	**Not Applicable**
TST	**Test Procedure**
WAS	**Well Access Systems**

Table 1, Abbrevatians and definitions

Reference documents

Document name	Description
Raw material drawing requirements	
ADM0003	Test specification
Web References	**Description**
Books	
Ukjent forfatter, «Veiledning for bacheloroppgaven for bachelor I ingeniørfag Kongsberg», HIBU, 2013	
O.H.Graven and T.Strøm, «Prosjekthåndbok», HIBU, 2013	

Table 2, Reference documents

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1.0 Scope

This document forms the basis for this bachelor thesis. Any changes to any of the requirements need to be approved by the *Owner* of the requirement.

The thesis is based on the challenge regarding raw material *DWG* for forged components within the WAS department. This could typically be Riser joints, or other riser products that are exposed to high fatigue utilization.

All requirements are a product of this statement:
– ***Should FMC or raw material supplier make the raw material drawing?***

1.1 Brief Description of Product

Our system should secure quality in all places of the delivery chain, and make the processes related to raw materials at FMC more efficient.

2.0 Document History

Revision	Description	Date	Sign
00	Created document	20.01.14	NOH
A	Released document	13.02.14	NOH
01	Updated document with new layout	22.05.14	NOH
B	Released document	25.05.14	NOH

Table 3, Document history

2.1 Order of Precedence

In the event of conflict between proposed requirements, the order of precedence is:

- Requirements set, and owned by our customer (FMC)
- Functional requirements
- Non-functional requirements

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3.0 Requirements

3.1 Functional Requirements

3.1.1 The system must give a clear output regarding who should make the raw material drawings for FMC.

- **Owner: Per Inge Myrann**

Atm. this is not clearly defined. Sometimes FMC makes the drawings, while other times, the supplier of the raw material will make the raw material drawing.

3.1.2 The system must decrease the lead time by 10%

- **Owner: Per Inge Myrann**

The typical lead time for raw materials is about 20 weeks, or more. Reducing the lead time will be one of the main goals with this project.

3.1.3 The system must decrease the product price by 5%

- **Owner: Group**

A requirement is to reduce the price of the product. This should be a consequence of better specifications from FMC.

3.2 Non Functional Requirements

3.2.1 The system must remove all concession request

- **Owner: Group**

By specifying the drawings/specifications better, all concession request's should be avoided. These are a very big "time thief".

3.2.2 The system must secure the safety of the workers

- **Owner: Group**

Whoever makes the raw material drawings, should take the safety of the workers in consideration. Especially handling is one of the big challenges here, since all parts weight more than 20kg

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3.2.3 The system must gather all stakeholders interests

- **Owner: Nils Olav Huseby**

  There are a lot of stakeholders to the product; FMC's customer (Etc. Statoil or Total), the forge, the manufacturing plant, FMC's material department (material properties/material testing), FMC's designers (geometry).

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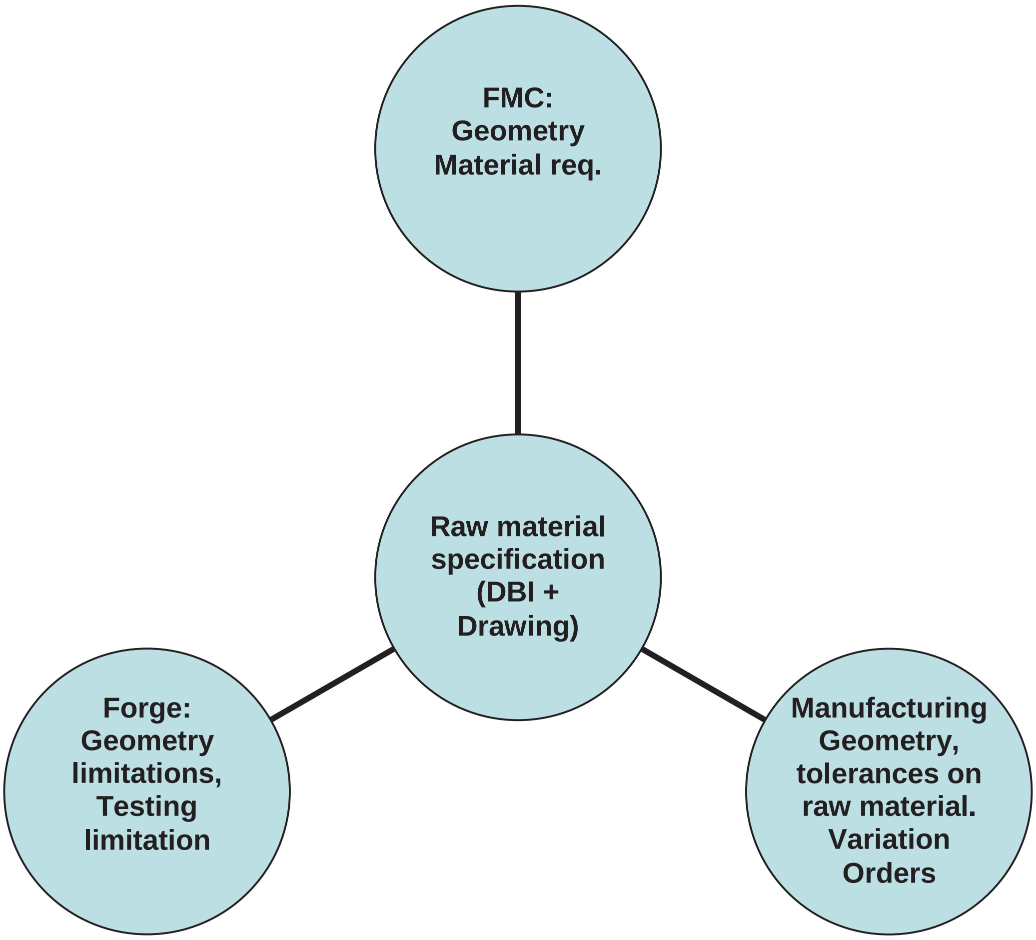

Figure 1, Stakeholders

4.0 System Testing

- System will be tested according to ADM0003 (Test specification)
- The test procedure contains both verification and validation of the system.

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Test specification

Rev	ECN No.	Date	Reviewed By	Approved By	Status
B	N/A	25.05.2014	Erlend Lindhartsen	Morten Mikalsen	Released

Summary:

This test specification will cover the testing of our system, which will be in accordance to the *requirement specification.*

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Abbreviations

Abbreviation	Description
HSE	Health Safety and Enviroment

Table 1, Abbreviations and definitions

Reference documents

Document name	Description
TECH0001	Requirement specification

Table 2, Reference documents

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1.0 Scope

This document will cover the testing, and strategy behind the testing of our system.

2.0 Document History

Revision	Description	Date	Sign
00	Created document	04.04.14	NOH
A	Released Document	09.04.14	NOH
01	Updated with new layout	12.05.14	NOH
B	Released Document	25.05.14	NOH

Table 3, Document history

3.0 Test Strategy

1. We will build/test our system with 2 week intervals.

2. The testing will be done by verifying that our system is functioning correctly by using sub suppliers for FMC, and validating our information/test results with FMC, to see that we are building what our customer wants.

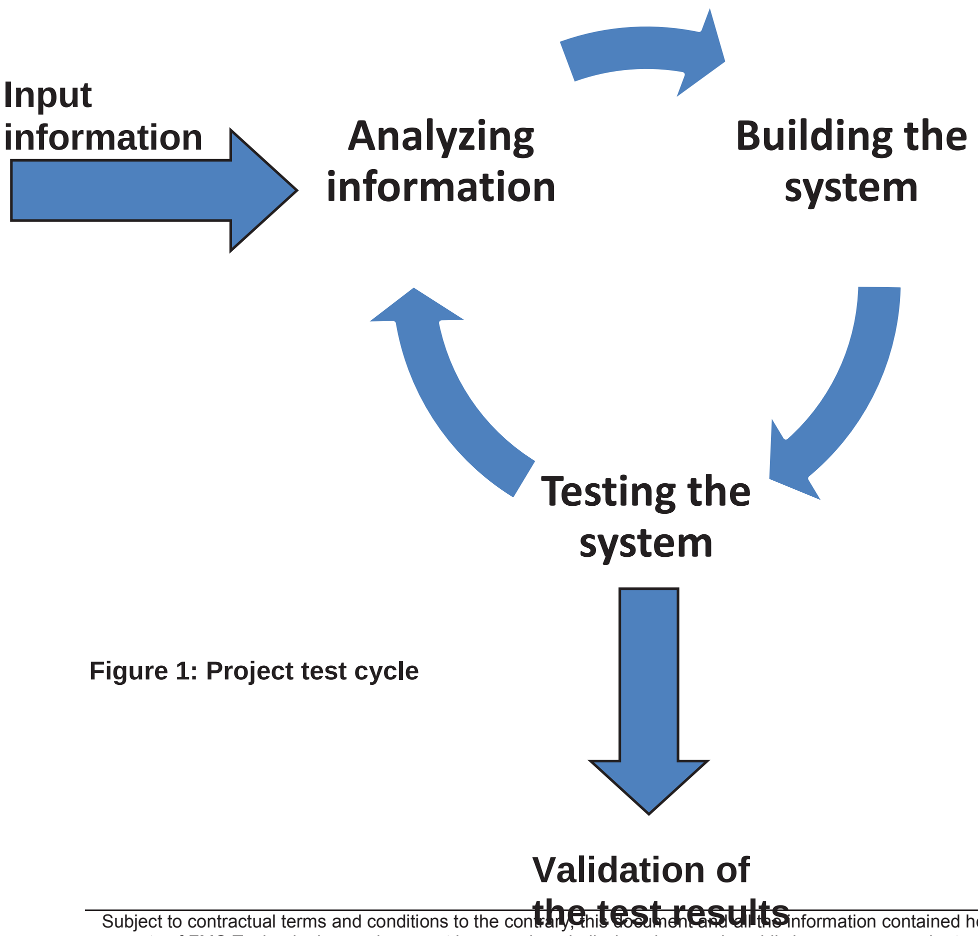

Figure 1: Project test cycle

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4.0 Testing

4.1 Requirements

Table 4: Requirements from Requirement specification

		Req Class	Owner
3.1.1	The system must give a clear output regarding who should make the raw material drawings for FMC	Main requirement	Per Inge Myrann
3.1.2	The system must decrease the lead time for raw materials by 10%	Functional requirement	Per Inge Myrann
3.1.3	The system must decrease the final price of the product by 5%	Functional requirement	Group
3.2.1	The system must remove all concession requests from our sub suppliers	Non-functional requirement	Group
3.2.2	The system must secure the safety of the workers	Non-functional requirement	Group
3.2.3	The system must gather all stakeholders interests	Non-functional requirement	Nils Olav Huseby

Table 5, Requirements from Requirement specification

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4.2 Test Procedure

4.2.1 In project test

1. The system must give a clear output regarding who should make the raw material drawings for FMC

   a) This will be tested by comparing hours spent internally and externally, and a conclusion based on feedback from FMC and Suppliers

2. Our system should remove all concession requests from our sub suppliers

   a) This will be tested by sending a proposal of the project to the sub supplier. Main parameters will be as follows:

      (i) If implemented, how many % will this system decrease the need of concession requests?

      (ii) If less than 100%, any improvement proposals?

3. Our system should decrease the final price of the product by 5%

   a) This will be tested by sending a proposal of the project to the sub supplier, and the output of test number 1. Main parameters will be as follows:

      (i) If implemented, how much can this potentially reduce the final cost of the product?

      (ii) If less than 5%, what can be done to improve further?

4. Our system must decrease the lead time for raw materials by 10%

   a) This will be tested by sending a proposal of the project to the sub supplier, and the output of test number 1. Main parameters will be as follows:

      (i) If implemented, how much can this potentially reduce the lead time of the product?

      (ii) If less than 10%, what can be done to improve further?

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5. Our system must secure the safety of the workers

   a) This will be tested by involving the HSE responsible at the suppliers, and HSE personnel at FMC.

      (i) If implemented, will this have any safety impact?

4.2.2 Post project test

1. This system can be tested post project to verify the in project test's. This can be done by comparing similar products before, and after implementation of the system. Main

   a) Lead time

   b) Price

   c) Number of concession request's

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Appendix A – Test results

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Test results

Supplier A	**2(i)**	**2(ii): Measures and comments**
20.05	$\approx 30\%$	Sub supplier A was ambiguous on this question. They claimed that the number of CR would go down if the raw material drawing is sufficient to they're standard, but the number of CR would not disappear completely.
22.05	$\approx 100\%$	Sub suppliers should be involved earlier in the process, and the drawing must be approved before it's released
Supplier B	**2(i)**	**2(ii): Measures and comments**
20.05	$\approx 30\%$	Sub supplier B was ambiguous on this question. They claimed that the number of CR would go down if the raw material drawing is sufficient to they're standard, but the number of CR would not disappear completely.
22.05	$\approx 100\%$	Sub suppliers should be involved earlier in the process, and the drawing must be approved before it's released
Supplier C	**2(i)**	**2(ii): Measures and comments**
20.05	$\approx 30\%$	Sub supplier C was ambiguous on this question. They claimed that the number of CR would go down if the raw material drawing is sufficient to they're standard, but the number of CR would not disappear completely. Most of the CR are not related to raw material drawings.
22.05	$\approx 100\%$	Sub suppliers should be involved earlier in the process, and the drawing must be approved before it's released
Supplier D	**2(i)**	**2(ii): Measures and comments**
24.05	N/A	Sub supplier A was ambiguous on this question
24.05	N/A	

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Supplier A	**3(i)**	**3(ii): Measures and comments**
22.05	$\approx 0\%$	Supplier A makes in all cases new raw material drawings
23.05	$> 5\%$	With earlier involvement in the process
Supplier B	**3(i)**	**3(ii): Measures and comments**
22.05	$\approx 0\%$	Supplier B makes in all cases new raw material drawings
23.05	$> 5\%$	With earlier involvement in the process
Supplier C	**3(i)**	**3(ii): Measures and comments**
22.05	$\approx 0\%$	Supplier C makes in all cases new raw material drawings
23.05	$> 5\%$	With earlier involvement in the process
Supplier D	**3(i)**	**3(ii): Measures and comments**
22.05	$\approx 0\%$	Supplier D makes in all cases new raw material drawings
23.05	$> 5\%$	With earlier involvement in the process
Supplier A	**4(i)**	**4(ii): Measures and comments**
24.05	$\approx 0\%$	A raw material drawing cannot reduce delivery time. Making the drawing takes maximum two days.
25.05	$> 50\%$	By standardizing locations for test specimens in prolongations, equals a reduction in delivery time by potentially 50% or more
Supplier B	**4(i)**	**4(ii): Measures and comments**
24.05	$> 0\%$	A raw material drawing cannot reduce delivery time. Making the drawing takes maximum two days.

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25.05	$> 50\%$	By standardizing locations for test specimens in prolongations, equals a reduction in delivery time by potentially 50% or more
Supplier C	**4(i)**	**4(ii): Measures and comments**
24.05	$> 0\%$	A raw material drawing cannot reduce delivery time. Making the drawing takes maximum two days.
25.05	$> 50\%$	By standardizing locations for test specimens in prolongations, equals a reduction in delivery time by potentially 50% or more
Supplier D	**4(i)**	**4(ii): Measures and comments**
24.05	$> 0\%$	A raw material drawing cannot reduce delivery time. Making the drawing takes maximum two days.
25.05	$> 50\%$	By standardizing locations for test specimens in prolongations, equals a reduction in delivery time by potentially 50% or more

Post project test

This is not applicable for FMC

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Concept Evaluation

Rev	ECN No.	Date	Reviewed By	Approved By	Status
A	N/A	20.05.2014	Erlend Lindhartsen	Nils Olav Huseby	Released

Summary:

This document is a description of the process we have used to select suiting concepts for us, in the process of creating our system.

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Abbreviations and definitions

Abbreviation / definitions	Description
Manufacturing	Means the process of machining the part.
VOR	Variation order request
RFQ	Request For Quotation
ECN	Engineering Change Notification
SRM	Supplier Relationship Management
CPI	Customer Provided Item
FAST	Function Analysis System Technique

Table 1, Abbreviations and definitions

Reference documents

Document name	Description

Table 2, Reference documents

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Selection of concepts

1.0 Scope

This document is the basis for the selection of the concepts we have chosen.

2.0 Document History

Revision	Description	Date	Sign
00	Created Document	20.05.14	NOH
A	Released Document	25.05.14	NOH

Table 3, Document History

3.0 Evaluation of concepts in regards to the system

We have made a FAST diagram to define the higher order function of the system, and the how / why's. This is because we wanted a clear definition to each and every function of the system.

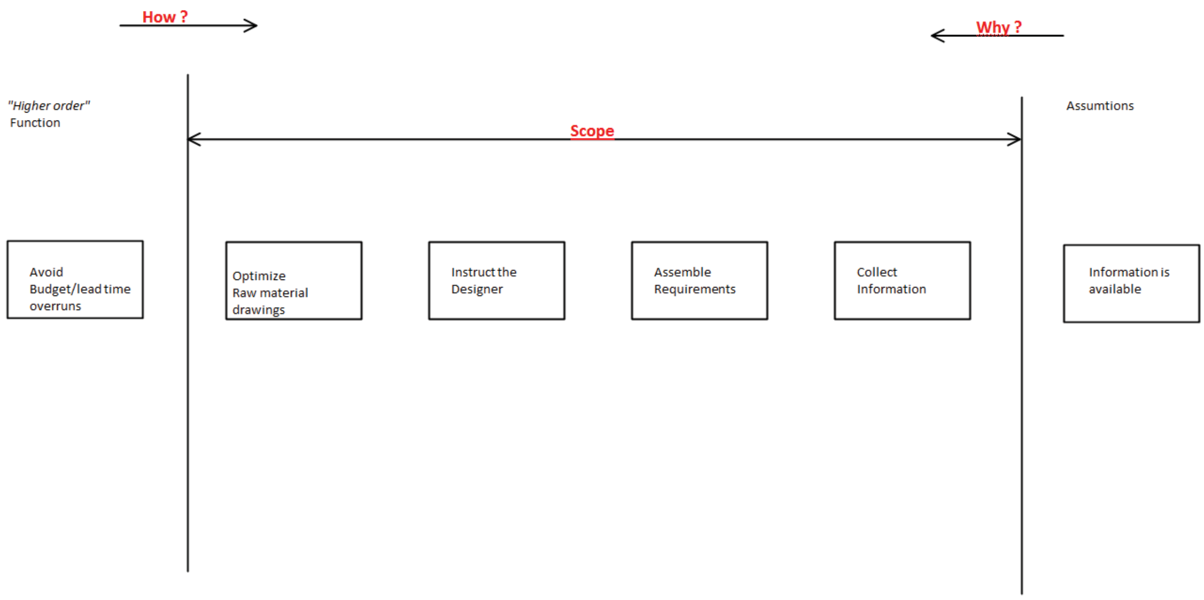

Figure 1, FAST diagram

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We have three different concepts for evaluation regarding the basic fundamentals of the system. This is also a concept definition that will give a clear answer to Requirement number 1 in the requirement specification: "The system should give a clear output regarding who should make the raw material drawings"

3.1 Concepts for system:

	Description
1	**FMC makes all the raw material drawings, including process drawings for the suppliers, and the suppliers approve them.**
	Pros: - FMC has full control of the whole process. Cons: - The process is very different from supplier to supplier, and this will require a very in-depth competence about the process and suppliers.
2	**The suppliers make all the raw material drawings for the full process, based on the final geometry, and FMC approves them.**
	Pros: - The suppliers can make their custom process for this part in particular, and they will know that it is a good approved process. Cons: - FMC still needs to spend a lot of time approving these drawings. - The drawings are not reusable between the different suppliers for different projects - If the final geometry is updated with an ECN, this will not be automatically communicated through SRM. And the supplier document (Drawing) will not be shown as an affected drawing of the ECN. - Final geometry needs to be finished before sending an RFQ.
3	**FMC makes the raw material drawing as a Semi-finished geometry, and the suppliers make all the process drawings.**
	Pros: - FMC can send a RFQ on the same "as delivered" geometry to all suppliers of raw materials. - The semi-finished geometry will give a better predictability to how the raw material

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	looks like when it arrives to the machining supplier if delivered as a CPI. - Will avoid VOR's from suppliers that get a raw material with unexpected amounts of stock material. - This is a proven approach, because most other suppliers use it with great results. - Drawings can be reused for the same parts. - RFQ to raw material suppliers can be sent out a lot earlier, with extra added stock material, which allows for design freedom on the finished geometry. Cons: - Requires more knowledge from FMC to create these drawings. - Will be hours invested at FMC that might not reduce the price, since suppliers most likely want to make their own drawings anyway.

Table 4, Concepts for system

From these three concepts, we can see that it is definitely concept number 3 that has the most pros compared to cons.

Additionally this was the concept that most other customer use, and is therefore a "proven process".

The main benefit with this concept is that FMC can order the raw materials much sooner, as long as the finished geometry is within the "envelope" of the raw material.

4.0 Concepts for the system design

A brainstorming and elimination of most concepts defined these five concepts as the ones we wanted to investigate further.

	Description
1	**Make a design guideline that the engineers/designers at FMC can use for designing the raw material drawings.**
	Pros: - Everybody can use it, and it is widely available - Can be updated, and be a great way of spreading new information - Easy to use and relate to. - Good as a reference document in discussions

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	- Can be used to identify special cases which requires more focus Cons: - May be challenging to cover all cases, and it might be difficult to find a guideline that will be suitable for all suppliers.
2	**Make a template for a drawing**
	Pros: - Eliminates designing hours for raw material drawings Cons: - Will be more or less impossible to cover all kinds of different designs, and special cases
3	**Hire a consultant or representative from the suppliers to have a course at FMC to teach the engineers and designers all the considerations needed**
	Pros: - Designers and engineers will learn from somebody with first-hand experience on the subject. Cons: - Might give very supplier specific information and considerations - Will only give a temporary enhancement of the competence in the subject - Could be costly
4	**Video Course for the engineers and designers**
	Pros: - Could be an online course for everybody that is interested to attend - Can easily be updated Cons: - Requires a huge amount of hours to create - Cannot be used as a reference when actually designing.
5	**Checklist**
	Pros: - Can have very clear questions with Yes / No answers - Will secure that the designer has remembered everything Cons:

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	- Difficult to explain a lot of the considerations with a checklist. Designing a raw material drawing would typically require more than yes/no questions - Can just as well be implemented into a guideline - Suits better as a supplement for the other systems

Table 5, Concepts for system design

We have for our system chosen to use a Design Guideline, combined with a checklist, as we believe this will be a long term sustainable system, compared to the other concepts of systems.

We believe that the system we develop will have potential to be used for a long time, but will require continuous adjustments according to feedback from the suppliers.

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