University of
Stavanger

Faculty of Science and Technology

MASTER'S THESIS

Study program/ Specialization: Industrial Economy – Project Management	Spring semester, 2014 Restricted access
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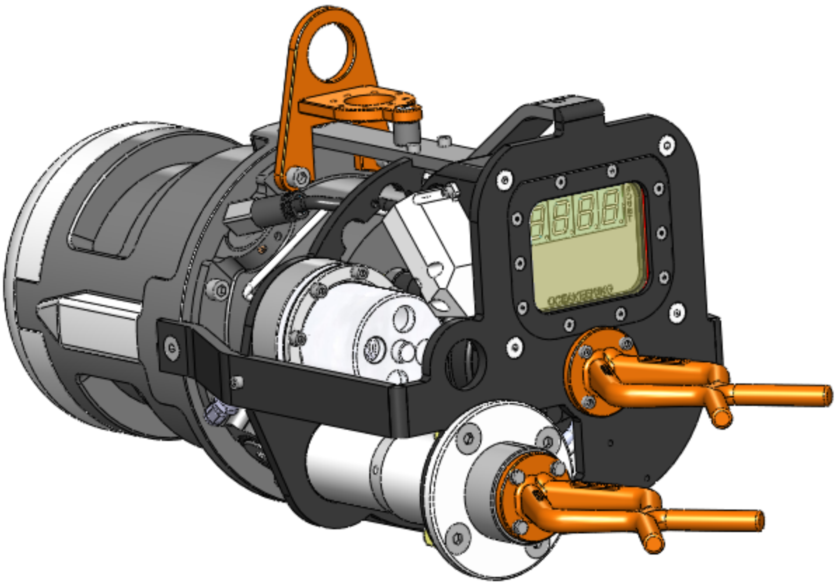
Title of thesis:
Concept study of torque feedback implementation for Oceaneering torque tool

Credits (ECTS): 30

Key words: Concept study, subsea torque tool, Oceaneering, torque feedback, FEM analyses, Ansys	Pages: 97 + enclosure: 69 Stavanger, 12.06.2014 Date/year



Concept study of torque feedback implementation for Oceaneering torque tool

Written by Erik Eide

Master Thesis, Spring 2014
Industrial Economics

University of Stavanger

Abstract

As per now, Oceaneering does not have a 38 000 Nm torque tool with torque feedback for subsea application. As one of Oceaneerings competitors delivers this type of tool with torque feedback within +/- 10 % accuracy, it is essential for Oceaneering to develop a functioning reliable tool with higher accuracy to be able to regain lost market share for these products. The objective of this thesis has been to develop an alternative concept to an already existing concept for torque feedback. Testing of an old 17 000 Nm torque tool with the existing concept revealed high deviation in accuracy (+/- 20 %) which is not acceptable. The condition of the strain gauges in the tool is unknown.

Several concepts were evaluated during concept phase. The concept with the assumed highest accuracy was not chosen as it was estimated to be too expensive to develop and produce. The chosen concept was a new idea and no similar solutions were found during research. Both HBM and Scansense found the concept very exciting and interesting.

Further, FEM analyses of the new concept and the existing concept were performed to determine the accuracy regarding strain distribution in the geometry. Due to the torque tool planetary gear system, the strain distribution changes with the position of the gear. For this reason, the torque feedback concept design has to be minimally affected by this effect. The target accuracy was set to +/- 5 % of read value.

The results from the analyses of the existing concept revealed more accurate results than first anticipated based on the test results from the existing tool with torque feedback. The results showed a deviation of 0.7 % between the gear simulated in position one and position two, and a deviation of 1.7 % between the gear simulated in position two and position three. These results are within accuracy target and it is recommended to perform additional analyses in different positions and to further investigate the condition of the existing tool.

The results from the analyses of the new concept are promising. The same positions as for the existing concept were analyzed and the accuracy was 0.3 % for both positions. The theory the concept is based on adds up with the analyses results, and these results deliver a higher accuracy than the existing concept. Due to the low cost associated with investigating the existing tool and equip it with 8-10 strain gauges to achieve higher accuracy, this is recommended.

Some technical challenges do exist regarding use of strain gauges for subsea application. However, Termo Tight does have experience with use of polypropylene for molding the strain gauges. As long as the strain gauges are exposed to hydrostatic pressure, these issues will be present independently of the concept.

As a result of this thesis, two valid concepts have been investigated and issues regarding strain gauges for subsea use have been revealed. With this work as basis, Oceaneering will have a very good starting point for developing a functioning solution for a torque tool with torque feedback.

Preface

This report is my master thesis of the master program in industrial economics at the University of Stavanger. The concept development of this thesis was challenging in itself, as the objective was to develop a concept solution for torque feedback function. With minimal experience in Ansys Workbench, this turned out to be a tremendous challenge. The learning curve was steep and the work of simplifying and tweaking the model to give a converged solution was not as straight forward as anticipated. However, it has been an educational process, which has given me a much better understanding of concept development and structural analysis in Ansys.

This project was presented to me through my team leader in Oceaneering AS, Dag Bjåstad. The challenges regarding development of a torque tool with better accuracy sounded exciting and challenging.

The core aim of this thesis has been to modify a class 6/7 torque tool by developing and implementing a torque feedback function concept. The first step was to establish some design concepts. Then a comprehensive study was necessary to investigate where and how the torque feedback function could be implemented. The torque feedback function was based on strain gauges mounted in pre-determined locations optimized for the strain distribution in the transducer ring. My experience as a project engineer in the DTS Tooling department at Oceaneering has been of great benefit in order to use the SolidWorks CAD software. This thesis has also been my first assignment as a structural engineer in the same department. I have gained a good understanding of Ansys and structural analysis, and I will be well prepared for my future work with strength analysis.

I would like to thank both my supervisors, Dag Bjåstad at Oceaneering AS and Associate Professor Ove Mikkelsen at the University of Stavanger. In addition, I would like to thank Zenon Taushanis, principle structural engineer at Oceaneering, for constructive feedback and useful guidance throughout the period of my work. I would also like to thank Jostein Mikal Hageberg, product development lead electronics at Oceaneering, for contributing with his knowledge on strain gauges and electronics in general.

Oceaneering AS deserves an acknowledgment for giving me the opportunity and flexibility for studying for my masters' degree.

I will like to extend my gratitude to my wonderful girlfriend, Linn Underbakke. Thank you for reading through my thesis and correcting my grammar and spelling, and thank you for your invaluable support and encouragement during the past five years as I have been studying part-time for my double degree, beside full time work. Thank you!

Stavanger, June 2014

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Erik Eide

Abbreviations

The abbreviations used throughout this report are listed in the following table:

Abbreviations	
Alu	Aluminum
Assy	Assembly
ccm	Cubic centimeter
GH	Gear housing
HPU	Hydraulic pressure unit
kNm	Kilo Newton meter
N/A	Not applicable / Not available
OAS	Oceaneering AS
Pos	Position
RG	Ring gear
ROV	Remotely Operated Vehicle
SAE	Subsea All Electric (an Oceaneering company. Originally named iFokus and acquired in 2006)
SGB	Strain gauge brick
TF	Torque feedback
TT	Torque tool Cl. 6/7
WF	Weighting factor

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Appendices

Appendix name	Appendix discription
Appendix A	Brainstorming minutes of meeting; concept development
Appendix B	Hand calculations, concept phase
Appendix C	Mark-up drawings
Appendix D	Reaction forces from ring gear and gear housing analysis
Appendix E	Hand calculations, analyses
Appendix F	Results from existing concept analyses
Appendix G	Results from new concept analyses
Appendix H	Ansys analyses files (on attached DVD)

1. Introduction

1.1 Background for the thesis

The background for this thesis is the need of innovative redesign of an existing torque tool combined class 6 and 7. This is a hydraulic driven tool mainly used for operating subsea valves. Oceaneering has in many years produced these tools, but lately the company has lost many sales opportunities due to another competitor on the market offering similar tool with both turn counter and torque feedback.

Subsea All Electric has a torque tool class 7 with both turn counter and torque feedback. This tool can only produce 17 000 Nm of torque and only three items were produced. These tools have not been commercialized, but have only been rented out and have mainly been operated by Oceaneering ROV pilots. The feedback from pilots is that the torque readings are not reliable and this function is therefore not used in operation. The stated accuracy of the tool is +/- 5 % of full scale (+/- 850 Nm).

This history has developed an urge to design a functioning torque tool class 6 & 7 with torque feedback. Due to the gearbox complexity it is desirable to develop a tool with this function based on the existing gearbox design. Due to issues with the existing SAE torque tool with torque feedback, it will be of great interest to study alternative concepts for the torque feedback function.

Oceaneering AS has a field proven torque tool class 7 with an output torque of 38 000 Nm. The target was to implement the concept already used on the SAE tool into the OAS tool. The product development department at OAS has modeled a concept design and the undersigned has done some detail design in order to be able to perform FEM analysis on the tool. This thesis will focus on this concept as an option, but also other alternative concepts will be studied.

It will be essential for Oceaneering to develop a functioning and reliable tool which performs better than the competitors to be able to regain lost market share. The main competitor is an Australian company named Velocious. They recently won the contract for delivering torque tool class 7 to the Åsgaard Gas Compression project. This thesis will hopefully provide useful information regarding alternative concepts to the existing one. The relevant tools are shown in Figure 1, Figure 2 and Figure 3 below:

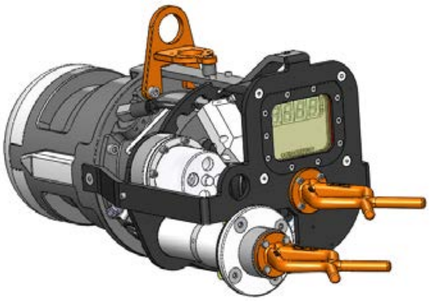


Figure 1: OAS TT

Figure 2: SAE TT

Figure 3: OAS Concept design TT

1.2 Objective

The objective for this master thesis is to study alternative concepts for torque feedback for the Oceaneering class 6 and 7 torque tool. The main objective is to study the existing concept and develop a few other alternative concepts that will be able to deliver torque readings within an accuracy of +/- 5 % of full scale. Many concepts need to be considered before a decision of elaborating a few concepts in further detail.

It is time consuming and expensive to redesign the existing field proven gearbox, and the original gearbox has been through many optimization processes to be as reliable and robust as it is today. For this reason it is desirable for Oceaneering to base the new concept on the existing gearbox design.

The main focus will be on concept study of a few concepts considered to be the most promising regarding to Oceaneerings targets. These targets are mainly associated with accuracy, weight and development and production cost. What the FEM analysis will involve in detail will appear as the concepts are developed.

The thesis will involve design and analysis of the most relevant concepts. The modeling will be performed by use of SolidWorks CAD software, and the FEM analysis will be performed in Ansys Workbench.

My personal objective for choosing this subject is to develop myself in concept design and structural analyses using Ansys Workbench and SolidWorks. The thesis will contribute to my knowledge, and understanding of both these software's. This will be very helpful for future assignments and challenges in my professional life.

1.3 Organization of this study

The thesis is organized with a description of the existing tool and design. This is followed by concept phase were several potential concepts are presented and evaluated. The evaluation process results in a concept which was further developed in detail concept design. FEM analysis is performed on this concept and the already existing concept. From the results, an evaluation and recommendation are presented in the conclusion chapter.

The concept phase continued a bit over the planned time. This made it even more challenging regarding the FEM analyses phase. Long days and many hours was necessary to be able to get it finished in time. With relatively little experience with Ansys, the learning curve was steep, and the work itself was more comprehensive than first anticipated.

Besides the above mentioned, the most challenging part of this thesis has been the research for strain gauges for subsea application. Very little information is available online and very few companies have experience on the field. However, some relevant information was gathered from two strain gauge suppliers located in Norway, namely HMB Norway and Scansense.

1.4 Limitations

A complete product development phase can be divided into five phases; concept development, system-level design, detail design, testing and refinement and production ramp up [1]. This thesis will be limited to the concept development phase and the system-level design.

This is a thesis based on new development and references to external literature will not be extensive.

The needs of the target market are identified and alternative products are generated and evaluated in a product development phase. As a result, a single product is selected for further development. For this thesis, the marked was already identified and the thesis is therefore limited to the product concept. In addition, analysis of the existing concept will be performed. The system-level design phase includes the definition of the product architecture. Complete detail design will not be part of this thesis due to the tool complexity and the workload of this thesis. Some detail design will be necessary in conjunction with the analyses.

Due to the complexity of the tool, simplifications have been necessary to make. Some simplifications regarding the forces acting from the cog wheels have been done and many simplifications to the model geometry have been necessary to achieve a good basis for the FEM analyses. These simplifications are described in detail in the thesis.

Detail dimensions of the tool are considered as sensitive information and are therefore kept out of the thesis whenever possible.

Ansys Workbench does not have the same applicable documentation package as Ansys classic. This is not a thesis about Ansys. For this reason, not every aspect of the software is described and elaborated. However, all the functions used in the software and where they are applied are described.

Many user-defined functions are used in the Ansys analyses. But in regards to the contact set-up, many functions are kept to program controlled. Functions kept to program controlled are as followed: formulation, detection method, penetration tolerances, normal stiffness, update stiffness and pinball region.

This is a thesis based on new development and references to external literature will not be extensive.

1.5 Software

Mainly three software programs have been used in this thesis, namely:

- Solid Works Premium 2012
- Ansys Workbench NLS 15.0
- Mathcad Prime 2.0

All these software's were provided by Oceaneering during the writing of this thesis.

Solid Works Premium 2012:

Solid Works Premium is a comprehensive 3D mechanical CAD (computer-aided design) program that runs on Microsoft Windows. Although the premium version includes add-ins for simulations and design validations, these functions have not been used in this thesis. For this purpose Ansys Workbench has been chosen due to its capabilities and reputation within the academic community of simulations and analyses.

In this thesis, Solid Works has been used to design the different concepts and most simplifications of parts and assemblies' prior Ansys analysis has been performed in Solid Works. Some small simplifications have in addition been performed in Ansys Design Modeler.

Ansys 15.0 Professional Workbench NLS:

Ansys is a software program for FEM-analyses known for its advanced analysis capabilities, but also for its user friendly interface. The license available through Oceaneering is the Professional NLS version. This version supports non-linear mechanical analysis with bi-linear materials. The program is well integrated with the Solid Works CAD program. This allows for easy implementation of Solid Works geometries into the Ansys Workbench platform.

Ansys has been used for the structural analysis on both the existing concept and the new suggested concept. The program was chosen above the Solid Works Simulations due to its capabilities regarding post data analysis, meshing algorithm and opportunities, contacts between parts and non-linearity possibilities. As analysis of assemblies is a vital part of the thesis, this is crucial feature as many contacts are non-linear. In many ways, Ansys workbench is superior compared to Solid Works Simulations.

PTC Mathcad Prime 2.0:

Mathcad Prime 2.0 is the industry-standard software for solving and documenting engineering calculations. Unlike spread shits, word processing and presentation software, Mathcad has the ability to easily display calculations, text, data and images in a single worksheet. [2]

This program is used to calculate and present the hand calculations throughout this thesis.

2 Torque tool description

This chapter will give an introduction to the torque tool class 7. A brief description of where the tool is used, what it does and how it is constructed will be given. This will involve a detailed description of the original tool without torque feedback and the existing tool with torque feedback. In addition, the existing concept will also be elaborated in this chapter.

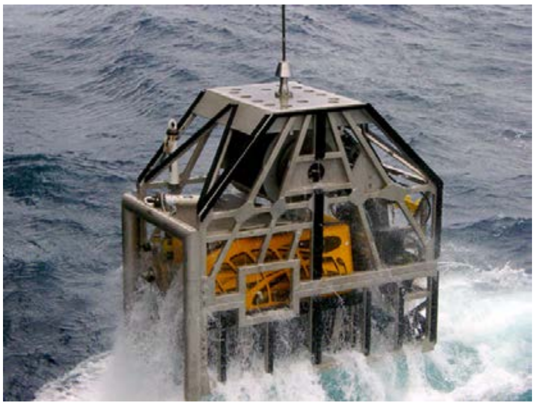
2.1 The purpose of the torque tool

The subsea marked has really escalated over the past 25 years. It is often more cost efficient with subsea installations compared to stationary rigs. At the same time, these solutions create a flexibility which makes it possible to expand the exploration activities in a larger pace than before. The most essential tool for making this possible has been the ROV. It has made it possible to operate deeper and simultaneously eliminate the need of human divers.

ROVs are free-swimming submersible crafts that can be used to perform tasks such as valve operations, hydraulic functions, and other general tasks [3]. One of the most commonly used ROV tools are torque tools. These tools are rated into seven classes, from class 1 to class 7, depending on the maximum torque applicable on valve buckets according to a standard. They are mostly used for override or operation of subsea tree valves, SCM lock down, running tool operations, shackle release and other functions requiring high torque [4].

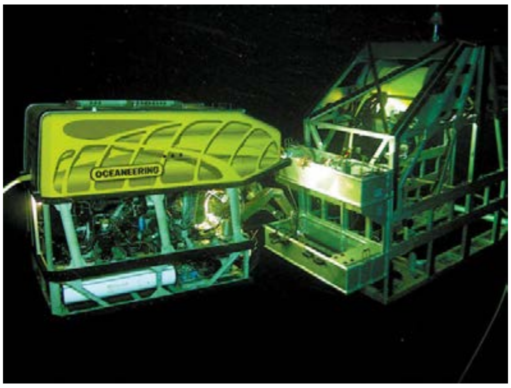
The NORSOK standard U-102 classifies the ROVs into a total of five categories. The class III is the work class vehicles. This ROV class is according to NORSOK defined as “vehicles large enough to carry additional sensors and/or manipulators”.

“A standard ROV system consists normally of a Launch and recovery system (LARS) which is placed on deck, a tether management system (TMS), a control unit and the ROV itself. The LARS handles the TMS with the ROV attached when it is being deployed through the splash zone. The TMS is held by a reinforced umbilical cable which supplies the TMS and the ROV with electrical power and communication lines” [5]. An Oceaneering TMS is shown in Picture 1.



Picture 1: ROV deployed in a TMS (cage type) [6]

“When the ROV arrives at its working depth it is released from the TMS and can then execute its designated tasks. The ROV is powered through an umbilical, called a tether, from the TMS” [5]. The ROV is normally maneuvered by hydraulic driven thrusters. The hydraulic power is generated by a hydraulic power unit installed in the ROV. The control unit can either be a custom made 20 feet offshore container (Picture 3) or an integrated control room on a rig or vessel. Picture 2 shows a submerged ROV behind a TMS.



Picture 2: ROV behind a TMS (cage type) [7]

Picture 3: Control unit (custom container)

The torque tool class 7, which is the class relevant for this thesis, is described in the ISO 13628-8 to have a maximum torque output of 34 000 Nm. These tools are commonly used to operate subsea equipment such as trees, manifolds, control modules and templates, and are suitable for any operation requiring a rotary override [8].

2.2 The reason for implementing torque feedback function

Torque feedback function will allow real time readings for the actual moment produced by the tool. This can either by read directly on the torque tool display or displayed in the control unit if the tool is connected with electrical cable from the tool to the ROV.

There are two main reasons for implementing this function. These are customer requirements and more control over applied torque.

Today’s method is relatively inaccurate and inconvenient. The method is based on supplied pressure only. This is verified by a calibration jig onshore (Figure 4). The tool is docked into the torque analyzer, and different pressure rates are tested and the given torque for each pressure rate is noted.

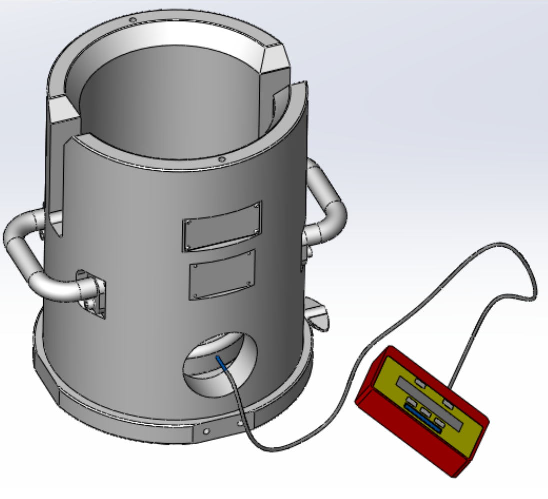


Figure 4: 3D model of Torque analyzer / calibration jig

With torque feedback function, it will still be necessary with torque analyzer. This will be required for calibrating the tool offshore and to be able to verify actual torque if this is required for the operation.

2.3 Description of torque tool class 7 in general

A brief description of the most essential components in a torque tool class 7 relevant for this thesis will be described in this section. The main design driver for the torque tool class 7 is the docking interface. This will be described in the Interfaces section.

All tools on the market are based on planetary gear boxes. These gear systems are chosen for use in the torque tools due to their advantages, such as compact and light weight design with high torque transmission, compared to other gear systems. A basic introduction to planetary gears will be given in the chapter Planetary gears below.

The existing Oceaneering concept for torque feedback is based on the use of strain gauges. This was the concept used in the SAE tool, and it seems like this is the concept used for the Velocious tool as well (see Picture 4: Velocious torque tool in box). How strain gauges can be used for this application will be described in section 2.9.

Planetary gears

The planetary gearbox consists of the following three main components (see Figure 5)

- Sun gear
- Gear carrier and planet gears
- Ring gear

Each of these three components can be the input, output or can be held still. Depending on which component plays which role determines the gear ratio of the gearbox [9]. For torque tool class 7, which produces 38 000 Nm of torque, it is not sufficient with one stage, compared the size of hydraulic motor suitable. The torque tools described in this thesis has all a three stage gearbox to achieve needed ratio.

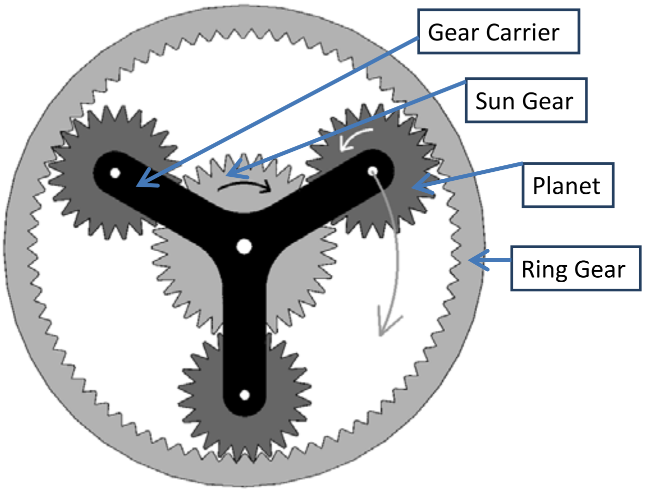


Figure 5: Planetary gear principle

In a three stage planetary gear, the output of stage one becomes the input of stage two, and the output of stage two becomes the input of stage three. Finally, the output of stage three is the torque tool interface.

Advantages with planetary gears:

- Low weight compared to a normal transmission
- High efficiency, high ratio
- Low radial loading
- Compact design

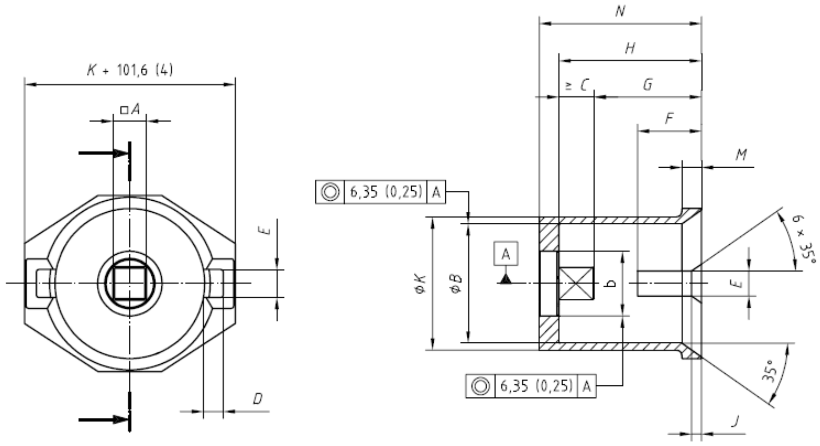
Disadvantages with planetary gears:

- Complicated construction (high requirements for production)
- Higher production costs

Interfaces

The main design driver for the torque tool class 7 is the docking interface. The tool needs to be designed to fit into the interface described in ISO 13628-8: Remotely Operated Vehicle (ROV) interfaces on subsea production systems. This means that there is no part of the actual tool that is described in any standard. The standard only stats the interface dimensions and the maximum torque appliable for the interface.

The receptacle interface shown in Figure 6 consists of a tubular housing with a top mounting plate. The mounting plate consists of two torque reaction slots located 180° apart. The maximum design torque for class 7 is stated to be 33 895 Nm [8]. The maximum torque for most class 7 torque tools are 38 000 Nm due to client requirements. A drawing from the standard is presented below to illustrate the dimensions of the receptacle bucket. The dimensions are stated in the table aside. As we can read from the table, the only difference between the class 6 and class 7 standard is the dimensions for the A square.



a Clearance both ends.
b See Note in Table 4.

	Class 6	Class 7
A square	66.67	88.90
B	243.0	243.0
C min.	89.0	89.0
D	82.25	82.25
E	44.5	44.5
F	178.0	178.0
G min.	222.0	222.0
G max.	228.0	228.0

Figure 6: Dimensions for receptacle (torque bucket)

The interface towards the ROV is normally done by hydraulic subsea connectors, called hot stab (male) and receptacle (female). To lines are needed in the stab system, one for pressure and one for return. The hydraulics is supplied from the ROVs HPU. The maximum appliable pressure from the ROV HPU is normally 207 BAR. Figure 7 shows an Oceaneering dual port receptacle and hot stab.

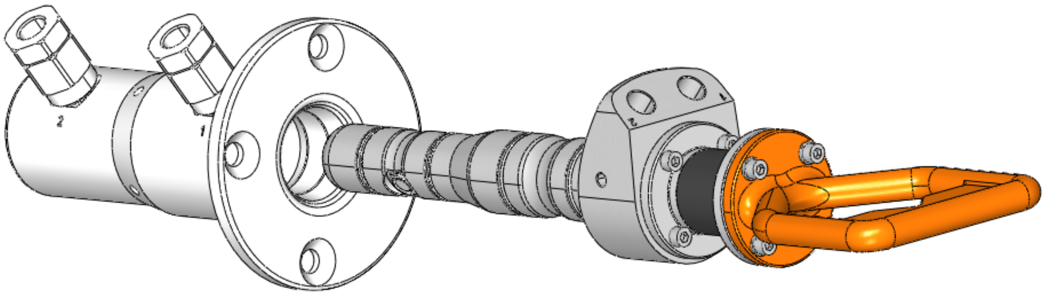


Figure 7: Receptacle and hot stab

Hydrostatic pressure compensator

The planetary gearboxes are filled with oil for lubrication. For the torque tool to withstand the hydrostatic forces from the seawater, the gearbox needs to be compensated. This is normally taken care of by a simple spring loaded piston compensator. The gearbox is pressurized with a slightly overpressure, compressing the compensator spring. When the tool is submerged, the seawater presses on the compensator and the initial differential overpressure is obtained.

Torque sensor

There are only two known torque tools with torque feedback on the market. They are both based on the same principle. This principle will be described briefly in this chapter. The torque sensor is an integrated torque cell positioned between the gearbox and the torque tool reaction fins, giving real time information of applied torque. The Torque cell has strain gauges attached. This device is often called a torque transducer. The strain measured in the strain gauges are processed through a software program which further displays the torque readings on the display. The torque cell is calibrated against a torque calibration unit. Detail description of the torque sensor will be further elaborated in section 2.4.

Other considerations and configurations

Other design considerations need to be taken regarding the ROV handling of the tool, such as weight and size. The tool can be operated fixed to the ROV or it can be handled by the ROV manipulator. The maximum handling weight for the manipulator arm varies and is also dependent on the manipulator working position. Normally a weights over 80 kg in water can be problematic. On older ROVs with only two vertical thrusters, a heavy tool can get the ROV out of its horizontal position. Thrusting with the vertical thrusters will not only contribute to vertical movement, but also horizontal movement, depending on the ROV angle in the water.

In addition, other configurations are often added to the tools to ease the operation. Such configurations can be as followed:

- Interchangeable interfaces to operate different interface classes (class 6 and class 7).
- Interchangeable hydraulic motor alternatives for different torque applications.
- Electronic turn counter and torque sensors. It is only Velocious which offers torque feedback per January 2014. SAE produced three items for rental purposes in the mid-2000.
- Subsea electronic display for turns and applied torque readings

2.4 Detail information of SAE torque tool

In this section the SAE torque tool will be described. The tool is complex and exists of many parts not relevant to understand the functioning of the tool. The main components are shown in Figure 8 and technical data are shown in Table 1 below. There are two interfaces for the ROV, one for horizontal docking and one for vertical docking. This solution is necessary due to the weight of the tool. The ROV will not be able to hold the tool in horizontal position from the vertical interface handle, and vice versa.

A qualification test performed by undersigned in December 2013 revealed large variation in torque feedback accuracy. The variation spanned from close to 0 % deviation to 20 % deviation on torque read from tool and actual torque measured by the torque transducer.[10]

All the 3D models of this tool are based on a step file. This step file is the only 3D material available for this tool.

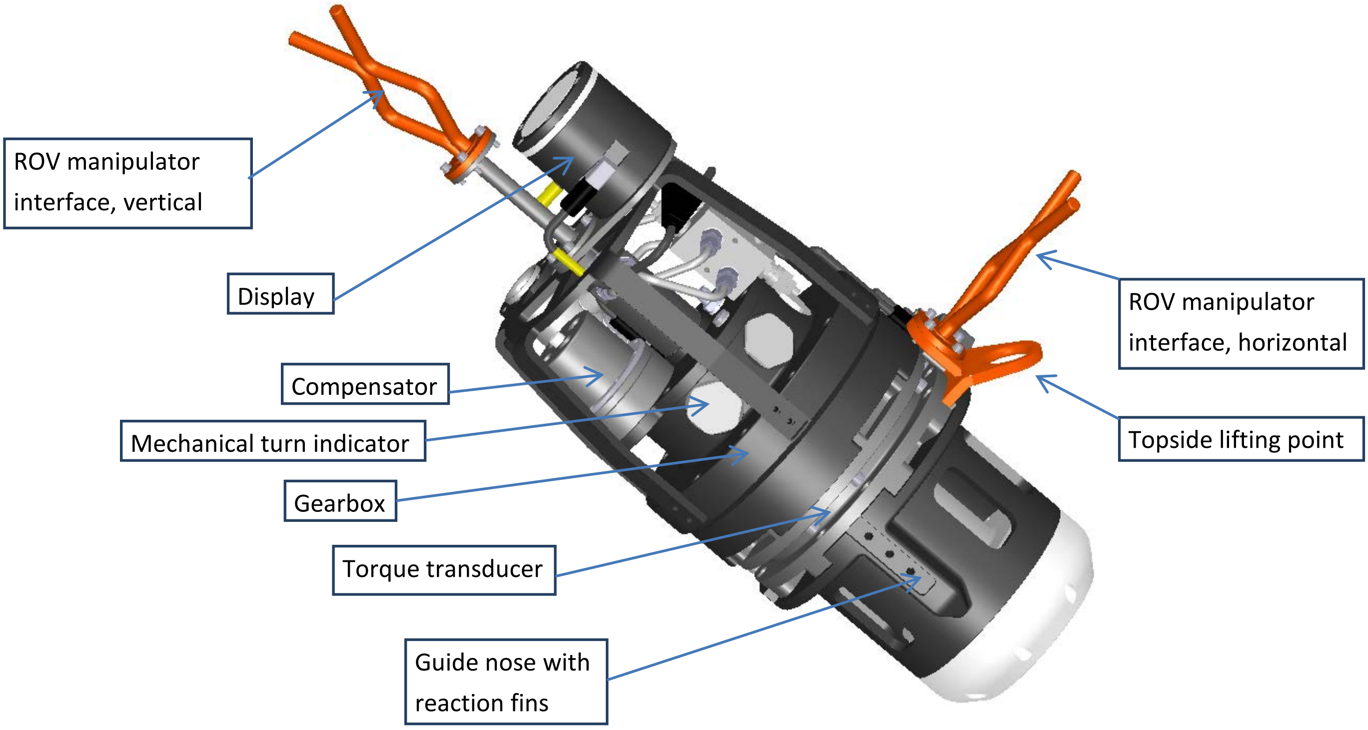


Figure 8: SAE TT main components

Technical data:	
Overall dimension, diameter x length:	Ø386x764mm
Weight (in air / submerged):	75 kg / 52 kg
Max torque, CW and CCW:	17 000 Nm
Depth rating:	3 000 m

Table 1: SAE TT technical data

In addition to the torque feedback, the tool is also equipped with a digital turn counter showing the turns on the display. The tool has also a backup solution for the digital turn counter. This is mechanical turn indicator which shows the rotation of the gear through three plastic glass windows.

Figure 9 shows an exploded view model of the main parts relevant for the mechanical functioning of the tool. Bolts, seals and other parts not relevant to explain the mechanical functioning of the tool is not shown in this figure.

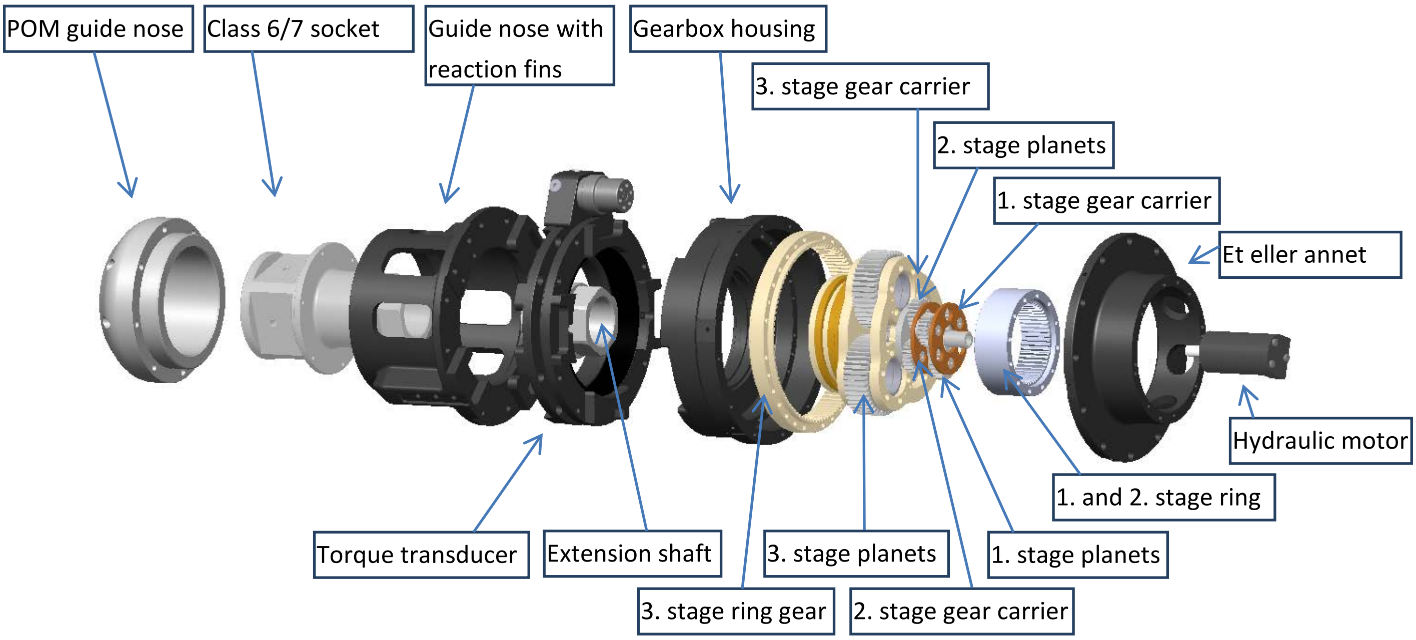


Figure 9: SAE TT exploded view of model

The POM guide nose is the first part which will hit the interface bucket when docking. The material ensures no damage to the bucket coating with impact. The interface is interchangeable between either a class 6 or class 7 sockets. This part is exposed to seawater and the steel quality is 165M stainless steel. The rest of the main structure exposed to seawater is of anodized sea water resistant aluminum of grade 6082 T6. The aluminum is chosen to minimize the weight. The gearbox parts not exposed to seawater consist of a quenched and tempered carbon steel material followed by nitrite hardened surface. The hydraulic motor is a 100 ccm standard motor with coating for corrosion protection.

The torque transducer is designed to be between the guide with reaction fins and the gearbox housing. This design ensures that all the torque will be transferred from the third stage ring gear, through the transducer, and the reaction force will be transferred to the interface bucket from the reaction fins.

Figure 10 and Figure 11 gives an illustration of the gearbox design. The first and second stage of the planetary gear has an individual ring gear which is mounted onto the third stage planet carrier. This design gives a compact design compared with shearing the same ring gear for all the three stages, due to the smaller diameter of the first and second stage ring gear.

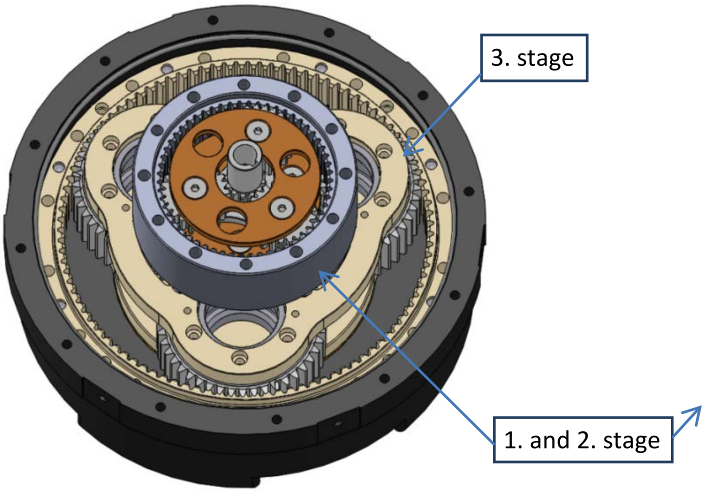


Figure 10: SAE TT gearbox design

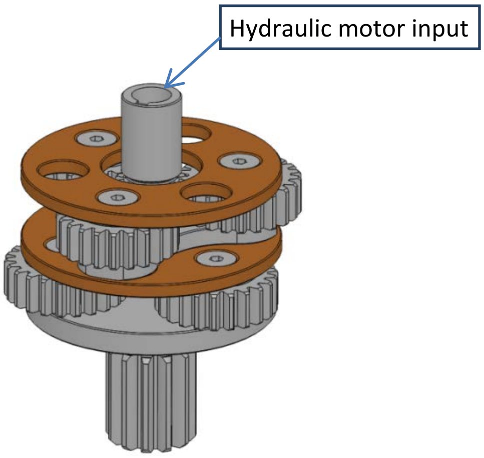


Figure 11: SAE TT first and second stage gear

Figure 12 shows a section cut of the torque transducer. The transducer is designed to have an oil filled compartment where the strain gauges are mounted. The exact number of strain gauges is unknown, but there are either two or four strain gauges mounted with equal spacing. Due to the compartment, a compensator is necessary to compensate for the hydrostatic pressure from the seawater. The compensator itself is connected to the oil filled compartment through drilled channels in a compensator bracket and in the transducer itself.

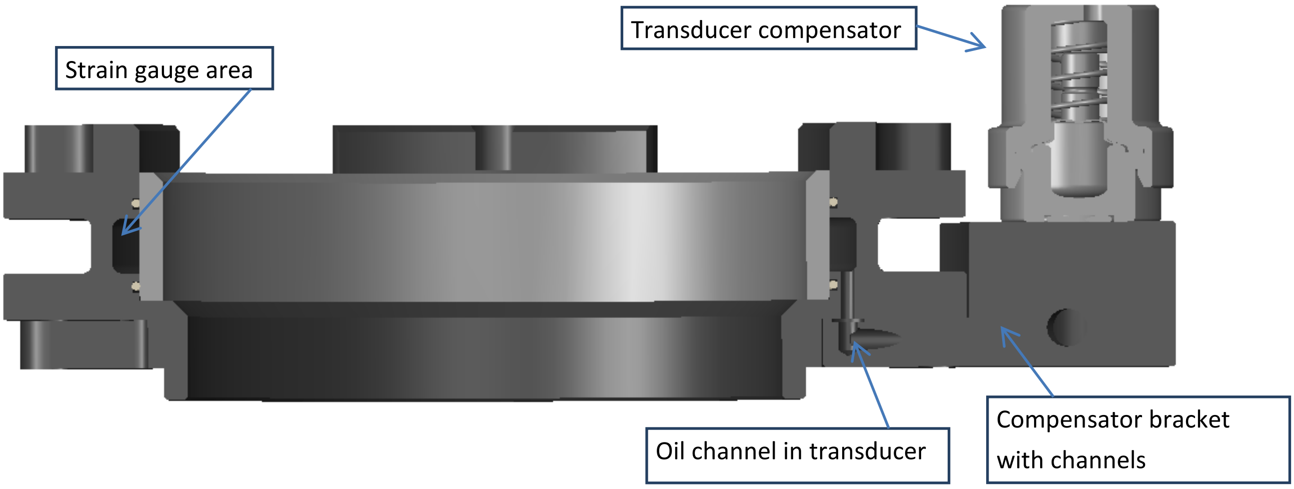


Figure 12: Section cut of torque transducer

2.5 Detail information of OAS torque tool

As for the SAE TT, the brief description of the original OAS tool will be described in this section. The OAS concept for a TT with torque feedback is based on this tool and gearbox system, while the transducer concept is based on the transducer design from the SAE tool. The main components on the tool are shown in Figure 13. As we can see, the model shows a dummy hot stab placed in the receptacle. The function of the dummy stab is to protect any contaminants from getting into the hydraulic lines. Technical data are described in Table 2.

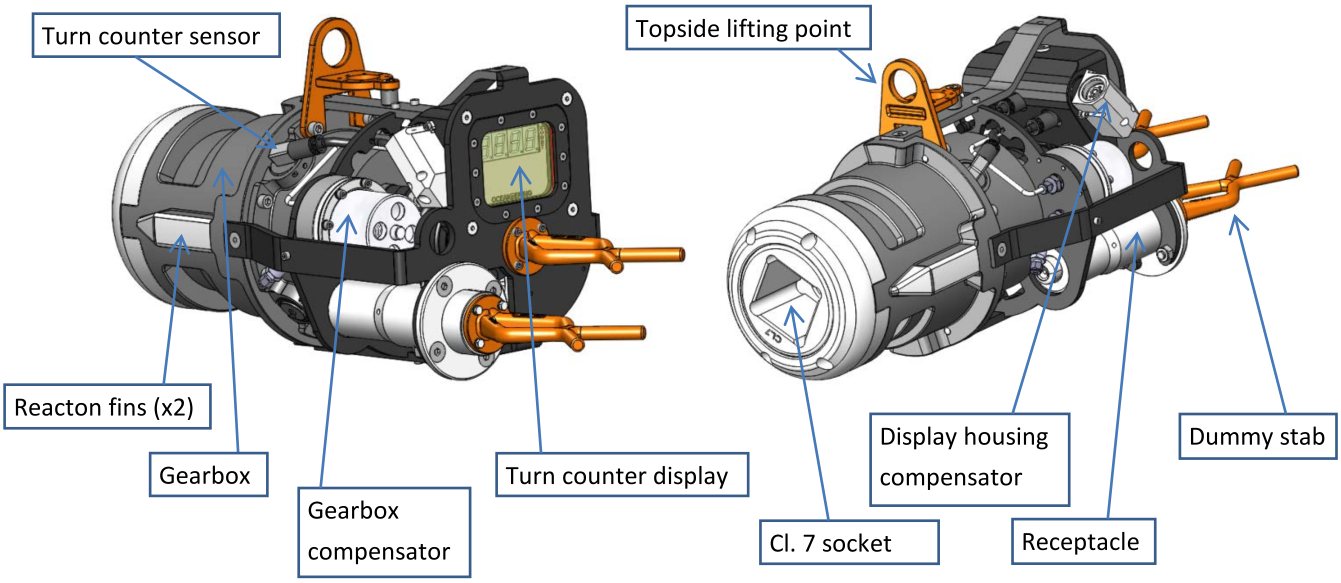


Figure 13: OAS TT main components

Technical data:	
Overall dimension, length x width x height :	736 mm x 380 mm x 474 mm
Weight (in air / submerged):	88 kg / 65 kg
Max torque, CW and CCW:	38 000 Nm
Depth rating:	3 000 m

Table 2: OAS TT technical data

The compensator is connected to the gearbox by stainless steel tubing. In addition to the digital turn counter, this tool does also have a mechanical turn counter for backup. The electrical turn counter uses a magnet sensor which counts magnets on the third stage planet carrier with a magnet sensor. The signal is transferred though an electrical cable. This is illustrated in Figure 14.

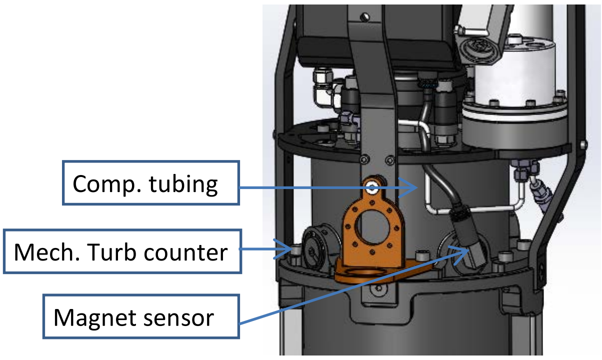


Figure 14: Detail components

Figure 16 will give an illustration of the gearbox design. This gearbox distinguishes itself from the SAE tool mainly by sharing the same ring gear for all the three stages and that the cog wheels for stage three are higher to be able to withstand higher torque (up to 38 000Nm).

Figure 15 is a section cut of the gear box. The figure shows two of three planets. The design is similar with easy changeable interfaces. The tool is driven by a stronger hydraulic motor (200 ccm) to deliver the stated torque. This tool does not have the opportunity of torque feedback.

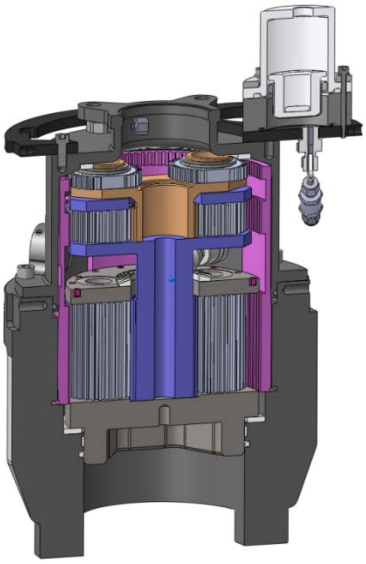


Figure 15: OAS TT Gearbox design

In addition to a higher third stage gear, this design has a mechanical turn counter between the third and the second stage planet carrier. This results in a longer design for this gearbox. The third stage planet carrier does also function as a direct interface for the class 6 or class 7 sockets. Since the design is similar, the ratios over the gears are similar. To be able to produce the required amount of torque, a higher torque input is needed. This is solved by using a 200 ccm hydraulic motor instead of a 100ccm motor. This tool can be delivered as a 17 000 Nm tool. In those cases the tool is delivered with a 100ccm motor. The same materials as for the SAE TT are used for the different parts in the gearbox. Figure 16 shows exploded view of the gear box main parts.

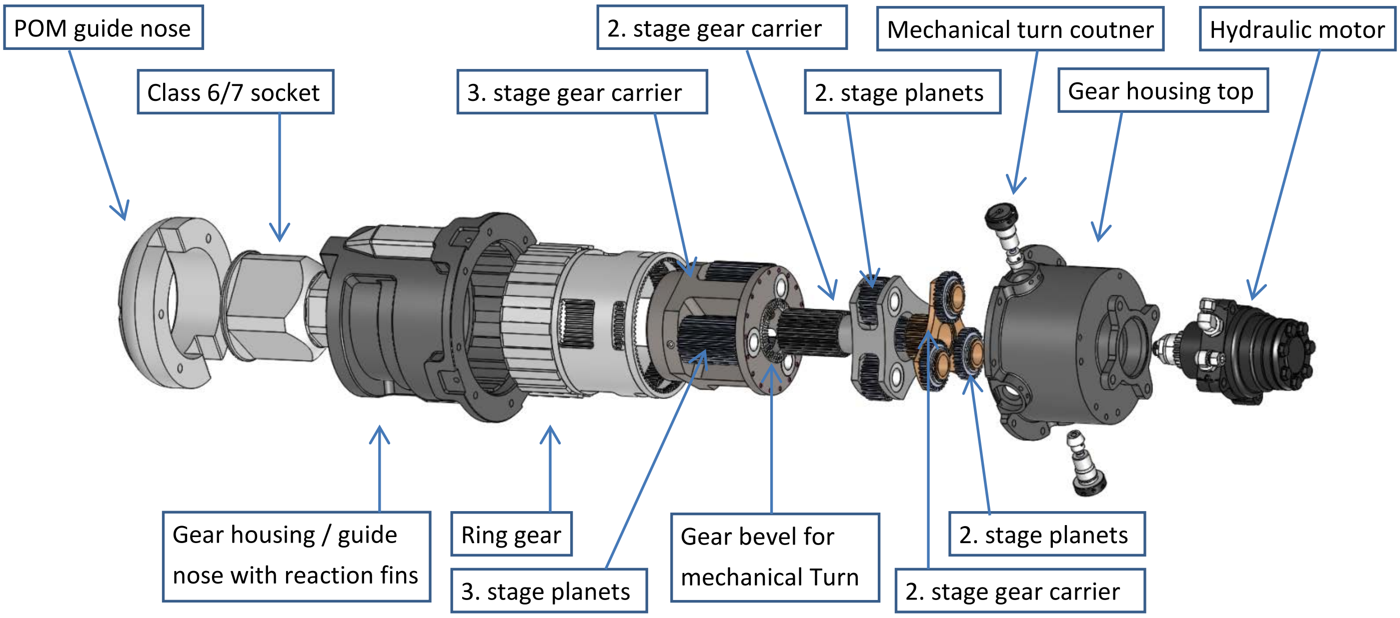


Figure 16: OAS TT exploded view

2.6 Detail information of suggested concept

A brief description of the OAS suggested concept will be outlined in this chapter. The torque transducer design is based on the SAE tool design and the gearbox and tool itself is exactly the same as on an existing torque tool with a torque output of 38 000 Nm. The main components on the tool are shown in Figure 17 and technical data presented in Table 3.

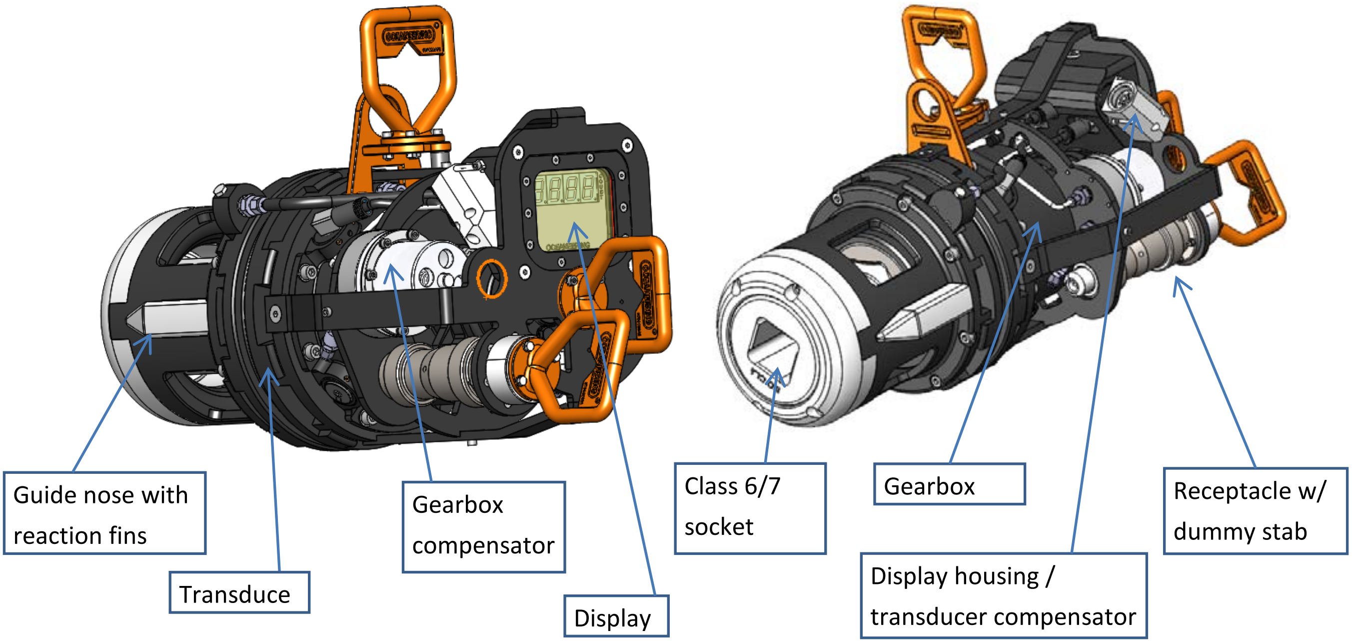


Figure 17: OAS concept design main components

OAS Concept Design Technical Data:	
Overall dimension, length x width x height :	852 mm x 478 x 351
Estimated weight (in air / submerged):	82 kg / 110 kg
Max torque, CW and CCW:	38 000 Nm
Depth rating:	3 000 m

Table 3: OAS concept tool technical data

Figure 18 shows a section cut of the tool. The moment reaction torque travels the same path as for the SAE tool. All the torque passes through the transducer from the tool output interface to the tool reaction fins.

The planetary gear is exactly the same as on the OAS tool. However, the gear housing has been modified to be able to implement the torque transducer.

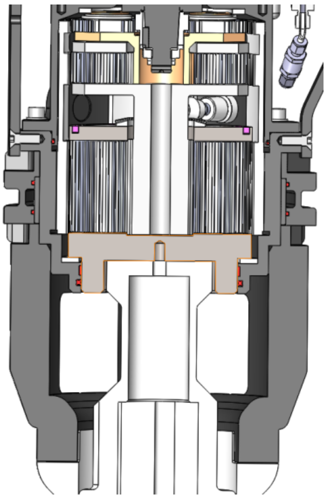


Figure 18: OAS Concept section cut

Figure 19 shows a section cut of the transducer assembly. The strain gauges will be mounted inside a compensated oil filled reservoir. This design differs from the SAE tool by not having a separate compensator. In this design, the volume for the torque transducer is connected to the turn counter housing volume, sharing the same compensator. The design will be more cost effective due to less machined parts. This detail design is done by undersigned.

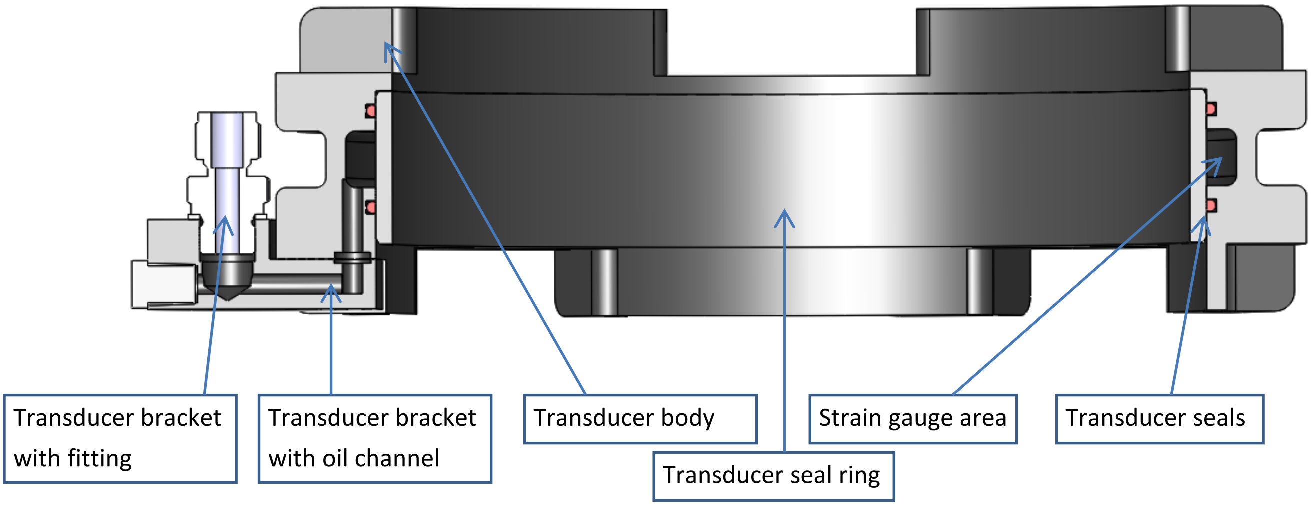


Figure 19: Torque transducer section cut

In Figure 20, the gear box and the parts above it has not been exploded as the rest of the model, hence this part is the same design as for the original OAS torque tool described in the previous section. The figure clearly illustrates the difference in the gear housing design. To implement the torque transducer, it was necessary to split the original gear housing in two parts, making space for the transducer to fit.

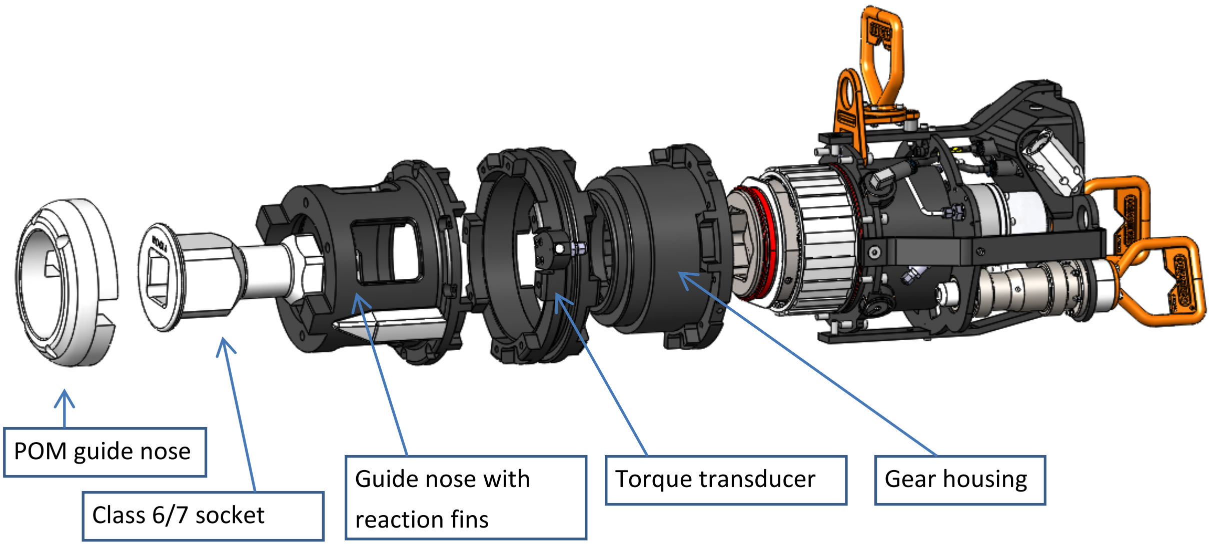


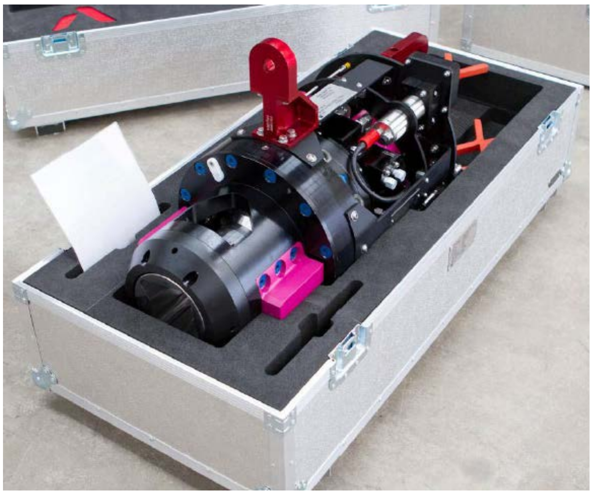
Figure 20: OAS concept design exploded view

2.7 Competitive tool on the marked

The Velocious torque tool class 7 is the only competitive tool on the market. It is also based on a planetary gearbox. The two things that differentiate their tool from Oceaneerings tool is the weight and the torque readout. This tool has the torque feedback in advantage, but the weight is 109 kg in water. This exceeds the ROV manipulator capacity and it is therefore necessary to add buoyancy to lower the weight of the tool in water. The buoyancy is attached to the red lifting lug, as shown on Picture 4 and Picture 5. Technical specifications for the tool are presented in Table 4.

Technical Specifications Velocious torque tool	
Weight in air	140 kg
Weight in water	109 kg without buoyancy 45 kg with buoyancy
Depth rating	3000 m
Torque output	5.000 Nm – 40.000 Nm
Operational temp	-15°C to 45°C
Torque readout accuracy	+/- 10 % FS
Features: Dual simulation display/turn count, low battery warning, automated sleep mode	

Table 4: Velocious TT technical specifications



Picture 4: Velocious torque tool in box

Picture 5: Velocious torque tool lifted

2.8 Oceaneering Aim of Development

To be able to regain market shear from Oceaneerings competitors, they are dependent on a successful development which results in a tool more accurate and lighter then competitive tools. The main goal of any business is to make profit. The torque tools are already expensive to produce. Adding an extra function such as torque feedback will increase the already high production cost. It will therefore be essential to keep the estimated production cost for the concepts as low as possible. In total we can sum up the main aim of development with the following:

- Better accuracy than +/- 10 % of full scale. Aim of accuracy is +/- 5 %
- Minimize the weight and avoid buoyancy dependence
- Keep production cost as low as possible

2.9 Strain gauges

Introduction to strain gauges

Strain gauges are the fundamental measuring element for many types of sensors, such as pressure sensors, load cells and torque cells. The majority of strain gauges used are of the foil type. They are available in a wide choice of shapes and sizes to suit a wide range of applications. They consist of a pattern of resistive foil which is mounted on a backing material. The principle of operation is that when the foil is subjected to stress, the resistance of the foil changes in a defined way [11].

Sir Charles Wheatstone (1802-1875) found in 1843 a bridge circuit for measuring electrical resistance, called the Wheatstone bridge circuit. Unknown resistances are compared with a well-defined resistance in the circuit. The Wheatstone bridge is also well suited to measure small changes of resistance and is therefore suitable for measuring the resistance change in strain gauges [12].

Strain gauges are connected into a Wheatstone bridge circuit with a combination of four active gauges (full bridge), two gauges (half bridge) or one gauge (quarter bridge). When half and quarter bridges are used, the bridge is completed with precision resistors, which are incorporated in the instruments (Figure 21). U_E is the bridge input voltage and U_A is the bridge output voltage. [11]

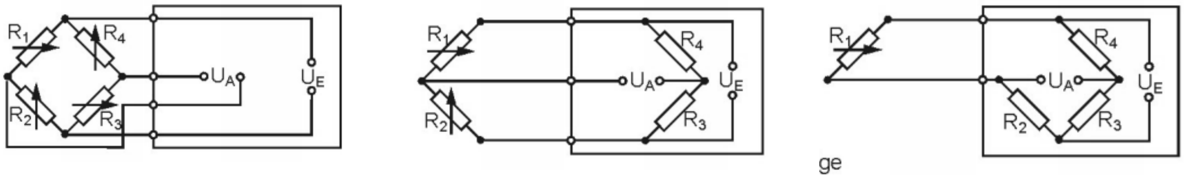


Figure 21: Full, half and quarter Wheatstone bridge [12]

The Wheatstone bridge is completed with a stabilized DC supply. As stress is applied to the bonded strain gauge, resistive changes take place and unbalance the Wheatstone bridge. The result is a signal output related to the stress value. This signal value is small and electrical amplifiers are used to increase the signal level, normally to 5 to 10 volts.

An unfortunate characteristic of strain gauges is that a change in resistance will occur with a change in temperature. This is a highly relevant issue regarding strain gauges in torque tools, as they are operated under different temperatures. However, this effect from changes in temperature can be compensated for in the Wheatstone bridge. This will be briefly described by using a quarter bridge Wheatstone circuit, as shown in Figure 22.

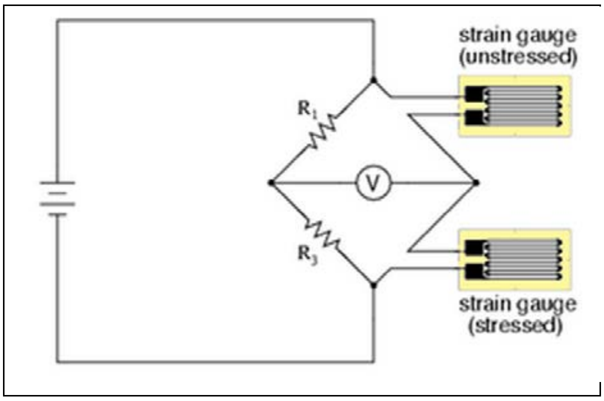


Figure 22: Quarter bridge with temperature compensation [11]

By using a dummy strain gauge in place of R2, so that both elements of the rheostat arm will change resistance in the same proportion when the temperature changes, resulting in canceling the effect of temperature change [11].

The temperature effect can also be compensated by use of a full bridge circuit, provided that they are all subjected to the same change in temperature [12].

When several bridges are needed to achieve the required amount of strain gauges, the circuits can be coupled in parallel. This will result in an average signal output from the circuits, which is exactly what is desirable for the readings.

Effect of hydrostatic pressure on strain gauges

This thesis will not involve a full elaboration and investigation of the effect of the hydrostatic pressure on foil strain gauges. This section will evaluate the viability for use of foil strain gauge in a hydrostatic environment. In this thesis concepts with strain gauges for shear strain and strain gauges for compression are described.

The effect of high pressure on foil strain gauges were investigated and described in a paper by R.V Milligan from 1964. It was extremely difficult to find research material regarding this topic and this was the most relevant paper found. A hydrostatic pressurized tube with foil strain gauges mounted on the inside of the tube was investigated. The pressure tested was up to 140 000 PSI (approximately 9655 BAR). For this thesis the maximum pressure will be 300 BAR (3000 meter water depth). A linear pressure strain response was obtained, which makes it possible to correct the readings for strain gauges exposed to hydrostatic pressure. From the experiment, it was concluded that the changes in resistance due to pressure were negligible when sufficient time was allowed to reach the thermal equilibrium [13]. This tells us that the effect in the pressure range relevant for the torque tool will be minimal as long as the strain gauges are temperature compensated. However, it can be relevant to test the actual deviation with a torque tool in a hydrostatic pressure tank.

Oceaneering has in many years delivered a smaller torque tool (class 1-4, maximum 2 700 Nm) with torque feedback. The solution for the torque feedback is similar with the existing concept, but the planetary gear consist of four planets and it has a different design making it more suited for this type of torque feedback. This tool has been used with success regarding the torque feedback and the use of foil strain gauges in a pressurized environment. The strain gauges on this tool are placed inside the tool in the same oil filled compensated volume as the gear. An indication that this will not be any major issue is that when the tool is lowered from surface to subsea, the torque feedback is stable (displaying approximately zero Nm). Any effect from the hydrostatic pressure would affect the readings on the display.

As the minimal effect of the hydrostatic pressure is linear, it is possible implement a function for resetting the readings to zero in the operational depth. This can be solved by implementing this in the tool software, in addition to a physical reset button on the tool.

As a conclusion, there are several challenges regarding strain gauges for subsea purposes and a final conclusion regarding concept will probably not be possible to determine before after prototype testing. As per now, Oceaneering does not have a 38 000 Nm torque tool with torque feedback for subsea application. As one of Oceaneerings competitors delivers this type of tool with torque feedback within +/- 10 % accuracy, it is essential for Oceaneering to develop a functioning reliable tool with higher accuracy to be able to regain lost market share for these products. The objective of this thesis has been to develop an alternative concept to an already existing concept for torque feedback. Testing of an old 17 000 Nm torque tool with the existing concept revealed high deviation in accuracy (+/- 20 %) which are not acceptable. The condition of this tool regarding strain gauges is unknown.

Several concepts were evaluated during concept development, and the concept with the assumed highest accuracy was not chosen as this was estimated to be expensive to develop and produce. The chosen concept was a new idea and no similar solutions were found during research. Both HBM and Scansense found the concept very exciting and interesting.

Further, FEM analyses of the new concept and the existing concept were performed to determine the accuracy regarding strain distribution in the geometry. Due to the torque tool planetary gear system the strain distribution changes with the position of the gear. For this reason, the torque feedback concept design needs to be minimally affected by this effect. The target accuracy was set to +/- 5 % if read value.

The results from the analyses of the existing concept revealed more accurate results than first anticipated based on the existing test results from the older tool. The results showed a deviation of 0.7 % between the gear simulated in position one and position two, and a deviation of 1.7 % between the gear simulated in position two and position three. These results are within accuracy target and it is recommended to perform additional analyses in different positions and to further investigate the condition of the existing tool.

The results from the analyses of the new concept are promising. The same positions as for the existing concept were analyzed and the accuracy was 0.3 % for both positions. The theory the concept is based on adds up with the analyses results and these results deliver a higher accuracy than the existing concept. Due to the low cost is associated with investigating the existing tool and equip it with 8-10 strain gauges to achieve higher accuracy, this is recommended.

Some technical challenges do exist regarding use of strain gauges for subsea application. However, Termo Tight does have experience with use of polypropylene for molding the strain gauges in. As long as the strain gauges are exposed to hydrostatic pressure, these issues will be present independently of the concept.

As a result of this thesis, two valid concepts have been investigated and issues regarding strain gauges for subsea use have been revealed. With this work as basis, Oceaneering will have a very good starting point for developing a functioning solution.

3 Concept development phase

We already have one concept for the torque feedback function. This in only based on earlier ideas with uncertainty attached to the accuracy. It would not be very innovative to just proceed with this concept without investigating other alternatives. Innovation needs to be secured. This is what keeps the competition a step behind. However, the situations as per now is that Oceaneering is one step behind and needs to succeed with this product to again take the lead on the torque tool market.

Through the concept phase, a large number of ideas were created. Not all is even presented in this thesis. When a sufficient amount of ideas are created, decisions need to be made on which ones to further develop. Development cost time and money and it is, for most organizations, not practical to develop every idea. Not even every idea will be possible to develop. An evaluation of the most promising ideas will be performed in this chapter. The most promising idea, the one most likely to achieve the development targets, will be further developed. [14]

The result before the next chapter will then be two concepts ready for further development and analysis, hereby referred to as the existing concept and the new concept.

3.1 Concept development methods

The front-end concept development phase can be presented schematically as show in Figure 23.

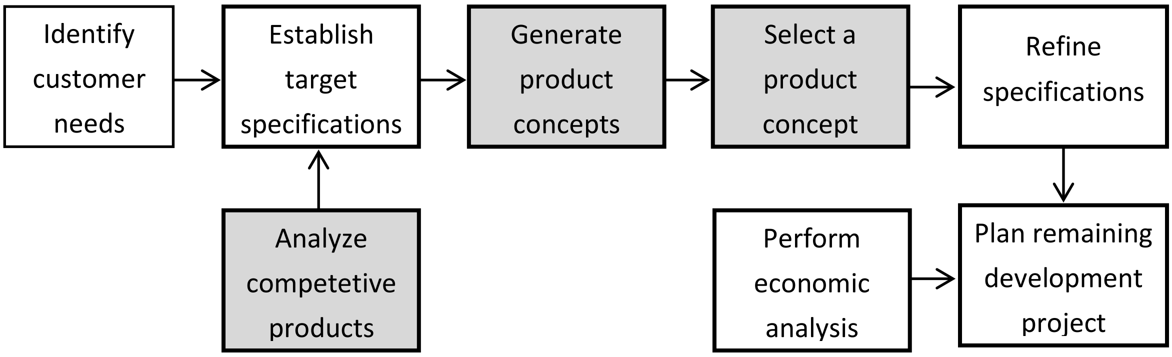


Figure 23: Front-end concept development [1]

The customers for this tool can be separated into two categories, internal and external customers. The internal customer will be Oceaneering rental department which will be tools for rental purposes. The external customers will be other oil-service and operator companies. The specifications for both internal and external customers are already known. The main required specification is a torque feedback function. In the previous chapter, the only competitive product on the market was analyzed, and the target is to deliver a more accurate product regarding torque feedback than Velocious does. With reference to Figure 23, this chapter will consist of product concept generation and selecting a product concept.

There are many well-known methods for concept development. In this thesis mainly two methods are used to create new ideas. These two methods are brainstorming and research. Other methods can be cause- and effect trees, brain-writing, problem decomposition, SCAMPER and concept fan, to mention a few. A brief description of the two methods used will be presented below.

Brainstorming [14]

One of the simplest forms for concept generation is brainstorming. This method works best in relatively small groups. A suitable amount of people will be 3-6. People in the group throw out ideas as they pop into mind.

The ideas are then used to spark other ideas. The amount of people attending the brainstorming can affect the outcome. Not enough diverse and unique ideas are created with too few people. Too many, voices get drowned out and slows the productivity. The participants should be encouraged to throw out any idea that comes to mind, even if it does not directly apply. Even if the idea does not directly apply, it can spark other useful ideas from the other participants. It is important to discuss the ideas in a positive manner to keep a high rate of creative flow, as negative attitudes will close people down and prevent new ideas to the surface. It is recommended not to pick apart ideas until a sufficient number of ideas have been generated.

Research [14]

Research can be very valuable in concept design phases. Research on existing designs can expose flaws and help define challenges with a design. The research should not result in a product as good as the competitors, but better. The next technology leap upward should be made from the highest point.

Research in other markets than where the product is intended to be used can be very effective. Adapting an existing technology into a different market is one of the methods with highest rate of success when it comes to technology development in the subsea industry. It is therefore important to do research across markets.

3.2 Idea generation

Oceaneering has many experienced engineers with knowledge to the torque tool. In addition to my-self, the following persons attended the brain storming meeting:

- Jostein Mikal Hageberg, Product Development Lead (product development department)
- Dag Bjåstad, Structural Lead (structural engineering department)
- Zenon Taushanis, Principal Engineer (structural engineering department)
- Torleif Carlsen, Structural Engineer (structural engineering department)
- Arnstein Vevle, Senior Operational Support Engineer (operational support department)

The meeting took place at Oceaneerings facilities in Jåttåvågen, Stavanger 17.02.2014. The minutes of meeting is attached in appendix A.

After thoroughly studying the tool in the brainstorming meeting, three main principle ideas were repeated:

- Implement strain gauges on the shaft
- Measure on the reaction fins. Either by pressure sensors (type of strain gauge) or conventional strain gauges.
- Transducer ring (as on the existing concept)

Time from my part, after the brainstorming, has been used to investigate other practical feasible concepts. Only one more idea came to mind. We now that the rotation of the gear can affect the readings in the strain gauges in the torque transducer for the existing design. It is desirable with a design that is not affected of this effect, meaning any possible change in strain distribution due to gear rotation can be eliminated. This can be achieved by inserting strain gauges on separate plates with measuring device between the tool guide and the gear housing interfaces.

With the constraints introduced by the fact that the gear cannot be re-designed, many of these are promising and there are good alternatives to the existing concept.

In addition to the existing concept, three more principle ideas are possible solutions. However, at this point one can say that these two ideas bring more questions than answers to the table. The main questions at this point of the concept phase are obviously; which technology can be applied to ensure accurate and reliable reading, and how can this technology be implemented into the tool?

Further investigation and development of these ideas will be presented in the next section of this report. An evaluation will be done to easily be able to differentiate the pros and cons for each concept.

3.3 Further development of generated ideas

Two principle ideas were introduced during the brainstorming meeting, and one principle idea sparked out as a result of the meeting. These ideas can easily be evolved into several concepts. Further concept development of these ideas will be presented in this section.

The concepts are only explained and developed briefly in this section. The purpose of this chapter is to develop and described concept thoroughly enough that advantages and disadvantages can be identified. On this basis, the concepts can be compared and evaluated against each other.

Measurements on the shaft

After research on measuring moment on a rotation shaft, only one solution seems to be practical feasible, and that is conventional strain gauges directly mounted onto the shaft. The main advantage with strain gauges on the shaft is that there will be no effect from the rotation of the gear. As a result of this, it is likely to believe that high accuracy and reliability can be achieved.

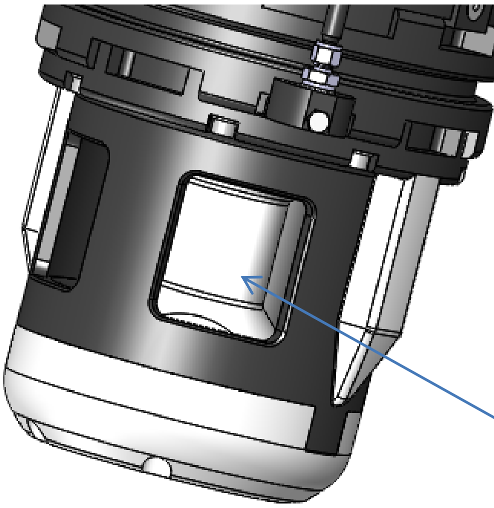


Figure 24: Area for measurements on shafts

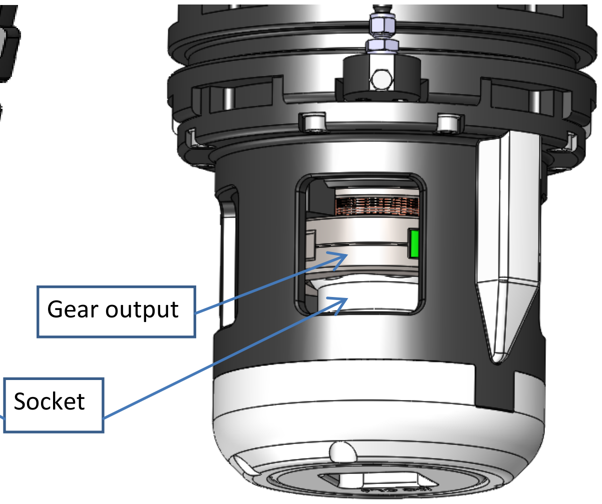


Figure 25: Concept with inductive transmission

Figure 24 shows the area for measurements on the shaft. Figure 25 shows a concept were the gear output has been extended to fit different measurement technologies.

The main challenge with concepts based on this idea is that the location where the strain gauges are mounted rotates. This means that the signal and power transferring needs to be wireless. Several solutions for strain gauge measurement on rotation shafts already exist, but none of these were applicable for subsea use. It is considered that the following solutions can be of interest:

- Signal and power transferring through a slip ring.
- Inductive signal and power transferring
- Battery pack attached in the shaft and signal transferring with
  - Bluetooth (high frequency signals get absorbed quickly in water)
  - RFID (Radio Frequency Identification)

The tool design needs to be similar to the existing concept. The existing concept is usable for mounting strain gauges onto the socket, but as this is a tool with interchangeable sockets, the technology needed to be implemented onto each socket to cover the whole range.

A more practical solution will be to extend the output gear shaft in order to implement the technology.

Signal and power transferring through a slip ring

Signal and power transferring through a slip ring is a well-known technology. The problem will be that the slip ring is worn and needs to be replaced at regular intervals. In addition, the parts cannot be exposed to seawater. This means the parts need to be in a compensated oil filled volume. As a result of this, the pressure from the slip ring needs to be higher than in an environment with only air. The reason for this is to ensure that the slip ring makes contact through the oil film that will lie on the part surfaces. This will cause additional ware on the slip ring and it is uncertain how successful the signal transmitting will be.

Inductive signal and power transferring

After further research, technologies are available. However, no solutions have been found for subsea applications. Both HBM Norge and Coba measuring technic has been contacted. As many other businesses, HMB was skeptical to adapt their technology for subsea use and they were not willing to be part of a subsea application development.

A meeting was arranged with Coba, a one man business. Coba is the agency for KMT Telemetry in Norway, and they were positive to look at solutions to use their technology in subsea environment. Jostein Hageberg and undersigned attended a meeting with Coba. Coba will contribute to adapt the technology to fit to the torque tool, while Oceaneering will contribute with knowledge of electronics in pressurized environment.

The main concern with the KMT solution is that the signal transferring is at 2.4 GHz bandwidth. This is a high frequency signal which very quickly gets absorbed in water. However, design with very small distance between transmitter and receiver can be achieved. The tool can be designed to have a distance of 1 mm between receiver and transmitter. It is important that the distance does not get too small due to possibility of crevice corrosion.

Figure 26 shows a concept were the KMT system has been customized for subsea use on the torque tool. The tool guide is hided to get a better view of the concept. To fit the technology onto the tool, the gear output shaft needed to be extended.

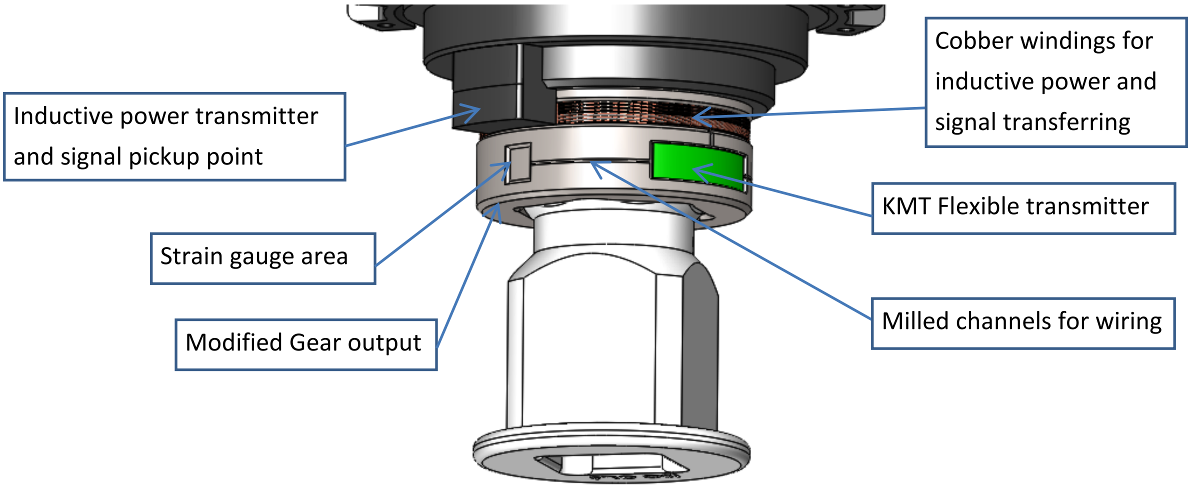
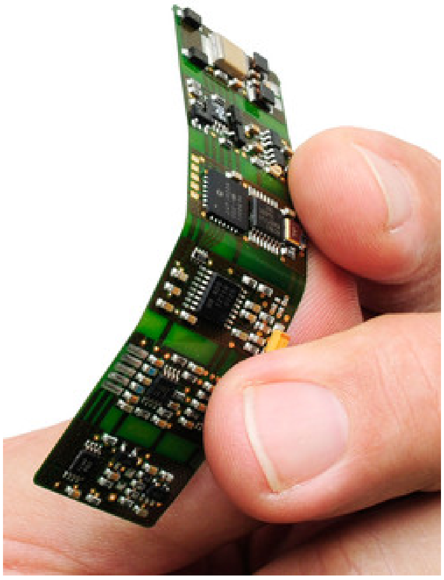


Figure 26: Customized KMT system on torque tool

KMT are specialized on digital telemetry systems for strain gage applications on rotating shafts. The principle of the system is based on induction with windings around the shaft. The magnetic field of this winding enables inductive transmission of the signal to a pickup coil [15]. An illustration picture of the system attached to the shaft is shown in Picture 6.

Picture 6: KMT system on shaft [15]

This system needs to be adapted for subsea application. The windings can be mounted into a groove in the gear shaft and then covered with a molding plastic to protect it from seawater, and at the same time not interfering with the magnetic field. The transmitter part is rather large and bulky. This can be replaced with another transmitter from KMT. This is an extremely flat and flexible transmitter which can be integrated into the shaft the same way as the windings.



Picture 7: KMT flexible transmitter [16]

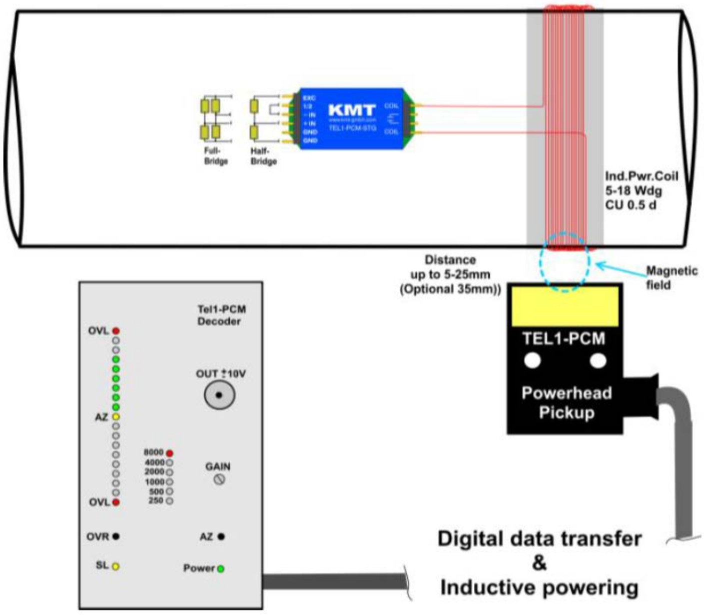


Figure 27: KMT block diagram [17]

The flexible transmitter is shown in Picture 7. This card only measures 70mm x 20mm x 2mm and weighs less than 2 grams. Further, the digital data transfer and the inductive powering unit need to be modified to fit into the torque tool [16]. A block diagram of the system is shown in Figure 27. Oceaneering is dependent on collaboration with KMT for adapting these parts to fit the torque tool. If KTM shows no interest in further collaboration for adapting these products for subsea use, a possible idea is to make this development in-house based on Bluetooth technology. The Bluetooth chips can be purchased in very small sizes and a circular antenna can be integrated to ensure short enough distance to the pick-up point.

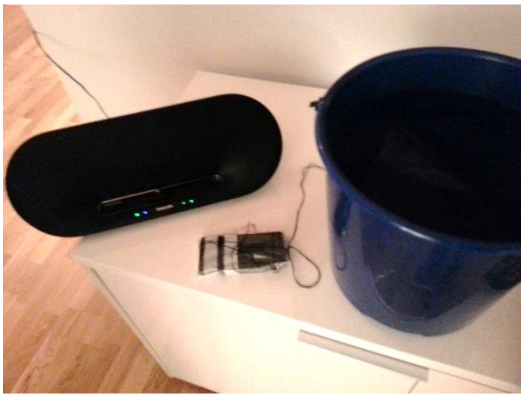
The Bluetooth signals are transmitted in the 2.4 GHz bandwidth (between 2.4 GHz and 2.485 GHz) and these high frequencies are quickly absorbed in water [18]. After a discussion with an electro engineer and research on the internet, no data were found regarding approximately transmitting length in water. This resulted in a small experiment to determine if this actually is a viable solution. The experiment set-up is shown in Picture 8.

The distance for a Bluetooth signal to travel can be designed to be 1 mm. To test how well the signal was transmitted, a cell phone was lowered down into a bucket with water while the phone was connected to a bluetooth speaker, playing a song. At all-time the phone was surrounded from all angles with a minimum of 5 cm of water (Picture 9).

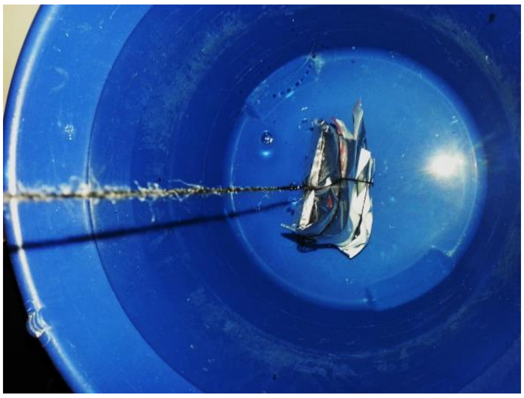
The bluetooth speaker played the song without any interference and not at any point did the speaker loose the connection with the phone.

The experiment was a success and it can be stated that there should not be any problems transmitting a bluetooth signal 1 mm in seawater.

The bluetooth transmitter in a cell phone has an effect of approximately 2.5 milliwatt [18], meaning a low amount of effect is needed to transmit these signals.



Picture 8: Experiment set-up



Picture 9: Cell phone in water

Battery pack attached in the shaft

A solution with a battery pack attached to the shaft would make the signal transferring easier. There would be no need of cobber windings for inductive transfer. However, it would be challenging to adapt a battery pack in the shaft that would be easy to access for recharging. To ensure no short circuit of the batteries, they need to be installed in a hermetically closed environment. This will also result in thicker wall thickness to avoid the compartment from collapsing by the hydrostatic pressure.

Overall, this solution can use similar design as for the inductive power and signal transferring design. With a battery pack, there will be no need for the cobber windings since there will be no inductive power transferring. See Figure 26 for reference.

Measurements on the reaction fins

There are mainly two different techniques that can be used to measure the moment in the reaction fins area. These two alternatives are either by use of strain gauges (conventional or piezoelectric) or by pressure sensors. The pressure sensors need to be directly in contact with the bucket interface, while strain gauges can be placed close to the reaction fins or in the reaction fins themselves. These concepts will be elaborated further in this chapter.

The reaction force to the fins will occur in the torque bucket as shown on Figure 28 and Figure 29, represented with the existing tool.

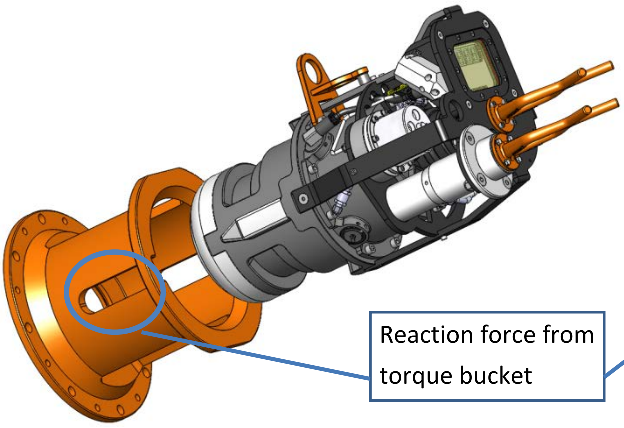


Figure 28: Existing tool undocked in interface bucket

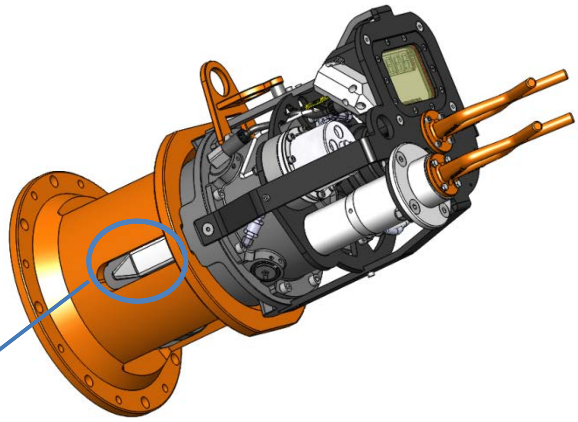


Figure 29: Existing tool docket in interface bucket

Pressure sensors

This concept is based on the fact that the moment from the tool in theory can be relatively easily measured as a force/pressure directly on the reaction fins as they are interfacing with the torque bucket. Many challenges needs to be sorted out for this concept to function as required. These challenges are identified and described below.

The main challenge is that there does not exist pressure sensors that can be directly mounted into the fins. The issue is that they are too fragile and does not withstand the mechanical forces acting on them. The solution to this is to use pressure sensors inside an oil filled volume with pistons acting against the torque bucket. The pressure sensor inside the oil filled volume will then measure the hydrostatic pressure generated from the mechanical contact between the torque bucket and the piston in the reaction fins. Many challenges are introduced with a design based on this pressure sensor concept.

- The oil filled volume needs to be completely air vented. Any trapped air in the system will result in inaccurate readings. Small volumes are sensitive to temperature changes which also will affect the readings. A temperature compensator will be necessary.
- The hydrostatic pressure will affect the readings dependent on water depth. Depth measuring is required for compensating for the hydrostatic pressure from the sea water.
- Only the pistons can interface the bucket in the reaction fin area. For this reason, the pistons need to be having a small distance from the rest of the reaction fin area. This will make them

exposed to impact when the torque tool is entering the bucket. The design needs to be robust.

- Sealing between the piston and the reaction fin can be challenging since the piston is exposed for impacts.
- Forces on the pistons resulting in high internal pressure in the system.
- Channels needs to be drilled in the reaction fins. This will reduce the structural integrity of the reaction fins. The space available can be an issue

The advantages with the concept are that the technology is simple and well proven and the existing electronics on the tool can be used. However, there are uncertainties associated with the reliability and accuracy. This results in high risk regarding the functional design.

The forces acting on the reaction fins will be 163.7 kN with a moment of 40 kNm (ref. Appendix B). The pressure inside the channels will be dependent on the tube diameter. A relevant pressure sensor from Keller-druck was looked up. The sensors can be used up to 1000 BAR and has a diameter of 15 mm. The pressure inside the system will be dependent on the size of the piston in the reaction fin. To ensure that only the piston surface is interacting with the torque bucket would requre a certin amount of size. The internal pressure will increase with small piston area, but the structural integrity will be comprimised with larger area to minimize the maximum pressure.

To illustrate an example, the diameter of the pressure sensor has been used. With an area in the reaction fin at this size acting as a pistion, the internal pressure would be approximately 9400 BAR (ref. appendix B). To decrease maximum pressure, the area would have to be more than 9 times larger. Such large area would compremise the structural integrity of the reaction fins. With the constraints regarding the reaction fin deisng and area, this solution will not be viable. See Figure 30 and Figure 31 for simple models/illustrations of the concept.

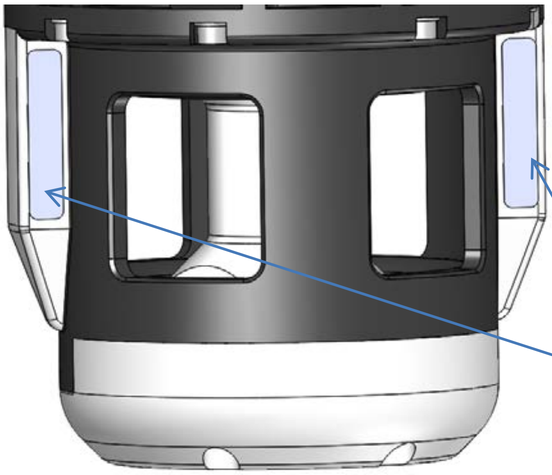


Figure 30: Reaction fin pressure sensor concept

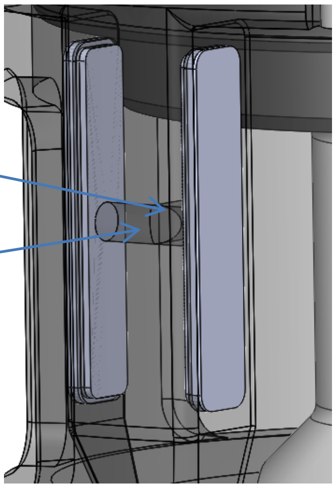


Figure 31: Reaction fin pistons

Strain gauges close to the reaction fins on existing tool

From extended testing of the existing class 7 torque tool with torque feedback, it can be concluded that it is likely to believe that variation in the third stage gear position affects the strain distribution in the tool [10]. This effect will affect the readings in the strain gauges and give an inaccurate result. It cannot be determined how large this effect will be in the reaction fin area and FEM analysis needs to be performed to determine the exact variations.

However, looking at Figure 32, a section cut of the lower part of the existing tool) we can see that the potential strain gauge areas are very close to the third stage planet gears. For this concept the variation in strain distribution will be too high to achieve accurate readings with strain gauges. The strain gauges could be integrated in a milled groove inside the gear housing, just behind the reaction fins. Small diameter channels can be drilled in the reaction fin for strain gauge wiring. The strain gauges will be protected from the environments and will be in pressure compensated oil filled volume (gear housing).

The most challenging factor with this design is that the tool guide with the reaction fins functions as the gear housing. The result is that the gear housing is likely to be affected of the gear rotation, hence the distance to the third stage planet gears.

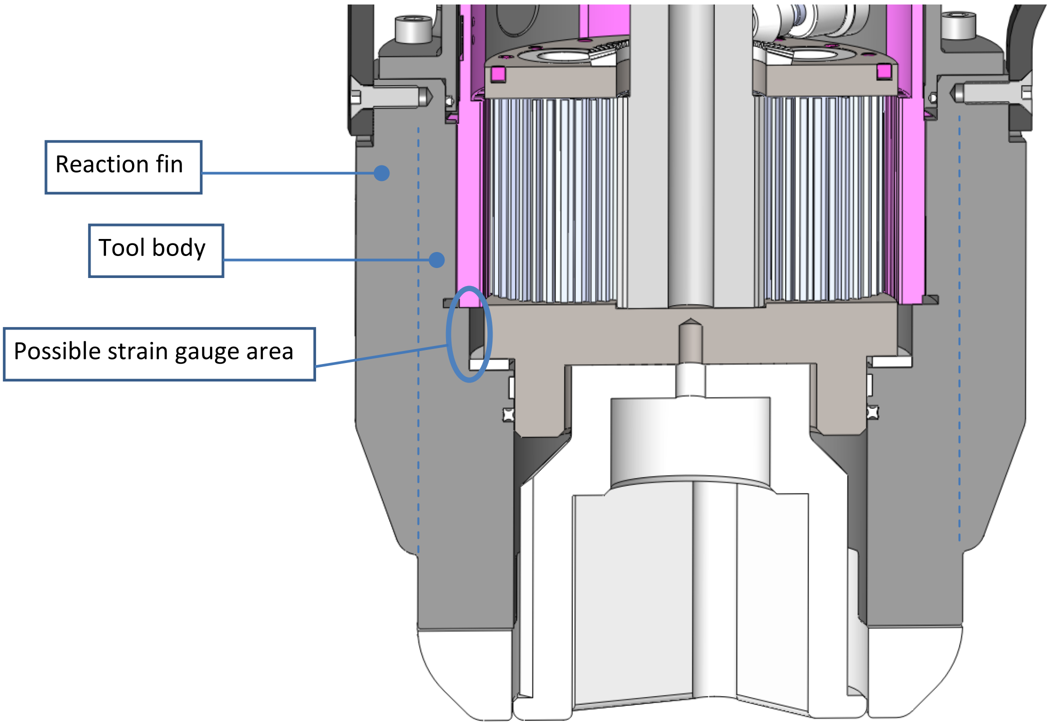


Figure 32: Strain gauges in reaction fins area on existing tool (section cut)

Strain gauges close to the reaction fins on existing concept design

The existing concept design has an advantage with the gear housing not being part of the tool guide with the reaction fins. It is likely to believe that the effect from the rotating gear will be significantly smaller on the tool guide due to the distance from the ring gear, compared to the original design.

A similar solution to the concept described in the previous section (Strain gauges close to the reaction fins on existing tool) can be used to integrate strain gauges in the area close to the reaction fins. Strain gauges in the reaction fins area on the existing tool would be in the oil filled compensated gear housing. For this concept it would be easiest to make grooves for the strain gauges and the wiring which can be covered with mold plastic to ensure protection from the sea water. The strain gauges will not be exposed to impact damage since the area is protected by the tool guide itself.

The main advantage with this concept compared to the existing concept with torque adapter is the production cost. However, it is absolutely necessary to perform analysis in Ansys to determine how accurate this design can be. These results can be extracted and interpreted from the analysis on existing concept. Figure 33 shows a section cut of the tool with the intended location for strain gauges. The area for the strain gauges can be designed to achieve the optimal strain area for measuring. This can be achieved by either strengthen or weaken the local area where the strain gauges will be implemented.

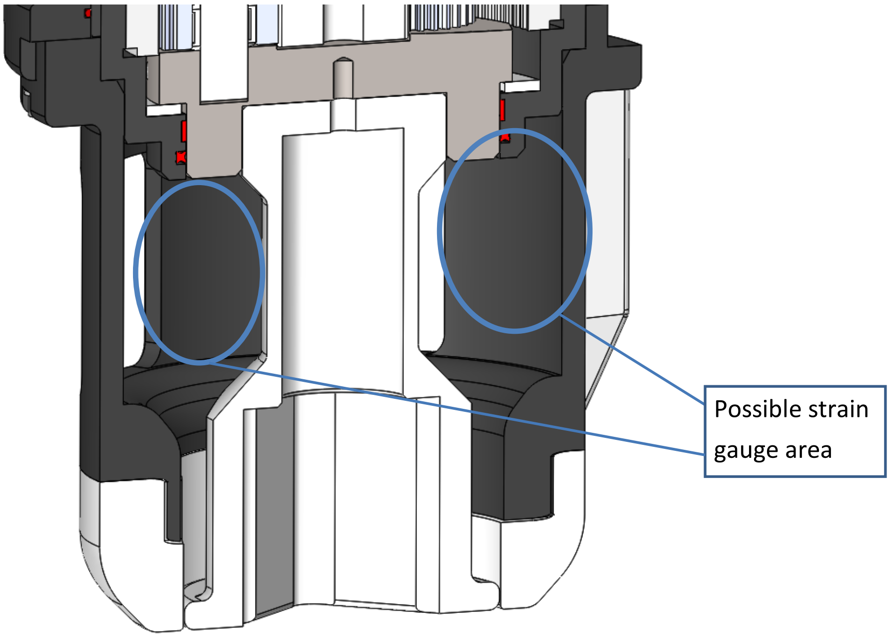


Figure 33: Strain gauge are close to reaction fins

Strain gauges integrated in the reaction fins

Strain gauges integrated in the reaction fins can be divided into two different concepts. One option is to integrate strain gauges in the fins geometry as they already are. This concept will have exactly the same assumptions as the concept with strain gauges near the reaction fins on the back of the tool guide and analysis in Ansys is necessary to ensure no change in the strain distribution due to the rotation of the gear.

To ensure no effect from the rotation of the gear, the reaction fins can be designed as a sandwich construction. The sandwich construction needs to be mounted such that an eventual affect from the rotating gear does not affect the readings. The design needs to stay of three layers with the strain gauges attached to the center layer. The result will be that only the compression forces will be measured by the strain gauges.

The second option on the existing concept:

The tool guide can be machined without the fins which will reduce the production cost of this part since the whole part can be machined in the lath. With the existing design, much material needs to be removed by milling from the outside diameter and down to the inner diameter of the reaction fins.

The concept design allows the reaction fin area to be completely removed and design for separate reaction fins. This will ensure that the pressure on the strain gauge plate in the sandwich construction will experience optimal force distribution. The main challenge will be to integrate the reaction fins part and still ensure the structural integrity of the tool guide and the reaction fins, hence the amount of reaction forces and the moment. With attachable reaction fins on this design it would be extremely difficult, possibly impossible, to maintain the required structural integrity. Forces acting on the reaction fins are 166.7 kN with a moment of 40 kNm (ref. appendix B). The concept is illustrated in Figure 34 and Figure 35.

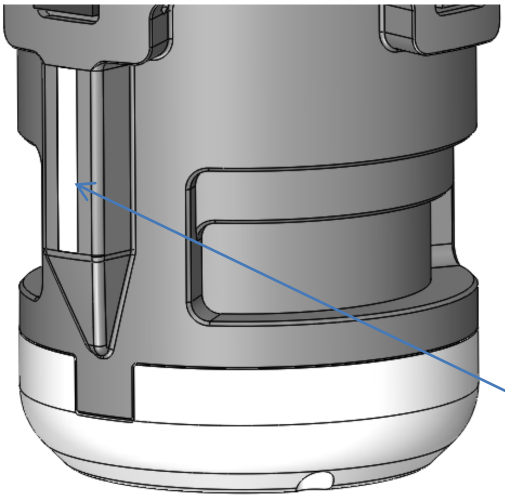


Figure 34: Strain gauges in reaction fins

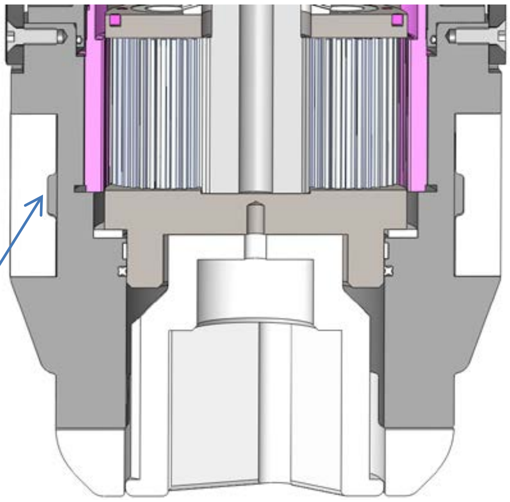


Figure 35: Section cut of strain gauges in reaction fins

The second option on the existing tool:

By using the original tool guide, the reaction fins needs to be machined such that a strain gauge plate can be fitted inside the reaction fin. The pressure against the plates will be constant while the local strain distribution can very. The tolerances for the strain gauge plates need to be fit passes due to ensure constant contact between the tool guide and the plate. The tool guide surrounding the strain gauge plate will stiffen the tool guide and prevent optimal force distribution directly onto the strain gauge plate.

However, the existing design is more compact and it will be favorable to integrate a possible solution with sliced reaction fins in this concept. This concept will be challenging regarding the detail design. All the reaction forces go through the reaction fins and it is important to keep the structural integrity in this area. The interface bucket is standardized, meaning that this area has constrains regarding design possibilities. In addition, there are not much space for the strain gauge plates, hence the detail design will be challenging and demanding. Figure 36 and Figure 37 illustrates the concept.

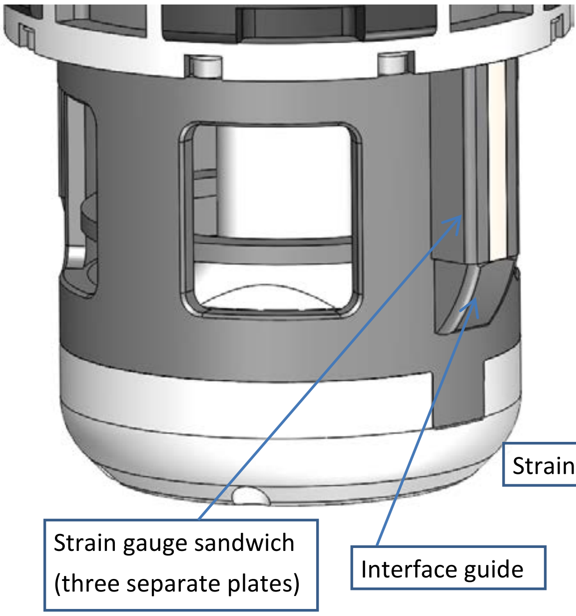


Figure 36: Strain gauges in reaction fins

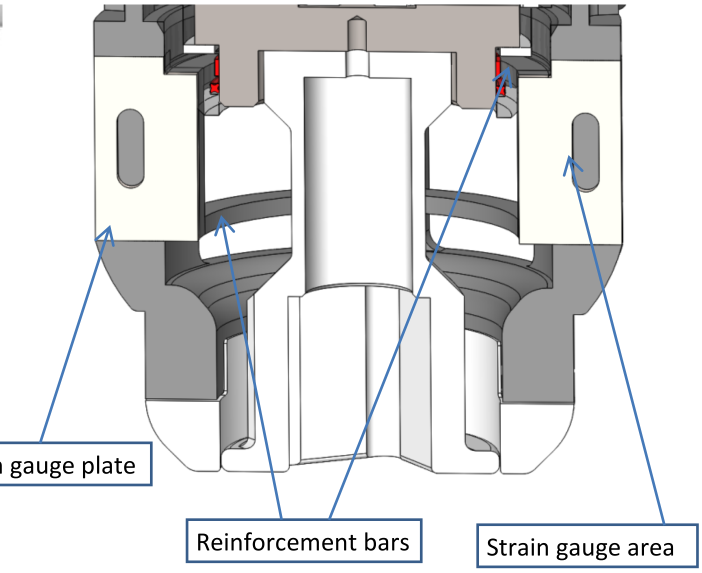


Figure 37: Section cut strain gauges in reaction fins

The torque tool bucket will apply a force on the reaction fins, resulting in a moment around the tool guide wall. Reinforcement of the reaction fins will be necessary to obtain the structural integrity for this concept. This can be achieved by mounting reinforcement bars that will act against the moment from the torque bucket. The lower interface guide needs to have a smaller width than the strain gauge sandwich. This is to ensure that only the strain gauge sandwich is interfacing against the bucket when the tool is operated.

Measuring in reaction area between gear housing and guide

Based on the concept with strain gauges used to measure pressure in a separate plate in the reaction fins, one can further develop this principle and implement in the area where the original torque transducer is placed. The idea is that the torque transducer itself can be removed, and the gear housing and the guide can be directly connected together. Between the interface areas, separate bricks with strain gauges can be installed. The strain gages will measure the compression in the bricks, which will not be affected of the gear rotation. See Figure 38 for model sketch of the concept.

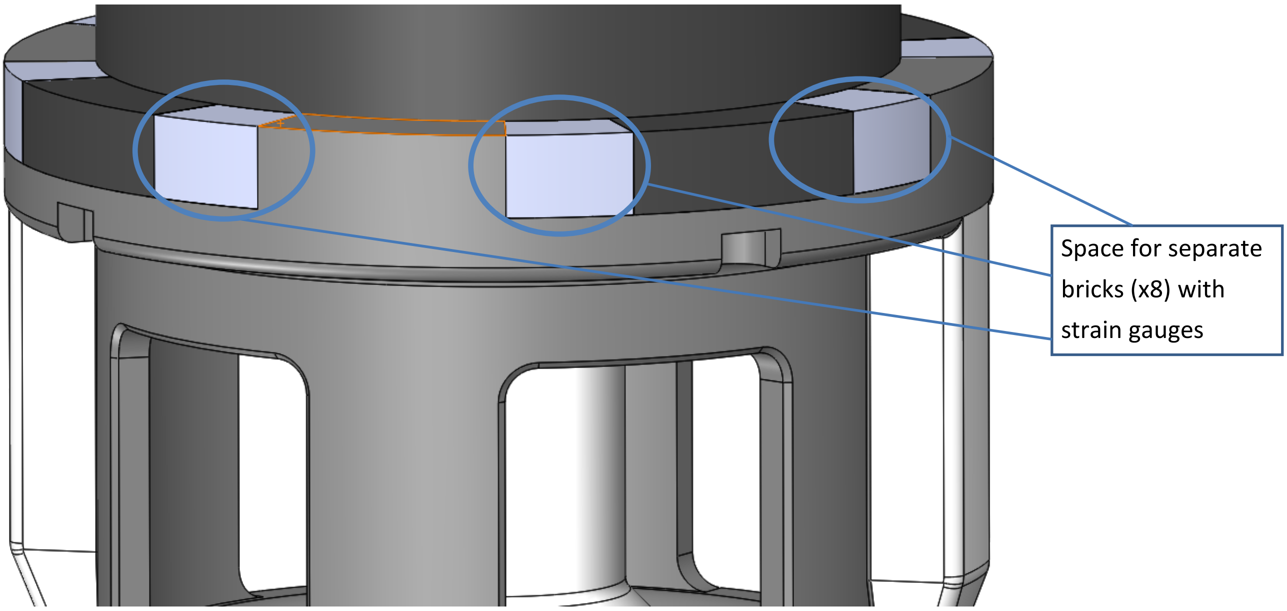


Figure 38: Measuring between gear housing and tool guide

The advantage with this concept compared to the reaction fin concept is that the force/pressure the strain gauges will measure will be divided by more than two reaction interfaces and the structural integrity of the reaction fins will not be compromised. The total forces will be divided by the amount of interfaces in the design. With four interfaces, the forces on each interface will be half of the forces on the reaction fins, given the same diameter. From equation 2 in appendix B, we can see that the forces will decrease by increasing the diameter.

The strain gauges can either by inserted on the metal bricks and then mold plastic can be used to protect the strain gauge from sea water. Normal strain will be read out with the strain gauges, hence compression strain gauges is needed. These are more sensitive to hydrostatic pressure and there are some challenges regarding this issue. However, it has been tried out with covering the strain gauges with polypropylene, but the results are not documented. Another possibility is to implement a pressure sensor to be able to calibrate for the hydrostatic pressure effect.

Another solution is to design the strain gauge bricks to be contained in oil filled compensated volume. There are many ways this can be achieved by detail design. Figure 38 shows only a concept of how plates with strain gauges can be used. This area will not affect the gear design, hence there are no constraints regarding design in this area. This solution will ensure any effect from the rotating gear.

3.4 Evaluation of concepts

The objective of this section is to evaluate the concepts described in the previous section. As a result of the evaluation a concept shall be chosen for further development and analysis. The concepts described in the previous chapter are summarized in Table 5.

Principle ideas:	**Generated concepts:**
Measurements in shaft	Slip ring concept
	Inductive signal and power transferring
	Battery pack in shaft
Measurements in reaction fins	Pressure sensors
	Strain gauges close to reaction fins on existing tool
	Strain gauges close to reaction fins on existing concept
	Strain gauges integrated in reaction fins (conventional)
	Strain gauges integrated in reaction fins (sandwich construction)
Measurements in reaction area between gear housing and tool guide	Strain gauges attached to separate bricks measuring compression.

Table 5: Generated concepts

These concepts will be evaluated after the following criteria:

- Production cost evaluation
- Detail design development cost evaluation.
- Design complexity
- Technology complexity
- Weight and size evaluation
- Assumed accuracy

The concepts are evaluated in the following evaluation tables below. The different criteria are given a weighting factor to differentiate between the criteria. The weighting factor is given based on the impotency of each criterion. The evaluation is based on a scale with the following classification and score intervals given in Table 6. The further description in the evaluation is used to determine were in the scale interval to set the score. Scores presented in parenthesis are scores not multiplied with the WF.

Classifications	**Score interval**
Low	9-10
Low to moderate	7-8
Moderate	5-6
Moderate to high	2-4
High	0-2

Table 6: Evaluation classifications

Slip ring concept			
Criteria:	**Evaluation:**	**WF:**	**Score:**
Production cost evaluation:	*Moderate to high*. Many parts included in the system.	0.7	2.1 (3)
Detail design development cost evaluation:	*Moderate to high*. Testing required for the slip ring signal and power transferring.	0.4	1.6 (4)
Design complexity:	*Moderate*. Concept design needs to be based on the gear house principle from the existing concept. Not any identified challenges regarding design.	0.6	3 (5)
Technology complexity:	*Moderate to high*. Well-known technology. Slip ring will ware. Needs to be in compensated oil filled volume. Not especially suited for subsea environment.	0.8	2.4 (3)
Weight and size:	*Moderate to high*. Based on existing concept. Extra parts needed in the design.	0.7	2.1 (3)
Assumed accuracy risk:	*Low*. Measurement directly on output shat assumed to give the best accuracy.	1	10 (10)
Conclusion:	Low risk regarding design. High risk regarding slip ring in oil filled volume. Risk associated with the signal and power transferring.	N/A	21.2 (28)

Table 7: Slip ring concept evaluation

Inductive signal and power transferring concept			
Criteria:	**Evaluation:**	**WF:**	**Score:**
Production cost evaluation:	*High*. System for topside application cost approximately 30 000 NOK. Subsea adapted system estimated to exceed this cost.	0.7	0.7 (1)
Detail design development cost evaluation:	*High*. Parts of KMT system needs to be developed for subsea application. High design development cost.	0.4	0.4 (1)
Design complexity:	*Moderate to high*. Many new parts need to be designed.	0.6	2.4 (4)
Technology complexity:	*High*. Not used in subsea applications. To ensure satisfactory signal and power transferring, testing is required. Can be tested without prototype.	0.8	1.6 (2)
Weight and size:	*Moderate to high*.	0.7	2.8 (4)
Assumed accuracy risk:	*Low*. Measurement directly on output shat assumed to give the best accuracy.	1	10 (10)
Conclusion:	Expensive solution with complex technology and high both production cost and development cost.	N/A	17.9 (22)

Table 8: Inductive signal and power transferring concept evaluation

Battery pack in shaft concept			
Criteria:	**Evaluation:**	**WF:**	**Score:**
Production cost evaluation:	*High*. Can be assumed to cost some less than the concept with inductive power transferring.	0.7	1.4 (2)
Detail design development cost evaluation:	*Moderate to high*. Testing will be required for the 2,4GHz signal transferring.	0.4	1.6 (4)
Design complexity:	*Moderate to high*. Can be complicated to provide a functional design for the battery pack (which needs to be in a hermetically closed area).	0.6	2.4 (4)
Technology complexity:	*High*. Inductive power transferring not necessary. Signals transferred in the 2,4 GHz bandwidth most likely to be able to transfer signal 1mm in sea water.	0.8	1.6 (2)
Weight and size:	*Moderate*. Based on existing concept.	0.7	3.5 (5)
Assumed accuracy risk:	*Low*. Measurement directly on output shat assumed to give the best accuracy.	1	10 (10)
Conclusion:	(moderate) Risk associated with signal transferring. Complex technology and high production cost.	N/A	20.5 (27)

Table 9: Battery pack in shaft concept evaluation

Pressure sensors concept			
Criteria:	**Evaluation:**	**WF:**	**Score:**
Production cost evaluation:	*Moderate*. Inexpensive technology. Need of extra machined parts for the hydrostatic pressure sensor housing. Extra production cost for tool guide (channels).	0.7	3.5 (5)
Detail design development cost evaluation:	*Moderate to high*. Time and testing regarding sealing and friction associated with pressure and accuracy, respectively.	0.4	1.2 (3)
Design complexity:	*High*. Challenging to design the interface pistons and seals to withstand the high pressure generated.	0.6	1.2 (2)
Technology complexity:	*Low*. Well known technology with hydrostatic pressure measuring.	0.8	7.2 (9)
Weight and size:	*Moderate to high*. Needs to be based on existing concept regarding the tool guide. This to fit the pressure sensor area.	0.7	2.8 (4)
Assumed accuracy risk:	*Low to moderate*. Friction in piston can affect the measurements. Dependent on only piston interfacing with the torque bucket in the rotating direction.	1	7 (7)
Conclusion:	Risk associated with the pistons: Risk regarding sealing. Risk regarding attack angle relative to the torque bucket (friction can be occur and affect the actual readings).	N/A	22.9 (30)

Table 10: Pressure sensors concept evaluation

Strain gauges close to reaction fins on existing tool			
Criteria:	**Evaluation:**	**WF:**	**Score:**
Production cost evaluation:	*Low*. Minimal of extra parts needed. Inexpensive technology.	0.7	6.3 (9)
Detail design development cost evaluation:	*Low*. Relatively small changes to implement concept.	0.4	3.6 (9)
Design complexity:	*Moderate*. Can in some degree be challenging implementing the strain gauges in the existing design.	0.6	3.6 (6)
Technology complexity:	*Low*. Well-known technology.	0.8	7.2 (9)
Weight and size:	*Low*. Small amount of extra weight will be added for this concept.	0.7	7 (10)
Assumed accuracy risk:	*High*. Assumed to be affected by the gear rotation. Target accuracy difficult to be achieved.	1	0 (0)
Conclusion:	High risk associated with not achieving accuracy target (+/- 5 %). Otherwise many good features regarding concept.	N/A	27.7 (43)

Table 11: Strain gauges close to reaction fins on existing tool concept evaluation

Strain gauges close to reaction fins on existing concept			
Criteria:	**Evaluation:**	**WF:**	**Score:**
Production cost evaluation:	*Moderate*. Some additional costs associated with tool guide (compared to existing tool).	0.7	3.5 (5)
Detail design development cost evaluation:	*Low*. Relatively small changes to implement concept.	0.4	3.6 (9)
Design complexity:	*Low*. No obstruction or challenges regarding implementation of concept.	0.6	5.4 (9)
Technology complexity:	*Low*. Well-known technology.	0.8	7.2 (9)
Weight and size:	*Moderate*. Concept based on existing concept.	0.7	3.5 (5)
Assumed accuracy risk:	*Moderate to high*. High uncertainty regarding the effect of the rotating gear. Larger distance from the ring gear may reduce the local variation in local strain. Some effect assumed to be present.	1	3 (3)
Conclusion:	Strain gauges close to the ring gear. This will give local variation in strain which will affect the readings. Concept not suited for torque feedback implementation.	N/A	26.2 (40)

Table 12: Strain gauges close to reaction fins on existing concept evaluation

Strain gauges integrated in reaction fins			
Criteria:	**Evaluation:**	**WF:**	**Score:**
Production cost evaluation:	*Low to moderate*. Few extra machined part necessary in design. Can result in relatively high production cost for the strain gauge plate area.	0.7	4.9 (7)
Detail design development cost evaluation:	*Low*. Relatively small changes to implement concept.	0.4	3.6 (9)
Design complexity:	*Moderate*. Challenges regarding wire routing. Needs to be fitted with press fit.	0.6	3 (5)
Technology complexity:	*Low*. Well-known technology.	0.8	7.2 (9)
Weight and size:	*Low*. Based on existing tool. Minimal of extra weight added.	0.7	6.3 (9)
Assumed accuracy risk:	*Moderate to high*. Likely to believe that the upper part of the reaction fin will stiffen the reaction fin and may contribute to inaccurate readings. Readings dependent on not damaged torque bucket. Damages to torque tool may affect the strain gauge readings.	1	4 (4)
Conclusion:	High risk regarding not achieving accuracy target.	N/A	29 (43)

Table 13: Strain gauges integrated in reaction fins concept evaluation

Strain gauges integrated in reaction fins (sandwich construction)			
Criteria:	**Evaluation:**	**WF:**	**Score:**
Production cost evaluation:	*Moderate to high*. Many extra parts required for the design.	0.7	2.8 (4)
Detail design development cost evaluation:	*Moderate*. Can be challenging obtaining the structural integrity of the reaction fins.	0.4	2.4 (6)
Design complexity:	*Moderate to high*. Challenging implementing strain gauges for compression readings due to space available in the reaction fins (standard measures).	0.6	2.4 (4)
Technology complexity:	*Low*. Well-known technology.	0.8	6.4 (8)
Weight and size:	*Moderate*. Concept based on existing concept.	0.7	3.5 (5)
Assumed accuracy risk:	*Low to moderate*. Not affected by the gear rotation. Readings dependent on not damaged torque bucket. Damages to torque tool may affect the strain gauge readings.	1	8 (8)
Conclusion:	Concept assumed suited for torque feedback implementation. Some risk regarding accuracy target.	N/A	25.5 (35)

Table 14: Strain gauges integrated in reaction fins (sandwich construction) concept evaluation

Strain gauges attached to separate bricks measuring compression			
Criteria:	**Evaluation:**	**WF:**	**Score:**
Production cost evaluation:	*Moderate*. Extra machined part for strain gauge bricks.	0.7	4.2 (6)
Detail design development cost evaluation:	Low. Relatively easy detail design for implementing the concept.	0.4	3.6 (9)
Design complexity:	*Low to moderate*. Relatively many strain gauges necessary. Challenges regarding strain gauge brick design and wire routing. Can be implemented in oil filled volume.	0.6	4.8 (8)
Technology complexity:	*Low*. Well-known technology.	0.8	7.2 (9)
Weight and size:	*Moderate*. Concept based on existing concept.	0.7	4.2 (6)
Assumed accuracy risk:	*Low*. Not affected by the gear rotation. Not affected by tool interface against torque bucket.	1	9 (9)
Conclusion:	Concept assumed well suited for torque feedback implementation. Strain gauges will measure reaction forces and not torque. Possibly necessary with pressure sensor to compensate for hydrostatic pressure effect.	N/A	33 (47)

Table 15: Strain gauges attached to separate plates measuring compression concept evaluation

Concept:	**Score:**
Inductive signal and power transferring concept	17.9 (22)
Battery pack in shaft concept	20.5 (27)
Slip ring concept	21.2 (28)
Pressure sensors concept	22.9 (30)
Strain gauges integrated in reaction fins (sandwich construction)	25.5 (35)
Strain gauges close to reaction fins on existing concept	26.2 (40)
Strain gauges close to reaction fins on existing tool	27.7 (43)
Strain gauges integrated in reaction fins (conventional)	29 (43)
Strain gauges attached to separate bricks measuring compression	33 (47)

Table 16: Concepts in ascending order by score

Table 16 shows the concepts in ascending order by score. The concept scoring the highest is the concept with strain gauges attached to separate plates measuring the compression. This will be the chosen concept for further detail design and analysis, in addition to analysis on the existing concept.

The concept evaluation is performed as thorough as possible given the information available. Parts of the evaluation are based on earlier experiences with the Oceaneering torque tool and the SAE torque tool, this especially with respect to the strain variation due to gear rotation.

Further analysis for the chosen concept can reveal valuable information relevant for other concepts regarding the strain distribution. This will be further commented in the chapter 4, covering the analyses.

3.5 Detail Concept Design

The finished detail concept design will be elaborated in this section. The design is not a complete detail design, but the remaining detail design can be solved with simple solutions with respect to the finished detail concept design. The objective with the detail concept design was to have a concept ready for analyses and at the same time ensure that no unforeseen challenges will arise during the detail design. The remaining design consists mainly in detail how to route the wiring up to the turn counter housing. The new detail concept design is shown in Figure 39.

The new concept differs from the original tool with the following parts:

- Gear housing (redesigned)
- Transducer assembly (x2)
- Tool nose guide (originally part of gear housing on original tool)

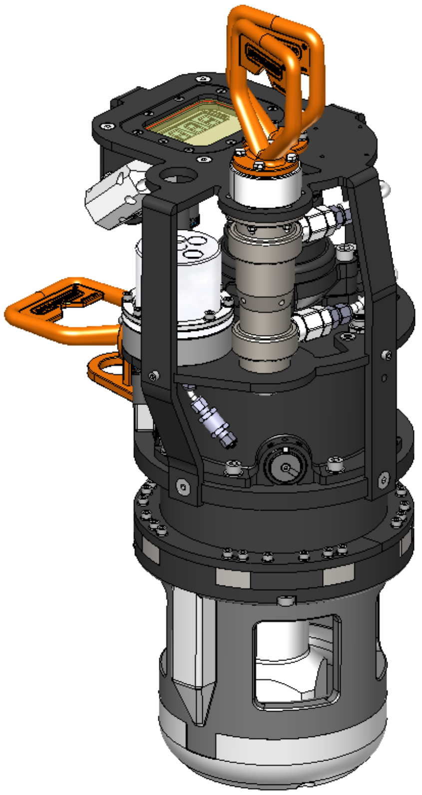


Figure 39: Detail concept design

The gear housing and the tool nose guide has been designed to fit the strain gauge brick concept. The parts are shown in Figure 40 and Figure 41, respectively. The moment transferring occurs over the four moment transferring parts (drive dogs), with the strain gauge plates in between. The strain gauge bricks have parallel sides to minimize the radial forces when compressed, hence the interacting parts has parallel sides.

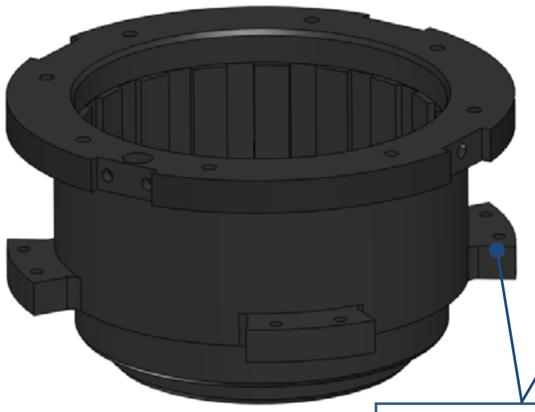


Figure 40: Gear housing

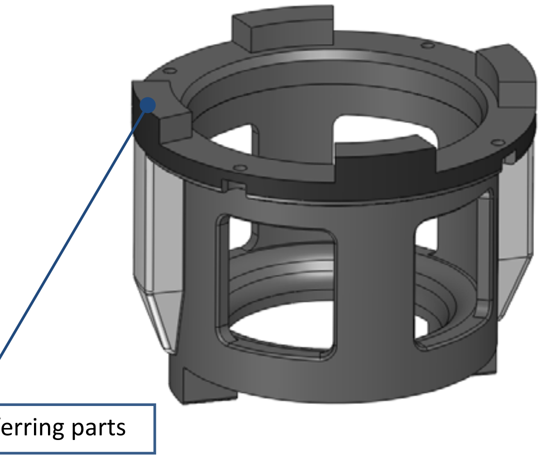


Figure 41: Tool nose guide

The chosen materials for these parts are aluminum alloy 6082-t6, which are further anodized (black) for improved corrosion resistance. The yield strength and ultimate strength of the material is 260 MPa and 310 MPa, respectively. The material is chosen due to its light weight, relatively high strength and corrosion resistance. To ease assemble of the strain gauge bricks, these can be assembled toghether on a half circle plate (see Figure 42). The two wires from each strain gauge can then be molded with plastic into the grove (see Figure 43) in the plate and led to a common point where they are joined together in a cable. Due to the geometry, two half-moon plates are necessary. The mold plastic will protect the strain gauges and the wiring against the sea water and keep them in place in the groove during assembly of the transducer.

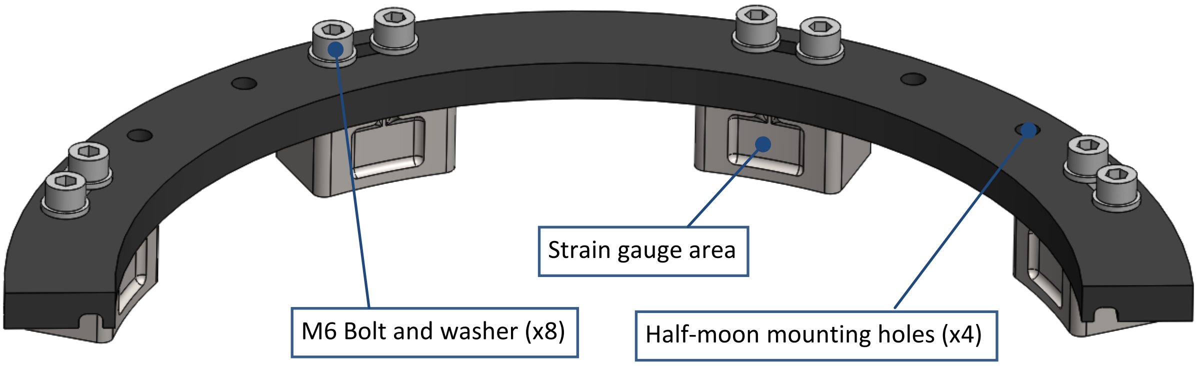


Figure 42: Transducer assembly, top view

The plate will not be exposed to any tangential or radial forces. The only purpose is to ease the assembling of the strain gauges and to keep the strain gauges in place. The strain gauge plates can be mounted onto the half-moon plate by use of two M6 bolts. The mounting hole in the half-moon plate is a groove for allowing the strain gauges too move slightly. The purpose is to ensure that no forces are transferred over the half-moon plate. For this reason, the plate can be in a plastic material which is neutral in water. Alternative plastics can be POM or PEHD.

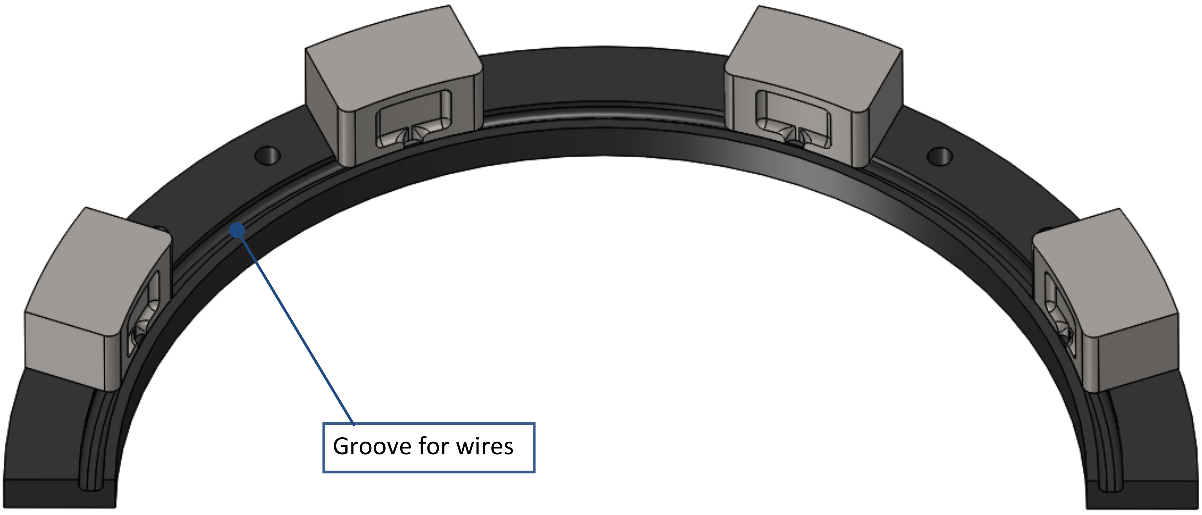


Figure 43: Transducer assembly, bottom view

The transducer assembly can be mounted onto the gear housing by use of a total of 4x M6 bolts on each half-moon. Figure 44 shows the transducer assembly mounted onto the gear housing. To be able to see the bolts, the gear housing is shown in transparent mode. The tool nose guide is mounted onto the gear housing by use of 4x M10 bolts.

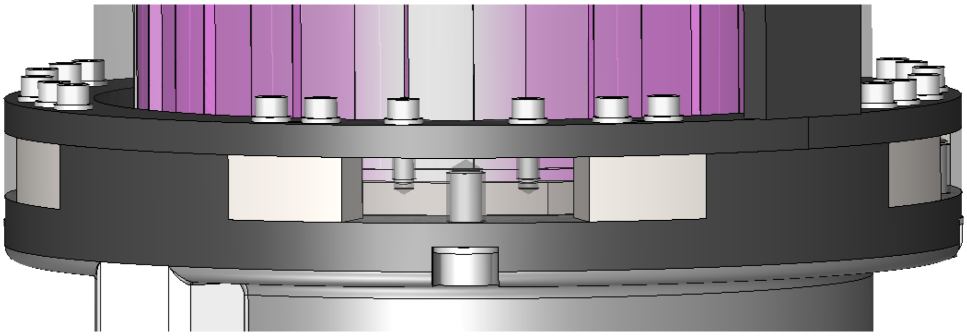


Figure 44: Transducer assy, gear housing and tool nose guide assembled

The strain gauge brick has a milled groove for the strain gauge to be mounted in (Figure 45). When mounted, the two wires from the strain gauges are led away from the strain gauge brick through the milled channel. Then the strain gauge needs to be sealed and covered with mold plastic for seawater protection. The two thread tapped holes are designed for the M6 bolt to hit the bottom of the strain gauge brick to ensure pre-tensioning of the bolt, keeping it from loosen. This is achieved in the strain gauge brick instead of the half-moon plate to keep the friction forces between the surfaces as low as possible. This is done to ensure that no forces are transferred through the half-moon plate. The material is likely to be in high alloyed corrosion resistant steel.

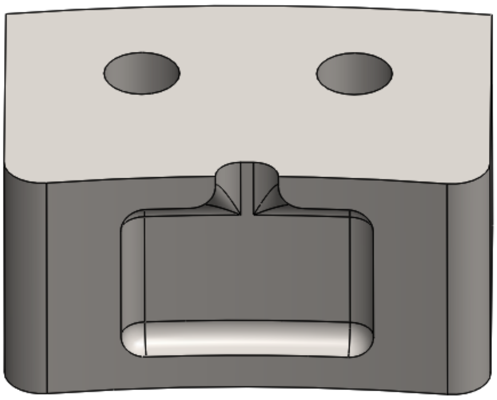


Figure 45: Strain gauge brick

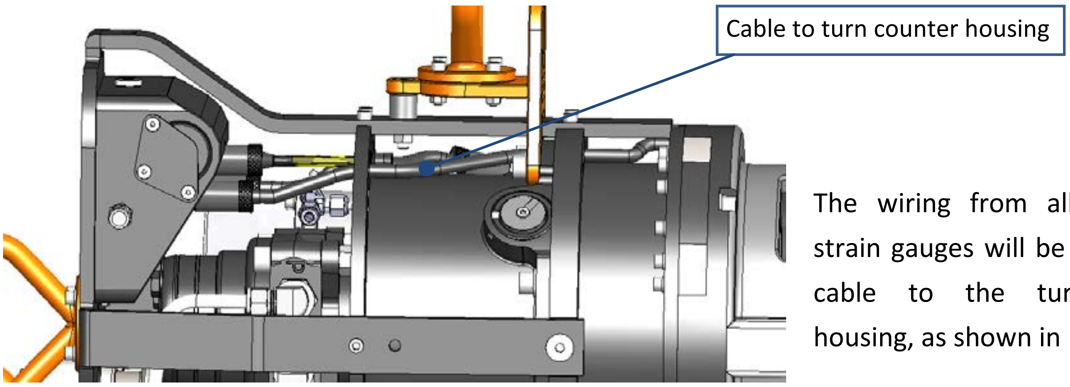


Figure 46: Cable routed to turn counter housing

The wiring from all the eight strain gauges will be routed in a cable to the turn counter housing, as shown in Figure 46.

4 Analysis

4.1 Introduction to analysis

The analyses performed in this thesis are complicated and comprehensive. To be able to get the Ansys analyses to converge, it is essential to simplify the model sufficiently. A lot of time and effort has been devoted to the simplification process and the meshing process. As the mesh is essential for the analyses, an introduction regarding this will be given in this section.

The analyses have been divided into three sections for this thesis; analysis of ring gear and gear housing, analysis of existing concept and analysis of new concept. The ring gear part is identical for both the concepts and the reason why this has been extracted from the two other analyses will be further elaborated in section 0.

Mesh and mesh quality

A continuous object has infinite degrees of freedom. Finite element method reduces this from infinite to finite by means of meshing [19]. The mesh quality plays a significant role in the accuracy and stability of the numerical computation. Regardless of the type of mesh used, checking the quality of the mesh is essential. Ansys allows us to check the orthogonal quality. To determine the orthogonal quality of a given cell, the following quantities are calculated for each face *i*:

- The normalized dot product of the area vector of a face ($\vec{A}_i$) and a vector from centroid of the cell to the centroid of the face ($\vec{f}_i$): $\frac{\vec{A}_i \cdot \vec{f}_i}{|\vec{A}_i|\,|\vec{f}_i|}$ (eq. 1)
- The normalized dot product of the area vector of a face ($\vec{A}_i$) and a vector from the centroid of the cell to the centroid of the adjacent cell that shares that face ($\vec{C}_i$): $\frac{\vec{A}_i \cdot \vec{C}_i}{|\vec{A}_i|\,|\vec{C}_i|}$ (eq. 2)

The minimum value that results from calculating equation 1 and equation 2 for all the faces is then defined as the orthogonal quality of the element. Therefore, the worst cells will have an orthogonal quality closer to 0 and the best cells will have an orthogonal quality closer to 1. Figure 47 Shows the vectors used to compute orthogonal quality. [20]

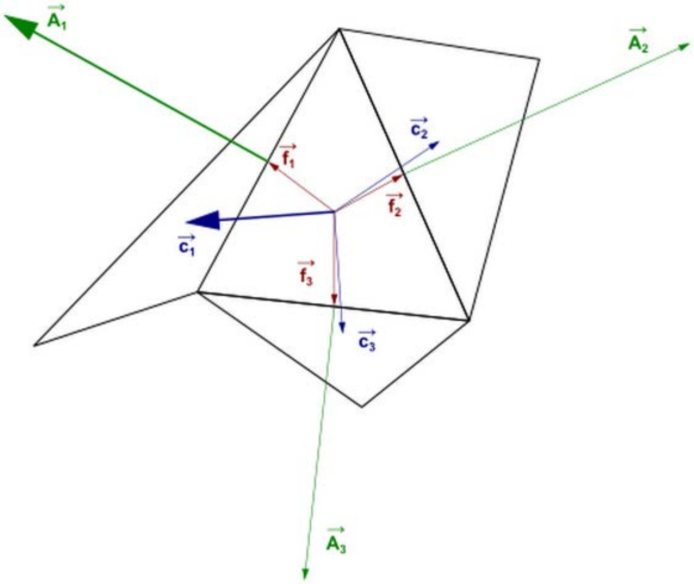


Figure 47: Vectors used to compute orthogonal quality [20]

Element type:

The mesh in the model consists mainly of hexahedral elements. It is achieved by using a mesh function called hex-dominant. This function forces the generation of as many hexahedral elements (hex20 elements) as possible and fills up the remaining space with pyramid (pyr13), tetrahedral (tet10) and prism elements.

Many analysis experiments have been done on comparison different types of mesh and a principle rule is to avoid use of tetrahedron elements when possible as they are much too stiff. These experiments conclude that quadric hexahedron elements are very good and can always be used. The disadvantage with the quadratic hexahedral elements is that the solving time goes up. [21] Figure 48 shoes a quadric hexahedral element.

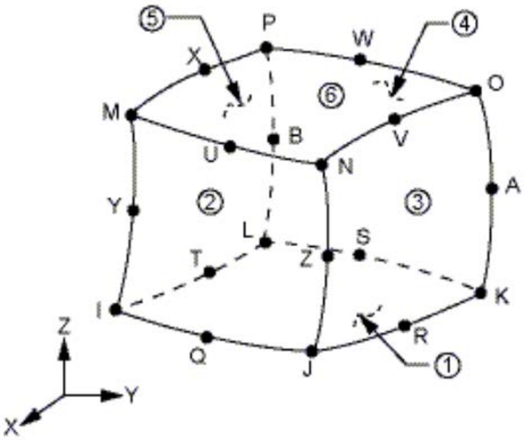


Figure 48: 20 node quadric hexahedral element [22]

Newton-Raphson Method:

Linear structures are well-suited to FEM analysis, which is based on linear matrix algebra. The matrix used is Hooke`s law, F=Ku, where F=force, u=displacement and K=stiffness. In this thesis we have nonlinear models as we have changing status in contacts between elements and bi-linear materials. [23]

To solve nonlinear analyses, Ansys is using an iterative series of linear approximations, with corrections. The process used in Ansys is called the Newton-Raphson Method, and each iteration is known as equilibrium iteration. [23]

The total load F_a is applied in iteration 1 in Figure 49. The result is x_1. Using the displacement, the internal forces F_1 can be calculated. If $F_a \neq F_1$, the system is not in equilibrium. Based on the current conditions a new stiffness matrix (the slope of the dotted line) is calculated. The difference of F_a-F_1 is the "out-of-balance" force, called the residual force. The residual force must be small enough for the solution to converge, meaning it must be within an acceptable tolerance. This process is repeated until F_a=F_i, which is after 4 iterations in this example. The system has achieved equilibrium and the solution is converged. [23]

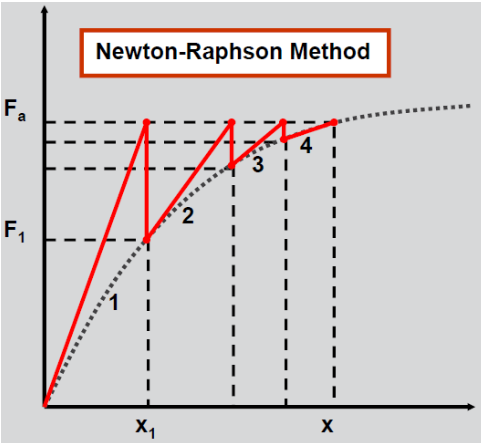


Figure 49: Newton-Raphson Method example [23]

4.2 Analysis of ring gear and gear housing

4.2.1 Scope of analysis

To sufficiently set up the ring gear and the gear housing, a total of 72 frictionless contacts are needed to fully define the scenario when the 18 splines in the ring gear interact with the splines in the gear housing. For future references, splines are referred to as the 18 fins interacting with each other to transfer forces between the two bodies. This amount of contacts is not desirable, if even practical possible in the main analysis model. For this reason the ring gear and the gear housing is analyzed separately from the rest of the model.

The objective for this analysis is to extract the reaction forces in the gear housing. These forces will then be placed onto the main analysis model as forces. As a result, the amount of contacts is reduced and the model itself is reduced to contain a less amount of elements. The element reduction has a large impact as the element size needed in the ring gear is relatively small (2-3 mm), due to the geometry. As the ring gear and gear housing interfaces exactly the same for both concept, the forces extracted from this analysis is used in both main analyses.

The main analysis will be performed with the gear simulated in two positions. This can be done just be shifting the reaction forces, extracted from this analysis, in the main analysis. This will be the case for this thesis. The extracted forces will be shifted a number of splines ahead to achieve the simulated rotation. However, to achieve maximum variation, this analysis can be run in two positions, as the moment interaction points can be either on the thicker part or the thinner part of the ring gear. This is shown in Figure 50 and Figure 51 below.

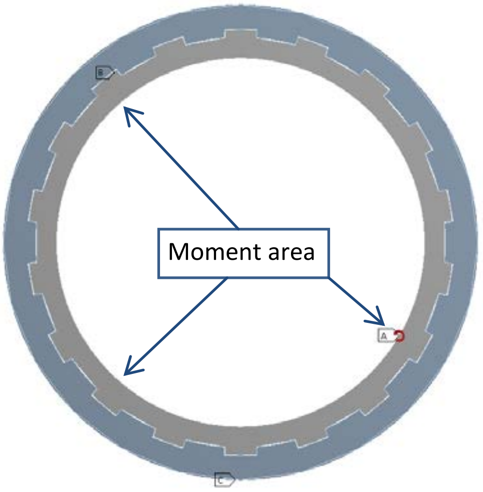


Figure 50: Moment interact the thicker part

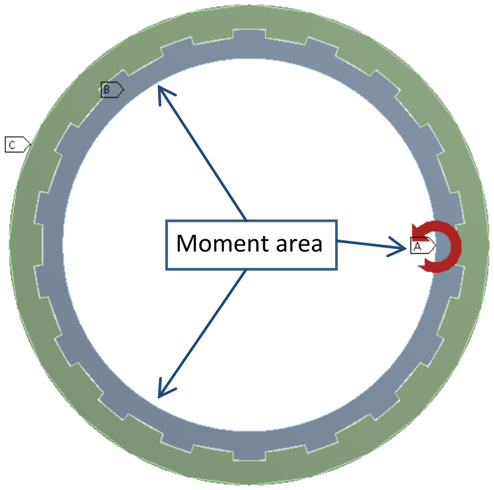


Figure 51: Moment interact on the thinner part

The forces are relatively complicated distributed in this analysis and due to necessary simplifications taken; the forces from one position are not exactly the same as for the second position. The most important consideration is to have equal force input in both positions in the main analysis. For this reason, only forces extracted from one analysis (Figure 50) is used as input forces for the main analyses.

4.2.2 Simplified model for analysis

The model for this analysis has been modified in two steps. The ring gear and the gear housing are simplified as illustrated in Figure 52 and Figure 53.

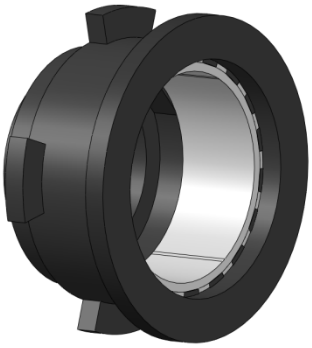


Figure 52: Ring gear and gear housing

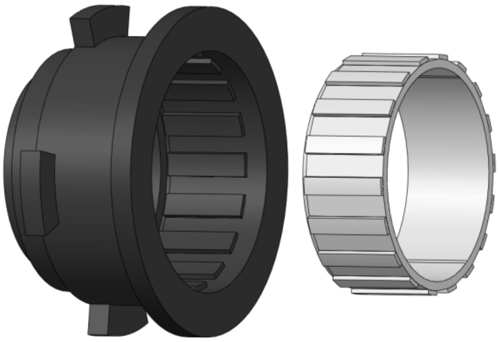


Figure 53: Ring gear and gear housing exploded view

To extract the reaction forces (due to applied moment on ring gear) the model can be further simplified. The complete simplification is shown in Figure 54. The area with the splines has a total height of 78 mm. In the complete model this has been reduced to 16 mm (reduction factor of 4.875).

In addition, the two parts has been modified with respect to tolerances. This is an issue regarding contact analysis with high (fine) tolerances. To simplify, the model has been modified in the middle of the stated tolerances on drawings. See mark-up drawings in appendix C (drawing nr. 970033431 and 970033432). The ring gear has been slightly rotated to the left (Figure 55) to achieve initial contact with the gear housing.

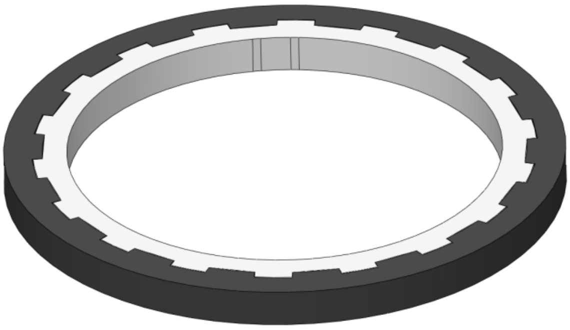


Figure 54: Simplified model for analysis

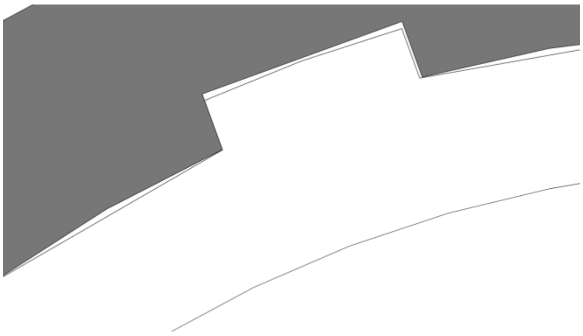


Figure 55: Close-up of contact regions

4.2.3 Model set-up

Material Properties:

The material properties for the components are defined in Table 17. The materials used in Ansys are bi-linear as the license does not support fully non-linear material curves. Using bi-linear materials will result in a more conservative approach compared to non-linear materials.

Component	Material	Poisson ratio	Yield Strength [MPa]	Tensile Strength [MPa]	Young's Modulus [GPa]
Ring gear	SiS 2541 (34CrNiMoS6) (160<t<250)	0,3	600	800	210
Gear housing	Alu 6082-T6	0,33	260	310	71

Table 17: Material properties

To fully define the materials as bi-linear material it is necessary to calculate the tangent modulus. The slope of the tangent drawn to the stress-strain curve at a given stress value is called the tangent modulus [24]. The bi-linear material curve for Alu 6082-T6 is shown in Figure 56. The tangent modulus is calculated as followed:

$$E_t = \frac{\sigma_{UTS} - \sigma_{Yield}}{\varepsilon_{Break} - \varepsilon_{Yield}}, \text{ where}$$

σ_{UTS} = Ultimate tensile strength
σ_{Yield} = Yield strength
ε_{Break} = Elongation at break
ε_{Yield} = Elongation at yield

For many steels, the ε_{Yield} is very low and can be neglected. The relevant tangent modulus is calculated in appendix H, section 1.

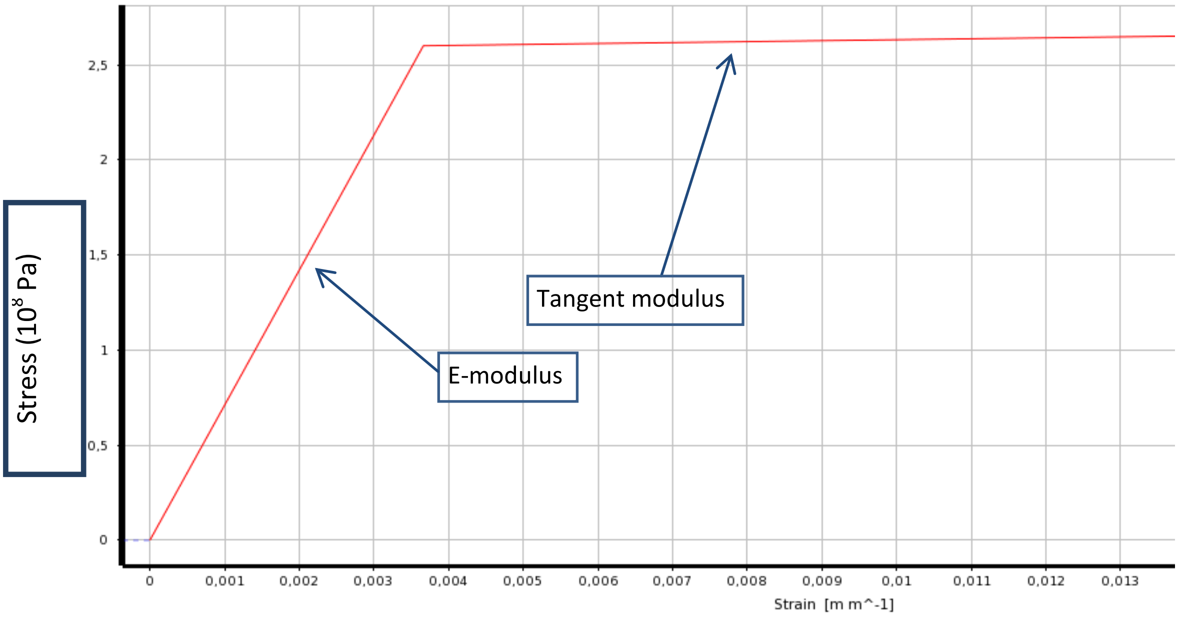


Figure 56: Bi-linear stress-strain curve for Alu 6082-T6 (from Ansys engineering data)

As a comment to Figure 56, Ansys uses an unusual strain notation. This equals to the more common mm/mm notation.

Loads and supports:

The moment is applied on three places equally distributed around the ring gear. This simulates the cog wheels interaction with the ring gear. The applied moment is around the y-axis (Figure 57). This is shown in an unconventional way in software, as the moment is shown around one of the three selected surfaces. The y-axis is placed in the center of the ring gear. The moment applied is 40 000 Nm. The ring gear splines have a height of 78 mm. The height of the simplified model is 8 mm (symmetry about the xz-plane has be used), which is a reduction by a factor of 9.75. The moment applied has subsequently been reduced with this factor.

As symmetry is about the xz-plane, there is no need for support in the z-direction.

A cylindrical support is applied on the outer diameter surface of the gear housing. This support is defined as fixed in tangential and radial direction, while the axial direction is free. All the loads and supports on the model are illustrated in Figure 57.

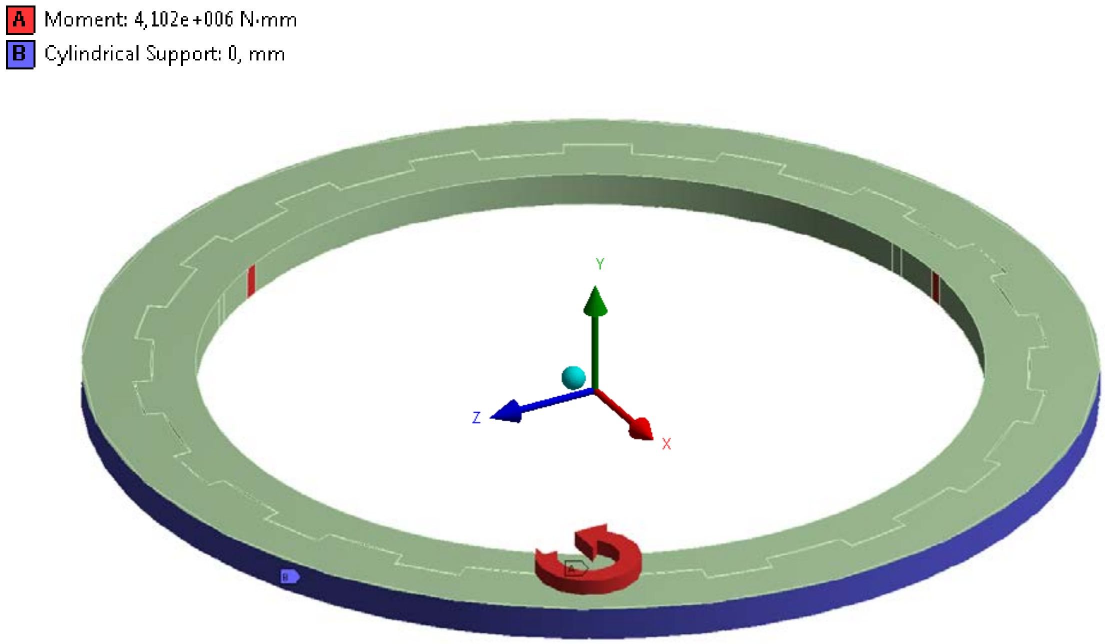


Figure 57: Load and supports

Contacts:

The interactions between the surfaces on the two components are defined by use of frictionless contacts. There are a total of 18 splines which results in a total of 72 contacts. An excerpt of the complete model with contacts is shown Figure 58. All contacts around located as contact A are user defined to adjust to touch. This reduces the solving time and the possibility for the program to detecting the contacts as the program is told that initial contact exists. The contacts are shown with blue color (target side) or red color (contact side), depending on wish side showing in the illustration.

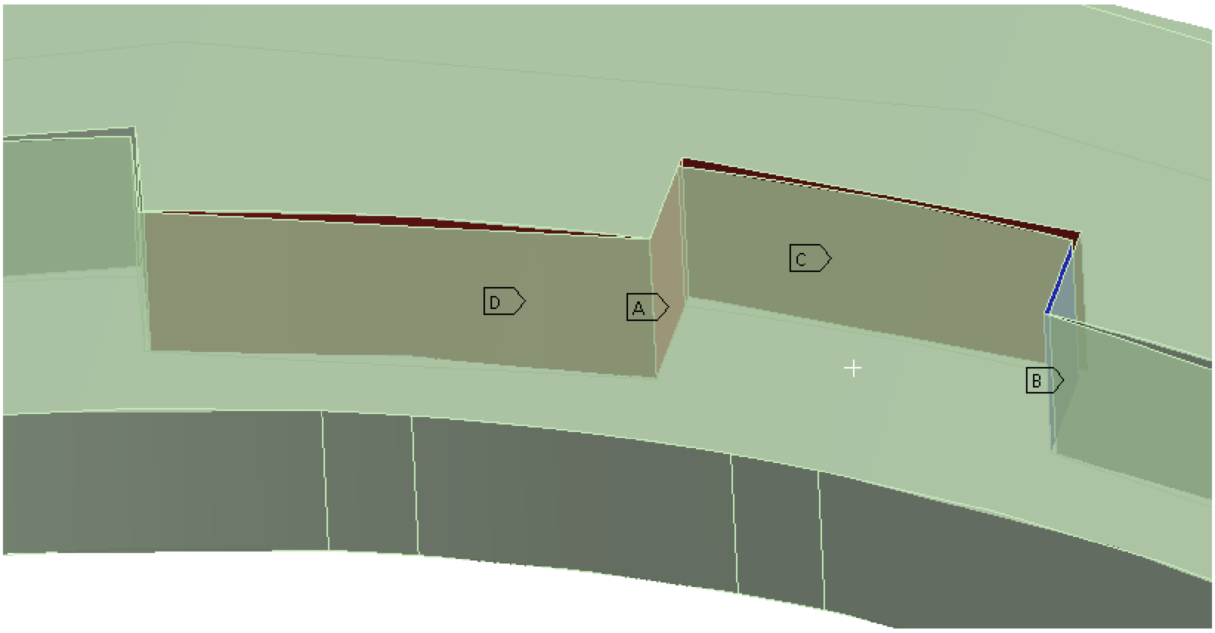


Figure 58: Frictionless contacts

For future reference, the contact areas are given the names as illustrated in Figure 58. The moment is applied in counter clockwise direction.

The frictionless contact allows the surfaces to slide freely. The contact can open and close depending on the loading. This is a simplification compared to frictional contact, but the solving time reduces drastically and convergence is easier to achieve.

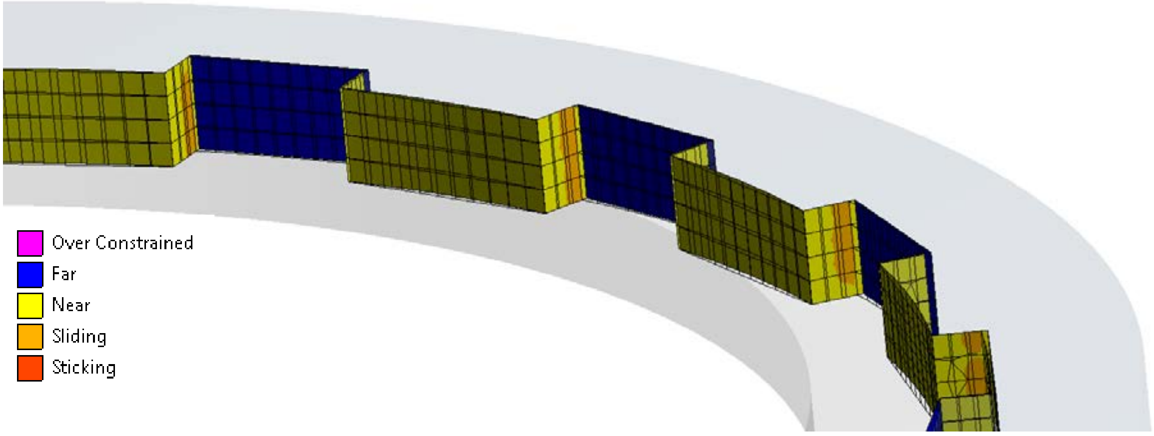


Figure 59: Initial contact status

Ansys contact tool has been used to analyze the initial contacts. An excerpt of the model illustrating the initial contact status is shown in Figure 59. There are a certain degree of miss-match between the reference color and the color on the geometry. The yellow color can appear as greener in some cases. All contacts are found and appear as expected.

4.2.4 Mesh

To optimize the mesh for this geometry, two different user-defined controls are used. These are hex-dominant method and body sizing with an element size of 2 mm (side lengths). This is an average number and the mesh size can vary in a miner degree depending on the geometry. The mesh is shown in Figure 60. The mesh consist of a total of 25 168 elements and 115 019 nodes, which are relatively high numbers compared to the geometry size.

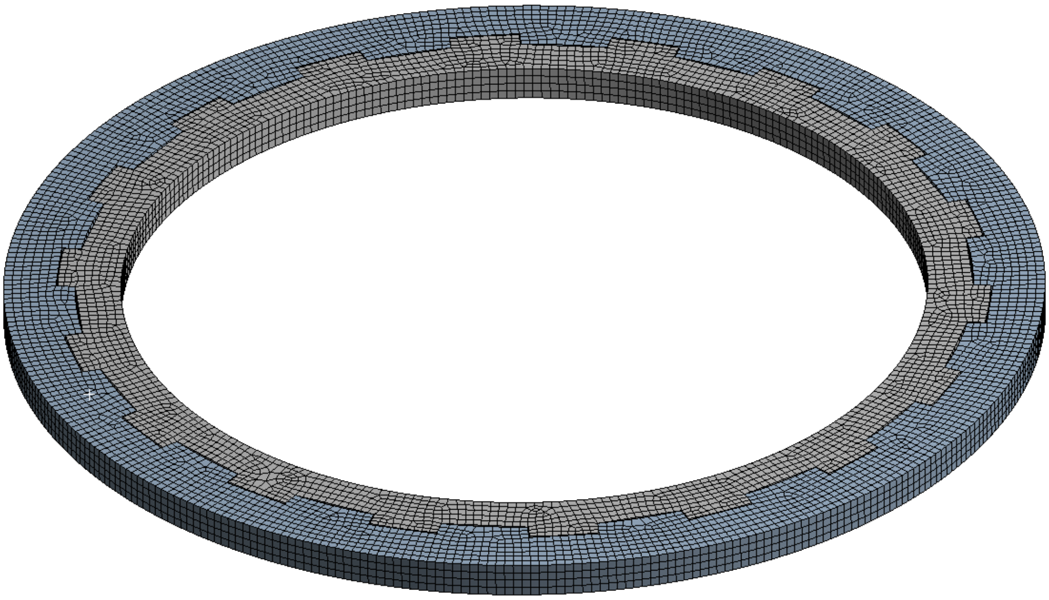


Figure 60: Generated mesh

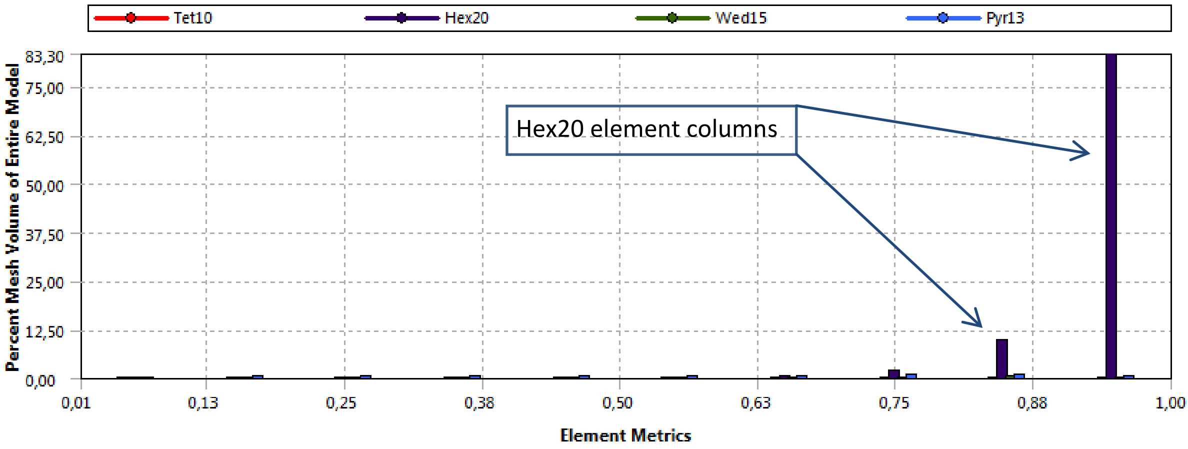


Figure 61: Mesh quality

The mesh quality is shown in Figure 61. The columns illustrate the percentage of elements with a certain quality mesh. The mesh consists mainly of hex20 elements. Due to the simplicity of the geometry, a very high mesh quality is achieved.

4.2.5 Results

The contact result plot shows (Figure 62) that the contacts interact as expected, compared to the input moment. Some splines have a sliding contact and some have a near contact. This is reasonable as the first splines close to the moment input will take up more than the following splines.

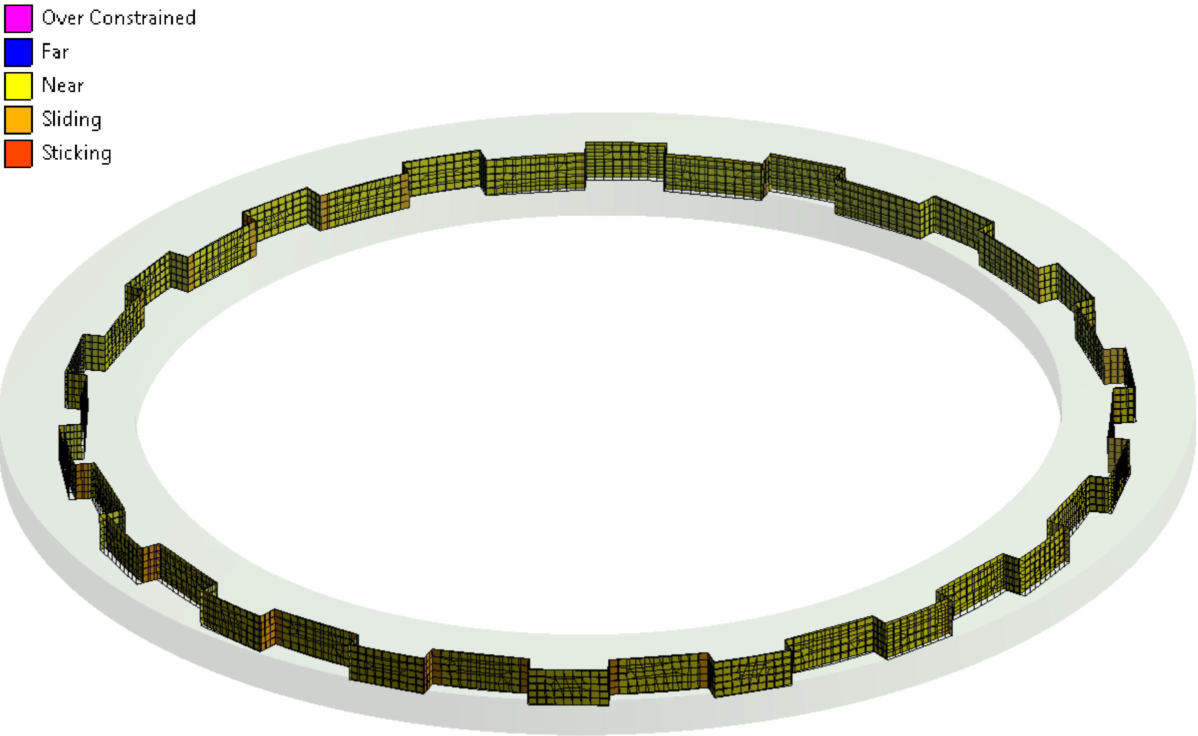


Figure 62: Contacts plot

As Figure 63 illustrate, the contact goes in a small degree onto contact area 3, but the main contact area is in contact area 1. Some contact is also observed in contact area 2. In total, the reaction forces in all the splines are very complicated and needs to be simplified to be applied into the main analysis.

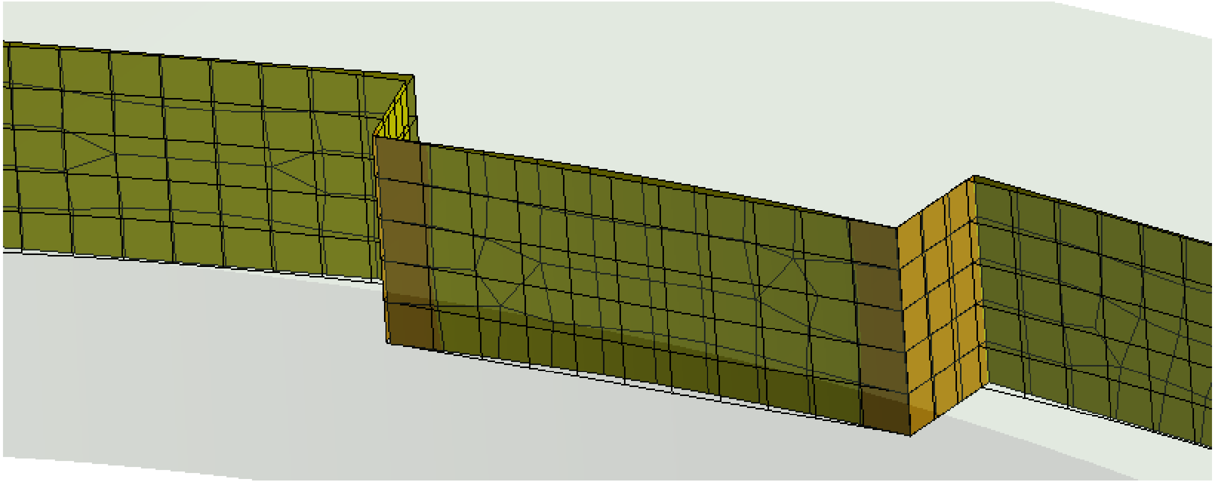


Figure 63: Contacts plot close-up

The reaction forces have been extracted from each contact in cylindrical coordinates (Figure 64). The forces are time demanding to analyze precisely and accurate as the reaction forces only appears on part of the contact area of the contacts. Due to this, a simplification has been made for the forces applied in the main analyses. The objective is to get a similar force distribution as when the cog wheels rotates, and this is achieved within an acceptable tolerance. The forces from the result are shown in appendix D.

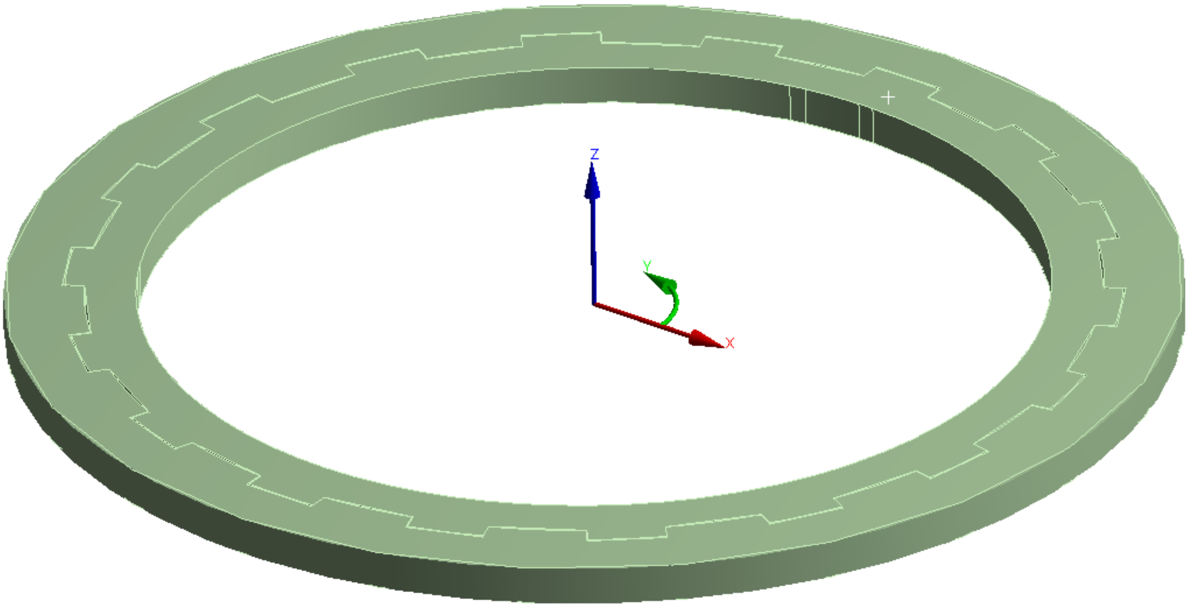


Figure 64: Cylincrical coordinate system

The simplification made is that the forces from all the four contact areas will be applied on two contact areas in the main analysis, namely contact area 1 and contact area 2. Forces for contact area 2 are applied directly in the contact area two in the main analysis.

Contact area 1 consists of the sum of the following reaction forces:

- Y-direction for contact area 1 and contact area 4
- X-direction for contact area 1 and contact area 4

The forces applied in the main analysis are listed in Table 18.

These forces have been multiplied by a factor of 9.75. This was the reduction factor used in the simplified gear housing and ring gear analysis.

The analysis took about two hours to run and the moment was set to decrease with increments of 10 % of full load. The solving time would have been drastically higher if the model was not simplified as it is. It was challenging to get the solution to converge but using symmetric contacts, increasing the number of load increments and use of symmetry made it converge.

	Reaction forces applied in the main analysis			
Spline no.	**Y1+Y4 [N]** (applied on contact area A)	**X1+X4 [N]** (applied on contact area A)	**Y2 [N]** (applied on contact area B)	**X2 [N]** (applied on contact area B)
1	36826	20465	0	0
2	69059	51890	-1063	12870
3	88	18184	-488	5753
4	29	341	-351	4310
5	3832	273	0	0
6	34515	2720	0	0
7	36904	20339	0	0
8	69303	51841	-1053	12792
9	88	18262	-536	5928
10	29	351	-351	4300
11	3871	273	0	0
12	34466	2720	0	0
13	36875	20495	0	0
14	69098	51714	-1082	13065
15	88	18194	-497	5801
16	29	273	-351	4310
17	3949	283	0	0
18	34535	2720	0	0

Table 18: Reaction forces in cylindrical coordinates

The forces presented in Table 18 are the forces used as input forces for the main analysis for the existing and the new concept design. The moment input from the analysis is located in spline no. 1, 7 and 13. To achieve a steadier model for the main analysis, the forces in the z-direction have been neglected. The simplified model does not have any bolts keeping the model together in the z-direction. By presenting forces in the local z-direction it will be necessary to add virtual supports. As these forces are small compared to the x- and y-directed forces, it will only affect the result in a miner degree.

Check of moment input and moment output is shown in appendix E, section 2. The moment input is compared to the cylindrical reaction force in the cylindrical support.

4.2.6 Conclusion

The main objective with this analysis is to get a similar distribution of the forces as with the ring gear. Due to the complexity of the analysis, and the complexity of transferring the forces from this analysis to the main analyses, some simplifications have been done. This uncertainty will not affect the main analysis as the most important consideration is to have variation in the force magnitude in the two different positions.

4.3 Analysis of existing concept

4.3.1 Scope of analysis

The scope of this analysis is to investigate if strain gauges can be mounted inside the transducer and get readings which do not vary with the gear rotation. To investigate this it is necessary to analyze three separate scenarios, where the variable is the position of the third stage cog wheels engagements. This will be further elaborated in the model set up section. Constant strains independent on the position of the gear will result in a concept with small deviations regarding to torque feedback readings.

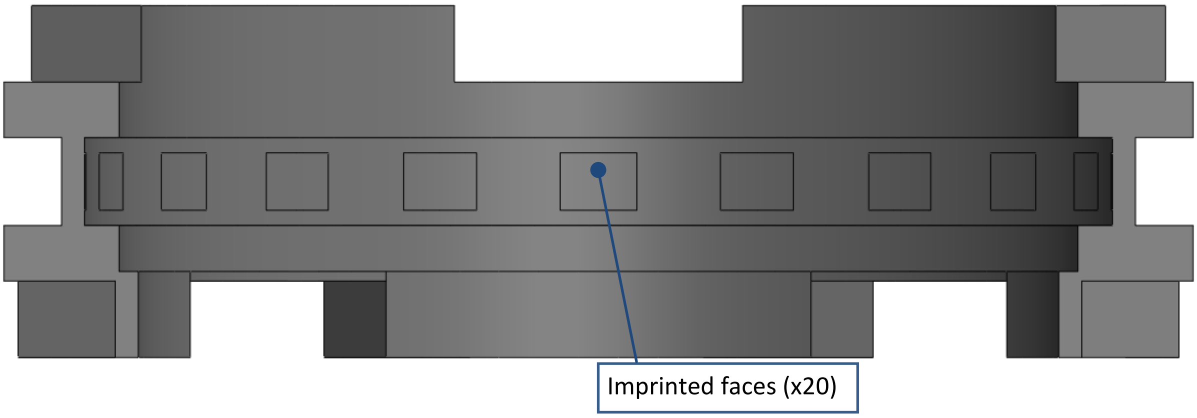


Figure 65: Transducer section cut showing SG area

Figure 65 shows the transducer strain gauge area. The main objective of the analysis is to investigate how the strain distribution changes by changing the cog wheel engagement positions. Imprint faces are designed into the model in SW. A total 20 imprinted faces are model around the inner diameter of the torque transducer. Each imprint simulates the area for a strain gauge. In existing tool a total of 2 or 4 strain gauges are used (uncertain). By using 20 imprinted faces it will be possible to analyze how the accuracy will vary with the number of strain gauges. The imprinted faces are necessary to read results from these particular areas.

As a secondary objective, this analysis can be used to investigate the strain distribution on other parts of the tool which can be subjected for strain gauges measurements for torque feedback. The following concepts can be investigated to determine the viability of the concept:

- Strain gauges close to the reaction fins on the existing design

Uncertainty regarding the strain distribution is associated with this concept. However, should the analysis reveal that the strain distribution in this area is satisfactory, torque feedback implementation can be done with a low cost regarding both development and production cost.

4.3.2 Simplified model for analysis

The complete 3D model consists of a total of several hundred parts. Of these parts, it is only a few that is relevant for the analysis. The parts relevant are the parts exposed and transferring the forces and moment. Figure 66 shows exploded view of the relevant parts.

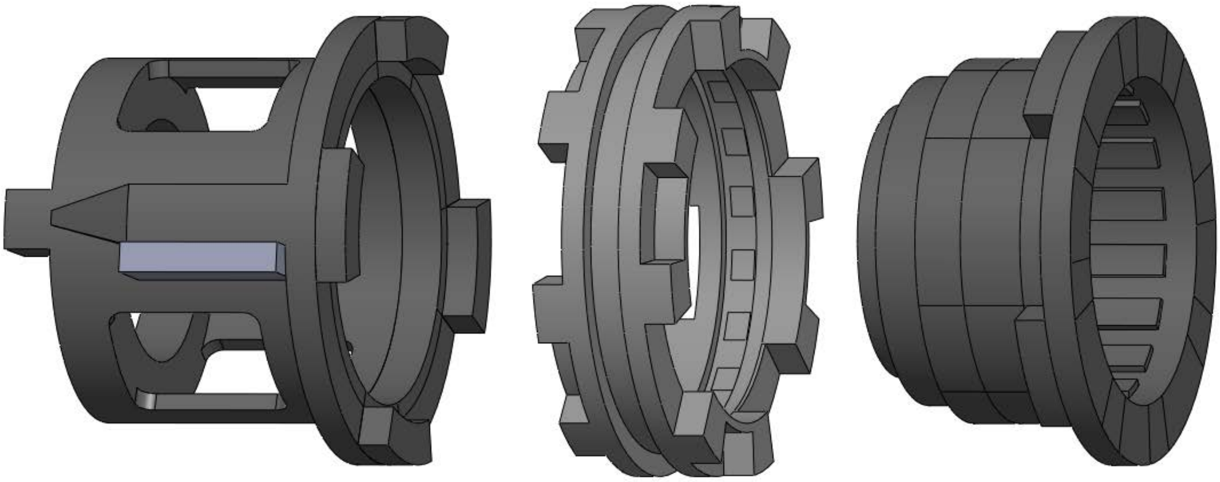


Figure 66: Simplified model in exploded view

This is a relatively complicated analysis with several parts. All these parts are relevant to simulate the actual strain distribution occurring due to the gear rotation. Each part has been simplified by removing irrelevant holes, cuts, radiuses and seal grooves. The simplifications are mainly done to optimize the mesh generation. The torque bucket is included in the model to simulate the actual interface to the reaction fins.

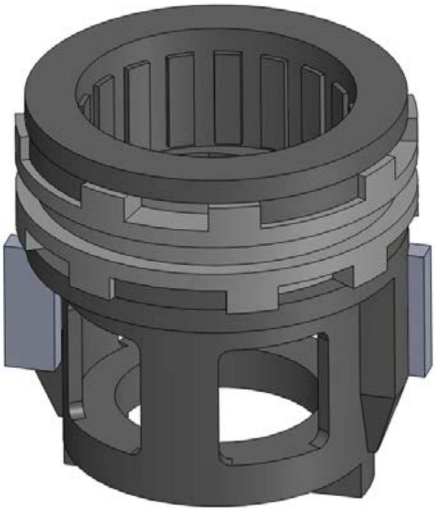


Figure 67: Simplified model

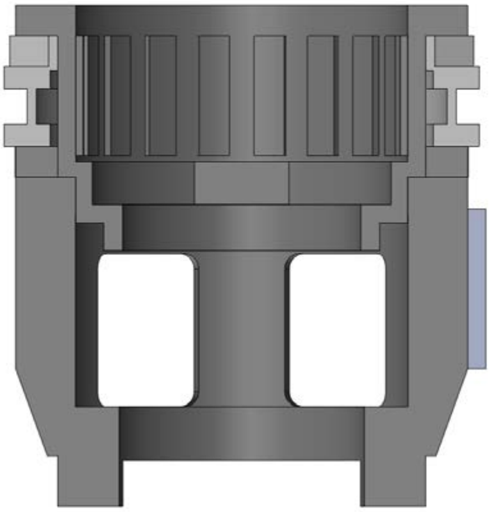


Figure 68: Section cut of simplified model

Figure 67 and Figure 68 shows the complete simplified model. The ring gear has been modified to only consist of the third stage gear area as this is where the forces are transferred to the gear housing through the 18 splines. The first two stages will contribute too many more different possible positions compared to one stage. This can be neglected for the analysis for comparing the strain distribution.

4.3.3 Model set-up

Material Properties:

The material properties for the components are defined in Table 19. The materials used in Ansys are bi-linear. Tangent modulus is calculated in appendix E, section 1.

Component	Material	Poisson ratio	Yield Strength [MPa]	Tensile Strength [MPa]	Young's Modulus [GPa]
Gear housing	Alu 6082-T6	0.33	260	310	71
Tool guide	Alu 6082-T6	0.33	260	310	71
Torque transducer	Alu 6082-T6	0.33	260	310	71
Reaction plates	S355 (17<t<40)	0.3	345	470	210

Table 19: Material properties

Supports:

The reaction plates illustrate the torque tool interface bucket and are constrained with fixed supports on the back of the plates. This type of support does not allow any movement in any degrees of freedom. A displacement support is placed underneath the tool guide on the two bottom faces to constrain it in the axial direction; hence the y-direction displacement is set to zero. Standard earth gravity is added to the model. A cylindrical support, fixed in radial direction, is placed on the bottom inner diameter of the tool guide. The supports are shown in Figure 69.

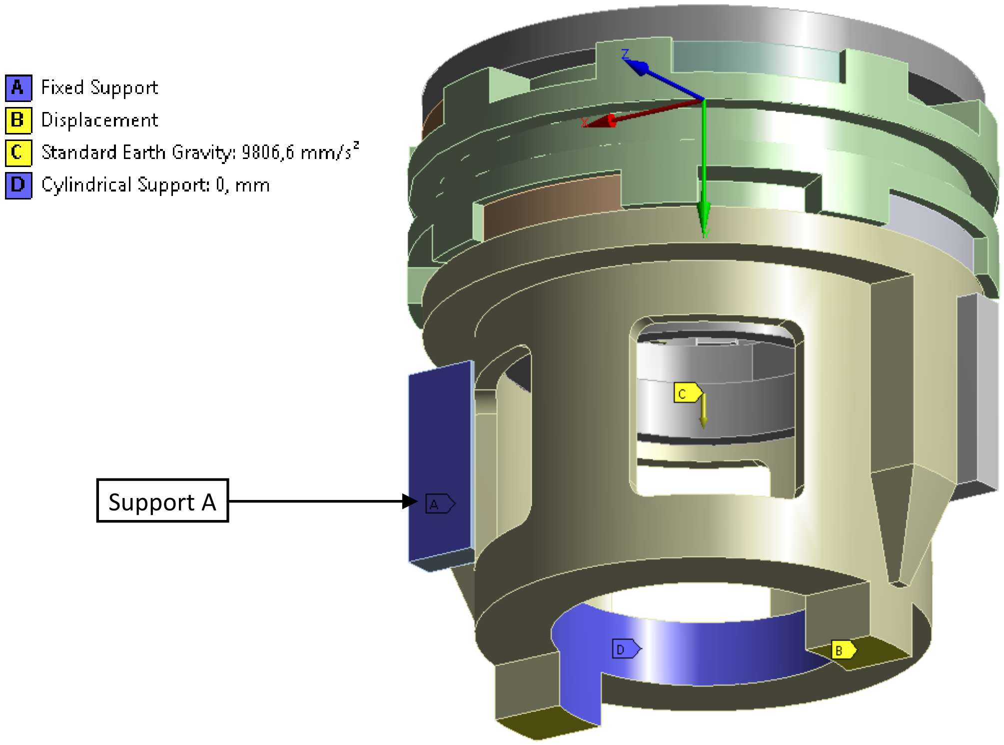


Figure 69: Tool guide and reaction plates supports

As there are no bolts constraining the gear housing in the axial direction (y-direction), it is necessary to add constraints. An attempt with only standard earth gravity was tried out, but the solution would not converge. Due to the geometry, the deformation results in small axial forces acting on the gear housing and the gear housing will have rigid body motions.

Displacement supports with zero displacement in the y-direction is used to fully constrain the gear housing. By use of imprinted faces on the top of the geometry, the displacement supports are reduced to contain only the area were bolts attaches the ring gear housing to the torque transducer. The constraints are placed as shown in Figure 70.

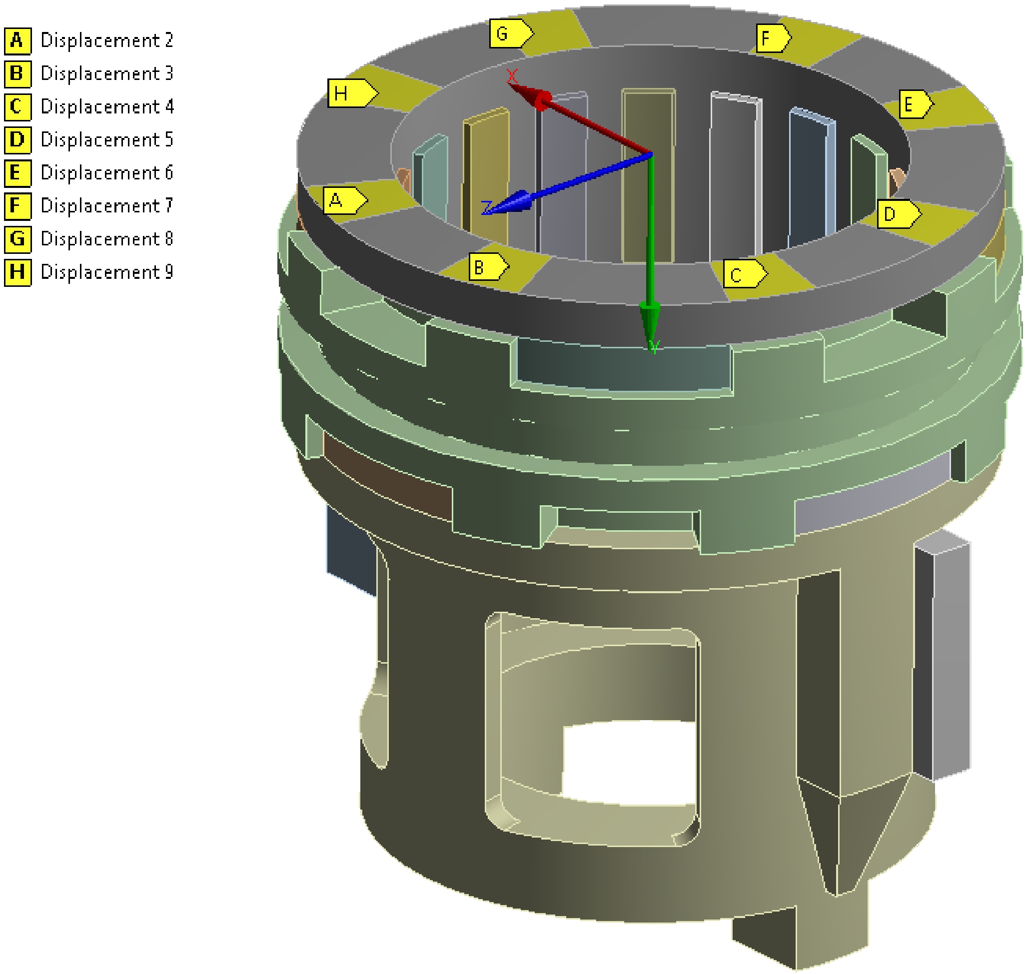


Figure 70: Gear housing displacement supports

Loads:

As stated earlier, the reaction forces from the ring gear and gear housing analysis is applied on the splines in this model. The forces are applied, as stated in Table 18, on the faces shown in Figure 71. The forces are applied as components in a cylindrical coordinate system with the z-axis in the center of the model. Radial forces (x-direction) and tangential forces are applied (y-direction).

The simulated rotation of the gear is achieved by shifting the applied forces one spline ahead. This is further elaborated in this section.

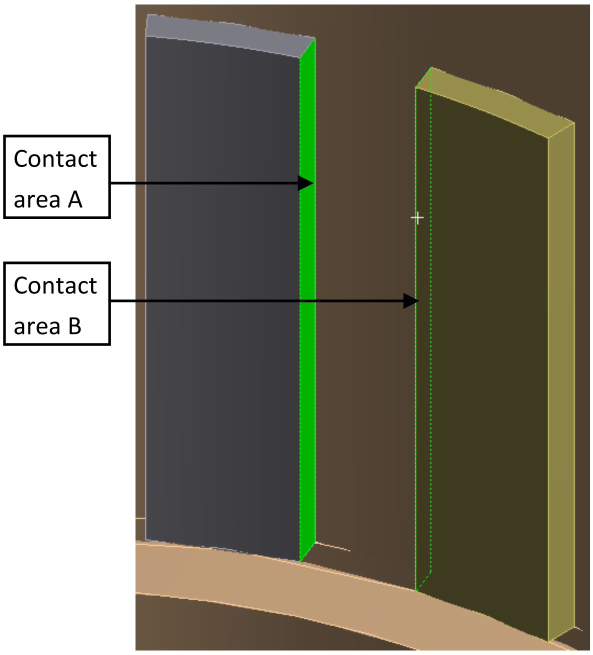


Figure 71: Areas for applied forces

Position 1:

For position 1, forces are applied in the position as shown in Figure 72. The spline force locations in the figure shows were the moments interact in the ring gear and gear housing analysis. All the forces from the ring gear and gear housing are applied in ascending order from 1 to 18.

The forces results in the moment to work counter-clockwise (in y-direction).

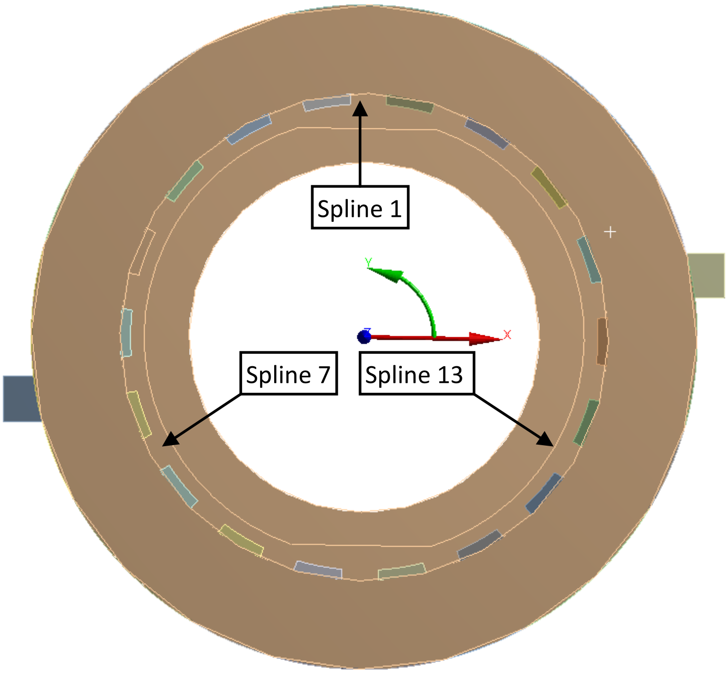


Figure 72: Location for forces applied for position 1

Position 2:

The applied loads for position 2 are exactly the same as for position one, only the force picture is shifted one spline ahead. This means that the forces applied on spline 1 is now applied on the spline ahead. This is shown in Figure 73.

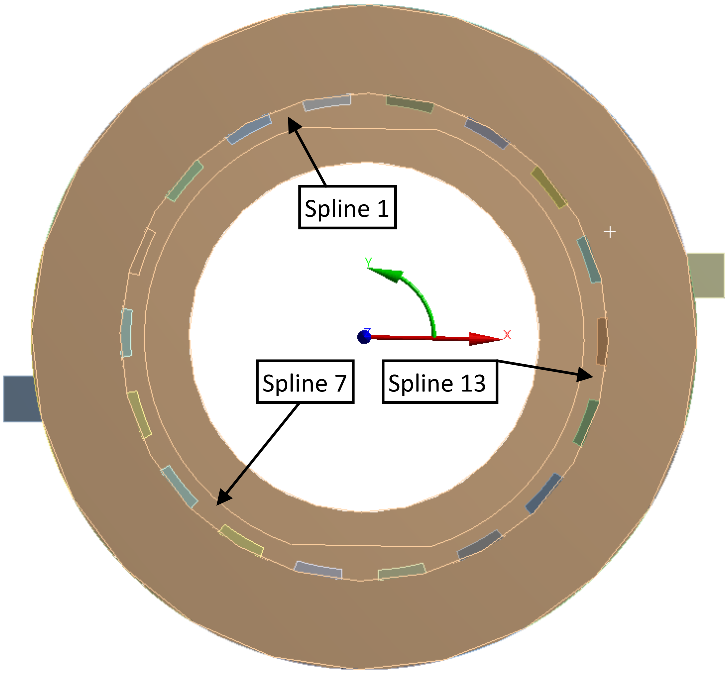


Figure 73: Location for forces applied for position 2

Position 3:

For position 3, the forces are shifted just another spline ahead, as shown in Figure 74.

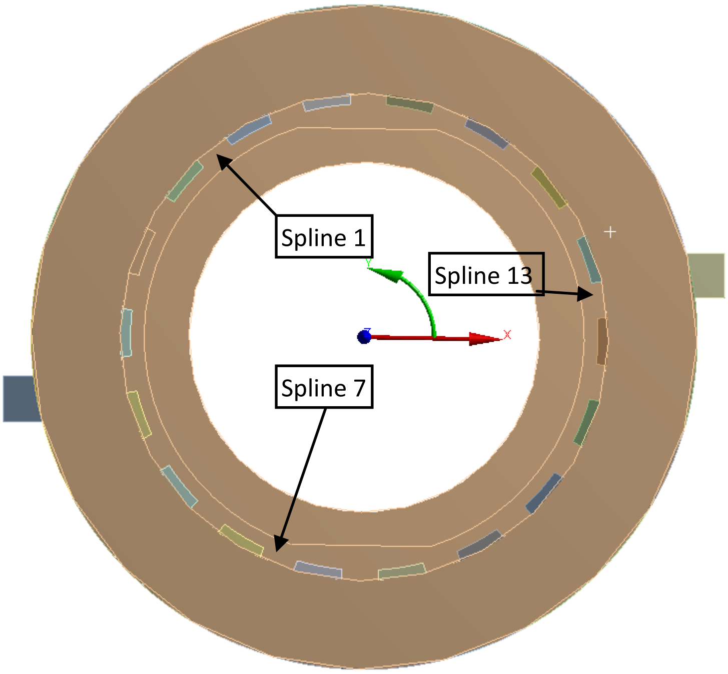


Figure 74: Location for forces applied for position 3

Contacts:

All contacts used in between parts interacting with each other are set to frictionless contacts. A total of 32 contacts have been used to fully define the interacting parts. The interface treatment is set to adjust to touch as all the contacts will have initial contact.

Figure 75 and Figure 76 shows the contacts between the gear housing and the transducer. The moment is acting counter-clockwise and the gear housing will push the transducer were contact A is shown on the figure. One contact is placed between each gear housing interaction fin and the transducer. Contacts are also defined between bottom of the interaction fins and the transducer (contact B).

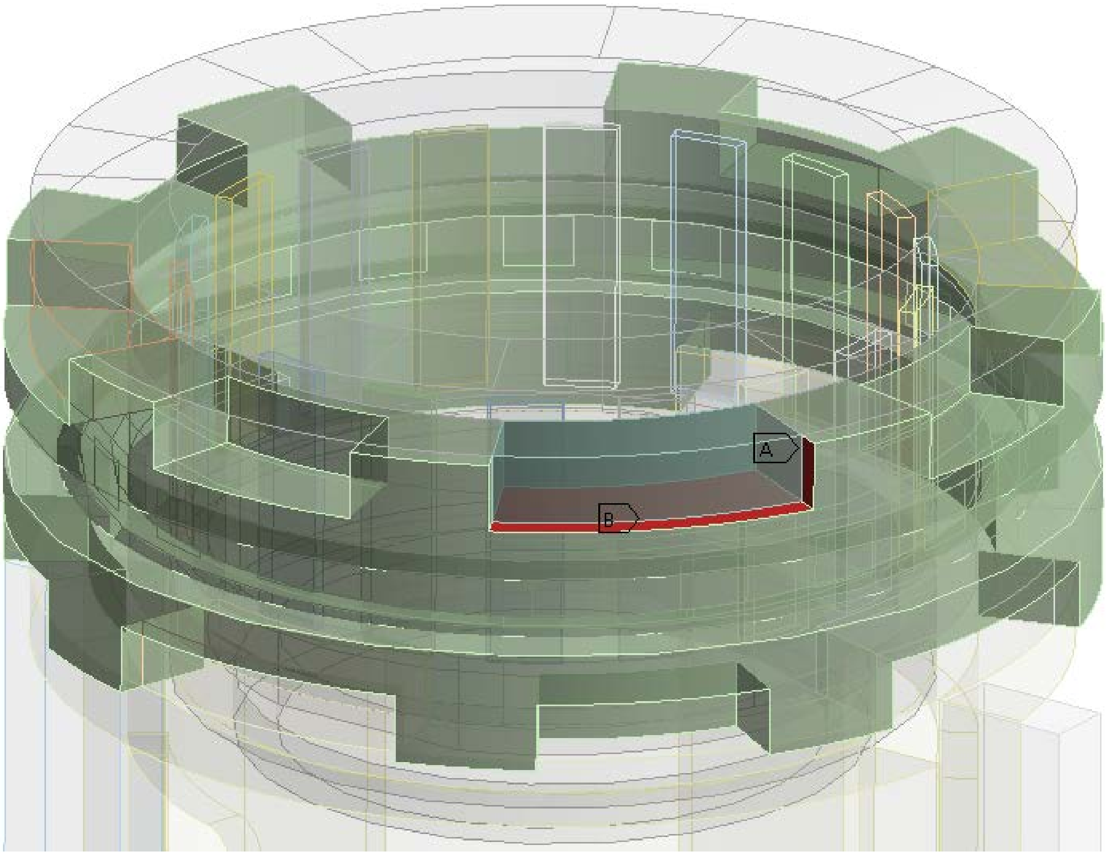


Figure 75: Gear housing and transducer contacts

Contacts are also defined between the transducer top and the gear housing and between the inner diameter of the upper transducer and the outer gear housing diameter (ref. Figure 76).

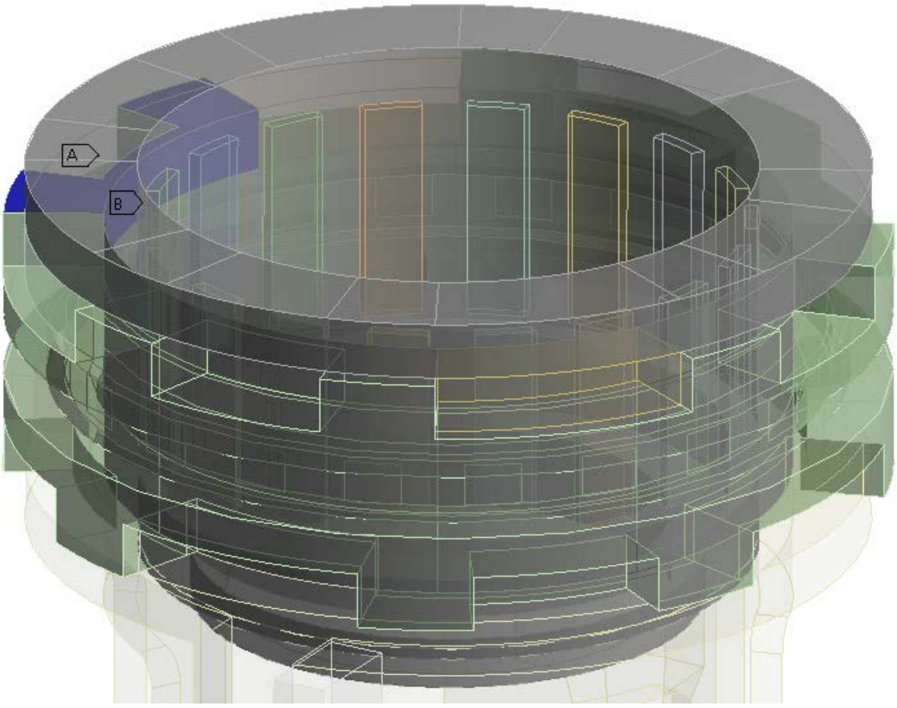


Figure 76: Gear housing and transducer contacts

As for the upper part, between the transducer and the gear housing, similar contacts are defined, as shown in Figure 77.

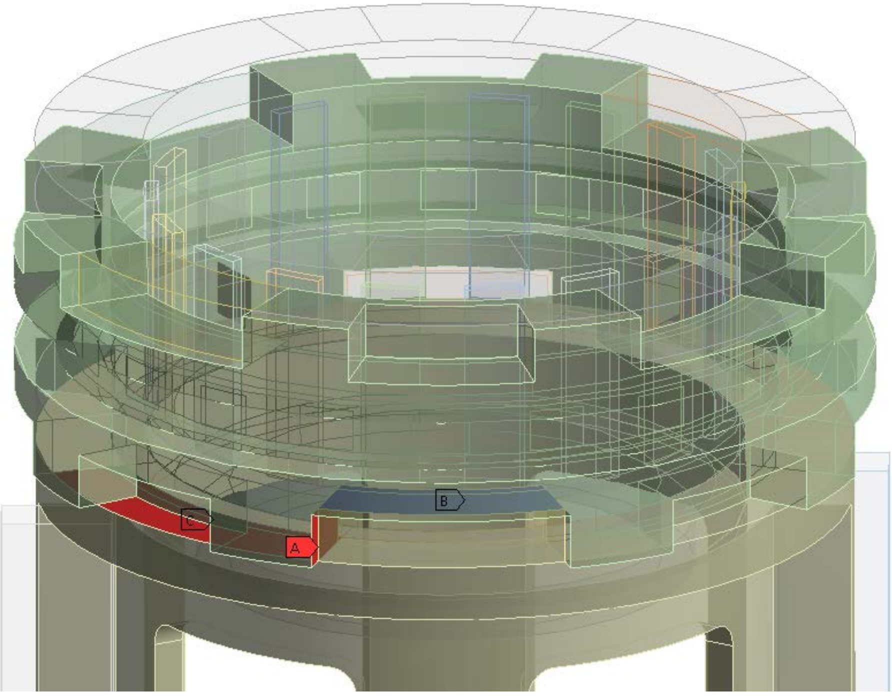


Figure 77: Tool guide and transducer contacts

Figure 78 shows the contact between the tool guide and the gear housing. One contact is placed on each tool guide interaction fin.

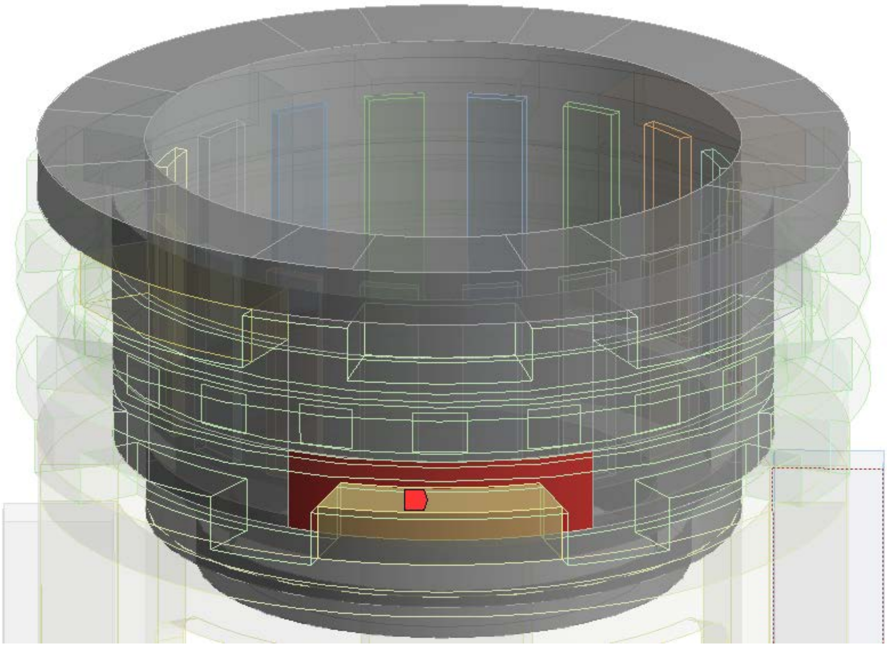


Figure 78: Gear housing and tool guide contacts

Figure 79 shows the contacts between the reaction plates and the tool guide.

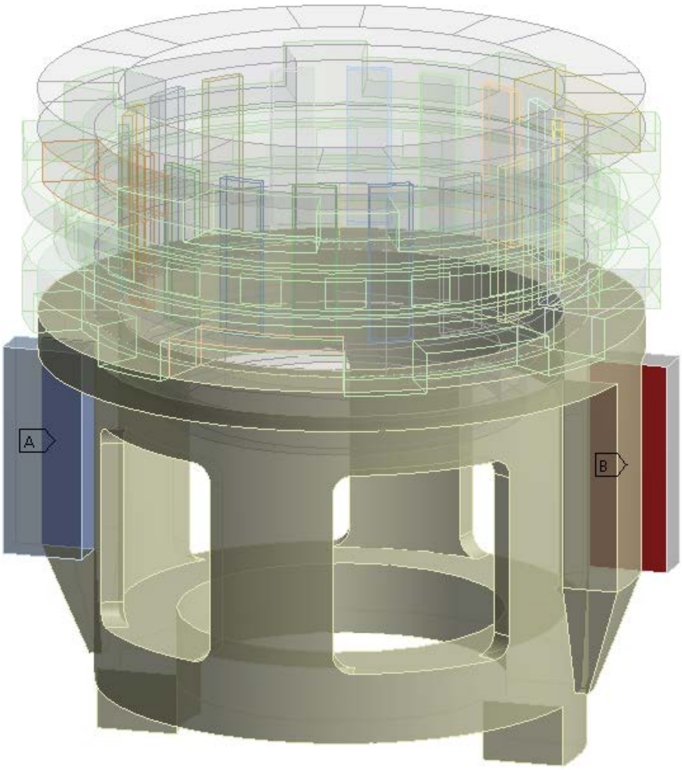


Figure 79: Tool guide and reaction plate contacts

Figure 80 shows the initial contact status for the model. The figure shows that contacts are found and are as expected compared to applied forces and defined contacts.

Initial contact analysis is important to avoid starting analysis were contacts are not found or sufficiently defined. The result of not checking initial contacts can be incorrect solutions or time lost waiting on an analysis which eventually will fail (not converge).

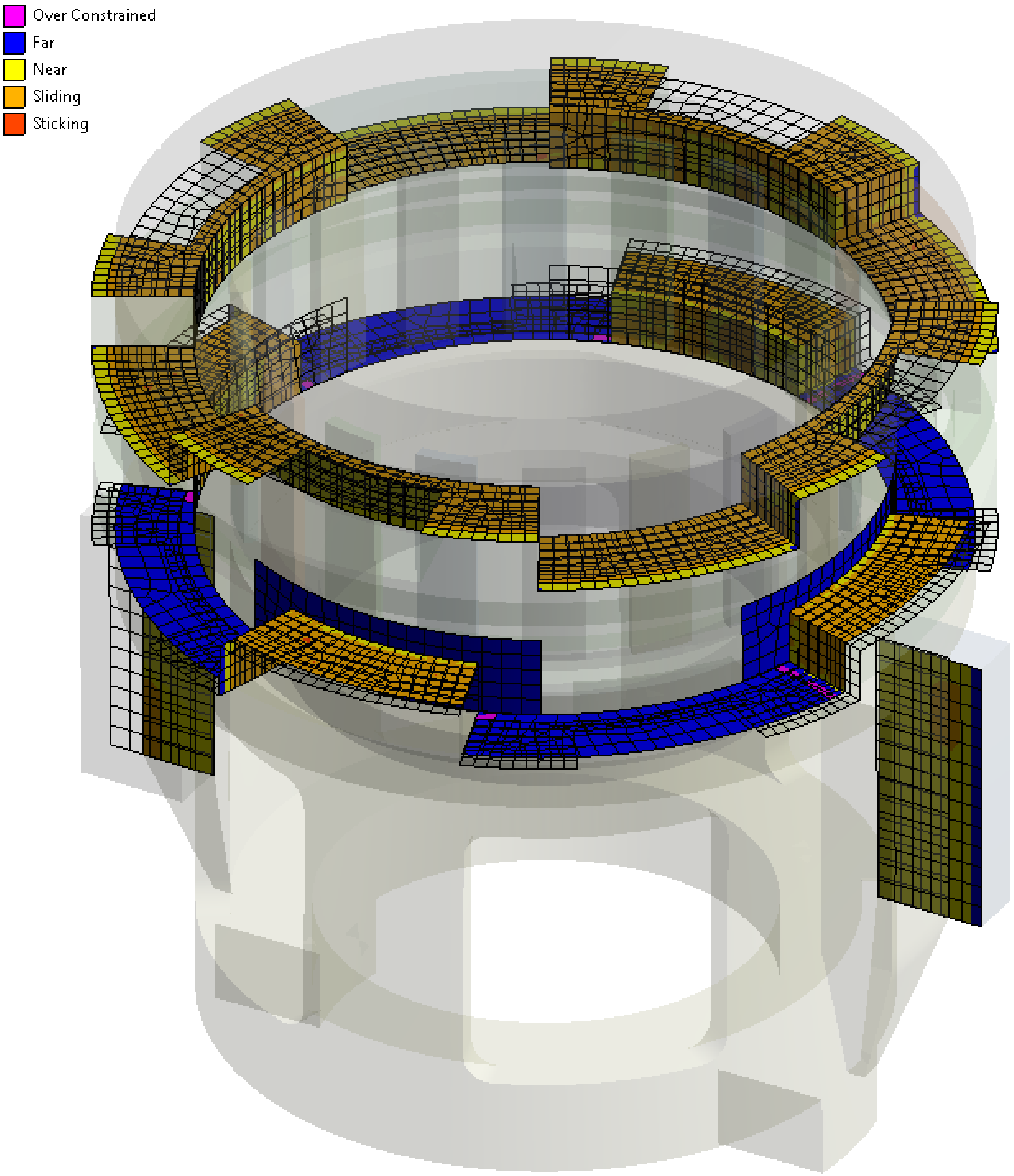


Figure 80: Initial contact status

4.3.4 Mesh

To optimize the mesh for this geometry, two different user-defined controls are used. These are hex-dominant method and body sizing. The mesh is shown in Figure 81.

The mesh consist of a total of;

- 55 643 elements
- 222 602 nodes

Different mesh sizes have been used on independent bodies. To achieve this, the bodies have been separated to consist of several individual parts with shared topology, called multi-body parts. The multi-body parts behave as one part in the analysis. This will be further elaborated in this section.

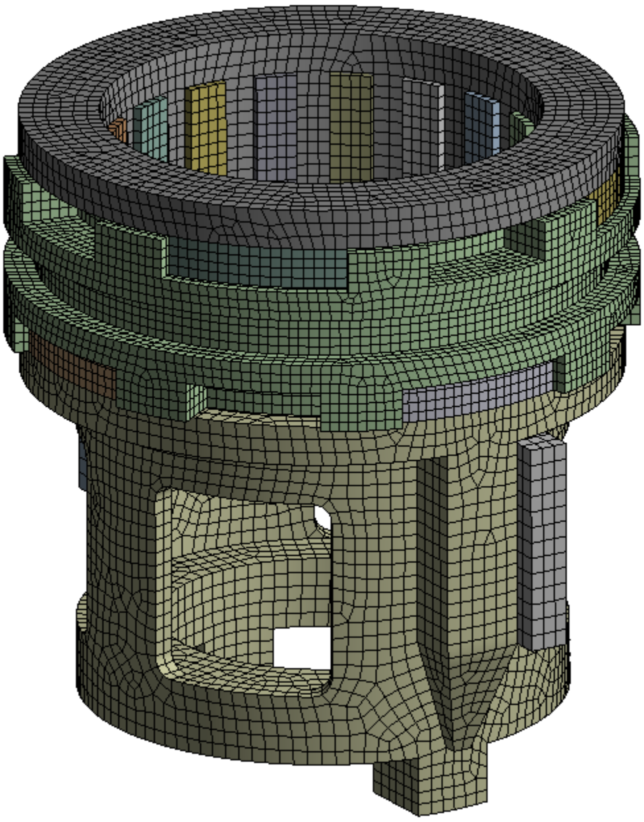


Figure 81: Generated mesh

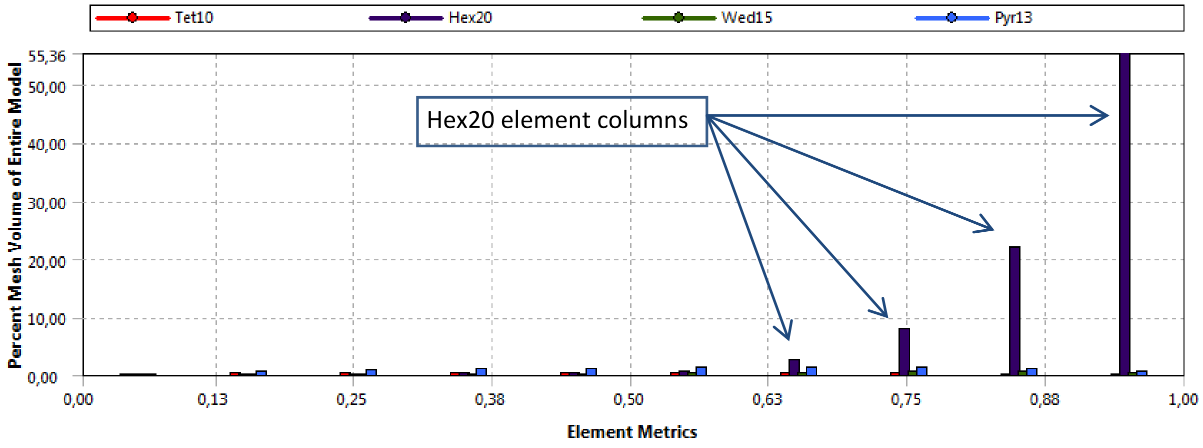


Figure 82: Mesh quality

The mesh quality is shown in Figure 82. The columns illustrate the percentage of elements with a certain quality mesh. The mesh consists mainly of hex20 elements. Due to the complexity of the geometry it is not expected to achieve as high quality as for the ring gear and gear housing analysis. However, after optimizing the mesh, the quality achieved is considered to be very good taken into consideration the geometry complexity.

It is desirable to have smaller mesh in the area where the strain gauge bricks are located. This will increase the local accuracy. To ensure smooth contact between the different parts and elements, the same mesh size has been used in these areas. To achieve this, the tool guide and the gear housing have been separated into multi-body parts. This is shown in Figure 83 and Figure 84.

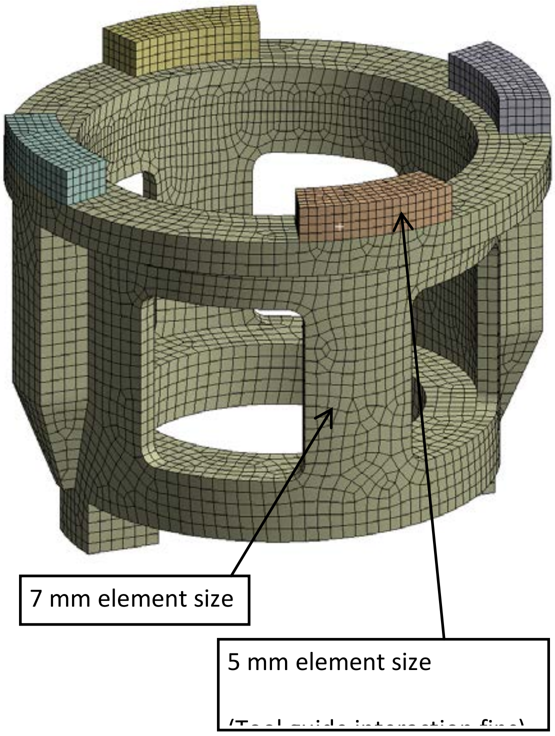


Figure 83: Tool guide multi-body part mesh

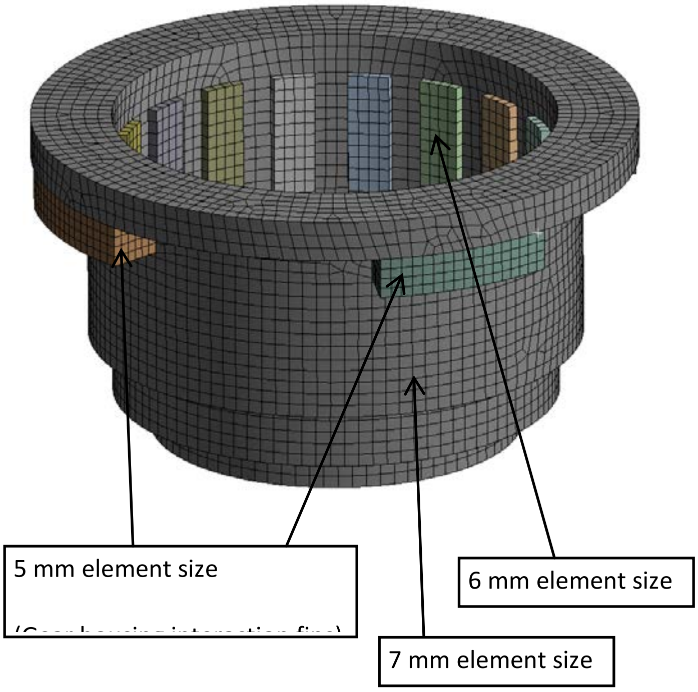


Figure 84: Gear housing multi-body part mesh

The element size on the parts reacting with the torque transducer is 5 mm, while the rest of the bodies have 7 mm element size. The torque transducer has also a 5 mm element size. The splines inside the ring gear have an element size of 6 mm. The size is selected to get 4 elements in the width of the splines. The result is an even mesh consisting of hex20 elements. A summary of the element sizes used for this model is shown in Table 20.

Part:	**Element size:**
Torque transducer	5 mm
Gear housing interaction fins	5 mm
Tool guide interaction fins	5 mm
Gear housing splines	6 mm
Gear housing	7 mm
Tool guide	7 mm
Reaction plates	8mm

Table 20: Element sizes

4.3.5 Results

The final contacts on the model have been investigated. The result is as expected and sliding contact occurs where the gear housing and tool guide are in contact with the transducer. Sliding contact also occur in the contact between tool guide and reaction plates. Figure 85 shows the final contacts for position. Similar contacts are observed for the additional two positions analyzed.

Figure 86 shows the pressure areas on the torque transducer. The upper part of the transducer experience pressure from the gear housing (area 1) and the lower part push onto the tool guide (area 2). This is observed on all the interaction points between the parts interacting with the torque transducer.

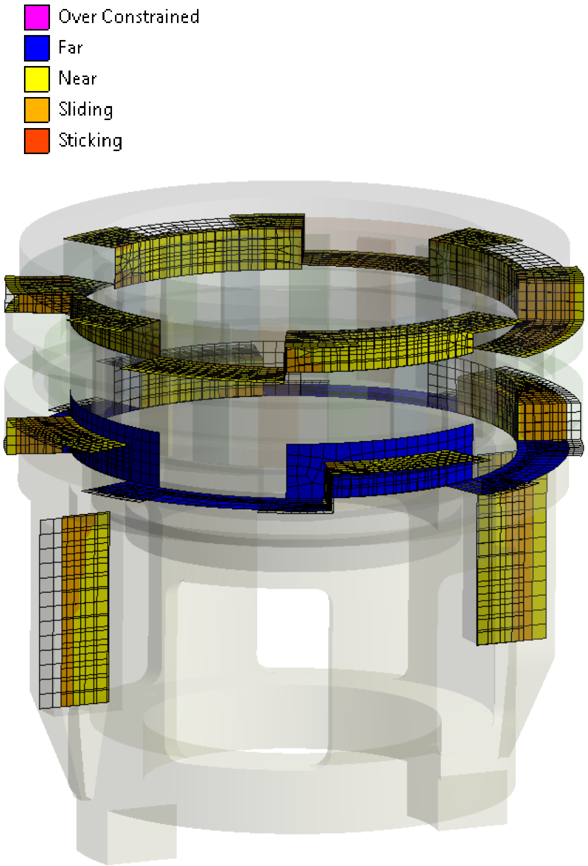


Figure 85: Final contacts for existing concept analysis

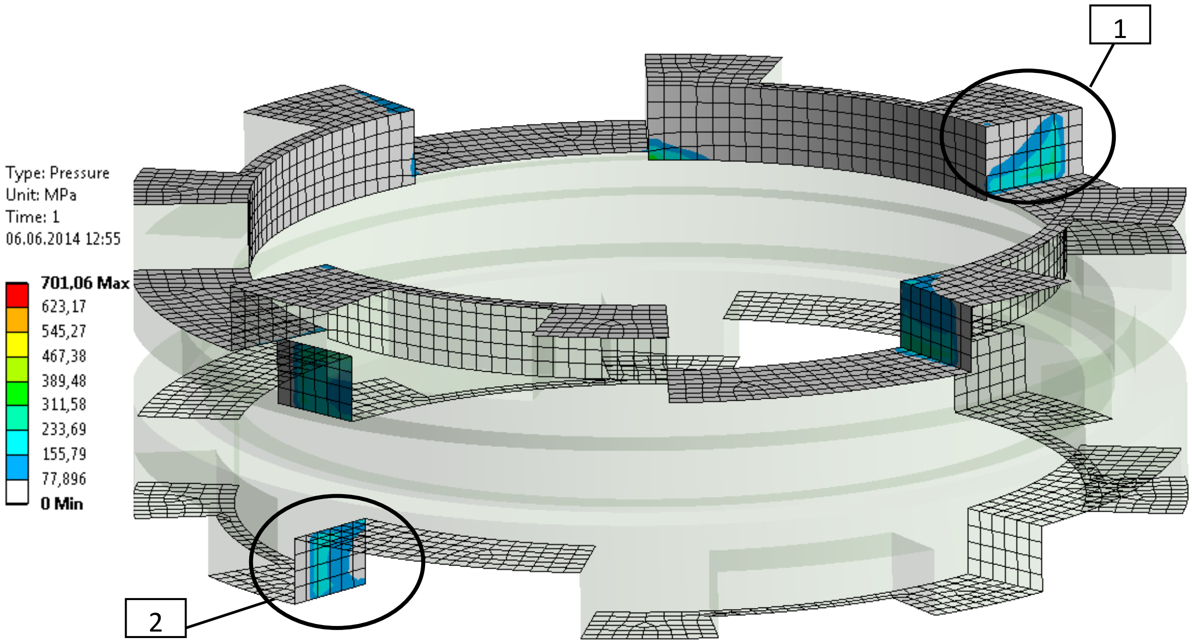


Figure 86: Transducer pressure areas

Shear elastic strain results in the yz-plane have been extracted from Ansys results for each imprinted face around the torque transducer. The yz-plane is the tangential and axial direction. By using a shear strain gauge, this is the strains that will be read out from the strain gauges.

On each imprinted face, a total of 62 nodes are part of the result plots. The elements in this region are of the hex20 type and the number of nodes corresponds with the graphics, shown in Figure 87. The nodes are illustrated as triangles. Each node is given an individual number by the software. Identical mesh is used for the analysis in the different simulated position, ensuring that node locations are the same in each position.

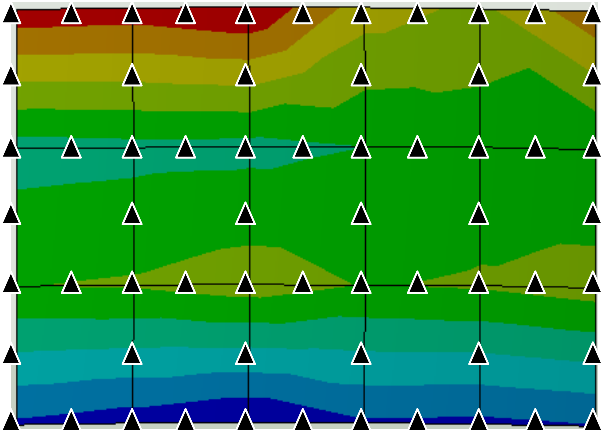


Figure 87: Node locations for the 62 nodes

As stated earlier, the transducer was modified to have 20 imprinted faces to read out strain results. The existing tool with torque feedback is equipped with two or four strain gauges. No documentation on this is available, but the manufacturer of the transducer confirmed that it is either two or four gauges on the existing tool. To be able to extend the analysis of the data, and to analyze different possible positions of four equally spaced strain gauges, it was decided to have 20 imprinted faces. This also made it possible to perform a sensitivity analysis regarding the amount of strain gauges and the position of them.

Figure 88 shows the location of the imprinted faces. From here on they are referred to as SG (strain gauge) as this is the strain gauge position.

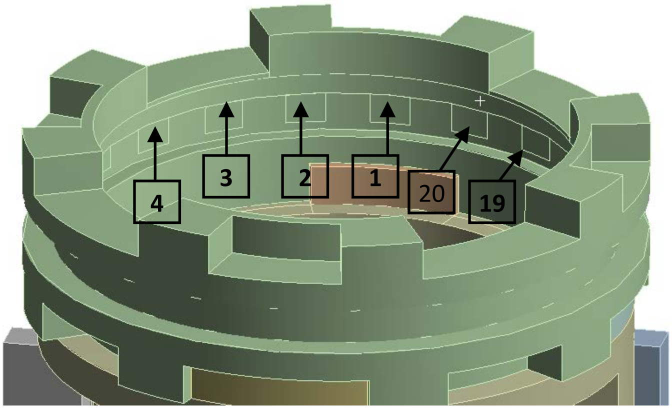


Figure 88: Imprinted faces location

For all comparison analyzes the results between position 1 and position 2 and between position 1 and position 3 has been compared to each other. The results reveal the simulated accuracy of the torque feedback function. To get a full overview of the accuracy, more gear positions would be necessary to simulate. However, this is extremely time-demanding and exceeds the work load of this thesis. In spite of this, a conclusion will be made regarding the target accuracy for this concept.

From the exported data from Ansys, the following scenarios have been analyzed:

- 20 strain gauges.
- 10 equally spaced strain gauges, 2 different strain gauge positions analyzed.
- 4 equally spaced strain gauges, 5 different strain gauge positions analyzed.
- 2 equally spaced strain gauges, 3 different strain gauge positions analyzed.

The exported results have been calculated to give an average strain percentage difference between the two positions. To calculate the percentage difference between each strain gauge position, all the exported nodal strain results from one position has been added together. The percentage difference between these two sums is then calculated to give the accuracy between two positions by use of one strain gauge. This is a good approximation to actual values read from the strain gauge area. When several strain gauges are used, the sum of position 1 for each strain gauge is added together. The same is done for position two, before a new percentage difference is calculated. All results are attached in appendix F. As this is conceptual design, transducer thickness needs to be re-designed to get optimal strain readings for the strain gauges. This will go under detail design; this is not part of the scope of work for this thesis. The results from the analyses are presented in Table 21.

Existing concept results		
Amount of strain gauges and strain gauge positions	**Deviation Pos 1 to Pos 2 [%]**	**Deviation Pos 1 to Pos 3 [%]**
20 strain gauges (sum of all strain gauges)	0	0
10 strain gauges, even numbers (SG 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20)	0.7	1.7
10 strain gauges, odd numbers (SG 1, 3, 5, 7, 9, 11, 13, 15, 17 and 19)	0.7	1.6
4 strain gauges (SG 1, 6, 11 ,16)	0.5	0.3
4 strain gauges (SG 2,7,12,17)	2.5	0.8
4 strain gauges (SG 3,8,13,18)	0.1	1.3
4 strain gauges (SG 4, 9, 14, 19)	0.1	0.9
4 strain gauges (SG 5, 10, 15, 20)	1.7	0.1
2 strain gauges (SG 1, 11)	0.6	3.1
2 strain gauges (SG 2, 12)	1.9	8.0
2 strain gauges (SG 3, 13)	3.9	3.6

Table 21: Existing concept analyses results

It was time demanding and challenging to get the solution to converge. The solving time for one analysis was approximately 12 hours. Many more analysis than the three final analyses has been run, as it has been necessary to implement improvements to model. In total, this turned out to be a much more time-demanding task than anticipated. Hand calculations for validating moment input and moment output are shown in appendix E, section 3.

4.3.6 Conclusion

The results show no deviation for the analysis consisting of 20 strain gauges. In practice, it will be difficult and expensive to mount that many strain gauges in the torque transducer. From the results we can read that the amount of strain gauges around the transducer does affect the result.

The result for the two positions with 10 strain gauges shows a larger deviation compared to the 20 strain gauges analysis. This is as expected. The 4 strain gauge analysis shows, in some strain gauge positions, a better result compared to the 10 strain gauges analysis. The maximum deviation with the four strain gauges (SG 2, 7, 12 and 17) does have higher deviation than the 10 strain gauges analysis. And an even larger variation in deviation is observed for the two strain gauges analysis.

From this it can be concluded that the variation in deviation are depending on the gear position. To get a full overview of the actual deviation it is necessary with additional analyses with more gear positions simulated. This exceeds the workload of this thesis and it is for this reason not analyzed. However, it is clearly that this concept has a good possibility to achieve within the accuracy target by use of four strain gauges. Alternatively, 8-10 strain gauges can be used to achieve a better accuracy.

The strain readings are a bit small and the overall recommendation from both HBM and Scansense is to have readings above 1×10^{-3} mm/mm. This is a necessary factor to achieve high repeatability, based on Scansense and HBM experience. This means that the transducer wall thickness should be designed thinner to achieve good readings from a low moment to the maximum moment.

Other factors than gear position and strain gauge location can affect the readings. The most challenging element will be tolerances associated with the machining of the parts. Not to use pre-calibrated transducer and instead calibrate them when installed in the tool will minimize this effect. Another idea is to implement thin pieces of a soft material between the pressure areas of the transducer and the opposite parts to compensate for the tolerances. This can contribute to distribute the tolerances equally and thereby eliminate the effect.

The result from the analyses indicates much more accurate results than experienced from the testing of the already existing tool. The amount of strain gauges is uncertain for this tool and it should be disassembled to reveal the actual amount and location. In addition, this is an old well-used tool and the condition of the strain gauges is unknown as well. It is therefore highly recommended to investigate the existing tool before proceeding with any potential prototyping. This tool is mostly offshore and it has not been possible to investigate this during the writing of this thesis.

Analysis results from this concept look promising, but cannot be absolutely determined before analysis of additional simulated gear positions has been performed. On the basis of the additional analysis, a conclusion can be made rather to proceed with prototyping or to drop the concept.

The same type of strain gauge as for the new concept can be used for the existing concept. This is described in section 4.3.6. This strain gauge is a full bridge four grid strain gauge which can be used to measure either compression or shear strain. The only difference is that the strain gauge will be rotated 45° compared to Figure 107.

4.4 Analysis of new concept

4.4.1 Introduction

The scope of this analysis is the same as for the existing concept analysis. The objective is to investigate if strain gauges mounted onto the strain gauge plates will give constant strains that are not dependent on the gear rotation. As for the previous analysis, it will be necessary to analyze three separate scenarios, where the variable is the position of the third stage cog wheels engagements. The set-up will be elaborated in the model set-up section. Constant sum of strains independent of the position of the gear will result in a concept with small deviations regarding to torque feedback readings.

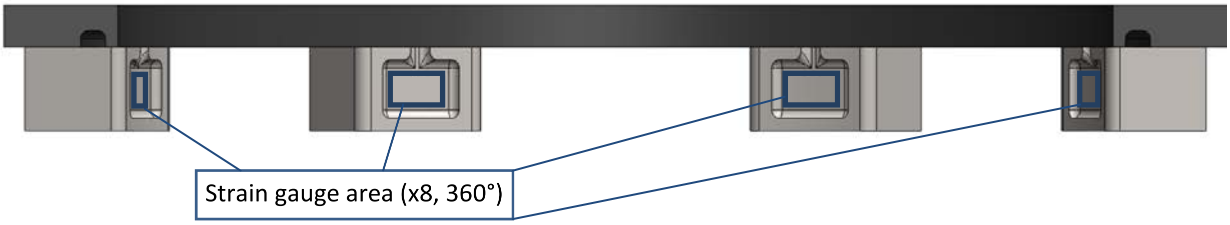


Figure 89: Section cut of strain gauge assembly

Figure 89 shows the strain gauge areas on the strain gauge bricks. The main objective of the analysis is to investigate how the strain distribution changes by changing the cog wheel engagement positions. It is assumed that the separate strain value will vary in the different strain gauge bricks, depending on the position of the gear. However, the moment acting on all the strain gauge bricks must be constant with a given moment, independent of the gear rotation. The objective is to analyze the total variation in strain in the strain gauge area with three different simulated gear positions.

4.4.2 Simplified model for analysis

The tool and the whole gear assembly, except the gear housing, are similar to the existing concept design. The model has been simplified down to only consist of the most relevant parts for the analysis. Holes in relevant parts, such as strain gauge bricks, have also been removed to optimize the mesh. Removing these holes will result in a mesh with a higher amount of hexahedral elements. Removing the holes will affect the structural integrity of the parts, but can be ignored as this will not be part of the scope for this analysis. This can easily be addressed in the final detail design.

The interface bucket has been replaced with two reaction plates. This has been done to minimize the amount of elements in the model. Figure 90 shows exploded view of the relevant parts. The grooves have been removed on the strain gauge bricks, but the area of the groove is replaced with an imprint face. By doing this, it will be possible to extract results from these particular areas.

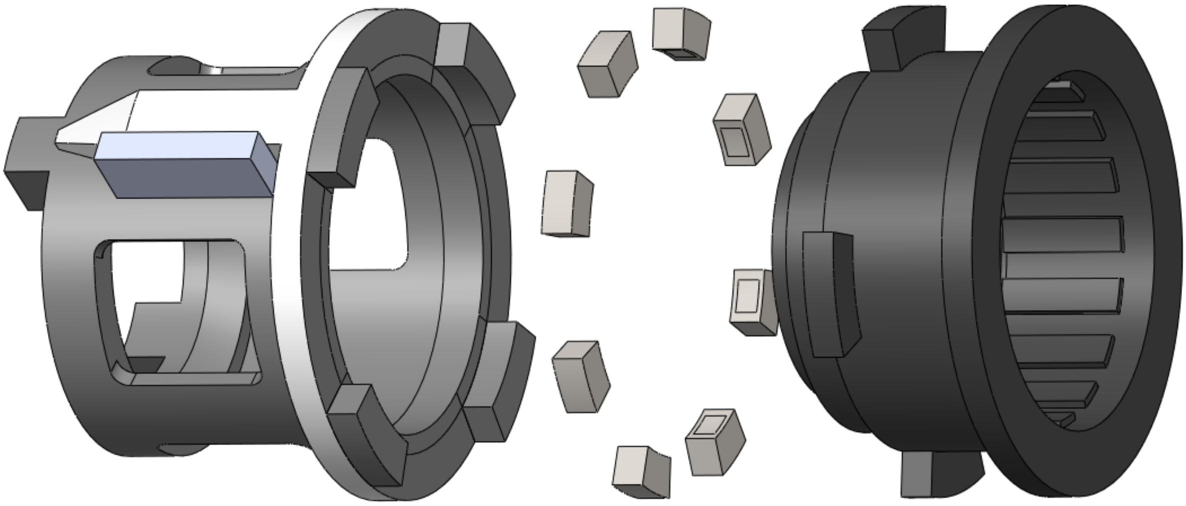


Figure 90: Simplified model in exploded view

The same simplifications has been done to this model, and all irrelevant holes, cuts, radiuses and seal grooves have been removed. Figure 91 and Figure 92 shows the complete simplified model.

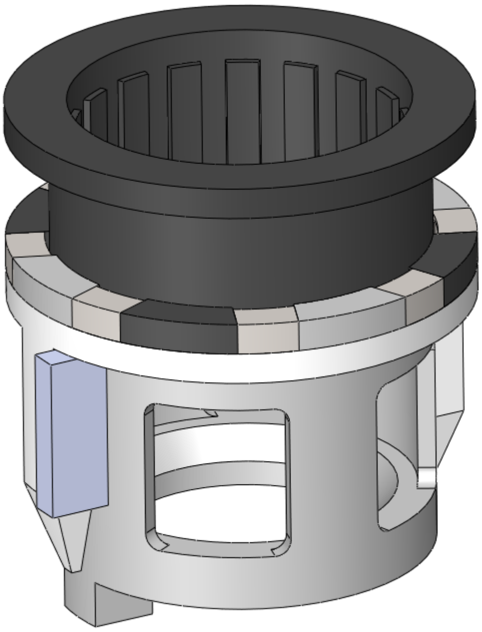


Figure 91: Simplified model

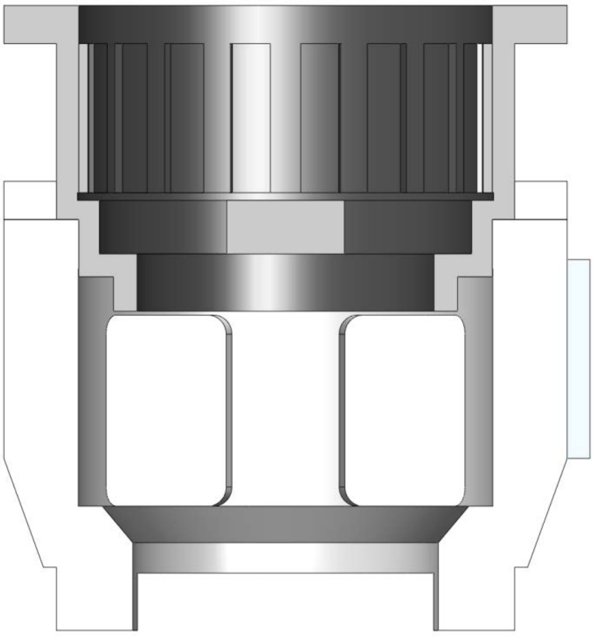


Figure 92: Section cut of simplified model

4.4.3 Model set-up

Material Properties:

The material properties for the components are defined in Table 22. The materials used in Ansys are bi-linear.

Component	Material	Poisson ratio	Yield Strength [MPa]	Tensile Strength [MPa]	Young's Modulus [GPa]
Gear housing	Alu 6082-T6	0.33	260	310	71
Tool guide	Alu 6082-T6	0.33	260	310	71
Strain gauge bricks	S165M	0.3	613	860	210
Reaction plates	S355 (17<t<40)	0.3	345	470	210

Table 22: Material properties

Supports:

The reaction plates illustrate the torque tool interface bucket and are constrained with fixed supports (ref. Figure 93, A) on the back of the plates. A displacement support (ref. Figure 93, B) is placed underneath the tool guide on the two bottom faces to constrain it in the axial direction; hence the y-direction displacement is set to zero. Standard earth gravity is added to the model (ref. Figure 93, C).

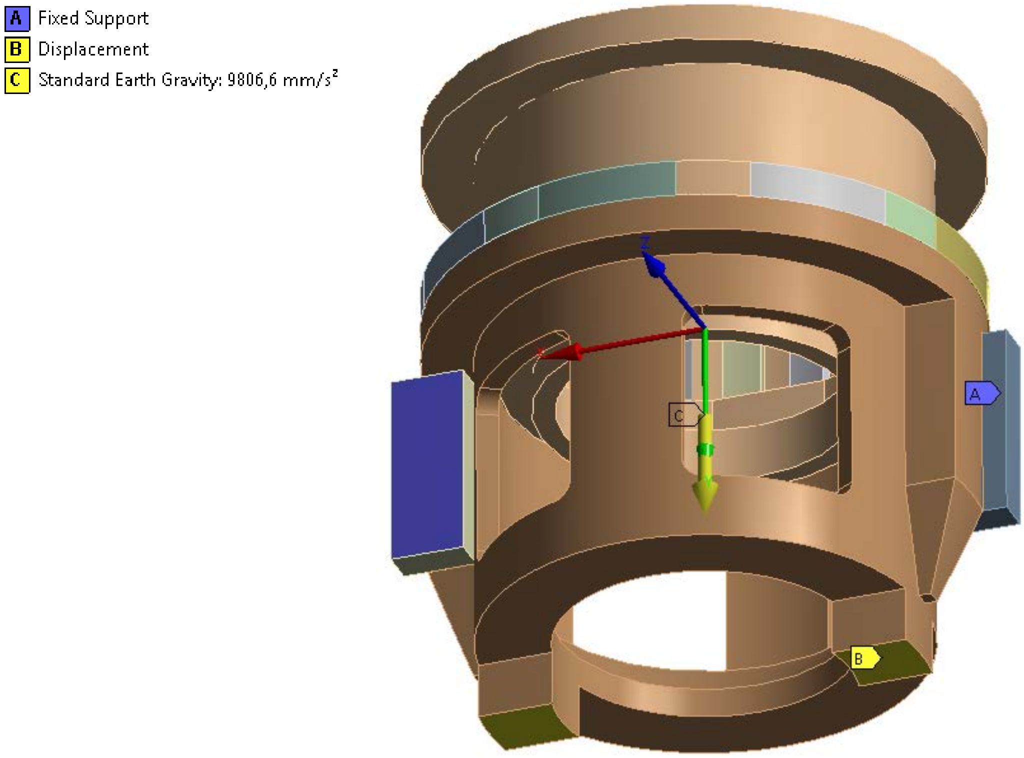


Figure 93: Reaction plates fixed support and tool guide displacement support

All holes for fastening are removed in the simplified model for the SGBs and the tool guide. For this reason there is no easy way of constraining the SGBs in the model. Although the SGBs are designed to not get any radial forces due to compression, this will occur due the material stiffness, which is not infinite. To be able to get the solution to converge it was necessary to use cylindrical support (ref. Figure 94) on the outer diameter of the SGBs. Cylindrical supports was fixed only in radial direction. One cylindrical support was set onto each SGB to be able to read the reaction forces from each SGB.

It is worth to mention that this would probably not be any issue with frictional contacts. However, this would be extremely time-demanding and challenging to get converged and solved. Due to the compression forces, high friction forces will occur in practice and these will prevent the radial movement of the SGBs.

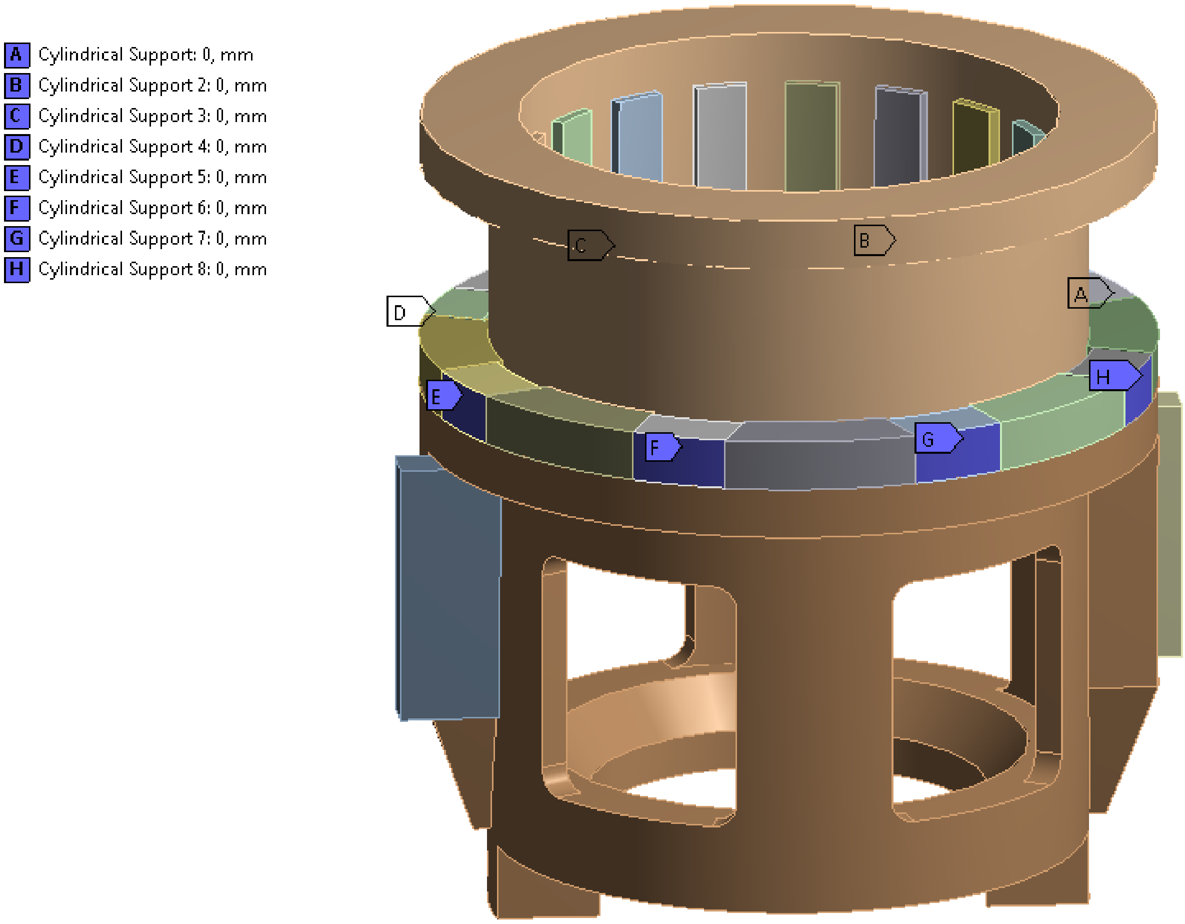


Figure 94: Cylindrical support on SGBs

As there are no bolts constraining neither the gear housing nor the SGBs in the axial direction (y-direction), it is necessary to constrain these. An attempt with only standard earth gravity was tried out, but the solution would not converge. The reason for this is that the tool guide interaction fins are stiffer at the bottom due to the geometry. This result in a larger deformation at the top of the tool guide interaction fins. This will result in axial forces and the SGBs and the gear housing will have rigid body motions.

Displacement supports with zero displacement in the y-direction is used to fully constrain the SGBs and the gear housing. The constraints are placed as shown in Figure 95. A total of 12 displacement supports are used.

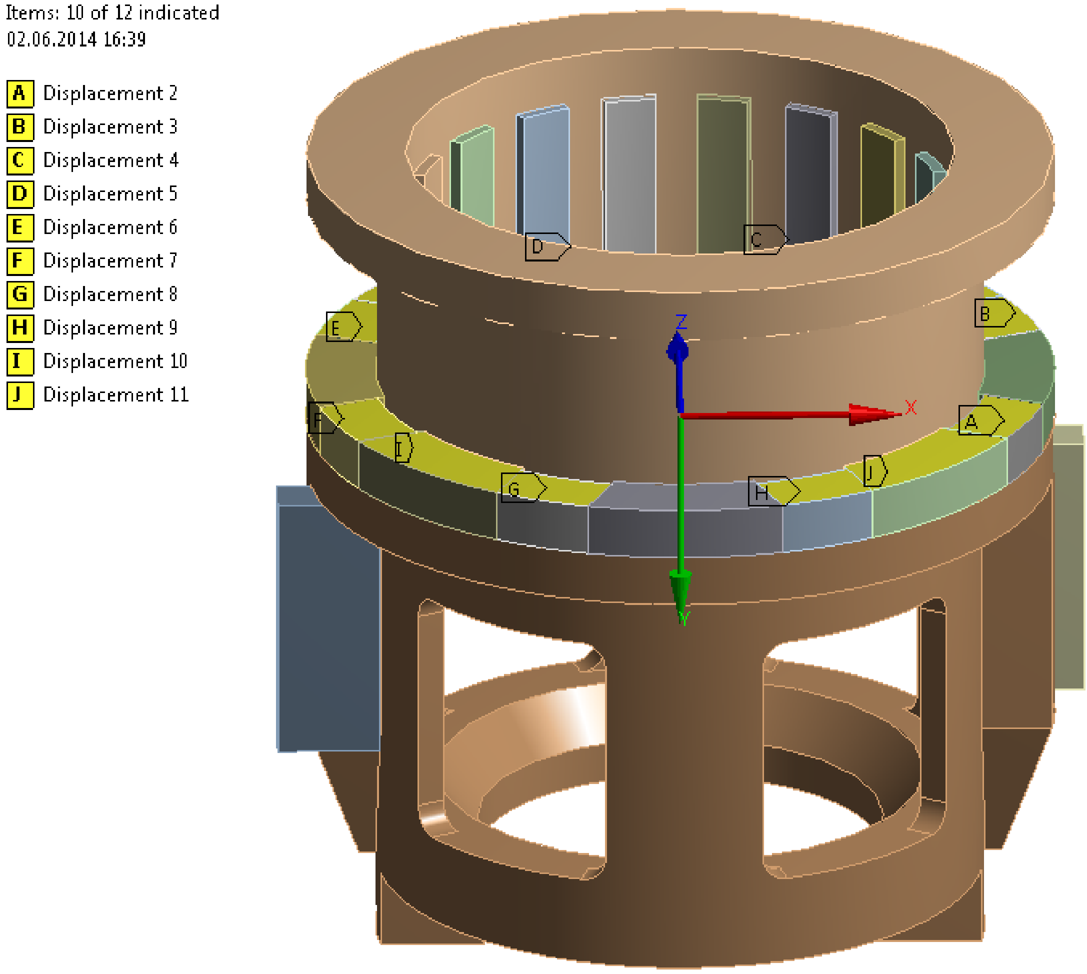


Figure 95: SGB and gear housing displacement supports

Loads:

The loads for this analysis are applied just as for the analysis of the existing concept (ref. section 4.3.3, Loads).

Contacts:

All contacts used in between parts interacting with each other are set to frictionless contact. A total of 34 contacts have been used to fully define the interacting parts. The interface treatment is set to adjust to touch as all the contacts will have initial contact.

Figure 96 shows the contacts between the SGBs, gear housing and tool guide. The SGB has contacts on each side, interacting with the tool guide on one side (contact B) and the gear housing on the other (contact A). The SGB has also a contact against the tool guide on the bottom (contact C). These count for 24 of total amount of contacts. The SGBs has a gap between the SGBs themselves and the gear housing outer diameter. No contacts are defined in this area.

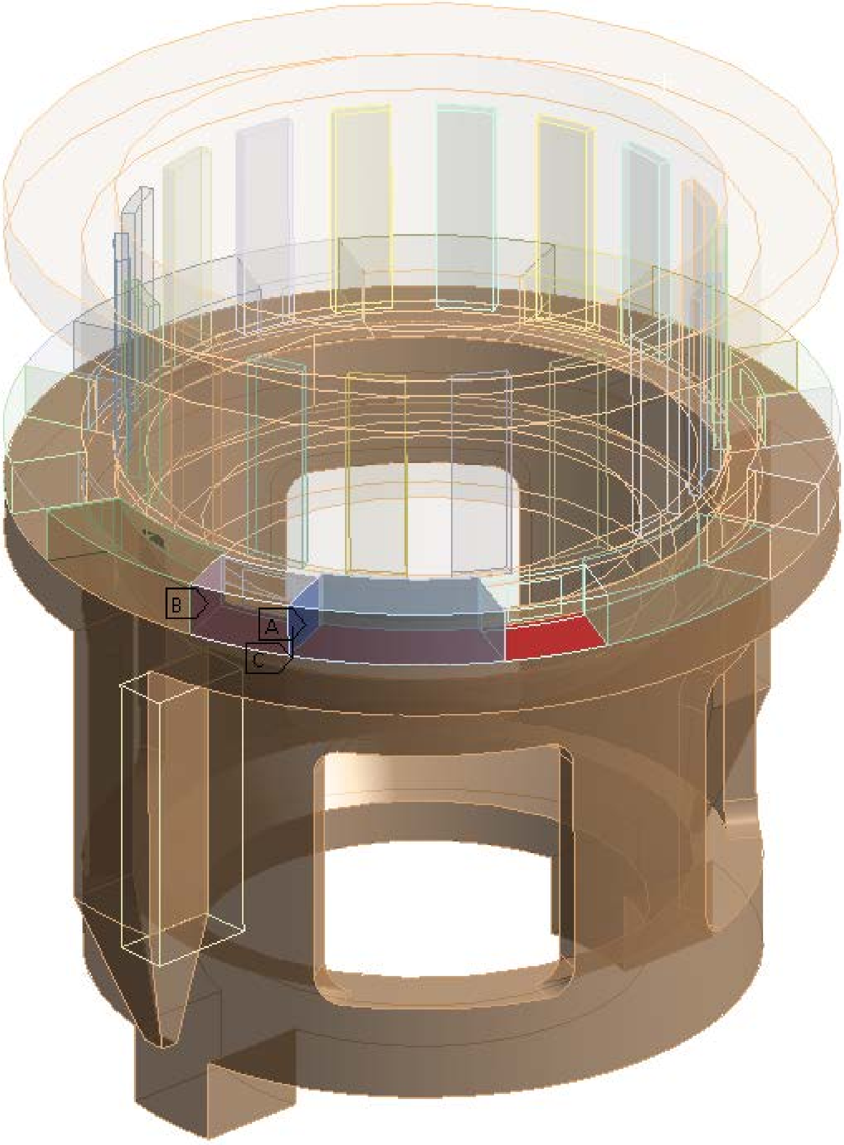


Figure 96: Contacts between SGBs, gear housing and tool guide

Figure 97 shows the contact between the bottom of the gear housing interaction fins and the top of the tool guide (contact A). With all the four interaction fins, a total of four contacts are present around the tool.

Contact C (Figure 97) is the contact between the inner face diameter of the tool guide interaction fins and the outer diameter of the gear housing (four contacts in total).

Contact B shows the contact between the tool guide and the reaction plate (one on each side).

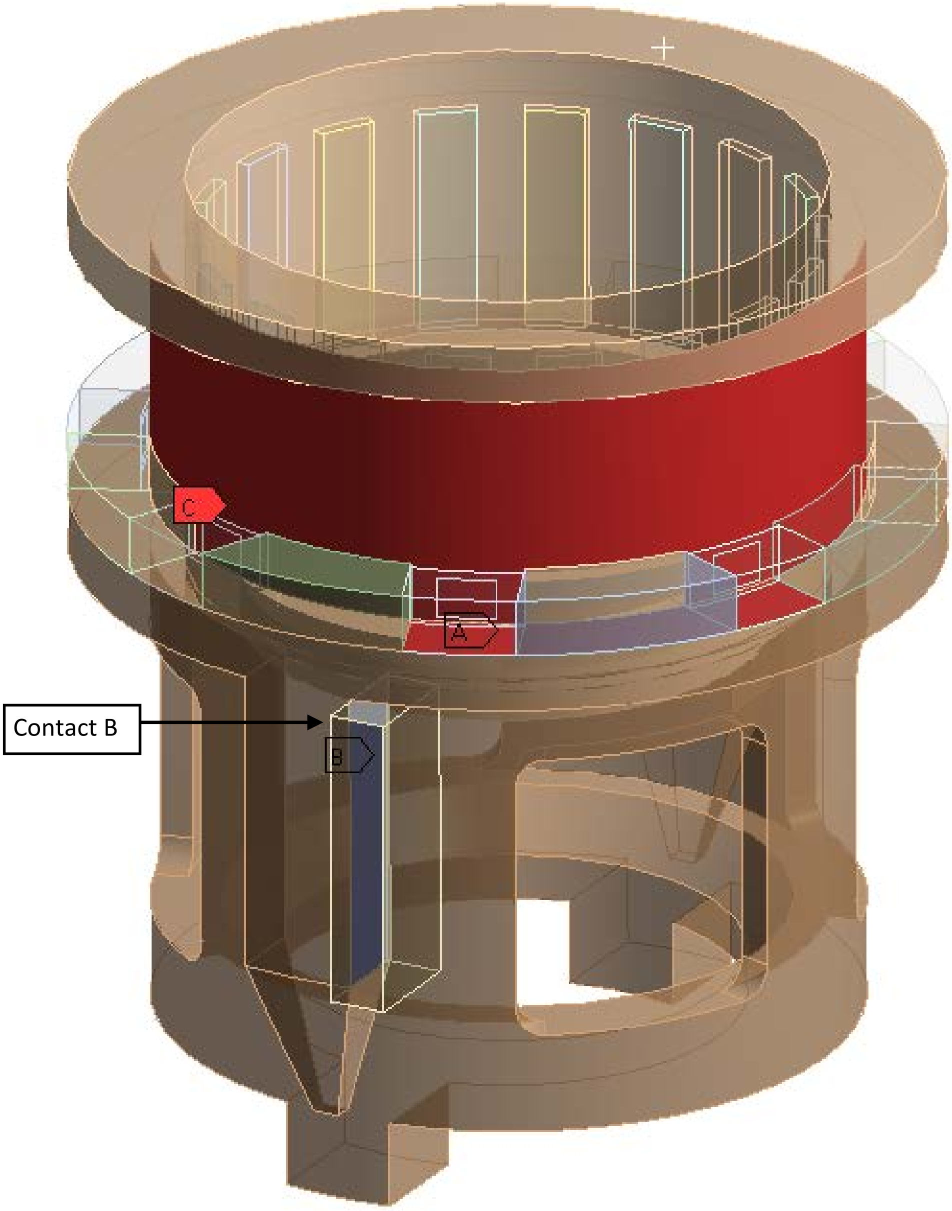


Figure 97: Contacts between gear housing and tool guide and tool guide and reaction plates

Figure 98 shows the initial contact status for the model. The figure shows that contacts are found and are as expected compared to the applied forces and the defined contacts. The contact area on one of the reaction plates is defined as far. However, this is defined as sliding on the other side.

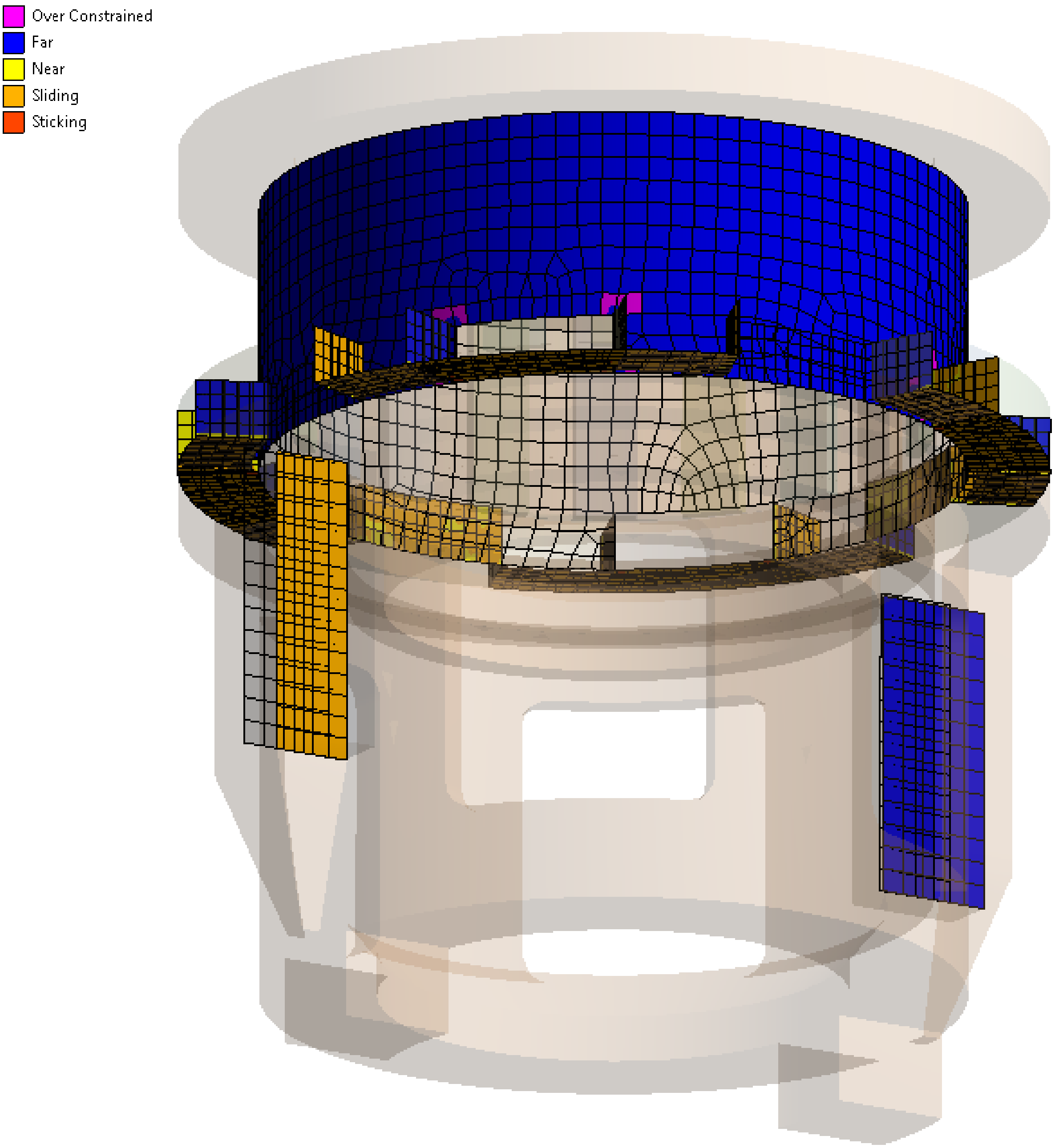


Figure 98: Initial contact status

4.4.4 Mesh

To optimize the mesh for this geometry, two different user-defined controls are used. These are hex-dominant method and body sizing. The mesh is shown in Figure 99.

The mesh consist of a total of;

- 37 448 elements
- 138 930 nodes

Different mesh sizes have been used on independent bodies. To achieve this, the bodies have been separated to consist of several individual parts with shared topology. The multi-body parts behave as one part in the analysis. This will be further elaborated in this section.

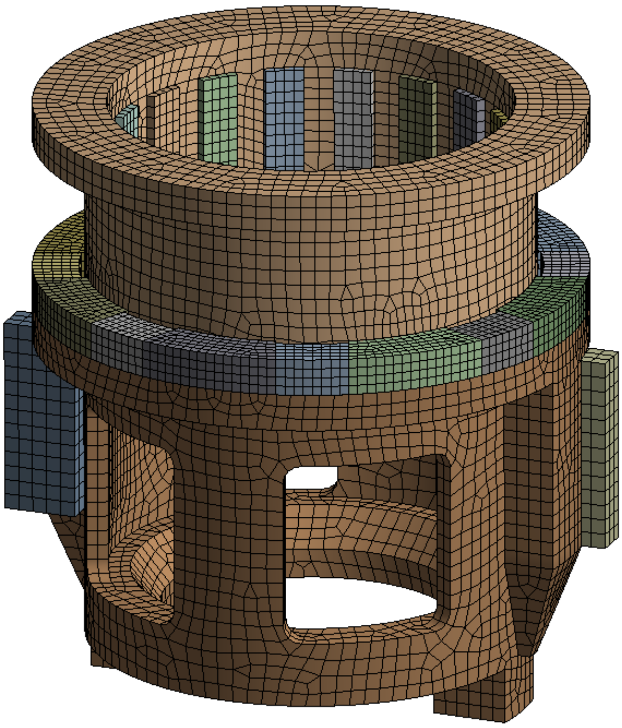


Figure 99: Generated mesh

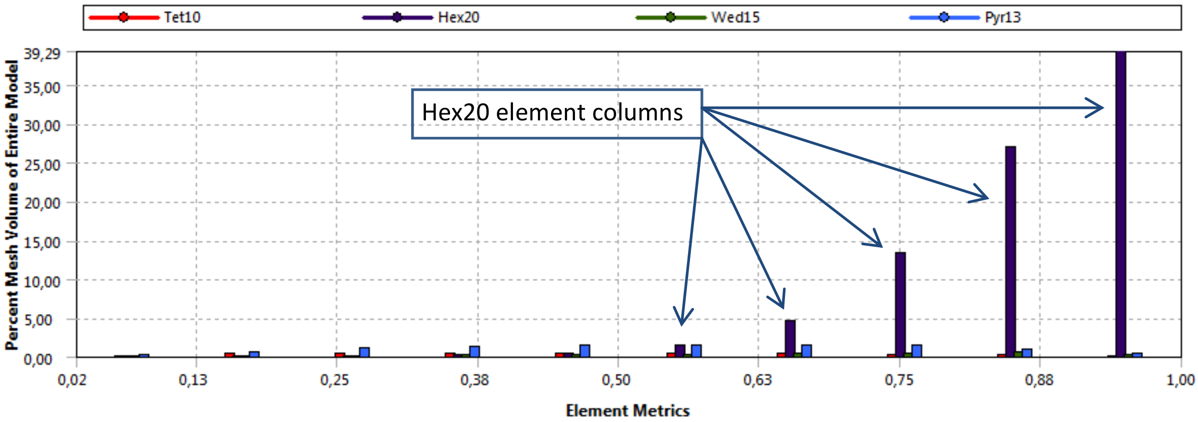


Figure 100: Mesh quality

The mesh quality is shown in Figure 100. The columns illustrate the percentage of elements with a certain quality mesh. The mesh consists mainly of hex20 elements. Due to the complexity of the geometry it is not expected to achieve as high quality as for the ring gear and gear housing analysis. However, after optimizing the mesh, the quality achieved is considered to be very good taken into consideration the geometry complexity.

It is desirable to have smaller mesh in the area where the strain gauge bricks are located. To ensure smooth contact between the different parts and elements the same mesh size has been used in these areas. To achieve this, the tool guide and the gear housing have been separated into multi-body parts. This is shown in Figure 101 and Figure 102.

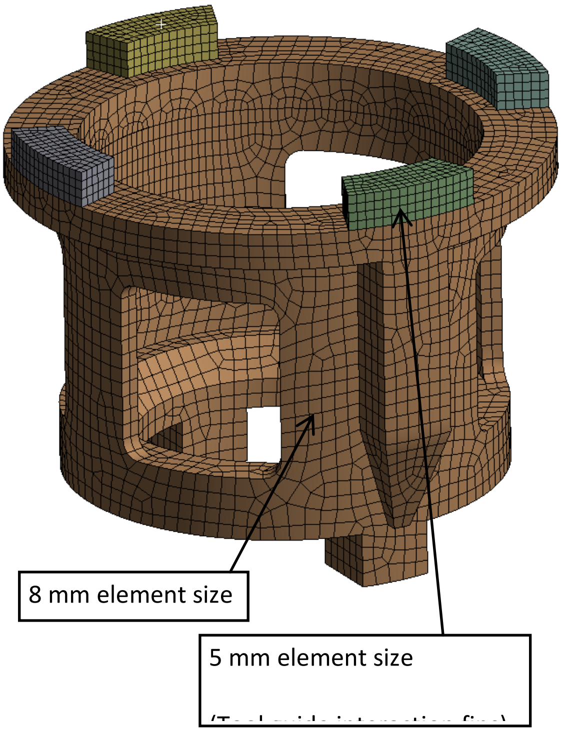


Figure 101: Tool guide multi-body part mesh

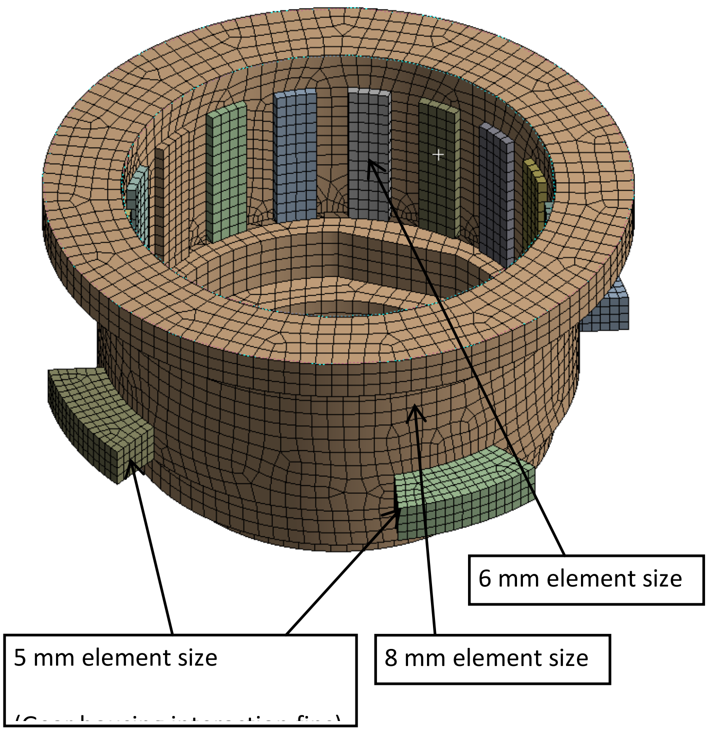


Figure 102: Gear housing multi-body part mesh

The element size on the parts reacting with the strain gauge bricks are 5 mm, while the rest of the bodies have 8 mm element size. The strain gauge bricks have also a 5 mm element size. The splines inside the ring gear have an element size of 6 mm. The size is selected to get 4 elements in the width of the splines. The result is an even mesh consisting of hex20 elements. A summary of the element sizes used for this model is shown in Table 23.

Part:	Element size:
Strain gauge bricks	5 mm
Gear housing interaction fins	5 mm
Tool guide interaction fins	5 mm
Gear housing splines	6 mm
Gear housing	8 mm
Tool guide	8 mm
Reaction plates	8mm

Table 23: Element sizes

4.4.5 Results

The final contacts on the model have been investigated. The result is as expected and sliding contact occurs where the gear housing and tool guide are in contact with the SGBs. Sliding contacts also occur in the contact between tool guide and reaction plates. Figure 103 shows the final contacts for position 1. Similar contacts are observed for the additional two positions analyzed.

Figure 104 shows the pressure areas on the SGBs. It is observed that each second SGB experience pressure contact. This is as expected from the geometry. The pressure magnitude on the different SGBs due varies in some degree between the analyzed positions, which is as expected.

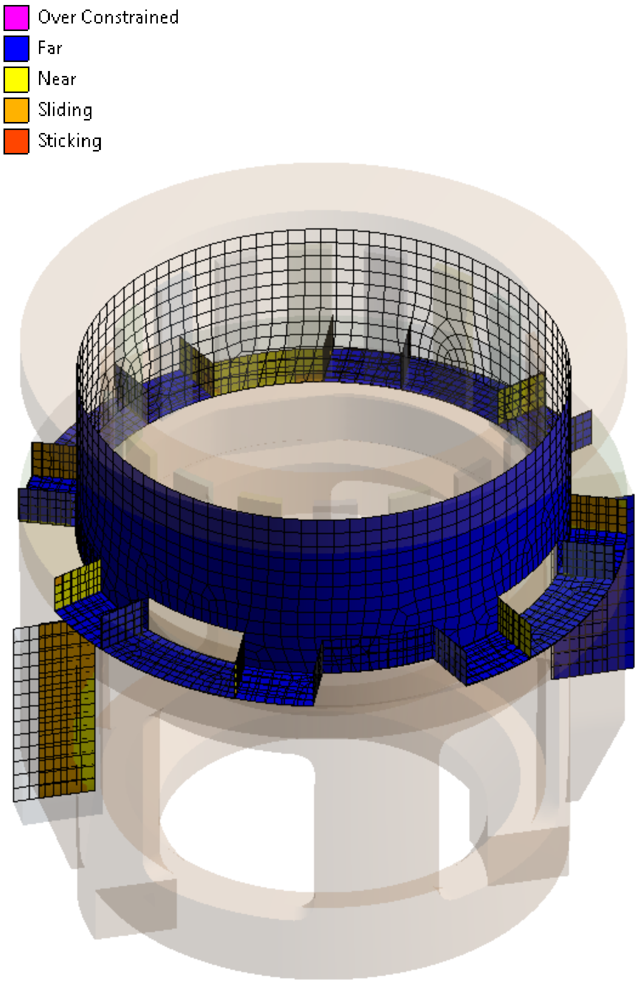


Figure 103: Final contacts for new concept analysis

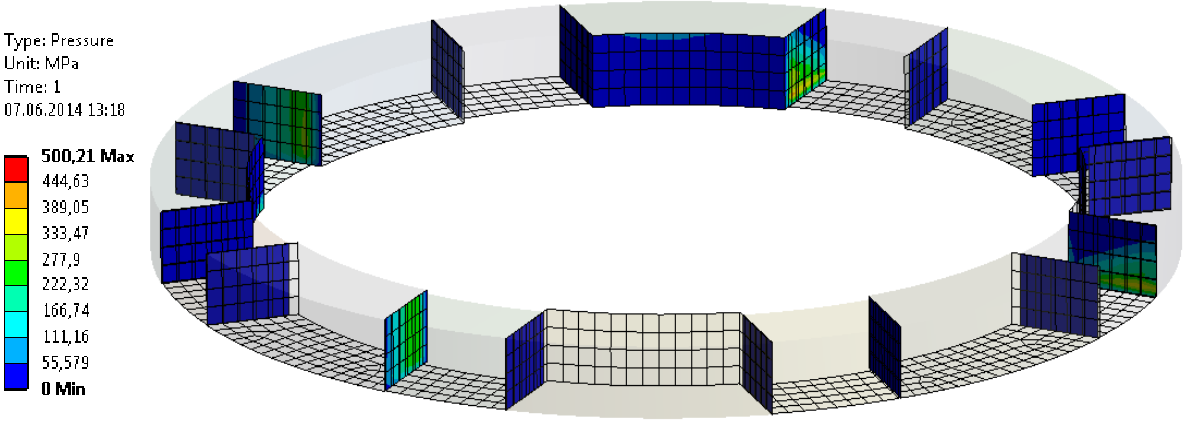


Figure 104: SGB pressure areas

As it was necessary to add cylindrical support in the radial direction for the SGBs, the reaction forces from these supports have been analyzed. The reaction forces vary from 4 N to 829 N in the radial direction. However, this is not the amount of forces the bolts holding the SGBs in place will experience. The contacts used in the analysis are frictionless. In practice, the SGBs will be kept in place be the friction forces introduced due to the pressure from each side of the SGBs.

Normal elastic strain results in the yz-plane have been extracted from the Ansys results for the imprinted faces on each SGB. This is the strains that will be read out from the strain gauges mounted to read the normal strain (compression strain gauges).

The mesh distribution for the imprinted faces is similar to the mesh on the existing concept. The total amount of nodes is 62. These regions consist of hex20 elements. Each node is given an individual number by the software. Identical mesh is used for the analysis in the different simulated positions, ensuring that node locations are the same in each position. Figure 105 shows the element net (mesh) of the imprinted faces.

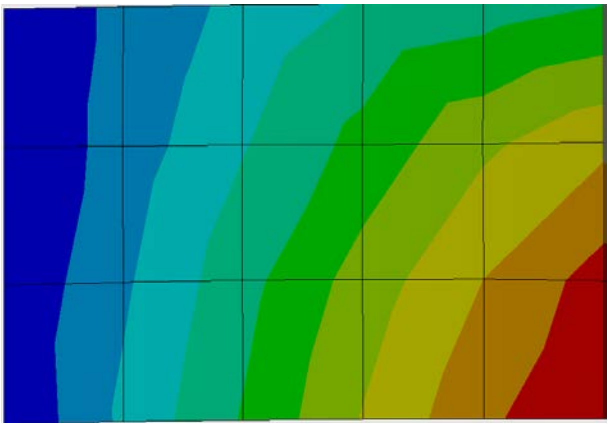


Figure 105: Imprinted face on SGB

Figure 106 shows the location of the imprinted faces. From here on they are referred to as SG (strain gauge) as this is the strain gauge position.

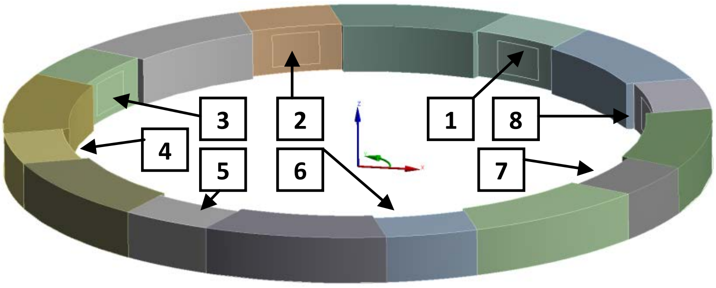


Figure 106: Location for imprinted faces on SGBs

For all comparison analyzes the results between position 1 and position 2 and between position 1 and position 3 has been compared to each other. Compared to the existing concept, it will not be necessary for further analysis in other gear positions to ensure the accuracy of the concept.

From the exported data from Ansys, the following scenarios have been analyzed:

- 8 strain gauges.
- 4 strain gauges, all strain gauges with actual compression (ever second strain gauge)
- 4 strain gauges, all strain gauges with no actual compression (ever second strain gauge)
- 2 strain gauges, two different strain gauge positions

The same procedure for calculating the deviations between the analyses has been used for this concept as for the existing concept (ref. section 4.2.5). All results are attached in appendix G.

In this is conceptual design, the SGBs needs to be re-designed to get optimal strain readings for the strain gauges. This will go under detail design, which is not part of the scope of work for this thesis.

The deviation results from the different scenarios are presented in Table 24 below.

New concept results		
Amount of strain gauges and strain gauge positions	**Deviation Pos 1 to Pos 2 [%]**	**Deviation Pos 1 to Pos 3 [%]**
8 strain gauges (sum of all strain gauges)	0.5	0.5
4 strain gauges, with compression (SGs 1, 3, 5 and 7)	0.3	0.3
4 strain gauges, no compression (SGs 2, 4, 6 and 8)	28.6	51.1
2 strain gauges (only compression), SG 1 and 5	6.6	0.8
2 strain gauges (only compression), SG 3 and 8	24.1	27.7

Table 24: New concept analyses results

It was time demanding and challenging to get the solution to converge. The solving time for one analysis was approximately 14 hours. Many more analysis than the three final analyses has been run, as it has been necessary to implement improvements to the model. In total, this turned out to be a much more time-demanding task than anticipated. Hand calculations for validating moment input and moment output are shown in appendix E, section 4.

4.4.6 Conclusion

The results show a small deviation of 0.5 % for all the 8 strain gauges. This is a very low deviation and the theory the concept is based on do deliver promising results. For the analyzed direction, only each second SGB experience compression. For the other direction, the opposite will occur: The SGB which did not experience compression will now do, and vice versa. This occurs due to the concept geometry.

For the analyzed results for 4 strain gauges, the deviation for the SGB with compression is reduced to 0.3 % deviation for both the simulated positions. The strain gauges with no compression do not affect the complete readings very much. To achieve as good results as possible, the strain gauges can be coupled to read from only 4 strain gauges in one direction and the other 4 strain gauges in the other direction.

The two analyses with two strain gauges are performed as sensitivity analyses to verify the theory the concept is based on. The results show a much higher deviation with only two strain gauges and that the results vary between the two positions. This is as expected as the total force picture is not measured.

As we can see from the results, there is a very high deviation on the strain gauges with no compression. The deviation between position 1 and 2 are 28.6 % and the deviation between position 1 and 3 are 51.1 %. The large deviation can be explained by the very small readings as they are close to zero. When comparing the scenario with all 8 strain gauges against the two scenarios with 4 strain gauges it can be observed that the difference between the scenario with 8 strain gauges and the scenario with 4 strain gauges in compression is only 0.2 %. This difference is the effect of the no compression readings and even with high deviation in these readings; the effect is marginal on the 8 strain gauge readings.

The deviation with 2 strain gauges has a high difference between results from SG 1 and 5 and SG 3 and 8. The actual forces on the difference strain gauges vary, depending on the simulated gear position. This is an expected result when not measuring on all the strain gauges or all the strain gauges in compression.

As a recommendation for strain gauge location on the SGBs, the strain gauges should be mounted on top or bottom of the strain gauge brick to better be able to measure the moment reaction over the entire radial direction of the SGBs. It is likely to believe that the strain gauges in this location, the readings will be less affected by machining tolerances. However, the tolerance effect will be reduced as the calibration must be performed after installation of the torque feedback function in the tool.

The strain readings are too small and the overall recommendation from both HBM and Scansense is to have readings above 1 x 10^{-3} mm/mm. This is a necessary factor to achieve high repeatability, based on Scansense and HMB experience.

The HBM VY41 is a suitable strain gauge for measuring compression. This is a full bridge gauge with four measuring grids. As shown in Figure 107, the gauge must be mounted in a 45 degrees angle, resulting in two grids in the compression direction and two grids 90° on the compression direction. This result in a high electrical signal from the gauge and the effect of temperature differences will be compensated for. [25]

Figure 107: HBM VY41 strain gauge [25]

HBM has experience with molding with polypropylene performed by a company named Termo Tight. They have experience with use of molding of strain gauges used down to 3000 meter depth. However, uncertainty is associated with this, and prototyping and testing will be necessary to validate this.

5 Conclusions & Recommendations

5.1 Conclusions

The objective of this thesis was to develop an alternative concept to the already existing one, and further analyze and evaluate them. Great uncertainty was associated with the existing torque tool based on accuracy testing. For this reason it was desirable from Oceaneerings behalf to perform analyses on this concept and simultaneously develop a new concept.

Several concepts were evaluated, but the concept with the assumed highest accuracy was not chosen. This was determined on the basis that this concept would be expensive to develop and produce, and Oceaneering was open to expand their horizon and think outside the box. This resulted in the strain gauge brick concept. This was also a more challenging task regarding analyzes, as the concepts with strain gauges directly on the shaft would be relatively easy to analyze, as they are not affected by the gear rotation.

The results from the analyses of the existing concept revealed more accurate results than first anticipated based on the existing test results from the existing tool. No investigation of the tool is performed and the amount of strain gauges and the condition of them is unknown. For this reason there is a possibility that the strain gauges were defect during testing.

Based on the results from the analyses performed in this thesis, there is high probability that this concept can deliver accuracy within accuracy target. With 10 strain gauges simulated in the analyses, the deviation varies from 0.7 to 1.7 %. Oceaneering themselves have many years of experience measuring shear strain on class 4 torque tools. Based on the results and the unknown condition of the existing torque tool, it is highly recommended with additional analyses and to investigate this tool before proceeding with any prototyping.

The results from the analyses of the new concept are promising. The accuracy from the analyses was 0.3 % when measuring on the 4 strain gauges actually experiences compression. To achieve as high accuracy as possible it is recommended to measure on only the 4 strain gauges experiencing compression (each second) in each direction. This concept is dependent on strain gauges on each SGB to deliver required accuracy. This is clearly shown in the analyses with only 2 strain gauges in different positions.

As there is very little experience with compression strain gauges for subsea use, there is higher uncertainty attached to this concept. Dialog with HBM Norway revealed that there exist solutions with molded polypropylene which will result in marginal effect from the hydrostatic pressure. HBM have delivered strain gauges which have been mounted by Termo Tight for applications down to 3000 meters. However, this cannot be documented and demands further investigation and testing. The challenges regarding the compression strain gauges are issues that have been revealed during the writing of this thesis.

As a conclusion for the analyses performed in this thesis, both concepts show results within accuracy target. With regards to the strain distribution they are both valid as functioning concept for torque feedback implementation. However, some analyses in additional positions should be performed for the existing concept to ensure the accuracy.

The thesis reveals other technical challenges than only the strain distribution issue. These challenges with regards to strain gauges need to be resolved to get a complete functioning concept. As both concepts show results within the target accuracy, it is these challenges that need to be evaluated to be able to take a good decision on a concept. These challenges regarding strain gauges are issues that will be present for any concept for torque feedback by use of strain gauges exposed to hydrostatic pressure.

As Oceaneering already possess a torque tool with torque feedback which is suitable for investigation and further testing, this is recommended before any decision making on one of these concepts.

As a result of this thesis, two valid concepts have been investigated and issues regarding strain gauges for subsea use have been revealed. With this work as basis, Oceaneering will have a very good starting point for developing a functioning solution.

5.2 Recommendations for further work

Analyses in additional positions should be performed. With an existing torque tool with torque feedback available it is recommended to investigate this tool to determine the condition and the amount of strain gauges. Independent of the findings, the tool should be equipped with 8-10 equally spaced strain gauges and then tested out in accordance with the existing qualification procedure to determine the accuracy. With accuracy within accuracy target, further testing in hydrostatic pressure tank should be performed. If complete testing results in target accuracy, detail concept and making of prototype of the existing 38 kNm torque tool should be initiated.

The new concept is, by all means, is very exciting and is a very good alternative to the existing concept. If further analyses on the existing concept reveal lower accuracy in other positions, it should be evaluated to further develop this concept.

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Appendices

Appendix A: MOM, brainstorming meeting

Appendix B: Hand calculations, concept phase

Appendix C: Mark-up drawings

Appendix D: Reaction forces from ring gear and gear housing analysis

Appendix E: Hand calculations, analysis

Appendix F: Results from existing concept analyses

Appendix G: Results from new concept analyses

Appendix H: Ansys analyses files (on attached DVD)

Appendix A

Brainstorming minutes of meeting;
concept development

Minutes of Meeting

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4068 Stavanger, Norway
Phone: 51 82 51 00 – Telefax: 51 82 52 90

Subject:	Brainstorming, torque feedback function concept development	Date:	17.02.2014
Project No.:	N/A	Time:	12:15 – 13:30
Ref. No.:	N/A	Location:	PD Meeting room
Chaired by:	Erik Eide		
Minute by:	Erik Eide		
Participants:	Jostein Mikal Hageberg, Dag Bjåstad, Zenon Taushanis, Torleif Carlsen, Arnstein Vevle, Erik Eide		

Item	Minutes	
1	The agenda for the meeting was to turn our minds inside out for come up with conceptual designs for a torque feedback function to implement in the existing torque tool class 7. The meeting was held in a meeting room in the product development department. Models of the existing tool and the existing concept were printed out in advance. The models were also view in SolidWorks on a large flat screen TV. While investigating the model from every angle and through section cut, ideas were thrown out. It was communicated that gear design is the only aspect of the tool which can`t be redesigned. In addition, the existing concept design was also investigated hence this design might spark ideas which are not that easily seen on the original tool.	
2	All participants had knowledge to the tool, and brief explanation was not required. However, undersigned explained the issues with an earlier torque feedback function in Oceaneering. Strain gauges were mounted directly onto the ring gear. The result was that the cog wheels affected the strain distribution. The strain distribution constantly changed as the cog wheels passed the location of the strain gauges. The meeting proceeded with this in mind: The strain gauges must not be affected by the rotation of the cog wheels. This will affect the readings and the calibration will no longer be valid.	
3	After thoroughly studying the tool, three main principle ideas were repeated: - In some way implement strain gauges on the shaft (see sketch below this table). - Measure on the reaction fins. Either by pressure sensors (type of strain gauge) or conventional strain gauges (see sketches below this table). - Original torque transducer ring. Implementing measurement in the area near the hydraulic motor interface was mentioned, but it is likely to believe that any deviation will be escaladed through the gear stages.	
4	Strain gauges on the shaft: A solution for strain gauges directly on the tool socket was a promising idea. The place will most likely give extremely accurate measurements hence the rotation of the gear will not affect the readings. As the tool has interchangeable sockets, the measuring mechanism would have to be mounted on every socket (four in total). Extension of the gear shaft where the socket interfaces can be extended. However, in both solutions the tool needs to be extended. As the shaft rotates, this introduces challenges regarding signal and power transmitting from the rotating shaft to the tool.	
5	Measurement on the reaction fins: Different concept more measuring the reaction fins where discussed. 1. Implement pressure sensor in the fins. The pressure sensor needs to be placed inside an oil filled volume. Pistons must then be implemented as a contact to the torque tool interface. With the pistons normal in the reaction fin face could cause problems due to the angle of attack not to be normal on. The solution would not be affected of the gear rotation. 2. Implement strain gauges as close as possible to the fins. To get correct strain level where the strain gauges can be attached must be weakened. FEM analysis in Ansys must be performed to determine if this is a functional solution. 3. Make the reaction fins as separate parts which is mounted onto the tool guide. A sandwich solution where pressure sensors inside can be functional. This solution can be designed to make the inner sandwich construction not independent of any strain variations due to gear rotation. It is still unknown if these strain variations will occur at this distance from the ring gear.	

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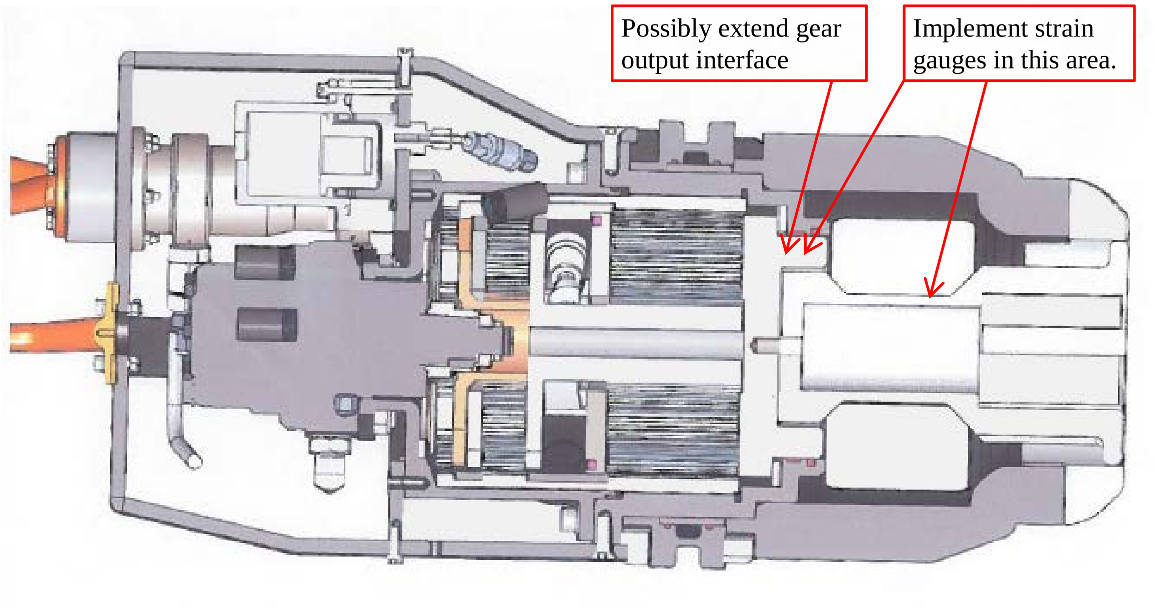
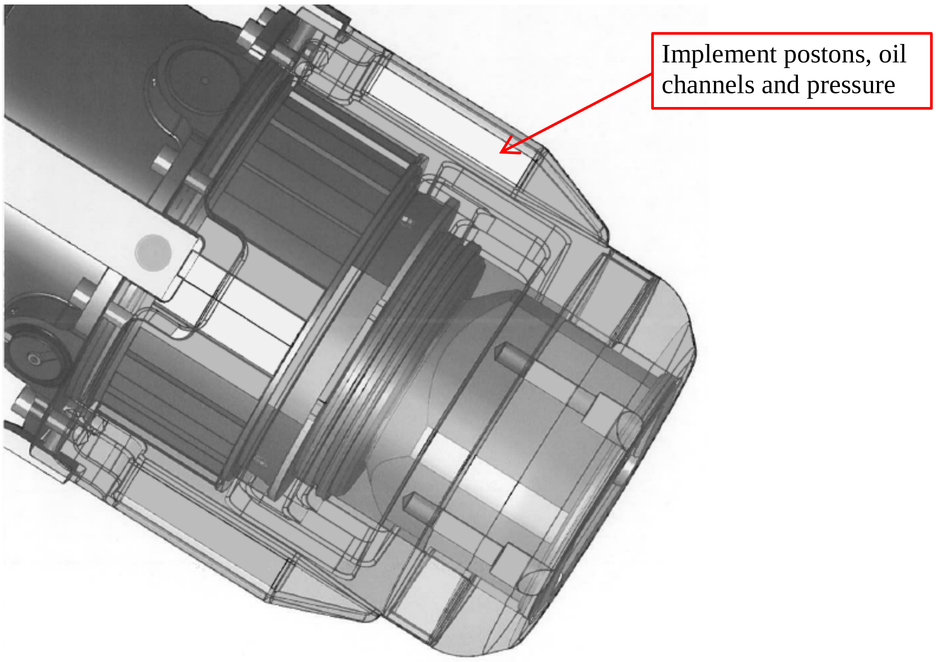
Item	Minutes	
6	Original transducer ring (existing concept): This was discussed, and the solution can be functional. However, it can`t be expected to achieve the same accuracy as if the measurements where done on the socket/shaft. We now that only +/- 10 % of full scale was achieve on the extended testing on the existing SAE tool.	
7	Sketches below is a result of what was discussed and explained on the model shown on the TV.	

Sketches

Measurements directly on tool shaft (section cut of existing concept):



Measurement on reaction fins:



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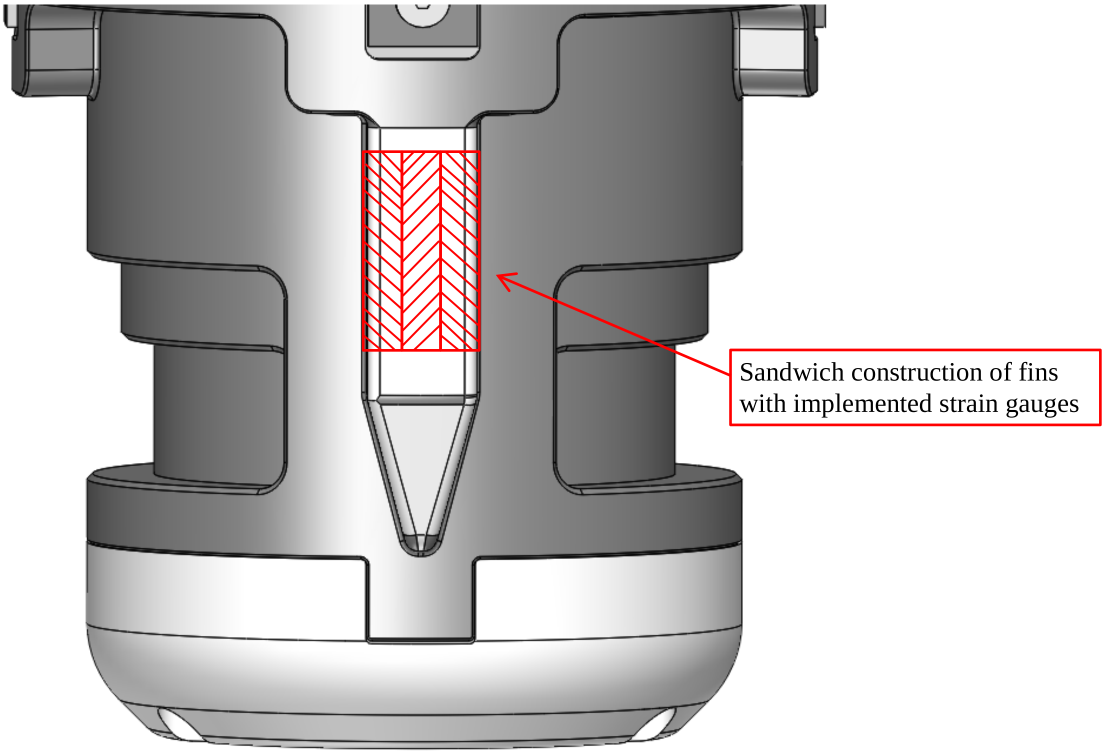
Measurement on reaction fins, sandwich construction of fins:

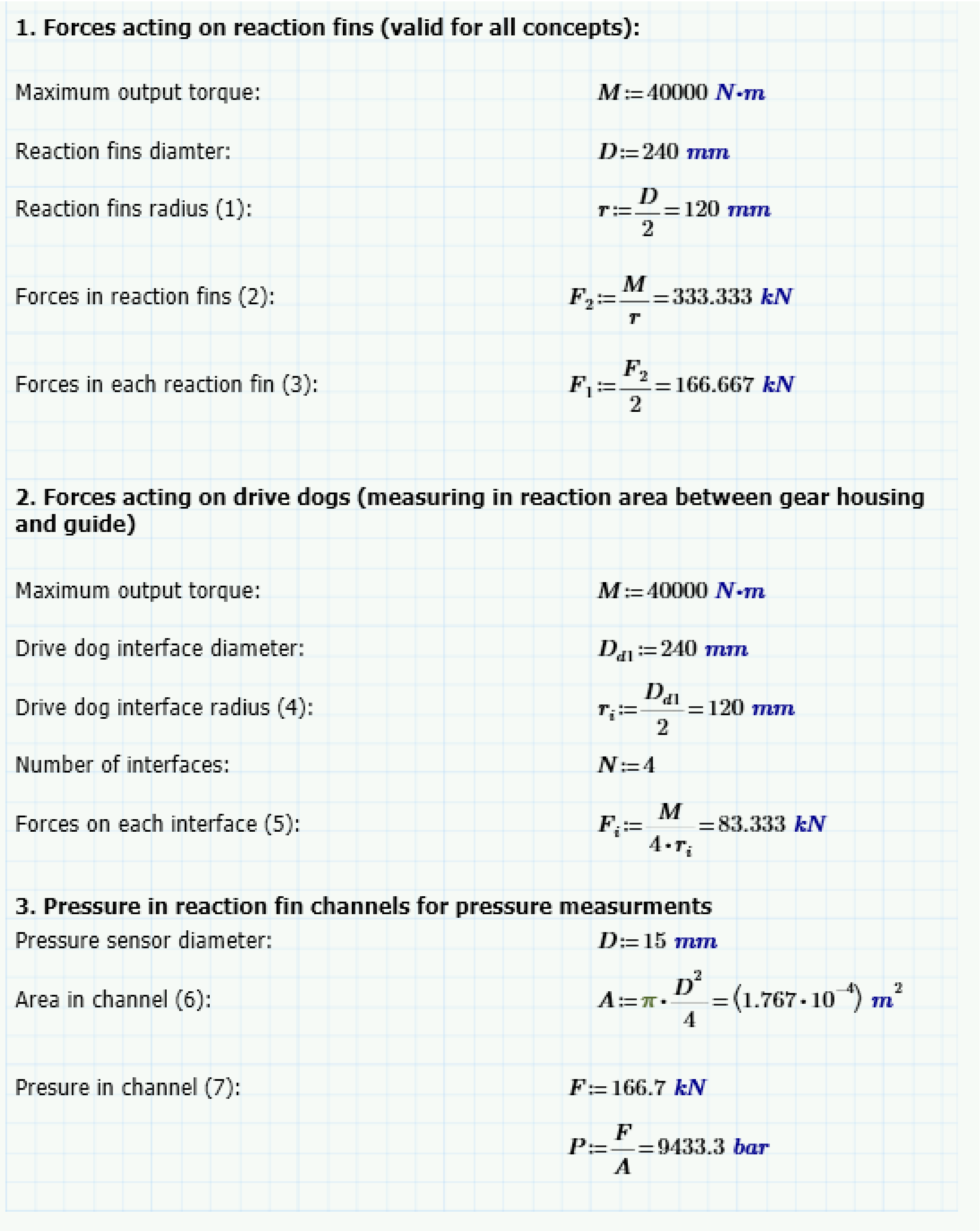


Appendix B

Hand calculations, concept phase

- Forces acting on reaction fins
- Forces acting on drive dogs
- Pressure in reaction fin channels for pressure measurements

Hand calculations, concept phase



1. Forces acting on reaction fins (valid for all concepts):

Maximum output torque: $M := 40000\ N \cdot m$

Reaction fins diamter: $D := 240\ mm$

Reaction fins radius (1): $r := \frac{D}{2} = 120\ mm$

Forces in reaction fins (2): $F_2 := \frac{M}{r} = 333.333\ kN$

Forces in each reaction fin (3): $F_1 := \frac{F_2}{2} = 166.667\ kN$

2. Forces acting on drive dogs (measuring in reaction area between gear housing and guide)

Maximum output torque: $M := 40000\ N \cdot m$

Drive dog interface diameter: $D_{d1} := 240\ mm$

Drive dog interface radius (4): $r_i := \frac{D_{d1}}{2} = 120\ mm$

Number of interfaces: $N := 4$

Forces on each interface (5): $F_i := \frac{M}{4 \cdot r_i} = 83.333\ kN$

3. Pressure in reaction fin channels for pressure measurments

Pressure sensor diameter: $D := 15\ mm$

Area in channel (6): $A := \pi \cdot \frac{D^2}{4} = \left(1.767 \cdot 10^{-4}\right)\ m^2$

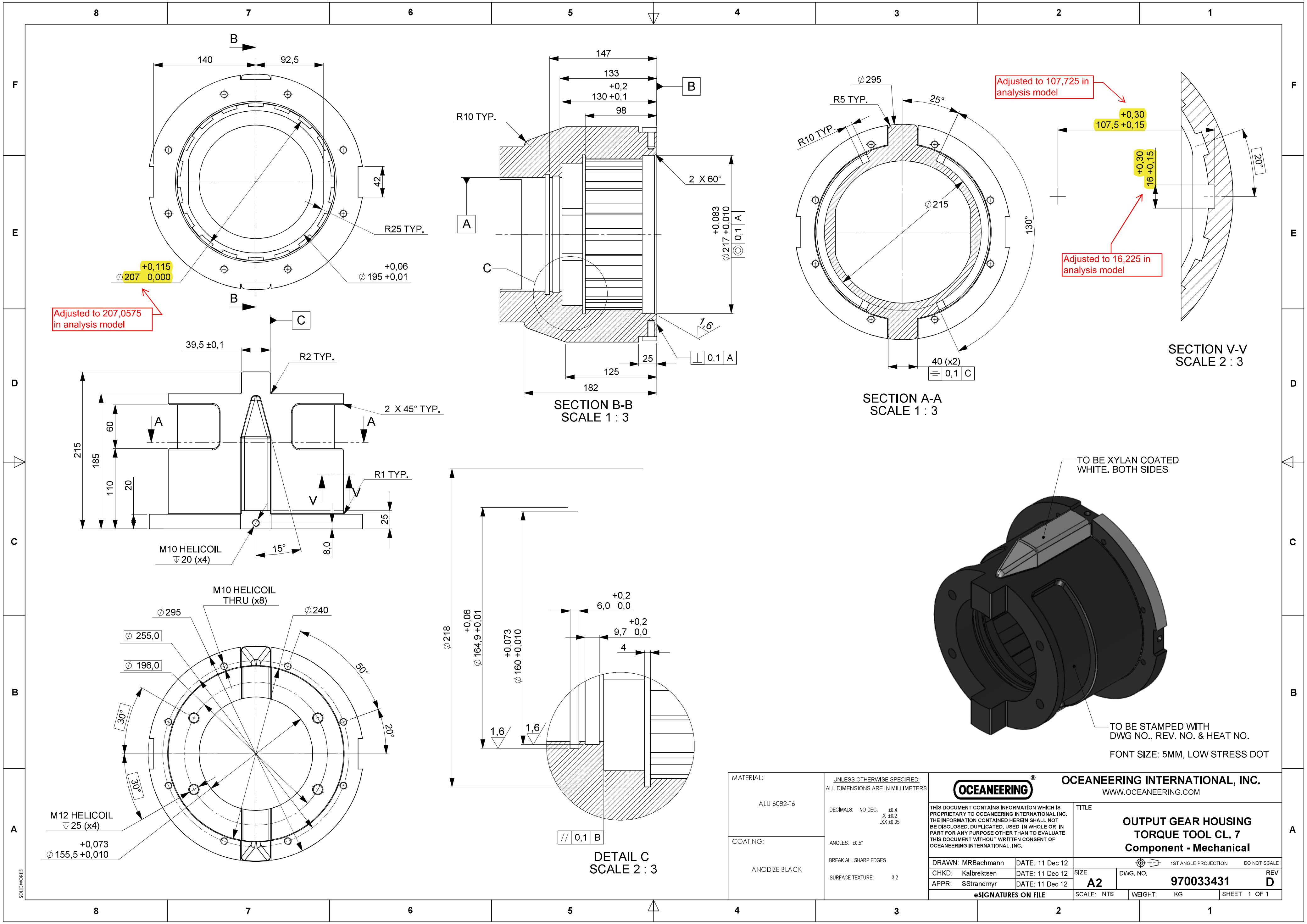
Presure in channel (7): $F := 166.7\ kN$

$$P := \frac{F}{A} = 9433.3\ bar$$

Appendix C

Mark-up drawings

- Drawing no. 970033431 with mark-up
- Drawing no. 970033432 with mark-up



MATERIAL:
ALU 6082-T6

COATING:
ANODIZE BLACK

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE IN MILLIMETERS

DECIMALS: NO DEC. ±0.4
.X ±0.2
.XX ±0.05

ANGLES: ±0.5°

BREAK ALL SHARP EDGES

SURFACE TEXTURE: 3.2

OCEANEERING INTERNATIONAL, INC.
WWW.OCEANEERING.COM

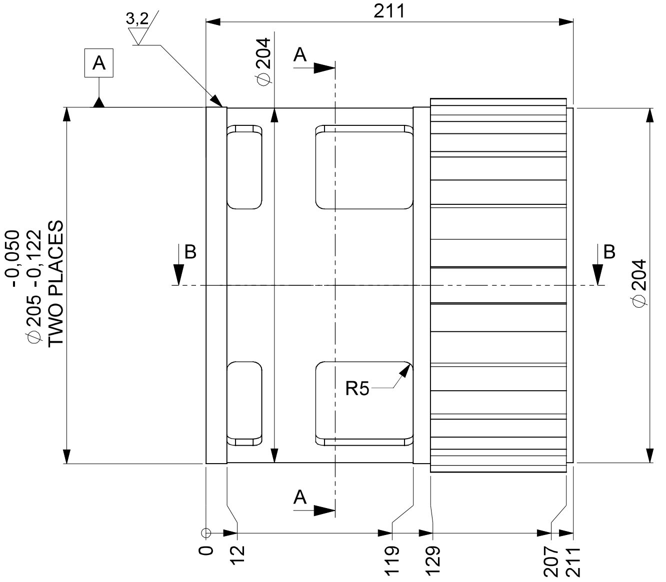
TITLE
OUTPUT GEAR HOUSING
TORQUE TOOL CL. 7
Component - Mechanical

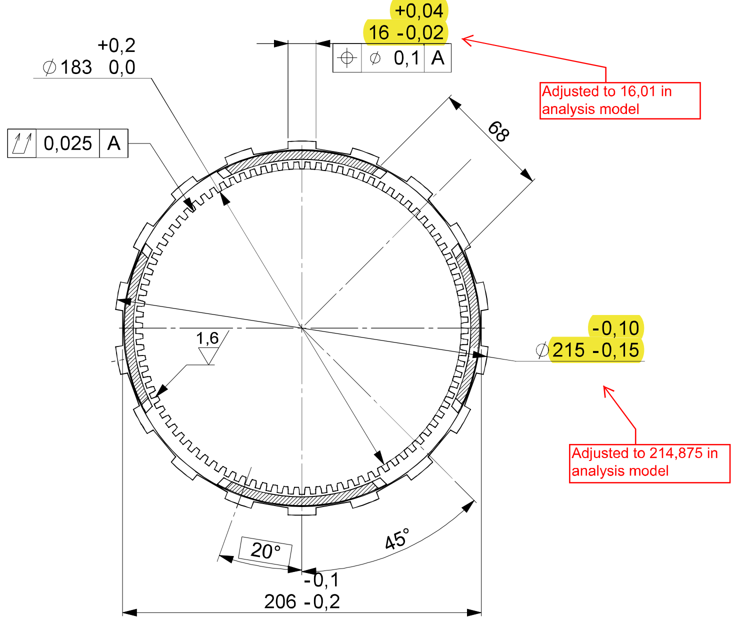
DRAWN: MRBachmann	DATE: 11 Dec 12
CHKD: Kalbrektsen	DATE: 11 Dec 12
APPR: SStrandmyr	DATE: 11 Dec 12

eSIGNATURES ON FILE

1ST ANGLE PROJECTION
DO NOT SCALE

SIZE A2
DWG. NO. 970033431
REV D
SCALE: NTS
WEIGHT: KG
SHEET 1 OF 1





Adjusted to 16,01 in analysis model

Adjusted to 214,875 in analysis model

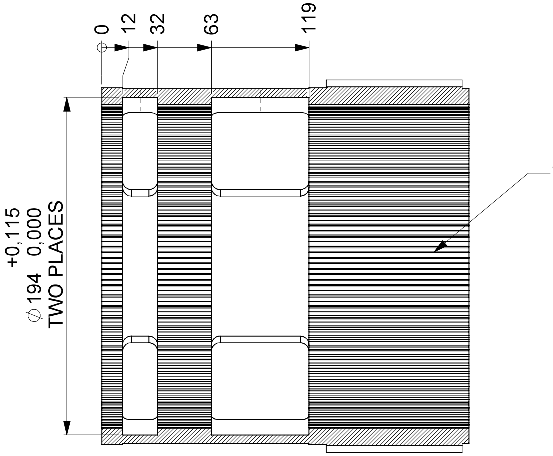
SECTION A-A

NOTE:

GENERAL TOLERANCES ± 0,15

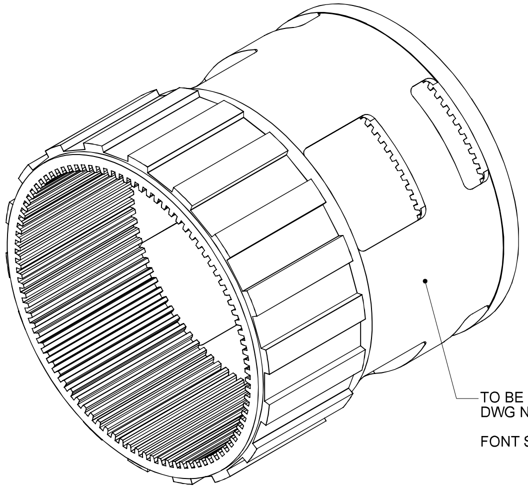
HARDENED TO 43 ± 1 HRC BEFORE MACHINING OF TEETH.
NITRIDE HARDENED TO 58 ± 1 HRC. 0,3MM MINIMUM DEPTH.

INTERNAL TEETH DATA:
BASIC RACK PROFILE ISO 53
PRESSURE ANGLE 20°
MODULE 2
NUMBER OF TEETH 93
ADDENDUM MOD. COEFFICIENT +0,25
PIN MEASUREMENT BETWEEN Ø3 PINS
183,819 +0,15 +0,2



TEETH IN LINE 3 PLACES
(TO BE CUT SIMULTANIOUSLY)

SECTION B-B



TO BE STAMPED WITH
DWG NO., REV. NO. & HEAT NO.

FONT SIZE: 5MM, LOW STRESS DOT

MATERIAL: SIS 2541	UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE IN MILLIMETERS DECIMALS: NO DEC. ±0.4 .X ±0.2 .XX ±0.05 ANGLES: ±0.5° BREAK ALL SHARP EDGES SURFACE TEXTURE: 3.2	OCEANEERING®	OCEANEERING INTERNATIONAL, INC. WWW.OCEANEERING.COM
COATING: N/A		THIS DOCUMENT CONTAINS INFORMATION WHICH IS PROPRIETARY TO OCEANEERING INTERNATIONAL INC. THE INFORMATION CONTAINED HEREIN SHALL NOT BE DISCLOSED, DUPLICATED, USED IN WHOLE OR IN PART FOR ANY PURPOSE OTHER THAN TO EVALUATE THIS DOCUMENT WITHOUT WRITTEN CONSENT OF OCEANEERING INTERNATIONAL, INC.	TITLE RING GEAR TORQUE TOOL CL. 7 **Component - Mechanical**

DRAWN: SKNTollefsen	DATE: 11 Dec 12	1ST ANGLE PROJECTION		DO NOT SCALE
CHKD: Kalbrektsen	DATE: 11 Dec 12	SIZE A2	DWG. NO. 970033432	REV D
APPR: SStrandmyr	DATE: 11 Dec 12	SCALE: NTS	WEIGHT: KG	SHEET 1 OF 1
eSIGNATURES ON FILE				

SOLIDWORKS

Appendix D

Reaction forces from ring gear and gear housing analysis

- Reaction forces in cylindrical coordinates extracted analysis
- Reaction forces (multiplied by 9.75) in cylindrical coordinates
- Reaction forces simplified for use in main analyses

Reaction forces in cylindrical coordinates extracted from ring gear and gear housing analysis

Spline no.	Y1 [N]	Y2 [N]	Y3 [N]	Y4 [N]	X1 [N]	X2 [N]	X3 [N]	X4 [N]	Z1 [N]	Z2 [N]	Z3 [N]	Z4 [N]
1	3020	0	0	757	325	0	0	1774	-5	-1	-2	53
2	6527	-109	-78	556	1730	1320	-7	3592	139	90	-82	-31
3	22	-50	0	-13	364	590	0	1501	28	38	-12	-25
4	1	-36	0	2	13	442	0	22	0	31	-7	-1
5	393	0	-46	0	28	0	-3	0	6	0	-6	-2
6	3200	0	0	340	251	0	0	28	13	1	-15	18
7	3016	0	0	769	325	0	0	1761	-5	-1	-3	54
8	6549	-108	-77	559	1724	1312	-7	3593	138	97	-83	-36
9	22	-55	0	-13	368	608	0	1505	28	37	-12	-28
10	1	-36	0	2	13	441	0	23	0	31	-7	-1
11	397	0	-46	0	28	0	-3	0	6	0	-6	-2
12	3196	0	0	339	251	0	0	28	13	1	-14	17
13	3015	0	0	767	325	0	0	1777	-4	-1	-2	45
14	6534	-111	-78	553	1723	1340	-7	3581	139	90	-80	-28
15	22	-51	0	-13	365	595	0	1501	28	38	-12	-28
16	1	-36	0	2	10	442	0	18	0	31	-7	-1
17	405	0	-46	0	29	0	-3	0	6	0	-6	-2
18	3201	0	0	341	251	0	0	28	13	1	-14	17

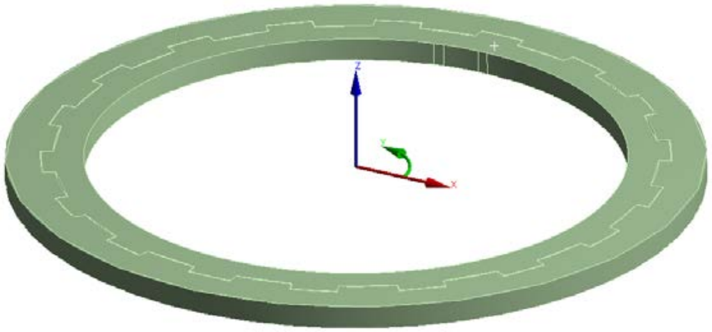
Y1: Reaction forces in y-direction in contact area 1
Y2: Reaction forces in y-direction in contact area 2
Y3: Reaction forces in y-direction in contact area 3
Y4: Reaction forces in y-direction in contact area 4

X1: Reaction forces in x-direction in contact area 1
X2: Reaction forces in x-direction in contact area 2
X3: Reaction forces in x-direction in contact area 3
X4: Reaction forces in x-direction in contact area 4

Z1: Reaction forces in z-direction in contact area 1
Z2: Reaction forces in z-direction in contact area 2
Z3: Reaction forces in z-direction in contact area 3
Z4: Reaction forces in z-direction in contact area 4

Reaction forces (multiplied by 9.75) in cylindrical coordinates extracted from ring gear and gear housing analysis

Spline no.	Y1 [N]	Y2 [N]	Y3 [N]	Y4 [N]	X1 [N]	X2 [N]	X3 [N]	X4 [N]	Z1 [N]	Z2 [N]	Z3 [N]	Z4 [N]
1	29445	0	0	7381	3169	0	0	17297	-49	-10	-20	517
2	63638	-1063	-761	5421	16868	12870	-68	35022	1355	878	-800	-302
3	215	-488	0	-127	3549	5753	0	14635	273	371	-117	-244
4	10	-351	0	20	127	4310	0	215	0	302	-68	-10
5	3832	0	-449	0	273	0	-29	0	59	0	-59	-20
6	31200	0	0	3315	2447	0	0	273	127	10	-146	176
7	29406	0	0	7498	3169	0	0	17170	-49	-10	-29	527
8	63853	-1053	-751	5450	16809	12792	-68	35032	1346	946	-809	-351
9	215	-536	0	-127	3588	5928	0	14674	273	361	-117	-273
10	10	-351	0	20	127	4300	0	224	0	302	-68	-10
11	3871	0	-449	0	273	0	-29	0	59	0	-59	-20
12	31161	0	0	3305	2447	0	0	273	127	10	-137	166
13	29396	0	0	7478	3169	0	0	17326	-39	-10	-20	439
14	63707	-1082	-761	5392	16799	13065	-68	34915	1355	878	-780	-273
15	215	-497	0	-127	3559	5801	0	14635	273	371	-117	-273
16	10	-351	0	20	98	4310	0	176	0	302	-68	-10
17	3949	0	-449	0	283	0	-29	0	59	0	-59	-20
18	31210	0	0	3325	2447	0	0	273	127	10	-137	166



The simplified gear housing and the ring gear with the cylindrical coordinate system is shown to the left. The moment is acting counter clockwise.

X: Radial direction

Y: Tangential direction

Z: Axial direction

Reaction forces simplified for use in main analysis

Spline no.	Y1+Y4 (applied on contact area 1)	X1+X4 (on contact area 1)	Y2 (on contact area 2)	X2 (on contact area 2)
1	36826	20465	0	0
2	69059	51890	-1063	12870
3	88	18184	-488	5753
4	29	341	-351	4310
5	3832	273	0	0
6	34515	2720	0	0
7	36904	20339	0	0
8	69303	51841	-1053	12792
9	88	18262	-536	5928
10	29	351	-351	4300
11	3871	273	0	0
12	34466	2720	0	0
13	36875	20495	0	0
14	69098	51714	-1082	13065
15	88	18194	-497	5801
16	29	273	-351	4310
17	3949	283	0	0
18	34535	2720	0	0

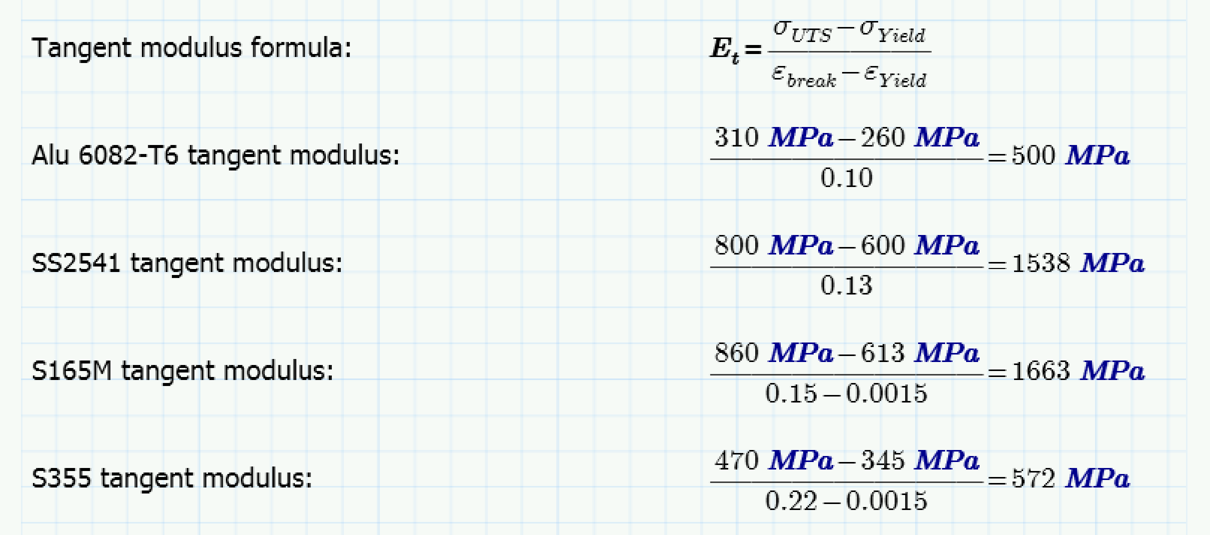
Appendix E

Hand calculations, analyses

- Calculation of tangent modulus bi-linear material property
- Moment check for ring gear and gear housing analysis
- Moment check for existing concept (position 1, 2 and 3)
- Moment check for new concept (position 1, 2 and 3)

Hand calculations, analyses

1. Calculation of tangent modulus bi-linear material property



Tangent modulus formula: $E_t = \frac{\sigma_{UTS} - \sigma_{Yield}}{\varepsilon_{break} - \varepsilon_{Yield}}$

Alu 6082-T6 tangent modulus: $\frac{310\ MPa - 260\ MPa}{0.10} = 500\ MPa$

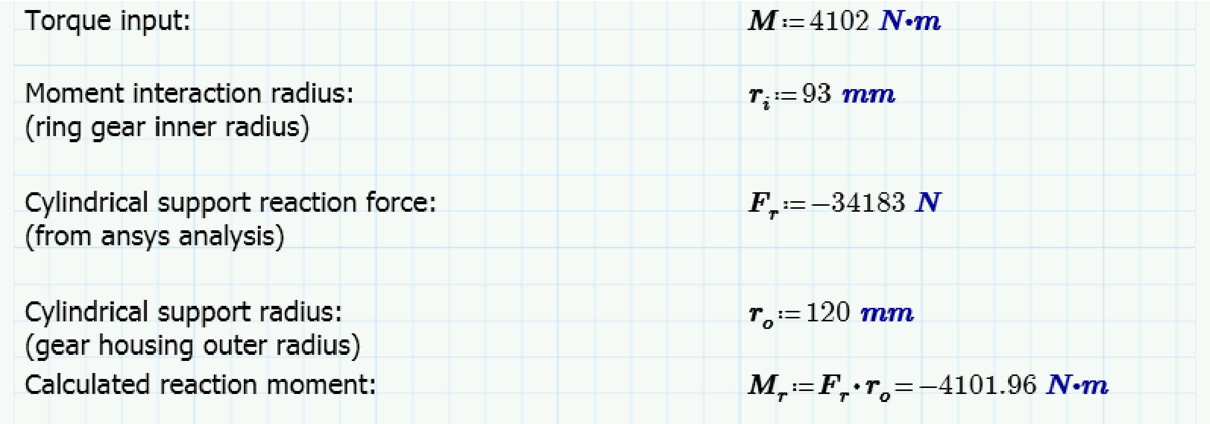
SS2541 tangent modulus: $\frac{800\ MPa - 600\ MPa}{0.13} = 1538\ MPa$

S165M tangent modulus: $\frac{860\ MPa - 613\ MPa}{0.15 - 0.0015} = 1663\ MPa$

S355 tangent modulus: $\frac{470\ MPa - 345\ MPa}{0.22 - 0.0015} = 572\ MPa$

Comment: The elongation at yield material property was found for neither Alu 6082-T6 nor SS2541. This property is very small and neglecting it will only affect the tangent modulus in a miner degree.

2. Moment check for ring gear and gear housing analysis



Torque input: $M := 4102\ N \cdot m$

Moment interaction radius:
(ring gear inner radius) $r_i := 93\ mm$

Cylindrical support reaction force:
(from ansys analysis) $F_r := -34183\ N$

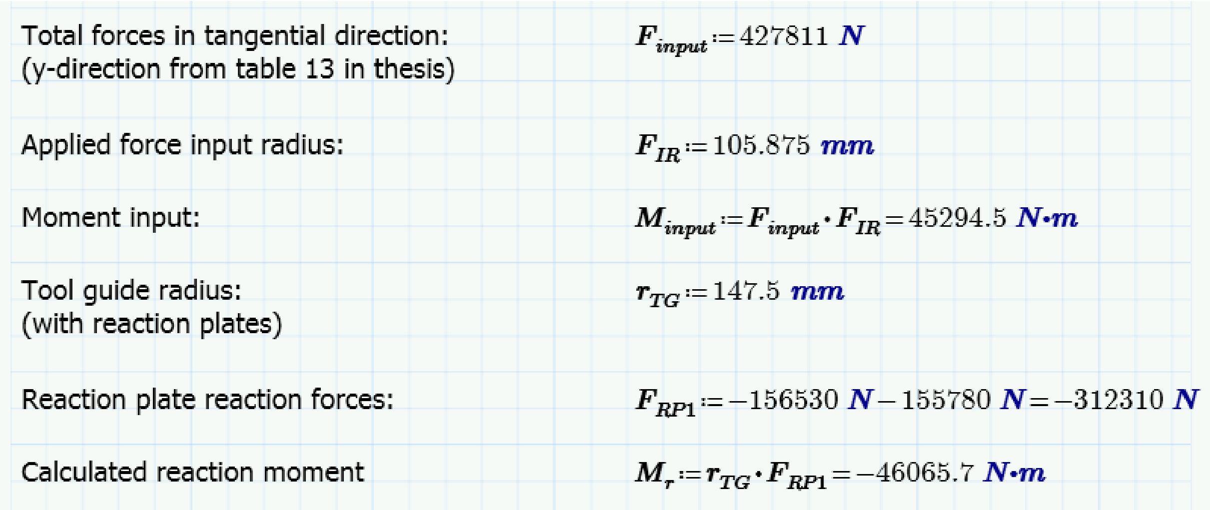
Cylindrical support radius:
(gear housing outer radius) $r_o := 120\ mm$

Calculated reaction moment: $M_r := F_r \cdot r_o = -4101.96\ N \cdot m$

Comment: The input moment is approximately equal to the calculated reaction moment. A deviation of 0,04 Nm is within the acceptable tolerance.

3. Moment check for existing concept (position 1, 2 and 3)

The following calculations are to verify that the input moment equals to the output moment.



Total forces in tangential direction: (y-direction from table 13 in thesis)	$F_{input} := 427811\ N$
Applied force input radius:	$F_{IR} := 105.875\ mm$
Moment input:	$M_{input} := F_{input} \cdot F_{IR} = 45294.5\ N \cdot m$
Tool guide radius: (with reaction plates)	$r_{TG} := 147.5\ mm$
Reaction plate reaction forces:	$F_{RP1} := -156530\ N - 155780\ N = -312310\ N$
Calculated reaction moment	$M_r := r_{TG} \cdot F_{RP1} = -46065.7\ N \cdot m$

Comment: The calculated reaction moment is slightly higher than the actual input moment. These are simplified calculation as radius at were the forces are unknown due to the complex force distribution over from the reaction fins on the tool guide to the reaction plates. For the hand calculation, the outer radius is used as an approximation. In practice, the real radius will be smaller due to deformation when full load is applied.

To verify that actual input corresponds to output moment, the reaction moment was read out from the Ansys. The moment reaction is 45 008 Nm. This is slightly lower than calculated input moment. This can be explained by the applied force input radius measurement. The uncertainties regarding this radius in the hand calculations explain the small deviations. The actual pressure distribution is shown in Figure 1, and explains the difficulties regarding hand calculations of moment reaction.

The conclusion is that there are some deviations in the hand calculations, but this has reasonable explanations due to uncertainties in applied forces radius and moment reaction radius.

The Ansys moment reaction results verify that input moment equals output moment (reaction moment). The read reaction moment is 45 008 Nm. This is valid for all three positions.

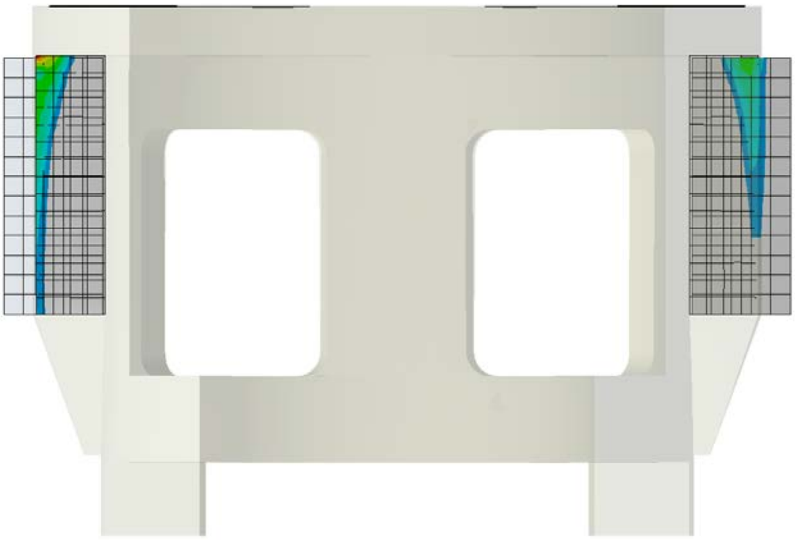
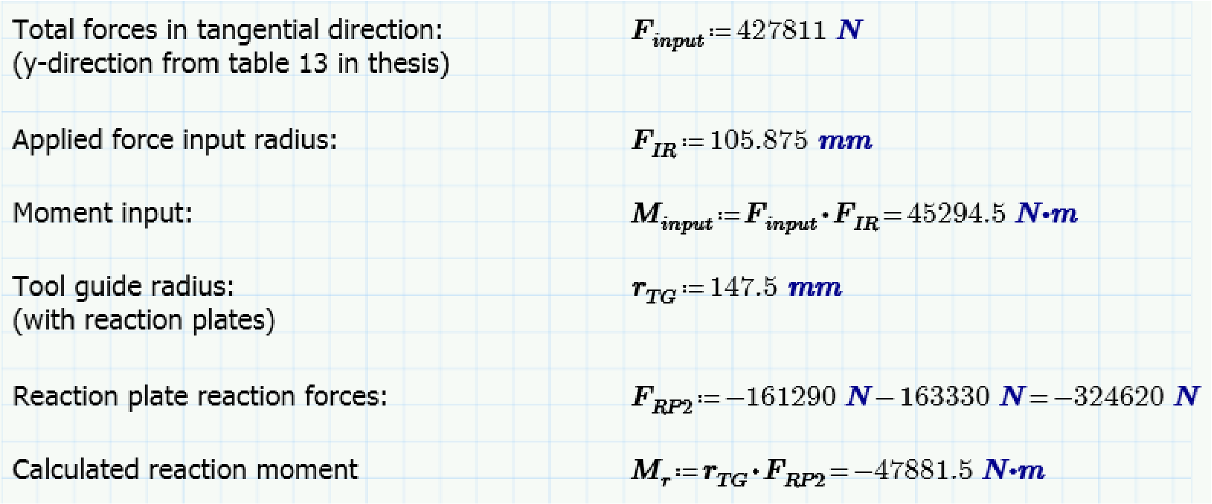


Figure 1: Pressure distribution on reaction fins

4. Moment check for new concept (position 1, 2 and 3)

The following calculations are to verify that the input moment equals to the output moment.



Total forces in tangential direction: (y-direction from table 13 in thesis)	$F_{input} := 427811\ N$
Applied force input radius:	$F_{IR} := 105.875\ mm$
Moment input:	$M_{input} := F_{input} \cdot F_{IR} = 45294.5\ N \cdot m$
Tool guide radius: (with reaction plates)	$r_{TG} := 147.5\ mm$
Reaction plate reaction forces:	$F_{RP2} := -161290\ N - 163330\ N = -324620\ N$
Calculated reaction moment	$M_r := r_{TG} \cdot F_{RP2} = -47881.5\ N \cdot m$

Comment: Same as for moment check for existing concept.

Appendix F

Results from existing concept analyses

- Results from position 1 and position 2
- Results from position 1 and position 3
- Excel formulas used for existing concept

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 1 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 1	**Pos 1**	**Pos 2**		**SG 2**	**Pos 1**	**Pos 2**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
10179	2,75E-03	2,73E-03	0,8	10191	2,14E-03	2,14E-03	0,4
10180	2,79E-03	2,76E-03	1,2	10192	1,98E-03	2,01E-03	1,7
10181	2,89E-03	2,84E-03	1,7	10193	1,90E-03	1,95E-03	2,7
10182	2,96E-03	2,89E-03	2,2	10194	1,98E-03	2,02E-03	1,7
10187	2,91E-03	2,71E-03	6,7	10195	2,13E-03	2,11E-03	0,7
10188	2,91E-03	2,73E-03	6,4	10196	2,04E-03	2,04E-03	0,0
10189	2,90E-03	2,72E-03	6,1	10197	1,98E-03	1,99E-03	0,3
10190	2,89E-03	2,72E-03	6,1	10198	1,94E-03	1,95E-03	0,7
10575	2,95E-03	2,86E-03	3,0	10579	2,14E-03	2,18E-03	1,8
10576	3,08E-03	2,95E-03	4,1	10580	2,10E-03	2,10E-03	0,0
10577	2,88E-03	2,70E-03	6,1	10581	1,88E-03	1,91E-03	1,7
10578	2,89E-03	2,76E-03	4,4	10582	1,76E-03	1,78E-03	1,3
10611	2,87E-03	2,68E-03	6,8	10615	2,27E-03	2,22E-03	2,1
10612	3,06E-03	2,90E-03	5,1	10616	2,19E-03	2,15E-03	1,6
10613	2,57E-03	2,57E-03	0,2	10617	2,00E-03	2,04E-03	1,8
10614	2,86E-03	2,79E-03	2,4	10618	1,76E-03	1,79E-03	1,5
14017	2,98E-03	2,84E-03	4,5	10823	1,80E-03	1,80E-03	0,0
14018	3,12E-03	2,98E-03	4,6	10824	1,93E-03	1,92E-03	0,8
14019	3,03E-03	2,94E-03	2,9	10825	2,04E-03	2,01E-03	1,1
14020	3,05E-03	2,91E-03	4,5	10826	1,85E-03	1,85E-03	0,4
14021	3,02E-03	2,87E-03	4,9	10827	2,07E-03	2,06E-03	0,3
14022	3,00E-03	2,91E-03	3,1	10828	1,93E-03	1,93E-03	0,3
14023	2,94E-03	2,87E-03	2,6	10829	1,88E-03	1,88E-03	0,2
14024	3,07E-03	2,96E-03	3,6	10830	1,81E-03	1,82E-03	0,7
52646	2,77E-03	2,74E-03	1,0	52697	2,05E-03	2,07E-03	1,0
52648	2,66E-03	2,65E-03	0,5	52699	2,07E-03	2,09E-03	1,1
52649	2,85E-03	2,80E-03	1,8	52700	1,97E-03	1,98E-03	0,6
52651	2,84E-03	2,80E-03	1,5	52702	1,94E-03	1,98E-03	2,1
52653	2,91E-03	2,85E-03	2,1	52704	1,93E-03	1,94E-03	0,8
52655	2,92E-03	2,87E-03	2,0	52706	1,94E-03	1,98E-03	2,2
52657	2,95E-03	2,88E-03	2,5	52708	1,91E-03	1,94E-03	1,2
52660	2,95E-03	2,88E-03	2,6	52711	2,06E-03	2,09E-03	1,8
52661	3,01E-03	2,92E-03	2,9	52712	2,03E-03	2,04E-03	0,7
52680	2,91E-03	2,72E-03	6,6	52714	2,08E-03	2,08E-03	0,3
52682	2,89E-03	2,70E-03	6,8	52716	2,20E-03	2,17E-03	1,4
52683	2,97E-03	2,79E-03	5,8	52717	2,08E-03	2,06E-03	0,9
52685	2,91E-03	2,73E-03	6,3	52719	2,01E-03	2,01E-03	0,2
52687	3,02E-03	2,85E-03	5,5	52721	1,99E-03	1,98E-03	0,4
52689	2,90E-03	2,72E-03	6,1	52723	1,96E-03	1,97E-03	0,5
52691	2,97E-03	2,82E-03	5,3	52725	1,92E-03	1,92E-03	0,1
52694	2,89E-03	2,71E-03	6,1	52728	1,91E-03	1,93E-03	1,2
52695	2,94E-03	2,78E-03	5,3	52729	1,87E-03	1,87E-03	0,3
53959	3,01E-03	2,91E-03	3,6	53969	2,12E-03	2,14E-03	0,9
53961	3,07E-03	2,93E-03	4,6	53971	2,14E-03	2,13E-03	0,8
53962	3,07E-03	2,96E-03	3,9	53972	2,08E-03	2,08E-03	0,2
53964	2,88E-03	2,73E-03	5,2	53974	1,82E-03	1,85E-03	1,5
53966	2,88E-03	2,78E-03	3,4	53976	1,76E-03	1,79E-03	1,4
53967	2,93E-03	2,80E-03	4,4	53977	1,78E-03	1,79E-03	0,6
54048	2,97E-03	2,79E-03	6,0	54056	2,23E-03	2,19E-03	1,9
54050	3,04E-03	2,89E-03	5,0	54058	2,11E-03	2,08E-03	1,4
54052	2,72E-03	2,68E-03	1,4	54060	1,88E-03	1,91E-03	1,7
54054	2,90E-03	2,83E-03	2,5	54062	1,79E-03	1,81E-03	1,1
61374	3,01E-03	2,88E-03	4,5	54521	1,83E-03	1,82E-03	0,2
61375	2,96E-03	2,86E-03	3,5	54522	1,80E-03	1,81E-03	0,4
61377	3,09E-03	2,95E-03	4,6	54524	1,98E-03	1,97E-03	0,9
61378	3,07E-03	2,92E-03	4,8	54525	1,89E-03	1,88E-03	0,6
61379	3,06E-03	2,94E-03	3,9	54526	1,93E-03	1,92E-03	0,5
61381	3,04E-03	2,93E-03	3,7	54528	2,05E-03	2,04E-03	0,7
61382	3,02E-03	2,93E-03	3,0	54530	1,87E-03	1,86E-03	0,3
61383	2,99E-03	2,90E-03	2,8	54532	2,00E-03	1,99E-03	0,3
61386	3,05E-03	2,92E-03	4,3	54534	1,91E-03	1,90E-03	0,3
61388	3,03E-03	2,93E-03	3,4	54536	1,85E-03	1,85E-03	0,2
SUM:	**1,82E-01**	**1,75E-01**	**4,0**	**SUM:**	**1,22E-01**	**1,23E-01**	**0,3**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 2 of 16
Node numbers and associated strains [mm/mm] exported from ansys

SG 3	Pos 1	Pos 2		SG 4	Pos 1	Pos 2	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
10171	2,61E-03	2,80E-03	6,8	10207	2,98E-03	3,26E-03	8,6
10172	2,51E-03	2,68E-03	6,5	10208	3,18E-03	3,46E-03	8,1
10173	2,39E-03	2,55E-03	6,5	10209	3,27E-03	3,55E-03	7,9
10174	2,25E-03	2,42E-03	7,1	10210	3,26E-03	3,54E-03	8,0
10175	1,86E-03	2,09E-03	10,7	10211	3,22E-03	3,72E-03	13,3
10176	1,98E-03	2,24E-03	11,7	10212	3,32E-03	3,80E-03	12,6
10177	2,12E-03	2,39E-03	11,5	10213	3,38E-03	3,81E-03	11,3
10178	2,25E-03	2,54E-03	11,5	10214	3,40E-03	3,78E-03	10,0
10571	2,02E-03	2,18E-03	7,4	10587	3,16E-03	3,45E-03	8,3
10572	1,86E-03	2,09E-03	11,0	10588	3,25E-03	3,68E-03	11,8
10573	2,41E-03	2,72E-03	11,4	10589	3,29E-03	3,60E-03	8,6
10574	2,51E-03	2,87E-03	12,5	10590	3,08E-03	3,45E-03	10,6
10607	1,67E-03	1,91E-03	12,4	10623	3,08E-03	3,57E-03	13,7
10608	1,74E-03	1,99E-03	12,8	10624	3,23E-03	3,73E-03	13,6
10609	2,66E-03	2,87E-03	7,5	10625	2,70E-03	2,96E-03	9,0
10610	2,59E-03	2,92E-03	11,1	10626	2,88E-03	3,23E-03	10,9
10831	2,34E-03	2,67E-03	12,6	10839	3,26E-03	3,69E-03	11,7
10832	2,02E-03	2,32E-03	13,0	10840	3,36E-03	3,83E-03	12,2
10833	1,88E-03	2,16E-03	13,2	10841	3,37E-03	3,87E-03	12,8
10834	2,18E-03	2,50E-03	12,8	10842	3,32E-03	3,83E-03	13,3
10835	2,00E-03	2,26E-03	11,4	10843	3,32E-03	3,76E-03	11,6
10836	2,14E-03	2,41E-03	11,3	10844	3,34E-03	3,77E-03	11,4
10837	2,29E-03	2,58E-03	11,1	10845	3,28E-03	3,69E-03	11,2
10838	2,44E-03	2,75E-03	11,0	10846	3,12E-03	3,52E-03	11,2
52612	2,56E-03	2,74E-03	6,7	52765	3,08E-03	3,36E-03	8,3
52614	2,63E-03	2,84E-03	7,1	52767	2,84E-03	3,11E-03	8,8
52615	2,53E-03	2,77E-03	8,9	52768	3,05E-03	3,39E-03	10,0
52617	2,45E-03	2,62E-03	6,5	52770	3,23E-03	3,51E-03	8,0
52619	2,40E-03	2,63E-03	8,8	52772	3,23E-03	3,58E-03	9,7
52621	2,32E-03	2,49E-03	6,8	52774	3,26E-03	3,55E-03	8,0
52623	2,26E-03	2,48E-03	8,8	52776	3,30E-03	3,66E-03	9,7
52626	2,13E-03	2,30E-03	7,2	52779	3,21E-03	3,49E-03	8,2
52627	2,12E-03	2,34E-03	9,2	52780	3,29E-03	3,65E-03	9,8
52629	1,92E-03	2,16E-03	11,2	52782	3,27E-03	3,76E-03	13,0
52631	1,77E-03	2,00E-03	11,5	52784	3,15E-03	3,65E-03	13,5
52632	1,87E-03	2,12E-03	12,0	52785	3,27E-03	3,77E-03	13,3
52634	2,05E-03	2,32E-03	11,6	52787	3,35E-03	3,80E-03	12,0
52636	2,00E-03	2,28E-03	12,4	52789	3,35E-03	3,83E-03	12,7
52638	2,18E-03	2,46E-03	11,5	52791	3,39E-03	3,79E-03	10,7
52640	2,15E-03	2,44E-03	12,2	52793	3,37E-03	3,82E-03	11,8
52643	2,33E-03	2,63E-03	11,4	52796	3,34E-03	3,69E-03	9,3
52644	2,29E-03	2,61E-03	12,1	52797	3,33E-03	3,73E-03	10,9
53949	1,94E-03	2,13E-03	9,2	53991	3,20E-03	3,57E-03	10,1
53951	1,80E-03	2,04E-03	11,9	53993	3,24E-03	3,71E-03	12,7
53952	1,93E-03	2,17E-03	11,2	53994	3,28E-03	3,72E-03	11,7
53954	2,46E-03	2,79E-03	12,0	53996	3,18E-03	3,52E-03	9,6
53956	2,55E-03	2,89E-03	11,8	53998	2,98E-03	3,34E-03	10,7
53957	2,42E-03	2,77E-03	12,6	53999	3,17E-03	3,57E-03	11,2
54040	1,70E-03	1,95E-03	12,6	54073	3,16E-03	3,65E-03	13,7
54042	1,81E-03	2,08E-03	13,0	54075	3,27E-03	3,78E-03	13,4
54044	2,62E-03	2,89E-03	9,3	54077	2,79E-03	3,10E-03	9,9
54046	2,52E-03	2,83E-03	11,1	54079	3,00E-03	3,37E-03	11,0
54539	2,26E-03	2,58E-03	12,7	54557	3,31E-03	3,76E-03	12,0
54540	2,39E-03	2,71E-03	11,8	54558	3,19E-03	3,60E-03	11,5
54542	1,95E-03	2,24E-03	13,1	54560	3,37E-03	3,85E-03	12,5
54543	2,10E-03	2,41E-03	12,9	54561	3,32E-03	3,76E-03	11,7
54544	2,08E-03	2,37E-03	12,1	54563	3,35E-03	3,85E-03	13,0
54546	1,94E-03	2,21E-03	12,3	54564	3,36E-03	3,82E-03	12,1
54548	2,23E-03	2,54E-03	11,9	54566	3,32E-03	3,79E-03	12,4
54550	2,07E-03	2,33E-03	11,3	54568	3,33E-03	3,76E-03	11,5
54552	2,21E-03	2,49E-03	11,2	54570	3,31E-03	3,73E-03	11,3
54554	2,37E-03	2,66E-03	11,1	54572	3,20E-03	3,60E-03	11,2
SUM:	**1,36E-01**	**1,52E-01**	**10,7**	**SUM:**	**2,00E-01**	**2,25E-01**	**11,1**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 3 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 5	**Pos 1**	**Pos 2**		**SG 6**	**Pos 1**	**Pos 2**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
10167	1,80E-03	1,89E-03	4,7	10215	2,71E-03	2,43E-03	10,5
10168	1,99E-03	2,02E-03	1,3	10216	3,02E-03	2,66E-03	11,8
10169	2,20E-03	2,18E-03	1,2	10217	3,03E-03	2,62E-03	13,7
10170	2,41E-03	2,31E-03	4,2	10218	2,78E-03	2,41E-03	13,3
10203	3,23E-03	3,04E-03	5,8	10591	3,16E-03	2,80E-03	11,5
10204	2,90E-03	2,79E-03	3,8	10592	3,33E-03	2,86E-03	14,0
10205	2,44E-03	2,42E-03	0,8	10593	2,69E-03	2,34E-03	12,8
10206	2,09E-03	2,10E-03	0,8	10594	2,78E-03	2,40E-03	13,5
10569	2,70E-03	2,52E-03	6,9	10627	3,31E-03	2,88E-03	13,1
10570	3,02E-03	2,79E-03	7,3	10628	3,38E-03	2,90E-03	14,2
10585	1,83E-03	1,93E-03	5,2	10629	2,65E-03	2,37E-03	10,9
10586	1,75E-03	1,84E-03	4,6	10630	2,70E-03	2,35E-03	13,1
10605	3,57E-03	3,32E-03	6,8	10645	2,84E-03	2,45E-03	13,9
10606	3,25E-03	3,01E-03	7,5	10646	3,01E-03	2,60E-03	13,7
10621	1,70E-03	1,86E-03	8,3	10647	2,93E-03	2,58E-03	11,7
10622	1,75E-03	1,85E-03	5,4	10648	2,81E-03	2,50E-03	10,8
10847	1,98E-03	1,99E-03	0,4	10855	3,14E-03	2,74E-03	12,8
10848	2,13E-03	2,10E-03	1,3	10856	2,95E-03	2,55E-03	13,4
10849	2,97E-03	2,79E-03	6,0	10857	2,81E-03	2,44E-03	13,2
10850	2,26E-03	2,20E-03	2,4	10858	2,99E-03	2,57E-03	14,3
10851	2,61E-03	2,50E-03	4,3	10859	3,17E-03	2,74E-03	13,6
10852	2,37E-03	2,30E-03	2,9	10860	3,23E-03	2,78E-03	13,9
10853	2,71E-03	2,56E-03	5,7	10861	2,87E-03	2,48E-03	13,8
10854	1,88E-03	1,92E-03	1,9	10862	3,27E-03	2,85E-03	12,9
52595	1,90E-03	1,95E-03	2,9	52800	2,68E-03	2,40E-03	10,6
52597	1,75E-03	1,87E-03	6,5	52801	2,76E-03	2,47E-03	10,7
52598	1,84E-03	1,90E-03	3,2	52802	2,76E-03	2,44E-03	11,9
52600	2,10E-03	2,10E-03	0,0	52805	3,09E-03	2,73E-03	11,7
52602	2,06E-03	2,06E-03	0,0	52806	2,97E-03	2,62E-03	11,7
52604	2,31E-03	2,24E-03	2,8	52807	3,15E-03	2,76E-03	12,4
52606	2,29E-03	2,24E-03	2,1	52809	3,17E-03	2,74E-03	13,4
52609	2,56E-03	2,41E-03	5,6	52810	3,02E-03	2,61E-03	13,6
52610	2,56E-03	2,43E-03	5,0	52811	3,13E-03	2,70E-03	13,8
52748	3,06E-03	2,92E-03	4,9	52813	2,73E-03	2,37E-03	13,1
52750	3,40E-03	3,18E-03	6,3	52814	2,81E-03	2,43E-03	13,6
52751	3,10E-03	2,91E-03	5,9	52815	2,82E-03	2,44E-03	13,5
52753	2,67E-03	2,60E-03	2,5	54001	3,24E-03	2,83E-03	12,8
52755	2,76E-03	2,64E-03	4,0	54003	3,35E-03	2,88E-03	14,1
52757	2,26E-03	2,26E-03	0,0	54004	3,30E-03	2,85E-03	13,5
52759	2,35E-03	2,31E-03	1,5	54006	2,73E-03	2,37E-03	13,2
52762	1,96E-03	2,02E-03	2,9	54008	2,74E-03	2,37E-03	13,3
52763	2,04E-03	2,05E-03	0,6	54009	2,82E-03	2,44E-03	13,7
53944	2,86E-03	2,66E-03	7,1	54081	3,35E-03	2,89E-03	13,6
53946	3,13E-03	2,90E-03	7,4	54084	3,31E-03	2,84E-03	14,1
53947	2,86E-03	2,68E-03	6,6	54087	2,68E-03	2,36E-03	12,0
53984	1,79E-03	1,88E-03	4,9	54090	2,76E-03	2,39E-03	13,2
53987	1,75E-03	1,84E-03	5,0	54126	2,93E-03	2,52E-03	13,8
53988	1,87E-03	1,91E-03	2,4	54127	2,92E-03	2,51E-03	14,1
54036	3,41E-03	3,17E-03	7,1	54129	3,09E-03	2,67E-03	13,6
54038	3,11E-03	2,90E-03	6,8	54131	2,87E-03	2,54E-03	11,3
54068	1,72E-03	1,85E-03	6,9	54132	3,04E-03	2,66E-03	12,3
54070	1,81E-03	1,88E-03	3,6	54134	2,88E-03	2,53E-03	12,1
54575	2,12E-03	2,10E-03	1,1	54593	3,05E-03	2,65E-03	13,1
54576	1,93E-03	1,95E-03	1,1	54594	3,16E-03	2,74E-03	13,2
54578	2,19E-03	2,15E-03	1,8	54595	3,21E-03	2,80E-03	12,8
54579	2,25E-03	2,20E-03	2,2	54597	2,88E-03	2,50E-03	13,3
54580	2,00E-03	2,01E-03	0,2	54598	2,97E-03	2,56E-03	13,8
54582	2,79E-03	2,64E-03	5,2	54600	2,84E-03	2,46E-03	13,5
54583	2,84E-03	2,67E-03	5,8	54602	3,08E-03	2,65E-03	13,9
54585	2,43E-03	2,35E-03	3,4	54603	2,93E-03	2,52E-03	14,1
54587	2,49E-03	2,40E-03	3,6	54605	3,20E-03	2,76E-03	13,7
54589	2,54E-03	2,43E-03	4,4	54607	3,25E-03	2,82E-03	13,4
SUM:	**1,48E-01**	**1,45E-01**	**2,3**	**SUM:**	**1,85E-01**	**1,61E-01**	**13,0**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 4 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 7	**Pos 1**	**Pos 2**		**SG 8**	**Pos 1**	**Pos 2**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9875	2,06E-03	1,80E-03	13,0	10219	2,54E-03	2,50E-03	1,6
9876	1,98E-03	1,76E-03	11,2	10220	2,49E-03	2,45E-03	1,5
9877	2,01E-03	1,77E-03	12,2	10221	2,43E-03	2,39E-03	1,4
9878	2,07E-03	1,80E-03	12,9	10222	2,35E-03	2,32E-03	1,3
9879	2,18E-03	1,90E-03	13,1	10223	2,45E-03	2,39E-03	2,5
9880	1,98E-03	1,73E-03	12,4	10224	2,55E-03	2,49E-03	2,2
9881	1,95E-03	1,73E-03	11,5	10225	2,67E-03	2,62E-03	1,7
9882	2,16E-03	1,88E-03	12,9	10226	2,76E-03	2,72E-03	1,5
9883	2,05E-03	1,89E-03	7,7	10595	2,25E-03	2,21E-03	1,5
9884	2,09E-03	1,91E-03	8,4	10596	2,22E-03	2,16E-03	2,8
9885	2,04E-03	1,83E-03	10,1	10597	2,86E-03	2,82E-03	1,2
9886	2,03E-03	1,81E-03	11,0	10598	2,86E-03	2,81E-03	1,6
9887	2,09E-03	1,85E-03	11,4	10631	2,36E-03	2,29E-03	2,9
9888	2,16E-03	1,91E-03	11,6	10632	2,27E-03	2,20E-03	3,2
9889	2,26E-03	2,00E-03	11,4	10633	2,57E-03	2,52E-03	1,6
9890	2,19E-03	1,95E-03	11,1	10634	2,75E-03	2,70E-03	1,7
9891	2,19E-03	1,97E-03	10,3	10649	2,44E-03	2,39E-03	2,0
9892	2,19E-03	1,99E-03	9,0	10650	2,65E-03	2,60E-03	1,9
9893	2,25E-03	2,08E-03	7,6	10651	2,50E-03	2,45E-03	2,2
9894	2,21E-03	2,07E-03	6,3	10652	2,55E-03	2,50E-03	1,9
9895	2,24E-03	1,95E-03	13,2	10653	2,73E-03	2,68E-03	1,9
9896	2,14E-03	1,85E-03	13,5	10654	2,62E-03	2,56E-03	2,0
9897	1,93E-03	1,73E-03	10,3	10655	2,34E-03	2,28E-03	2,2
9898	1,98E-03	1,79E-03	9,7	10656	2,39E-03	2,33E-03	2,5
51620	2,07E-03	1,80E-03	12,9	52817	2,51E-03	2,47E-03	1,6
51621	2,02E-03	1,77E-03	12,7	52819	2,55E-03	2,51E-03	1,6
51622	2,11E-03	1,84E-03	12,9	52820	2,59E-03	2,55E-03	1,8
51623	2,05E-03	1,80E-03	12,0	52822	2,46E-03	2,42E-03	1,5
51625	1,99E-03	1,76E-03	11,7	52824	2,52E-03	2,48E-03	1,7
51626	1,96E-03	1,74E-03	11,4	52826	2,39E-03	2,36E-03	1,4
51627	2,11E-03	1,92E-03	9,3	52828	2,43E-03	2,39E-03	1,7
51628	1,98E-03	1,77E-03	10,5	52831	2,30E-03	2,27E-03	1,4
51630	2,04E-03	1,78E-03	12,6	52832	2,34E-03	2,30E-03	1,7
51631	2,00E-03	1,75E-03	12,3	52834	2,50E-03	2,44E-03	2,4
51632	2,10E-03	1,88E-03	10,6	52836	2,40E-03	2,34E-03	2,7
51634	2,13E-03	1,85E-03	13,0	52837	2,42E-03	2,36E-03	2,5
51635	2,13E-03	1,89E-03	11,6	52839	2,61E-03	2,55E-03	2,0
51637	2,17E-03	1,89E-03	13,0	52841	2,52E-03	2,47E-03	2,2
51638	2,19E-03	1,92E-03	12,1	52843	2,71E-03	2,67E-03	1,6
51639	2,21E-03	1,92E-03	13,1	52845	2,64E-03	2,59E-03	1,9
51641	1,97E-03	1,73E-03	12,0	52848	2,81E-03	2,77E-03	1,3
51642	2,01E-03	1,78E-03	11,3	52849	2,75E-03	2,70E-03	1,7
51644	2,02E-03	1,82E-03	9,9	54011	2,23E-03	2,19E-03	2,2
51645	1,94E-03	1,73E-03	10,9	54013	2,24E-03	2,18E-03	3,0
51647	2,12E-03	1,86E-03	12,2	54014	2,28E-03	2,22E-03	2,5
51648	2,15E-03	1,87E-03	13,2	54016	2,86E-03	2,82E-03	1,4
51650	2,07E-03	1,90E-03	8,0	54018	2,80E-03	2,76E-03	1,6
51651	1,99E-03	1,81E-03	8,9	54019	2,79E-03	2,75E-03	1,7
51655	2,06E-03	1,87E-03	9,3	54092	2,31E-03	2,24E-03	3,1
51658	2,04E-03	1,82E-03	10,6	54094	2,33E-03	2,26E-03	2,9
51661	2,06E-03	1,83E-03	11,3	54096	2,66E-03	2,61E-03	1,7
51664	2,12E-03	1,88E-03	11,5	54098	2,70E-03	2,65E-03	1,8
51667	2,15E-03	1,88E-03	12,5	54136	2,47E-03	2,42E-03	2,1
51671	2,23E-03	1,98E-03	11,2	54137	2,50E-03	2,45E-03	2,0
51672	2,25E-03	1,97E-03	12,3	54138	2,39E-03	2,34E-03	2,1
51676	2,19E-03	1,96E-03	10,7	54140	2,60E-03	2,55E-03	1,9
51679	2,19E-03	1,98E-03	9,7	54141	2,69E-03	2,64E-03	1,9
51682	2,22E-03	2,04E-03	8,3	54143	2,56E-03	2,51E-03	2,1
51685	2,23E-03	2,08E-03	6,9	54144	2,45E-03	2,39E-03	2,4
51688	2,10E-03	1,93E-03	7,9	54146	2,58E-03	2,53E-03	2,0
51693	2,19E-03	1,90E-03	13,4	54148	2,67E-03	2,62E-03	1,9
51698	1,95E-03	1,76E-03	10,0	54151	2,36E-03	2,31E-03	2,3
SUM:	**1,30E-01**	**1,16E-01**	**11,1**	**SUM:**	**1,56E-01**	**1,53E-01**	**2,0**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 5 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 9	Pos 1	Pos 2		SG 10	Pos 1	Pos 2	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
10199	3,09E-03	3,11E-03	0,6	10183	-9,43E-05	3,41E-04	127,7
10200	3,01E-03	3,06E-03	1,4	10184	8,33E-05	5,25E-04	84,1
10201	2,87E-03	2,95E-03	2,7	10185	2,81E-04	7,30E-04	61,4
10202	2,63E-03	2,76E-03	4,9	10186	5,85E-04	1,01E-03	42,3
10231	1,84E-03	1,87E-03	1,8	10227	1,24E-03	1,60E-03	22,5
10232	2,19E-03	2,21E-03	0,8	10228	7,09E-04	1,09E-03	34,9
10233	2,48E-03	2,46E-03	0,6	10229	2,25E-04	6,11E-04	63,2
10234	2,53E-03	2,51E-03	1,0	10230	-1,42E-04	2,34E-04	161,0
10583	2,30E-03	2,48E-03	6,9	10599	-1,99E-04	1,59E-04	225,5
10584	2,05E-03	2,20E-03	7,1	10600	-1,78E-04	3,01E-04	159,1
10603	2,62E-03	2,58E-03	1,4	10601	8,67E-04	1,26E-03	31,2
10604	2,94E-03	2,91E-03	0,9	10602	1,12E-03	1,55E-03	27,8
10619	1,45E-03	1,55E-03	6,2	10635	-1,23E-04	2,88E-04	142,7
10620	1,73E-03	1,87E-03	7,9	10636	-1,53E-04	3,50E-04	143,9
10639	3,14E-03	3,14E-03	0,0	10637	1,61E-03	1,93E-03	16,6
10640	3,12E-03	3,11E-03	0,5	10638	1,37E-03	1,77E-03	22,4
10657	2,87E-03	2,86E-03	0,4	10665	3,81E-04	8,88E-04	57,1
10658	2,94E-03	2,97E-03	1,0	10666	7,64E-05	5,98E-04	87,2
10659	2,72E-03	2,78E-03	2,2	10667	-1,03E-04	4,25E-04	124,3
10660	2,73E-03	2,74E-03	0,5	10668	4,66E-04	9,37E-04	50,3
10661	2,50E-03	2,54E-03	1,6	10669	9,24E-04	1,36E-03	32,2
10662	2,18E-03	2,27E-03	3,6	10670	-9,57E-05	4,04E-04	123,7
10663	2,41E-03	2,53E-03	4,5	10671	1,41E-04	6,42E-04	78,0
10664	3,07E-03	3,07E-03	0,2	10672	7,38E-04	1,22E-03	39,7
52731	3,05E-03	3,08E-03	1,0	52663	-5,74E-06	4,33E-04	101,3
52733	3,12E-03	3,13E-03	0,3	52665	-1,09E-04	3,14E-04	134,8
52734	3,08E-03	3,09E-03	0,4	52666	-9,89E-05	3,83E-04	125,8
52736	2,94E-03	3,00E-03	2,0	52668	1,82E-04	6,27E-04	71,0
52738	2,98E-03	3,01E-03	1,2	52670	7,98E-05	5,61E-04	85,8
52740	2,75E-03	2,86E-03	3,8	52672	4,32E-04	8,71E-04	50,4
52742	2,80E-03	2,87E-03	2,5	52674	3,31E-04	8,09E-04	59,1
52745	2,46E-03	2,62E-03	5,9	52677	7,26E-04	1,14E-03	36,2
52746	2,52E-03	2,64E-03	4,7	52678	6,61E-04	1,12E-03	40,9
52868	2,02E-03	2,04E-03	1,3	52851	9,73E-04	1,34E-03	27,5
52870	1,65E-03	1,71E-03	3,8	52853	1,42E-03	1,76E-03	19,3
52871	2,01E-03	2,07E-03	2,8	52854	1,08E-03	1,48E-03	27,0
52873	2,33E-03	2,34E-03	0,0	52856	4,67E-04	8,50E-04	45,1
52875	2,34E-03	2,37E-03	1,3	52858	5,87E-04	1,01E-03	42,0
52877	2,50E-03	2,48E-03	0,8	52860	4,04E-05	4,22E-04	90,4
52879	2,60E-03	2,60E-03	0,0	52862	1,83E-04	6,27E-04	70,8
52882	2,57E-03	2,54E-03	1,2	52865	-1,71E-04	1,97E-04	187,0
52883	2,70E-03	2,68E-03	0,7	52866	-1,19E-04	3,19E-04	137,3
53979	2,17E-03	2,34E-03	7,0	54021	-1,89E-04	2,30E-04	182,0
53981	1,89E-03	2,04E-03	7,4	54023	-1,66E-04	3,25E-04	150,9
53982	2,23E-03	2,36E-03	5,7	54024	-1,37E-04	3,53E-04	138,8
54031	2,78E-03	2,75E-03	1,1	54026	9,93E-04	1,41E-03	29,3
54033	3,03E-03	3,01E-03	0,7	54028	1,25E-03	1,66E-03	24,9
54034	2,91E-03	2,89E-03	0,7	54029	9,29E-04	1,39E-03	33,0
54064	1,59E-03	1,71E-03	7,1	54100	-1,38E-04	3,19E-04	143,3
54066	1,96E-03	2,07E-03	5,6	54102	-1,29E-04	3,87E-04	133,2
54108	3,13E-03	3,12E-03	0,2	54104	1,49E-03	1,85E-03	19,4
54110	3,09E-03	3,09E-03	0,2	54106	1,15E-03	1,57E-03	26,6
54154	2,80E-03	2,80E-03	0,0	54172	2,28E-04	7,42E-04	69,3
54155	2,97E-03	2,97E-03	0,1	54173	4,23E-04	9,13E-04	53,6
54157	2,83E-03	2,88E-03	1,6	54174	5,59E-04	1,06E-03	47,0
54158	2,83E-03	2,86E-03	0,8	54176	-1,29E-05	5,12E-04	102,5
54159	3,00E-03	3,02E-03	0,6	54177	1,09E-04	6,20E-04	82,5
54161	2,61E-03	2,66E-03	1,9	54179	-9,95E-05	4,15E-04	124,0
54162	2,57E-03	2,66E-03	3,3	54181	6,95E-04	1,15E-03	39,6
54164	2,61E-03	2,64E-03	1,1	54182	3,04E-04	7,90E-04	61,6
54166	2,34E-03	2,40E-03	2,6	54184	8,31E-04	1,29E-03	35,7
54168	2,30E-03	2,40E-03	4,1	54186	2,29E-05	5,24E-04	95,6
SUM:	**1,59E-01**	**1,62E-01**	**1,8**	**SUM:**	**2,45E-02**	**5,20E-02**	**52,9**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 6 of 16
Node numbers and associated strains [mm/mm] exported from ansys

SG 11	Pos 1	Pos 2		SG 12	Pos 1	Pos 2	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9851	2,06E-03	2,12E-03	2,8	9827	1,16E-03	1,08E-03	6,5
9852	2,18E-03	2,28E-03	4,6	9828	1,19E-03	1,10E-03	6,9
9853	2,18E-03	2,24E-03	2,4	9829	1,26E-03	1,18E-03	6,4
9854	2,11E-03	2,19E-03	3,4	9830	1,15E-03	1,07E-03	6,8
9855	2,17E-03	2,28E-03	4,9	9831	1,13E-03	1,06E-03	6,3
9856	2,29E-03	2,38E-03	3,5	9832	1,20E-03	1,11E-03	7,1
9857	2,11E-03	2,15E-03	1,9	9833	1,17E-03	1,08E-03	7,1
9858	2,28E-03	2,37E-03	4,1	9834	1,26E-03	1,18E-03	6,4
9859	2,02E-03	2,05E-03	1,2	9835	1,43E-03	1,39E-03	3,0
9860	2,16E-03	2,20E-03	2,0	9836	1,41E-03	1,36E-03	3,6
9861	2,23E-03	2,29E-03	2,5	9837	1,40E-03	1,34E-03	4,3
9862	2,34E-03	2,43E-03	3,6	9838	1,40E-03	1,33E-03	4,8
9863	2,23E-03	2,33E-03	4,2	9839	1,42E-03	1,35E-03	4,8
9864	2,46E-03	2,61E-03	5,6	9840	1,46E-03	1,40E-03	4,2
9865	1,85E-03	2,01E-03	7,9	9841	1,53E-03	1,49E-03	2,4
9866	1,86E-03	1,99E-03	6,6	9842	1,46E-03	1,40E-03	3,9
9867	1,95E-03	2,07E-03	5,9	9843	1,43E-03	1,37E-03	4,6
9868	1,97E-03	2,07E-03	4,9	9844	1,53E-03	1,46E-03	4,2
9869	1,96E-03	2,05E-03	4,4	9845	1,60E-03	1,54E-03	4,0
9870	1,94E-03	2,02E-03	4,1	9846	1,51E-03	1,45E-03	4,0
9871	2,16E-03	2,30E-03	6,1	9847	1,38E-03	1,31E-03	4,7
9872	2,30E-03	2,42E-03	5,2	9848	1,37E-03	1,30E-03	5,1
9873	2,01E-03	2,04E-03	1,3	9849	1,16E-03	1,09E-03	5,5
9874	2,00E-03	2,04E-03	2,3	9850	1,19E-03	1,12E-03	5,4
51538	2,09E-03	2,16E-03	3,1	51455	1,14E-03	1,07E-03	6,4
51539	2,08E-03	2,14E-03	2,4	51456	1,16E-03	1,08E-03	6,8
51540	2,01E-03	2,09E-03	3,6	51457	1,38E-03	1,31E-03	5,0
51541	2,03E-03	2,08E-03	2,5	51458	1,17E-03	1,10E-03	5,9
51543	2,15E-03	2,24E-03	4,0	51460	1,17E-03	1,09E-03	6,9
51544	2,17E-03	2,28E-03	4,7	51461	1,19E-03	1,11E-03	7,0
51545	2,24E-03	2,33E-03	4,0	51462	1,22E-03	1,14E-03	6,7
51546	2,06E-03	2,18E-03	5,2	51463	1,29E-03	1,22E-03	5,8
51548	2,15E-03	2,21E-03	2,9	51465	1,23E-03	1,15E-03	6,7
51549	2,24E-03	2,31E-03	3,0	51466	1,26E-03	1,18E-03	6,4
51550	2,14E-03	2,19E-03	2,2	51467	1,36E-03	1,29E-03	5,1
51551	2,21E-03	2,26E-03	2,5	51468	1,32E-03	1,25E-03	5,5
51553	2,04E-03	2,13E-03	4,2	51470	1,14E-03	1,07E-03	6,6
51555	2,22E-03	2,33E-03	4,5	51471	1,16E-03	1,08E-03	6,9
51556	2,01E-03	2,14E-03	5,7	51472	1,27E-03	1,21E-03	5,4
51557	2,17E-03	2,29E-03	5,5	51474	1,27E-03	1,21E-03	4,8
51559	2,29E-03	2,38E-03	3,8	51475	1,14E-03	1,08E-03	5,9
51560	2,32E-03	2,40E-03	3,6	51477	1,18E-03	1,10E-03	7,1
51562	2,13E-03	2,18E-03	2,0	51478	1,32E-03	1,24E-03	5,7
51563	2,06E-03	2,09E-03	1,6	51480	1,35E-03	1,27E-03	5,5
51565	2,25E-03	2,35E-03	4,1	51482	1,34E-03	1,26E-03	5,6
51566	2,29E-03	2,40E-03	4,6	51483	1,31E-03	1,24E-03	5,7
51568	2,09E-03	2,12E-03	1,6	51485	1,42E-03	1,37E-03	3,3
51569	2,02E-03	2,04E-03	1,2	51486	1,29E-03	1,24E-03	4,1
51573	2,19E-03	2,24E-03	2,3	51491	1,40E-03	1,35E-03	4,0
51576	2,29E-03	2,36E-03	3,1	51494	1,40E-03	1,34E-03	4,6
51579	2,29E-03	2,38E-03	3,9	51497	1,41E-03	1,34E-03	4,8
51582	2,34E-03	2,46E-03	4,9	51500	1,44E-03	1,38E-03	4,5
51585	2,38E-03	2,51E-03	5,4	51503	1,41E-03	1,35E-03	4,6
51589	1,85E-03	2,00E-03	7,3	51507	1,49E-03	1,45E-03	3,1
51590	2,01E-03	2,16E-03	6,9	51508	1,45E-03	1,40E-03	3,4
51594	1,90E-03	2,03E-03	6,2	51512	1,45E-03	1,38E-03	4,3
51597	1,96E-03	2,07E-03	5,4	51515	1,48E-03	1,41E-03	4,4
51600	1,97E-03	2,06E-03	4,7	51518	1,57E-03	1,50E-03	4,1
51603	1,95E-03	2,04E-03	4,3	51521	1,55E-03	1,49E-03	4,0
51606	1,97E-03	2,03E-03	3,2	51524	1,35E-03	1,29E-03	4,6
51610	2,23E-03	2,36E-03	5,6	51528	1,37E-03	1,30E-03	4,8
51615	2,00E-03	2,04E-03	1,8	51533	1,17E-03	1,11E-03	5,4
SUM:	**1,32E-01**	**1,37E-01**	**3,9**	**SUM:**	**8,22E-02**	**7,80E-02**	**5,1**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 7 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 13	**Pos 1**	**Pos 2**		**SG 14**	**Pos 1**	**Pos 2**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9803	2,04E-03	1,98E-03	2,9	9779	4,68E-03	4,39E-03	6,3
9804	2,17E-03	2,08E-03	4,4	9780	4,55E-03	4,31E-03	5,2
9805	2,27E-03	2,17E-03	4,5	9781	4,74E-03	4,42E-03	6,8
9806	2,53E-03	2,37E-03	6,3	9782	4,68E-03	4,42E-03	5,7
9807	1,81E-03	1,78E-03	1,7	9783	4,57E-03	4,25E-03	7,0
9808	1,99E-03	1,95E-03	2,4	9784	4,79E-03	4,50E-03	6,0
9809	1,76E-03	1,74E-03	0,8	9785	4,71E-03	4,45E-03	5,5
9810	2,43E-03	2,27E-03	6,6	9786	4,60E-03	4,24E-03	7,7
9811	2,70E-03	2,51E-03	7,1	9787	3,98E-03	3,83E-03	3,7
9812	2,52E-03	2,38E-03	5,7	9788	4,27E-03	4,11E-03	3,9
9813	2,40E-03	2,32E-03	3,4	9789	4,43E-03	4,25E-03	4,2
9814	2,30E-03	2,25E-03	2,3	9790	4,46E-03	4,24E-03	4,8
9815	1,95E-03	1,93E-03	1,2	9791	4,35E-03	4,11E-03	5,5
9816	1,91E-03	1,89E-03	0,9	9792	4,14E-03	3,88E-03	6,4
9817	1,61E-03	1,63E-03	1,0	9793	4,13E-03	3,79E-03	8,3
9818	1,80E-03	1,82E-03	0,6	9794	4,44E-03	4,12E-03	7,2
9819	1,96E-03	1,95E-03	0,3	9795	4,56E-03	4,26E-03	6,5
9820	2,24E-03	2,19E-03	2,5	9796	4,67E-03	4,41E-03	5,7
9821	2,37E-03	2,24E-03	5,3	9797	4,70E-03	4,47E-03	4,9
9822	2,63E-03	2,43E-03	7,6	9798	4,62E-03	4,42E-03	4,2
9823	1,66E-03	1,65E-03	0,5	9799	4,32E-03	4,12E-03	4,7
9824	1,68E-03	1,66E-03	1,4	9800	4,52E-03	4,30E-03	4,9
9825	2,75E-03	2,54E-03	7,8	9801	4,30E-03	3,92E-03	8,7
9826	2,86E-03	2,63E-03	7,8	9802	4,37E-03	4,03E-03	7,8
51373	2,16E-03	2,08E-03	3,7	51291	4,71E-03	4,40E-03	6,6
51374	1,92E-03	1,88E-03	2,3	51292	4,68E-03	4,40E-03	6,0
51375	2,02E-03	1,97E-03	2,7	51293	4,62E-03	4,32E-03	6,7
51376	2,17E-03	2,12E-03	2,6	51294	4,57E-03	4,31E-03	5,6
51378	2,22E-03	2,12E-03	4,5	51296	4,62E-03	4,36E-03	5,4
51379	2,08E-03	2,01E-03	3,5	51297	4,63E-03	4,38E-03	5,3
51380	2,30E-03	2,17E-03	5,6	51298	4,41E-03	4,21E-03	4,6
51381	2,21E-03	2,13E-03	3,4	51299	4,44E-03	4,22E-03	5,0
51383	2,40E-03	2,27E-03	5,4	51301	4,77E-03	4,46E-03	6,4
51384	2,34E-03	2,25E-03	3,9	51302	4,67E-03	4,33E-03	7,3
51386	2,48E-03	2,32E-03	6,4	51303	4,65E-03	4,34E-03	6,7
51387	2,52E-03	2,37E-03	6,0	51305	4,74E-03	4,46E-03	5,8
51388	2,64E-03	2,46E-03	7,1	51306	4,56E-03	4,33E-03	4,9
51390	1,78E-03	1,76E-03	1,3	51308	4,58E-03	4,24E-03	7,4
51391	1,88E-03	1,85E-03	1,5	51309	4,46E-03	4,18E-03	6,3
51392	1,75E-03	1,72E-03	1,6	51310	4,47E-03	4,14E-03	7,4
51394	1,87E-03	1,84E-03	1,7	51312	4,75E-03	4,48E-03	5,8
51395	1,98E-03	1,95E-03	1,4	51313	4,73E-03	4,46E-03	5,8
51397	1,78E-03	1,78E-03	0,1	51315	4,71E-03	4,46E-03	5,2
51398	1,71E-03	1,70E-03	0,7	51316	4,61E-03	4,37E-03	5,2
51400	2,40E-03	2,26E-03	5,9	51318	4,52E-03	4,18E-03	7,4
51401	2,64E-03	2,45E-03	7,2	51319	4,45E-03	4,08E-03	8,2
51403	2,61E-03	2,44E-03	6,4	51321	4,13E-03	3,97E-03	3,8
51404	2,73E-03	2,52E-03	7,4	51322	4,15E-03	3,97E-03	4,2
51408	2,46E-03	2,35E-03	4,5	51326	4,35E-03	4,18E-03	4,1
51411	2,35E-03	2,28E-03	2,9	51329	4,45E-03	4,25E-03	4,5
51414	2,12E-03	2,09E-03	1,8	51332	4,40E-03	4,18E-03	5,1
51417	1,93E-03	1,91E-03	1,1	51335	4,24E-03	3,99E-03	5,9
51420	1,80E-03	1,78E-03	1,1	51338	4,25E-03	3,95E-03	7,1
51424	1,71E-03	1,72E-03	0,8	51342	4,28E-03	3,95E-03	7,7
51425	1,64E-03	1,64E-03	0,3	51343	4,22E-03	3,86E-03	8,5
51429	1,88E-03	1,88E-03	0,1	51347	4,50E-03	4,19E-03	6,8
51432	2,10E-03	2,07E-03	1,5	51350	4,62E-03	4,34E-03	6,1
51435	2,30E-03	2,21E-03	3,9	51353	4,69E-03	4,44E-03	5,3
51438	2,50E-03	2,34E-03	6,5	51356	4,66E-03	4,45E-03	4,6
51441	2,74E-03	2,53E-03	7,7	51359	4,57E-03	4,36E-03	4,6
51445	1,67E-03	1,65E-03	0,9	51363	4,42E-03	4,21E-03	4,8
51450	2,80E-03	2,59E-03	7,8	51368	4,33E-03	3,98E-03	8,3
SUM:	**1,35E-01**	**1,30E-01**	**3,8**	**SUM:**	**2,79E-01**	**2,63E-01**	**5,9**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 8 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 15	**Pos 1**	**Pos 2**		**SG 16**	**Pos 1**	**Pos 2**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9755	3,47E-03	3,41E-03	1,5	9731	2,73E-03	3,15E-03	13,3
9756	3,56E-03	3,52E-03	1,1	9732	3,18E-03	3,57E-03	11,0
9757	4,09E-03	4,12E-03	0,7	9733	3,32E-03	3,72E-03	10,7
9758	3,77E-03	3,77E-03	0,1	9734	2,87E-03	3,24E-03	11,5
9759	3,76E-03	3,76E-03	0,2	9735	2,63E-03	3,01E-03	12,6
9760	3,31E-03	3,21E-03	2,9	9736	3,00E-03	3,38E-03	11,3
9761	3,10E-03	2,98E-03	3,9	9737	2,94E-03	3,35E-03	12,2
9762	3,18E-03	3,10E-03	2,7	9738	3,29E-03	3,65E-03	9,9
9763	4,46E-03	4,60E-03	3,0	9739	2,39E-03	2,71E-03	11,7
9764	4,46E-03	4,57E-03	2,5	9740	2,50E-03	2,79E-03	10,5
9765	4,15E-03	4,22E-03	1,6	9741	2,65E-03	2,94E-03	9,7
9766	3,76E-03	3,74E-03	0,6	9742	2,91E-03	3,19E-03	8,8
9767	3,14E-03	3,09E-03	1,4	9743	3,09E-03	3,37E-03	8,3
9768	2,93E-03	2,86E-03	2,4	9744	3,30E-03	3,59E-03	7,9
9769	2,73E-03	2,59E-03	5,2	9745	3,45E-03	3,79E-03	8,9
9770	2,83E-03	2,71E-03	4,3	9746	3,15E-03	3,51E-03	10,4
9771	2,99E-03	2,89E-03	3,4	9747	3,03E-03	3,41E-03	11,3
9772	3,19E-03	3,11E-03	2,4	9748	2,83E-03	3,23E-03	12,3
9773	3,37E-03	3,34E-03	0,7	9749	2,69E-03	3,10E-03	13,1
9774	3,58E-03	3,62E-03	1,1	9750	2,56E-03	2,98E-03	14,0
9775	2,98E-03	2,84E-03	4,9	9751	3,60E-03	3,97E-03	9,1
9776	3,05E-03	2,93E-03	3,8	9752	3,60E-03	3,93E-03	8,4
9777	4,24E-03	4,33E-03	2,1	9753	2,44E-03	2,85E-03	14,2
9778	4,02E-03	4,08E-03	1,3	9754	2,58E-03	3,01E-03	14,2
51209	3,61E-03	3,59E-03	0,8	51125	2,68E-03	3,08E-03	13,0
51210	3,39E-03	3,31E-03	2,2	51126	2,83E-03	3,25E-03	12,8
51211	3,33E-03	3,26E-03	2,1	51127	2,71E-03	3,12E-03	13,2
51212	3,61E-03	3,58E-03	1,0	51128	2,66E-03	3,08E-03	13,8
51214	3,66E-03	3,65E-03	0,5	51130	3,25E-03	3,64E-03	10,9
51215	3,66E-03	3,64E-03	0,6	51131	3,09E-03	3,48E-03	11,1
51216	3,43E-03	3,36E-03	2,0	51132	3,06E-03	3,46E-03	11,6
51217	3,37E-03	3,32E-03	1,7	51133	3,10E-03	3,49E-03	11,1
51219	3,93E-03	3,95E-03	0,4	51135	3,30E-03	3,68E-03	10,3
51220	3,93E-03	3,94E-03	0,3	51136	3,24E-03	3,62E-03	10,5
51221	4,27E-03	4,34E-03	1,6	51137	3,46E-03	3,84E-03	9,9
51222	4,17E-03	4,23E-03	1,4	51139	2,75E-03	3,13E-03	12,0
51224	3,57E-03	3,56E-03	0,3	51140	2,93E-03	3,31E-03	11,4
51225	3,90E-03	3,92E-03	0,7	51141	2,90E-03	3,29E-03	11,9
51227	3,96E-03	3,99E-03	0,7	51142	2,76E-03	3,09E-03	10,7
51229	3,20E-03	3,09E-03	3,4	51144	2,57E-03	2,90E-03	11,6
51230	3,15E-03	3,05E-03	3,2	51145	2,54E-03	2,93E-03	13,4
51232	3,14E-03	3,04E-03	3,3	51147	3,14E-03	3,51E-03	10,6
51233	2,97E-03	2,84E-03	4,1	51148	2,95E-03	3,29E-03	10,1
51234	3,04E-03	2,91E-03	4,4	51150	2,89E-03	3,29E-03	12,3
51236	3,16E-03	3,09E-03	2,1	51152	3,19E-03	3,51E-03	9,1
51237	3,12E-03	3,01E-03	3,2	51153	3,44E-03	3,79E-03	9,1
51239	4,46E-03	4,58E-03	2,7	51155	2,45E-03	2,75E-03	11,1
51240	4,35E-03	4,46E-03	2,5	51156	2,42E-03	2,78E-03	13,0
51244	4,30E-03	4,39E-03	2,0	51161	2,57E-03	2,86E-03	10,1
51247	3,95E-03	3,98E-03	0,6	51164	2,78E-03	3,06E-03	9,3
51250	3,45E-03	3,41E-03	0,9	51167	3,00E-03	3,28E-03	8,5
51253	3,04E-03	2,98E-03	1,9	51170	3,20E-03	3,48E-03	8,1
51256	2,99E-03	2,90E-03	3,1	51173	3,45E-03	3,76E-03	8,1
51260	2,78E-03	2,65E-03	4,8	51177	3,30E-03	3,65E-03	9,6
51261	2,86E-03	2,71E-03	5,0	51178	3,53E-03	3,88E-03	9,0
51265	2,91E-03	2,80E-03	3,8	51182	3,09E-03	3,47E-03	10,8
51268	3,09E-03	3,00E-03	2,9	51185	2,93E-03	3,32E-03	11,8
51271	3,28E-03	3,23E-03	1,5	51188	2,76E-03	3,16E-03	12,7
51274	3,47E-03	3,48E-03	0,2	51191	2,62E-03	3,04E-03	13,6
51277	3,80E-03	3,85E-03	1,2	51194	2,57E-03	2,99E-03	14,1
51281	3,02E-03	2,89E-03	4,3	51198	3,60E-03	3,95E-03	8,8
51286	4,13E-03	4,20E-03	1,7	51204	2,51E-03	2,93E-03	14,2
SUM:	**2,18E-01**	**2,16E-01**	**0,9**	**SUM:**	**1,83E-01**	**2,06E-01**	**11,0**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 9 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 17	Pos 1	Pos 2		SG 18	Pos 1	Pos 2	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9707	1,51E-03	2,06E-03	26,7	9683	2,14E-03	2,02E-03	5,8
9708	1,32E-03	1,81E-03	27,1	9684	2,36E-03	2,19E-03	7,1
9709	1,41E-03	1,96E-03	27,8	9685	1,96E-03	1,82E-03	6,9
9710	1,35E-03	1,88E-03	28,1	9686	2,23E-03	2,07E-03	7,5
9711	1,34E-03	1,83E-03	27,2	9687	2,10E-03	1,95E-03	7,5
9712	1,35E-03	1,89E-03	28,6	9688	1,97E-03	1,87E-03	4,9
9713	1,38E-03	1,93E-03	28,6	9689	2,27E-03	2,13E-03	6,1
9714	1,49E-03	2,05E-03	27,2	9690	2,39E-03	2,25E-03	5,9
9715	1,79E-03	2,26E-03	20,8	9691	2,46E-03	2,38E-03	3,5
9716	1,67E-03	2,11E-03	20,9	9692	2,43E-03	2,35E-03	3,4
9717	1,67E-03	2,11E-03	20,8	9693	2,36E-03	2,28E-03	3,3
9718	1,65E-03	2,08E-03	20,6	9694	2,27E-03	2,19E-03	3,7
9719	1,60E-03	2,00E-03	19,8	9695	2,05E-03	1,97E-03	3,8
9720	1,62E-03	1,96E-03	17,2	9696	1,87E-03	1,86E-03	0,8
9721	1,62E-03	1,96E-03	17,2	9697	1,84E-03	1,73E-03	6,0
9722	1,60E-03	1,99E-03	19,2	9698	1,99E-03	1,84E-03	7,8
9723	1,60E-03	2,01E-03	20,6	9699	2,10E-03	1,93E-03	8,0
9724	1,59E-03	2,02E-03	21,2	9700	2,22E-03	2,05E-03	7,8
9725	1,59E-03	2,04E-03	22,1	9701	2,34E-03	2,17E-03	7,2
9726	1,61E-03	2,03E-03	20,7	9702	2,45E-03	2,29E-03	6,6
9727	1,60E-03	2,15E-03	25,6	9703	1,79E-03	1,72E-03	3,8
9728	1,61E-03	2,13E-03	24,7	9704	1,83E-03	1,79E-03	2,4
9729	1,33E-03	1,76E-03	24,5	9705	2,51E-03	2,36E-03	5,8
9730	1,35E-03	1,78E-03	24,4	9706	2,50E-03	2,33E-03	6,7
51043	1,46E-03	2,01E-03	27,2	50961	2,12E-03	1,98E-03	6,7
51044	1,50E-03	2,05E-03	27,0	50962	2,05E-03	1,94E-03	5,4
51045	1,55E-03	2,05E-03	24,4	50963	2,20E-03	2,07E-03	5,9
51046	1,56E-03	2,09E-03	25,7	50964	2,21E-03	2,10E-03	4,7
51048	1,34E-03	1,85E-03	27,6	50966	2,30E-03	2,13E-03	7,3
51049	1,33E-03	1,82E-03	27,1	50967	2,37E-03	2,22E-03	6,5
51050	1,46E-03	1,90E-03	22,9	50968	2,35E-03	2,18E-03	7,1
51051	1,32E-03	1,79E-03	25,8	50969	2,43E-03	2,26E-03	6,9
51053	1,38E-03	1,92E-03	28,0	50971	2,03E-03	1,88E-03	7,2
51054	1,39E-03	1,94E-03	28,2	50972	1,96E-03	1,85E-03	5,9
51055	1,50E-03	1,99E-03	24,4	50973	1,97E-03	1,83E-03	7,3
51057	1,35E-03	1,89E-03	28,4	50974	1,87E-03	1,77E-03	5,4
51058	1,47E-03	1,94E-03	24,2	50976	2,17E-03	2,01E-03	7,5
51060	1,34E-03	1,86E-03	27,9	50977	2,25E-03	2,10E-03	6,8
51061	1,47E-03	1,92E-03	23,3	50978	2,23E-03	2,06E-03	7,7
51062	1,34E-03	1,81E-03	25,8	50980	2,10E-03	1,94E-03	7,8
51064	1,36E-03	1,91E-03	28,7	50982	2,01E-03	1,92E-03	4,3
51065	1,50E-03	1,98E-03	24,4	50983	1,90E-03	1,83E-03	3,6
51067	1,44E-03	1,99E-03	27,9	50985	2,33E-03	2,19E-03	6,0
51068	1,52E-03	2,02E-03	24,5	50986	2,31E-03	2,20E-03	4,7
51070	1,58E-03	2,08E-03	24,0	50988	2,41E-03	2,30E-03	4,6
51071	1,55E-03	2,10E-03	26,4	50989	2,45E-03	2,31E-03	5,9
51073	1,73E-03	2,19E-03	20,9	50991	2,45E-03	2,36E-03	3,5
51074	1,69E-03	2,20E-03	23,2	50992	2,49E-03	2,37E-03	4,7
51078	1,67E-03	2,11E-03	20,8	50996	2,39E-03	2,31E-03	3,4
51081	1,66E-03	2,09E-03	20,7	50999	2,32E-03	2,23E-03	3,5
51084	1,62E-03	2,04E-03	20,2	51002	2,16E-03	2,08E-03	3,7
51087	1,61E-03	1,98E-03	18,5	51005	1,96E-03	1,92E-03	2,4
51090	1,49E-03	1,87E-03	20,6	51008	1,85E-03	1,82E-03	1,6
51094	1,61E-03	1,97E-03	18,2	51012	1,92E-03	1,78E-03	6,9
51095	1,47E-03	1,86E-03	20,6	51013	1,82E-03	1,73E-03	4,9
51099	1,60E-03	2,00E-03	19,9	51017	2,05E-03	1,88E-03	7,9
51102	1,59E-03	2,01E-03	20,9	51020	2,16E-03	1,99E-03	7,9
51105	1,59E-03	2,03E-03	21,7	51023	2,28E-03	2,11E-03	7,5
51108	1,60E-03	2,03E-03	21,4	51026	2,39E-03	2,23E-03	6,9
51111	1,61E-03	2,08E-03	22,7	51029	2,48E-03	2,31E-03	6,6
51115	1,60E-03	2,14E-03	25,1	51033	1,81E-03	1,76E-03	3,1
51120	1,34E-03	1,77E-03	24,4	51038	2,51E-03	2,35E-03	6,3
SUM:	**9,39E-02**	**1,23E-01**	**23,7**	**SUM:**	**1,36E-01**	**1,28E-01**	**5,7**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 10 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 19	**Pos 1**	**Pos 2**		**SG 20**	**Pos 1**	**Pos 2**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9659	2,28E-03	2,05E-03	9,7	9899	1,26E-03	7,89E-04	37,2
9660	2,81E-03	2,66E-03	5,3	9900	4,64E-04	-7,22E-05	115,5
9661	2,55E-03	2,41E-03	5,6	9901	1,94E-04	-3,51E-04	280,6
9662	2,32E-03	2,15E-03	7,3	9902	8,49E-04	3,44E-04	59,4
9663	2,07E-03	1,86E-03	10,2	9903	1,50E-03	1,05E-03	29,9
9664	2,51E-03	2,32E-03	7,4	9904	5,10E-04	-9,64E-06	101,9
9665	2,71E-03	2,55E-03	6,0	9905	8,87E-04	4,01E-04	54,8
9666	2,68E-03	2,55E-03	4,8	9906	2,05E-04	-3,28E-04	260,2
9667	1,29E-03	1,07E-03	16,9	9907	2,26E-03	1,88E-03	16,9
9668	1,74E-03	1,57E-03	9,5	9908	1,74E-03	1,32E-03	23,8
9669	2,08E-03	1,95E-03	6,2	9909	1,14E-03	6,93E-04	39,4
9670	2,34E-03	2,24E-03	4,5	9910	4,97E-04	3,39E-05	93,2
9671	2,54E-03	2,42E-03	4,4	9911	1,25E-04	-3,47E-04	377,6
9672	2,60E-03	2,51E-03	3,5	9912	-4,33E-05	-5,06E-04	1069,9
9673	2,81E-03	2,67E-03	4,8	9913	-1,52E-05	-5,12E-04	3264,0
9674	2,81E-03	2,66E-03	5,2	9914	1,24E-04	-3,76E-04	402,6
9675	2,73E-03	2,58E-03	5,4	9915	3,32E-04	-1,58E-04	147,7
9676	2,68E-03	2,48E-03	7,3	9916	5,84E-04	1,18E-04	79,8
9677	2,44E-03	2,22E-03	9,1	9917	1,04E-03	6,18E-04	40,7
9678	2,14E-03	1,88E-03	12,1	9918	1,43E-03	1,05E-03	26,5
9679	2,84E-03	2,70E-03	4,9	9919	3,61E-05	-5,04E-04	1495,8
9680	2,74E-03	2,62E-03	4,6	9920	4,88E-05	-4,77E-04	1076,8
9681	1,62E-03	1,36E-03	16,2	9921	1,97E-03	1,58E-03	19,7
9682	1,81E-03	1,55E-03	14,3	9922	1,72E-03	1,32E-03	23,4
50879	2,17E-03	1,96E-03	10,0	51703	1,05E-03	5,67E-04	46,1
50880	2,39E-03	2,19E-03	8,5	51704	1,38E-03	9,19E-04	33,2
50881	2,36E-03	2,14E-03	9,4	51705	1,15E-03	7,04E-04	38,8
50882	2,04E-03	1,80E-03	11,7	51706	1,49E-03	1,05E-03	29,2
50884	2,76E-03	2,61E-03	5,7	51708	3,30E-04	-2,11E-04	164,1
50885	2,74E-03	2,61E-03	5,1	51709	6,57E-04	1,36E-04	79,3
50886	2,81E-03	2,66E-03	5,3	51710	4,87E-04	-4,09E-05	108,4
50887	2,82E-03	2,68E-03	5,1	51711	3,98E-04	-1,15E-04	128,9
50889	2,44E-03	2,28E-03	6,4	51713	1,99E-04	-3,39E-04	270,1
50890	2,63E-03	2,48E-03	5,8	51714	1,59E-04	-3,64E-04	328,2
50891	2,61E-03	2,48E-03	5,2	51715	1,15E-04	-4,27E-04	470,1
50892	2,44E-03	2,32E-03	5,1	51717	8,68E-04	3,72E-04	57,1
50894	2,20E-03	2,01E-03	8,7	51718	7,16E-04	2,31E-04	67,8
50895	2,42E-03	2,24E-03	7,4	51720	1,19E-03	7,25E-04	39,2
50896	2,20E-03	2,05E-03	6,8	51721	1,62E-03	1,19E-03	26,6
50898	1,90E-03	1,72E-03	9,9	51722	1,73E-03	1,31E-03	24,1
50899	1,84E-03	1,61E-03	12,8	51724	6,99E-04	1,96E-04	72,0
50901	2,61E-03	2,44E-03	6,7	51725	3,58E-04	-1,68E-04	147,1
50902	2,59E-03	2,40E-03	7,4	51726	5,04E-04	1,21E-05	97,6
50904	2,72E-03	2,57E-03	5,7	51728	1,02E-03	5,47E-04	46,1
50906	2,61E-03	2,49E-03	4,6	51730	1,65E-04	-3,37E-04	304,7
50907	2,71E-03	2,59E-03	4,7	51731	1,27E-04	-4,02E-04	416,6
50909	1,52E-03	1,32E-03	12,7	51733	2,00E-03	1,60E-03	19,8
50910	1,46E-03	1,22E-03	16,5	51734	2,12E-03	1,73E-03	18,2
50914	1,91E-03	1,76E-03	7,7	51737	1,44E-03	1,01E-03	30,0
50917	2,21E-03	2,10E-03	5,3	51740	8,20E-04	3,64E-04	55,6
50920	2,44E-03	2,33E-03	4,4	51743	3,11E-04	-1,57E-04	150,5
50923	2,57E-03	2,47E-03	3,9	51746	4,07E-05	-4,27E-04	1148,5
50926	2,67E-03	2,56E-03	4,0	51749	2,77E-06	-4,91E-04	17836,5
50930	2,81E-03	2,67E-03	5,0	51753	5,42E-05	-4,45E-04	920,1
50931	2,82E-03	2,68E-03	4,9	51754	1,04E-05	-5,08E-04	4966,5
50935	2,77E-03	2,62E-03	5,3	51758	2,28E-04	-2,67E-04	217,3
50938	2,71E-03	2,54E-03	6,3	51761	4,58E-04	-2,00E-05	104,4
50941	2,56E-03	2,35E-03	8,1	51764	8,13E-04	3,68E-04	54,8
50944	2,29E-03	2,05E-03	10,5	51767	1,24E-03	8,34E-04	32,5
50947	1,97E-03	1,71E-03	13,1	51770	1,58E-03	1,19E-03	24,8
50951	2,79E-03	2,66E-03	4,8	51774	4,25E-05	-4,90E-04	1255,1
50956	1,71E-03	1,45E-03	15,2	51779	1,84E-03	1,45E-03	21,4
SUM:	**1,48E-01**	**1,38E-01**	**7,1**	**SUM:**	**4,83E-02**	**1,89E-02**	**60,9**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 11 of 16

Analyses results

	20 strain gauges:				10 strain gauges, even numbers		
	SUM Pos 1	SUM Pos 2	Diff %		SUM Pos 1	SUM Pos 2	Diff %
	4,59E-02	4,61E-02	0,3		2,22E-02	2,21E-02	0,6
	4,68E-02	4,68E-02	0,1		2,25E-02	2,22E-02	1,2
	4,73E-02	4,72E-02	0,1		2,24E-02	2,20E-02	1,6
	4,71E-02	4,70E-02	0,3		2,27E-02	2,24E-02	1,3
	4,73E-02	4,70E-02	0,5		2,41E-02	2,39E-02	0,9
	4,68E-02	4,66E-02	0,5		2,34E-02	2,31E-02	1,2
	4,58E-02	4,59E-02	0,0		2,29E-02	2,28E-02	0,5
	4,64E-02	4,61E-02	0,6		2,25E-02	2,21E-02	1,8
	4,75E-02	4,75E-02	0,0		2,32E-02	2,31E-02	0,5
	4,78E-02	4,79E-02	0,2		2,31E-02	2,31E-02	0,2
	4,78E-02	4,81E-02	0,6		2,35E-02	2,35E-02	0,3
	4,76E-02	4,78E-02	0,6		2,30E-02	2,29E-02	0,5
	4,46E-02	4,44E-02	0,5		2,15E-02	2,13E-02	0,9
	4,47E-02	4,48E-02	0,1		2,13E-02	2,12E-02	0,1
	4,57E-02	4,56E-02	0,2		2,27E-02	2,23E-02	1,8
	4,62E-02	4,63E-02	0,2		2,27E-02	2,25E-02	1,1
	4,61E-02	4,62E-02	0,2		2,25E-02	2,23E-02	0,7
	4,69E-02	4,70E-02	0,3		2,28E-02	2,28E-02	0,2
	4,76E-02	4,78E-02	0,4		2,30E-02	2,31E-02	0,4
	4,81E-02	4,83E-02	0,4		2,38E-02	2,39E-02	0,5
	4,69E-02	4,70E-02	0,0		2,33E-02	2,32E-02	0,5
	4,56E-02	4,58E-02	0,4		2,24E-02	2,23E-02	0,5
	4,71E-02	4,71E-02	0,1		2,29E-02	2,28E-02	0,5
	4,82E-02	4,81E-02	0,1		2,37E-02	2,36E-02	0,6
	4,59E-02	4,59E-02	0,1		2,20E-02	2,18E-02	0,9
	4,57E-02	4,59E-02	0,5		2,22E-02	2,21E-02	0,6
	4,60E-02	4,62E-02	0,3		2,23E-02	2,23E-02	0,4
	4,68E-02	4,69E-02	0,3		2,30E-02	2,29E-02	0,3
	4,69E-02	4,70E-02	0,2		2,24E-02	2,22E-02	0,9
	4,74E-02	4,74E-02	0,1		2,31E-02	2,28E-02	1,2
	4,73E-02	4,73E-02	0,1		2,27E-02	2,25E-02	0,8
	4,68E-02	4,67E-02	0,2		2,30E-02	2,27E-02	1,3
	4,75E-02	4,74E-02	0,3		2,30E-02	2,26E-02	1,5
	4,73E-02	4,71E-02	0,4		2,28E-02	2,26E-02	1,1
	4,84E-02	4,80E-02	0,7		2,36E-02	2,32E-02	1,4
	4,80E-02	4,79E-02	0,2		2,32E-02	2,31E-02	0,6
	4,72E-02	4,70E-02	0,5		2,32E-02	2,30E-02	0,8
	4,78E-02	4,78E-02	0,1		2,39E-02	2,36E-02	1,1
	4,73E-02	4,72E-02	0,1		2,37E-02	2,34E-02	1,3
	4,56E-02	4,55E-02	0,2		2,30E-02	2,28E-02	0,7
	4,40E-02	4,40E-02	0,1		2,18E-02	2,16E-02	1,0
	4,55E-02	4,55E-02	0,1		2,20E-02	2,18E-02	0,8
	4,54E-02	4,52E-02	0,4		2,25E-02	2,22E-02	1,4
	4,58E-02	4,58E-02	0,1		2,29E-02	2,29E-02	0,3
	4,60E-02	4,59E-02	0,2		2,18E-02	2,16E-02	0,7
	4,78E-02	4,76E-02	0,4		2,34E-02	2,30E-02	1,7
	4,88E-02	4,92E-02	0,8		2,42E-02	2,41E-02	0,1
	4,84E-02	4,87E-02	0,6		2,40E-02	2,41E-02	0,2
	4,71E-02	4,71E-02	0,1		2,28E-02	2,28E-02	0,1
	4,66E-02	4,69E-02	0,5		2,22E-02	2,23E-02	0,4
	4,73E-02	4,75E-02	0,4		2,31E-02	2,29E-02	1,2
	4,63E-02	4,66E-02	0,5		2,24E-02	2,23E-02	0,6
	4,55E-02	4,56E-02	0,3		2,19E-02	2,18E-02	0,3
	4,54E-02	4,54E-02	0,0		2,21E-02	2,19E-02	1,0
	4,56E-02	4,56E-02	0,1		2,25E-02	2,24E-02	0,8
	4,55E-02	4,55E-02	0,1		2,20E-02	2,19E-02	0,6
	4,65E-02	4,66E-02	0,3		2,27E-02	2,26E-02	0,3
	4,71E-02	4,72E-02	0,1		2,28E-02	2,28E-02	0,0
	4,86E-02	4,87E-02	0,2		2,39E-02	2,39E-02	0,0
	4,80E-02	4,81E-02	0,3		2,37E-02	2,37E-02	0,2
	4,68E-02	4,68E-02	0,2		2,32E-02	2,30E-02	0,6
	4,72E-02	4,71E-02	0,2		2,31E-02	2,29E-02	0,6
SUM ALL:	**2,90E+00**	**2,90E+00**	**0,0**	**SUM ALL:**	**1,42E+00**	**1,41E+00**	**0,7**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 12 of 16

Analyses results

	10 strain gauges, odd numbers				4 strain gauges (1, 6, 11, 16)		
	SUM Pos 1	**SUM Pos 2**	**Diff %**		**SUM Pos 1**	**SUM Pos 2**	**Diff %**
	2,37E-02	2,40E-02	1,2		1,03E-02	1,04E-02	1,7
	2,43E-02	2,46E-02	1,2		1,12E-02	1,13E-02	0,9
	2,49E-02	2,52E-02	1,2		1,14E-02	1,14E-02	0,1
	2,44E-02	2,46E-02	0,6		1,07E-02	1,07E-02	0,1
	2,32E-02	2,31E-02	0,2		1,09E-02	1,08E-02	0,6
	2,34E-02	2,34E-02	0,1		1,15E-02	1,13E-02	1,6
	2,29E-02	2,31E-02	0,6		1,06E-02	1,06E-02	0,7
	2,40E-02	2,41E-02	0,4		1,12E-02	1,11E-02	0,9
	2,43E-02	2,44E-02	0,5		1,07E-02	1,05E-02	1,7
	2,46E-02	2,48E-02	0,6		1,11E-02	1,08E-02	2,4
	2,43E-02	2,46E-02	1,4		1,04E-02	1,03E-02	1,2
	2,45E-02	2,49E-02	1,6		1,08E-02	1,07E-02	1,0
	2,31E-02	2,31E-02	0,1		1,10E-02	1,08E-02	1,9
	2,35E-02	2,35E-02	0,2		1,18E-02	1,17E-02	1,2
	2,30E-02	2,33E-02	1,5		1,08E-02	1,09E-02	1,4
	2,34E-02	2,38E-02	1,5		1,07E-02	1,08E-02	1,1
	2,36E-02	2,38E-02	1,1		1,11E-02	1,11E-02	0,2
	2,41E-02	2,42E-02	0,7		1,09E-02	1,08E-02	0,4
	2,46E-02	2,47E-02	0,3		1,05E-02	1,05E-02	0,3
	2,43E-02	2,44E-02	0,4		1,05E-02	1,05E-02	0,6
	2,36E-02	2,37E-02	0,6		1,20E-02	1,19E-02	0,6
	2,32E-02	2,35E-02	1,2		1,21E-02	1,20E-02	0,7
	2,42E-02	2,43E-02	0,2		1,03E-02	1,02E-02	0,4
	2,45E-02	2,46E-02	0,4		1,09E-02	1,09E-02	0,5
	2,38E-02	2,41E-02	1,1		1,02E-02	1,04E-02	1,5
	2,35E-02	2,38E-02	1,4		1,03E-02	1,05E-02	1,5
	2,37E-02	2,39E-02	1,0		1,03E-02	1,04E-02	1,1
	2,38E-02	2,40E-02	0,8		1,06E-02	1,07E-02	0,7
	2,45E-02	2,48E-02	1,2		1,13E-02	1,14E-02	0,7
	2,43E-02	2,46E-02	1,2		1,13E-02	1,14E-02	0,4
	2,47E-02	2,48E-02	0,7		1,14E-02	1,14E-02	0,0
	2,39E-02	2,41E-02	0,8		1,11E-02	1,12E-02	0,1
	2,46E-02	2,48E-02	0,8		1,16E-02	1,15E-02	0,6
	2,44E-02	2,45E-02	0,3		1,11E-02	1,10E-02	0,9
	2,48E-02	2,48E-02	0,1		1,13E-02	1,12E-02	1,3
	2,48E-02	2,48E-02	0,2		1,07E-02	1,06E-02	1,1
	2,40E-02	2,40E-02	0,2		1,11E-02	1,10E-02	1,2
	2,39E-02	2,42E-02	0,8		1,15E-02	1,14E-02	1,2
	2,36E-02	2,38E-02	1,0		1,10E-02	1,08E-02	1,6
	2,26E-02	2,27E-02	0,4		1,04E-02	1,04E-02	0,5
	2,22E-02	2,24E-02	0,8		1,04E-02	1,04E-02	0,6
	2,35E-02	2,37E-02	0,8		1,12E-02	1,11E-02	0,7
	2,29E-02	2,30E-02	0,6		1,14E-02	1,13E-02	1,7
	2,29E-02	2,29E-02	0,2		1,13E-02	1,11E-02	1,5
	2,42E-02	2,43E-02	0,3		1,12E-02	1,12E-02	0,2
	2,44E-02	2,46E-02	0,8		1,14E-02	1,13E-02	0,5
	2,47E-02	2,51E-02	1,6		1,03E-02	1,02E-02	1,6
	2,44E-02	2,46E-02	1,1		1,03E-02	1,01E-02	1,5
	2,43E-02	2,43E-02	0,3		1,08E-02	1,06E-02	2,4
	2,44E-02	2,46E-02	0,6		1,10E-02	1,09E-02	1,1
	2,42E-02	2,46E-02	1,8		1,10E-02	1,10E-02	0,3
	2,39E-02	2,43E-02	1,5		1,13E-02	1,13E-02	0,2
	2,37E-02	2,39E-02	0,9		1,19E-02	1,18E-02	0,8
	2,32E-02	2,35E-02	1,0		1,13E-02	1,12E-02	0,2
	2,31E-02	2,32E-02	0,6		1,18E-02	1,18E-02	0,4
	2,35E-02	2,37E-02	0,7		1,09E-02	1,09E-02	0,3
	2,38E-02	2,40E-02	0,9		1,09E-02	1,09E-02	0,2
	2,43E-02	2,44E-02	0,3		1,06E-02	1,06E-02	0,0
	2,47E-02	2,48E-02	0,4		1,07E-02	1,06E-02	0,2
	2,43E-02	2,44E-02	0,3		1,05E-02	1,04E-02	0,1
	2,36E-02	2,38E-02	0,9		1,21E-02	1,20E-02	0,8
	2,42E-02	2,42E-02	0,2		1,08E-02	1,07E-02	0,8
SUM ALL:	**1,48E+00**	**1,49E+00**	**0,7**	**SUM ALL:**	**6,82E-01**	**6,79E-01**	**0,5**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 13 of 16

Analyses results

	4 strain gauges (2, 7, 12, 17)				4 strain gauges (3, 8, 13, 18)		
	SUM Pos 1	SUM Pos 2	Diff %		SUM Pos 1	SUM Pos 2	Diff %
	6,86E-03	7,08E-03	3,1		9,33E-03	9,30E-03	0,4
	6,46E-03	6,68E-03	3,3		9,53E-03	9,40E-03	1,3
	6,58E-03	6,85E-03	3,9		9,04E-03	8,94E-03	1,2
	6,56E-03	6,78E-03	3,2		9,36E-03	9,18E-03	2,0
	6,78E-03	6,90E-03	1,8		8,23E-03	8,20E-03	0,3
	6,57E-03	6,78E-03	3,1		8,48E-03	8,54E-03	0,7
	6,48E-03	6,73E-03	3,7		8,81E-03	8,88E-03	0,9
	6,84E-03	7,05E-03	3,0		9,83E-03	9,78E-03	0,5
	7,41E-03	7,72E-03	4,0		9,43E-03	9,28E-03	1,6
	7,27E-03	7,48E-03	2,9		9,03E-03	8,97E-03	0,6
	6,99E-03	7,19E-03	2,8		1,00E-02	1,01E-02	1,1
	6,84E-03	7,00E-03	2,3		9,94E-03	1,01E-02	1,7
	7,38E-03	7,42E-03	0,5		8,03E-03	8,10E-03	0,8
	7,43E-03	7,42E-03	0,1		7,79E-03	7,94E-03	1,9
	7,41E-03	7,49E-03	1,1		8,68E-03	8,76E-03	0,9
	7,03E-03	7,13E-03	1,5		9,14E-03	9,27E-03	1,4
	7,02E-03	7,15E-03	1,7		8,84E-03	8,95E-03	1,3
	7,24E-03	7,39E-03	2,0		9,13E-03	9,15E-03	0,3
	7,48E-03	7,68E-03	2,6		9,08E-03	9,02E-03	0,7
	7,18E-03	7,39E-03	2,9		9,81E-03	9,72E-03	0,9
	7,28E-03	7,47E-03	2,5		8,18E-03	8,31E-03	1,6
	7,05E-03	7,21E-03	2,2		8,27E-03	8,43E-03	1,8
	6,29E-03	6,46E-03	2,5		9,89E-03	9,77E-03	1,3
	6,32E-03	6,51E-03	3,0		1,02E-02	1,00E-02	1,5
	6,73E-03	6,95E-03	3,3		9,35E-03	9,27E-03	0,8
	6,75E-03	6,99E-03	3,5		9,16E-03	9,17E-03	0,1
	7,01E-03	7,18E-03	2,4		9,34E-03	9,36E-03	0,2
	6,71E-03	6,98E-03	3,8		9,28E-03	9,26E-03	0,3
	6,43E-03	6,64E-03	3,2		9,44E-03	9,36E-03	0,8
	6,43E-03	6,66E-03	3,5		9,16E-03	9,07E-03	1,0
	6,71E-03	6,90E-03	2,6		9,35E-03	9,23E-03	1,3
	6,65E-03	6,87E-03	3,1		9,07E-03	8,96E-03	1,2
	6,68E-03	6,89E-03	3,1		8,90E-03	8,80E-03	1,2
	6,73E-03	6,95E-03	3,1		8,71E-03	8,69E-03	0,3
	7,16E-03	7,33E-03	2,2		8,62E-03	8,48E-03	1,6
	6,88E-03	7,05E-03	2,4		8,69E-03	8,63E-03	0,7
	6,76E-03	6,91E-03	2,2		9,46E-03	9,33E-03	1,4
	6,66E-03	6,81E-03	2,2		8,56E-03	8,61E-03	0,6
	6,89E-03	7,01E-03	1,8		9,01E-03	9,05E-03	0,4
	6,74E-03	6,85E-03	1,7		8,64E-03	8,69E-03	0,7
	6,38E-03	6,64E-03	4,0		9,02E-03	9,16E-03	1,6
	6,56E-03	6,74E-03	2,7		8,91E-03	9,09E-03	1,9
	6,89E-03	7,19E-03	4,2		8,28E-03	8,28E-03	0,1
	6,95E-03	7,14E-03	2,7		8,06E-03	8,12E-03	0,7
	7,13E-03	7,29E-03	2,2		9,01E-03	8,95E-03	0,7
	6,82E-03	7,05E-03	3,2		1,04E-02	1,04E-02	0,4
	6,97E-03	7,24E-03	3,7		1,04E-02	1,05E-02	0,4
	6,75E-03	7,04E-03	4,1		1,04E-02	1,04E-02	0,2
	7,36E-03	7,51E-03	2,0		8,87E-03	8,86E-03	0,2
	7,21E-03	7,33E-03	1,7		8,80E-03	8,86E-03	0,6
	6,97E-03	7,12E-03	2,0		9,57E-03	9,67E-03	1,1
	6,96E-03	7,04E-03	1,1		9,11E-03	9,31E-03	2,1
	6,88E-03	6,93E-03	0,7		8,38E-03	8,61E-03	2,6
	7,13E-03	7,20E-03	1,0		8,51E-03	8,66E-03	1,8
	7,16E-03	7,20E-03	0,5		7,79E-03	7,95E-03	2,0
	7,13E-03	7,22E-03	1,3		8,62E-03	8,72E-03	1,2
	7,19E-03	7,33E-03	1,8		9,03E-03	9,06E-03	0,4
	7,43E-03	7,60E-03	2,3		9,08E-03	9,04E-03	0,5
	7,25E-03	7,46E-03	2,8		9,57E-03	9,49E-03	0,9
	7,05E-03	7,29E-03	3,3		9,87E-03	9,71E-03	1,6
	7,07E-03	7,25E-03	2,4		8,37E-03	8,53E-03	1,8
	6,31E-03	6,48E-03	2,7		1,00E-02	9,90E-03	1,4
SUM ALL:	**4,28E-01**	**4,39E-01**	**2,5**	**SUM ALL:**	**5,63E-01**	**5,63E-01**	**0,1**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 14 of 16

Analyses results

	4 strain gauges (4, 9, 14, 19)				4 strain gauges (5, 10, 15, 20)		
	SUM Pos 1	SUM Pos 2	Diff %		SUM Pos 1	SUM Pos 2	Diff %
	1,30E-02	1,28E-02	1,7		6,43E-03	6,44E-03	0,1
	1,36E-02	1,35E-02	0,5		6,10E-03	5,99E-03	1,8
	1,34E-02	1,33E-02	0,8		6,77E-03	6,68E-03	1,4
	1,29E-02	1,29E-02	0,1		7,61E-03	7,44E-03	2,3
	1,17E-02	1,17E-02	0,0		9,72E-03	9,44E-03	2,9
	1,28E-02	1,28E-02	0,2		7,43E-03	7,08E-03	4,7
	1,33E-02	1,33E-02	0,0		6,65E-03	6,41E-03	3,6
	1,32E-02	1,31E-02	1,0		5,33E-03	5,11E-03	4,2
	1,07E-02	1,08E-02	0,9		9,23E-03	9,15E-03	0,8
	1,13E-02	1,16E-02	2,2		9,03E-03	8,99E-03	0,5
	1,24E-02	1,24E-02	0,3		7,99E-03	8,10E-03	1,3
	1,28E-02	1,28E-02	0,2		7,13E-03	7,16E-03	0,4
	1,14E-02	1,17E-02	2,0		6,70E-03	6,36E-03	5,2
	1,17E-02	1,20E-02	2,5		5,99E-03	5,72E-03	4,6
	1,28E-02	1,26E-02	1,7		6,03E-03	5,86E-03	2,8
	1,32E-02	1,31E-02	1,0		6,08E-03	5,95E-03	2,1
	1,34E-02	1,34E-02	0,2		5,69E-03	5,61E-03	1,3
	1,37E-02	1,37E-02	0,3		5,98E-03	5,93E-03	0,8
	1,32E-02	1,33E-02	0,8		7,27E-03	7,18E-03	1,3
	1,28E-02	1,29E-02	0,5		7,73E-03	7,81E-03	1,0
	1,30E-02	1,31E-02	1,0		6,55E-03	6,19E-03	5,5
	1,28E-02	1,29E-02	1,3		5,37E-03	5,16E-03	3,9
	1,16E-02	1,15E-02	0,9		9,07E-03	9,11E-03	0,5
	1,24E-02	1,22E-02	1,6		8,36E-03	8,53E-03	2,0
	1,30E-02	1,28E-02	1,6		6,56E-03	6,54E-03	0,3
	1,30E-02	1,28E-02	1,5		6,41E-03	6,42E-03	0,2
	1,31E-02	1,29E-02	1,4		6,22E-03	6,25E-03	0,5
	1,28E-02	1,26E-02	1,2		7,38E-03	7,36E-03	0,3
	1,36E-02	1,36E-02	0,2		6,13E-03	6,06E-03	1,2
	1,34E-02	1,34E-02	0,0		7,06E-03	6,89E-03	2,4
	1,33E-02	1,34E-02	0,6		6,54E-03	6,37E-03	2,5
	1,29E-02	1,30E-02	0,6		7,05E-03	6,75E-03	4,3
	1,30E-02	1,30E-02	0,2		7,35E-03	7,16E-03	2,6
	1,26E-02	1,26E-02	0,2		8,12E-03	7,83E-03	3,6
	1,21E-02	1,22E-02	0,9		9,21E-03	8,86E-03	3,8
	1,25E-02	1,26E-02	1,3		9,21E-03	8,99E-03	2,4
	1,24E-02	1,25E-02	0,3		7,42E-03	7,24E-03	2,4
	1,27E-02	1,27E-02	0,0		8,43E-03	8,31E-03	1,5
	1,26E-02	1,25E-02	0,3		7,88E-03	7,86E-03	0,3
	1,23E-02	1,23E-02	0,6		7,46E-03	7,35E-03	1,6
	1,25E-02	1,23E-02	1,6		5,63E-03	5,46E-03	3,1
	1,34E-02	1,33E-02	0,5		5,42E-03	5,24E-03	3,3
	1,27E-02	1,28E-02	0,7		6,14E-03	5,74E-03	6,5
	1,25E-02	1,27E-02	1,8		7,03E-03	6,68E-03	4,9
	1,26E-02	1,28E-02	0,9		6,05E-03	5,79E-03	4,4
	1,31E-02	1,29E-02	1,4		6,03E-03	5,90E-03	2,1
	1,17E-02	1,16E-02	0,1		9,46E-03	9,69E-03	2,4
	1,17E-02	1,16E-02	0,3		9,26E-03	9,50E-03	2,5
	1,10E-02	1,13E-02	2,6		9,01E-03	8,88E-03	1,4
	1,19E-02	1,22E-02	2,5		7,76E-03	7,63E-03	1,7
	1,28E-02	1,27E-02	0,3		6,97E-03	6,96E-03	0,2
	1,29E-02	1,29E-02	0,1		6,04E-03	6,00E-03	0,7
	1,30E-02	1,31E-02	0,3		5,34E-03	5,25E-03	1,8
	1,32E-02	1,32E-02	0,5		5,19E-03	5,07E-03	2,3
	1,32E-02	1,33E-02	0,2		5,62E-03	5,41E-03	3,7
	1,34E-02	1,34E-02	0,1		5,37E-03	5,24E-03	2,4
	1,37E-02	1,37E-02	0,5		5,66E-03	5,61E-03	0,9
	1,32E-02	1,33E-02	0,4		6,78E-03	6,65E-03	1,8
	1,28E-02	1,29E-02	0,8		8,25E-03	8,14E-03	1,3
	1,25E-02	1,25E-02	0,0		8,11E-03	8,17E-03	0,7
	1,29E-02	1,30E-02	1,1		6,38E-03	6,09E-03	4,6
	1,15E-02	1,14E-02	1,0		8,54E-03	8,61E-03	0,8
SUM ALL:	**7,87E-01**	**7,87E-01**	**0,1**	**SUM ALL:**	**4,39E-01**	**4,31E-01**	**1,7**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 15 of 16

Analyses results

	2 Strain gauges (1, 11)				**2 Strain gauges (2, 12)**		
	SUM Pos 1	**SUM Pos 2**	**Diff %**		**SUM Pos 1**	**SUM Pos 2**	**Diff %**
	4,81E-03	4,85E-03	0,8		3,29E-03	3,23E-03	2,0
	4,97E-03	5,04E-03	1,4		3,16E-03	3,11E-03	1,5
	5,08E-03	5,08E-03	0,1		3,16E-03	3,13E-03	0,9
	5,07E-03	5,08E-03	0,2		3,13E-03	3,09E-03	1,4
	5,08E-03	5,00E-03	1,6		3,26E-03	3,17E-03	2,7
	5,21E-03	5,11E-03	2,0		3,24E-03	3,15E-03	2,6
	5,00E-03	4,87E-03	2,7		3,15E-03	3,07E-03	2,4
	5,17E-03	5,09E-03	1,6		3,19E-03	3,12E-03	2,1
	4,97E-03	4,91E-03	1,3		3,57E-03	3,57E-03	0,1
	5,24E-03	5,16E-03	1,6		3,51E-03	3,46E-03	1,5
	5,10E-03	4,99E-03	2,3		3,28E-03	3,25E-03	0,9
	5,23E-03	5,20E-03	0,7		3,16E-03	3,11E-03	1,4
	5,10E-03	5,01E-03	1,9		3,69E-03	3,57E-03	3,2
	5,52E-03	5,51E-03	0,2		3,65E-03	3,55E-03	2,6
	4,43E-03	4,58E-03	3,4		3,53E-03	3,53E-03	0,0
	4,72E-03	4,78E-03	1,3		3,23E-03	3,20E-03	0,9
	4,93E-03	4,91E-03	0,2		3,23E-03	3,17E-03	2,0
	5,09E-03	5,05E-03	0,8		3,46E-03	3,38E-03	2,3
	4,99E-03	4,99E-03	0,0		3,64E-03	3,55E-03	2,4
	4,99E-03	4,93E-03	1,1		3,36E-03	3,29E-03	2,0
	5,18E-03	5,17E-03	0,2		3,44E-03	3,37E-03	2,1
	5,30E-03	5,33E-03	0,6		3,30E-03	3,22E-03	2,3
	4,96E-03	4,90E-03	1,0		3,04E-03	2,97E-03	2,2
	5,07E-03	5,00E-03	1,3		2,99E-03	2,94E-03	1,7
	4,86E-03	4,90E-03	0,8		3,20E-03	3,14E-03	1,6
	4,74E-03	4,78E-03	0,8		3,23E-03	3,17E-03	1,7
	4,86E-03	4,89E-03	0,5		3,35E-03	3,29E-03	1,7
	4,87E-03	4,88E-03	0,2		3,11E-03	3,08E-03	0,9
	5,06E-03	5,09E-03	0,6		3,10E-03	3,03E-03	2,1
	5,10E-03	5,15E-03	1,0		3,13E-03	3,09E-03	1,3
	5,19E-03	5,21E-03	0,4		3,14E-03	3,08E-03	1,9
	5,02E-03	5,05E-03	0,7		3,35E-03	3,31E-03	1,1
	5,16E-03	5,14E-03	0,5		3,26E-03	3,19E-03	2,1
	5,15E-03	5,03E-03	2,4		3,34E-03	3,26E-03	2,6
	5,04E-03	4,89E-03	2,9		3,56E-03	3,46E-03	2,8
	5,17E-03	5,06E-03	2,3		3,40E-03	3,31E-03	2,7
	4,95E-03	4,86E-03	1,9		3,15E-03	3,08E-03	2,3
	5,24E-03	5,18E-03	1,2		3,14E-03	3,06E-03	2,8
	4,91E-03	4,85E-03	1,1		3,23E-03	3,17E-03	1,8
	5,14E-03	5,11E-03	0,6		3,19E-03	3,12E-03	2,0
	5,17E-03	5,08E-03	1,7		3,05E-03	3,01E-03	1,5
	5,25E-03	5,18E-03	1,3		3,05E-03	2,97E-03	2,5
	5,15E-03	5,08E-03	1,3		3,44E-03	3,38E-03	1,6
	5,13E-03	5,02E-03	2,1		3,49E-03	3,40E-03	2,6
	5,33E-03	5,31E-03	0,4		3,42E-03	3,34E-03	2,3
	5,17E-03	5,13E-03	0,8		3,13E-03	3,08E-03	1,5
	4,96E-03	4,90E-03	1,3		3,18E-03	3,16E-03	0,7
	4,95E-03	4,84E-03	2,1		3,07E-03	3,03E-03	1,4
	5,16E-03	5,03E-03	2,4		3,63E-03	3,53E-03	2,7
	5,33E-03	5,25E-03	1,5		3,51E-03	3,42E-03	2,6
	5,00E-03	5,06E-03	1,1		3,29E-03	3,26E-03	1,1
	5,25E-03	5,29E-03	0,9		3,23E-03	3,18E-03	1,4
	5,39E-03	5,39E-03	0,0		3,24E-03	3,17E-03	2,1
	4,81E-03	4,86E-03	0,8		3,30E-03	3,26E-03	1,2
	5,09E-03	5,10E-03	0,2		3,44E-03	3,37E-03	2,0
	4,97E-03	4,95E-03	0,4		3,34E-03	3,27E-03	2,2
	5,02E-03	5,02E-03	0,2		3,41E-03	3,34E-03	2,2
	5,01E-03	4,99E-03	0,3		3,62E-03	3,54E-03	2,2
	4,97E-03	4,96E-03	0,1		3,42E-03	3,35E-03	2,0
	4,95E-03	4,93E-03	0,4		3,35E-03	3,28E-03	2,0
	5,28E-03	5,28E-03	0,1		3,28E-03	3,21E-03	2,2
	5,04E-03	4,97E-03	1,3		3,02E-03	2,96E-03	2,0
SUM ALL:	**3,14E-01**	**3,12E-01**	**0,6**	**SUM ALL:**	**2,04E-01**	**2,01E-01**	**1,9**

Existing concept analyses, pos 1 and pos 2 (one spline ahead), page 16 of 16

Analyses results

	2 Strain gauges (3, 13)		
	SUM Pos 1	SUM Pos 2	Diff %
	4,65E-03	4,78E-03	2,7
	4,68E-03	4,76E-03	1,7
	4,66E-03	4,72E-03	1,4
	4,77E-03	4,79E-03	0,3
	3,67E-03	3,86E-03	5,0
	3,97E-03	4,18E-03	5,1
	3,88E-03	4,14E-03	6,3
	4,68E-03	4,81E-03	2,7
	4,72E-03	4,68E-03	0,7
	4,38E-03	4,47E-03	2,0
	4,81E-03	5,04E-03	4,5
	4,81E-03	5,12E-03	6,0
	3,62E-03	3,83E-03	5,5
	3,65E-03	3,89E-03	6,1
	4,27E-03	4,50E-03	5,1
	4,40E-03	4,73E-03	7,1
	4,30E-03	4,63E-03	7,2
	4,26E-03	4,51E-03	5,5
	4,24E-03	4,40E-03	3,6
	4,81E-03	4,93E-03	2,4
	3,66E-03	3,91E-03	6,4
	3,82E-03	4,07E-03	6,1
	5,04E-03	5,12E-03	1,4
	5,30E-03	5,38E-03	1,5
	4,72E-03	4,82E-03	2,1
	4,56E-03	4,71E-03	3,3
	4,55E-03	4,74E-03	4,1
	4,62E-03	4,74E-03	2,4
	4,62E-03	4,76E-03	2,8
	4,40E-03	4,50E-03	2,2
	4,56E-03	4,65E-03	2,0
	4,34E-03	4,43E-03	2,0
	4,52E-03	4,61E-03	1,8
	4,25E-03	4,41E-03	3,4
	4,25E-03	4,32E-03	1,6
	4,39E-03	4,50E-03	2,3
	4,69E-03	4,77E-03	1,7
	3,78E-03	4,04E-03	6,4
	4,06E-03	4,32E-03	5,9
	3,89E-03	4,16E-03	6,5
	4,20E-03	4,47E-03	6,0
	4,27E-03	4,56E-03	6,3
	3,72E-03	3,91E-03	4,9
	3,50E-03	3,74E-03	6,2
	4,33E-03	4,43E-03	2,3
	5,10E-03	5,25E-03	2,7
	5,16E-03	5,34E-03	3,3
	5,15E-03	5,29E-03	2,7
	4,16E-03	4,30E-03	3,1
	4,16E-03	4,36E-03	4,7
	4,75E-03	4,98E-03	4,6
	4,45E-03	4,74E-03	6,2
	4,05E-03	4,36E-03	7,1
	4,10E-03	4,43E-03	7,5
	3,58E-03	3,88E-03	7,7
	3,98E-03	4,29E-03	7,3
	4,18E-03	4,44E-03	5,8
	4,24E-03	4,42E-03	4,1
	4,73E-03	4,87E-03	2,9
	4,81E-03	4,87E-03	1,1
	3,88E-03	4,15E-03	6,4
	5,17E-03	5,25E-03	1,5
SUM ALL:	**2,71E-01**	**2,82E-01**	**3,9**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 1 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 1	Pos 1	Pos 3		SG 2	Pos 1	Pos 3	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
10179	2,75E-03	2,34E-03	14,8	10191	2,14E-03	1,77E-03	17,1
10180	2,79E-03	2,38E-03	14,7	10192	1,98E-03	1,66E-03	16,1
10181	2,89E-03	2,47E-03	14,7	10193	1,90E-03	1,58E-03	16,5
10182	2,96E-03	2,53E-03	14,4	10194	1,98E-03	1,64E-03	17,2
10187	2,91E-03	2,22E-03	23,7	10195	2,13E-03	1,75E-03	17,9
10188	2,91E-03	2,23E-03	23,4	10196	2,04E-03	1,71E-03	16,3
10189	2,90E-03	2,24E-03	22,7	10197	1,98E-03	1,69E-03	14,8
10190	2,89E-03	2,24E-03	22,6	10198	1,94E-03	1,69E-03	12,9
10575	2,95E-03	2,50E-03	15,1	10579	2,14E-03	1,79E-03	16,2
10576	3,08E-03	2,53E-03	17,9	10580	2,10E-03	1,68E-03	19,9
10577	2,88E-03	2,23E-03	22,5	10581	1,88E-03	1,69E-03	9,9
10578	2,89E-03	2,30E-03	20,4	10582	1,76E-03	1,46E-03	16,6
10611	2,87E-03	2,18E-03	24,0	10615	2,27E-03	1,82E-03	19,7
10612	3,06E-03	2,44E-03	20,4	10616	2,19E-03	1,72E-03	21,5
10613	2,57E-03	2,19E-03	14,7	10617	2,00E-03	1,69E-03	15,3
10614	2,86E-03	2,36E-03	17,6	10618	1,76E-03	1,45E-03	18,1
14017	2,98E-03	2,38E-03	20,2	10823	1,80E-03	1,45E-03	19,5
14018	3,12E-03	2,50E-03	20,0	10824	1,93E-03	1,52E-03	21,4
14019	3,03E-03	2,50E-03	17,3	10825	2,04E-03	1,59E-03	22,1
14020	3,05E-03	2,44E-03	20,0	10826	1,85E-03	1,47E-03	20,8
14021	3,02E-03	2,40E-03	20,6	10827	2,07E-03	1,64E-03	20,8
14022	3,00E-03	2,48E-03	17,5	10828	1,93E-03	1,52E-03	21,4
14023	2,94E-03	2,43E-03	17,5	10829	1,88E-03	1,48E-03	21,2
14024	3,07E-03	2,53E-03	17,7	10830	1,81E-03	1,45E-03	19,6
52646	2,77E-03	2,36E-03	14,7	52697	2,05E-03	1,71E-03	16,6
52648	2,66E-03	2,27E-03	14,8	52699	2,07E-03	1,73E-03	16,2
52649	2,85E-03	2,39E-03	16,2	52700	1,97E-03	1,61E-03	18,3
52651	2,84E-03	2,43E-03	14,7	52702	1,94E-03	1,62E-03	16,3
52653	2,91E-03	2,44E-03	16,0	52704	1,93E-03	1,57E-03	18,6
52655	2,92E-03	2,50E-03	14,6	52706	1,94E-03	1,61E-03	16,9
52657	2,95E-03	2,47E-03	16,1	52708	1,91E-03	1,55E-03	19,0
52660	2,95E-03	2,52E-03	14,8	52711	2,06E-03	1,71E-03	16,7
52661	3,01E-03	2,53E-03	16,1	52712	2,03E-03	1,64E-03	19,1
52680	2,91E-03	2,23E-03	23,6	52714	2,08E-03	1,73E-03	17,1
52682	2,89E-03	2,20E-03	23,9	52716	2,20E-03	1,78E-03	18,9
52683	2,97E-03	2,31E-03	22,1	52717	2,08E-03	1,67E-03	19,9
52685	2,91E-03	2,24E-03	23,1	52719	2,01E-03	1,70E-03	15,6
52687	3,02E-03	2,36E-03	21,6	52721	1,99E-03	1,61E-03	18,8
52689	2,90E-03	2,24E-03	22,7	52723	1,96E-03	1,69E-03	13,9
52691	2,97E-03	2,34E-03	21,3	52725	1,92E-03	1,58E-03	17,7
52694	2,89E-03	2,23E-03	22,6	52728	1,91E-03	1,69E-03	11,5
52695	2,94E-03	2,31E-03	21,4	52729	1,87E-03	1,57E-03	16,1
53959	3,01E-03	2,52E-03	16,5	53969	2,12E-03	1,74E-03	18,0
53961	3,07E-03	2,48E-03	19,1	53971	2,14E-03	1,70E-03	20,7
53962	3,07E-03	2,53E-03	17,8	53972	2,08E-03	1,66E-03	20,4
53964	2,88E-03	2,26E-03	21,4	53974	1,82E-03	1,58E-03	13,2
53966	2,88E-03	2,33E-03	19,0	53976	1,76E-03	1,45E-03	17,4
53967	2,93E-03	2,34E-03	20,3	53977	1,78E-03	1,46E-03	18,1
54048	2,97E-03	2,31E-03	22,1	54056	2,23E-03	1,77E-03	20,6
54050	3,04E-03	2,42E-03	20,5	54058	2,11E-03	1,65E-03	21,8
54052	2,72E-03	2,28E-03	16,2	54060	1,88E-03	1,57E-03	16,6
54054	2,90E-03	2,39E-03	17,5	54062	1,79E-03	1,45E-03	18,9
61374	3,01E-03	2,41E-03	20,1	54521	1,83E-03	1,46E-03	20,2
61375	2,96E-03	2,40E-03	18,8	54522	1,80E-03	1,45E-03	19,6
61377	3,09E-03	2,47E-03	20,0	54524	1,98E-03	1,55E-03	21,7
61378	3,07E-03	2,45E-03	20,3	54525	1,89E-03	1,49E-03	21,1
61379	3,06E-03	2,49E-03	18,7	54526	1,93E-03	1,52E-03	21,4
61381	3,04E-03	2,47E-03	18,7	54528	2,05E-03	1,61E-03	21,4
61382	3,02E-03	2,49E-03	17,4	54530	1,87E-03	1,48E-03	21,0
61383	2,99E-03	2,47E-03	17,4	54532	2,00E-03	1,58E-03	21,1
61386	3,05E-03	2,46E-03	19,1	54534	1,91E-03	1,50E-03	21,3
61388	3,03E-03	2,50E-03	17,6	54536	1,85E-03	1,47E-03	20,4
SUM:	**1,82E-01**	**1,48E-01**	**18,9**	**SUM:**	**1,22E-01**	**9,98E-02**	**18,3**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 2 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 3	Pos 1	Pos 3		SG 4	Pos 1	Pos 3	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
10171	2,61E-03	2,76E-03	5,6	10207	2,98E-03	3,90E-03	23,6
10172	2,51E-03	2,58E-03	2,9	10208	3,18E-03	4,09E-03	22,1
10173	2,39E-03	2,40E-03	0,5	10209	3,27E-03	4,15E-03	21,2
10174	2,25E-03	2,25E-03	0,0	10210	3,26E-03	4,10E-03	20,6
10175	1,86E-03	2,00E-03	6,8	10211	3,22E-03	4,32E-03	25,3
10176	1,98E-03	2,15E-03	8,1	10212	3,32E-03	4,42E-03	24,9
10177	2,12E-03	2,34E-03	9,3	10213	3,38E-03	4,45E-03	24,0
10178	2,25E-03	2,55E-03	11,9	10214	3,40E-03	4,43E-03	23,2
10571	2,02E-03	1,97E-03	2,2	10587	3,16E-03	3,96E-03	20,2
10572	1,86E-03	1,88E-03	1,3	10588	3,25E-03	4,27E-03	24,0
10573	2,41E-03	2,82E-03	14,8	10589	3,29E-03	4,25E-03	22,6
10574	2,51E-03	2,99E-03	16,0	10590	3,08E-03	4,18E-03	26,3
10607	1,67E-03	1,83E-03	8,9	10623	3,08E-03	4,13E-03	25,4
10608	1,74E-03	1,81E-03	3,9	10624	3,23E-03	4,35E-03	25,7
10609	2,66E-03	2,93E-03	9,2	10625	2,70E-03	3,61E-03	25,2
10610	2,59E-03	3,02E-03	14,0	10626	2,88E-03	3,96E-03	27,2
10831	2,34E-03	2,69E-03	13,2	10839	3,26E-03	4,41E-03	26,2
10832	2,02E-03	2,21E-03	8,4	10840	3,36E-03	4,54E-03	26,0
10833	1,88E-03	2,01E-03	6,6	10841	3,37E-03	4,56E-03	26,0
10834	2,18E-03	2,44E-03	10,7	10842	3,32E-03	4,49E-03	26,0
10835	2,00E-03	2,10E-03	4,4	10843	3,32E-03	4,40E-03	24,5
10836	2,14E-03	2,28E-03	6,2	10844	3,34E-03	4,45E-03	25,0
10837	2,29E-03	2,50E-03	8,5	10845	3,28E-03	4,40E-03	25,4
10838	2,44E-03	2,75E-03	11,0	10846	3,12E-03	4,24E-03	26,3
52612	2,56E-03	2,67E-03	4,3	52765	3,08E-03	3,99E-03	22,8
52614	2,63E-03	2,85E-03	7,5	52767	2,84E-03	3,75E-03	24,4
52615	2,53E-03	2,76E-03	8,3	52768	3,05E-03	4,07E-03	25,0
52617	2,45E-03	2,49E-03	1,8	52770	3,23E-03	4,12E-03	21,7
52619	2,40E-03	2,54E-03	5,7	52772	3,23E-03	4,24E-03	23,8
52621	2,32E-03	2,32E-03	0,3	52774	3,26E-03	4,13E-03	20,9
52623	2,26E-03	2,34E-03	3,3	52776	3,30E-03	4,30E-03	23,2
52626	2,13E-03	2,11E-03	1,1	52779	3,21E-03	4,03E-03	20,4
52627	2,12E-03	2,17E-03	2,1	52780	3,29E-03	4,25E-03	22,6
52629	1,92E-03	2,07E-03	7,5	52782	3,27E-03	4,37E-03	25,1
52631	1,77E-03	1,92E-03	7,8	52784	3,15E-03	4,22E-03	25,4
52632	1,87E-03	2,00E-03	6,7	52785	3,27E-03	4,40E-03	25,7
52634	2,05E-03	2,24E-03	8,7	52787	3,35E-03	4,43E-03	24,5
52636	2,00E-03	2,18E-03	8,3	52789	3,35E-03	4,49E-03	25,5
52638	2,18E-03	2,44E-03	10,7	52791	3,39E-03	4,44E-03	23,6
52640	2,15E-03	2,39E-03	10,0	52793	3,37E-03	4,49E-03	25,0
52643	2,33E-03	2,69E-03	13,4	52796	3,34E-03	4,34E-03	22,9
52644	2,29E-03	2,62E-03	12,6	52797	3,33E-03	4,42E-03	24,7
53949	1,94E-03	1,93E-03	0,5	53991	3,20E-03	4,12E-03	22,2
53951	1,80E-03	1,85E-03	2,6	53993	3,24E-03	4,31E-03	24,9
53952	1,93E-03	1,99E-03	2,9	53994	3,28E-03	4,34E-03	24,3
53954	2,46E-03	2,91E-03	15,4	53996	3,18E-03	4,21E-03	24,5
53956	2,55E-03	3,00E-03	15,0	53998	2,98E-03	4,07E-03	26,7
53957	2,42E-03	2,84E-03	14,6	53999	3,17E-03	4,30E-03	26,3
54040	1,70E-03	1,82E-03	6,4	54073	3,16E-03	4,24E-03	25,6
54042	1,81E-03	1,91E-03	5,3	54075	3,27E-03	4,42E-03	25,9
54044	2,62E-03	2,97E-03	11,7	54077	2,79E-03	3,78E-03	26,3
54046	2,52E-03	2,88E-03	12,6	54079	3,00E-03	4,10E-03	26,7
54539	2,26E-03	2,56E-03	12,0	54557	3,31E-03	4,48E-03	26,1
54540	2,39E-03	2,72E-03	12,1	54558	3,19E-03	4,33E-03	26,3
54542	1,95E-03	2,11E-03	7,5	54560	3,37E-03	4,55E-03	26,0
54543	2,10E-03	2,32E-03	9,6	54561	3,32E-03	4,47E-03	25,7
54544	2,08E-03	2,24E-03	7,2	54563	3,35E-03	4,53E-03	26,0
54546	1,94E-03	2,05E-03	5,5	54564	3,36E-03	4,50E-03	25,5
54548	2,23E-03	2,47E-03	9,6	54566	3,32E-03	4,44E-03	25,3
54550	2,07E-03	2,19E-03	5,3	54568	3,33E-03	4,42E-03	24,8
54552	2,21E-03	2,39E-03	7,4	54570	3,31E-03	4,42E-03	25,2
54554	2,37E-03	2,62E-03	9,8	54572	3,20E-03	4,32E-03	25,9
SUM:	**1,36E-01**	**1,48E-01**	**8,0**	**SUM:**	**2,00E-01**	**2,65E-01**	**24,6**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 3 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 5	**Pos 1**	**Pos 3**		**SG 6**	**Pos 1**	**Pos 3**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
10167	1,80E-03	2,39E-03	24,6	10215	2,71E-03	2,29E-03	15,5
10168	1,99E-03	2,51E-03	20,6	10216	3,02E-03	2,66E-03	11,9
10169	2,20E-03	2,67E-03	17,5	10217	3,03E-03	2,61E-03	14,0
10170	2,41E-03	2,74E-03	12,0	10218	2,78E-03	2,30E-03	17,1
10203	3,23E-03	3,50E-03	7,7	10591	3,16E-03	2,85E-03	9,8
10204	2,90E-03	3,28E-03	11,5	10592	3,33E-03	2,87E-03	13,7
10205	2,44E-03	2,94E-03	17,2	10593	2,69E-03	2,22E-03	17,5
10206	2,09E-03	2,64E-03	20,8	10594	2,78E-03	2,24E-03	19,4
10569	2,70E-03	2,89E-03	6,5	10627	3,31E-03	2,92E-03	11,7
10570	3,02E-03	3,22E-03	6,3	10628	3,38E-03	2,92E-03	13,6
10585	1,83E-03	2,50E-03	26,8	10629	2,65E-03	2,20E-03	17,1
10586	1,75E-03	2,45E-03	28,4	10630	2,70E-03	2,17E-03	19,8
10605	3,57E-03	3,73E-03	4,5	10645	2,84E-03	2,36E-03	17,1
10606	3,25E-03	3,44E-03	5,4	10646	3,01E-03	2,55E-03	15,4
10621	1,70E-03	2,37E-03	28,0	10647	2,93E-03	2,51E-03	14,2
10622	1,75E-03	2,44E-03	28,4	10648	2,81E-03	2,39E-03	14,9
10847	1,98E-03	2,58E-03	23,1	10855	3,14E-03	2,67E-03	14,9
10848	2,13E-03	2,65E-03	19,6	10856	2,95E-03	2,42E-03	17,8
10849	2,97E-03	3,28E-03	9,6	10857	2,81E-03	2,28E-03	18,9
10850	2,26E-03	2,76E-03	18,3	10858	2,99E-03	2,45E-03	18,2
10851	2,61E-03	3,02E-03	13,7	10859	3,17E-03	2,68E-03	15,5
10852	2,37E-03	2,83E-03	16,5	10860	3,23E-03	2,76E-03	14,7
10853	2,71E-03	3,04E-03	10,9	10861	2,87E-03	2,33E-03	18,8
10854	1,88E-03	2,49E-03	24,5	10862	3,27E-03	2,84E-03	13,3
52595	1,90E-03	2,45E-03	22,5	52800	2,68E-03	2,25E-03	16,3
52597	1,75E-03	2,38E-03	26,3	52801	2,76E-03	2,34E-03	15,3
52598	1,84E-03	2,44E-03	24,5	52802	2,76E-03	2,29E-03	17,2
52600	2,10E-03	2,59E-03	19,0	52805	3,09E-03	2,75E-03	10,9
52602	2,06E-03	2,58E-03	20,0	52806	2,97E-03	2,59E-03	13,0
52604	2,31E-03	2,71E-03	14,8	52807	3,15E-03	2,75E-03	12,6
52606	2,29E-03	2,75E-03	17,0	52809	3,17E-03	2,76E-03	12,9
52609	2,56E-03	2,82E-03	9,2	52810	3,02E-03	2,58E-03	14,6
52610	2,56E-03	2,89E-03	11,4	52811	3,13E-03	2,68E-03	14,3
52748	3,06E-03	3,39E-03	9,5	52813	2,73E-03	2,26E-03	17,3
52750	3,40E-03	3,62E-03	6,1	52814	2,81E-03	2,33E-03	17,1
52751	3,10E-03	3,39E-03	8,6	52815	2,82E-03	2,32E-03	18,0
52753	2,67E-03	3,11E-03	14,2	54001	3,24E-03	2,86E-03	11,8
52755	2,76E-03	3,15E-03	12,6	54003	3,35E-03	2,90E-03	13,7
52757	2,26E-03	2,79E-03	18,9	54004	3,30E-03	2,85E-03	13,5
52759	2,35E-03	2,85E-03	17,7	54006	2,73E-03	2,23E-03	18,5
52762	1,96E-03	2,57E-03	23,7	54008	2,74E-03	2,20E-03	19,6
52763	2,04E-03	2,61E-03	21,9	54009	2,82E-03	2,28E-03	19,1
53944	2,86E-03	3,05E-03	6,4	54081	3,35E-03	2,92E-03	12,6
53946	3,13E-03	3,33E-03	5,8	54084	3,31E-03	2,84E-03	14,2
53947	2,86E-03	3,13E-03	8,5	54087	2,68E-03	2,18E-03	18,4
53984	1,79E-03	2,47E-03	27,6	54090	2,76E-03	2,22E-03	19,3
53987	1,75E-03	2,45E-03	28,4	54126	2,93E-03	2,45E-03	16,2
53988	1,87E-03	2,52E-03	25,7	54127	2,92E-03	2,40E-03	17,7
54036	3,41E-03	3,59E-03	4,9	54129	3,09E-03	2,61E-03	15,4
54038	3,11E-03	3,36E-03	7,5	54131	2,87E-03	2,45E-03	14,5
54068	1,72E-03	2,40E-03	28,2	54132	3,04E-03	2,59E-03	14,6
54070	1,81E-03	2,47E-03	26,4	54134	2,88E-03	2,41E-03	16,4
54575	2,12E-03	2,67E-03	20,6	54593	3,05E-03	2,55E-03	16,3
54576	1,93E-03	2,54E-03	23,8	54594	3,16E-03	2,68E-03	15,2
54578	2,19E-03	2,70E-03	18,9	54595	3,21E-03	2,76E-03	14,0
54579	2,25E-03	2,74E-03	18,0	54597	2,88E-03	2,35E-03	18,3
54580	2,00E-03	2,57E-03	22,0	54598	2,97E-03	2,43E-03	18,0
54582	2,79E-03	3,15E-03	11,6	54600	2,84E-03	2,31E-03	18,8
54583	2,84E-03	3,16E-03	10,2	54602	3,08E-03	2,56E-03	16,8
54585	2,43E-03	2,89E-03	15,9	54603	2,93E-03	2,39E-03	18,5
54587	2,49E-03	2,93E-03	15,1	54605	3,20E-03	2,72E-03	15,0
54589	2,54E-03	2,94E-03	13,6	54607	3,25E-03	2,80E-03	14,0
SUM:	**1,48E-01**	**1,76E-01**	**15,9**	**SUM:**	**1,85E-01**	**1,56E-01**	**15,6**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 4 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 7	Pos 1	Pos 3		SG 8	Pos 1	Pos 3	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9875	2,06E-03	1,51E-03	27,0	10219	2,54E-03	2,37E-03	6,8
9876	1,98E-03	1,46E-03	26,0	10220	2,49E-03	2,31E-03	7,3
9877	2,01E-03	1,47E-03	26,7	10221	2,43E-03	2,23E-03	8,0
9878	2,07E-03	1,51E-03	27,1	10222	2,35E-03	2,15E-03	8,8
9879	2,18E-03	1,62E-03	25,7	10223	2,45E-03	2,10E-03	14,1
9880	1,98E-03	1,45E-03	26,7	10224	2,55E-03	2,20E-03	13,6
9881	1,95E-03	1,44E-03	26,0	10225	2,67E-03	2,33E-03	12,7
9882	2,16E-03	1,60E-03	26,0	10226	2,76E-03	2,43E-03	12,1
9883	2,05E-03	1,66E-03	18,9	10595	2,25E-03	2,02E-03	10,2
9884	2,09E-03	1,67E-03	20,0	10596	2,22E-03	1,91E-03	13,9
9885	2,04E-03	1,57E-03	22,8	10597	2,86E-03	2,53E-03	11,4
9886	2,03E-03	1,55E-03	23,6	10598	2,86E-03	2,56E-03	10,4
9887	2,09E-03	1,59E-03	23,9	10631	2,36E-03	2,01E-03	14,9
9888	2,16E-03	1,65E-03	23,6	10632	2,27E-03	1,92E-03	15,3
9889	2,26E-03	1,78E-03	21,0	10633	2,57E-03	2,40E-03	6,4
9890	2,19E-03	1,71E-03	22,1	10634	2,75E-03	2,51E-03	8,7
9891	2,19E-03	1,72E-03	21,8	10649	2,44E-03	2,17E-03	11,2
9892	2,19E-03	1,74E-03	20,5	10650	2,65E-03	2,39E-03	9,6
9893	2,25E-03	1,82E-03	19,1	10651	2,50E-03	2,18E-03	12,8
9894	2,21E-03	1,79E-03	19,0	10652	2,55E-03	2,29E-03	10,3
9895	2,24E-03	1,68E-03	25,1	10653	2,73E-03	2,42E-03	11,3
9896	2,14E-03	1,57E-03	26,6	10654	2,62E-03	2,30E-03	12,1
9897	1,93E-03	1,44E-03	25,0	10655	2,34E-03	2,05E-03	12,2
9898	1,98E-03	1,49E-03	24,8	10656	2,39E-03	2,06E-03	13,8
51620	2,07E-03	1,51E-03	27,0	52817	2,51E-03	2,34E-03	7,1
51621	2,02E-03	1,48E-03	26,9	52819	2,55E-03	2,38E-03	6,6
51622	2,11E-03	1,55E-03	26,5	52820	2,59E-03	2,38E-03	8,2
51623	2,05E-03	1,53E-03	25,3	52822	2,46E-03	2,27E-03	7,7
51625	1,99E-03	1,47E-03	26,4	52824	2,52E-03	2,30E-03	8,8
51626	1,96E-03	1,45E-03	26,0	52826	2,39E-03	2,19E-03	8,4
51627	2,11E-03	1,64E-03	22,3	52828	2,43E-03	2,20E-03	9,6
51628	1,98E-03	1,47E-03	25,4	52831	2,30E-03	2,08E-03	9,5
51630	2,04E-03	1,49E-03	26,9	52832	2,34E-03	2,10E-03	10,5
51631	2,00E-03	1,46E-03	26,7	52834	2,50E-03	2,15E-03	13,9
51632	2,10E-03	1,61E-03	23,5	52836	2,40E-03	2,05E-03	14,5
51634	2,13E-03	1,57E-03	26,4	52837	2,42E-03	2,08E-03	13,9
51635	2,13E-03	1,61E-03	24,3	52839	2,61E-03	2,26E-03	13,2
51637	2,17E-03	1,61E-03	25,9	52841	2,52E-03	2,19E-03	13,2
51638	2,19E-03	1,67E-03	23,9	52843	2,71E-03	2,38E-03	12,4
51639	2,21E-03	1,65E-03	25,4	52845	2,64E-03	2,31E-03	12,4
51641	1,97E-03	1,45E-03	26,3	52848	2,81E-03	2,48E-03	11,7
51642	2,01E-03	1,51E-03	24,7	52849	2,75E-03	2,43E-03	11,7
51644	2,02E-03	1,56E-03	22,9	54011	2,23E-03	1,96E-03	12,0
51645	1,94E-03	1,44E-03	25,5	54013	2,24E-03	1,92E-03	14,6
51647	2,12E-03	1,59E-03	25,0	54014	2,28E-03	1,98E-03	13,0
51648	2,15E-03	1,58E-03	26,3	54016	2,86E-03	2,54E-03	10,9
51650	2,07E-03	1,67E-03	19,4	54018	2,80E-03	2,53E-03	9,6
51651	1,99E-03	1,55E-03	21,8	54019	2,79E-03	2,49E-03	10,9
51655	2,06E-03	1,62E-03	21,4	54092	2,31E-03	1,97E-03	15,1
51658	2,04E-03	1,56E-03	23,2	54094	2,33E-03	1,99E-03	14,5
51661	2,06E-03	1,57E-03	23,8	54096	2,66E-03	2,46E-03	7,6
51664	2,12E-03	1,62E-03	23,8	54098	2,70E-03	2,45E-03	9,1
51667	2,15E-03	1,61E-03	25,1	54136	2,47E-03	2,18E-03	12,0
51671	2,23E-03	1,75E-03	21,6	54137	2,50E-03	2,23E-03	10,7
51672	2,25E-03	1,73E-03	23,0	54138	2,39E-03	2,11E-03	11,7
51676	2,19E-03	1,71E-03	21,9	54140	2,60E-03	2,34E-03	9,9
51679	2,19E-03	1,73E-03	21,2	54141	2,69E-03	2,41E-03	10,5
51682	2,22E-03	1,78E-03	19,8	54143	2,56E-03	2,24E-03	12,4
51685	2,23E-03	1,80E-03	19,1	54144	2,45E-03	2,12E-03	13,3
51688	2,10E-03	1,64E-03	21,8	54146	2,58E-03	2,29E-03	11,2
51693	2,19E-03	1,63E-03	25,8	54148	2,67E-03	2,36E-03	11,7
51698	1,95E-03	1,47E-03	24,9	54151	2,36E-03	2,06E-03	13,0
SUM:	**1,30E-01**	**9,89E-02**	**23,9**	**SUM:**	**1,56E-01**	**1,39E-01**	**11,2**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 5 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 9	**Pos 1**	**Pos 3**		**SG 10**	**Pos 1**	**Pos 3**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
10199	3,09E-03	2,91E-03	6,0	10183	-9,43E-05	4,69E-04	120,1
10200	3,01E-03	2,86E-03	5,2	10184	8,33E-05	7,17E-04	88,4
10201	2,87E-03	2,76E-03	4,0	10185	2,81E-04	9,64E-04	70,8
10202	2,63E-03	2,59E-03	1,4	10186	5,85E-04	1,33E-03	56,0
10231	1,84E-03	1,82E-03	1,1	10227	1,24E-03	1,92E-03	35,6
10232	2,19E-03	2,18E-03	0,5	10228	7,09E-04	1,36E-03	48,0
10233	2,48E-03	2,43E-03	2,1	10229	2,25E-04	8,29E-04	72,9
10234	2,53E-03	2,48E-03	2,1	10230	-1,42E-04	4,01E-04	135,5
10583	2,30E-03	2,30E-03	0,2	10599	-1,99E-04	2,67E-04	174,6
10584	2,05E-03	2,02E-03	1,3	10600	-1,78E-04	4,19E-04	142,5
10603	2,62E-03	2,55E-03	2,7	10601	8,67E-04	1,65E-03	47,3
10604	2,94E-03	2,79E-03	5,1	10602	1,12E-03	1,97E-03	43,2
10619	1,45E-03	1,48E-03	2,0	10635	-1,23E-04	3,62E-04	134,0
10620	1,73E-03	1,75E-03	1,4	10636	-1,53E-04	4,51E-04	134,0
10639	3,14E-03	2,94E-03	6,5	10637	1,61E-03	2,31E-03	30,2
10640	3,12E-03	2,93E-03	6,3	10638	1,37E-03	2,19E-03	37,4
10657	2,87E-03	2,74E-03	4,6	10665	3,81E-04	1,19E-03	68,0
10658	2,94E-03	2,79E-03	5,0	10666	7,64E-05	8,24E-04	90,7
10659	2,72E-03	2,60E-03	4,4	10667	-1,03E-04	5,88E-04	117,6
10660	2,73E-03	2,62E-03	3,9	10668	4,66E-04	1,26E-03	63,0
10661	2,50E-03	2,41E-03	3,4	10669	9,24E-04	1,72E-03	46,4
10662	2,18E-03	2,13E-03	2,5	10670	-9,57E-05	5,80E-04	116,5
10663	2,41E-03	2,35E-03	2,4	10671	1,41E-04	8,77E-04	83,9
10664	3,07E-03	2,90E-03	5,6	10672	7,38E-04	1,56E-03	52,9
52731	3,05E-03	2,88E-03	5,6	52663	-5,74E-06	5,93E-04	101,0
52733	3,12E-03	2,92E-03	6,3	52665	-1,09E-04	4,15E-04	126,3
52734	3,08E-03	2,90E-03	5,8	52666	-9,89E-05	5,29E-04	118,7
52736	2,94E-03	2,81E-03	4,6	52668	1,82E-04	8,40E-04	78,3
52738	2,98E-03	2,83E-03	5,1	52670	7,98E-05	7,70E-04	89,6
52740	2,75E-03	2,68E-03	2,7	52672	4,32E-04	1,15E-03	62,3
52742	2,80E-03	2,68E-03	4,2	52674	3,31E-04	1,08E-03	69,2
52745	2,46E-03	2,44E-03	0,9	52677	7,26E-04	1,49E-03	51,2
52746	2,52E-03	2,47E-03	1,9	52678	6,61E-04	1,45E-03	54,3
52868	2,02E-03	2,00E-03	0,8	52851	9,73E-04	1,64E-03	40,8
52870	1,65E-03	1,65E-03	0,3	52853	1,42E-03	2,11E-03	32,7
52871	2,01E-03	1,97E-03	1,9	52854	1,08E-03	1,82E-03	40,7
52873	2,33E-03	2,30E-03	1,3	52856	4,67E-04	1,10E-03	57,4
52875	2,34E-03	2,30E-03	2,0	52858	5,87E-04	1,31E-03	55,2
52877	2,50E-03	2,45E-03	2,1	52860	4,04E-05	6,14E-04	93,4
52879	2,60E-03	2,52E-03	3,1	52862	1,83E-04	8,53E-04	78,5
52882	2,57E-03	2,51E-03	2,5	52865	-1,71E-04	3,34E-04	151,2
52883	2,70E-03	2,61E-03	3,4	52866	-1,19E-04	4,90E-04	124,3
53979	2,17E-03	2,16E-03	0,7	54021	-1,89E-04	3,43E-04	155,0
53981	1,89E-03	1,89E-03	0,1	54023	-1,66E-04	4,35E-04	138,1
53982	2,23E-03	2,19E-03	1,9	54024	-1,37E-04	5,00E-04	127,4
54031	2,78E-03	2,67E-03	4,0	54026	9,93E-04	1,81E-03	45,1
54033	3,03E-03	2,86E-03	5,7	54028	1,25E-03	2,08E-03	40,1
54034	2,91E-03	2,76E-03	4,8	54029	9,29E-04	1,77E-03	47,5
54064	1,59E-03	1,62E-03	1,7	54100	-1,38E-04	4,07E-04	134,0
54066	1,96E-03	1,94E-03	0,8	54102	-1,29E-04	5,20E-04	124,7
54108	3,13E-03	2,93E-03	6,4	54104	1,49E-03	2,25E-03	33,7
54110	3,09E-03	2,91E-03	5,9	54106	1,15E-03	1,96E-03	41,3
54154	2,80E-03	2,68E-03	4,2	54172	2,28E-04	1,01E-03	77,4
54155	2,97E-03	2,82E-03	5,1	54173	4,23E-04	1,22E-03	65,4
54157	2,83E-03	2,70E-03	4,7	54174	5,59E-04	1,38E-03	59,4
54158	2,83E-03	2,71E-03	4,5	54176	-1,29E-05	7,07E-04	101,8
54159	3,00E-03	2,84E-03	5,3	54177	1,09E-04	8,50E-04	87,2
54161	2,61E-03	2,51E-03	3,9	54179	-9,95E-05	5,84E-04	117,0
54162	2,57E-03	2,48E-03	3,4	54181	6,95E-04	1,49E-03	53,4
54164	2,61E-03	2,52E-03	3,7	54182	3,04E-04	1,07E-03	71,5
54166	2,34E-03	2,27E-03	3,0	54184	8,31E-04	1,64E-03	49,5
54168	2,30E-03	2,24E-03	2,5	54186	2,29E-05	7,29E-04	96,9
SUM:	**1,59E-01**	**1,54E-01**	**3,5**	**SUM:**	**2,45E-02**	**6,75E-02**	**63,7**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 6 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 11	**Pos 1**	**Pos 3**		**SG 12**	**Pos 1**	**Pos 3**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9851	2,06E-03	2,81E-03	26,5	9827	1,16E-03	1,18E-03	2,2
9852	2,18E-03	3,01E-03	27,6	9828	1,19E-03	1,30E-03	8,8
9853	2,18E-03	2,86E-03	23,7	9829	1,26E-03	1,42E-03	10,9
9854	2,11E-03	2,90E-03	27,1	9830	1,15E-03	1,24E-03	6,9
9855	2,17E-03	3,01E-03	27,8	9831	1,13E-03	1,19E-03	4,8
9856	2,29E-03	3,02E-03	24,0	9832	1,20E-03	1,29E-03	7,1
9857	2,11E-03	2,75E-03	23,5	9833	1,17E-03	1,22E-03	4,2
9858	2,28E-03	3,01E-03	24,4	9834	1,26E-03	1,41E-03	11,1
9859	2,02E-03	2,49E-03	18,8	9835	1,43E-03	1,52E-03	5,5
9860	2,16E-03	2,67E-03	19,0	9836	1,41E-03	1,50E-03	6,1
9861	2,23E-03	2,77E-03	19,4	9837	1,40E-03	1,50E-03	6,9
9862	2,34E-03	2,94E-03	20,3	9838	1,40E-03	1,52E-03	7,7
9863	2,23E-03	2,86E-03	21,9	9839	1,42E-03	1,56E-03	8,7
9864	2,46E-03	3,11E-03	20,8	9840	1,46E-03	1,64E-03	11,1
9865	1,85E-03	2,74E-03	32,4	9841	1,53E-03	1,78E-03	13,9
9866	1,86E-03	2,73E-03	31,9	9842	1,46E-03	1,60E-03	8,8
9867	1,95E-03	2,82E-03	30,9	9843	1,43E-03	1,50E-03	4,3
9868	1,97E-03	2,79E-03	29,4	9844	1,53E-03	1,55E-03	1,3
9869	1,96E-03	2,75E-03	28,5	9845	1,60E-03	1,56E-03	2,5
9870	1,94E-03	2,67E-03	27,6	9846	1,51E-03	1,44E-03	4,4
9871	2,16E-03	3,02E-03	28,5	9847	1,38E-03	1,62E-03	15,1
9872	2,30E-03	3,06E-03	24,8	9848	1,37E-03	1,59E-03	14,2
9873	2,01E-03	2,61E-03	22,9	9849	1,16E-03	1,19E-03	2,9
9874	2,00E-03	2,69E-03	25,8	9850	1,19E-03	1,19E-03	0,6
51538	2,09E-03	2,85E-03	26,8	51455	1,14E-03	1,19E-03	3,5
51539	2,08E-03	2,78E-03	25,0	51456	1,16E-03	1,20E-03	3,2
51540	2,01E-03	2,78E-03	27,5	51457	1,38E-03	1,37E-03	0,5
51541	2,03E-03	2,75E-03	26,1	51458	1,17E-03	1,19E-03	1,4
51543	2,15E-03	2,95E-03	27,3	51460	1,17E-03	1,27E-03	7,9
51544	2,17E-03	3,01E-03	27,7	51461	1,19E-03	1,30E-03	7,9
51545	2,24E-03	3,01E-03	25,8	51462	1,22E-03	1,36E-03	10,0
51546	2,06E-03	2,92E-03	29,2	51463	1,29E-03	1,41E-03	8,2
51548	2,15E-03	2,88E-03	25,4	51465	1,23E-03	1,35E-03	9,1
51549	2,24E-03	2,94E-03	23,8	51466	1,26E-03	1,42E-03	11,0
51550	2,14E-03	2,81E-03	23,6	51467	1,36E-03	1,51E-03	9,8
51551	2,21E-03	2,81E-03	21,6	51468	1,32E-03	1,52E-03	13,2
51553	2,04E-03	2,85E-03	28,2	51470	1,14E-03	1,21E-03	5,9
51555	2,22E-03	3,01E-03	26,1	51471	1,16E-03	1,23E-03	5,6
51556	2,01E-03	2,87E-03	29,8	51472	1,27E-03	1,37E-03	6,9
51557	2,17E-03	3,01E-03	28,1	51474	1,27E-03	1,34E-03	5,5
51559	2,29E-03	3,01E-03	24,2	51475	1,14E-03	1,19E-03	3,8
51560	2,32E-03	2,98E-03	22,1	51477	1,18E-03	1,25E-03	5,7
51562	2,13E-03	2,71E-03	21,3	51478	1,32E-03	1,39E-03	5,6
51563	2,06E-03	2,68E-03	23,2	51480	1,35E-03	1,38E-03	2,6
51565	2,25E-03	2,93E-03	23,2	51482	1,34E-03	1,48E-03	9,9
51566	2,29E-03	3,03E-03	24,6	51483	1,31E-03	1,50E-03	12,7
51568	2,09E-03	2,58E-03	18,9	51485	1,42E-03	1,51E-03	5,9
51569	2,02E-03	2,55E-03	20,9	51486	1,29E-03	1,35E-03	4,4
51573	2,19E-03	2,72E-03	19,2	51491	1,40E-03	1,50E-03	6,5
51576	2,29E-03	2,85E-03	19,9	51494	1,40E-03	1,51E-03	7,3
51579	2,29E-03	2,90E-03	21,1	51497	1,41E-03	1,54E-03	8,2
51582	2,34E-03	2,98E-03	21,3	51500	1,44E-03	1,60E-03	10,0
51585	2,38E-03	3,08E-03	22,8	51503	1,41E-03	1,62E-03	12,6
51589	1,85E-03	2,73E-03	32,2	51507	1,49E-03	1,69E-03	11,5
51590	2,01E-03	2,88E-03	30,3	51508	1,45E-03	1,70E-03	14,5
51594	1,90E-03	2,77E-03	31,4	51512	1,45E-03	1,55E-03	6,6
51597	1,96E-03	2,81E-03	30,2	51515	1,48E-03	1,52E-03	2,7
51600	1,97E-03	2,77E-03	29,0	51518	1,57E-03	1,56E-03	0,6
51603	1,95E-03	2,71E-03	28,1	51521	1,55E-03	1,50E-03	3,4
51606	1,97E-03	2,68E-03	26,7	51524	1,35E-03	1,32E-03	2,2
51610	2,23E-03	3,04E-03	26,6	51528	1,37E-03	1,61E-03	14,7
51615	2,00E-03	2,65E-03	24,3	51533	1,17E-03	1,19E-03	1,7
SUM:	**1,32E-01**	**1,76E-01**	**25,4**	**SUM:**	**8,22E-02**	**8,82E-02**	**6,8**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 7 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 13	**Pos 1**	**Pos 3**		**SG 14**	**Pos 1**	**Pos 3**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9803	2,04E-03	2,08E-03	100,0	9779	4,68E-03	3,89E-03	16,9
9804	2,17E-03	2,14E-03	100,0	9780	4,55E-03	3,78E-03	16,8
9805	2,27E-03	2,25E-03	100,0	9781	4,74E-03	3,93E-03	17,2
9806	2,53E-03	2,42E-03	100,0	9782	4,68E-03	3,90E-03	16,7
9807	1,81E-03	1,87E-03	100,0	9783	4,57E-03	3,78E-03	17,2
9808	1,99E-03	2,00E-03	100,0	9784	4,79E-03	3,99E-03	16,7
9809	1,76E-03	1,80E-03	100,0	9785	4,71E-03	3,94E-03	16,3
9810	2,43E-03	2,32E-03	100,0	9786	4,60E-03	3,77E-03	17,9
9811	2,70E-03	2,53E-03	100,0	9787	3,98E-03	3,34E-03	16,1
9812	2,52E-03	2,46E-03	100,0	9788	4,27E-03	3,62E-03	15,4
9813	2,40E-03	2,46E-03	100,0	9789	4,43E-03	3,77E-03	14,9
9814	2,30E-03	2,36E-03	100,0	9790	4,46E-03	3,79E-03	14,9
9815	1,95E-03	2,07E-03	100,0	9791	4,35E-03	3,70E-03	14,9
9816	1,91E-03	2,00E-03	100,0	9792	4,14E-03	3,52E-03	15,0
9817	1,61E-03	1,61E-03	100,0	9793	4,13E-03	3,40E-03	17,8
9818	1,80E-03	1,81E-03	100,0	9794	4,44E-03	3,70E-03	16,5
9819	1,96E-03	1,99E-03	100,0	9795	4,56E-03	3,84E-03	15,8
9820	2,24E-03	2,21E-03	100,0	9796	4,67E-03	3,98E-03	14,8
9821	2,37E-03	2,27E-03	100,0	9797	4,70E-03	4,04E-03	14,0
9822	2,63E-03	2,41E-03	100,0	9798	4,62E-03	4,00E-03	13,5
9823	1,66E-03	1,68E-03	100,0	9799	4,32E-03	3,59E-03	17,0
9824	1,68E-03	1,72E-03	100,0	9800	4,52E-03	3,79E-03	16,2
9825	2,75E-03	2,55E-03	100,0	9801	4,30E-03	3,51E-03	18,5
9826	2,86E-03	2,58E-03	100,0	9802	4,37E-03	3,61E-03	17,3
51373	2,16E-03	2,17E-03	100,0	51291	4,71E-03	3,91E-03	17,1
51374	1,92E-03	1,97E-03	100,0	51292	4,68E-03	3,89E-03	16,8
51375	2,02E-03	2,04E-03	100,0	51293	4,62E-03	3,83E-03	17,1
51376	2,17E-03	2,22E-03	100,0	51294	4,57E-03	3,84E-03	15,9
51378	2,22E-03	2,20E-03	100,0	51296	4,62E-03	3,84E-03	16,8
51379	2,08E-03	2,07E-03	100,0	51297	4,63E-03	3,86E-03	16,6
51380	2,30E-03	2,23E-03	100,0	51298	4,41E-03	3,70E-03	16,1
51381	2,21E-03	2,18E-03	100,0	51299	4,44E-03	3,69E-03	16,9
51383	2,40E-03	2,34E-03	100,0	51301	4,77E-03	3,96E-03	16,9
51384	2,34E-03	2,36E-03	100,0	51302	4,67E-03	3,85E-03	17,5
51386	2,48E-03	2,37E-03	100,0	51303	4,65E-03	3,88E-03	16,5
51387	2,52E-03	2,44E-03	100,0	51305	4,74E-03	3,95E-03	16,7
51388	2,64E-03	2,49E-03	100,0	51306	4,56E-03	3,84E-03	15,9
51390	1,78E-03	1,83E-03	100,0	51308	4,58E-03	3,78E-03	17,5
51391	1,88E-03	1,97E-03	100,0	51309	4,46E-03	3,74E-03	16,1
51392	1,75E-03	1,79E-03	100,0	51310	4,47E-03	3,70E-03	17,3
51394	1,87E-03	1,90E-03	100,0	51312	4,75E-03	3,97E-03	16,5
51395	1,98E-03	1,99E-03	100,0	51313	4,73E-03	3,99E-03	15,8
51397	1,78E-03	1,80E-03	100,0	51315	4,71E-03	3,99E-03	15,2
51398	1,71E-03	1,74E-03	100,0	51316	4,61E-03	3,86E-03	16,3
51400	2,40E-03	2,30E-03	100,0	51318	4,52E-03	3,74E-03	17,2
51401	2,64E-03	2,45E-03	100,0	51319	4,45E-03	3,64E-03	18,2
51403	2,61E-03	2,49E-03	100,0	51321	4,13E-03	3,48E-03	15,7
51404	2,73E-03	2,54E-03	100,0	51322	4,15E-03	3,46E-03	16,6
51408	2,46E-03	2,46E-03	100,0	51326	4,35E-03	3,70E-03	15,1
51411	2,35E-03	2,41E-03	100,0	51329	4,45E-03	3,78E-03	14,9
51414	2,12E-03	2,21E-03	100,0	51332	4,40E-03	3,75E-03	14,9
51417	1,93E-03	2,03E-03	100,0	51335	4,24E-03	3,61E-03	15,0
51420	1,80E-03	1,86E-03	100,0	51338	4,25E-03	3,57E-03	16,2
51424	1,71E-03	1,71E-03	100,0	51342	4,28E-03	3,55E-03	17,2
51425	1,64E-03	1,65E-03	100,0	51343	4,22E-03	3,45E-03	18,1
51429	1,88E-03	1,90E-03	100,0	51347	4,50E-03	3,77E-03	16,1
51432	2,10E-03	2,10E-03	100,0	51350	4,62E-03	3,91E-03	15,3
51435	2,30E-03	2,24E-03	100,0	51353	4,69E-03	4,01E-03	14,4
51438	2,50E-03	2,34E-03	100,0	51356	4,66E-03	4,02E-03	13,8
51441	2,74E-03	2,50E-03	100,0	51359	4,57E-03	3,89E-03	14,8
51445	1,67E-03	1,70E-03	100,0	51363	4,42E-03	3,69E-03	16,6
51450	2,80E-03	2,57E-03	100,0	51368	4,33E-03	3,56E-03	17,9
SUM:	**1,82E-01**	**1,33E-01**	**27,0**	**SUM:**	**2,79E-01**	**2,34E-01**	**16,3**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 8 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 15	**Pos 1**	**Pos 3**		**SG 16**	**Pos 1**	**Pos 3**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9755	3,47E-03	2,99E-03	13,8	9731	2,73E-03	3,12E-03	12,5
9756	3,56E-03	3,14E-03	11,6	9732	3,18E-03	3,53E-03	9,9
9757	4,09E-03	3,77E-03	8,0	9733	3,32E-03	3,69E-03	9,9
9758	3,77E-03	3,44E-03	8,8	9734	2,87E-03	3,22E-03	11,0
9759	3,76E-03	3,37E-03	10,6	9735	2,63E-03	3,00E-03	12,2
9760	3,31E-03	2,80E-03	15,4	9736	3,00E-03	3,36E-03	10,8
9761	3,10E-03	2,54E-03	17,9	9737	2,94E-03	3,31E-03	11,4
9762	3,18E-03	2,65E-03	16,8	9738	3,29E-03	3,61E-03	9,1
9763	4,46E-03	4,32E-03	3,0	9739	2,39E-03	2,73E-03	12,4
9764	4,46E-03	4,22E-03	5,2	9740	2,50E-03	2,78E-03	10,1
9765	4,15E-03	3,83E-03	7,9	9741	2,65E-03	2,93E-03	9,5
9766	3,76E-03	3,31E-03	11,9	9742	2,91E-03	3,17E-03	8,1
9767	3,14E-03	2,68E-03	14,6	9743	3,09E-03	3,35E-03	7,9
9768	2,93E-03	2,44E-03	17,0	9744	3,30E-03	3,56E-03	7,2
9769	2,73E-03	2,22E-03	18,6	9745	3,45E-03	3,74E-03	7,8
9770	2,83E-03	2,35E-03	16,9	9746	3,15E-03	3,48E-03	9,4
9771	2,99E-03	2,54E-03	15,0	9747	3,03E-03	3,38E-03	10,3
9772	3,19E-03	2,79E-03	12,5	9748	2,83E-03	3,20E-03	11,4
9773	3,37E-03	3,06E-03	9,0	9749	2,69E-03	3,06E-03	12,0
9774	3,58E-03	3,39E-03	5,4	9750	2,56E-03	2,94E-03	12,9
9775	2,98E-03	2,39E-03	19,9	9751	3,60E-03	3,92E-03	8,0
9776	3,05E-03	2,47E-03	19,1	9752	3,60E-03	3,88E-03	7,1
9777	4,24E-03	4,04E-03	4,8	9753	2,44E-03	2,85E-03	14,3
9778	4,02E-03	3,79E-03	5,9	9754	2,58E-03	2,98E-03	13,4
51209	3,61E-03	3,18E-03	12,1	51125	2,68E-03	3,06E-03	12,4
51210	3,39E-03	2,89E-03	14,6	51126	2,83E-03	3,22E-03	11,9
51211	3,33E-03	2,82E-03	15,2	51127	2,71E-03	3,09E-03	12,3
51212	3,61E-03	3,15E-03	12,8	51128	2,66E-03	3,05E-03	13,0
51214	3,66E-03	3,29E-03	10,2	51130	3,25E-03	3,61E-03	9,9
51215	3,66E-03	3,25E-03	11,1	51131	3,09E-03	3,45E-03	10,4
51216	3,43E-03	2,97E-03	13,4	51132	3,06E-03	3,42E-03	10,6
51217	3,37E-03	2,97E-03	12,1	51133	3,10E-03	3,45E-03	10,1
51219	3,93E-03	3,60E-03	8,4	51135	3,30E-03	3,65E-03	9,5
51220	3,93E-03	3,57E-03	9,2	51136	3,24E-03	3,58E-03	9,7
51221	4,27E-03	3,99E-03	6,6	51137	3,46E-03	3,80E-03	9,0
51222	4,17E-03	3,90E-03	6,4	51139	2,75E-03	3,11E-03	11,6
51224	3,57E-03	3,25E-03	8,9	51140	2,93E-03	3,29E-03	10,9
51225	3,90E-03	3,61E-03	7,3	51141	2,90E-03	3,27E-03	11,2
51227	3,96E-03	3,60E-03	9,2	51142	2,76E-03	3,07E-03	10,3
51229	3,20E-03	2,67E-03	16,6	51144	2,57E-03	2,89E-03	11,2
51230	3,15E-03	2,67E-03	15,2	51145	2,54E-03	2,92E-03	13,2
51232	3,14E-03	2,60E-03	17,4	51147	3,14E-03	3,49E-03	9,9
51233	2,97E-03	2,45E-03	17,4	51148	2,95E-03	3,27E-03	9,5
51234	3,04E-03	2,47E-03	18,9	51150	2,89E-03	3,26E-03	11,4
51236	3,16E-03	2,66E-03	15,7	51152	3,19E-03	3,48E-03	8,5
51237	3,12E-03	2,56E-03	17,9	51153	3,44E-03	3,75E-03	8,1
51239	4,46E-03	4,27E-03	4,2	51155	2,45E-03	2,76E-03	11,2
51240	4,35E-03	4,18E-03	3,9	51156	2,42E-03	2,79E-03	13,4
51244	4,30E-03	4,02E-03	6,5	51161	2,57E-03	2,85E-03	9,8
51247	3,95E-03	3,57E-03	9,8	51164	2,78E-03	3,05E-03	8,9
51250	3,45E-03	2,99E-03	13,1	51167	3,00E-03	3,26E-03	8,0
51253	3,04E-03	2,56E-03	15,8	51170	3,20E-03	3,46E-03	7,5
51256	2,99E-03	2,45E-03	18,1	51173	3,45E-03	3,72E-03	7,2
51260	2,78E-03	2,29E-03	17,8	51177	3,30E-03	3,61E-03	8,6
51261	2,86E-03	2,31E-03	19,3	51178	3,53E-03	3,83E-03	7,9
51265	2,91E-03	2,45E-03	15,9	51182	3,09E-03	3,43E-03	9,8
51268	3,09E-03	2,67E-03	13,7	51185	2,93E-03	3,29E-03	10,8
51271	3,28E-03	2,93E-03	10,7	51188	2,76E-03	3,13E-03	11,7
51274	3,47E-03	3,23E-03	7,2	51191	2,62E-03	3,00E-03	12,5
51277	3,80E-03	3,59E-03	5,7	51194	2,57E-03	2,96E-03	13,1
51281	3,02E-03	2,43E-03	19,5	51198	3,60E-03	3,90E-03	7,6
51286	4,13E-03	3,91E-03	5,4	51204	2,51E-03	2,92E-03	13,8
SUM:	**2,18E-01**	**1,92E-01**	**11,5**	**SUM:**	**1,83E-01**	**2,04E-01**	**10,3**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 9 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 17	Pos 1	Pos 3		SG 18	Pos 1	Pos 3	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9707	1,51E-03	2,27E-03	33,6	9683	2,14E-03	2,15E-03	0,4
9708	1,32E-03	2,10E-03	36,9	9684	2,36E-03	2,32E-03	1,6
9709	1,41E-03	2,20E-03	35,9	9685	1,96E-03	2,00E-03	2,2
9710	1,35E-03	2,15E-03	37,1	9686	2,23E-03	2,21E-03	1,2
9711	1,34E-03	2,13E-03	37,5	9687	2,10E-03	2,10E-03	0,1
9712	1,35E-03	2,17E-03	37,9	9688	1,97E-03	2,03E-03	3,2
9713	1,38E-03	2,18E-03	37,0	9689	2,27E-03	2,24E-03	1,2
9714	1,49E-03	2,27E-03	34,4	9690	2,39E-03	2,34E-03	1,9
9715	1,79E-03	2,40E-03	25,4	9691	2,46E-03	2,40E-03	2,6
9716	1,67E-03	2,31E-03	27,5	9692	2,43E-03	2,38E-03	2,3
9717	1,67E-03	2,33E-03	28,4	9693	2,36E-03	2,32E-03	1,5
9718	1,65E-03	2,33E-03	29,4	9694	2,27E-03	2,25E-03	0,8
9719	1,60E-03	2,27E-03	29,3	9695	2,05E-03	2,09E-03	1,8
9720	1,62E-03	2,24E-03	27,4	9696	1,87E-03	2,00E-03	6,4
9721	1,62E-03	2,19E-03	25,9	9697	1,84E-03	1,91E-03	3,5
9722	1,60E-03	2,22E-03	27,7	9698	1,99E-03	2,00E-03	0,2
9723	1,60E-03	2,24E-03	28,8	9699	2,10E-03	2,08E-03	1,0
9724	1,59E-03	2,24E-03	29,1	9700	2,22E-03	2,19E-03	1,6
9725	1,59E-03	2,25E-03	29,3	9701	2,34E-03	2,30E-03	1,5
9726	1,61E-03	2,21E-03	27,3	9702	2,45E-03	2,42E-03	1,4
9727	1,60E-03	2,34E-03	31,5	9703	1,79E-03	1,93E-03	7,3
9728	1,61E-03	2,32E-03	30,7	9704	1,83E-03	1,98E-03	7,6
9729	1,33E-03	2,05E-03	35,3	9705	2,51E-03	2,45E-03	2,5
9730	1,35E-03	2,09E-03	35,6	9706	2,50E-03	2,46E-03	1,8
51043	1,46E-03	2,24E-03	34,7	50961	2,12E-03	2,13E-03	0,2
51044	1,50E-03	2,27E-03	34,0	50962	2,05E-03	2,09E-03	1,7
51045	1,55E-03	2,26E-03	31,5	50963	2,20E-03	2,19E-03	0,4
51046	1,56E-03	2,29E-03	32,2	50964	2,21E-03	2,20E-03	0,2
51048	1,34E-03	2,12E-03	37,0	50966	2,30E-03	2,27E-03	1,4
51049	1,33E-03	2,12E-03	37,2	50967	2,37E-03	2,33E-03	1,7
51050	1,46E-03	2,16E-03	32,2	50968	2,35E-03	2,31E-03	1,6
51051	1,32E-03	2,07E-03	36,1	50969	2,43E-03	2,39E-03	1,7
51053	1,38E-03	2,18E-03	36,5	50971	2,03E-03	2,05E-03	1,1
51054	1,39E-03	2,19E-03	36,4	50972	1,96E-03	2,02E-03	2,7
51055	1,50E-03	2,22E-03	32,5	50973	1,97E-03	2,00E-03	1,2
51057	1,35E-03	2,16E-03	37,5	50974	1,87E-03	1,96E-03	4,7
51058	1,47E-03	2,20E-03	32,9	50976	2,17E-03	2,15E-03	0,6
51060	1,34E-03	2,15E-03	37,7	50977	2,25E-03	2,22E-03	1,2
51061	1,47E-03	2,20E-03	33,3	50978	2,23E-03	2,20E-03	1,4
51062	1,34E-03	2,11E-03	36,6	50980	2,10E-03	2,09E-03	0,5
51064	1,36E-03	2,18E-03	37,4	50982	2,01E-03	2,06E-03	2,5
51065	1,50E-03	2,25E-03	33,5	50983	1,90E-03	2,01E-03	5,4
51067	1,44E-03	2,23E-03	35,6	50985	2,33E-03	2,29E-03	1,5
51068	1,52E-03	2,26E-03	32,5	50986	2,31E-03	2,28E-03	1,3
51070	1,58E-03	2,29E-03	30,9	50988	2,41E-03	2,36E-03	2,1
51071	1,55E-03	2,30E-03	32,9	50989	2,45E-03	2,40E-03	2,2
51073	1,73E-03	2,35E-03	26,5	50991	2,45E-03	2,39E-03	2,4
51074	1,69E-03	2,37E-03	28,4	50992	2,49E-03	2,43E-03	2,5
51078	1,67E-03	2,32E-03	27,9	50996	2,39E-03	2,35E-03	1,9
51081	1,66E-03	2,33E-03	28,9	50999	2,32E-03	2,29E-03	1,1
51084	1,62E-03	2,30E-03	29,4	51002	2,16E-03	2,17E-03	0,5
51087	1,61E-03	2,25E-03	28,4	51005	1,96E-03	2,05E-03	4,1
51090	1,49E-03	2,17E-03	31,4	51008	1,85E-03	1,99E-03	7,0
51094	1,61E-03	2,20E-03	26,8	51012	1,92E-03	1,95E-03	1,9
51095	1,47E-03	2,12E-03	30,4	51013	1,82E-03	1,92E-03	5,4
51099	1,60E-03	2,23E-03	28,2	51017	2,05E-03	2,04E-03	0,4
51102	1,59E-03	2,24E-03	28,9	51020	2,16E-03	2,13E-03	1,3
51105	1,59E-03	2,24E-03	29,2	51023	2,28E-03	2,24E-03	1,6
51108	1,60E-03	2,23E-03	28,3	51026	2,39E-03	2,36E-03	1,4
51111	1,61E-03	2,26E-03	29,0	51029	2,48E-03	2,44E-03	1,6
51115	1,60E-03	2,33E-03	31,1	51033	1,81E-03	1,96E-03	7,4
51120	1,34E-03	2,07E-03	35,5	51038	2,51E-03	2,45E-03	2,2
SUM:	**9,39E-02**	**1,38E-01**	**32,0**	**SUM:**	**1,36E-01**	**1,36E-01**	**0,1**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 10 of 16

Node numbers and associated strains [mm/mm] exported from ansys

SG 19	**Pos 1**	**Pos 3**		**SG 20**	**Pos 1**	**Pos 3**	
Node	Strain	Strain	Diff %	Node	Strain	Strain	Diff %
9659	2,28E-03	2,12E-03	7,0	9899	1,26E-03	4,67E-04	62,8
9660	2,81E-03	2,76E-03	1,8	9900	4,64E-04	-3,37E-04	172,6
9661	2,55E-03	2,46E-03	3,3	9901	1,94E-04	-5,80E-04	398,4
9662	2,32E-03	2,21E-03	4,9	9902	8,49E-04	5,03E-05	94,1
9663	2,07E-03	1,90E-03	8,3	9903	1,50E-03	7,16E-04	52,2
9664	2,51E-03	2,41E-03	4,1	9904	5,10E-04	-2,76E-04	154,2
9665	2,71E-03	2,64E-03	2,6	9905	8,87E-04	9,38E-05	89,4
9666	2,68E-03	2,61E-03	2,5	9906	2,05E-04	-5,57E-04	372,4
9667	1,29E-03	1,09E-03	16,0	9907	2,26E-03	1,52E-03	32,8
9668	1,74E-03	1,59E-03	8,9	9908	1,74E-03	1,00E-03	42,3
9669	2,08E-03	1,96E-03	6,1	9909	1,14E-03	4,17E-04	63,5
9670	2,34E-03	2,23E-03	4,7	9910	4,97E-04	-1,89E-04	138,1
9671	2,54E-03	2,42E-03	4,6	9911	1,25E-04	-5,31E-04	524,8
9672	2,60E-03	2,52E-03	3,1	9912	-4,33E-05	-6,51E-04	1405,9
9673	2,81E-03	2,79E-03	0,6	9913	-1,52E-05	-6,64E-04	4257,4
9674	2,81E-03	2,77E-03	1,3	9914	1,24E-04	-5,70E-04	559,0
9675	2,73E-03	2,70E-03	1,2	9915	3,32E-04	-3,81E-04	214,9
9676	2,68E-03	2,56E-03	4,4	9916	5,84E-04	-1,31E-04	122,5
9677	2,44E-03	2,29E-03	6,5	9917	1,04E-03	3,36E-04	67,7
9678	2,14E-03	1,92E-03	10,0	9918	1,43E-03	7,31E-04	48,9
9679	2,84E-03	2,80E-03	1,2	9919	3,61E-05	-6,90E-04	2009,7
9680	2,74E-03	2,68E-03	2,2	9920	4,88E-05	-6,61E-04	1455,5
9681	1,62E-03	1,39E-03	14,2	9921	1,97E-03	1,22E-03	37,8
9682	1,81E-03	1,62E-03	10,4	9922	1,72E-03	9,64E-04	43,9
50879	2,17E-03	2,01E-03	7,6	51703	1,05E-03	2,59E-04	75,4
50880	2,39E-03	2,26E-03	5,5	51704	1,38E-03	5,92E-04	57,0
50881	2,36E-03	2,20E-03	6,7	51705	1,15E-03	4,01E-04	65,1
50882	2,04E-03	1,87E-03	8,5	51706	1,49E-03	7,16E-04	51,9
50884	2,76E-03	2,70E-03	2,2	51708	3,30E-04	-4,59E-04	239,1
50885	2,74E-03	2,69E-03	2,2	51709	6,57E-04	-1,44E-04	121,9
50886	2,81E-03	2,77E-03	1,6	51710	4,87E-04	-3,07E-04	163,0
50887	2,82E-03	2,78E-03	1,5	51711	3,98E-04	-3,59E-04	190,3
50889	2,44E-03	2,34E-03	4,0	51713	1,99E-04	-5,69E-04	385,0
50890	2,63E-03	2,55E-03	3,0	51714	1,59E-04	-5,75E-04	461,0
50891	2,61E-03	2,54E-03	2,9	51715	1,15E-04	-6,35E-04	649,6
50892	2,44E-03	2,35E-03	4,0	51717	8,68E-04	7,20E-05	91,7
50894	2,20E-03	2,05E-03	6,5	51718	7,16E-04	-4,05E-05	105,7
50895	2,42E-03	2,31E-03	4,5	51720	1,19E-03	4,05E-04	66,0
50896	2,20E-03	2,08E-03	5,4	51721	1,62E-03	8,59E-04	46,9
50898	1,90E-03	1,74E-03	8,5	51722	1,73E-03	9,70E-04	44,0
50899	1,84E-03	1,64E-03	10,9	51724	6,99E-04	-9,14E-05	113,1
50901	2,61E-03	2,53E-03	3,3	51725	3,58E-04	-4,17E-04	216,4
50902	2,59E-03	2,48E-03	4,3	51726	5,04E-04	-2,33E-04	146,2
50904	2,72E-03	2,67E-03	1,9	51728	1,02E-03	2,56E-04	74,8
50906	2,61E-03	2,52E-03	3,5	51730	1,65E-04	-5,44E-04	430,2
50907	2,71E-03	2,65E-03	2,4	51731	1,27E-04	-6,09E-04	579,7
50909	1,52E-03	1,34E-03	11,9	51733	2,00E-03	1,26E-03	36,9
50910	1,46E-03	1,24E-03	15,0	51734	2,12E-03	1,37E-03	35,1
50914	1,91E-03	1,77E-03	7,3	51737	1,44E-03	7,08E-04	50,8
50917	2,21E-03	2,09E-03	5,4	51740	8,20E-04	1,14E-04	86,1
50920	2,44E-03	2,33E-03	4,7	51743	3,11E-04	-3,61E-04	216,1
50923	2,57E-03	2,47E-03	3,9	51746	4,07E-05	-5,92E-04	1553,5
50926	2,67E-03	2,60E-03	2,7	51749	2,77E-06	-6,56E-04	23794,6
50930	2,81E-03	2,78E-03	1,0	51753	5,42E-05	-6,17E-04	1238,5
50931	2,82E-03	2,80E-03	0,9	51754	1,04E-05	-6,77E-04	6579,3
50935	2,77E-03	2,74E-03	1,2	51758	2,28E-04	-4,76E-04	308,8
50938	2,71E-03	2,63E-03	2,8	51761	4,58E-04	-2,56E-04	155,9
50941	2,56E-03	2,42E-03	5,4	51764	8,13E-04	1,02E-04	87,4
50944	2,29E-03	2,10E-03	8,1	51767	1,24E-03	5,33E-04	56,9
50947	1,97E-03	1,77E-03	10,2	51770	1,58E-03	8,48E-04	46,2
50951	2,79E-03	2,74E-03	1,7	51774	4,25E-05	-6,76E-04	1691,3
50956	1,71E-03	1,50E-03	12,2	51779	1,84E-03	1,09E-03	40,7
SUM:	**1,48E-01**	**1,41E-01**	**4,7**	**SUM:**	**4,83E-02**	**2,57E-03**	**94,7**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 11 of 16

Analyses results

	20 Strain gauges				10 strain gauges, even numbers		
	SUM Pos 1	SUM Pos 2	Diff %		SUM Pos 1	SUM Pos 3	Diff %
	4,59E-02	4,58E-02	0,3		2,22E-02	2,16E-02	2,8
	4,68E-02	4,70E-02	0,3		2,25E-02	2,20E-02	2,1
	4,73E-02	4,73E-02	0,1		2,24E-02	2,20E-02	1,8
	4,71E-02	4,69E-02	0,6		2,27E-02	2,21E-02	2,6
	4,73E-02	4,72E-02	0,3		2,41E-02	2,37E-02	1,7
	4,68E-02	4,66E-02	0,4		2,34E-02	2,30E-02	1,9
	4,58E-02	4,56E-02	0,5		2,29E-02	2,23E-02	2,6
	4,64E-02	4,61E-02	0,7		2,25E-02	2,18E-02	3,1
	4,75E-02	4,66E-02	1,8		2,32E-02	2,25E-02	3,1
	4,78E-02	4,70E-02	1,5		2,31E-02	2,25E-02	2,8
	4,78E-02	4,83E-02	0,9		2,35E-02	2,33E-02	1,1
	4,76E-02	4,81E-02	1,2		2,30E-02	2,29E-02	0,7
	4,46E-02	4,40E-02	1,4		2,15E-02	2,08E-02	2,9
	4,47E-02	4,44E-02	0,7		2,13E-02	2,11E-02	1,0
	4,57E-02	4,64E-02	1,6		2,27E-02	2,27E-02	0,2
	4,62E-02	4,70E-02	1,8		2,27E-02	2,27E-02	0,2
	4,61E-02	4,67E-02	1,4		2,25E-02	2,23E-02	0,7
	4,69E-02	4,70E-02	0,2		2,28E-02	2,25E-02	1,4
	4,76E-02	4,73E-02	0,5		2,30E-02	2,25E-02	2,2
	4,81E-02	4,81E-02	0,1		2,38E-02	2,35E-02	1,2
	4,69E-02	4,71E-02	0,2		2,33E-02	2,32E-02	0,5
	4,56E-02	4,57E-02	0,3		2,24E-02	2,22E-02	0,9
	4,71E-02	4,68E-02	0,7		2,29E-02	2,24E-02	2,3
	4,82E-02	4,83E-02	0,2		2,37E-02	2,34E-02	1,4
	4,59E-02	4,57E-02	0,3		2,20E-02	2,14E-02	2,8
	4,57E-02	4,57E-02	0,0		2,22E-02	2,16E-02	2,7
	4,60E-02	4,59E-02	0,3		2,23E-02	2,18E-02	2,6
	4,68E-02	4,67E-02	0,1		2,30E-02	2,26E-02	1,7
	4,69E-02	4,71E-02	0,5		2,24E-02	2,20E-02	1,8
	4,74E-02	4,74E-02	0,1		2,31E-02	2,26E-02	2,1
	4,73E-02	4,74E-02	0,1		2,27E-02	2,24E-02	1,3
	4,68E-02	4,67E-02	0,2		2,30E-02	2,25E-02	2,2
	4,75E-02	4,75E-02	0,2		2,30E-02	2,26E-02	1,8
	4,73E-02	4,72E-02	0,2		2,28E-02	2,24E-02	1,8
	4,84E-02	4,80E-02	0,8		2,36E-02	2,31E-02	2,1
	4,80E-02	4,78E-02	0,4		2,32E-02	2,29E-02	1,4
	4,72E-02	4,71E-02	0,1		2,32E-02	2,28E-02	1,7
	4,78E-02	4,79E-02	0,2		2,39E-02	2,34E-02	2,0
	4,73E-02	4,75E-02	0,5		2,37E-02	2,32E-02	2,2
	4,56E-02	4,55E-02	0,2		2,30E-02	2,25E-02	2,3
	4,40E-02	4,39E-02	0,1		2,18E-02	2,11E-02	3,1
	4,55E-02	4,55E-02	0,1		2,20E-02	2,15E-02	2,1
	4,54E-02	4,47E-02	1,7		2,25E-02	2,18E-02	3,2
	4,58E-02	4,50E-02	1,7		2,29E-02	2,22E-02	3,1
	4,60E-02	4,53E-02	1,6		2,18E-02	2,12E-02	2,8
	4,78E-02	4,79E-02	0,4		2,34E-02	2,30E-02	1,5
	4,88E-02	4,93E-02	1,0		2,42E-02	2,40E-02	0,7
	4,84E-02	4,87E-02	0,6		2,40E-02	2,38E-02	1,0
	4,71E-02	4,63E-02	1,6		2,28E-02	2,21E-02	3,1
	4,66E-02	4,62E-02	0,8		2,22E-02	2,18E-02	2,0
	4,73E-02	4,79E-02	1,2		2,31E-02	2,30E-02	0,6
	4,63E-02	4,70E-02	1,5		2,24E-02	2,25E-02	0,4
	4,55E-02	4,60E-02	1,0		2,19E-02	2,19E-02	0,2
	4,54E-02	4,60E-02	1,4		2,21E-02	2,21E-02	0,1
	4,56E-02	4,60E-02	0,9		2,25E-02	2,26E-02	0,2
	4,55E-02	4,57E-02	0,4		2,20E-02	2,17E-02	1,4
	4,65E-02	4,66E-02	0,3		2,27E-02	2,23E-02	1,6
	4,71E-02	4,69E-02	0,5		2,28E-02	2,23E-02	2,3
	4,86E-02	4,85E-02	0,1		2,39E-02	2,35E-02	1,6
	4,80E-02	4,77E-02	0,6		2,37E-02	2,32E-02	2,0
	4,68E-02	4,70E-02	0,6		2,32E-02	2,31E-02	0,2
	4,72E-02	4,71E-02	0,4		2,31E-02	2,26E-02	2,0
SUM ALL:	**2,90E+00**	**2,90E+00**	**0,0**	**SUM ALL:**	**1,42E+00**	**1,39E+00**	**1,7**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 12 of 16

Analyses results

	10 strain gauges, odd numbers				4 strain gauges (1, 6, 11, 16)		
	SUM Pos 1	SUM Pos 3	Diff %		SUM Pos 1	SUM Pos 3	Diff %
	2,37E-02	2,42E-02	2,1		1,03E-02	1,06E-02	2,9
	2,43E-02	2,49E-02	2,5		1,12E-02	1,16E-02	3,5
	2,49E-02	2,53E-02	1,7		1,14E-02	1,16E-02	1,7
	2,44E-02	2,47E-02	1,4		1,07E-02	1,09E-02	2,2
	2,32E-02	2,34E-02	1,1		1,09E-02	1,11E-02	1,8
	2,34E-02	2,37E-02	1,1		1,15E-02	1,15E-02	0,4
	2,29E-02	2,33E-02	1,6		1,06E-02	1,05E-02	1,0
	2,40E-02	2,44E-02	1,6		1,12E-02	1,11E-02	1,2
	2,43E-02	2,41E-02	0,6		1,07E-02	1,06E-02	0,2
	2,46E-02	2,46E-02	0,3		1,11E-02	1,09E-02	2,0
	2,43E-02	2,50E-02	2,8		1,04E-02	1,01E-02	2,7
	2,45E-02	2,53E-02	2,9		1,08E-02	1,06E-02	2,5
	2,31E-02	2,31E-02	0,0		1,10E-02	1,08E-02	2,6
	2,35E-02	2,34E-02	0,4		1,18E-02	1,16E-02	1,6
	2,30E-02	2,38E-02	3,4		1,08E-02	1,12E-02	3,5
	2,34E-02	2,43E-02	3,7		1,07E-02	1,09E-02	2,5
	2,36E-02	2,44E-02	3,3		1,11E-02	1,12E-02	1,3
	2,41E-02	2,45E-02	1,7		1,09E-02	1,09E-02	0,3
	2,46E-02	2,48E-02	1,1		1,05E-02	1,06E-02	0,9
	2,43E-02	2,46E-02	1,4		1,05E-02	1,05E-02	0,4
	2,36E-02	2,38E-02	1,0		1,20E-02	1,20E-02	0,5
	2,32E-02	2,35E-02	1,4		1,21E-02	1,22E-02	0,3
	2,42E-02	2,44E-02	0,7		1,03E-02	1,02E-02	0,5
	2,45E-02	2,49E-02	1,8		1,09E-02	1,10E-02	1,0
	2,38E-02	2,43E-02	1,9		1,02E-02	1,05E-02	2,8
	2,35E-02	2,41E-02	2,5		1,03E-02	1,06E-02	2,5
	2,37E-02	2,41E-02	1,9		1,03E-02	1,05E-02	1,9
	2,38E-02	2,41E-02	1,4		1,06E-02	1,10E-02	3,3
	2,45E-02	2,51E-02	2,6		1,13E-02	1,16E-02	2,7
	2,43E-02	2,48E-02	2,2		1,13E-02	1,17E-02	3,1
	2,47E-02	2,50E-02	1,5		1,14E-02	1,17E-02	2,2
	2,39E-02	2,43E-02	1,6		1,11E-02	1,15E-02	2,8
	2,46E-02	2,49E-02	1,3		1,16E-02	1,17E-02	1,2
	2,44E-02	2,48E-02	1,3		1,11E-02	1,10E-02	1,0
	2,48E-02	2,49E-02	0,4		1,13E-02	1,11E-02	1,5
	2,48E-02	2,49E-02	0,6		1,07E-02	1,06E-02	1,8
	2,40E-02	2,43E-02	1,4		1,11E-02	1,12E-02	1,0
	2,39E-02	2,45E-02	2,3		1,15E-02	1,15E-02	0,4
	2,36E-02	2,43E-02	3,1		1,10E-02	1,10E-02	0,6
	2,26E-02	2,31E-02	1,9		1,04E-02	1,05E-02	0,3
	2,22E-02	2,28E-02	2,7		1,04E-02	1,04E-02	0,7
	2,35E-02	2,40E-02	2,0		1,12E-02	1,11E-02	1,4
	2,29E-02	2,29E-02	0,1		1,14E-02	1,14E-02	0,3
	2,29E-02	2,28E-02	0,3		1,13E-02	1,13E-02	0,6
	2,42E-02	2,41E-02	0,4		1,12E-02	1,11E-02	0,6
	2,44E-02	2,49E-02	2,1		1,14E-02	1,13E-02	0,9
	2,47E-02	2,53E-02	2,6		1,03E-02	1,01E-02	2,2
	2,44E-02	2,49E-02	2,1		1,03E-02	1,01E-02	2,0
	2,43E-02	2,42E-02	0,1		1,08E-02	1,05E-02	3,1
	2,44E-02	2,45E-02	0,2		1,10E-02	1,08E-02	1,8
	2,42E-02	2,49E-02	2,8		1,10E-02	1,10E-02	0,1
	2,39E-02	2,46E-02	2,5		1,13E-02	1,12E-02	0,8
	2,37E-02	2,41E-02	1,8		1,19E-02	1,18E-02	1,1
	2,32E-02	2,39E-02	2,9		1,13E-02	1,14E-02	1,3
	2,31E-02	2,35E-02	1,5		1,18E-02	1,19E-02	0,9
	2,35E-02	2,40E-02	2,1		1,09E-02	1,10E-02	0,5
	2,38E-02	2,43E-02	2,2		1,09E-02	1,10E-02	0,8
	2,43E-02	2,46E-02	1,1		1,06E-02	1,07E-02	0,6
	2,47E-02	2,50E-02	1,3		1,07E-02	1,08E-02	0,9
	2,43E-02	2,45E-02	0,9		1,05E-02	1,05E-02	0,4
	2,36E-02	2,39E-02	1,4		1,21E-02	1,21E-02	0,3
	2,42E-02	2,45E-02	1,2		1,08E-02	1,09E-02	0,6
SUM ALL:	**1,48E+00**	**1,51E+00**	**1,6**	**SUM ALL:**	**6,82E-01**	**6,84E-01**	**0,3**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 13 of 16

Analyses results

	4 strain gauges (2, 7, 12, 17)				4 strain gauges (3, 8, 13, 18)		
	SUM Pos 1	**SUM Pos 3**	**Diff %**		**SUM Pos 1**	**SUM Pos 3**	**Diff %**
	6,86E-03	6,73E-03	1,9		9,33E-03	9,36E-03	0,3
	6,46E-03	6,52E-03	0,9		9,53E-03	9,35E-03	1,9
	6,58E-03	6,68E-03	1,4		9,04E-03	8,89E-03	1,7
	6,56E-03	6,54E-03	0,3		9,36E-03	9,03E-03	3,6
	6,78E-03	6,69E-03	1,3		8,23E-03	8,07E-03	1,9
	6,57E-03	6,62E-03	0,8		8,48E-03	8,38E-03	1,2
	6,48E-03	6,53E-03	0,9		8,81E-03	8,70E-03	1,2
	6,84E-03	6,97E-03	1,8		9,83E-03	9,64E-03	1,9
	7,41E-03	7,37E-03	0,6		9,43E-03	8,92E-03	5,4
	7,27E-03	7,16E-03	1,5		9,03E-03	8,63E-03	4,4
	6,99E-03	7,10E-03	1,6		1,00E-02	1,01E-02	1,2
	6,84E-03	6,87E-03	0,4		9,94E-03	1,02E-02	2,2
	7,38E-03	7,23E-03	2,0		8,03E-03	8,00E-03	0,4
	7,43E-03	7,25E-03	2,5		7,79E-03	7,73E-03	0,8
	7,41E-03	7,44E-03	0,5		8,68E-03	8,85E-03	2,0
	7,03E-03	6,97E-03	0,7		9,14E-03	9,33E-03	2,0
	7,02E-03	6,90E-03	1,7		8,84E-03	8,93E-03	1,0
	7,24E-03	7,05E-03	2,6		9,13E-03	9,00E-03	1,5
	7,48E-03	7,22E-03	3,5		9,08E-03	8,76E-03	3,5
	7,18E-03	6,91E-03	3,8		9,81E-03	9,55E-03	2,6
	7,28E-03	7,27E-03	0,2		8,18E-03	8,12E-03	0,7
	7,05E-03	7,00E-03	0,7		8,27E-03	8,29E-03	0,2
	6,29E-03	6,17E-03	1,9		9,89E-03	9,56E-03	3,4
	6,32E-03	6,23E-03	1,5		1,02E-02	9,85E-03	3,4
	6,73E-03	6,64E-03	1,2		9,35E-03	9,30E-03	0,6
	6,75E-03	6,68E-03	1,0		9,16E-03	9,29E-03	1,4
	7,01E-03	6,80E-03	3,1		9,34E-03	9,37E-03	0,3
	6,71E-03	6,63E-03	1,2		9,28E-03	9,18E-03	1,1
	6,43E-03	6,43E-03	0,0		9,44E-03	9,30E-03	1,4
	6,43E-03	6,48E-03	0,8		9,16E-03	8,92E-03	2,7
	6,71E-03	6,71E-03	0,1		9,35E-03	9,08E-03	2,9
	6,65E-03	6,67E-03	0,3		9,07E-03	8,75E-03	3,5
	6,68E-03	6,66E-03	0,3		8,90E-03	8,66E-03	2,7
	6,73E-03	6,80E-03	1,0		8,71E-03	8,60E-03	1,3
	7,16E-03	7,12E-03	0,6		8,62E-03	8,34E-03	3,3
	6,88E-03	6,92E-03	0,5		8,69E-03	8,49E-03	2,2
	6,76E-03	6,72E-03	0,6		9,46E-03	9,15E-03	3,3
	6,66E-03	6,60E-03	0,8		8,56E-03	8,43E-03	1,5
	6,89E-03	6,92E-03	0,4		9,01E-03	8,99E-03	0,2
	6,74E-03	6,69E-03	0,8		8,64E-03	8,59E-03	0,6
	6,38E-03	6,50E-03	1,9		9,02E-03	9,13E-03	1,2
	6,56E-03	6,58E-03	0,4		8,91E-03	9,05E-03	1,5
	6,89E-03	6,92E-03	0,4		8,28E-03	7,99E-03	3,5
	6,95E-03	6,78E-03	2,4		8,06E-03	7,78E-03	3,5
	7,13E-03	7,03E-03	1,4		9,01E-03	8,62E-03	4,3
	6,82E-03	6,97E-03	2,1		1,04E-02	1,03E-02	1,1
	6,97E-03	6,98E-03	0,0		1,04E-02	1,04E-02	0,0
	6,75E-03	6,73E-03	0,4		1,04E-02	1,03E-02	1,3
	7,36E-03	7,21E-03	2,1		8,87E-03	8,60E-03	3,1
	7,21E-03	7,06E-03	2,0		8,80E-03	8,60E-03	2,3
	6,97E-03	6,97E-03	0,0		9,57E-03	9,81E-03	2,5
	6,96E-03	6,92E-03	0,6		9,11E-03	9,41E-03	3,2
	6,88E-03	6,85E-03	0,4		8,38E-03	8,59E-03	2,5
	7,13E-03	7,09E-03	0,7		8,51E-03	8,61E-03	1,1
	7,16E-03	7,10E-03	0,8		7,79E-03	7,78E-03	0,1
	7,13E-03	6,98E-03	2,1		8,62E-03	8,59E-03	0,3
	7,19E-03	7,01E-03	2,6		9,03E-03	8,88E-03	1,6
	7,43E-03	7,19E-03	3,2		9,08E-03	8,78E-03	3,3
	7,25E-03	7,01E-03	3,3		9,57E-03	9,29E-03	2,9
	7,05E-03	6,80E-03	3,6		9,87E-03	9,41E-03	4,7
	7,07E-03	7,06E-03	0,2		8,37E-03	8,41E-03	0,5
	6,31E-03	6,20E-03	1,7		1,00E-02	9,70E-03	3,4
SUM ALL:	**4,28E-01**	**4,25E-01**	**0,8**	**SUM ALL:**	**5,63E-01**	**5,56E-01**	**1,3**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 14 of 16

Analyses results

	4 strain gauges (4, 9, 14, 19)				4 strain gauges (5, 10, 15, 20)		
	SUM Pos 1	SUM Pos 3	Diff %		SUM Pos 1	SUM Pos 3	Diff %
	1,30E-02	1,28E-02	1,7		6,43E-03	6,32E-03	1,8
	1,36E-02	1,35E-02	0,5		6,10E-03	6,03E-03	1,1
	1,34E-02	1,33E-02	1,0		6,77E-03	6,82E-03	0,7
	1,29E-02	1,28E-02	0,7		7,61E-03	7,56E-03	0,7
	1,17E-02	1,18E-02	1,0		9,72E-03	9,50E-03	2,3
	1,28E-02	1,30E-02	1,4		7,43E-03	7,16E-03	3,6
	1,33E-02	1,35E-02	1,3		6,65E-03	6,41E-03	3,6
	1,32E-02	1,33E-02	0,6		5,33E-03	5,13E-03	3,9
	1,07E-02	1,07E-02	0,5		9,23E-03	9,00E-03	2,4
	1,13E-02	1,15E-02	1,6		9,03E-03	8,86E-03	1,9
	1,24E-02	1,25E-02	0,8		7,99E-03	8,38E-03	4,7
	1,28E-02	1,30E-02	1,4		7,13E-03	7,55E-03	5,5
	1,14E-02	1,17E-02	2,7		6,70E-03	6,24E-03	6,9
	1,17E-02	1,21E-02	3,6		5,99E-03	5,67E-03	5,3
	1,28E-02	1,27E-02	0,4		6,03E-03	6,23E-03	3,2
	1,32E-02	1,34E-02	0,8		6,08E-03	6,42E-03	5,3
	1,34E-02	1,37E-02	2,0		5,69E-03	5,93E-03	4,1
	1,37E-02	1,39E-02	1,6		5,98E-03	6,13E-03	2,5
	1,32E-02	1,35E-02	1,9		7,27E-03	7,27E-03	0,0
	1,28E-02	1,30E-02	1,7		7,73E-03	8,13E-03	4,9
	1,30E-02	1,32E-02	1,7		6,55E-03	6,45E-03	1,6
	1,28E-02	1,30E-02	2,0		5,37E-03	5,22E-03	2,8
	1,16E-02	1,16E-02	0,3		9,07E-03	9,18E-03	1,3
	1,24E-02	1,24E-02	0,0		8,36E-03	8,81E-03	5,0
	1,30E-02	1,28E-02	1,8		6,56E-03	6,48E-03	1,2
	1,30E-02	1,28E-02	1,5		6,41E-03	6,28E-03	2,0
	1,31E-02	1,30E-02	0,8		6,22E-03	6,19E-03	0,4
	1,28E-02	1,26E-02	1,1		7,38E-03	7,30E-03	1,1
	1,36E-02	1,36E-02	0,2		6,13E-03	6,18E-03	0,7
	1,34E-02	1,34E-02	0,3		7,06E-03	6,96E-03	1,3
	1,33E-02	1,34E-02	0,9		6,54E-03	6,49E-03	0,6
	1,29E-02	1,29E-02	0,1		7,05E-03	6,91E-03	2,0
	1,30E-02	1,30E-02	0,1		7,35E-03	7,37E-03	0,3
	1,26E-02	1,28E-02	1,4		8,12E-03	8,02E-03	1,3
	1,21E-02	1,23E-02	1,9		9,21E-03	9,09E-03	1,3
	1,25E-02	1,27E-02	1,6		9,21E-03	9,18E-03	0,3
	1,24E-02	1,26E-02	1,5		7,42E-03	7,41E-03	0,1
	1,27E-02	1,29E-02	1,4		8,43E-03	8,48E-03	0,5
	1,26E-02	1,27E-02	1,2		7,88E-03	7,86E-03	0,2
	1,23E-02	1,25E-02	0,9		7,46E-03	7,34E-03	1,6
	1,25E-02	1,25E-02	0,4		5,63E-03	5,48E-03	2,8
	1,34E-02	1,35E-02	1,2		5,42E-03	5,28E-03	2,5
	1,27E-02	1,28E-02	0,6		6,14E-03	5,61E-03	8,6
	1,25E-02	1,27E-02	2,1		7,03E-03	6,49E-03	7,7
	1,26E-02	1,28E-02	1,1		6,05E-03	5,75E-03	5,0
	1,31E-02	1,32E-02	0,4		6,03E-03	6,23E-03	3,3
	1,17E-02	1,17E-02	0,7		9,46E-03	1,01E-02	6,0
	1,17E-02	1,18E-02	0,7		9,26E-03	9,84E-03	5,8
	1,10E-02	1,13E-02	2,8		9,01E-03	8,72E-03	3,2
	1,19E-02	1,22E-02	2,9		7,76E-03	7,56E-03	2,5
	1,28E-02	1,28E-02	0,2		6,97E-03	7,29E-03	4,3
	1,29E-02	1,31E-02	1,4		6,04E-03	6,39E-03	5,5
	1,30E-02	1,33E-02	2,2		5,34E-03	5,47E-03	2,4
	1,32E-02	1,35E-02	1,7		5,19E-03	5,43E-03	4,4
	1,32E-02	1,35E-02	1,9		5,62E-03	5,71E-03	1,6
	1,34E-02	1,37E-02	1,9		5,37E-03	5,42E-03	0,8
	1,37E-02	1,39E-02	1,7		5,66E-03	5,83E-03	2,9
	1,32E-02	1,34E-02	1,7		6,78E-03	6,77E-03	0,2
	1,28E-02	1,30E-02	1,6		8,25E-03	8,41E-03	2,0
	1,25E-02	1,26E-02	1,0		8,11E-03	8,39E-03	3,3
	1,29E-02	1,31E-02	2,0		6,38E-03	6,32E-03	0,8
	1,15E-02	1,16E-02	0,7		8,54E-03	8,67E-03	1,5
SUM ALL:	**7,87E-01**	**7,94E-01**	**0,9**	**SUM ALL:**	**4,39E-01**	**4,39E-01**	**0,1**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 15 of 16

Analyses results

	2 Strain gauges (1, 11)				2 Strain gauges (2, 12)		
	SUM Pos 1	SUM Pos 3	Diff %		SUM Pos 1	SUM Pos 3	Diff %
	4,81E-03	5,15E-03	6,5		3,29E-03	2,95E-03	10,3
	4,97E-03	5,39E-03	7,8		3,16E-03	2,96E-03	6,5
	5,08E-03	5,33E-03	4,7		3,16E-03	3,00E-03	5,0
	5,07E-03	5,43E-03	6,6		3,13E-03	2,88E-03	8,2
	5,08E-03	5,23E-03	2,8		3,26E-03	2,93E-03	10,0
	5,21E-03	5,25E-03	0,8		3,24E-03	3,00E-03	7,5
	5,00E-03	4,99E-03	0,3		3,15E-03	2,91E-03	7,7
	5,17E-03	5,25E-03	1,5		3,19E-03	3,10E-03	2,9
	4,97E-03	4,99E-03	0,4		3,57E-03	3,31E-03	7,4
	5,24E-03	5,20E-03	0,8		3,51E-03	3,18E-03	9,3
	5,10E-03	4,99E-03	2,2		3,28E-03	3,20E-03	2,5
	5,23E-03	5,24E-03	0,1		3,16E-03	2,98E-03	5,5
	5,10E-03	5,04E-03	1,2		3,69E-03	3,38E-03	8,5
	5,52E-03	5,54E-03	0,4		3,65E-03	3,36E-03	7,9
	4,43E-03	4,94E-03	10,3		3,53E-03	3,47E-03	1,6
	4,72E-03	5,08E-03	7,2		3,23E-03	3,05E-03	5,6
	4,93E-03	5,20E-03	5,2		3,23E-03	2,95E-03	8,9
	5,09E-03	5,29E-03	3,8		3,46E-03	3,06E-03	11,4
	4,99E-03	5,25E-03	4,9		3,64E-03	3,15E-03	13,4
	4,99E-03	5,11E-03	2,5		3,36E-03	2,91E-03	13,4
	5,18E-03	5,42E-03	4,4		3,44E-03	3,26E-03	5,4
	5,30E-03	5,54E-03	4,2		3,30E-03	3,11E-03	5,7
	4,96E-03	5,04E-03	1,7		3,04E-03	2,68E-03	12,0
	5,07E-03	5,22E-03	2,9		2,99E-03	2,64E-03	11,6
	4,86E-03	5,21E-03	6,8		3,20E-03	2,90E-03	9,4
	4,74E-03	5,04E-03	6,0		3,23E-03	2,93E-03	9,2
	4,86E-03	5,16E-03	5,9		3,35E-03	2,99E-03	10,9
	4,87E-03	5,17E-03	5,8		3,11E-03	2,81E-03	9,7
	5,06E-03	5,40E-03	6,3		3,10E-03	2,84E-03	8,4
	5,10E-03	5,51E-03	7,4		3,13E-03	2,91E-03	7,2
	5,19E-03	5,49E-03	5,5		3,14E-03	2,91E-03	7,3
	5,02E-03	5,43E-03	7,6		3,35E-03	3,12E-03	6,8
	5,16E-03	5,41E-03	4,6		3,26E-03	2,99E-03	8,1
	5,15E-03	5,17E-03	0,3		3,34E-03	3,14E-03	6,0
	5,04E-03	5,01E-03	0,5		3,56E-03	3,29E-03	7,5
	5,17E-03	5,13E-03	0,9		3,40E-03	3,19E-03	6,3
	4,95E-03	5,08E-03	2,6		3,15E-03	2,91E-03	7,7
	5,24E-03	5,37E-03	2,5		3,14E-03	2,84E-03	9,7
	4,91E-03	5,11E-03	3,9		3,23E-03	3,06E-03	5,5
	5,14E-03	5,35E-03	4,0		3,19E-03	2,92E-03	8,3
	5,17E-03	5,25E-03	1,5		3,05E-03	2,88E-03	5,7
	5,25E-03	5,29E-03	0,6		3,05E-03	2,82E-03	7,5
	5,15E-03	5,22E-03	1,5		3,44E-03	3,13E-03	8,9
	5,13E-03	5,16E-03	0,7		3,49E-03	3,08E-03	11,7
	5,33E-03	5,46E-03	2,4		3,42E-03	3,14E-03	8,1
	5,17E-03	5,30E-03	2,4		3,13E-03	3,08E-03	1,5
	4,96E-03	4,91E-03	1,2		3,18E-03	2,96E-03	6,8
	4,95E-03	4,88E-03	1,3		3,07E-03	2,81E-03	8,5
	5,16E-03	5,03E-03	2,6		3,63E-03	3,27E-03	9,9
	5,33E-03	5,27E-03	1,0		3,51E-03	3,16E-03	9,9
	5,00E-03	5,17E-03	3,3		3,29E-03	3,11E-03	5,7
	5,25E-03	5,37E-03	2,4		3,23E-03	3,05E-03	5,5
	5,39E-03	5,49E-03	1,8		3,24E-03	3,08E-03	5,1
	4,81E-03	5,14E-03	6,3		3,30E-03	3,14E-03	4,8
	5,09E-03	5,35E-03	4,8		3,44E-03	3,25E-03	5,4
	4,97E-03	5,22E-03	4,8		3,34E-03	3,04E-03	8,9
	5,02E-03	5,30E-03	5,2		3,41E-03	3,04E-03	10,9
	5,01E-03	5,24E-03	4,5		3,62E-03	3,17E-03	12,4
	4,97E-03	5,20E-03	4,5		3,42E-03	2,98E-03	13,0
	4,95E-03	5,15E-03	3,8		3,35E-03	2,89E-03	13,5
	5,28E-03	5,50E-03	4,1		3,28E-03	3,11E-03	5,2
	5,04E-03	5,15E-03	2,2		3,02E-03	2,66E-03	11,8
SUM ALL:	**3,14E-01**	**3,24E-01**	**3,1**	**SUM ALL:**	**2,04E-01**	**1,88E-01**	**8,0**

Existing concept analyses, pos 1 and pos 3 (two splines ahead), page 16 of 16

Analyses results

	2 Strain gauges (3, 13)		
	SUM Pos 1	SUM Pos 3	Diff %
	4,65E-03	4,84E-03	3,9
	4,68E-03	4,72E-03	0,9
	4,66E-03	4,65E-03	0,1
	4,77E-03	4,67E-03	2,2
	3,67E-03	3,86E-03	5,0
	3,97E-03	4,15E-03	4,4
	3,88E-03	4,13E-03	6,2
	4,68E-03	4,87E-03	3,9
	4,72E-03	4,50E-03	4,6
	4,38E-03	4,34E-03	0,9
	4,81E-03	5,29E-03	9,1
	4,81E-03	5,35E-03	10,0
	3,62E-03	3,90E-03	7,2
	3,65E-03	3,81E-03	4,2
	4,27E-03	4,54E-03	5,9
	4,40E-03	4,82E-03	8,8
	4,30E-03	4,68E-03	8,2
	4,26E-03	4,42E-03	3,5
	4,24E-03	4,28E-03	0,9
	4,81E-03	4,85E-03	0,8
	3,66E-03	3,77E-03	3,0
	3,82E-03	4,00E-03	4,5
	5,04E-03	5,06E-03	0,3
	5,30E-03	5,33E-03	0,6
	4,72E-03	4,84E-03	2,5
	4,56E-03	4,82E-03	5,4
	4,55E-03	4,79E-03	5,2
	4,62E-03	4,71E-03	1,9
	4,62E-03	4,74E-03	2,5
	4,40E-03	4,39E-03	0,1
	4,56E-03	4,57E-03	0,1
	4,34E-03	4,28E-03	1,3
	4,52E-03	4,51E-03	0,3
	4,25E-03	4,43E-03	4,0
	4,25E-03	4,29E-03	0,9
	4,39E-03	4,45E-03	1,1
	4,69E-03	4,73E-03	0,9
	3,78E-03	4,01E-03	5,7
	4,06E-03	4,41E-03	7,9
	3,89E-03	4,18E-03	6,9
	4,20E-03	4,59E-03	8,4
	4,27E-03	4,62E-03	7,5
	3,72E-03	3,73E-03	0,3
	3,50E-03	3,58E-03	2,2
	4,33E-03	4,28E-03	1,1
	5,10E-03	5,36E-03	4,7
	5,16E-03	5,49E-03	6,0
	5,15E-03	5,38E-03	4,3
	4,16E-03	4,28E-03	2,7
	4,16E-03	4,32E-03	3,8
	4,75E-03	5,19E-03	8,4
	4,45E-03	4,92E-03	9,5
	4,05E-03	4,43E-03	8,4
	4,10E-03	4,43E-03	7,4
	3,58E-03	3,75E-03	4,5
	3,98E-03	4,22E-03	5,6
	4,18E-03	4,34E-03	3,7
	4,24E-03	4,29E-03	1,2
	4,73E-03	4,81E-03	1,6
	4,81E-03	4,68E-03	2,7
	3,88E-03	4,09E-03	5,1
	5,17E-03	5,19E-03	0,4
SUM ALL:	**2,71E-01**	**2,81E-01**	**3,6**

Excel formulas used in the excel calculations for existing concept

Table 1 shows an excerpt of the excel calculations for analyzing the deviation between position 1 and position 2 by use of 4 strain gauges. These formulas are representative for all the excel calculations for calculating the deviation between two positions.

	4 strain gauges (1, 6, 11, 16)		
	SUM Pos 1:	**SUM Pos 2:**	**Diff %**
	=B5+Y5+AW5+BR5	=C5+Z5+AX5+BS5	=ABS(1-((MIN(DB5:DC5)/MAX(DB5:DC5))))*100
	=B6+Y6+AW6+BR6	=C6+Z6+AX6+BS6	=ABS(1-((MIN(DB6:DC6)/MAX(DB6:DC6))))*100
	=B7+Y7+AW7+BR7	=C7+Z7+AX7+BS7	=ABS(1-((MIN(DB7:DC7)/MAX(DB7:DC7))))*100
	=B8+Y8+AW8+BR8	=C8+Z8+AX8+BS8	=ABS(1-((MIN(DB8:DC8)/MAX(DB8:DC8))))*100
	=B9+Y9+AW9+BR9	=C9+Z9+AX9+BS9	=ABS(1-((MIN(DB9:DC9)/MAX(DB9:DC9))))*100
	=B10+Y10+AW10+BR10	=C10+Z10+AX10+BS10	=ABS(1-((MIN(DB10:DC10)/MAX(DB10:DC10))))*100
	=B11+Y11+AW11+BR11	=C11+Z11+AX11+BS11	=ABS(1-((MIN(DB11:DC11)/MAX(DB11:DC11))))*100
	=B12+Y12+AW12+BR12	=C12+Z12+AX12+BS12	=ABS(1-((MIN(DB12:DC12)/MAX(DB12:DC12))))*100
	=B13+Y13+AW13+BR13	=C13+Z13+AX13+BS13	=ABS(1-((MIN(DB13:DC13)/MAX(DB13:DC13))))*100
	=B14+Y14+AW14+BR14	=C14+Z14+AX14+BS14	=ABS(1-((MIN(DB14:DC14)/MAX(DB14:DC14))))*100
	=B15+Y15+AW15+BR15	=C15+Z15+AX15+BS15	=ABS(1-((MIN(DB15:DC15)/MAX(DB15:DC15))))*100
	=B16+Y16+AW16+BR16	=C16+Z16+AX16+BS16	=ABS(1-((MIN(DB16:DC16)/MAX(DB16:DC16))))*100
SUM ALL:	**=SUM(DB5:DB16)**	**=SUM(DC5:DC16)**	**=ABS(1-((MIN(DB17:DC17)/MAX(DB17:DC17))))*100**

Table 1: Excel formulas for deviation calculations

Table 2 shows an excerpt of the excel calculations for SG 1 Pos 1 and Pos 2 with formulas. These formulas are representative for all the calculations for calculating the deviation between two positions for one SG and adding the strain readings. These calculations are not necessary for calculating the total deviation, shown in Table 1.

SG 1	**Pos 1**	**Pos 2**	
Node	Strain	Strain	Diff %
10179	0,002749	0,002726	=ABS(1-(MIN(B5:C5)/MAX(B5:C5)))*100
10180	0,0027945	0,0027605	=ABS(1-(MIN(B6:C6)/MAX(B6:C6)))*100
10181	0,0028932	0,0028429	=ABS(1-(MIN(B7:C7)/MAX(B7:C7)))*100
10182	0,0029551	0,0028905	=ABS(1-(MIN(B8:C8)/MAX(B8:C8)))*100
10187	0,0029108	0,0027148	=ABS(1-(MIN(B9:C9)/MAX(B9:C9)))*100
10188	0,0029143	0,0027275	=ABS(1-(MIN(B10:C10)/MAX(B10:C10)))*100
10189	0,002898	0,0027213	=ABS(1-(MIN(B11:C11)/MAX(B11:C11)))*100
10190	0,0028947	0,0027169	=ABS(1-(MIN(B12:C12)/MAX(B12:C12)))*100
10575	0,0029494	0,0028615	=ABS(1-(MIN(B13:C13)/MAX(B13:C13)))*100
10576	0,0030793	0,0029519	=ABS(1-(MIN(B14:C14)/MAX(B14:C14)))*100
10577	0,0028758	0,0026995	=ABS(1-(MIN(B15:C15)/MAX(B15:C15)))*100
10578	0,0028904	0,0027643	=ABS(1-(MIN(B16:C16)/MAX(B16:C16)))*100
SUM:	**=SUM(B5:B16)**	**=SUM(C5:C16)**	**=ABS(1-(MIN(B17:C17)/MAX(B17:C17)))*100**

Table 2: Excel calculations for single strain gauge readings

Appendix G

Results from new concept analyses

- Results from position 1 and position 2
- Results from position 1 and position 3
- Excel formulas used for new concept

New concept analyses, pos 1 and pos 2 (one spline ahead), page 1 of 7

Node numbers and associated strains [mm/mm] exported from ansys

SG 1	**Pos 1**	**Pos 2**		**SG 2**	**Pos 1**	**Pos 2**	
Node	Strain	Strain	**Diff%**	Node	Strain	Strain	**Diff%**
4750	-1,24E-03	-1,03E-03	20,6	3502	-3,25E-07	-1,07E-07	203,5
4751	-6,96E-04	-5,82E-04	19,6	3503	-8,65E-07	-2,90E-07	198,3
4752	-1,09E-03	-8,84E-04	23,8	3504	-2,06E-06	-7,12E-07	189,7
4753	-8,94E-04	-7,83E-04	14,2	3505	-4,52E-06	-1,47E-06	208,2
4754	-1,49E-03	-1,17E-03	27,5	3506	1,90E-06	7,46E-07	60,8
4755	-5,33E-04	-5,14E-04	3,6	3507	1,15E-06	4,40E-07	61,6
4756	-1,60E-03	-1,26E-03	26,2	3508	5,62E-07	2,12E-07	62,2
4757	-3,23E-04	-2,89E-04	11,7	3509	3,75E-07	1,41E-07	62,4
4758	-6,30E-04	-7,34E-04	16,5	3510	-1,29E-07	-4,33E-08	197,8
4759	-8,94E-04	-8,82E-04	1,3	3511	7,85E-08	3,35E-08	57,3
4760	-1,10E-03	-9,96E-04	10,5	3512	-9,32E-06	-3,08E-06	202,4
4761	-1,37E-03	-1,16E-03	17,9	3513	-2,56E-06	-2,56E-06	0,3
4762	-1,65E-03	-1,32E-03	24,6	3514	8,86E-06	3,82E-06	56,9
4763	-1,94E-03	-1,47E-03	31,5	3515	5,36E-06	3,76E-07	93,0
4764	-1,85E-03	-1,43E-03	29,9	3538	3,25E-06	1,29E-06	60,2
4765	-1,38E-03	-1,09E-03	26,7	3539	3,98E-06	2,10E-06	47,2
4766	-1,01E-03	-8,02E-04	26,2	3607	-4,27E-08	-1,70E-07	297,0
4767	-5,91E-04	-4,75E-04	24,5	3608	1,28E-06	4,44E-07	65,2
4768	-2,24E-04	-1,79E-04	25,4	3609	1,85E-06	6,11E-07	67,0
4769	1,38E-05	1,62E-05	15,0	3610	1,30E-07	2,30E-08	82,3
4770	-1,81E-04	-2,45E-04	35,5	3611	3,02E-06	6,93E-07	77,0
4771	-1,97E-05	-4,10E-05	107,5	3612	1,56E-07	5,95E-08	61,8
4772	-1,86E-03	-1,42E-03	30,9	3613	-9,80E-07	-8,65E-07	13,3
4773	-1,96E-03	-1,47E-03	33,6	3614	7,43E-07	2,76E-07	62,8
5538	-1,17E-03	-9,57E-04	22,1	4153	-5,95E-07	-1,99E-07	199,6
5539	-1,07E-03	-9,05E-04	17,8	4154	-2,26E-07	-7,50E-08	202,0
5540	-1,42E-03	-1,15E-03	23,7	4156	-8,46E-08	-2,38E-08	255,9
5541	-1,30E-03	-1,09E-03	19,2	4157	-1,46E-06	-5,00E-07	192,3
5542	-8,95E-04	-7,33E-04	22,1	4159	-3,68E-07	-1,34E-07	175,3
5543	-7,95E-04	-6,83E-04	16,5	4160	-3,29E-06	-1,09E-06	202,0
5544	-5,09E-04	-4,36E-04	17,0	4162	-1,05E-06	-4,41E-07	138,8
5545	-6,44E-04	-5,29E-04	21,8	4163	-6,90E-06	-2,26E-06	204,5
5546	-1,29E-03	-1,03E-03	25,9	4165	-2,75E-06	-1,17E-06	135,9
5547	-1,05E-03	-8,43E-04	24,9	4166	1,53E-06	5,93E-07	61,1
5548	-7,13E-04	-6,49E-04	10,0	4168	2,58E-06	1,02E-06	60,4
5549	-9,98E-04	-8,90E-04	12,2	4169	1,59E-06	5,95E-07	62,6
5550	-1,54E-03	-1,22E-03	26,8	4170	8,54E-07	3,26E-07	61,8
5551	-1,44E-03	-1,13E-03	27,1	4172	9,45E-07	3,58E-07	62,1
5552	-1,68E-03	-1,29E-03	29,4	4173	4,68E-07	1,77E-07	62,3
5553	-4,28E-04	-4,02E-04	6,5	4175	2,27E-07	8,73E-08	61,5
5554	-7,13E-04	-6,98E-04	2,2	4176	5,59E-07	2,08E-07	62,7
5555	-3,56E-04	-3,79E-04	6,5	4177	-2,52E-08	-4,88E-09	416,8
5556	-1,62E-03	-1,29E-03	25,4	4180	1,17E-07	4,65E-08	60,3
5557	-1,78E-03	-1,37E-03	30,1	4181	-5,94E-06	-2,82E-06	110,8
5558	-2,74E-04	-2,34E-04	17,0	4183	1,40E-06	-1,09E-06	177,9
5559	-1,71E-04	-1,65E-04	3,9	4184	-1,79E-06	-1,71E-06	4,7
5560	-7,61E-04	-8,07E-04	6,1	4185	7,11E-06	2,10E-06	70,5
5561	-4,05E-04	-4,89E-04	20,8	4188	6,41E-06	2,94E-06	54,1
5563	-9,98E-04	-9,39E-04	6,2	4189	4,21E-06	5,44E-07	87,1
5564	-1,23E-03	-1,08E-03	14,5	4237	3,62E-06	1,70E-06	53,1
5565	-1,51E-03	-1,24E-03	21,5	4238	2,55E-06	9,53E-07	62,7
5566	-1,79E-03	-1,40E-03	28,2	4239	3,50E-06	1,40E-06	60,1
5567	-1,95E-03	-1,47E-03	32,6	4382	9,04E-07	2,20E-07	75,6
5569	-1,62E-03	-1,26E-03	28,5	4383	4,35E-08	-7,30E-08	267,9
5570	-1,86E-03	-1,42E-03	30,4	4384	-5,06E-07	-5,16E-07	1,9
5571	-1,20E-03	-9,46E-04	26,5	4385	1,56E-06	5,28E-07	66,3
5572	-8,01E-04	-6,38E-04	25,5	4386	7,03E-07	2,33E-07	66,8
5573	-4,07E-04	-3,26E-04	24,7	4387	1,01E-06	3,60E-07	64,3
5574	-1,05E-04	-8,11E-05	29,5	4388	2,43E-06	6,47E-07	73,3
5575	-2,99E-06	-1,24E-05	314,4	4389	1,43E-07	4,13E-08	71,1
5577	-1,00E-04	-1,43E-04	42,6	4390	1,02E-06	-8,57E-08	108,4
5580	-1,91E-03	-1,44E-03	32,3	4391	4,49E-07	1,68E-07	62,7
SUM SG 1:	**-6,30E-02**	**-5,20E-02**	**21,2**	**SUM SG 2:**	**3,28E-05**	**5,02E-06**	**84,7**

New concept analyses, pos 1 and pos 2 (one spline ahead), page 2 of 7

Node numbers and associated strains [mm/mm] exported from ansys

SG 3	**Pos 1**	**Pos 2**		**SG 4**	**Pos 1**	**Pos 2**	
Node	Strain	Strain	**Diff%**	Node	Strain	Strain	**Diff%**
1343	-1,32E-03	-1,55E-03	17,8	5755	1,79E-08	4,57E-08	60,8
1344	-1,37E-03	-1,66E-03	21,5	5756	1,69E-08	4,37E-08	61,4
1345	-1,44E-03	-1,83E-03	27,3	5757	1,70E-08	4,41E-08	61,3
1346	-1,64E-03	-2,14E-03	30,4	5758	1,81E-08	4,62E-08	60,8
1347	-1,60E-03	-1,97E-03	23,2	5759	1,25E-08	3,28E-08	61,7
1348	-1,60E-03	-1,87E-03	17,4	5760	1,34E-08	3,43E-08	61,0
1349	-1,64E-03	-1,86E-03	13,8	5761	1,33E-08	3,41E-08	61,0
1350	-1,54E-03	-2,06E-03	33,9	5762	1,26E-08	3,28E-08	61,7
1351	-2,32E-03	-2,55E-03	9,9	5763	5,42E-09	1,36E-08	60,3
1352	-1,99E-03	-2,20E-03	10,6	5764	1,44E-08	3,63E-08	60,3
1353	-1,82E-03	-2,08E-03	14,5	5765	1,92E-08	4,85E-08	60,3
1354	-1,74E-03	-2,09E-03	20,3	5766	1,93E-08	4,85E-08	60,3
1355	-1,72E-03	-2,19E-03	27,5	5767	1,45E-08	3,64E-08	60,3
1356	-1,72E-03	-2,32E-03	35,0	5768	6,89E-09	1,73E-08	60,1
1357	-1,56E-03	-2,28E-03	46,7	5769	4,45E-09	1,29E-08	65,6
1358	-1,45E-03	-1,98E-03	36,9	5770	1,22E-08	3,22E-08	62,3
1359	-1,33E-03	-1,74E-03	30,2	5771	1,63E-08	4,26E-08	61,7
1360	-1,21E-03	-1,51E-03	24,9	5772	1,63E-08	4,27E-08	61,7
1361	-1,11E-03	-1,35E-03	21,7	5773	1,21E-08	3,21E-08	62,3
1362	-1,02E-03	-1,24E-03	21,3	5774	5,58E-09	1,58E-08	64,6
1363	-1,76E-03	-1,98E-03	12,1	5775	6,24E-09	1,63E-08	61,7
1364	-1,32E-03	-1,55E-03	17,3	5776	5,91E-09	1,61E-08	63,3
1365	-1,61E-03	-2,27E-03	40,9	5777	5,94E-09	1,62E-08	63,3
1366	-1,69E-03	-2,32E-03	37,1	5778	6,31E-09	1,65E-08	61,7
2107	-1,34E-03	-1,61E-03	19,7	6395	1,75E-08	4,49E-08	61,1
2108	-1,48E-03	-1,71E-03	15,6	6396	1,80E-08	4,59E-08	60,8
2109	-1,21E-03	-1,45E-03	19,6	6397	1,56E-08	3,99E-08	60,9
2110	-1,32E-03	-1,55E-03	17,5	6398	1,86E-08	4,71E-08	60,5
2111	-1,40E-03	-1,75E-03	24,5	6399	1,70E-08	4,39E-08	61,3
2112	-1,48E-03	-1,77E-03	19,3	6400	1,75E-08	4,49E-08	61,1
2113	-1,29E-03	-1,59E-03	23,1	6401	1,47E-08	3,83E-08	61,5
2114	-1,52E-03	-1,90E-03	25,1	6402	1,66E-08	4,32E-08	61,5
2115	-1,49E-03	-1,95E-03	30,7	6403	1,48E-08	3,84E-08	61,5
2116	-1,39E-03	-1,79E-03	28,7	6404	1,67E-08	4,33E-08	61,5
2117	-1,62E-03	-2,06E-03	26,9	6405	1,57E-08	4,02E-08	60,9
2118	-1,59E-03	-2,10E-03	32,1	6406	1,87E-08	4,73E-08	60,6
2119	-1,68E-03	-2,17E-03	28,9	6407	1,29E-08	3,34E-08	61,4
2120	-1,67E-03	-2,23E-03	33,8	6408	1,23E-08	3,25E-08	62,0
2121	-1,60E-03	-1,92E-03	20,3	6409	9,23E-09	2,44E-08	62,2
2122	-1,67E-03	-2,03E-03	21,7	6410	1,30E-08	3,36E-08	61,4
2123	-1,62E-03	-1,87E-03	15,6	6411	1,39E-08	3,53E-08	60,6
2124	-1,71E-03	-1,98E-03	15,9	6412	9,80E-09	2,53E-08	61,2
2125	-1,81E-03	-2,03E-03	12,1	6413	1,39E-08	3,52E-08	60,6
2126	-1,70E-03	-1,92E-03	13,0	6414	9,80E-09	2,53E-08	61,2
2127	-1,49E-03	-2,02E-03	35,4	6415	1,23E-08	3,25E-08	62,0
2128	-1,58E-03	-2,17E-03	37,5	6416	9,23E-09	2,45E-08	62,3
2129	-2,15E-03	-2,37E-03	10,2	6417	9,91E-09	2,50E-08	60,3
2130	-2,04E-03	-2,26E-03	10,8	6418	5,83E-09	1,50E-08	61,0
2131	-1,90E-03	-2,14E-03	12,5	6421	1,68E-08	4,24E-08	60,3
2132	-1,78E-03	-2,09E-03	17,3	6423	1,92E-08	4,85E-08	60,3
2133	-1,73E-03	-2,14E-03	23,9	6425	1,69E-08	4,25E-08	60,3
2134	-1,72E-03	-2,26E-03	31,3	6427	1,07E-08	2,68E-08	60,2
2135	-1,71E-03	-2,32E-03	36,0	6429	6,60E-09	1,69E-08	60,9
2137	-1,50E-03	-2,13E-03	42,0	6432	8,31E-09	2,26E-08	63,2
2138	-1,59E-03	-2,28E-03	43,7	6433	5,20E-09	1,46E-08	64,3
2141	-1,39E-03	-1,86E-03	33,7	6436	1,42E-08	3,74E-08	62,0
2143	-1,27E-03	-1,62E-03	27,7	6438	1,63E-08	4,26E-08	61,7
2145	-1,16E-03	-1,43E-03	23,4	6440	1,42E-08	3,74E-08	62,0
2147	-1,06E-03	-1,29E-03	21,5	6442	8,84E-09	2,39E-08	63,1
2149	-1,17E-03	-1,40E-03	19,0	6444	5,74E-09	1,59E-08	64,0
2152	-1,54E-03	-1,76E-03	14,4	6447	6,07E-09	1,62E-08	62,5
2155	-1,65E-03	-2,30E-03	38,9	6450	6,12E-09	1,63E-08	62,5
SUM SG 3:	**-9,65E-02**	**-1,20E-01**	**24,1**	**SUM SG 4:**	**7,81E-07**	**2,02E-06**	**61,3**

New concept analyses, pos 1 and pos 2 (one spline ahead), page 3 of 7

Node numbers and associated strains [mm/mm] exported from ansys

SG 5	**Pos 1**	**Pos 2**		**SG 6**	**Pos 1**	**Pos 2**	
Node	Strain	Strain	**Diff%**	Node	Strain	Strain	**Diff%**
2369	-1,12E-03	-9,92E-04	13,4	218	4,78E-08	2,86E-08	40,1
2370	-1,20E-03	-1,17E-03	2,6	219	6,24E-08	3,42E-08	45,3
2371	-1,36E-03	-1,43E-03	5,1	220	6,30E-08	-6,01E-07	1055,3
2372	-1,56E-03	-1,75E-03	11,6	221	4,72E-08	-2,21E-07	568,6
2373	-6,21E-04	-6,43E-04	3,4	222	4,24E-08	7,70E-07	94,5
2374	-2,86E-04	-2,61E-04	9,4	223	5,68E-08	7,23E-07	92,1
2375	-4,95E-05	-1,19E-05	316,4	224	5,68E-08	5,33E-07	89,3
2376	-1,56E-04	-5,39E-05	189,0	225	4,29E-08	3,49E-07	87,7
2377	-1,03E-03	-7,45E-04	38,3	226	1,84E-08	2,57E-08	28,4
2378	-4,83E-04	-2,84E-04	70,5	227	2,15E-08	6,32E-08	66,0
2379	-1,77E-03	-2,08E-03	17,3	228	2,35E-08	-5,20E-06	22235,2
2380	-1,80E-03	-2,14E-03	18,8	229	2,22E-08	3,46E-06	99,4
2381	-1,81E-03	-2,04E-03	13,2	230	1,74E-08	5,43E-07	96,8
2382	-1,78E-03	-2,05E-03	15,0	231	2,17E-08	1,34E-06	98,4
2405	-1,01E-03	-1,10E-03	8,9	236	2,10E-08	1,34E-07	84,3
2406	-1,38E-03	-1,52E-03	10,4	237	2,12E-08	1,77E-07	88,0
2409	-1,24E-03	-1,32E-03	6,5	291	4,34E-08	2,70E-07	83,9
2410	-7,44E-04	-7,52E-04	1,1	292	5,74E-08	4,49E-07	87,2
2411	-1,10E-03	-1,18E-03	7,9	293	5,87E-08	6,44E-07	90,9
2412	-9,63E-04	-9,51E-04	1,3	294	4,61E-08	4,91E-07	90,6
2413	-1,44E-03	-1,62E-03	12,0	295	6,09E-08	3,62E-07	83,2
2414	-6,75E-04	-5,68E-04	18,9	296	6,05E-08	1,79E-07	66,2
2415	-1,53E-03	-1,71E-03	12,1	297	4,60E-08	1,55E-07	70,4
2416	-4,37E-04	-3,79E-04	15,2	298	4,36E-08	1,24E-06	96,5
3025	-1,16E-03	-1,08E-03	7,5	999	5,51E-08	3,13E-08	43,1
3026	-1,08E-03	-8,68E-04	24,1	1000	3,31E-08	2,73E-08	17,5
3028	-9,00E-04	-7,80E-04	15,4	1001	4,69E-08	9,20E-08	49,0
3029	-1,28E-03	-1,30E-03	1,5	1002	6,27E-08	-2,83E-07	552,1
3031	-1,08E-03	-1,06E-03	2,0	1003	6,15E-08	1,07E-07	42,4
3032	-1,46E-03	-1,59E-03	8,6	1004	5,51E-08	-4,10E-07	843,9
3034	-1,30E-03	-1,37E-03	5,8	1005	6,19E-08	-1,20E-07	293,3
3035	-1,67E-03	-1,91E-03	14,6	1006	3,53E-08	-2,72E-06	7811,7
3037	-1,55E-03	-1,73E-03	11,8	1007	4,66E-08	1,35E-07	65,5
3038	-4,53E-04	-4,52E-04	0,4	1008	4,96E-08	7,46E-07	93,4
3039	-8,14E-04	-8,70E-04	6,8	1009	2,99E-08	6,57E-07	95,4
3041	-6,83E-04	-6,97E-04	2,1	1010	4,30E-08	1,00E-06	95,7
3042	-1,68E-04	-1,37E-04	22,8	1011	5,68E-08	6,27E-07	91,0
3044	-3,62E-04	-3,20E-04	12,8	1012	5,78E-08	6,83E-07	91,5
3045	-1,03E-04	-3,29E-05	212,0	1013	4,98E-08	4,41E-07	88,7
3047	-3,20E-04	-1,69E-04	89,4	1014	5,71E-08	4,91E-07	88,4
3048	-2,96E-04	-2,16E-04	36,8	1015	3,20E-08	2,63E-07	87,8
3049	-7,57E-04	-5,14E-04	47,1	1016	4,31E-08	3,09E-07	86,1
3052	-5,79E-04	-4,25E-04	36,1	1017	2,00E-08	4,44E-08	55,1
3053	-1,79E-03	-2,11E-03	18,0	1019	2,13E-08	9,84E-08	78,4
3055	-1,79E-03	-2,10E-03	16,9	1020	3,37E-08	1,09E-07	69,1
3056	-1,67E-03	-1,93E-03	15,6	1021	2,28E-08	-8,67E-07	3899,9
3057	-1,79E-03	-2,05E-03	14,1	1022	2,19E-08	2,40E-06	99,1
3060	-1,59E-03	-1,78E-03	11,9	1023	3,41E-08	1,98E-06	98,3
3061	-1,61E-03	-1,83E-03	13,7	1024	1,95E-08	9,44E-07	97,9
3108	-1,19E-03	-1,31E-03	9,8	1026	3,27E-08	1,28E-06	97,5
3110	-1,05E-03	-1,14E-03	8,4	1034	2,11E-08	1,55E-07	86,4
3111	-1,41E-03	-1,57E-03	11,2	1035	3,22E-08	2,02E-07	84,0
3115	-1,17E-03	-1,25E-03	7,2	1121	5,04E-08	3,59E-07	86,0
3116	-1,10E-03	-1,13E-03	3,1	1122	4,47E-08	2,13E-07	79,0
3117	-1,38E-03	-1,51E-03	9,6	1123	5,81E-08	5,46E-07	89,4
3118	-9,20E-04	-9,67E-04	5,1	1124	5,90E-08	3,14E-07	81,2
3119	-8,54E-04	-8,52E-04	0,2	1125	5,98E-08	5,03E-07	88,1
3120	-5,90E-04	-5,66E-04	4,4	1126	5,12E-08	9,40E-07	94,6
3121	-1,27E-03	-1,40E-03	10,2	1127	5,35E-08	4,26E-07	87,5
3122	-8,19E-04	-7,59E-04	7,9	1128	4,48E-08	8,63E-07	94,8
3123	-1,49E-03	-1,66E-03	12,0	1129	6,07E-08	2,71E-07	77,6
3124	-5,56E-04	-4,74E-04	17,4	1130	5,33E-08	1,67E-07	68,2
SUM SG 5:	**-6,56E-02**	**-6,86E-02**	**4,7**	**SUM SG 6:**	**2,67E-06**	**1,90E-05**	**85,9**

New concept analyses, pos 1 and pos 2 (one spline ahead), page 4 of 7

Node numbers and associated strains [mm/mm] exported from ansys

SG 7	**Pos 1**	**Pos 2**		**SG 8**	**Pos 1**	**Pos 2**	
Node	Strain	Strain	**Diff%**	Node	Strain	Strain	**Diff%**
9193	-2,29E-03	-2,20E-03	4,4	6888	5,57E-08	3,33E-08	40,1
9194	-2,15E-03	-1,99E-03	8,1	6889	6,51E-08	3,93E-08	39,5
9195	-2,17E-03	-1,91E-03	13,9	6890	5,75E-08	3,51E-08	39,0
9196	-2,30E-03	-1,90E-03	20,8	6891	3,11E-08	1,98E-08	36,5
9197	-1,48E-03	-1,35E-03	9,3	6892	1,38E-08	9,81E-09	28,9
9198	-1,29E-03	-1,25E-03	2,9	6893	5,32E-09	4,36E-09	18,0
9199	-1,15E-03	-1,18E-03	2,3	6894	-4,84E-09	-2,37E-09	103,7
9200	-1,51E-03	-1,51E-03	0,3	6895	4,92E-09	3,31E-09	32,6
9201	-2,57E-03	-2,50E-03	2,9	6896	2,79E-08	1,65E-08	40,8
9202	-1,96E-03	-1,94E-03	1,3	6897	1,87E-08	1,13E-08	39,7
9203	-2,46E-03	-1,93E-03	27,5	6898	3,26E-09	3,51E-09	7,0
9204	-2,43E-03	-1,90E-03	27,8	6899	5,08E-09	4,30E-09	15,4
9205	-2,25E-03	-1,70E-03	32,3	6900	1,69E-08	1,04E-08	38,8
9206	-2,32E-03	-1,79E-03	29,3	6901	1,14E-08	5,97E-09	47,5
9229	-1,72E-03	-1,48E-03	16,8	6924	2,07E-08	1,64E-08	20,5
9230	-1,96E-03	-1,59E-03	23,6	6925	2,86E-08	1,92E-08	32,7
9298	-2,02E-03	-1,76E-03	14,6	6993	1,86E-08	1,20E-08	35,5
9299	-1,65E-03	-1,52E-03	9,0	6994	2,68E-08	1,77E-08	33,8
9300	-1,84E-03	-1,59E-03	15,8	6995	2,99E-08	1,91E-08	36,3
9301	-1,91E-03	-1,76E-03	8,4	6996	2,60E-08	1,62E-08	37,8
9302	-2,08E-03	-1,69E-03	22,7	6997	4,01E-08	2,56E-08	36,2
9303	-1,87E-03	-1,80E-03	3,9	6998	4,56E-08	2,82E-08	38,1
9304	-2,21E-03	-1,81E-03	21,5	6999	3,87E-08	2,36E-08	39,1
9305	-1,54E-03	-1,49E-03	3,5	7000	2,44E-08	1,65E-08	32,5
9849	-2,22E-03	-2,09E-03	6,2	7536	6,04E-08	3,63E-08	39,8
9850	-2,43E-03	-2,35E-03	3,6	7537	4,18E-08	2,49E-08	40,3
9852	-2,08E-03	-2,00E-03	4,2	7539	4,72E-08	2,84E-08	39,7
9853	-2,16E-03	-1,95E-03	11,0	7540	6,13E-08	3,72E-08	39,3
9855	-2,03E-03	-1,88E-03	8,3	7542	5,53E-08	3,38E-08	39,0
9856	-2,24E-03	-1,91E-03	17,3	7543	4,43E-08	2,74E-08	38,1
9858	-2,10E-03	-1,84E-03	14,3	7545	4,88E-08	3,03E-08	37,8
9859	-2,38E-03	-1,92E-03	24,1	7546	1,71E-08	1,16E-08	32,2
9861	-2,25E-03	-1,86E-03	21,1	7548	2,86E-08	1,80E-08	37,1
9862	-1,38E-03	-1,30E-03	6,3	7549	9,54E-09	7,06E-09	25,9
9863	-1,60E-03	-1,41E-03	13,2	7550	1,73E-08	1,32E-08	23,7
9865	-1,57E-03	-1,43E-03	9,2	7552	2,03E-08	1,38E-08	32,1
9866	-1,22E-03	-1,21E-03	0,4	7553	2,42E-10	1,00E-09	75,8
9868	-1,41E-03	-1,37E-03	3,3	7555	1,20E-08	8,19E-09	31,6
9869	-1,33E-03	-1,34E-03	0,8	7556	3,97E-11	4,69E-10	91,5
9871	-1,74E-03	-1,72E-03	0,9	7558	1,18E-08	7,30E-09	38,2
9872	-1,53E-03	-1,50E-03	1,8	7559	1,18E-08	7,67E-09	34,9
9873	-2,27E-03	-2,22E-03	2,2	7560	2,33E-08	1,39E-08	40,4
9876	-1,91E-03	-1,87E-03	2,5	7563	2,87E-08	1,74E-08	39,3
9877	-2,45E-03	-1,92E-03	27,7	7564	4,17E-09	3,91E-09	6,4
9879	-2,38E-03	-1,85E-03	28,5	7566	8,23E-09	5,13E-09	37,6
9880	-2,32E-03	-1,86E-03	24,8	7567	1,56E-08	1,02E-08	34,4
9881	-2,29E-03	-1,75E-03	30,7	7568	1,41E-08	8,16E-09	42,3
9884	-2,11E-03	-1,64E-03	28,1	7571	2,27E-08	1,47E-08	35,4
9885	-2,20E-03	-1,74E-03	26,1	7572	1,80E-08	1,14E-08	36,8
9932	-1,84E-03	-1,53E-03	20,3	7619	2,46E-08	1,78E-08	27,5
9934	-1,78E-03	-1,53E-03	16,3	7621	2,53E-08	1,78E-08	29,9
9935	-2,02E-03	-1,64E-03	23,1	7622	2,65E-08	1,79E-08	32,6
10071	-1,93E-03	-1,68E-03	15,2	7765	2,27E-08	1,49E-08	34,5
10072	-1,96E-03	-1,76E-03	11,5	7766	2,86E-08	1,78E-08	37,9
10073	-2,11E-03	-1,79E-03	18,1	7767	2,84E-08	1,84E-08	35,1
10074	-1,75E-03	-1,55E-03	12,5	7768	3,62E-08	2,30E-08	36,5
10075	-1,78E-03	-1,64E-03	8,7	7769	3,50E-08	2,23E-08	36,3
10076	-1,59E-03	-1,50E-03	6,3	7770	2,71E-08	1,77E-08	34,6
10077	-1,96E-03	-1,64E-03	19,3	7771	3,31E-08	2,09E-08	36,8
10078	-1,89E-03	-1,78E-03	6,1	7772	2,52E-08	1,63E-08	35,2
10079	-2,14E-03	-1,75E-03	22,1	7773	4,28E-08	2,69E-08	37,2
10080	-1,70E-03	-1,64E-03	3,7	7774	4,21E-08	2,59E-08	38,6
SUM SG 7:	**-1,21E-01**	**-1,07E-01**	**13,4**	**SUM SG 8:**	**1,63E-06**	**1,04E-06**	**36,4**

New concept analyses, pos 1 and pos 2 (one spline ahead), page 5 of 7

Analyses results

	8 Strain gauges				4 strain gauges (compression)		
	SUM POS 1	**SUM POS 2**	**Diff %**		**SUM POS 1**	**SUM POS 2**	**Diff %**
	-5,98E-03	-5,77E-03	3,6		-5,98E-03	-5,77E-03	3,6
	-5,96E-03	-5,40E-03	10,3		-5,41E-03	-5,40E-03	0,2
	-5,67E-03	-6,06E-03	6,8		-6,07E-03	-6,06E-03	0,2
	-6,61E-03	-6,58E-03	0,4		-6,40E-03	-6,58E-03	2,7
	-4,59E-03	-5,14E-03	11,8		-5,19E-03	-5,14E-03	1,1
	-4,66E-03	-3,90E-03	19,5		-3,70E-03	-3,90E-03	5,3
	-3,37E-03	-4,31E-03	28,1		-4,43E-03	-4,32E-03	2,7
	-4,81E-03	-3,91E-03	22,8		-3,53E-03	-3,92E-03	10,8
	-6,24E-03	-6,52E-03	4,5		-6,55E-03	-6,52E-03	0,4
	-5,06E-03	-5,30E-03	4,7		-5,33E-03	-5,30E-03	0,5
	-6,95E-03	-7,09E-03	2,0		-7,15E-03	-7,09E-03	0,9
	-7,08E-03	-7,30E-03	3,0		-7,34E-03	-7,30E-03	0,6
	-7,14E-03	-7,26E-03	1,7		-7,43E-03	-7,26E-03	2,3
	-7,47E-03	-7,64E-03	2,3		-7,76E-03	-7,64E-03	1,6
	-6,22E-03	-6,28E-03	1,0		-6,14E-03	-6,28E-03	2,3
	-6,64E-03	-6,18E-03	7,4		-6,17E-03	-6,18E-03	0,2
	-5,97E-03	-5,62E-03	6,3		-5,60E-03	-5,62E-03	0,3
	-4,62E-03	-4,25E-03	8,5		-4,20E-03	-4,26E-03	1,4
	-4,63E-03	-4,30E-03	7,8		-4,27E-03	-4,30E-03	0,7
	-4,12E-03	-3,93E-03	4,7		-3,88E-03	-3,93E-03	1,4
	-5,26E-03	-5,53E-03	5,0		-5,46E-03	-5,53E-03	1,2
	-4,05E-03	-3,96E-03	2,2		-3,89E-03	-3,96E-03	1,9
	-5,37E-03	-7,22E-03	34,5		-7,20E-03	-7,22E-03	0,2
	-5,53E-03	-5,65E-03	2,3		-5,63E-03	-5,66E-03	0,4
	-6,69E-03	-5,74E-03	16,6		-5,89E-03	-5,74E-03	2,8
	-6,15E-03	-5,83E-03	5,6		-6,05E-03	-5,83E-03	3,8
	-5,26E-03	-5,37E-03	2,2		-5,61E-03	-5,37E-03	4,4
	-6,18E-03	-5,89E-03	4,9		-6,07E-03	-5,89E-03	2,9
	-5,82E-03	-5,41E-03	7,5		-5,41E-03	-5,41E-03	0,1
	-6,08E-03	-5,94E-03	2,3		-5,97E-03	-5,94E-03	0,5
	-5,48E-03	-5,23E-03	4,8		-5,19E-03	-5,23E-03	0,7
	-6,08E-03	-6,26E-03	2,9		-6,21E-03	-6,26E-03	0,8
	-5,93E-03	-6,56E-03	10,6		-6,58E-03	-6,56E-03	0,3
	-4,51E-03	-4,38E-03	3,1		-4,28E-03	-4,38E-03	2,5
	-5,09E-03	-4,99E-03	2,0		-4,75E-03	-4,99E-03	5,0
	-4,55E-03	-5,12E-03	12,5		-4,84E-03	-5,12E-03	5,9
	-4,06E-03	-4,73E-03	16,5		-4,61E-03	-4,73E-03	2,7
	-4,99E-03	-5,05E-03	1,3		-4,88E-03	-5,05E-03	3,5
	-4,47E-03	-4,59E-03	2,8		-4,71E-03	-4,59E-03	2,5
	-5,40E-03	-4,33E-03	24,9		-4,16E-03	-4,33E-03	4,1
	-3,86E-03	-4,28E-03	10,7		-4,15E-03	-4,28E-03	3,1
	-5,45E-03	-5,09E-03	7,0		-5,09E-03	-5,09E-03	0,0
	-4,66E-03	-5,62E-03	20,5		-5,93E-03	-5,62E-03	5,5
	-7,56E-03	-7,31E-03	3,4		-7,71E-03	-7,31E-03	5,5
	-7,44E-03	-6,20E-03	20,0		-5,94E-03	-6,20E-03	4,4
	-5,84E-03	-6,12E-03	4,8		-5,73E-03	-6,12E-03	6,7
	-6,39E-03	-6,97E-03	9,0		-6,99E-03	-6,97E-03	0,3
	-6,49E-03	-6,17E-03	5,2		-6,14E-03	-6,17E-03	0,5
	-6,11E-03	-6,65E-03	8,8		-6,71E-03	-6,65E-03	0,8
	-5,80E-03	-6,00E-03	3,3		-6,04E-03	-6,00E-03	0,7
	-5,79E-03	-6,05E-03	4,5		-6,07E-03	-6,06E-03	0,3
	-6,65E-03	-6,86E-03	3,1		-6,94E-03	-6,87E-03	1,1
	-6,60E-03	-6,72E-03	1,9		-6,76E-03	-6,72E-03	0,5
	-6,52E-03	-6,28E-03	3,7		-6,18E-03	-6,28E-03	1,7
	-6,70E-03	-7,00E-03	4,6		-6,94E-03	-7,00E-03	1,0
	-5,91E-03	-5,32E-03	11,1		-5,25E-03	-5,33E-03	1,4
	-5,10E-03	-4,75E-03	7,4		-4,71E-03	-4,75E-03	1,0
	-4,14E-03	-3,82E-03	8,5		-3,75E-03	-3,82E-03	1,9
	-4,69E-03	-4,41E-03	6,4		-4,40E-03	-4,41E-03	0,4
	-3,98E-03	-3,95E-03	1,0		-3,88E-03	-3,95E-03	1,6
	-5,17E-03	-5,33E-03	3,0		-5,27E-03	-5,33E-03	1,1
	-4,01E-03	-5,86E-03	46,0		-5,82E-03	-5,86E-03	0,6
SUM ALL:	**-3,46E-01**	**-3,47E-01**	**0,5**	**SUM ALL:**	**-3,46E-01**	**-3,47E-01**	**0,3**

New concept analyses, pos 1 and pos 2 (one spline ahead), page 6 of 7

Analyses results

	4 strain gauges (no compression)				2 strain gauges (SG 1 and 5)		
	SUM POS 1	**SUM POS 2**	**Diff %**		**SUM POS 1**	**SUM POS 2**	**Diff %**
	-2,04E-07	5,93E-10	34425,5		-2,37E-03	-2,02E-03	17,1
	-7,21E-07	-1,73E-07	316,8		-1,89E-03	-1,75E-03	8,2
	-1,92E-06	-1,23E-06	55,9		-2,46E-03	-2,31E-03	6,1
	-4,42E-06	-1,62E-06	172,7		-2,46E-03	-2,53E-03	2,9
	1,97E-06	1,56E-06	21,0		-2,11E-03	-1,81E-03	16,5
	1,22E-06	1,20E-06	1,7		-8,19E-04	-7,76E-04	5,5
	6,27E-07	7,77E-07	19,3		-1,65E-03	-1,28E-03	28,9
	4,36E-07	5,26E-07	17,2		-4,79E-04	-3,43E-04	39,6
	-7,73E-08	1,26E-08	715,4		-1,66E-03	-1,48E-03	12,3
	1,33E-07	1,44E-07	7,7		-1,38E-03	-1,17E-03	18,2
	-9,28E-06	-8,23E-06	12,7		-2,87E-03	-3,07E-03	7,0
	-2,52E-06	9,60E-07	362,3		-3,17E-03	-3,30E-03	4,1
	8,91E-06	4,40E-06	50,6		-3,46E-03	-3,37E-03	2,6
	5,40E-06	1,74E-06	67,7		-3,72E-03	-3,52E-03	5,6
	3,30E-06	1,46E-06	55,8		-2,86E-03	-2,53E-03	13,4
	4,05E-06	2,33E-06	42,4		-2,76E-03	-2,61E-03	5,7
	3,56E-08	1,55E-07	77,1		-2,25E-03	-2,12E-03	6,1
	1,38E-06	9,53E-07	30,8		-1,34E-03	-1,23E-03	8,8
	1,95E-06	1,31E-06	33,1		-1,32E-03	-1,36E-03	3,1
	2,08E-07	5,46E-07	62,0		-9,50E-04	-9,35E-04	1,5
	3,12E-06	1,10E-06	64,9		-1,63E-03	-1,86E-03	14,6
	2,68E-07	2,83E-07	5,4		-6,95E-04	-6,09E-04	14,1
	-8,89E-07	-6,70E-07	32,8		-3,39E-03	-3,13E-03	8,2
	8,17E-07	1,54E-06	47,1		-2,40E-03	-1,85E-03	29,9
	-4,62E-07	-8,60E-08	437,3		-2,33E-03	-2,04E-03	14,4
	-1,34E-07	2,32E-08	675,4		-2,14E-03	-1,77E-03	20,9
	2,51E-08	1,37E-07	81,6		-2,32E-03	-1,93E-03	20,4
	-1,32E-06	-6,99E-07	88,7		-2,58E-03	-2,39E-03	8,0
	-2,34E-07	5,08E-08	560,3		-1,97E-03	-1,79E-03	10,2
	-3,17E-06	-1,43E-06	122,4		-2,26E-03	-2,27E-03	0,6
	-9,27E-07	-4,92E-07	88,5		-1,81E-03	-1,81E-03	0,1
	-6,83E-06	-4,93E-06	38,4		-2,31E-03	-2,44E-03	5,5
	-2,66E-06	-9,74E-07	173,0		-2,84E-03	-2,75E-03	3,0
	1,60E-06	1,39E-06	13,2		-1,51E-03	-1,29E-03	16,4
	2,64E-06	1,73E-06	34,4		-1,53E-03	-1,52E-03	0,6
	1,67E-06	1,66E-06	0,8		-1,68E-03	-1,59E-03	5,9
	9,24E-07	9,88E-07	6,5		-1,71E-03	-1,35E-03	26,4
	1,03E-06	1,08E-06	5,1		-1,80E-03	-1,45E-03	24,0
	5,28E-07	6,42E-07	17,8		-1,78E-03	-1,33E-03	33,9
	3,09E-07	6,19E-07	50,1		-7,47E-04	-5,70E-04	31,0
	6,17E-07	5,14E-07	16,6		-1,01E-03	-9,15E-04	10,3
	5,10E-08	3,44E-07	85,2		-1,11E-03	-8,94E-04	24,6
	1,80E-07	1,44E-07	20,0		-2,20E-03	-1,72E-03	28,0
	-5,91E-06	-2,69E-06	119,5		-3,56E-03	-3,48E-03	2,6
	1,45E-06	-9,44E-07	164,9		-2,07E-03	-2,33E-03	12,7
	-1,75E-06	-2,55E-06	45,8		-1,84E-03	-2,09E-03	13,8
	7,16E-06	4,53E-06	36,7		-2,55E-03	-2,85E-03	11,7
	6,47E-06	4,96E-06	23,4		-2,00E-03	-2,27E-03	13,7
	4,26E-06	1,54E-06	63,8		-2,61E-03	-2,77E-03	6,2
	3,70E-06	3,05E-06	17,6		-2,43E-03	-2,39E-03	1,7
	2,61E-06	1,17E-06	55,3		-2,56E-03	-2,38E-03	7,5
	3,57E-06	1,64E-06	53,9		-3,20E-03	-2,97E-03	8,0
	9,83E-07	6,12E-07	37,8		-3,12E-03	-2,72E-03	14,6
	1,25E-07	1,80E-07	30,5		-2,72E-03	-2,39E-03	13,6
	-4,15E-07	6,34E-08	753,6		-3,24E-03	-2,94E-03	10,2
	1,67E-06	9,02E-07	46,1		-2,12E-03	-1,91E-03	10,6
	8,14E-07	8,01E-07	1,6		-1,65E-03	-1,49E-03	11,1
	1,10E-06	1,35E-06	18,7		-9,98E-04	-8,92E-04	11,8
	2,52E-06	1,12E-06	55,6		-1,37E-03	-1,48E-03	7,7
	2,19E-07	9,37E-07	76,6		-8,22E-04	-7,72E-04	6,5
	1,13E-06	2,28E-07	79,8		-1,59E-03	-1,81E-03	13,9
	5,51E-07	3,77E-07	31,5		-2,47E-03	-1,92E-03	28,6
SUM ALL:	**3,79E-05**	**2,71E-05**	**28,6**	**SUM ALL:**	**-1,29E-01**	**-1,21E-01**	**6,6**

New concept analyses, pos 1 and pos 2 (one spline ahead), page 7 of 7

Analyses results

	2 strain gauges (SG 3 and 8)		
	SUM POS 1	**SUM POS 2**	**Diff %**
	-1,32E-03	-1,55E-03	17,8
	-1,37E-03	-1,66E-03	21,5
	-1,44E-03	-1,83E-03	27,3
	-1,64E-03	-2,14E-03	30,4
	-1,60E-03	-1,97E-03	23,2
	-1,60E-03	-1,87E-03	17,4
	-1,64E-03	-1,86E-03	13,8
	-1,54E-03	-2,06E-03	33,9
	-2,32E-03	-2,55E-03	9,9
	-1,99E-03	-2,20E-03	10,6
	-1,82E-03	-2,08E-03	14,5
	-1,74E-03	-2,09E-03	20,3
	-1,72E-03	-2,19E-03	27,5
	-1,72E-03	-2,32E-03	35,0
	-1,56E-03	-2,28E-03	46,7
	-1,45E-03	-1,98E-03	36,9
	-1,33E-03	-1,74E-03	30,2
	-1,21E-03	-1,51E-03	24,9
	-1,11E-03	-1,35E-03	21,7
	-1,02E-03	-1,24E-03	21,3
	-1,76E-03	-1,98E-03	12,1
	-1,32E-03	-1,55E-03	17,3
	-1,61E-03	-2,27E-03	40,9
	-1,69E-03	-2,32E-03	37,1
	-1,34E-03	-1,61E-03	19,7
	-1,48E-03	-1,71E-03	15,6
	-1,21E-03	-1,45E-03	19,6
	-1,32E-03	-1,55E-03	17,5
	-1,40E-03	-1,75E-03	24,5
	-1,48E-03	-1,77E-03	19,3
	-1,29E-03	-1,58E-03	23,1
	-1,52E-03	-1,90E-03	25,1
	-1,49E-03	-1,95E-03	30,7
	-1,39E-03	-1,79E-03	28,7
	-1,62E-03	-2,06E-03	26,9
	-1,59E-03	-2,10E-03	32,1
	-1,68E-03	-2,17E-03	28,9
	-1,67E-03	-2,23E-03	33,8
	-1,60E-03	-1,92E-03	20,3
	-1,67E-03	-2,03E-03	21,7
	-1,62E-03	-1,87E-03	15,6
	-1,71E-03	-1,98E-03	15,9
	-1,81E-03	-2,03E-03	12,1
	-1,70E-03	-1,92E-03	13,0
	-1,49E-03	-2,02E-03	35,4
	-1,58E-03	-2,17E-03	37,5
	-2,15E-03	-2,37E-03	10,2
	-2,04E-03	-2,26E-03	10,8
	-1,90E-03	-2,14E-03	12,5
	-1,78E-03	-2,08E-03	17,3
	-1,73E-03	-2,14E-03	23,9
	-1,72E-03	-2,26E-03	31,3
	-1,71E-03	-2,32E-03	36,0
	-1,50E-03	-2,13E-03	42,0
	-1,59E-03	-2,28E-03	43,7
	-1,39E-03	-1,86E-03	33,7
	-1,27E-03	-1,62E-03	27,7
	-1,16E-03	-1,43E-03	23,4
	-1,06E-03	-1,29E-03	21,5
	-1,17E-03	-1,40E-03	19,1
	-1,54E-03	-1,76E-03	14,4
	-1,65E-03	-2,30E-03	38,9
SUM ALL:	**-9,65E-02**	**-1,20E-01**	**24,1**

New concept analyses, pos 1 and pos 3 (two splines ahead), page 1 of 7

Node numbers and associated strains [mm/mm] exported from ansys

SG 1	**Pos 1**	**Pos 3**		**SG 2**	**Pos 1**	**Pos 3**	
Node	Strain	Strain	**Diff%**	Node	Strain	Strain	**Diff%**
4750	-1,24E-03	-1,21E-03	2,3	3502	-3,25E-07	2,27E-08	1533,1
4751	-6,96E-04	-7,38E-04	5,9	3503	-8,65E-07	3,07E-08	2920,8
4752	-1,09E-03	-1,06E-03	3,2	3504	-2,06E-06	3,08E-08	6786,0
4753	-8,94E-04	-9,67E-04	8,2	3505	-4,52E-06	2,30E-08	19773,5
4754	-1,49E-03	-1,38E-03	7,8	3506	1,90E-06	2,66E-08	98,6
4755	-5,33E-04	-7,29E-04	36,8	3507	1,15E-06	2,00E-08	98,3
4756	-1,60E-03	-1,47E-03	8,5	3508	5,62E-07	9,51E-09	98,3
4757	-3,23E-04	-4,40E-04	36,3	3509	3,75E-07	9,92E-09	97,4
4758	-6,30E-04	-1,15E-03	83,0	3510	-1,29E-07	9,09E-09	1519,0
4759	-8,94E-04	-1,16E-03	29,8	3511	7,85E-08	1,03E-08	86,8
4760	-1,10E-03	-1,21E-03	10,1	3512	-9,32E-06	1,18E-08	79099,2
4761	-1,37E-03	-1,34E-03	2,0	3513	-2,56E-06	1,01E-08	25607,7
4762	-1,65E-03	-1,52E-03	8,9	3514	8,86E-06	7,80E-09	99,9
4763	-1,94E-03	-1,69E-03	15,0	3515	5,36E-06	9,72E-09	99,8
4764	-1,85E-03	-1,73E-03	7,0	3538	3,25E-06	2,66E-08	99,2
4765	-1,38E-03	-1,31E-03	5,7	3539	3,98E-06	1,99E-08	99,5
4766	-1,01E-03	-9,72E-04	4,0	3607	-4,27E-08	2,87E-08	248,9
4767	-5,91E-04	-6,09E-04	3,1	3608	1,28E-06	2,77E-08	97,8
4768	-2,24E-04	-2,89E-04	28,8	3609	1,85E-06	2,76E-08	98,5
4769	1,38E-05	-5,70E-05	514,5	3610	1,30E-07	2,92E-08	77,5
4770	-1,81E-04	-5,27E-04	190,9	3611	3,02E-06	2,05E-08	99,3
4771	-1,97E-05	-1,91E-04	868,5	3612	1,56E-07	2,16E-08	86,1
4772	-1,86E-03	-1,69E-03	9,8	3613	-9,80E-07	2,15E-08	4652,7
4773	-1,96E-03	-1,70E-03	15,2	3614	7,43E-07	2,03E-08	97,3
5538	-1,17E-03	-1,14E-03	2,7	4153	-5,95E-07	2,67E-08	2330,8
5539	-1,07E-03	-1,09E-03	2,1	4154	-2,26E-07	1,59E-08	1524,2
5540	-1,42E-03	-1,34E-03	5,7	4156	-8,46E-08	2,21E-08	482,1
5541	-1,30E-03	-1,28E-03	2,2	4157	-1,46E-06	3,08E-08	4853,6
5542	-8,95E-04	-8,99E-04	0,4	4159	-3,68E-07	3,00E-08	1327,4
5543	-7,95E-04	-8,53E-04	7,2	4160	-3,29E-06	2,69E-08	12325,6
5544	-5,09E-04	-5,89E-04	15,6	4162	-1,05E-06	2,98E-08	3635,4
5545	-6,44E-04	-6,74E-04	4,7	4163	-6,90E-06	1,74E-08	39786,3
5546	-1,29E-03	-1,22E-03	5,8	4165	-2,75E-06	2,22E-08	12459,9
5547	-1,05E-03	-1,02E-03	3,6	4166	1,53E-06	2,33E-08	98,5
5548	-7,13E-04	-8,48E-04	18,8	4168	2,58E-06	2,66E-08	99,0
5549	-9,98E-04	-1,09E-03	9,2	4169	1,59E-06	2,72E-08	98,3
5550	-1,54E-03	-1,43E-03	8,2	4170	8,54E-07	1,47E-08	98,3
5551	-1,44E-03	-1,35E-03	6,8	4172	9,45E-07	2,02E-08	97,9
5552	-1,68E-03	-1,54E-03	8,9	4173	4,68E-07	9,71E-09	97,9
5553	-4,28E-04	-5,85E-04	36,6	4175	2,27E-07	1,01E-08	95,5
5554	-7,13E-04	-9,44E-04	32,4	4176	5,59E-07	1,51E-08	97,3
5555	-3,56E-04	-6,27E-04	76,1	4177	-2,52E-08	9,71E-09	359,5
5556	-1,62E-03	-1,49E-03	8,7	4180	1,17E-07	1,60E-08	86,4
5557	-1,78E-03	-1,59E-03	12,0	4181	-5,94E-06	1,09E-08	54490,6
5558	-2,74E-04	-3,64E-04	33,2	4183	1,40E-06	9,89E-09	99,3
5559	-1,71E-04	-3,15E-04	84,1	4184	-1,79E-06	1,58E-08	11469,0
5560	-7,61E-04	-1,16E-03	51,8	4185	7,11E-06	8,76E-09	99,9
5561	-4,05E-04	-8,40E-04	107,1	4188	6,41E-06	1,39E-08	99,8
5563	-9,98E-04	-1,19E-03	18,9	4189	4,21E-06	1,51E-08	99,6
5564	-1,23E-03	-1,28E-03	3,4	4237	3,62E-06	2,32E-08	99,4
5565	-1,51E-03	-1,43E-03	5,7	4238	2,55E-06	2,71E-08	98,9
5566	-1,79E-03	-1,60E-03	12,0	4239	3,50E-06	2,02E-08	99,4
5567	-1,95E-03	-1,70E-03	15,1	4382	9,04E-07	2,81E-08	96,9
5569	-1,62E-03	-1,52E-03	6,4	4383	4,35E-08	2,90E-08	33,3
5570	-1,86E-03	-1,71E-03	8,3	4384	-5,06E-07	2,51E-08	2116,8
5571	-1,20E-03	-1,14E-03	5,0	4385	1,56E-06	2,76E-08	98,2
5572	-8,01E-04	-7,90E-04	1,3	4386	7,03E-07	2,85E-08	95,9
5573	-4,07E-04	-4,49E-04	10,2	4387	1,01E-06	2,40E-08	97,6
5574	-1,05E-04	-1,73E-04	64,5	4388	2,43E-06	2,40E-08	99,0
5575	-2,99E-06	-1,24E-04	4051,4	4389	1,43E-07	2,54E-08	82,2
5577	-1,00E-04	-3,59E-04	257,5	4390	1,02E-06	2,10E-08	97,9
5580	-1,91E-03	-1,70E-03	12,5	4391	4,49E-07	2,10E-08	95,3
SUM SG 1:	**-6,30E-02**	**-6,46E-02**	**2,4**	**SUM SG 2:**	**3,28E-05**	**1,27E-06**	**96,1**

New concept analyses, pos 1 and pos 3 (two splines ahead), page 2 of 7

Node numbers and associated strains [mm/mm] exported from ansys

SG 3	Pos 1	Pos 3		SG 4	Pos 1	Pos 3	
Node	Strain	Strain	**Diff%**	Node	Strain	Strain	**Diff%**
1343	-1,32E-03	-1,57E-03	19,2	5755	1,79E-08	-1,26E-07	802,0
1344	-1,37E-03	-1,69E-03	23,4	5756	1,69E-08	-2,13E-07	1362,3
1345	-1,44E-03	-1,87E-03	29,7	5757	1,70E-08	-2,31E-07	1457,2
1346	-1,64E-03	-2,23E-03	35,8	5758	1,81E-08	-5,87E-08	424,3
1347	-1,60E-03	-2,05E-03	27,7	5759	1,25E-08	-1,97E-07	1668,4
1348	-1,60E-03	-1,94E-03	21,5	5760	1,34E-08	-4,83E-09	136,1
1349	-1,64E-03	-1,93E-03	17,6	5761	1,33E-08	-1,65E-07	1343,9
1350	-1,54E-03	-2,11E-03	37,1	5762	1,26E-08	-1,62E-07	1389,4
1351	-2,32E-03	-2,65E-03	14,3	5763	5,42E-09	1,09E-07	95,0
1352	-1,99E-03	-2,30E-03	15,8	5764	1,44E-08	1,53E-07	90,6
1353	-1,82E-03	-2,19E-03	20,4	5765	1,92E-08	1,43E-07	86,5
1354	-1,74E-03	-2,20E-03	26,5	5766	1,93E-08	6,06E-08	68,2
1355	-1,72E-03	-2,32E-03	34,9	5767	1,45E-08	-6,31E-08	536,1
1356	-1,72E-03	-2,48E-03	44,2	5768	6,89E-09	-1,42E-07	2161,3
1357	-1,56E-03	-2,27E-03	45,4	5769	4,45E-09	-2,47E-08	653,7
1358	-1,45E-03	-2,00E-03	38,2	5770	1,22E-08	-1,85E-07	1620,6
1359	-1,33E-03	-1,75E-03	30,9	5771	1,63E-08	-3,05E-07	1971,3
1360	-1,21E-03	-1,51E-03	24,8	5772	1,63E-08	-3,16E-07	2032,9
1361	-1,11E-03	-1,33E-03	20,2	5773	1,21E-08	-2,65E-07	2292,1
1362	-1,02E-03	-1,20E-03	17,5	5774	5,58E-09	-1,91E-07	3530,2
1363	-1,76E-03	-2,05E-03	16,2	5775	6,24E-09	2,19E-08	71,5
1364	-1,32E-03	-1,58E-03	19,0	5776	5,91E-09	-1,13E-07	2010,5
1365	-1,61E-03	-2,32E-03	43,6	5777	5,94E-09	-8,71E-08	1566,2
1366	-1,69E-03	-2,46E-03	44,9	5778	6,31E-09	-1,57E-07	2583,9
2107	-1,34E-03	-1,63E-03	21,4	6395	1,75E-08	-1,79E-07	1121,3
2108	-1,48E-03	-1,75E-03	18,4	6396	1,80E-08	-9,20E-08	610,8
2109	-1,21E-03	-1,45E-03	19,7	6397	1,56E-08	-1,46E-07	1033,2
2110	-1,32E-03	-1,57E-03	19,0	6398	1,86E-08	-3,26E-08	275,4
2111	-1,40E-03	-1,78E-03	26,6	6399	1,70E-08	-2,22E-07	1409,5
2112	-1,48E-03	-1,81E-03	22,4	6400	1,75E-08	-1,36E-07	877,0
2113	-1,29E-03	-1,60E-03	24,1	6401	1,47E-08	-1,87E-07	1373,0
2114	-1,52E-03	-1,96E-03	28,7	6402	1,66E-08	-2,64E-07	1692,1
2115	-1,49E-03	-1,99E-03	33,6	6403	1,48E-08	-2,14E-07	1548,3
2116	-1,39E-03	-1,81E-03	30,3	6404	1,67E-08	-2,68E-07	1708,6
2117	-1,62E-03	-2,14E-03	31,8	6405	1,57E-08	-3,18E-08	302,0
2118	-1,59E-03	-2,17E-03	36,4	6406	1,87E-08	4,21E-08	55,7
2119	-1,68E-03	-2,27E-03	35,3	6407	1,29E-08	-1,81E-07	1501,3
2120	-1,67E-03	-2,34E-03	40,3	6408	1,23E-08	-1,91E-07	1644,8
2121	-1,60E-03	-1,99E-03	24,6	6409	9,23E-09	-1,42E-07	1634,6
2122	-1,67E-03	-2,12E-03	27,1	6410	1,30E-08	-8,34E-08	743,0
2123	-1,62E-03	-1,93E-03	19,5	6411	1,39E-08	7,43E-08	81,3
2124	-1,71E-03	-2,06E-03	20,9	6412	9,80E-09	8,56E-09	12,6
2125	-1,81E-03	-2,11E-03	16,6	6413	1,39E-08	-1,14E-07	922,8
2126	-1,70E-03	-1,99E-03	17,0	6414	9,80E-09	-1,61E-07	1741,4
2127	-1,49E-03	-2,06E-03	37,6	6415	1,23E-08	-2,14E-07	1832,4
2128	-1,58E-03	-2,21E-03	40,5	6416	9,23E-09	-1,37E-07	1588,1
2129	-2,15E-03	-2,47E-03	14,9	6417	9,91E-09	1,31E-07	92,4
2130	-2,04E-03	-2,35E-03	15,1	6418	5,83E-09	6,52E-08	91,1
2131	-1,90E-03	-2,24E-03	18,0	6421	1,68E-08	1,48E-07	88,6
2132	-1,78E-03	-2,19E-03	23,3	6423	1,92E-08	1,02E-07	81,1
2133	-1,73E-03	-2,26E-03	30,7	6425	1,69E-08	-1,36E-09	108,0
2134	-1,72E-03	-2,40E-03	39,5	6427	1,07E-08	-1,03E-07	1064,2
2135	-1,71E-03	-2,47E-03	44,5	6429	6,60E-09	-1,49E-07	2363,3
2137	-1,50E-03	-2,13E-03	41,9	6432	8,31E-09	-1,04E-07	1350,7
2138	-1,59E-03	-2,29E-03	44,5	6433	5,20E-09	-5,59E-08	1175,1
2141	-1,39E-03	-1,87E-03	34,7	6436	1,42E-08	-2,46E-07	1824,8
2143	-1,27E-03	-1,63E-03	28,0	6438	1,63E-08	-3,10E-07	2001,2
2145	-1,16E-03	-1,42E-03	22,6	6440	1,42E-08	-2,91E-07	2143,9
2147	-1,06E-03	-1,26E-03	18,9	6442	8,84E-09	-2,28E-07	2683,0
2149	-1,17E-03	-1,39E-03	18,4	6444	5,74E-09	-1,52E-07	2748,9
2152	-1,54E-03	-1,81E-03	17,4	6447	6,07E-09	-4,55E-08	849,2
2155	-1,65E-03	-2,39E-03	44,3	6450	6,12E-09	-1,22E-07	2090,6
SUM SG 3:	**-9,65E-02**	**-1,23E-01**	**27,7**	**SUM SG 4:**	**7,81E-07**	**-6,75E-06**	**964,0**

New concept analyses, pos 1 and pos 3 (two splines ahead), page 3 of 7

Node numbers and associated strains [mm/mm] exported from ansys

SG 5	**Pos 1**	**Pos 3**		**SG 6**	**Pos 1**	**Pos 3**	
Node	Strain	Strain	**Diff%**	Node	Strain	Strain	**Diff%**
2369	-1,12E-03	-8,74E-04	28,6	218	4,78E-08	4,03E-07	88,2
2370	-1,20E-03	-1,10E-03	8,7	219	6,24E-08	5,07E-07	87,7
2371	-1,36E-03	-1,40E-03	2,7	220	6,30E-08	5,04E-07	87,5
2372	-1,56E-03	-1,71E-03	9,3	221	4,72E-08	2,27E-07	79,3
2373	-6,21E-04	-6,17E-04	0,6	222	4,24E-08	4,54E-07	90,6
2374	-2,86E-04	-2,38E-04	20,3	223	5,68E-08	5,51E-07	89,7
2375	-4,95E-05	1,07E-05	563,3	224	5,68E-08	5,35E-07	89,4
2376	-1,56E-04	-1,28E-05	1115,4	225	4,29E-08	4,01E-07	89,3
2377	-1,03E-03	-5,55E-04	85,6	226	1,84E-08	1,57E-07	88,3
2378	-4,83E-04	-1,85E-04	161,8	227	2,15E-08	1,91E-07	88,7
2379	-1,77E-03	-2,02E-03	14,2	228	2,35E-08	1,01E-07	76,8
2380	-1,80E-03	-2,07E-03	14,8	229	2,22E-08	3,38E-07	93,4
2381	-1,81E-03	-1,94E-03	7,4	230	1,74E-08	1,99E-07	91,3
2382	-1,78E-03	-1,95E-03	9,5	231	2,17E-08	4,49E-07	95,2
2405	-1,01E-03	-1,06E-03	5,5	236	2,10E-08	1,97E-07	89,3
2406	-1,38E-03	-1,46E-03	6,4	237	2,12E-08	2,05E-07	89,7
2409	-1,24E-03	-1,28E-03	3,4	291	4,34E-08	3,96E-07	89,1
2410	-7,44E-04	-7,20E-04	3,4	292	5,74E-08	5,28E-07	89,1
2411	-1,10E-03	-1,15E-03	4,5	293	5,87E-08	5,67E-07	89,6
2412	-9,63E-04	-9,05E-04	6,4	294	4,61E-08	4,63E-07	90,1
2413	-1,44E-03	-1,56E-03	8,2	295	6,09E-08	5,36E-07	88,6
2414	-6,75E-04	-5,01E-04	34,6	296	6,05E-08	5,30E-07	88,6
2415	-1,53E-03	-1,66E-03	8,8	297	4,60E-08	4,02E-07	88,5
2416	-4,37E-04	-3,40E-04	28,5	298	4,36E-08	4,73E-07	90,8
3025	-1,16E-03	-9,88E-04	17,5	999	5,51E-08	4,55E-07	87,9
3026	-1,08E-03	-7,14E-04	50,7	1000	3,31E-08	2,81E-07	88,2
3028	-9,00E-04	-6,88E-04	30,8	1001	4,69E-08	4,02E-07	88,4
3029	-1,28E-03	-1,25E-03	2,4	1002	6,27E-08	5,05E-07	87,6
3031	-1,08E-03	-1,00E-03	7,7	1003	6,15E-08	5,18E-07	88,1
3032	-1,46E-03	-1,55E-03	6,2	1004	5,51E-08	3,66E-07	84,9
3034	-1,30E-03	-1,34E-03	3,0	1005	6,19E-08	5,20E-07	88,1
3035	-1,67E-03	-1,86E-03	11,8	1006	3,53E-08	1,64E-07	78,5
3037	-1,55E-03	-1,69E-03	9,0	1007	4,66E-08	3,45E-07	86,5
3038	-4,53E-04	-4,27E-04	6,1	1008	4,96E-08	5,02E-07	90,1
3039	-8,14E-04	-8,39E-04	3,1	1009	2,99E-08	3,27E-07	90,8
3041	-6,83E-04	-6,69E-04	2,1	1010	4,30E-08	4,63E-07	90,7
3042	-1,68E-04	-1,13E-04	47,8	1011	5,68E-08	5,43E-07	89,6
3044	-3,62E-04	-2,89E-04	25,1	1012	5,78E-08	5,59E-07	89,7
3045	-1,03E-04	-1,07E-06	9520,1	1013	4,98E-08	4,68E-07	89,4
3047	-3,20E-04	-9,87E-05	223,7	1014	5,71E-08	5,32E-07	89,3
3048	-2,96E-04	-1,76E-04	67,9	1015	3,20E-08	3,03E-07	89,4
3049	-7,57E-04	-3,70E-04	104,6	1016	4,31E-08	3,99E-07	89,2
3052	-5,79E-04	-3,43E-04	68,9	1017	2,00E-08	1,74E-07	88,5
3053	-1,79E-03	-2,05E-03	14,5	1019	2,13E-08	1,94E-07	89,0
3055	-1,79E-03	-2,01E-03	12,2	1020	3,37E-08	2,96E-07	88,6
3056	-1,67E-03	-1,86E-03	11,9	1021	2,28E-08	2,19E-07	89,6
3057	-1,79E-03	-1,95E-03	8,4	1022	2,19E-08	3,93E-07	94,4
3060	-1,59E-03	-1,70E-03	6,9	1023	3,41E-08	4,00E-07	91,5
3061	-1,61E-03	-1,76E-03	9,0	1024	1,95E-08	3,24E-07	94,0
3108	-1,19E-03	-1,26E-03	6,0	1026	3,27E-08	4,60E-07	92,9
3110	-1,05E-03	-1,10E-03	5,0	1034	2,11E-08	2,01E-07	89,5
3111	-1,41E-03	-1,51E-03	7,3	1035	3,22E-08	2,96E-07	89,1
3115	-1,17E-03	-1,21E-03	3,9	1121	5,04E-08	4,62E-07	89,1
3116	-1,10E-03	-1,09E-03	0,8	1122	4,47E-08	3,99E-07	88,8
3117	-1,38E-03	-1,47E-03	6,4	1123	5,81E-08	5,48E-07	89,4
3118	-9,20E-04	-9,32E-04	1,4	1124	5,90E-08	5,29E-07	88,9
3119	-8,54E-04	-8,12E-04	5,1	1125	5,98E-08	5,51E-07	89,2
3120	-5,90E-04	-5,30E-04	11,5	1126	5,12E-08	5,20E-07	90,2
3121	-1,27E-03	-1,35E-03	6,6	1127	5,35E-08	4,99E-07	89,3
3122	-8,19E-04	-7,03E-04	16,5	1128	4,48E-08	4,68E-07	90,4
3123	-1,49E-03	-1,61E-03	8,5	1129	6,07E-08	5,33E-07	88,6
3124	-5,56E-04	-4,21E-04	32,2	1130	5,33E-08	4,66E-07	88,6
SUM SG 5:	**-6,56E-02**	**-6,50E-02**	**0,8**	**SUM SG 6:**	**2,67E-06**	**2,49E-05**	**89,3**

New concept analyses, pos 1 and pos 3 (two splines ahead), page 4 of 7

Node numbers and associated strains [mm/mm] exported from ansys

SG 7	**Pos 1**	**Pos 3**		**SG 8**	**Pos 1**	**Pos 3**	
Node	Strain	Strain	**Diff%**	Node	Strain	Strain	**Diff%**
9193	-2,29E-03	-1,95E-03	17,4	6888	5,57E-08	3,39E-08	39,0
9194	-2,15E-03	-1,78E-03	20,7	6889	6,51E-08	2,94E-08	54,9
9195	-2,17E-03	-1,71E-03	26,8	6890	5,75E-08	1,31E-08	77,2
9196	-2,30E-03	-1,70E-03	35,0	6891	3,11E-08	-1,31E-08	142,2
9197	-1,48E-03	-1,18E-03	24,7	6892	1,38E-08	-5,56E-08	503,2
9198	-1,29E-03	-1,07E-03	20,6	6893	5,32E-09	-5,34E-08	1103,2
9199	-1,15E-03	-9,74E-04	17,9	6894	-4,84E-09	-4,11E-08	749,5
9200	-1,51E-03	-1,27E-03	19,3	6895	4,92E-09	-2,33E-08	573,7
9201	-2,57E-03	-2,23E-03	15,5	6896	2,79E-08	2,43E-08	12,7
9202	-1,96E-03	-1,68E-03	16,6	6897	1,87E-08	2,01E-09	89,3
9203	-2,46E-03	-1,71E-03	44,1	6898	3,26E-09	-2,81E-08	960,5
9204	-2,43E-03	-1,67E-03	45,3	6899	5,08E-09	-2,22E-08	536,7
9205	-2,25E-03	-1,54E-03	46,0	6900	1,69E-08	5,27E-09	68,9
9206	-2,32E-03	-1,61E-03	43,8	6901	1,14E-08	-1,09E-08	195,6
9229	-1,72E-03	-1,31E-03	31,0	6924	2,07E-08	-4,06E-08	296,1
9230	-1,96E-03	-1,44E-03	36,4	6925	2,86E-08	-8,85E-09	131,0
9298	-2,02E-03	-1,58E-03	28,0	6993	1,86E-08	-2,97E-08	259,4
9299	-1,65E-03	-1,34E-03	23,7	6994	2,68E-08	-3,45E-08	228,8
9300	-1,84E-03	-1,42E-03	29,6	6995	2,99E-08	-2,68E-08	189,5
9301	-1,91E-03	-1,57E-03	21,9	6996	2,60E-08	-1,91E-08	173,3
9302	-2,08E-03	-1,52E-03	36,5	6997	4,01E-08	-1,38E-08	134,4
9303	-1,87E-03	-1,58E-03	18,4	6998	4,56E-08	-3,10E-09	106,8
9304	-2,21E-03	-1,63E-03	35,6	6999	3,87E-08	4,92E-09	87,3
9305	-1,54E-03	-1,29E-03	19,7	7000	2,44E-08	-1,86E-08	176,3
9849	-2,22E-03	-1,87E-03	19,0	7536	6,04E-08	3,16E-08	47,6
9850	-2,43E-03	-2,09E-03	16,3	7537	4,18E-08	2,92E-08	30,2
9852	-2,08E-03	-1,77E-03	17,8	7539	4,72E-08	1,94E-08	58,8
9853	-2,16E-03	-1,75E-03	23,7	7540	6,13E-08	2,12E-08	65,4
9855	-2,03E-03	-1,68E-03	21,3	7542	5,53E-08	1,31E-08	76,3
9856	-2,24E-03	-1,71E-03	30,9	7543	4,43E-08	-3,01E-11	100,1
9858	-2,10E-03	-1,65E-03	27,4	7545	4,88E-08	-3,42E-10	100,7
9859	-2,38E-03	-1,71E-03	39,5	7546	1,71E-08	-2,07E-08	221,1
9861	-2,25E-03	-1,66E-03	35,3	7548	2,86E-08	-1,61E-08	156,3
9862	-1,38E-03	-1,13E-03	22,8	7549	9,54E-09	-5,46E-08	672,4
9863	-1,60E-03	-1,25E-03	28,0	7550	1,73E-08	-4,79E-08	377,9
9865	-1,57E-03	-1,26E-03	24,2	7552	2,03E-08	-4,50E-08	322,1
9866	-1,22E-03	-1,02E-03	19,2	7553	2,42E-10	-4,72E-08	19580,9
9868	-1,41E-03	-1,18E-03	20,1	7555	1,20E-08	-4,16E-08	447,1
9869	-1,33E-03	-1,12E-03	18,7	7556	3,97E-11	-3,22E-08	81084,9
9871	-1,74E-03	-1,48E-03	17,8	7558	1,18E-08	-1,06E-08	190,0
9872	-1,53E-03	-1,28E-03	19,4	7559	1,18E-08	-2,65E-08	324,8
9873	-2,27E-03	-1,96E-03	16,0	7560	2,33E-08	1,32E-08	43,5
9876	-1,91E-03	-1,63E-03	17,5	7563	2,87E-08	3,47E-09	87,9
9877	-2,45E-03	-1,69E-03	44,7	7564	4,17E-09	-2,51E-08	702,4
9879	-2,38E-03	-1,64E-03	44,6	7566	8,23E-09	-1,65E-08	301,0
9880	-2,32E-03	-1,65E-03	40,5	7567	1,56E-08	-2,05E-08	231,8
9881	-2,29E-03	-1,58E-03	44,9	7568	1,41E-08	-2,80E-09	119,8
9884	-2,11E-03	-1,49E-03	41,3	7571	2,27E-08	-1,91E-09	108,4
9885	-2,20E-03	-1,56E-03	40,3	7572	1,80E-08	-1,45E-08	180,6
9932	-1,84E-03	-1,38E-03	33,9	7619	2,46E-08	-2,49E-08	201,2
9934	-1,78E-03	-1,37E-03	30,3	7621	2,53E-08	-3,37E-08	233,1
9935	-2,02E-03	-1,48E-03	36,5	7622	2,65E-08	-1,37E-08	151,8
10071	-1,93E-03	-1,50E-03	28,8	7765	2,27E-08	-3,21E-08	241,5
10072	-1,96E-03	-1,57E-03	25,0	7766	2,86E-08	-1,24E-08	143,2
10073	-2,11E-03	-1,60E-03	31,9	7767	2,84E-08	-3,06E-08	207,8
10074	-1,75E-03	-1,38E-03	26,8	7768	3,62E-08	-1,88E-08	151,9
10075	-1,78E-03	-1,45E-03	22,8	7769	3,50E-08	-2,03E-08	158,0
10076	-1,59E-03	-1,31E-03	21,8	7770	2,71E-08	-2,28E-08	183,9
10077	-1,96E-03	-1,47E-03	33,2	7771	3,31E-08	-1,64E-08	149,7
10078	-1,89E-03	-1,57E-03	20,2	7772	2,52E-08	-1,88E-08	174,7
10079	-2,14E-03	-1,57E-03	36,1	7773	4,28E-08	-8,45E-09	119,7
10080	-1,70E-03	-1,43E-03	19,0	7774	4,21E-08	9,45E-10	97,8
SUM SG 7:	**-1,21E-01**	**-9,46E-02**	**28,1**	**SUM SG 8:**	**1,63E-06**	**-8,75E-07**	**153,6**

New concept analyses, pos 1 and pos 3 (two splines ahead), page 5 of 7

Analyses results

	8 Strain gauges		
	SUM POS 1	SUM POS 2	Diff %
	-5,98E-03	-5,61E-03	6,5
	-5,96E-03	-5,31E-03	12,2
	-5,67E-03	-6,04E-03	6,5
	-6,61E-03	-6,61E-03	0,1
	-4,59E-03	-5,23E-03	13,9
	-4,66E-03	-3,98E-03	17,3
	-3,37E-03	-4,36E-03	29,5
	-4,81E-03	-3,83E-03	25,3
	-6,24E-03	-6,58E-03	5,4
	-5,06E-03	-5,33E-03	5,2
	-6,95E-03	-7,13E-03	2,5
	-7,08E-03	-7,28E-03	2,9
	-7,14E-03	-7,32E-03	2,5
	-7,47E-03	-7,73E-03	3,6
	-6,22E-03	-6,38E-03	2,5
	-6,64E-03	-6,21E-03	6,9
	-5,97E-03	-5,58E-03	7,1
	-4,62E-03	-4,18E-03	10,6
	-4,63E-03	-4,19E-03	10,7
	-4,12E-03	-3,73E-03	10,5
	-5,26E-03	-5,66E-03	7,5
	-4,05E-03	-3,85E-03	5,3
	-5,37E-03	-7,30E-03	36,0
	-5,53E-03	-5,78E-03	4,6
	-6,69E-03	-5,62E-03	19,0
	-6,15E-03	-5,64E-03	9,1
	-5,26E-03	-5,25E-03	0,3
	-6,18E-03	-5,85E-03	5,8
	-5,82E-03	-5,35E-03	8,7
	-6,08E-03	-5,93E-03	2,5
	-5,48E-03	-5,17E-03	6,0
	-6,08E-03	-6,20E-03	1,9
	-5,93E-03	-6,56E-03	10,6
	-4,51E-03	-4,38E-03	3,1
	-5,09E-03	-5,07E-03	0,2
	-4,55E-03	-5,19E-03	14,0
	-4,06E-03	-4,84E-03	19,0
	-4,99E-03	-5,15E-03	3,3
	-4,47E-03	-4,65E-03	4,1
	-5,40E-03	-4,28E-03	26,2
	-3,86E-03	-4,33E-03	12,0
	-5,45E-03	-5,02E-03	8,6
	-4,66E-03	-5,58E-03	19,7
	-7,56E-03	-7,31E-03	3,4
	-7,44E-03	-6,07E-03	22,5
	-5,84E-03	-6,04E-03	3,6
	-6,39E-03	-7,15E-03	11,8
	-6,49E-03	-6,38E-03	1,8
	-6,11E-03	-6,75E-03	10,5
	-5,80E-03	-6,11E-03	5,2
	-5,79E-03	-6,16E-03	6,3
	-6,65E-03	-6,99E-03	5,1
	-6,60E-03	-6,88E-03	4,2
	-6,52E-03	-6,31E-03	3,2
	-6,70E-03	-7,08E-03	5,7
	-5,91E-03	-5,32E-03	11,1
	-5,10E-03	-4,68E-03	9,0
	-4,14E-03	-3,71E-03	11,7
	-4,69E-03	-4,26E-03	10,2
	-3,98E-03	-3,79E-03	5,2
	-5,17E-03	-5,36E-03	3,6
	-4,01E-03	-5,94E-03	47,9
SUM ALL:	**-3,46E-01**	**-3,48E-01**	**0,5**

	4 strain gauges (compression)		
	SUM POS 1	SUM POS 2	Diff %
	-5,98E-03	-5,61E-03	6,5
	-5,41E-03	-5,31E-03	2,0
	-6,07E-03	-6,04E-03	0,5
	-6,40E-03	-6,61E-03	3,3
	-5,19E-03	-5,23E-03	0,8
	-3,70E-03	-3,98E-03	7,3
	-4,43E-03	-4,36E-03	1,6
	-3,53E-03	-3,83E-03	8,5
	-6,55E-03	-6,58E-03	0,5
	-5,33E-03	-5,33E-03	0,0
	-7,15E-03	-7,13E-03	0,3
	-7,34E-03	-7,28E-03	0,8
	-7,43E-03	-7,32E-03	1,5
	-7,76E-03	-7,73E-03	0,4
	-6,14E-03	-6,38E-03	3,8
	-6,17E-03	-6,21E-03	0,7
	-5,60E-03	-5,58E-03	0,5
	-4,20E-03	-4,18E-03	0,6
	-4,27E-03	-4,19E-03	2,0
	-3,88E-03	-3,73E-03	4,1
	-5,46E-03	-5,66E-03	3,6
	-3,89E-03	-3,85E-03	1,1
	-7,20E-03	-7,30E-03	1,3
	-5,63E-03	-5,78E-03	2,7
	-5,89E-03	-5,62E-03	4,8
	-6,05E-03	-5,64E-03	7,3
	-5,61E-03	-5,25E-03	7,0
	-6,07E-03	-5,85E-03	3,8
	-5,41E-03	-5,35E-03	1,0
	-5,97E-03	-5,93E-03	0,8
	-5,19E-03	-5,17E-03	0,4
	-6,21E-03	-6,20E-03	0,2
	-6,58E-03	-6,56E-03	0,3
	-4,28E-03	-4,38E-03	2,4
	-4,75E-03	-5,07E-03	6,9
	-4,84E-03	-5,19E-03	7,3
	-4,61E-03	-4,84E-03	4,9
	-4,88E-03	-5,15E-03	5,6
	-4,71E-03	-4,65E-03	1,2
	-4,16E-03	-4,28E-03	3,0
	-4,15E-03	-4,33E-03	4,3
	-5,09E-03	-5,02E-03	1,4
	-5,93E-03	-5,58E-03	6,3
	-7,71E-03	-7,31E-03	5,5
	-5,94E-03	-6,07E-03	2,3
	-5,73E-03	-6,04E-03	5,5
	-6,99E-03	-7,15E-03	2,3
	-6,14E-03	-6,38E-03	3,9
	-6,71E-03	-6,75E-03	0,7
	-6,04E-03	-6,11E-03	1,0
	-6,07E-03	-6,16E-03	1,4
	-6,94E-03	-6,99E-03	0,7
	-6,76E-03	-6,88E-03	1,8
	-6,18E-03	-6,31E-03	2,1
	-6,94E-03	-7,08E-03	2,0
	-5,25E-03	-5,32E-03	1,3
	-4,71E-03	-4,68E-03	0,5
	-3,75E-03	-3,71E-03	1,1
	-4,40E-03	-4,26E-03	3,2
	-3,88E-03	-3,79E-03	2,5
	-5,27E-03	-5,36E-03	1,6
	-5,82E-03	-5,94E-03	1,9
SUM ALL:	**-3,46E-01**	**-3,48E-01**	**0,3**

New concept analyses, pos 1 and pos 3 (two splines ahead), page 6 of 7

Analyses results

	4 strain gauges (no compression)				2 strain gauges (SG 1 and 5)		
	SUM POS 1	**SUM POS 2**	**Diff %**		**SUM POS 1**	**SUM POS 2**	**Diff %**
	-2,04E-07	3,34E-07	160,9		-2,37E-03	-2,09E-03	13,4
	-7,21E-07	3,54E-07	303,8		-1,89E-03	-1,84E-03	3,0
	-1,92E-06	3,16E-07	708,6		-2,46E-03	-2,46E-03	0,1
	-4,42E-06	1,79E-07	2575,2		-2,46E-03	-2,68E-03	8,9
	1,97E-06	2,28E-07	88,4		-2,11E-03	-2,00E-03	5,6
	1,22E-06	5,13E-07	58,0		-8,19E-04	-9,67E-04	18,1
	6,27E-07	3,39E-07	46,0		-1,65E-03	-1,46E-03	12,7
	4,36E-07	2,26E-07	48,1		-4,79E-04	-4,53E-04	5,7
	-7,73E-08	2,99E-07	125,8		-1,66E-03	-1,71E-03	2,9
	1,33E-07	3,56E-07	62,6		-1,38E-03	-1,34E-03	2,4
	-9,28E-06	2,28E-07	4173,8		-2,87E-03	-3,23E-03	12,6
	-2,52E-06	3,86E-07	752,2		-3,17E-03	-3,41E-03	7,6
	8,91E-06	1,49E-07	98,3		-3,46E-03	-3,45E-03	0,0
	5,40E-06	3,05E-07	94,3		-3,72E-03	-3,64E-03	2,3
	3,30E-06	1,58E-07	95,2		-2,86E-03	-2,80E-03	2,3
	4,05E-06	3,09E-08	99,2		-2,76E-03	-2,77E-03	0,5
	3,56E-08	8,98E-08	60,4		-2,25E-03	-2,25E-03	0,1
	1,38E-06	2,06E-07	85,1		-1,34E-03	-1,33E-03	0,4
	1,95E-06	3,03E-07	84,5		-1,32E-03	-1,43E-03	8,7
	2,08E-07	2,82E-07	26,4		-9,50E-04	-9,62E-04	1,3
	3,12E-06	5,64E-07	81,9		-1,63E-03	-2,09E-03	28,6
	2,68E-07	4,36E-07	38,5		-6,95E-04	-6,92E-04	0,3
	-8,89E-07	3,41E-07	360,7		-3,39E-03	-3,35E-03	0,9
	8,17E-07	3,18E-07	61,1		-2,40E-03	-2,04E-03	17,4
	-4,62E-07	3,35E-07	238,0		-2,33E-03	-2,12E-03	9,6
	-1,34E-07	2,34E-07	157,2		-2,14E-03	-1,80E-03	18,8
	2,51E-08	2,98E-07	91,6		-2,32E-03	-2,03E-03	14,2
	-1,32E-06	5,24E-07	351,6		-2,58E-03	-2,52E-03	2,3
	-2,34E-07	3,39E-07	168,9		-1,97E-03	-1,90E-03	3,8
	-3,17E-06	2,57E-07	1335,1		-2,26E-03	-2,41E-03	6,6
	-9,27E-07	3,62E-07	356,3		-1,81E-03	-1,93E-03	6,6
	-6,83E-06	-1,04E-07	6488,9		-2,31E-03	-2,54E-03	9,8
	-2,66E-06	1,37E-07	2034,0		-2,84E-03	-2,91E-03	2,4
	1,60E-06	2,03E-07	87,3		-1,51E-03	-1,44E-03	4,3
	2,64E-06	2,74E-07	89,6		-1,53E-03	-1,69E-03	10,5
	1,67E-06	4,87E-07	70,8		-1,68E-03	-1,76E-03	4,6
	9,24E-07	3,30E-07	64,3		-1,71E-03	-1,54E-03	11,1
	1,03E-06	3,47E-07	66,2		-1,80E-03	-1,63E-03	10,0
	5,28E-07	3,04E-07	42,3		-1,78E-03	-1,54E-03	15,5
	3,09E-07	4,48E-07	31,1		-7,47E-04	-6,83E-04	9,4
	6,17E-07	3,66E-07	40,7		-1,01E-03	-1,12E-03	11,1
	5,10E-08	4,30E-07	88,1		-1,11E-03	-9,97E-04	11,6
	1,80E-07	7,92E-08	55,9		-2,20E-03	-1,84E-03	19,9
	-5,91E-06	1,87E-08	31635,9		-3,56E-03	-3,63E-03	1,9
	1,45E-06	7,57E-08	94,8		-2,07E-03	-2,38E-03	15,0
	-1,75E-06	7,73E-08	2359,4		-1,84E-03	-2,18E-03	18,7
	7,16E-06	5,30E-07	92,6		-2,55E-03	-3,10E-03	21,4
	6,47E-06	4,78E-07	92,6		-2,00E-03	-2,54E-03	27,3
	4,26E-06	4,73E-07	88,9		-2,61E-03	-2,94E-03	12,8
	3,70E-06	5,60E-07	84,9		-2,43E-03	-2,54E-03	4,7
	2,61E-06	1,93E-07	92,6		-2,56E-03	-2,53E-03	1,1
	3,57E-06	2,00E-07	94,4		-3,20E-03	-3,12E-03	2,8
	9,83E-07	3,09E-07	68,6		-3,12E-03	-2,91E-03	7,2
	1,25E-07	3,11E-07	59,8		-2,72E-03	-2,61E-03	4,0
	-4,15E-07	4,86E-07	185,3		-3,24E-03	-3,18E-03	1,7
	1,67E-06	2,92E-07	82,5		-2,12E-03	-2,07E-03	2,1
	8,14E-07	2,49E-07	69,4		-1,65E-03	-1,60E-03	3,2
	1,10E-06	2,31E-07	79,1		-9,98E-04	-9,78E-04	2,0
	2,52E-06	2,79E-07	88,9		-1,37E-03	-1,53E-03	11,1
	2,19E-07	3,23E-07	32,2		-8,22E-04	-8,27E-04	0,6
	1,13E-06	5,00E-07	55,7		-1,59E-03	-1,97E-03	24,3
	5,51E-07	3,66E-07	33,6		-2,47E-03	-2,12E-03	16,4
SUM ALL:	**3,79E-05**	**1,85E-05**	**51,1**	**SUM ALL:**	**-1,29E-01**	**-1,30E-01**	**0,8**

New concept analyses, pos 1 and pos 3 (two splines ahead), page 7 of 7

Analyses results

	2 strain gauges (SG 3 and 8)		
	SUM POS 1	**SUM POS 2**	**Diff %**
	-1,32E-03	-1,57E-03	19,2
	-1,37E-03	-1,69E-03	23,4
	-1,44E-03	-1,87E-03	29,7
	-1,64E-03	-2,23E-03	35,8
	-1,60E-03	-2,05E-03	27,7
	-1,60E-03	-1,94E-03	21,5
	-1,64E-03	-1,93E-03	17,6
	-1,54E-03	-2,11E-03	37,1
	-2,32E-03	-2,65E-03	14,3
	-1,99E-03	-2,30E-03	15,8
	-1,82E-03	-2,19E-03	20,4
	-1,74E-03	-2,20E-03	26,5
	-1,72E-03	-2,32E-03	34,9
	-1,72E-03	-2,48E-03	44,2
	-1,56E-03	-2,27E-03	45,4
	-1,45E-03	-2,00E-03	38,2
	-1,33E-03	-1,75E-03	30,9
	-1,21E-03	-1,51E-03	24,8
	-1,11E-03	-1,33E-03	20,2
	-1,02E-03	-1,20E-03	17,5
	-1,76E-03	-2,05E-03	16,3
	-1,32E-03	-1,58E-03	19,0
	-1,61E-03	-2,32E-03	43,6
	-1,69E-03	-2,46E-03	44,9
	-1,34E-03	-1,63E-03	21,4
	-1,48E-03	-1,75E-03	18,4
	-1,21E-03	-1,45E-03	19,7
	-1,32E-03	-1,57E-03	19,0
	-1,40E-03	-1,78E-03	26,7
	-1,48E-03	-1,81E-03	22,4
	-1,29E-03	-1,60E-03	24,1
	-1,52E-03	-1,96E-03	28,7
	-1,49E-03	-1,99E-03	33,6
	-1,39E-03	-1,81E-03	30,3
	-1,62E-03	-2,14E-03	31,8
	-1,59E-03	-2,17E-03	36,4
	-1,68E-03	-2,27E-03	35,3
	-1,67E-03	-2,34E-03	40,3
	-1,60E-03	-1,99E-03	24,6
	-1,67E-03	-2,12E-03	27,1
	-1,62E-03	-1,93E-03	19,5
	-1,71E-03	-2,06E-03	20,9
	-1,81E-03	-2,11E-03	16,6
	-1,70E-03	-1,99E-03	17,0
	-1,49E-03	-2,06E-03	37,6
	-1,58E-03	-2,21E-03	40,5
	-2,15E-03	-2,47E-03	14,9
	-2,04E-03	-2,35E-03	15,1
	-1,90E-03	-2,24E-03	18,0
	-1,78E-03	-2,19E-03	23,3
	-1,73E-03	-2,26E-03	30,7
	-1,72E-03	-2,40E-03	39,5
	-1,71E-03	-2,47E-03	44,5
	-1,50E-03	-2,13E-03	41,9
	-1,59E-03	-2,29E-03	44,5
	-1,39E-03	-1,87E-03	34,7
	-1,27E-03	-1,63E-03	28,0
	-1,16E-03	-1,42E-03	22,6
	-1,06E-03	-1,26E-03	18,9
	-1,17E-03	-1,39E-03	18,4
	-1,54E-03	-1,81E-03	17,4
	-1,65E-03	-2,39E-03	44,3
SUM ALL:	**-9,65E-02**	**-1,23E-01**	**27,7**

Excel formulas used in the excel calculations for new concept

Table 1 shows an excerpt of the excel calculations for analyzing the deviation between position 1 and position 2 by use of 4 strain gauges. These formulas are representative for all the excel calculations for calculating the deviation between two positions.

	2 strain gauges (SG 1 and 5)		
	SUM POS 1:	**SUM POS 2:**	**Diff %**
	=B5+V5	=C5+W5	=ABS(1-((MIN(BC5:BD5)/MAX(BC5:BD5))))*100
	=B6+V6	=C6+W6	=ABS(1-((MIN(BC6:BD6)/MAX(BC6:BD6))))*100
	=B7+V7	=C7+W7	=ABS(1-((MIN(BC7:BD7)/MAX(BC7:BD7))))*100
	=B8+V8	=C8+W8	=ABS(1-((MIN(BC8:BD8)/MAX(BC8:BD8))))*100
	=B9+V9	=C9+W9	=ABS(1-((MIN(BC9:BD9)/MAX(BC9:BD9))))*100
	=B10+V10	=C10+W10	=ABS(1-((MIN(BC10:BD10)/MAX(BC10:BD10))))*100
	=B11+V11	=C11+W11	=ABS(1-((MIN(BC11:BD11)/MAX(BC11:BD11))))*100
	=B12+V12	=C12+W12	=ABS(1-((MIN(BC12:BD12)/MAX(BC12:BD12))))*100
	=B13+V13	=C13+W13	=ABS(1-((MIN(BC13:BD13)/MAX(BC13:BD13))))*100
	=B14+V14	=C14+W14	=ABS(1-((MIN(BC14:BD14)/MAX(BC14:BD14))))*100
	=B15+V15	=C15+W15	=ABS(1-((MIN(BC15:BD15)/MAX(BC15:BD15))))*100
	=B16+V16	=C16+W16	=ABS(1-((MIN(BC16:BD16)/MAX(BC16:BD16))))*100
SUM ALL:	**=SUM(BC5:BC16)**	**=SUM(BD5:BD16)**	**=ABS(1-((MIN(BC17:BD17)/MAX(BC17:BD17))))*100**

Table 1: Excel formulas for deviation calculations

Table 2 shows an excerpt of the excel calculations for SG 1 Pos 1 and Pos 2 with formulas. These formulas are representative for all the calculations for calculating the deviation between two positions for one SG and adding the strain readings. These calculations are not necessary for calculating the total deviation, shown in Table 1.

SG 1	**Pos 1**	**Pos 2**	
Node	Strain	Strain	**Diff%**
4750	-0,0012409	-0,0010289	=ABS(1-(MIN(B5:C5)/(MAX(B5:C5))))*100
4751	-0,00069647	-0,00058234	=ABS(1-(MIN(B6:C6)/(MAX(B6:C6))))*100
4752	-0,0010947	-0,00088433	=ABS(1-(MIN(B7:C7)/(MAX(B7:C7))))*100
4753	-0,00089426	-0,00078297	=ABS(1-(MIN(B8:C8)/(MAX(B8:C8))))*100
4754	-0,0014913	-0,0011701	=ABS(1-(MIN(B9:C9)/(MAX(B9:C9))))*100
4755	-0,00053275	-0,00051442	=ABS(1-(MIN(B10:C10)/(MAX(B10:C10))))*100
4756	-0,0015962	-0,0012647	=ABS(1-(MIN(B11:C11)/(MAX(B11:C11))))*100
4757	-0,00032302	-0,0002891	=ABS(1-(MIN(B12:C12)/(MAX(B12:C12))))*100
4758	-0,00062956	-0,00073352	=ABS(1-(MIN(B13:C13)/(MAX(B13:C13))))*100
4759	-0,00089352	-0,00088177	=ABS(1-(MIN(B14:C14)/(MAX(B14:C14))))*100
4760	-0,0011014	-0,00099636	=ABS(1-(MIN(B15:C15)/(MAX(B15:C15))))*100
4761	-0,0013675	-0,0011596	=ABS(1-(MIN(B16:C16)/(MAX(B16:C16))))*100
SUM SG 1:	**=SUM(B5:B16)**	**=SUM(C5:C16)**	**=ABS(1-(MIN(B17:C17)/(MAX(B17:C17))))*100**

Table 2: Excel calculations for single strain gauge readings

Appendix H

Ansys analyses files

- Ring gear and gear housing analyses
- Existing concept analyses
- New concept analyses

Ansys analyses files on attached DVD

The size of the solution files are too large to fit on a DVD.
For this reason the solution files are not part of the appendix.
All model set-ups are present and the analyses can be solved in Ansys Workbench.