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subsea 7

Faculty of Science and Technology

MASTER'S THESIS

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Abstract

This master thesis is written on the University of Stavanger spring 2011 in collaboration with Subsea 7. When transporting hydrocarbons from seabed to top side on a jacket platform there is always the need of a riser. Risers are attached to the platform leg or bracing by means of riser clamps. The riser loads together with environmental forces transfers large stresses to the clamps. To ensure that the clamps can withstand these loads over the design life, several analyses have to be performed. This thesis covers the design methodology and the most important analyses using a FE (Finite Element) tool, on one of the clamps designed by Subsea 7 for the Ekofisk 2/4-B platform.

Basically three analyses are performed; ULS (Ultimate Limit State) stress check and FLS (Fatigue Limit State) check for the clamp and the bolts, in addition to a non-linear slippage analysis. The action loads from the riser are given by the jacket operator. The environmental forces on the riser and the clamps are calculated to find the largest load combination in the horizontal- and vertical direction. For the various analyses different load- and material factors are applied to the forces. The worst load combination is applied in the analysis which is conducted in ANSYS, FE tool. The linear FE analysis has to be setup correctly to obtain good results.

The results for the ULS stress check are in general within allowable limits, i.e. below design yield. There is however some peak stresses in local areas that are above design yield. Common practice is to conduct a non-linear analysis and check if the peak stresses are due to secondary effects. To disregard the secondary effects the plastic strain obtained in the non-linear analysis have to be insignificant. The results obtained indicate that the peak stresses are due to secondary effects, hence the clamp meets the requirements for the ULS criteria.

In the FLS check three hot spots is checked including a weld. Stress ranges are obtained from the cyclical loads and the number of cycles during the design life calculated. The fatigue damage factor found shall not exceed the fatigue utilization factor calculated for the clamp. This ensures that the clamp will avoid fatigue damage in the design life. It is shown that welds are more fragile to fatigue than plated structures. Regardless all the hot spots are within allowable limits.

The slippage analysis is performed to find out if there is enough statically friction force in the riser clamp to avoid the clamp from sliding. The clamping force is depended of the bolt pre-tension. Too much tension can cause to high pressure on the jacket leg causing it to buckle and too low tension can cause the clamp to slip. The results show that there are sufficient sticking elements in the clamp to avoid slippage.

Preface

This master thesis is written by Ivar A. Devold during the spring of 2011 at the University of Stavanger. In November 2010 I contacted Professor Daniel Karunakaran who works at Subsea 7 S.A. (Subsea 7 Inc. before merged with Acergy S.A in January 2011) and asked if they had any subjects I could look into for my thesis. We had a meeting on Subsea 7 where we discussed possible subjects and came to the conclusion that a study into friction clamps would be the best topic for my thesis. The title of the master thesis became “Finite element analysis of a friction clamp located on a North Sea jacket”. The purpose of the thesis was in short to learn the design methodology including the tools, by perform finite element analyses on riser clamps. The tool used for the thesis was ANSYS v13 that is widely used in the industry, thus it was a good opportunity to get familiar with such tool.

In the start a lot of time was spent to get familiar with what friction clamps. Before starting using the analysis tool (ANSYS) I had to read and learn how the system works. The well known “trial and error method” was frequently used. Although most of the results were incorrect in the beginning I learned a lot from it.

I would like to give a special thanks to Professor Daniel Karunakaran my faculty supervisor and Siv.Ing Arild Østhus my external supervisor for great guiding trough the thesis. Another person that deserves acknowledgement is Dr. Dasharatha Achani for helping me a lot with ANSYS and the thesis in general. A thanks also goes to Dr. Qiang Chen and Siv.Ing Kristian Lindtveit for helping me. Gratitude goes to other people in Subsea 7 as well, which have gladly helped me with questions when I have asked.

Stavanger,

15. June 2011

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Ivar A. Devold

List of Contents

List of Symbols

A_s	Nominal stress area	[m^2]
A_s	Share area	[m^2]
C_A	Added mass coefficient	[-]
C_D	Drag coefficient	[-]
C_S	Slamming/impact coefficient	[-]
$F_{H,E}$	Horizontal riser force in east direction	[N]
$F_{H,S}$	Horizontal riser force in south direction	[N]
F_N	Normal sectional force	[N]
F_S	Slamming sectional force	[N]
$F_{V,max}$	Maximum vertical friction force	[N]
$F_{b,cap}$	Maximum capacity of bolt	[N]
F_b	Pre-tension force	[N]
F_{bd}	Dynamic force in bolt	[N]
F_d	Dynamic force	[N]
F_{fd}	Dynamic force in fundament	[N]
F_o	Pre-tension	[N]
F_{pre}	Allowed pre-tension force	[N]
H_{max}	Maximum wave height	[m]
H_s	Significant wave height	[m]
T_d	Design life in seconds	[s]
T_p	Peak period	[s]
$\bar{a}$	Intercept of the design S-N curve with the log N axis	[-]
f_{ub}	Ultimate stress for bolt	[MPa]
f_y	Yield stress	[MPa]
f_{yd}	Design yield	[MPa]
n_0	Number of cycles	[-]
p_d	Design pressure	[MPa]
p_d	Allowable pressure	[MPa]
u	Horizontal particle velocity	[m/s]
v	Fluid particle velocity	[m/s]
w	Vertical particle velocity	[m/s]
$\dot{u}$	Horizontal particle acceleration	[m/s^2]
$\dot{v}$	Fluid particle acceleration	[m/s^2]
$\dot{w}$	Vertical particle acceleration	[m/s^2]
γ_{Mb}	Material factor buckling	[-]
γ_b	Material factor for bolt	[-]
γ_s	Material factor for steel	[-]
$\sigma_{h,d}$	Design hoop stress	[MPa]
σ_{pc}	Contact pressure	[MPa]
v_0	Average zero-crossing frequency	[1/s]
$\Delta\sigma_o$	Stress range	[MPa]
h	Weibull stress range shape distribution parameter	[-]

A	Cross sectional area	[m^2]
D	Diameter	[mm]
D	Fatigue damage factor	[-]
E	Young's modulus	[MPa]
H	Trough-to-crest wave height	[m]
L	Length	[mm]
T	Wave period	[s]
d	Mean water depth	[m]
k	Stiffness	[N/m]
k	Wave number	[1/m]
m	Negative inverse slope of the S-N curve	[-]
q	Weibull scale parameter	[-]
t	Time	[s]
t	Thickness	[mm]
x	Displacement	[mm]
z	Distance from mean free surface positive upward	[m]
$\Gamma\left(1+\frac{m}{h}\right)$	Gamma function	[-]
ε	Strain	[-]
η	Fatigue utilization factor	[-]
λ	Wave length	[m]
μ	Friction factor	[-]
ρ	Mass density of fluid	[kg/m^3]
σ	Stress	[MPa]

1. Introduction

When recovering hydrocarbons from platforms there is always the need of risers. A riser is defined as a vertical or near-vertical segment of pipe connecting facilities above water to the subsea- base or pipeline (Guo, Shanhong, Chacko, & Ghalambor, 2005). Friction clamps are used to attach the riser securely to the legs or braces of the platform and are widely used on all North Sea jackets both over and under the sea surface. Riser and riser clamps transfer substantial loads from wave and currents to the jacket structure. Depending on the pipeline and the riser system the thermal expansion of the pipe may be transferred to the jacket trough the riser clamps. Thus there is important to design and construct these clamps to achieve a specific design life for the different platform requirements.

1.1. Scope of document

Subsea 7 have designed six riser clamps for an 18” ID riser on the Ekofisk 2/4-B platform that are already fabricated and installed. Several analyses need to be performed to assess whether the clamps have enough capacity to support the riser. The purpose of this thesis is to understand the design methodology, perform the required analyses and discuss the results for the capacity of the clamp against the relevant acceptance criteria from specified code/standard. Further the aim includes to get familiar with the FE (Finite Element) tool and compare the results to previous results from Subsea 7 (Subsea 7 [Internal document], 2006). The scope of work also includes identifying the forces acting on the clamp and specifying the bolt pre-tension before checking the clamp against structural failure criteria. The main contents of the thesis outlined as below:

- Specification of initial bolt tension and loss in tension
- ULS stress check with pre-tension in bolts and environmental loads from supported riser
- Non-linear slippage analyses
- Check of jacket leg for new stresses
- Fatigue check of critical details
- Fatigue check of bolts
- Summary and recommendations

This means the thesis will basically cover analyses for stress and fatigue checks against environmental and riser loads. Slippage analyses will be conducted to ensure that the static friction force from the jacket clamp is large enough to prevent the clamp from sliding.

The thesis work mainly focuses on the design and analysis part. The other important design considerations such as influence of thermal expansion, corrosion and installation/fabrication tolerances are not covered in this work.

1.2. Document description

In chapter 2 an introduction of basic riser clamp designs are presented to get an impression on riser clamps. Chapter 3 gives a description of the clamps designed by Subsea 7 including details of their function, location and the differences between them. The processes to find the loads act on the clamp are described in chapter 4. Chapter 5 explains some useful definition of terms and methods used in FEA (Finite Element Analysis). The setup of the various FE analyses is described in chapter 6. In chapter 7 the results are presented as well as the acceptance criteria. The summary, conclusions and discussions are stated in chapter 8. The references are found in chapter 9.

2. Basic riser clamp designs

There are different clamp designs to the various areas of use. For shallow water risers (less than 100 feet) the riser is guided by encircling clamps, not suspended. For deep water risers there normally is a suspension clamp located above or below the waterline to restrain the riser laterally. A slight gap should be used for the encirclement clamps so that the riser can move vertically and hang off the suspension clamp.

The spacing between each encirclement clamp is determined of the environmental loads, normally resulting in closer spacing in the splash zone. Near the seabed the spacing can be large due to the available bracing. The bottom clamp should not be too close to the sea bottom due to the expansion of the pipeline. Sometimes the clamps are attached to the jacket legs to have good support for the riser, but this exposes the riser for potential boat impact in the splash zone.

2.1. Basic clamps

The two most commonly used clamps are the anchor clamp and guide clamp shown in Figure 2.1 and Figure 2.2, respectively. The guide clamps are designed to allow vertical movement and therefore have an internal diameter slightly larger than the riser diameter. Anchor clamps restrain the riser so it is fixed. If there is no need of an anchor clamp, the guiding clamps will carefully squeeze the riser to support it. Normally the clamps are hinged in one end to make them easier to install, but this depends upon the application.

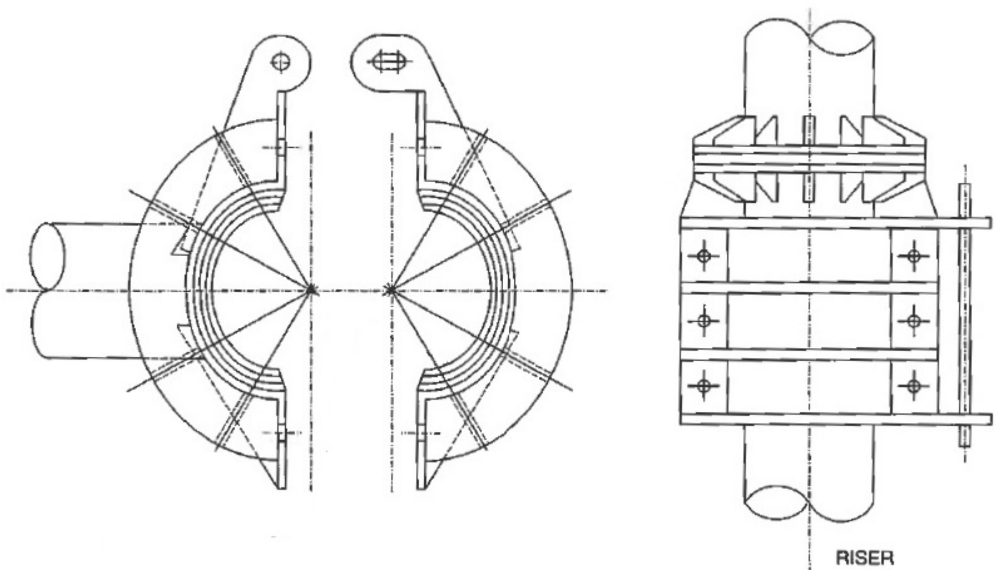


Figure 2.1 Typical anchor clamp (Guo,2005)

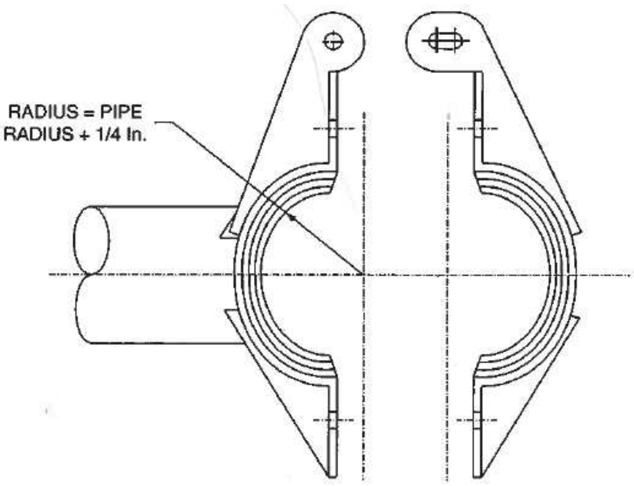


Figure 2.2 Typical guide clamp (Guo,2005)

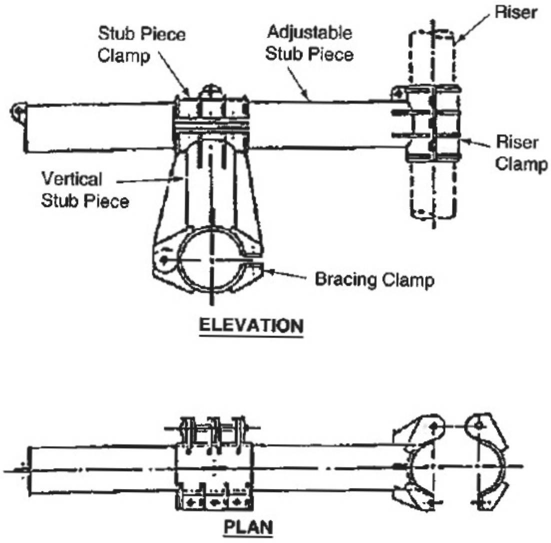


Figure 2.3 Widely used adjustable clamp (Guo,2005)

2.1.1. Adjustable clamps

Adjustable clamps have the possibility to change the position on the riser-end after installed on the jacket and are therefore more flexible. One of the most widely used adjustable clamp concept can be seen in Figure 2.3. It consists of a tubular stub piece fitted to the riser clamp. The adjustable stub piece is then connected to a vertical stub piece clamped to the bracing, like in the figure, or to a stub piece welded to the jacket. The maximum load of the stub piece is determined by the wall thickness where axial forces, shear forces and bending moments are taken into account. Adjustable stub pieces will result in large moments especially when the stub piece is fully extracted, and this will be transferred to the vertical stub piece and bracing in addition to the extra moment due to the offset of the vertical stub piece. This results in larger stiffness and higher grade materials.

Another type of adjustable clamp is shown in Figure 2.4. The clamp is used for the diagonals on jackets in the North Sea. Figure 2.5 illustrates another type that have a double clamp for the bracing and the stub piece and a single clamp for the riser connection. The double clamp can also be adjusted in the rotational plane as shown in Figure 2.6 to allow even more misalignment of the riser.

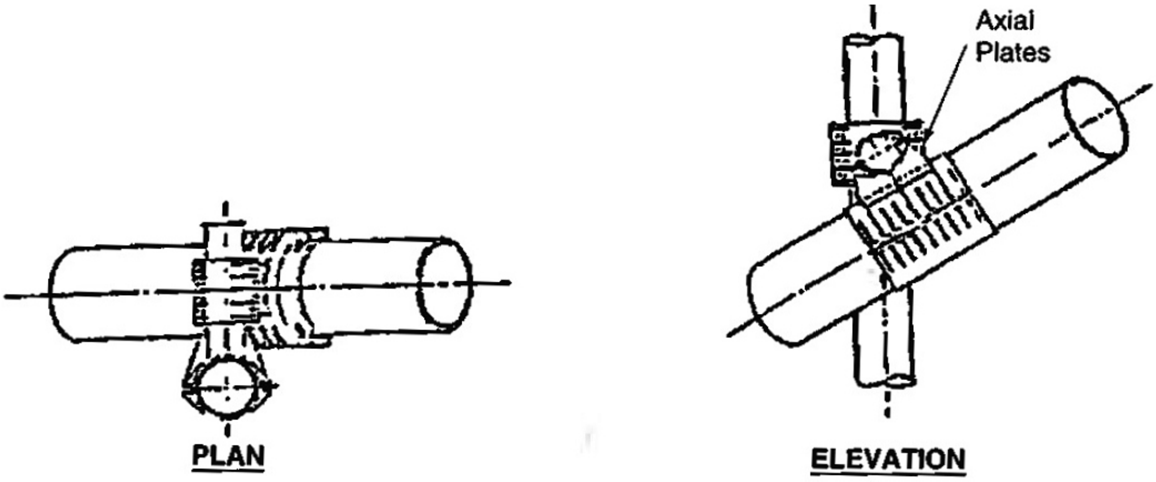


Figure 2.4 Another adjustable clamp
(Guo,2005)

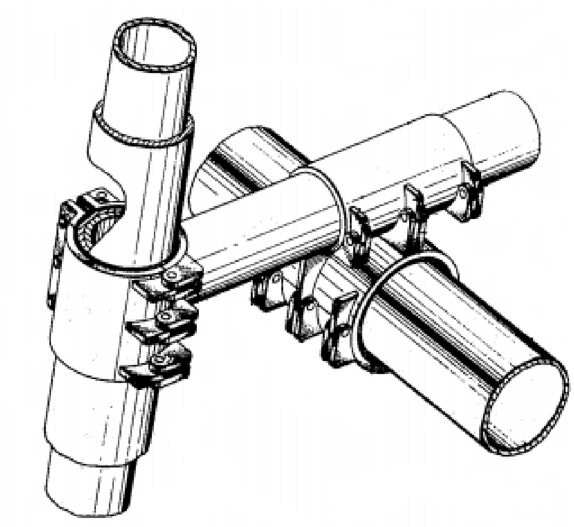


Figure 2.5 Double clamp design
(Hauber, 1973)

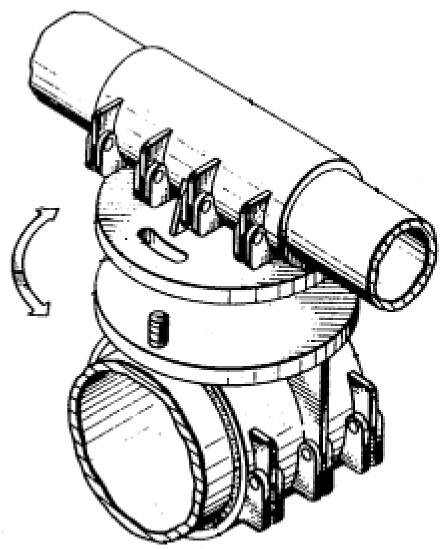


Figure 2.6 Rotating dual clamp
(Hauber, 1973)

2.1.2. Stub piece connection clamps

In addition to the vertical stub piece seen before in Figure 2.3, another alternative is to weld on a stub piece with a flange on the jacket. Figure 2.7 shows one with a plated clamp design and one with a tubular clamp design.

2.1.3. Load-bearing clamps

Load-bearing clamps are normally located above sea level and can either be welded directly on the jacket or be connected using a friction grip clamp. The strength of the stub piece depends of the fixity of the riser in the riser clamp. If it is completely fixed, all forces and moments will be transferred to the clamp and the stub piece has to be stronger. When the riser is to be seated, the riser is fitted with a flange that sits on top of the load-bearing riser clamp. The flange faces can be bolted together or resting on each other (see Figure 2.8). If the connection is not bolted, only translational and vertical forces will be transferred to the clamp resulting in a lighter clamp design than if the connection is bolted. During installation and testing of riser and pipeline, a temporary weight clamp (shown in Figure 2.9 and Figure 2.10) can be used to transfer the weight to the load-bearing clamp.

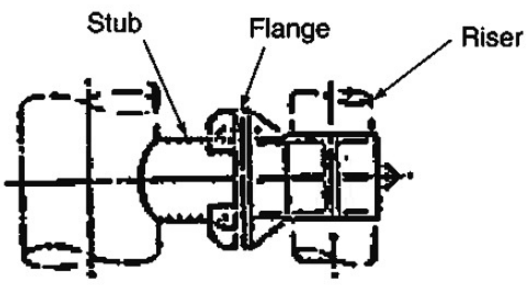


Figure 2.7 Stub piece clamp (Guo,2005)

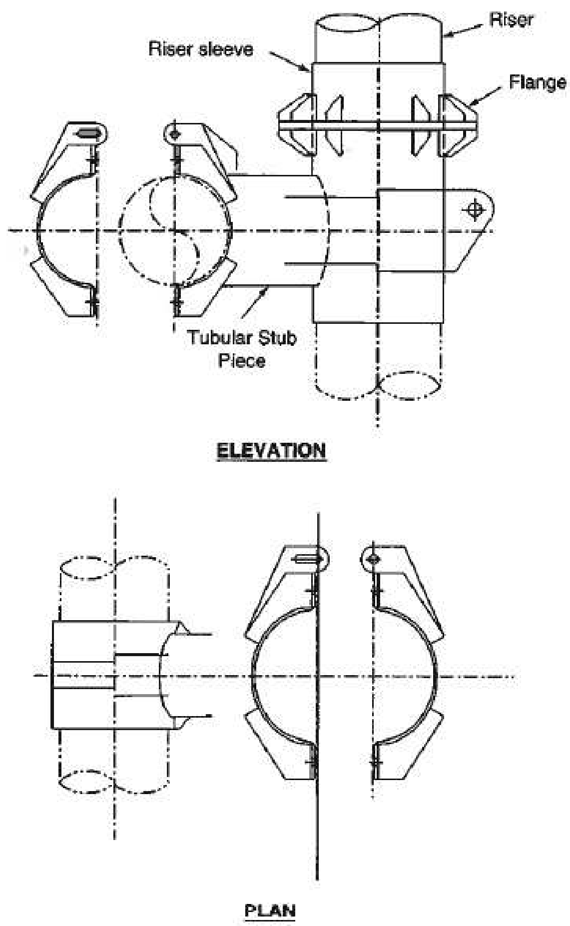


Figure 2.8 Typical load-bearing clamp (Guo,2005)

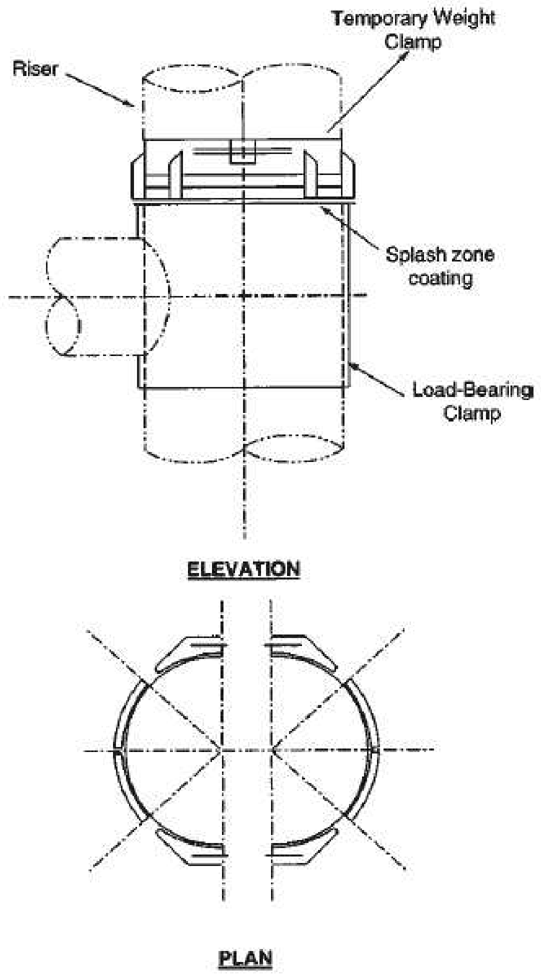


Figure 2.9 Temporary weight clamp (Guo,2005)

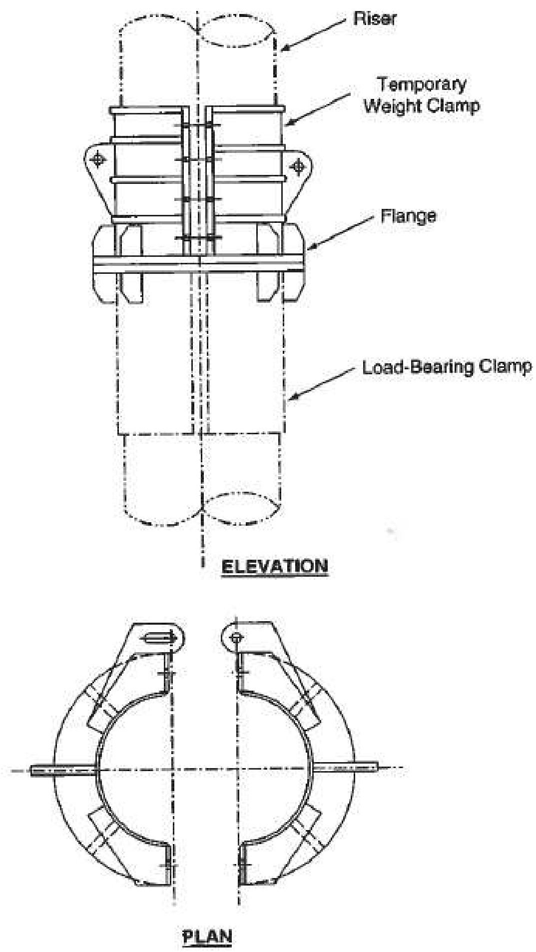


Figure 2.10 Another temporary weight clamp (Guo,2005)

3. Clamp study

The clamps in this thesis are of the type guiding clamps i.e., they make sure that the riser doesn't move in the horizontal direction while the vertical forces and weight of the riser is taken by a riser hang-off on the cellar deck.

There are constructed six clamps with different jacket OD and different elevations, data can be seen in Table 3.1.

Riser clamp	Jacket leg OD [inch]	Elevation (from seabed) [m]
Riser clamp 1	45	10,000
Riser clamp 2	45	25,000
Riser clamp 3	45	40,000
Riser clamp 4	45	54,000
Riser clamp 5	46	66,000
Riser clamp 6	42	78,000

Table 3.1 Clamp data

A drawing of the connection positions for the clamps on the jacket is presented in Appendix A. Special attention has to be taken for clamp 6 which according to the drawing is in the splash zone. In this zone there will be considerable larger forces due to wave loads and corrosion protection may not be sufficient.

Detailed clamp drawings are found in Appendix A. From the drawings, it can be seen that the clamps in general consist of three parts: the riser clamp assembly, jacket leg clamp assembly and clamp support bracket (see Figure 3.1).

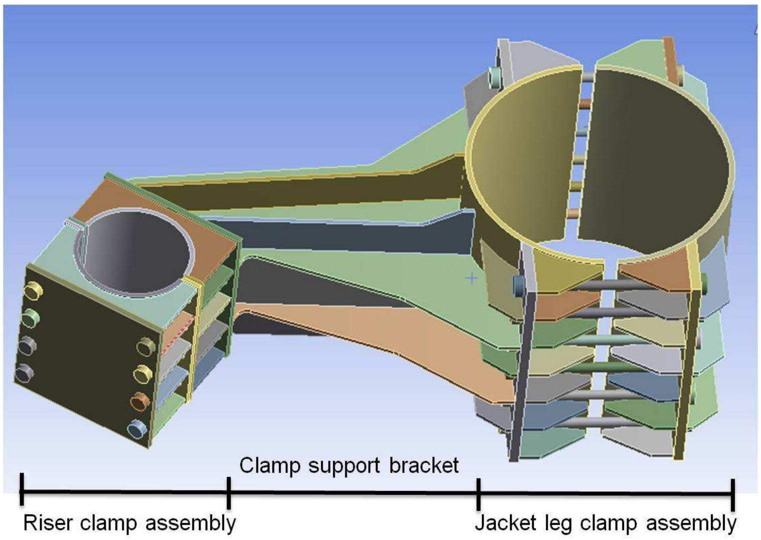


Figure 3.1 Clamp description

The support bracket transfers the force from the riser clamp to the jacket leg clamp. The bracket consists of many stiffener plates to make sure it is strong enough to withstand forces form different directions. The stiffeners are designed with smooth curves to avoid hot spots where stress concentrations can build up. The riser clamp assembly and the bracket are fitted together with a flange so there is the possibility for some adjustment under installation.

The riser clamp assembly consists of two shells connected with hinges for easier installation, and bolted together. The inside of the shells is coated with ribbed neoprene, a rubber-like coating, which will damp and take up small impact loads form the riser. The edges on the inside of the shells are rounded so that no sharp corners will wear on the riser. Also a riser bumper is part of the riser clamp for easier installation of the riser when guiding it into position.

The jacket leg clamp assembly also consists of two shells with hinges and bolts. The bracket is welded to the front shell. There is space between the clamp shells to make sure that the diameter of the clamp is smaller than the diameter of the leg when the clamp is tightened. Vertical plates with stiffeners support the tension from the bolts. The edges are rounded like the guide clamp of the same reason but to avoid damage on the jacket leg instead of the riser.

There are some differences between the clamps. Clamps 2, 3 and 4 are identical. Also clamp 5 is very much alike but has a larger diameter for the jacket clamp. Clamps 1 and 6 have different geometry. In addition clamp 6 uses another bolt material since it is in the splash zone. The riser guides are the same for all clamps except for clamp 6.

The clamp steel has these properties:

Yield strength	355	[MPa]
Tensile strength	510	[MPa]
E-modulus	207000	[MPa]
Poisson ratio	0.3	
Density	7850	[kg/m^3]

4. Pre analysis work

4.1. Bolt specification

Bolts are the connection elements in the jacket clamp and the riser clamp, and it's very important that the quality and strength are sufficient to ensure the specific design life. Different bolts have to be selected for different environments, like above and below water, and the pre-tension has to be correct to endure the dynamic loads and avoid fatigue. There have been situations where clamps have slipped and slide down the jacket leg because of pre-tension loss.

The most common bolts used for clamps are stud bolts. A stud bolt is basically a treaded rod which is fastened with nuts on each side. Earlier stud bolts were only treaded in the ends but they had a tendency to fail in the transition between the bar and the treads. Therefore it is now normal practice to use fully treaded stud bolts to prevent such stress concentrations.

To avoid bending stress in the stud bolts the bolt holes are in general large and spherical washers are used. If the length-diameter ratio of the rod are larger than 20 (L/D>20) a spherical nut and a spherical washer is used, see Figure 4.1. If the ratio is smaller than 20 (L/D<20) the assembly have a plane nut with a spherical seating washer on top of the spherical washer like in Figure 4.2.

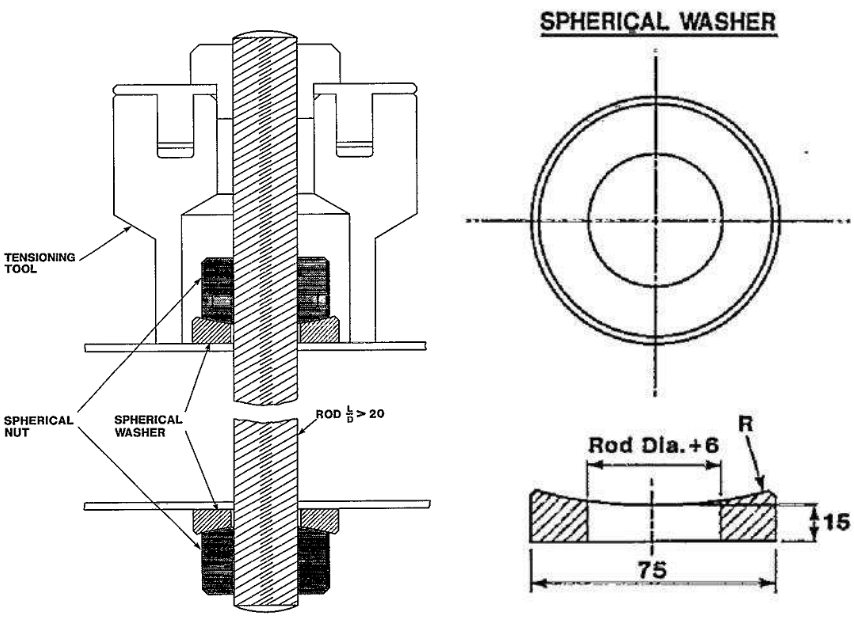


Figure 4.1 L-D ratio more than 20
(Scott, 1985)

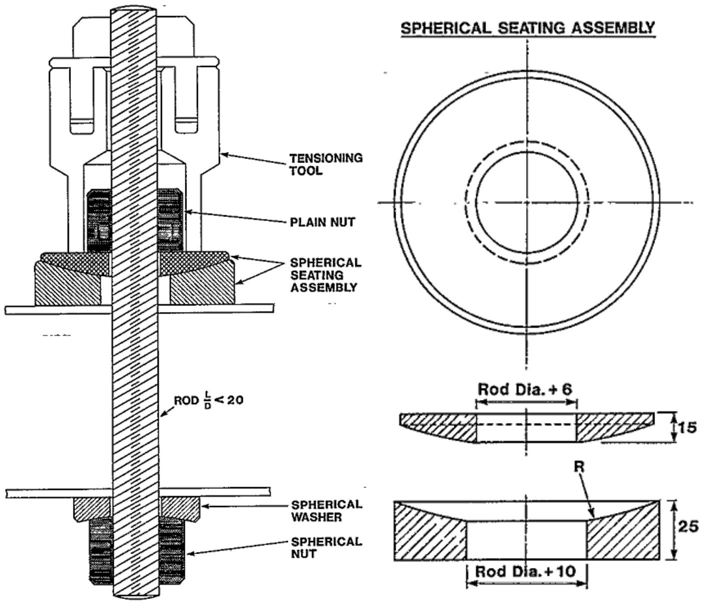


Figure 4.2 L-D ratio less than 20
(Scott, 1985)

4.1.1. Bolt quality

The quality depends upon the strength, environment exposure, corrosion resistance requirements and toughness requirements. The requirements are different when it is subsea, in the splash zone or on the deck side. Subsea 7 have been part of a Joint Industry Project (JIP) called "Bolts and Nuts", see Appendix B. The purpose was to create a guideline for the specification, design and installation of fasteners for the offshore oil and gas industry. The content is gathered from different standards (e.g. ISO, ASTM, and NORSOK) and intended as a guideline, but should not replace these standards.

The JIP concludes that:

- L7 bolts are recommended subsea with cathodic protection (CP)
- In the splash zone and where CP cannot be ensured alloy 625 fasteners should be used.

The report also recommends using ASTM A194 Grade 4 or Grade 7 nuts for L7 bolts. The chosen materials with mechanical properties are summarized in Table 4.1.

	Type	Yield strength	Ultimate strength
Bolts	ASTM A320, Grade L7	730 N/mm^2	860 N/mm^2
Nuts	ASTM A193, Grade 4/S3		
Spherical washers	Steel		
In the splash zone:			
Bolts	Inconel 625	414 N/mm^2	830 N/mm^2
Nuts	Inconel 625		
Spherical washers	Inconel 625		

Table 4.1 Bolt material data

The bolt sizes can be seen in Table 4.2. Note that the drawings aren't up to date. The M27 stud bolts have been changed to M33.

Riser clamp	Riser guide		Jacket clamp	
	Dimensions X Grip length	Nominal stress area, A_s	Dimensions X Grip length	Nominal stress area, A_s
Riser clamp 1	M33 X 700	694 mm^2	M45 X 780	1265 mm^2
Riser clamp 2	M33 X 700	694 mm^2	M45 X 780	1265 mm^2
Riser clamp 3	M33 X 700	694 mm^2	M45 X 780	1265 mm^2
Riser clamp 4	M33 X 700	694 mm^2	M45 X 780	1265 mm^2
Riser clamp 5	M33 X 700	694 mm^2	M45 X 780	1265 mm^2
Riser clamp 6	M33 X 700	694 mm^2	M45 X 780	1265 mm^2

Table 4.2 Bolt sizes

The length-diameter ratio for the riser guide bolts are:

$$\frac{L}{D} = \frac{700}{33} = 21{,}2 > 20$$

The ratio for the jacket clamp bolts are:

$$\frac{L}{D} = \frac{780}{45} = 17{,}3 < 20$$

Hence, there should be used spherical washer with spherical nut for the riser guide bolts and a seating washer with spherical washer for the jacket clamp bolts.

4.1.2. Pre-tension and tension loss

Bolts have low fatigue strength. For this reason the dynamic loads in the bolt have to be as low as possible. This is achieved by pre-loading the bolts under installation. From Figure 4.3 it can be seen that the pre-tension, F_0, is low. Because of this the bolt, F_{bd}, takes a larger portion of the dynamic load, F_d, than the foundation, F_{fd}. As shown in Figure 4.4 the pre-tension is larger, so the foundation takes more of the load while the bolt takes a much smaller share of the load. Bolts with a high length-diameter ratio have a lower stiffness than bolts with a low ratio. For more theory see (Waløen, 1976) and (Gelgele, 2008).

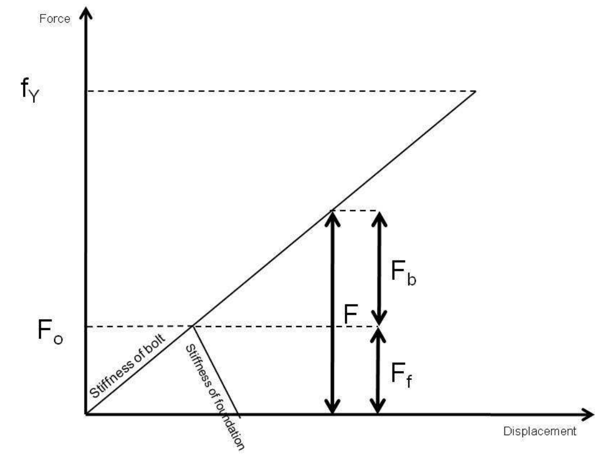


Figure 4.3 Diagram with low pre-tension

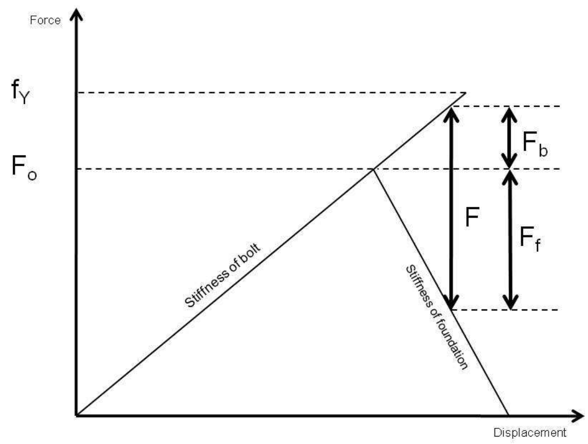


Figure 4.4 Diagram with high pre-tension

According to Hooke's law; a bolt with a displacement with low stiffness will experience a lower load than a bolt with higher stiffness (*F=kx*). Therefore a higher length-diameter ratio will result in lower fatigue.

Experience shows that over the time bolts will get a relaxation, or loss in pre-tension, because of plastic deformation in the foundation, bolt, etc. Thus the pre-tension should be as large as possible, but because of uncertainties in friction factors etc., it is hard to know the exact pre-load and the bolt can easily be damaged. It is common practice to use about 70-75% of yield stress for the pre-tension.

According to NS 3464 the maximum allowable pre-tension is:

$$F_{pre} = 0{,}63 \cdot f_{ub} \cdot A_s$$

where,

f_{ub} = ultimate stress of the bolt
A_s = share area

And according to North Sea Design Premises[1] (ConocoPhillips [Internal document], 1993), the initial relaxation after pre-tension is 15-20% and long term relaxation is 15%. These values are only to be used for initial design. For practical engineering work these values should be confirmed by the tensioner-jack supplier. To be on the safe side 20% is chosen for the initial relaxation. For the riser guiding clamps and Inconel 625 bolts the initial relaxation is 15%. This is because slippage is not critical for the riser guides and the Inconel 625 bolts are more ductile than the A320 bolts, therefore the Inconel 625 bolts will have a lower tension. The results can be seen in Table 4.3:

[1] The North Sea Design Premises (NSDP) is an internal document from ConocoPhillips, one of the Subsea 7 clients.

	M45		M33	
	A320 L7 [kN]	Inconel 625 [kN]	A320 L7 [kN]	Inconel 625 [kN]
Theoretical pre-tension	685,4	661,5	376,0	362,9
Compared to yield	74,2 %	126,3 %	74,2 %	126,3 %
Initial relaxation	20 %	15 %	15 %	15 %
Initial residual pre-tension	548,3	562,2	319,6	308,5
Long term relaxation	15 %	15 %	15 %	15 %
Lon term pre-tension	466,1	477,9	271,7	262,2

Table 4.3 Pre-tension, initial calculations

As mentioned, common practice is to use 70-75% of yield stress for pre-tension. From Table 4.3 it can be seen that the A320 bolts are good, but the Inconel 625 bolts are exceeding the 75% by much. This is not accepted. Therefore the theoretical pre-tension is set to 75% of yield for the Inconel bolts. This is shown in Table 4.4.

	M45		M33	
	A320 L7 [kN]	Inconel 625 [kN]	A320 L7 [kN]	Inconel 625 [kN]
Theoretical pre-tension	685,4	392,8	376,0	215,5
Compared to yield	74,2 %	75,0 %	74,2 %	75,0 %
Initial relaxation	20 %	15%	15 %	15 %
Initial residual pre-tension	548,3	333,9	319,6	183,2
Long term relaxation	15 %	15 %	15 %	15 %
Lon term pre-tension	466,1	283,8	271,7	155,7

Table 4.4 Pre-tension, corrected calculations

4.1.3. Tension tool

Common method subsea for pre-tension of bolts is to use axial hydraulic devices. They grip around the stud bolt and stretches it by hydraulic power to the desired tension, and the nut is then tighten through the opening in the bottom with a Tommy bar as seen in Figure 4.5. Such tools are accurate compared to a torque wrench because it eliminates the friction between the nut and foundation. An example of such equipment that could handle the pre-tension for the clamps is the Aqua-jack tool from Hydratight (see Figure 4.6). From the datasheet in Appendix C, tool no. AJ3 and AJ5 should be able to pre-tension the bolts for all clamps.

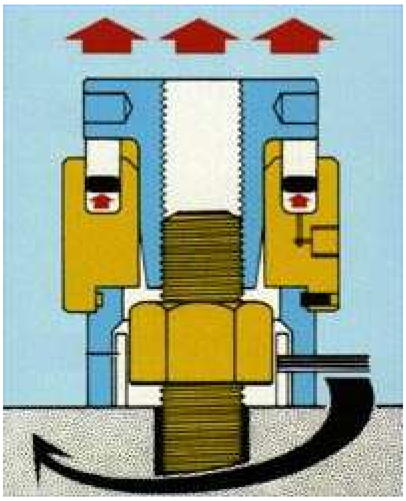


Figure 4.5 Axial tensioning principle (Hydratight, 2011)

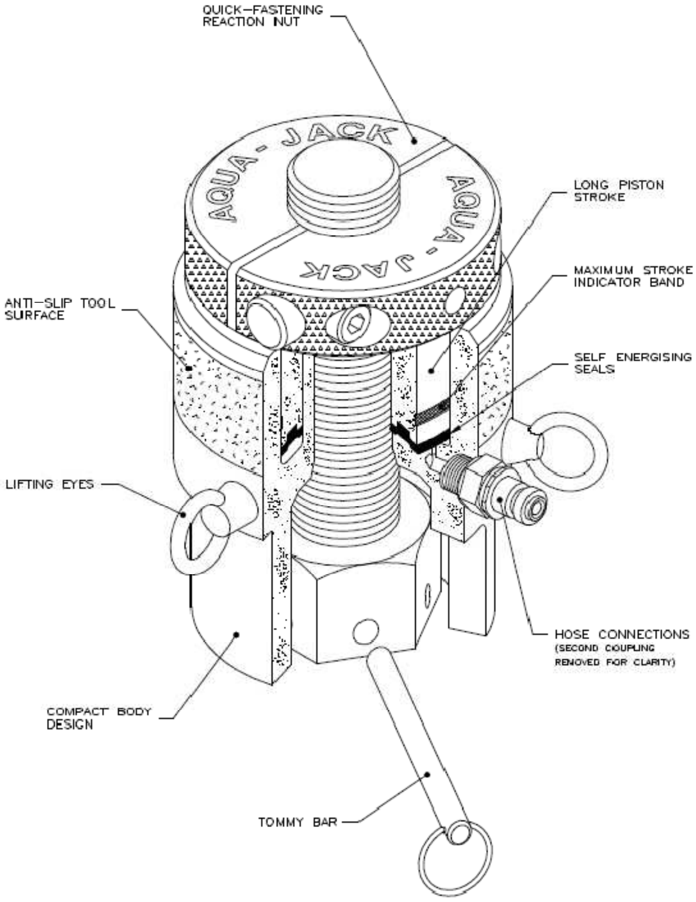


Figure 4.6 The Aqua-jack subsea bolt tensioner (Hydratight, 2011)

4.2. Riser and clamp loads

The weather in the North Sea is harsh and the forces on the riser can be large especially from the waves. The environmental loads (current and waves) will act on the riser and the guide clamp, and be transferred to the jacket clamp.

4.2.1. Riser loads

Table 4.5 presents given inputs of the support reactions from the platform operator:

Support Elevation	Load	Support reactions [kN]		
		F_Y (North)	F_X (East)	F_Z (Vertical)
Elevation +78000	Functional loads	13	-6	2
	Installation loads	±6	±1	±1
	Max. wave load	±131	±137	±16
Elevation +66000	Functional loads	-29	4	-4
	Installation loads	±19	±1	±3
	Max. wave load	±166	±169	±20
Elevation +54000	Functional loads	32	-2	4
	Installation loads	±27	±5	±4
	Max. wave load	±151	±146	±19
Elevation +40000	Functional loads	15	5	2
	Installation loads	±23	±13	±3
	Max. wave load	±126	±118	±15
Elevation +25000	Functional loads	-46	-20	-6
	Installation loads	±14	±12	±2
	Max. wave load	±89	±87	±11
Elevation +10000	Functional loads	164	72	21
	Installation loads	±4	±4	0
	Max. wave load	±69	±66	±9

Table 4.5 Support reactions

The axis system is given with y-axis pointing north, x-axis east, and z-axis upwards. The waves and currents that act on the clamp, and self-weight as well, is not included. Note that the functional loads are fixed in space and act simultaneously. The wave and installation loads could both vary 360° in direction and the vertical loads vary upwards and downwards.

4.2.2. Clamp loads

The waves and currents will not only act on the riser but also on the clamp, especially on the bracket. The wave and current forces are larger when applied perpendicular on the clamp. Therefore the loads are applied as shown in Figure 4.7. According to DNV-RP-C205 and Morison's load formula the sectional force is given as:

$$F_N = \rho(1 + C_A)A\dot{v} + \frac{1}{2}\rho C_D D v|v|$$

where,

ρ = mass density of fluid
C_A = added mass coefficient (with cross-sectional area as reference area)

A = cross sectional area
$\dot{v}$ = fluid particle acceleration
C_D = drag coefficient
D = diameter or typical cross-sectional dimension
v = fluid particle (waves and/or current) velocity

The total force consists of an added mass/inertia component and a drag component. The coefficients for added mass and drag can be found in Appendix D and E of the DNV-RP-C205. The acceleration and velocity are not in phase, so the maximum force will be a combination of these two components. The spreadsheets developed to find the largest horizontal and vertical force can be found in Appendix D. For simplicity the clamp is regarded as a cylinder with height/diameter of 0.8 m and a projected length of 2 m. The significant wave height, H_s, and the wave period, T, are set to be 13.1 m and 14.5 s, respectively (see Figure 4.8). This gives a maximum wave height of 24.3 m (H_{max}=1.86H_s). The current velocity is assumed to be 0.7 m/s and in the same direction as the waves.

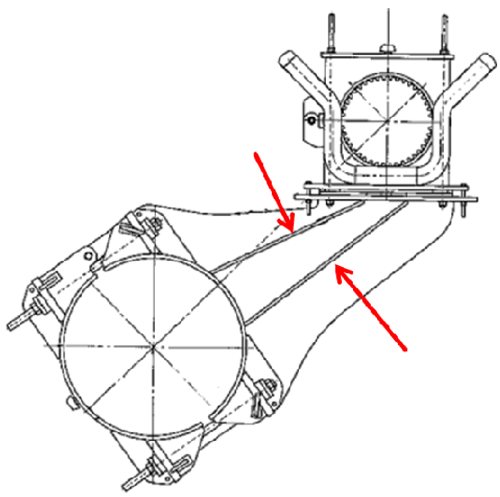


Figure 4.7 Wave and current on clamp

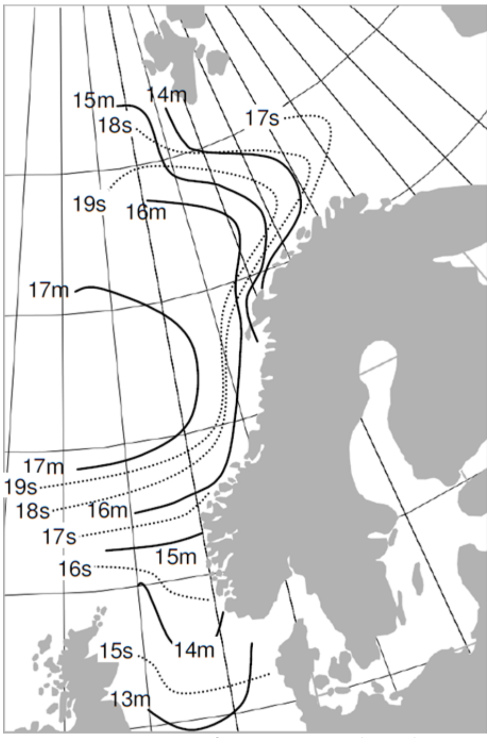


Figure 4.8 Significant wave height H_s and peak period T_p (NORSOK N-003)

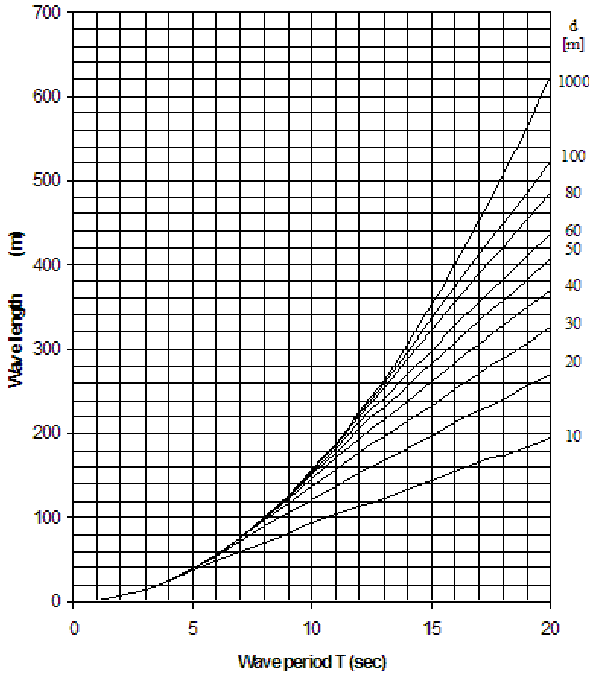


Figure 4.9 Wave length as function of wave period (DNV-RP-C205)

For Airy wave theory in general water depth (water depth is 73.8 m):

Horizontal particle velocity, u is:
$$\frac{\pi H}{T}\frac{\cosh[k(z+d)]}{\sinh(kd)}\cos\theta$$

Horizontal particle acceleration, $\dot{u}$ is:
$$\frac{2\pi^2 H}{T^2}\frac{\cosh[k(z+d)]}{\sinh(kd)}\sin\theta$$

Vertical particle velocity, w is:
$$\frac{\pi H}{T}\frac{\sinh[k(z+d)]}{\sinh(kd)}\sin\theta$$

Vertical particle acceleration, $\dot{w}$ is:
$$-\frac{2\pi^2 H}{T^2}\frac{\cosh[k(z+d)]}{\sinh(kd)}\cos\theta$$

where,

d = mean water depth
H = trough-to-crest wave height
k = 2π/λ = wave number
λ = wave length
T = wave period
z = distance from mean free surface positive upward
ϑ = kx-ωt; ω = 2π/T = angular wave frequency

The wave length, λ, is found to be 310 m using Figure 4.9. For the clamps within ±12.15 m (24.3/2) of the mean sea level, i.e. the two upper clamps can experience wave slamming/impact. The others will be fully submerged at any time and the conventional Morrison's equation with drag and added mass terms should be used.

In DNV-RP-C205 the slamming section force on a vertical slender structure is given as:

$$F_S = \frac{1}{2}\rho C_S D v^2$$

where

ρ = mass density of fluid
C_S = slamming/impact coefficient
D = diameter or typical cross-sectional dimension
v = fluid particle velocity

The slamming coefficient according to DNV should be 5.15 for a cylinder but the maximum slamming force doesn't act on the whole section area at once. The force only act on a small fraction of the area in the beginning and then gets distributed over the rest of the area until it is pure drag. Therefore it is common to use a higher drag coefficient instead of the slamming force. A drag coefficient of 2.4 for the top clamps is a good assumption.

The largest horizontal forces on the clamp due to wave/slamming and current loads identified in Appendix D are listed in Table 4.6.

Riser clamp	Elevation	z-value [m]	Horizontal wave force [kN]
Riser clamp 6	78000	4,2	96,2
Riser clamp 5	66000	-7,8	65,4
Riser clamp 4	54000	-19,8	37,1
Riser clamp 3	40000	-33,8	26,4
Riser clamp 2	25000	-48,8	20,0
Riser clamp 1	10000	-63,8	17,1

Table 4.6 Maximum horizontal wave forces on clamp

In Table 4.7 the largest vertical forces are listed.

Riser clamp	Elevation	z-value [m]	Vertical wave force [kN]
Riser clamp 6	78000	4,2	66,4
Riser clamp 5	66000	-7,8	39,0
Riser clamp 4	54000	-19,8	-18,0
Riser clamp 3	40000	-33,8	8,9
Riser clamp 2	25000	-48,8	-3,7
Riser clamp 1	10000	-63,8	-1,3

Table 4.7 Maximum vertical wave forces on clamp

The combined force of the horizontal and vertical forces is also presented in Appendix D. It can be seen that the combined force is dominated by the horizontal force and peaks when the horizontal force peaks (t=14s). These values can be seen in Table 4.8.

Riser clamp	Elevation	z-value [m]	Vertical wave force [kN]
Riser clamp 6	78000	4,2	-5,7
Riser clamp 5	66000	-7,8	-4,6
Riser clamp 4	54000	-19,8	-3,7
Riser clamp 3	40000	-33,8	-2,6
Riser clamp 2	25000	-48,8	-1,6
Riser clamp 1	10000	-63,8	-0,6

Table 4.8 Vertical wave forces when horizontal peaks

4.2.3. Self-weight

The self-weight of the clamps were given by Subsea 7 and are listed in Table 4.9.

Riser clamp	Elevation	Self-weight [kN]
Riser clamp 6	78000	-36,0
Riser clamp 5	66000	-31,5
Riser clamp 4	54000	-31,5
Riser clamp 3	40000	-31,5
Riser clamp 2	25000	-31,5
Riser clamp 1	10000	-36,0

Table 4.9 Weight of clamps

The forces act downwards.

4.2.4. Hydrostatic pressure

The enclosed area in between the stiffener plates in the bracket arm will experience hydrostatic pressure from the water. The water pressure increases 10 kPa for each meter of water depth. On the surface the pressure is 1 atm, equal to 101,325 kPa. This will give the clamps an absolute pressure of 1 atm plus the pressure from the water depth. But since the clamps are manufactured onshore under atmospheric pressure the gauge pressure acting on the clamp will only be the pressure due to water depth. The hydrostatic pressure for the different camps is shown in Table 4.10. Pressure due to waves washing over the clamps in the splash zone is small and neglected.

Riser clamp	Water depth [m]	Pressure [MPa]
Riser clamp 6	-4,2	0
Riser clamp 5	7,8	0,078
Riser clamp 4	19,8	0,198
Riser clamp 3	33,8	0,338
Riser clamp 2	48,8	0,488
Riser clamp 1	63,8	0,638

Table 4.10 Hydrostatic pressure

4.3. Critical load combinations

For the ULS stress and the slippage analysis the critical load combinations are needed to find the correct load factors. The load combination contributing to the largest moments on each clamp will be used. According to NORSOK N-001 the ultimate limit state shall be checked for two action combinations, a and b, with the action factors presented in Table 4.11.

Action combination	Permanent actions	Variable actions	Environmental actions
a	1,3	1,3	0,7
b	1,0	1,0	1,3

Table 4.11 Action factors for ULS

4.3.1. Horizontal load combination

The horizontal loads listed in Table 4.5 and Table 4.6 are combined and proper action factors applied according ULS criteria. Appendix E presents the spreadsheet developed to identify the largest twisting moments around the vertical axis, i.e. the jacket leg. To achieve the largest moments the variable riser loads (wave and installation loads) act perpendicular to its moment arm, i.e. in the 135° direction or 315° direction. At the same time the wave and current forces act in the same direction as the riser loads (see Figure 4.10). The functional loads are fixed. Note that in Appendix E the reaction loads listed in Table 4.5 are converted to riser loads, i.e. opposite direction. The functional and installation loads are categorized as permanent action and wave loads as environmental actions. For the horizontal forces the F_Y-values (north) are used and applied for the 135°/315° direction.

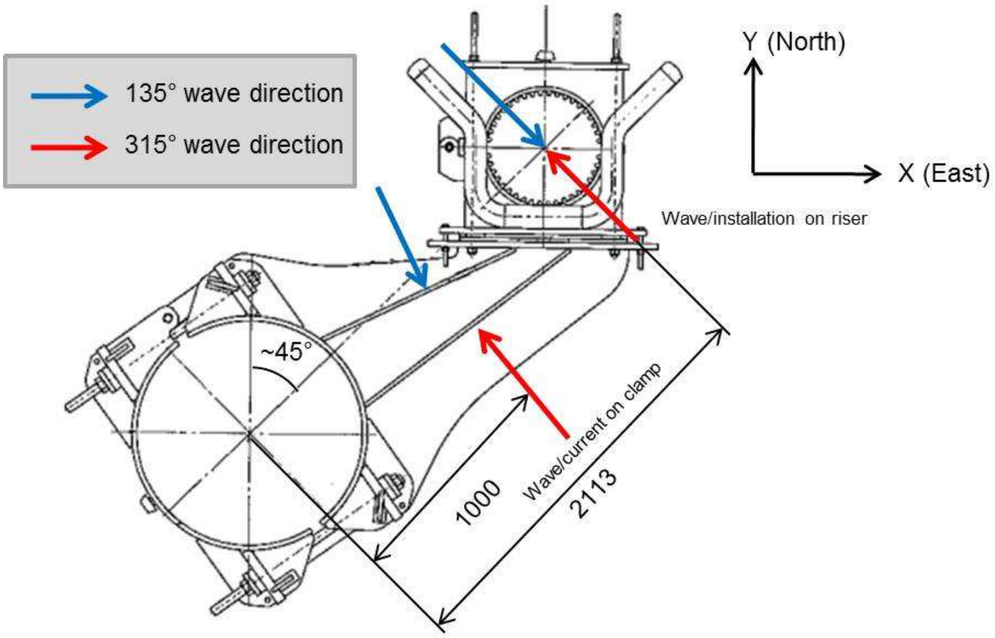


Figure 4.10 Force directions

The forces presented in Table 4.6 act perpendicular to the stiffener plates, i.e. 155° or 322° direction, as seen in Figure 4.10. Even though the wave forces on the clamp do not act in the exact same direction as for the riser (155/322 and 135/315) it is assumed that they can occur from the same wave conditions. The results from the spreadsheet can be seen in Table 4.12.

Riser clamp	Sum of moments ULS-a [kNm]		Sum of moments ULS-b [kNm]	
	135°	315°	135°	315°
Riser clamp 6	319,5	-187,4	**535,2**	-370,3
Riser clamp 5	282,6	-371,6	537,9	**-563,4**
Riser clamp 4	391,6	-236,7	**574,5**	-431,0
Riser clamp 3	288,9	-233,8	**446,6**	-386,8
Riser clamp 2	134,1	-224,0	262,7	**-318,7**
Riser clamp 1	306,4	65,0	**360,7**	-63,8

Table 4.12 Largest moments about jacket leg

The max values, in bold, show the load combination that gives the largest twisting moment about the jacket leg for each clamp.

4.3.2. Vertical load combination

To identify the most critical vertical load combination (see Appendix E) the F_Z-values (vertical) in Table 4.5 are used. The functional loads are fixed and the others, which can vary, applied up- and downward. The jacket leg has an inclination of 7°. Therefore the forces from the riser and the self-weight are converted to be parallel to the jacket leg while the wave

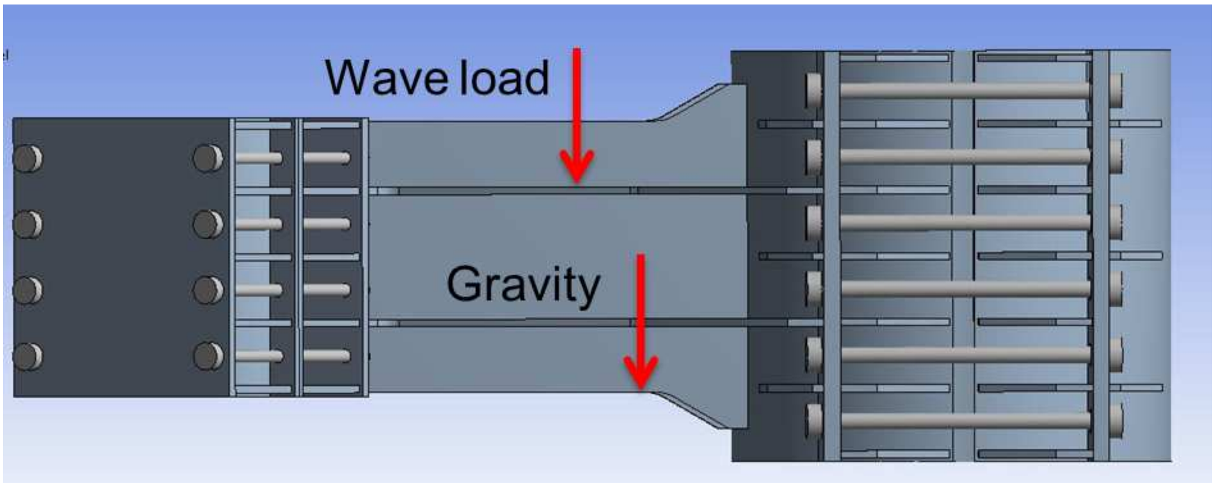


Figure 4.11 Vertical loads

loads on the clamp already are parallel. The horizontal component due to the parallelization is neglected. The clamp wave loads are conservatively applied downwards in same direction as the gravity. The wave loads and gravity act on the top of the bracket as seen in Figure 4.11. The moment arms are found using ANSYS. The results from Appendix E are presented in Table 4.13.

Riser clamp	Sum of moments ULS-a [kNm]		Sum of moments ULS-b [kNm]	
	Up	Down	Up	Down
Riser clamp 6	-64,0	-116,4	-78,1	**-169,5**
Riser clamp 5	-11,3	-86,4	-8,7	**-130,3**
Riser clamp 4	-16,0	-93,6	3,3	**-117,1**
Riser clamp 3	-12,3	-72,7	7,2	**-87,2**
Riser clamp 2	4,8	-38,4	18,2	**-50,1**
Riser clamp 1	-79,7	**-106,2**	-48,0	-97,1

Table 4.13 Largest moment in the vertical plane

The max values, in bold, show the load combination that gives the largest moment about the axis perpendicular to the jacket leg axis.

4.4. Slippage

Slippage can occur when there is not enough static friction between two surfaces. For the clamp this is important between the jacket clamp/jacket leg connection and to some extent the connection between the riser guide shells. The pre-tension in the bolts have to be sufficient to create enough static friction force so that no slippage occurs. Normal practice at subsea 7 is to use a safety factor of 2 on all external loads when performing a slippage analysis.

4.5. New stresses in jacket leg

The jacket leg is a cylindrical hollow column and can therefore be considered as a pipe. When the clamp is squeezed around the jacket leg it will apply pressure similar to how hydrostatic pressure adds hoop stress to a pipe section. This application can therefore be simplified as a pipe influenced by surrounding pressure. In NORSOK N-004 the hoop buckling stress can be calculated:

$$\sigma_{h,d} = \frac{p_d D}{2t} \leq \frac{f_y}{\gamma_{Mb}}$$

where,

$\sigma_{h,d}$ = design hoop stress
p_d = design pressure
f_y = yield stress
γ_{Mb} = material factor buckling
D = outer diameter

4.6. Fatigue (FLS)

According to NORSOK N-004 the aim of fatigue check is to ensure that the structure will have adequate fatigue life. Simplified this means that the structure shall not fail because of cracking during the design life of the structure. For fatigue it is the cycling loads that are assessed, i.e. wave loads. For FLS a factor of 1.0 is used for the environmental loads (see Table 4.14).

Action combination	Permanent actions	Variable actions	Environmental actions
FLS			1.0

Table 4.14 FLS factors

In addition according to NORSOK N-004 the number of load cycles shall be multiplied with the appropriate factor in Table 4.15.

Classification of structural components based on damage consequence	Access for inspection and repair		
	No access or in the splash zone	Accessible	
		Below splash zone	Above splash zone
Substantial consequences	10	3	2
Without substantial consequences	3	2	1

Table 4.15 Design fatigue factor (DFF)

For simplicity all clamps are classified as “No access or in the splash zone” and the “Without substantial consequences”. This means that a DFF factor of 3 is to be used in the calculations. The design life for the clamps is given to be 23 years.

The maximum wave load in the worst direction is conservatively used for the fatigue calculations. The simplified fatigue analysis in DNV-RP-C203 is used:

$$D = \frac{\upsilon_0 T_d}{\bar{a}} q^m \Gamma\left(1 + \frac{m}{h}\right) \leq \eta$$

where,

$$q = \frac{\Delta\sigma_o}{(\ln n_0)^{1/h}}$$

q	= Weibull scale parameter
υ_0	= average zero-crossing frequency
T_d	= design life in seconds
$\bar{a}$	= intercept of the design S-N curve with the log N axis
m	= negative inverse slope of the S-N curve
h	= Weibull stress range shape distribution parameter
$\Delta\sigma_o$	= stress range exceeded once out of n_0 cycles
n_0	= the number of cycles over the time period for which the stress range level $\Delta\sigma_o$ is defined
$\Gamma\left(1 + \frac{m}{h}\right)$	= gamma function

5. Definitions

Before reading the next chapters, there are some definitions and concepts that can be helpful in order to understand the context.

5.1. Linear vs. nonlinear analysis

In a linear analysis the equations obey Hooke's law:

$F = kx$

where,

F = force
k = stiffness (constant)
x = displacement

This means that the relationship between force and displacement (and stresses) is constant. If the force doubles, the displacement also doubles (see Figure 5.1). For example certain materials like steel, obey Hook's law in the elastic region where stress vs. strain is close to linear (yellow in Figure 5.2). The equation can be converted to this form:

$\sigma = E\epsilon$

There are in general three forms of nonlinearities:

- Geometric nonlinearities: Large deformations in a structure can cause non-linear behavior due to change in geometric configurations.
- Material nonlinearities: When the stress is in the plastic region (red in Figure 5.2) the material cannot be looked at as linear any more.
- Contact: Nonlinearity can come from an abrupt change in stiffness when two surfaces are coming into contact with each other.

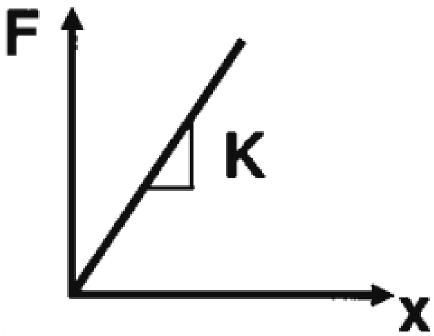


Figure 5.1 Linear curve (ANSYS,2005)

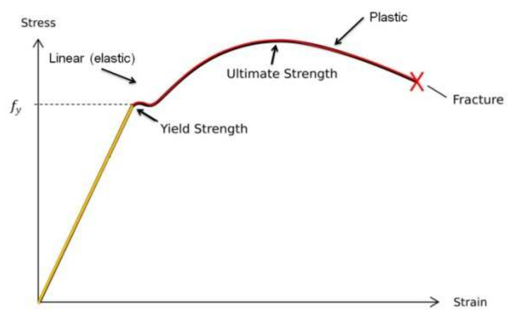


Figure 5.2 Elastic vs. Plastic

In a non-linear analysis the stiffness depends upon the displacement:

$$F = k(x)x$$

This means that if the force doubles the displacement necessarily doesn't (See Figure 5.3). A non-linear analysis uses iterations to find the solution because the relationship between *F* and *x* is not known in beforehand.

5.2. Convergence, load steps and substeps

As mentioned above non-linear solutions have to be iterated. The iteration method used is the Newton-Raphson Method which uses a series of linear approximation with corrections until the result is within a limit. When the limit is reached the equation is in equilibrium and the solution has converged. In Figure 5.4 a simple example is presented. There are two load steps, i.e. two changes in the loading, F_a (red) and F_b (yellow). Load F_a is again divided into two substeps, F_{a1} and F_{a2}. This means that 50% of the load F_a is applied in the first iteration until it converges, and then the second 50% is applied. When F_a has converged, F_b is applied in three substeps. Both loads have five iterations resulting in; two load steps, 5 substeps and ten iterations. (A force convergence graph from the ULS analysis is shown in Figure 5.5.)

5.3. Nonlinear contacts

A contact is non-linear when two surfaces touch each other such that they become mutually tangent (ANSYS, 2005). Linear contacts like bounded or "glued" are fairly easy and quick to solve, but non-linear contacts like frictional are hard to solve because the program have to iterate to obtain a solution.

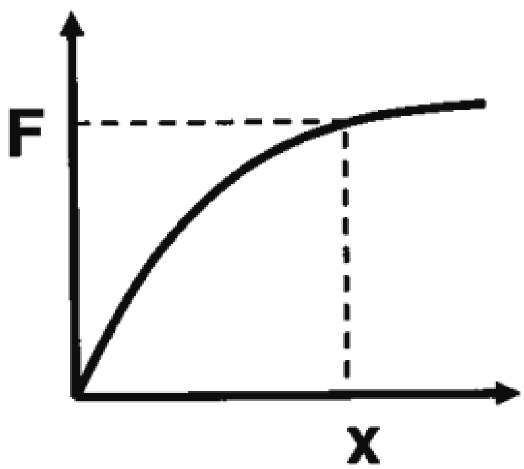


Figure 5.3 Nonlinear curve (ANSYS,2005)

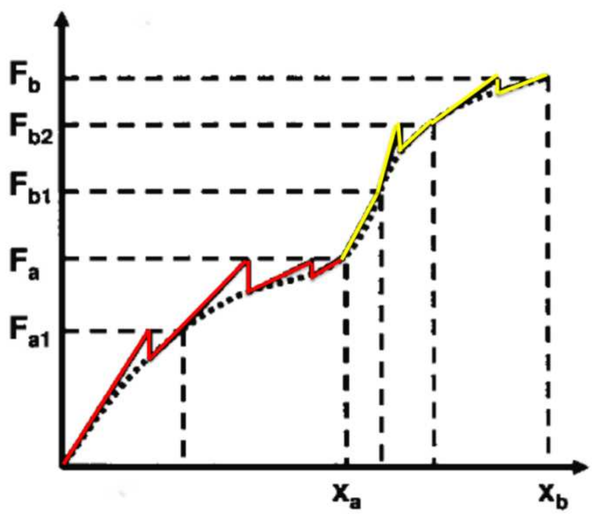


Figure 5.4 Newton-Raphson Method (ANSYS, 2005)

Figure 5.5 Force convergence graph

As mentioned, for non-linear contacts the systems contact status is dependent upon the stiffness. The stiffness is the most important parameter affecting both accuracy and convergence behavior. When two objects come into contact with each other they physically cannot interpenetrate. Therefore the FE program has to establish a relationship between the objects so they do not pass through each other. When this happens the program have enforced contact compatibility. When having penetration the program has failed to enforce contact compatibility. To manage this there are different mathematical algorithms available for the user to choose from. For frictional there is:

- Pure Penalty: $F_{normal} = k_{normal} x_{penetration}$
- Augmented Lagrange: $F_{normal} = k_{normal} x_{penetration} + \lambda$
- Normal Lagrange: $F_{normal} = DOF$

From the Pure Penalty and Augmented Lagrange it can be seen that ideally the normal stiffness should be infinite, which will result in zero penetration. This is not numerically possible but as long as the penetration is small or negligible the result will be accurate. The penetration should be less than 1-2% of the target element thickness. A high stiffness results in good accuracy but can cause oscillation in the convergence because the objects are bouncing off each other. Because the Augmented Lagrange has an additional term, λ, it is not that sensitive to the stiffness. This results in minimum penetration and good convergence. The Normal Lagrange adds an additional degree of freedom, contact pressure. This means that normal stiffness is not needed and the penetration is near zero, but the computer time is longer.

5.4. Discontinuities

Secondary stresses can come from discontinuities and lead to high local or nodal peak stresses. Such stresses is usually "fake" and can come from sudden changes in geometry (geometrical discontinuity) or from changes in material properties (material discontinuity), e.g. between two objects with different materials. "Fake" stresses from discontinuity, if proven, can be disregarded.

6. Analysis setup in ANSYS

The FE (Finite Element) analyses for the clamp design were performed using the general FE software ANSYS v13. ANSYS v13 workbench starts up with a project where analyze type is decided. To obtain a solution several steps have to be performed. For the ULS stress, slippage and fatigue check the static structural analysis is chosen.

As mentioned before, the purpose of this thesis was to be familiar with finite element software and to understand the structural analysis and design methodology. Since clamp 4 was identified to subject the largest horizontal forces, see Table 4.12, and that the vertical forces at this point were assumed to be less critical than the horizontal forces, clamp 4 was selected to be used for further analyses.

6.1. Engineering data

The first step, engineering data, is to define material properties. There is a standard data base of different materials to select from, but no material that matched with the material used on the clamp. Therefore two materials are created:

- "Clamp steel" for the general clamp
- "A320" for the A320 grade L7 bolts

The structural analysis performed is linear, i.e. the stress-strain relationship of the material is linear. The properties can be found in the ANSYS printouts (Appendix F[2]).

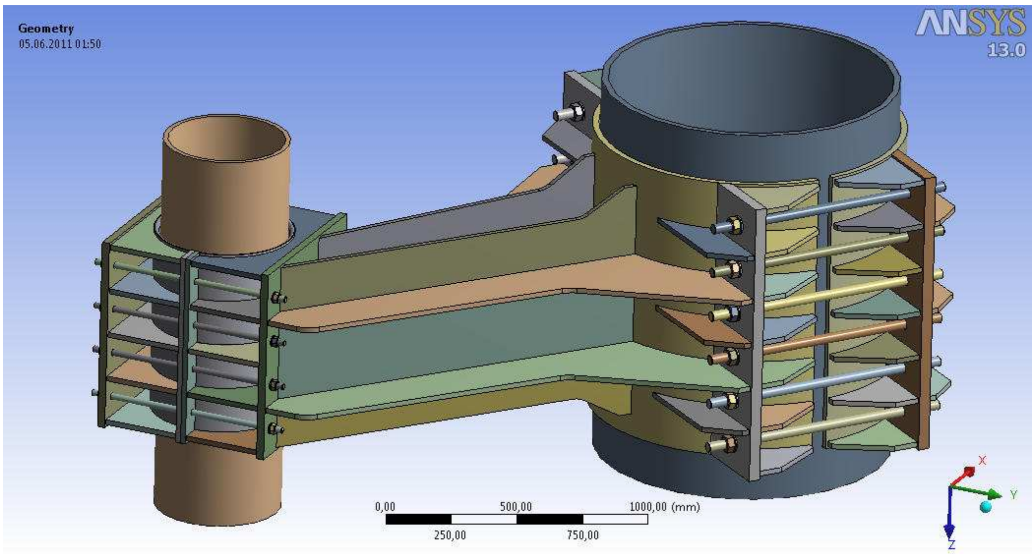
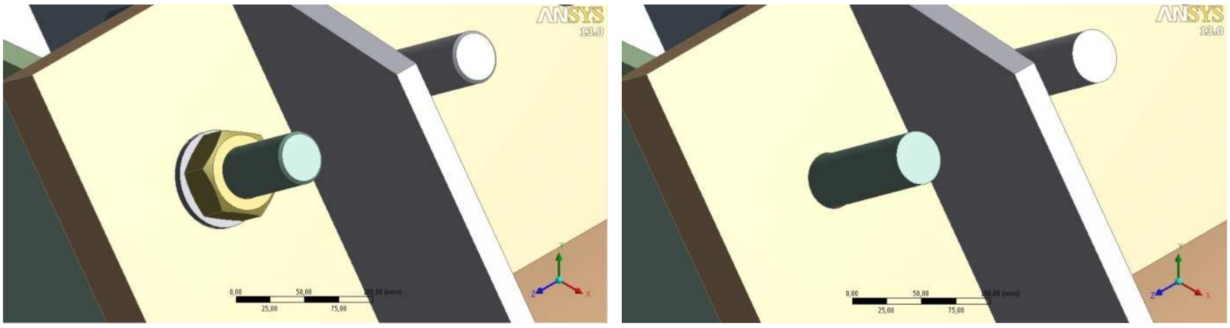


Figure 6.1 Imported clamp

[2] The ANSYS print-out of all analysis is too big to attach as appendix in the thesis. As of this reason only one analysis is included in the appendix as an example. The rest of the analyses are included in the digital version.

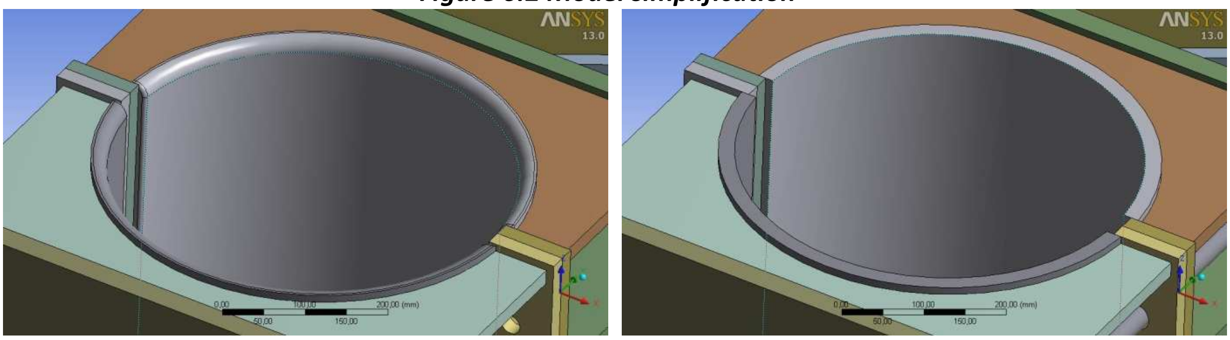
6.2. Geometry

Geometry for use in ANSYS workbench either can be modeled in Design Modeler or it can be imported from other CAD programs. Subsea 7 had designed the clamps in Inventor (CAD) so a simplified geometry with a section of the jacket leg and riser was imported to ANSYS (see Figure 6.1). FEA is very time consuming and if the geometry is complicated the computational time can be long. Therefore the geometry is simplified even more by removing objects that are not important for the analysis like nuts and washers. The same is done with unnecessary faces shown in Figure 6.2 and Figure 6.3. There were some problems finding the right clamp file to import. The file used was not up to date so some changes had to be made. The bolts and bolt holes were too small and was therefore enlarged. At the same time a little end piece was added in each end of the bolts to simulate the washer and nuts to obtain a better distribution of the pre-tension force, see Figure 6.4.



Before ***After***

Figure 6.2 Model simplification



Before ***After***

Figure 6.3 Model simplification

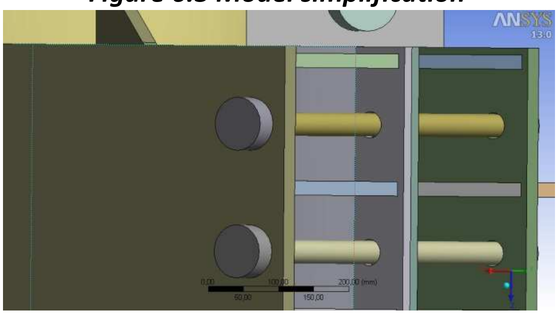


Figure 6.4 Washer/nut simplification

6.3. Model

In the model section it is necessary to describe the analysis environment like to establish boundary conditions, apply forces, define algorithms, etc. In the model the material properties are also assigned to its respective parts.

6.3.1. Connections

When the model is imported it recreates the different components, like stiffener plates, bolts, etc., as independent parts. The contacts between these parts have to be defined. There are several contact types available. The most relevant types for this analysis are bonded and frictional contact. ANSYS automatically applies bonded contact for the parts that have clearance within a defined range. These contacts have to be checked to be correct and some of them need to be changed if necessary. For example the contact between the two jacket clamp shells and the jacket leg is frictional and needed to be changed. Also the contact between the riser shells is frictional. A friction factor of 0.21 (steel to steel under water) is used for these contacts. MPC (Multi-Point Constraint) contact is a type of bonded contact and is often used to simulate welds. MPC contacts are used on the stiffener plates.

6.3.2. Mesh

In general the finite element (FE) mesh has great influence on computational time, memory usage, and accuracy of FE analysis. A reasonable mesh is obtained by simplifying the geometry. A mesh consists of elements which are jointed together in nodes. In FEA the mesh grid consists of material and structural properties that define how the model reacts when loads are applied. The node density should be larger where the stresses are high. The mesh should be symmetrical and “look good”, i.e. if the mesh grid is to be square the ratio between the height and length of the element should not be too far from 1. This is very important to obtain a good solution. The mesh for the clamp was fitted by using different methods on the various shapes. The mesh can be seen in Figure 6.5. The end and vertical plates (where the bolts are connected) plus the stiffener plates (where the forces and bending would be large) were sized with at least two layers/divisions to be able to take internal moments.

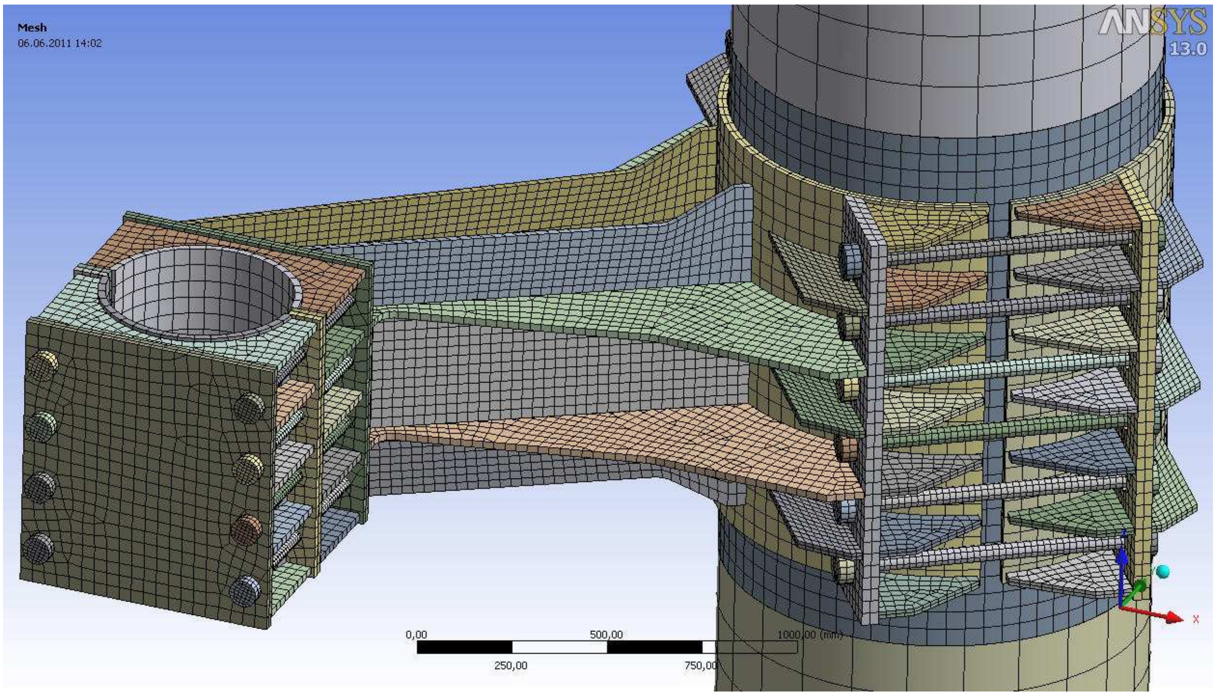


Figure 6.5 Mesh

6.4. General setup

After the FE mesh is completed, loads and boundary conditions on the FE model are to be established. The jacket leg was constrained on the faces on both the upper and the lower end. To be sure that the constraining didn't affect the clamp, the jacket leg was extended 3 m each way (see Figure 6.6). The loads are applied in two load steps; first the pre-tension is applied in the bolts and then the riser and clamp loads are applied. The pre-tension is locked in the second load step. Each load step has 5 substeps meaning a load increment of 20% for each convergence (see Figure 5.5).

(More specific details about connections, mesh, loads, supports, etc. may be found in the ANSYS print-outs in Appendix F.)

6.5. ULS setup

Two FE models were generated for the ULS stress check, one model to check the stresses in the clamp and the second model to check the stresses in the bolts. The theoretical pre-tension is conservatively multiplied with a factor of 1.3 for the clamp check and for the bolt check the theoretical pre-tension value is used.

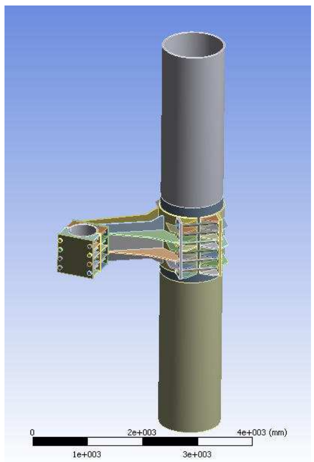


Figure 6.6 Extended jacket leg

6.5.1. Pre-tension applied

The bolt tensions calculated in Table 4.4 are applied without any relaxation and combined with a load factor of 1.3 for the clamp check. The pre-tension values for the different clamps are listed in Table 6.1. For the bolt check the theoretical tension presented in Table 4.4 is used.

Riser clamp	M45 [kN]	M33 [kN]
Riser clamp 6 (Inconel)	510,64	280,15
Riser clamp 5	891,02	488,8
Riser clamp 4	891,02	488,8
Riser clamp 3	891,02	488,8
Riser clamp 2	891,02	488,8
Riser clamp 1	891,02	488,8

Table 6.1 Pre-tension applied in ANSYS

ANSYS has a special function for pre-tension which was applied on each bolt. The applied pre-tension for clamp 4 can be seen in Figure 6.7.

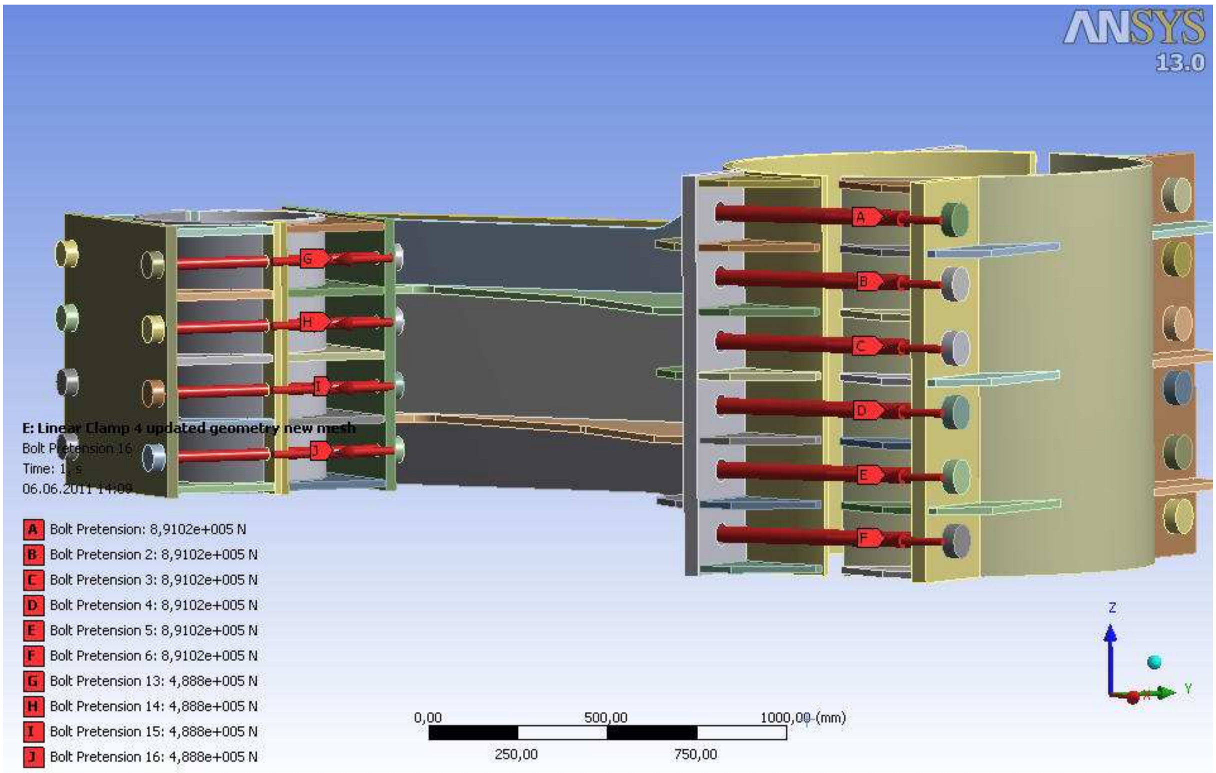


Figure 6.7 Bolt pre-tension applied

6.5.2. Loads applied

In chapter 4.3 the most critical load combinations were identified and a summary form Appendix E can be seen in Table 6.2.

	Clamp 1	Clamp 2	Clamp 3	Clamp 4	Clamp 5	Clamp 6
Bolt pre-load	X	X	X	X	X	X
ULS-b 135°	X	-	X	X	-	X
ULS-b 315°	-	X	-	-	X	-
ULS-b Up	-	-	-	-	-	-
ULS-b Down	X (ULS-a)	X	X	X	X	X

Table 6.2 Load directions

It shows that ULS-b gives the largest load combination on all clamps except vertical combination on clamp 1. This means that the loads should be combined with the correct ULS-a/b factors. The clamp is not symmetric horizontally and vertically, and the horizontal- and vertical force are not in phase. Because of this the clamp should be checked for stresses when applying peak horizontal force plus the contribution of vertical force at the same phase time, and vice versa. A stress check should also be performed when the combination of the horizontal and vertical loads is peaking. For the present thesis work, it is conservatively assumed that the maximum horizontal and maximum vertical wave loads act simultaneously. This will not be the case in reality.

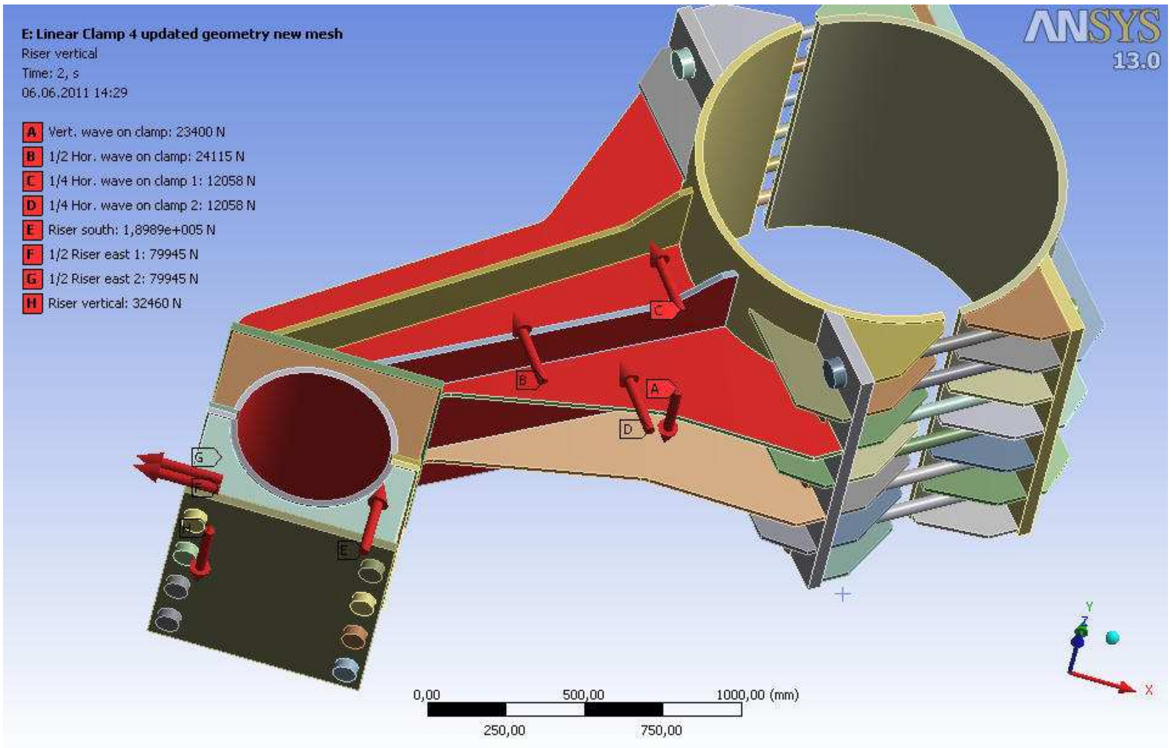


Figure 6.8 Riser and wave/current loads on clamp

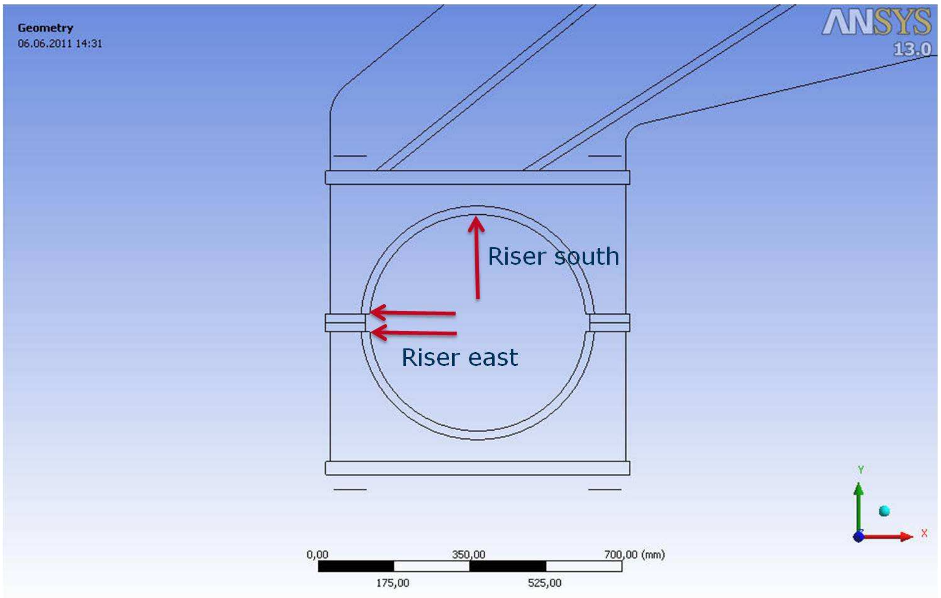


Figure 6.9 Load distribution on riser guide

The forces from the riser and wave/current loads on clamp 4 can be seen in Figure 6.8. The riser loads are distributed on riser guide as shown in Figure 6.9. The horizontal riser force in 135° direction is decomposed into global directions (south and east). The east component is divided into two new components and distributed equally on the two riser shells. The south component is applied on the inner shell. The vertical force acts on the outer shell. The friction factor between steel and neoprene is assumed to be 0.6 meaning that vertical friction force can reach maximum of:

$$F_{V,max} = \sqrt{{F_{H,S}}^2 + {F_{H,E}}^2} \cdot \mu = \sqrt{189{,}89^2 + 159{,}89^2} \cdot 0{,}6 = \underline{148{,}9kN}$$

where,

$F_{H,S}$ = horizontal riser force in south direction
$F_{H,E}$ = horizontal riser force in east direction
μ = friction factor

This means that if the vertical riser force is 148.9 kN or less, the whole force will be applied to the riser shell. The wave and current forces on the clamp are applied perpendicular on the bracket plates as shown in the figure. The loads applied on clamp 4 (load step 2) are listed in Table 6.3 and are for the worst load direction identified in Appendix E with the correct ULS-b factors. Remember that the functional loads are fixed.

	South [kN]	East [kN]	Parallel [kN]
Functional loads	32,00	2,00	-3,97
Installation loads	19,09	19,09	-3,97
Wave loads	138,80	138,80	-24,52
Sum	189,89	159,89	-32,46
Waves normal on clamp			48,23
Waves vertical on clamp			-23,40
Pressure on closed area			0,198 MPa

Table 6.3 Applied loads for clamp 4

6.6. Slippage setup

The slippage analysis is done by applying the theoretical pre-tension with initial and long term relaxation, i.e. a factor of 0.68. This result in a pre-tension of 466.1 kN for the M45 bolts and 271.7 kN for the M33 bolts. The forces from the riser and waves are applied with a factor of 2, see Table 6.4.

	South [kN]	East [kN]	Parallel [kN]
Functional loads	64,00	4,00	-7,94
Installation loads	38,18	38,18	-7,94
Wave loads	213,54	213,54	-37,72
Sum	315,72	255,72	-53,60
Waves normal on clamp			74,20
Waves vertical on clamp			-36,00
Pressure on closed area			0,396 MPa

Table 6.4 Applied loads for slippage analysis

6.7. FLS setup

For the fatigue check the forces are applied in the same way as for the ULS case only with the FLS factor of 1. Only cyclic loads are to be used for FLS, i.e. wave loads. The loads are applied in three steps. In first step the loads in the 135° direction starts from zero and goes to maximum. In step two the maximum load in the 135° direction alters to maximum in the 315° directions. Finally in the third step the loads returns to zero. The vertical wave forces are applied downwards in all steps. These loads can be seen in Table 6.5. Since it would be difficult to extract the cyclic stress range while having pre-tension in the bolts, the only way was to change the non-linear (frictional) contact to linear (bounded) contact. This simplified assumption is reasonable for a clamped connection where the sliding distance is near zero.

	South [kN]	East [kN]	Parallel [kN]
Functional loads	0	0	0
Installation loads	0	0	0
Wave loads	±106,77	±106,77	-18,86
Sum	±106,77	±106,77	-18,86
Waves normal on clamp			±37,10
Waves vertical on clamp			-18,00
Pressure on closed area			0 MPa

Table 6.5 Wave loads for FLS

7. Results

7.1. Acceptance criteria

To fulfill the requirements of design code or standard, the results for capacity should be checked against the acceptance criteria. The relevant acceptance criteria for different components are described in the following sections.

7.1.1. Bolt capacity

The maximum capacity of a bolt according to NS-EN-1993-1-8 is:

$$F_{b,cap} = \frac{0{,}9 \cdot f_{ub} A_s}{\gamma_b}$$

where,

f_{ub} = ultimate stress of the bolt
A_s = shear area
γ_b = material factor for bolt

According to NORSOK N-004 the material factor for bolts is 1.3 meaning the capacities are:

	M45 A320	M33 A320
Force, $F_{b,max}$ [kN]	753,2	413,2
Stress, $\sigma_{b,max}$ [MPa]	595,4	595,4

Table 7.1 Bolt capacity

7.1.2. Clamp capacity

For the clamp the yield is 355 MPa and the material factor for the steel according to NORSOK N-004 is 1.15. The design yield is then:

$$f_{yd} = \frac{f_y}{\gamma_s} = \frac{355}{1.15} = \underline{\underline{308{,}7}}$$

where,

f_y = yield stress for the clamp
γ_s = material factor for steel

This means that the stresses in the clamp should not exceed 308.7 MPa.

7.1.3. Slippage criteria

For the slippage check there should be enough statically frictional contact to ensure that the clamp doesn't slide.

7.1.4. Hoop buckling criteria

By using the most conservative material factor of 1.45 for the hoop buckling stress calculations in NORSOK N-004, the allowable pressure around the jacket leg can be:

$$p_d \leq \frac{2t\ f_y}{\gamma_{Mb} D} = \frac{2 \cdot 25{,}4 \cdot 355}{1{,}45 \cdot 1143} = 10{,}9\ MPa$$

where,

t = thickness
γ_{Mb} = material factor
D = outer diameter of jacket leg

7.1.5. Fatigue criteria

To ensure that the structure will not encounter fatigue, the fatigue damage, D, must be lower than the fatigue utilization factor η. The utilization factor is a function of design life and design life factor (DFF). On interpolation using the values from Table 7.2, a design life of 23 years and DFF of 3 (chapter 4.6) give the utilization factor:

$$\eta = 0{,}27 + (23 - 20)\left(\frac{0{,}33 - 0{,}27}{25 - 20}\right) = 0.306$$

DFF	Design life in years						
	5	10	15	20	25	30	50
1	4,0	2,0	1,33	1,00	0,80	0,67	0,40
2	2,0	1,0	0,67	0,50	0,40	0,33	0,20
3	1,33	0,67	0,44	0,33	0,27	0,22	0,13
5	0,80	0,40	0,27	0,20	0,16	0,13	0,08
10	0,40	0,20	0,13	0,10	0,08	0,07	0,04

Table 7.2 Utilization factor η as function of design life and design fatigue factor (DNV-RP-C203)

7.2. ULS stress check

When designing structures their capacity has to be checked against the ultimate limit state (ULS). This means that the structures have to avoid collapse when applying peak loads. The clamps have to resist the forces from the pre-tension, self-weight, waves and currents, and the loads transferred from the riser.

7.2.1. Bolt check

In Figure 7.1 the theoretical bolt tension and the environmental loads are applied. The figure shows that the resulting stresses in the M45 bolts are in the range between 360-450 MPa. The stresses in the M33 blots range between 420-430 MPa. The maximum stress of 907 MPa in Figure 7.2 occurs in the transition zone between the bolt and the washer/nut. This peak stress may not be "real" because the nut will be fastened to the threads on the stud bolt and the stress will be distributed.

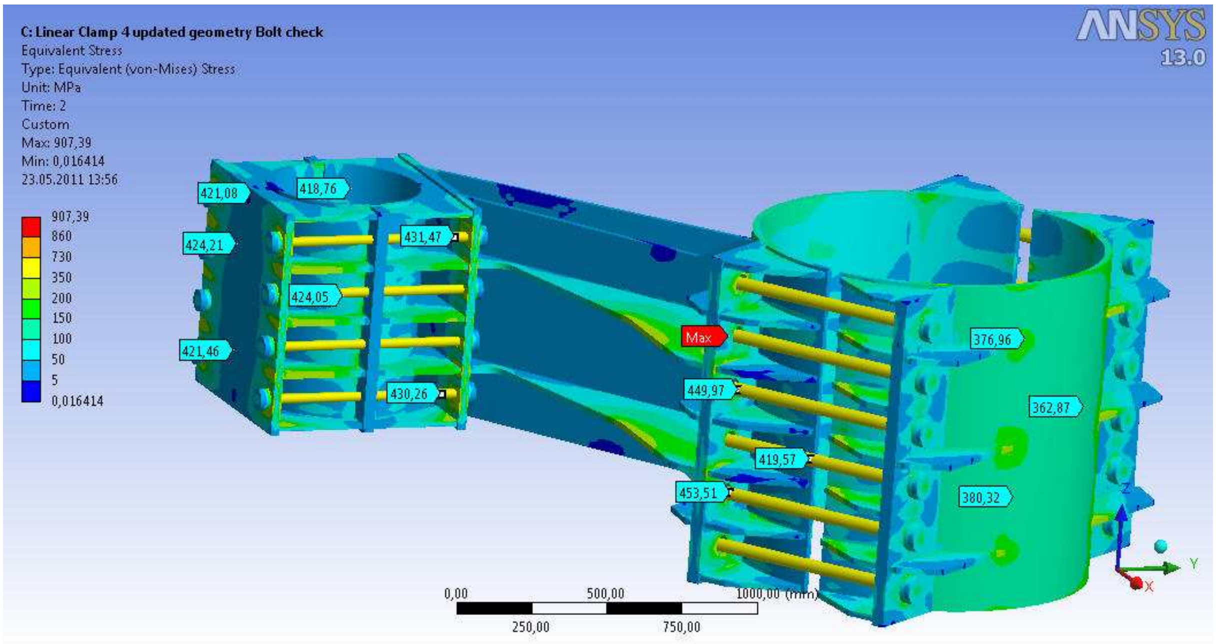


Figure 7.1 Bolt check

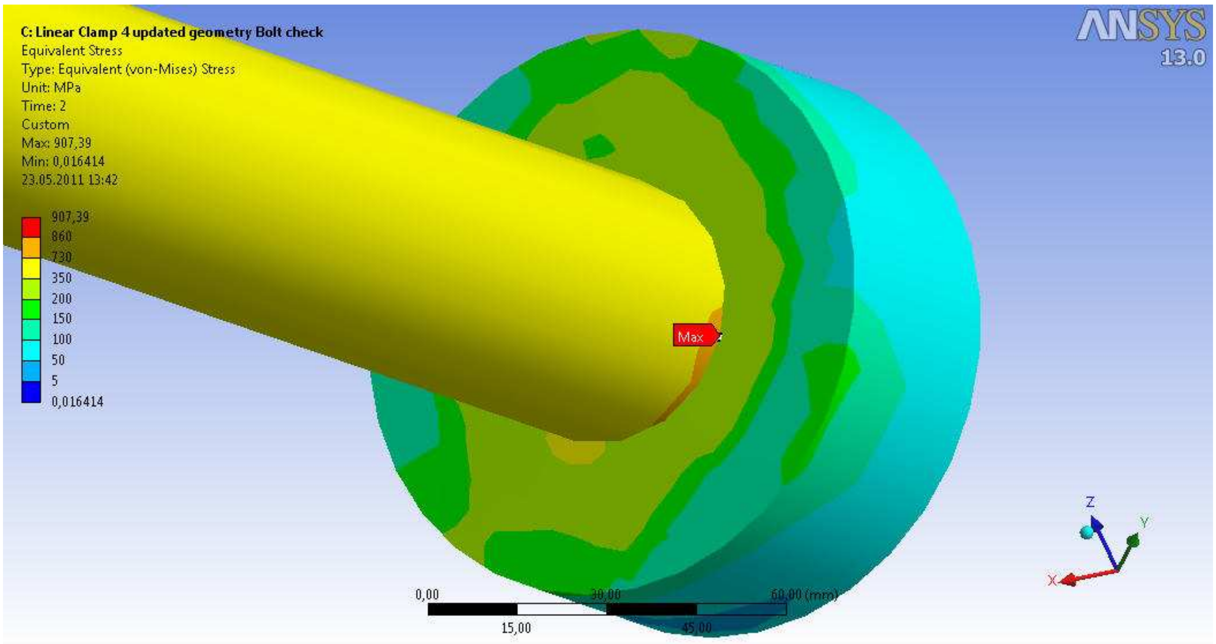


Figure 7.2 Max bolt stress

7.2.2. Bolt pre-tension only

Figure 7.3 shows the dominance of the pre-tension only (with a factor of 1.3) for the jacket clamp and riser clamp. An independent band was added to the stress range bar (the color bar to the left) to see the stress relationship between the jacket and riser clamp. The stress range bar is set so that stresses over yield (308.7 MPa) shows in orange and stresses over tensile stress in red. It can be seen that the brown color, less than 5 MPa, on the bracket indicates that there is negligible interaction between the clamps. This means that if further analysis is to be done on only the riser guide, the model can be divided into a sub model where the front jacket shell can be considered as bounded to the jacket leg. The maximum stress of 1198.6 MPa is on the edge of the washer/nut down to the end plate.

7.2.3. Bolt pre-tension, ULS-b 135° and ULS-b down

Figure 7.4 shows the results when bolt pre-tension and the environmental loads are applied. It can be seen that the change in the predicted stresses is insignificant. Further the figure show that the stresses are transferred more to one side.

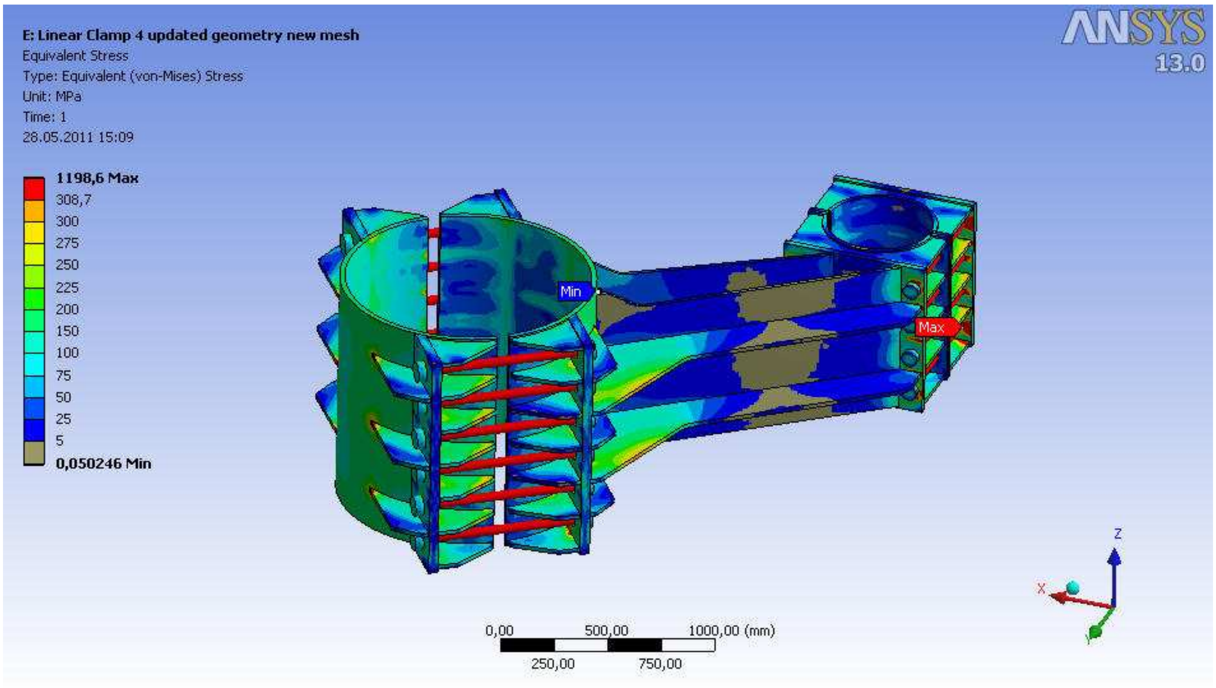


Figure 7.3 Pre-tension only

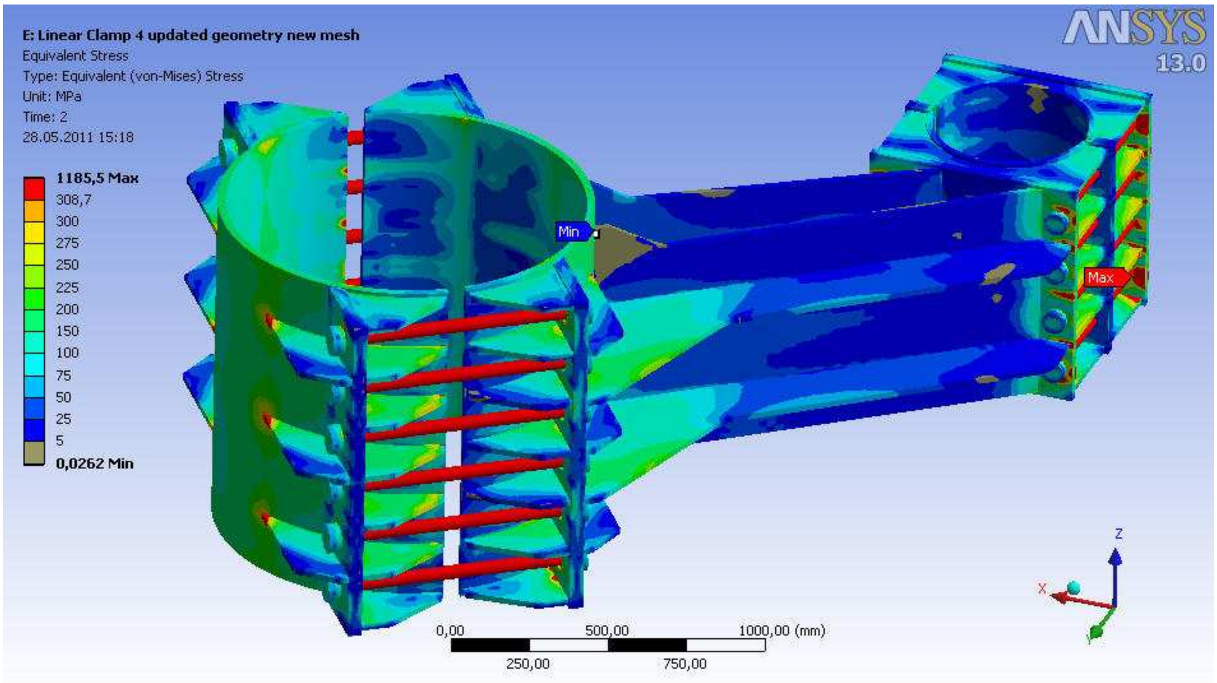


Figure 7.4 All loads applied

It can be seen in Figure 7.5 that the stresses are over design yield stress (308.7 MPa) in the transition region between the stiffener and the back shell. The highest predicted stress is 560.6 MPa. The stresses in back shell are typically 160-180 MPa, similar as for the action of pre-tension only.

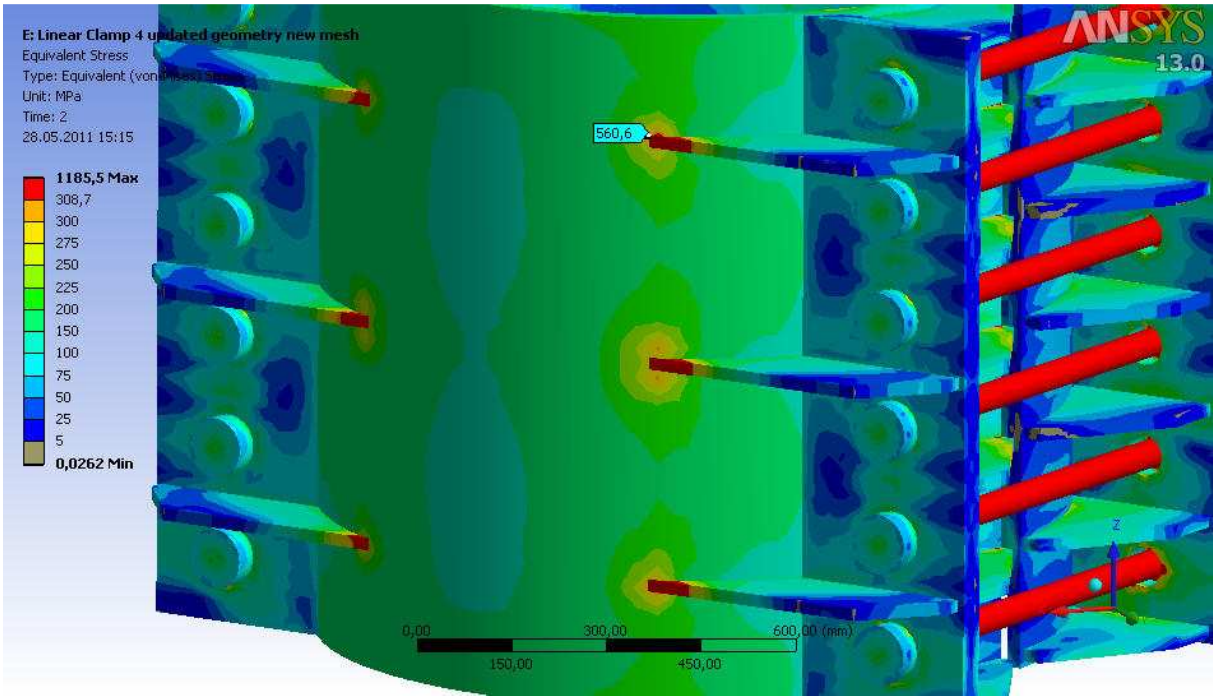


Figure 7.5 Stiffeners on back shell

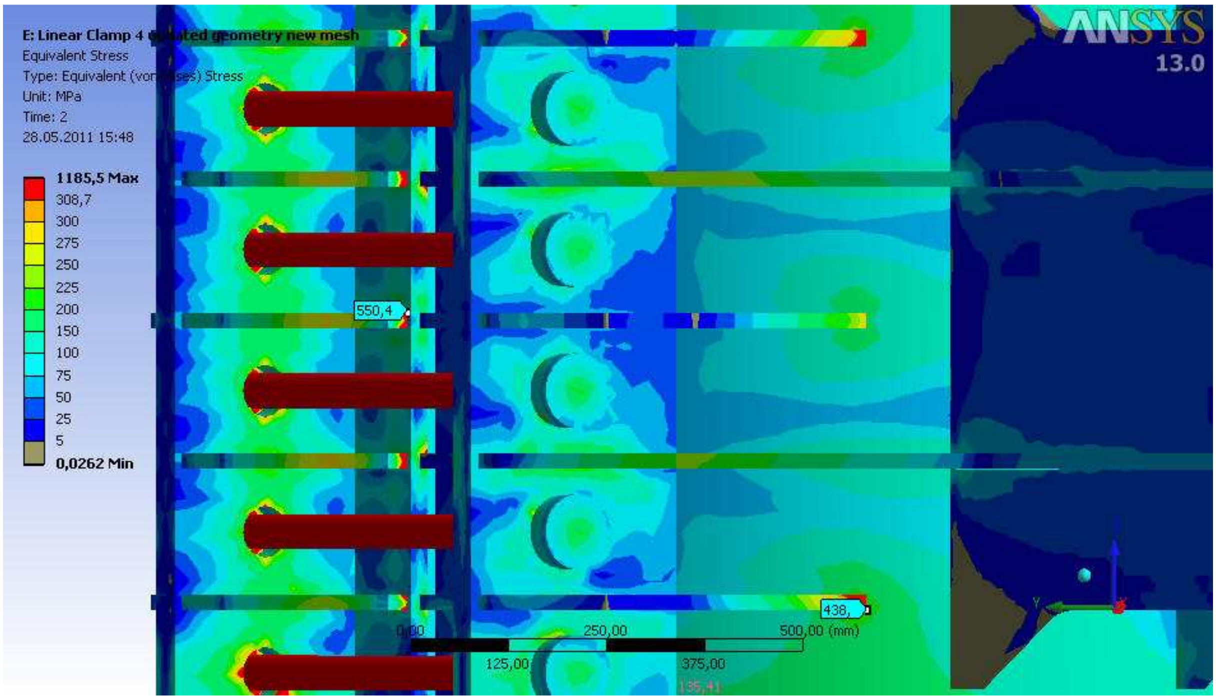


Figure 7.6 Front shell and side stiffeners

From Figure 7.6 it can be seen that the situation is the same for the horizontal stiffeners on the side and the stiffeners on the front shell. The peak stress is 550.4 MPa on the side stiffeners and 438 MPa on the front shell. On the other side (Figure 7.7) the stress is even higher at the same locations, with a maximum of 661.4 MPa on the side stiffener. The stiffeners on the front shell have a maximum stress of 490 MPa and in the bend on the horizontal plate of the clamp arm the stress is as high as 333.6 MPa.

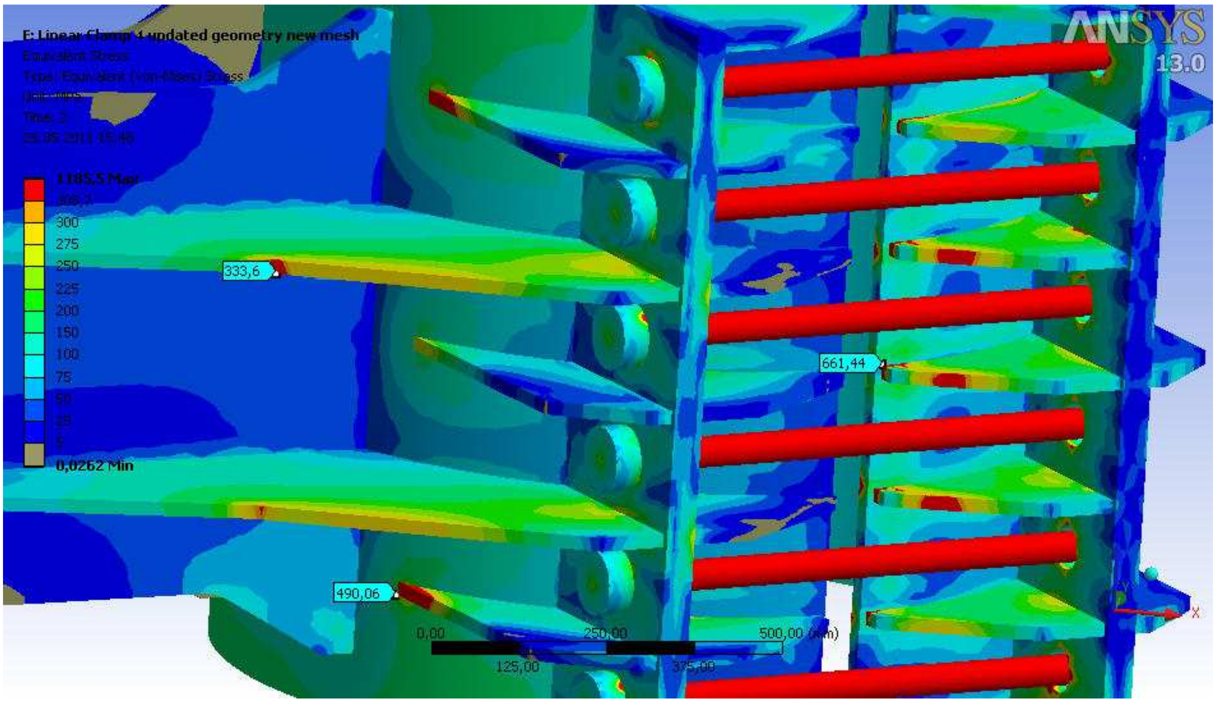


Figure 7.7 Other side

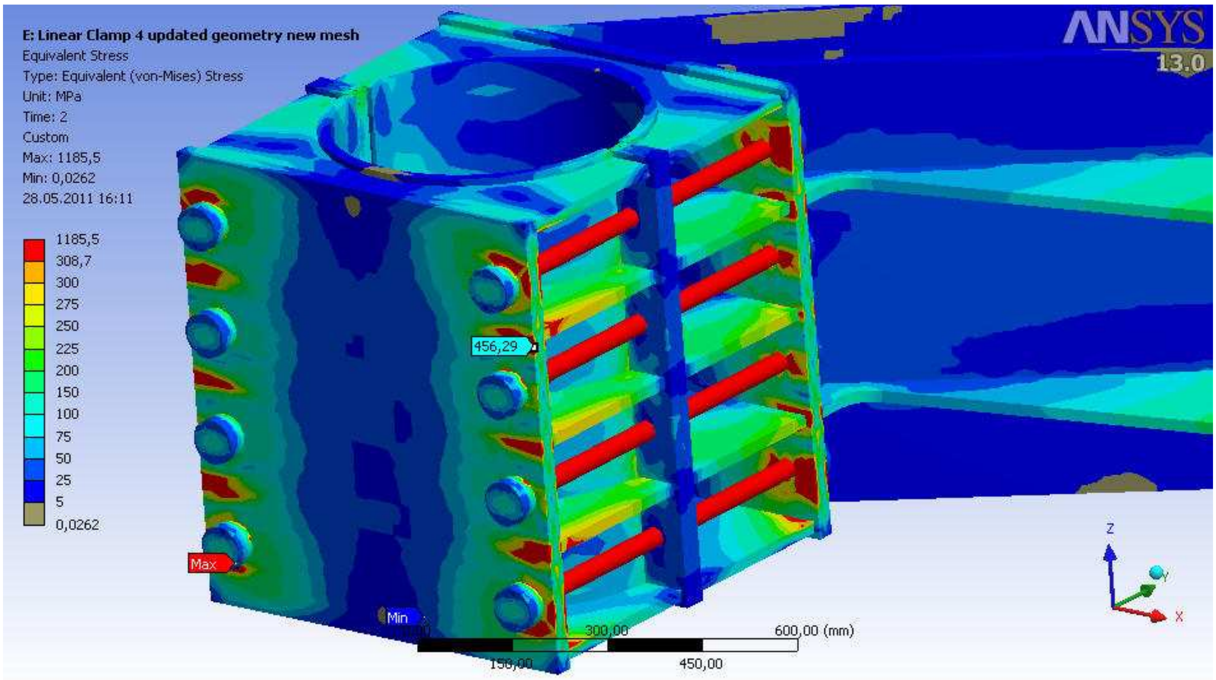


Figure 7.8 Riser guide

On the riser guide in Figure 7.8 the maximum stress is 456.3 MPa if the areas around the washer/bolts are ignored.

Several of these stresses that are peak can be unrealistic due to secondary effects such as material and geometrical discontinuities. Peak stresses due to secondary effect does not cause global distortion of the structure. Normal procedure to identify the peak stresses is trough stress linearization. The stresses after eliminating the peaks shall be checked whether they are within acceptable limits.

Alternatively the influence of secondary effects can be verified by performing non-linear analysis and check whether there is any plastic strain. The results for total strain (elastic + plastic) shall be within allowable limits.

The present work also covers non-linear analysis to verify the effects of peak stress. If there is high stresses above yield there should be plastic strain ($\sigma=E\varepsilon$), if not the stresses are “fake”. The non-linear analysis includes material curve that follows by bilinear isotropic hardening properties with ideal plastic flow (see Figure 7.9). The yield stress defined in the material curve corresponds to design yield that is 308.7 MPa after considering the material factor (1.15).

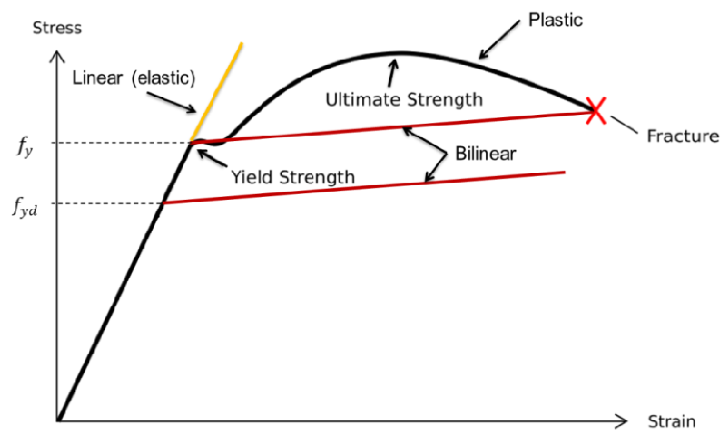


Figure 7.9 Bilinear illustration

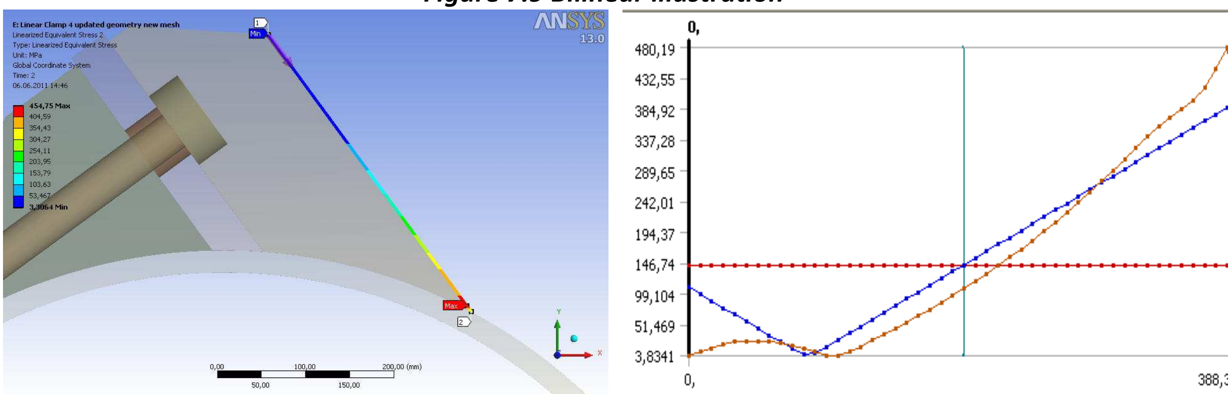


Figure 7.10 Linearized stress and plot

Figure 7.10 shows the linearized stress on the stiffener plate on the back shell. In the results plot it is show that the linearized stress (blue) now have a maximum of 385 MPa which was 560 MPa before linearization. Still the stresses are too high so a plastic strain check was conducted. The plastic strain from Figure 7.11 on the stiffener with the highest stress on the back shell has a maximum of 0.092% strain.

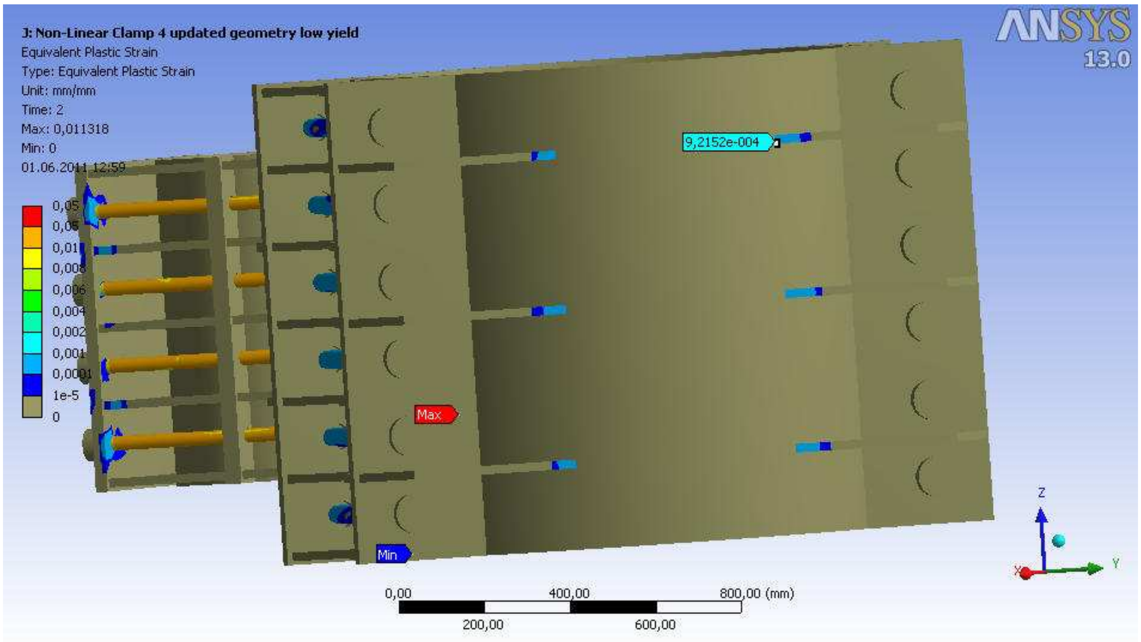


Figure 7.11 Plastic strain on back shell

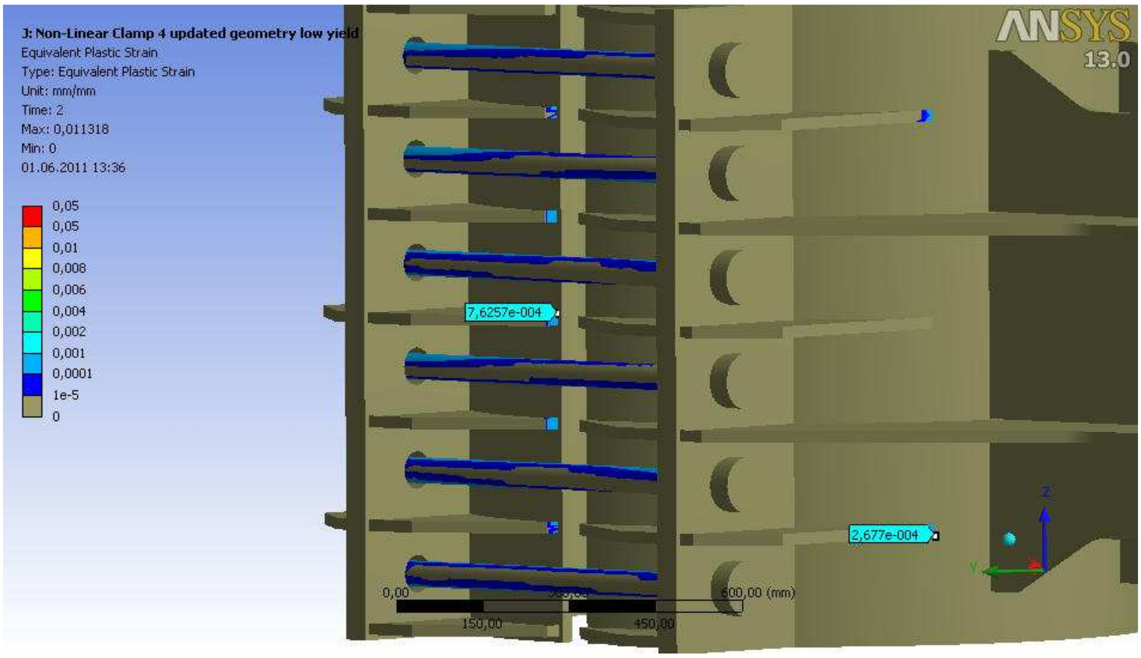


Figure 7.12 Plastic strain on the side and front shell

For the side and the front shell the plastic strains on the stiffeners are 0.076% and 0.027%, respectively (see Figure 7.12). Similarly Figure 7.13 shows the plastic strains for the side stiffener on the back shell (on the other side) which is 0.1%, and the strain for the stiffener on the front shell is 0.047%. The figure further shows zero plastic strain in the region on the horizontal plate where high stresses are found in linear analysis (see Figure 7.7).

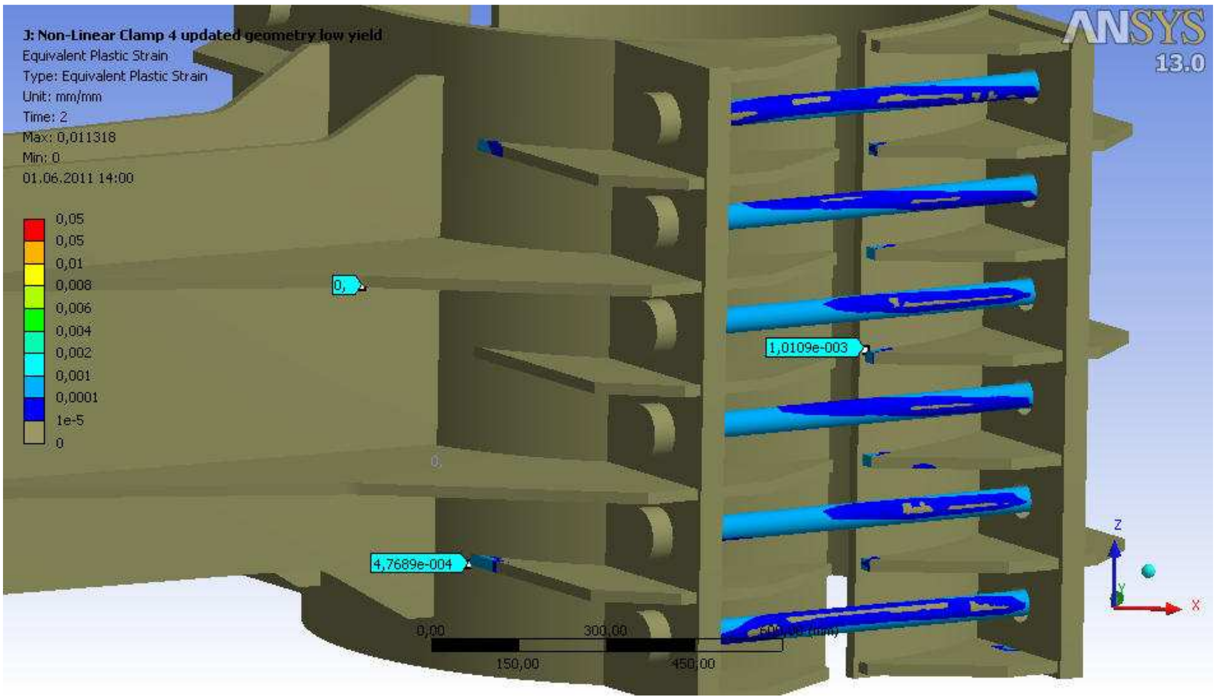


Figure 7.13 Plastic strain other side

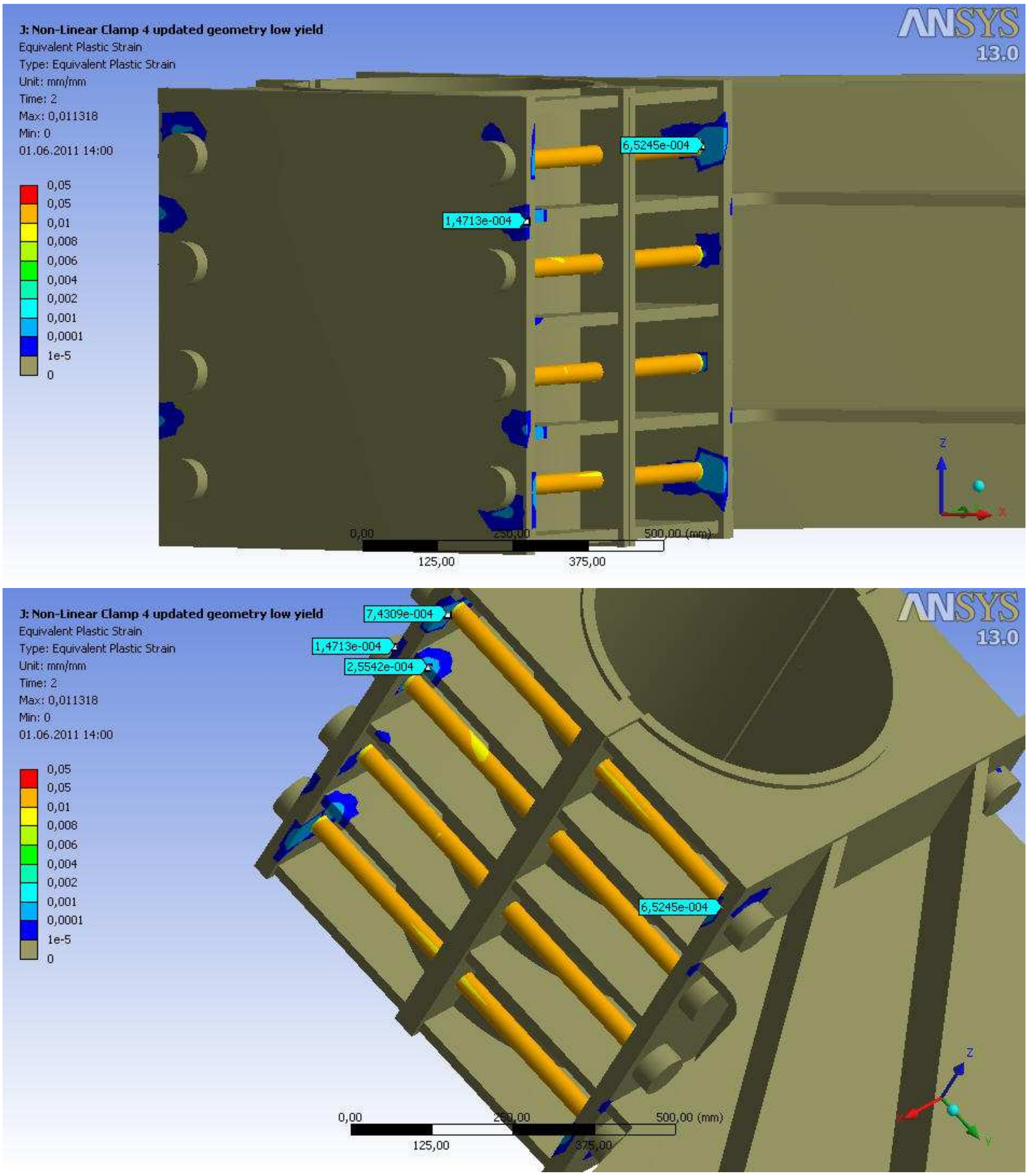


Figure 7.14 Plastic strain on riser guide

For the riser guide in Figure 7.14 the plastic strains do not exceed 0.074%.

7.3. Slippage analysis

Figure 7.15 shows the penetration on the back shell. Referring to chapter 5.3 the penetration can be 1-2 % of the thickness on the structural target element (jacket leg). The thickness of the leg is 25.4 mm which means that the penetration can maximum be 0.25 mm (i.e., 1%). The maximum penetration on the back shell is $5.9 \cdot e^{-7}$ mm slight to the side of the shell. In general the penetration is zero. Regardless the penetration is much below 0.25 mm. The front shell in Figure 7.16 has a maximum of $1.2 \cdot e^{-3}$ mm on the side edge of the shell. The rest of the front shell has in general zero penetration. Also here the penetration is well below the allowable value.

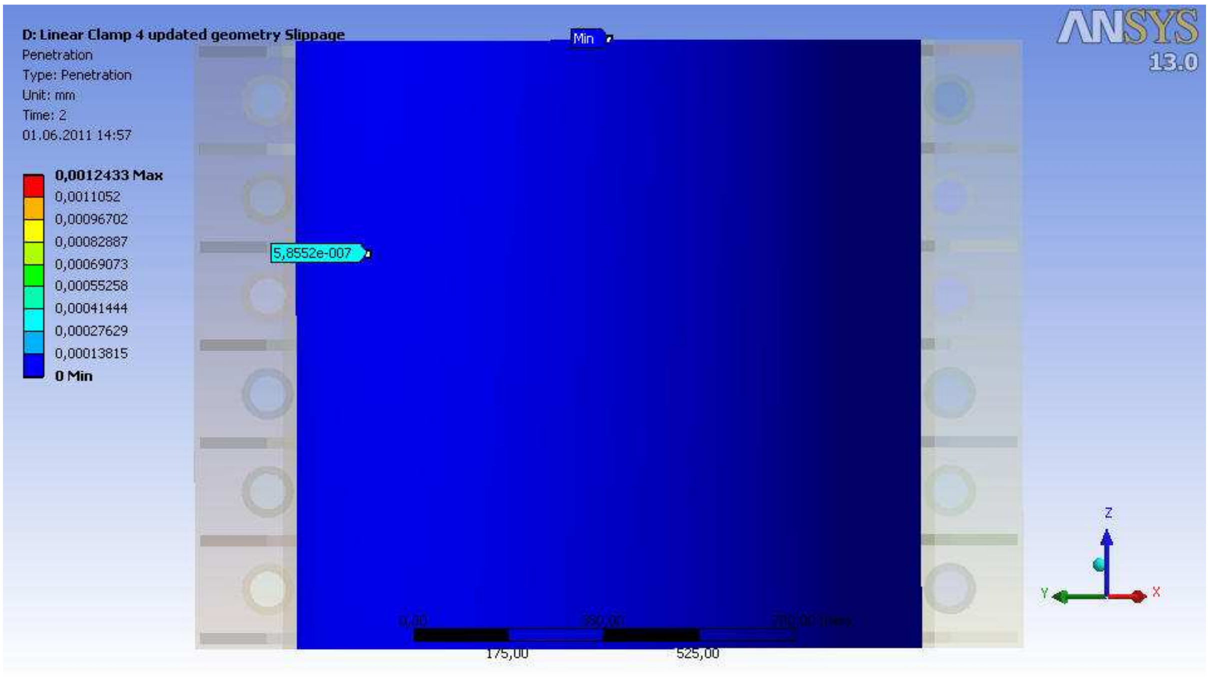


Figure 7.15 Penetration back shell

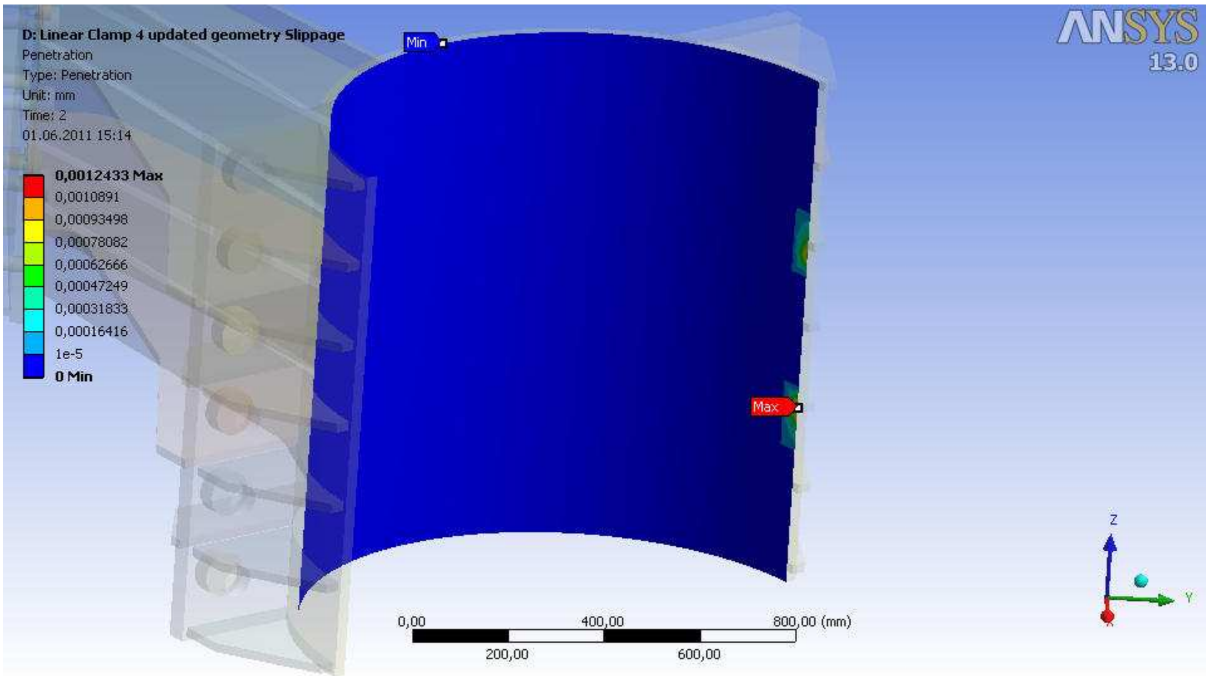


Figure 7.16 Penetration on front shell

In Figure 7.17 the contact status for the back shell can be seen, where red color means that there is enough static friction so that no slippage occurs. Approximately one half of the shell is sticking. The front shell is presented in Figure 7.18 and the result is much the same as for the back shell with some fewer elements sticking. These results can be confirmed by the graph in Figure 7.19 which shows the contacts over the time steps.

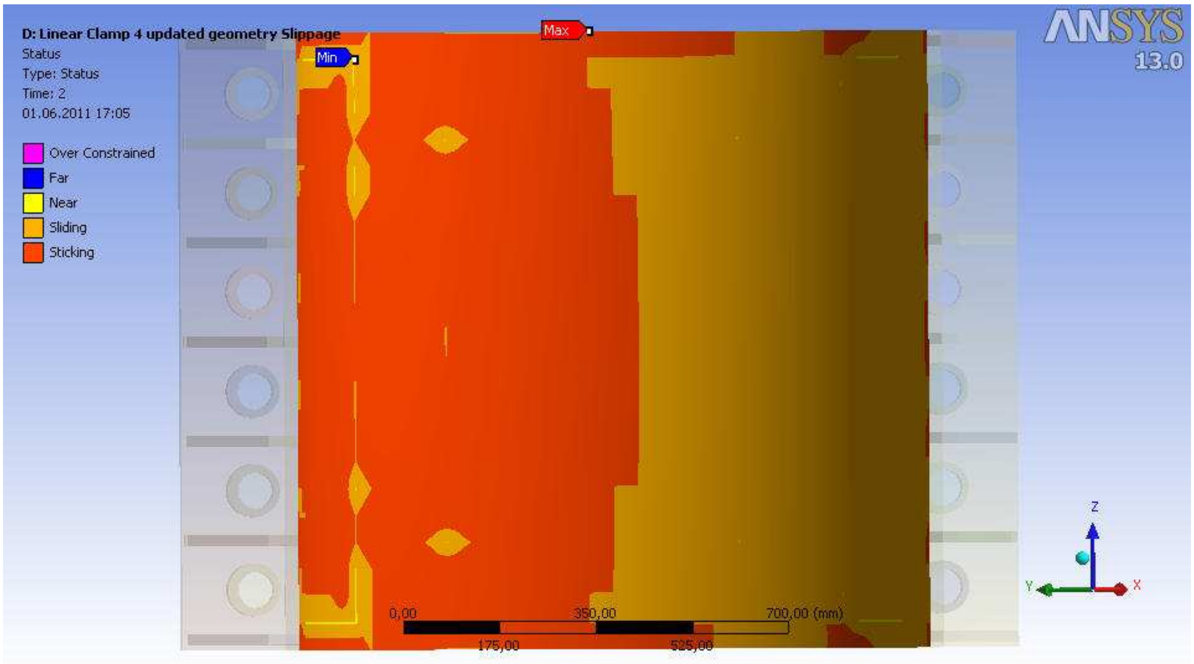


Figure 7.17 Status back shell

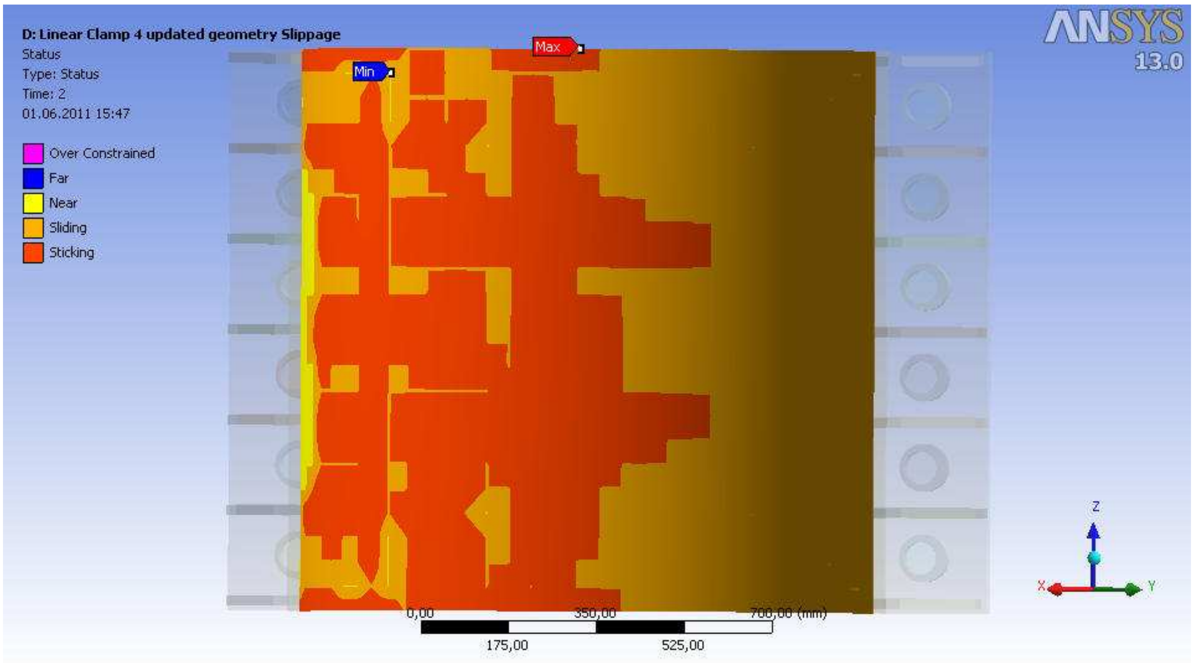


Figure 7.18 Status front shell

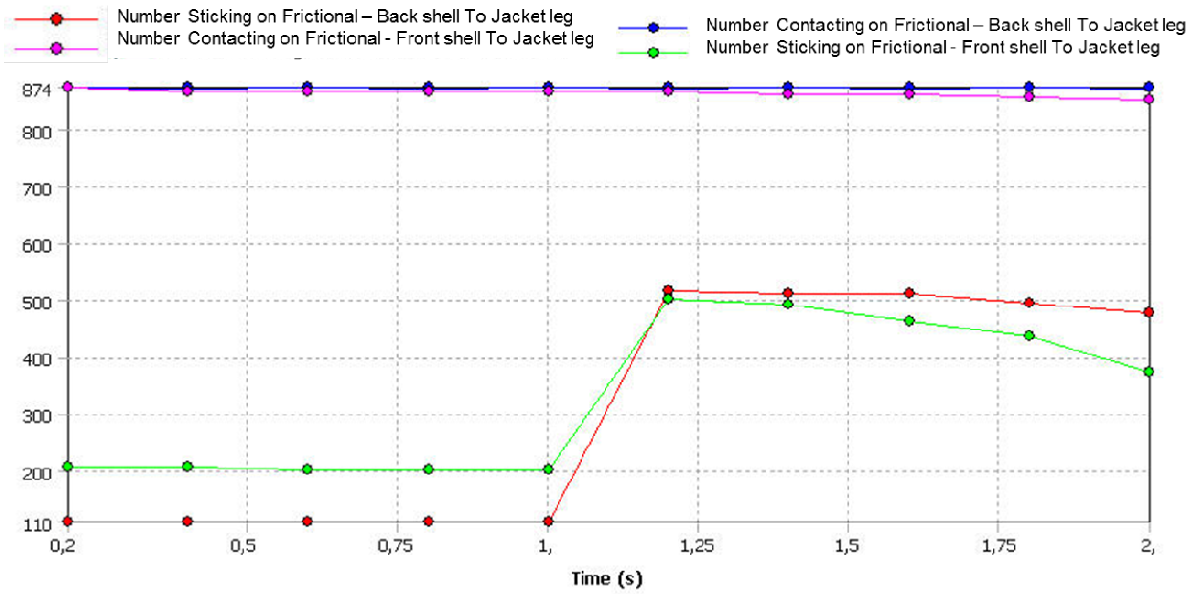


Figure 7.19 Element status for jacket clamp

Figure 7.20 shows the penetration between the contact surfaces on riser guide. The penetration is in general below 8.71·e^{-8}mm and the maximum of 1.27·e^{-7}mm is around the second lowest bolt hole.

The status for the frictional contact between the riser guide shells can be seen in Figure 7.21. The figure shows that approximately 60% of the elements are sticking. This can be confirmed by the graph in Figure 7.22. The other frictional contact between the riser guide shells is identical.

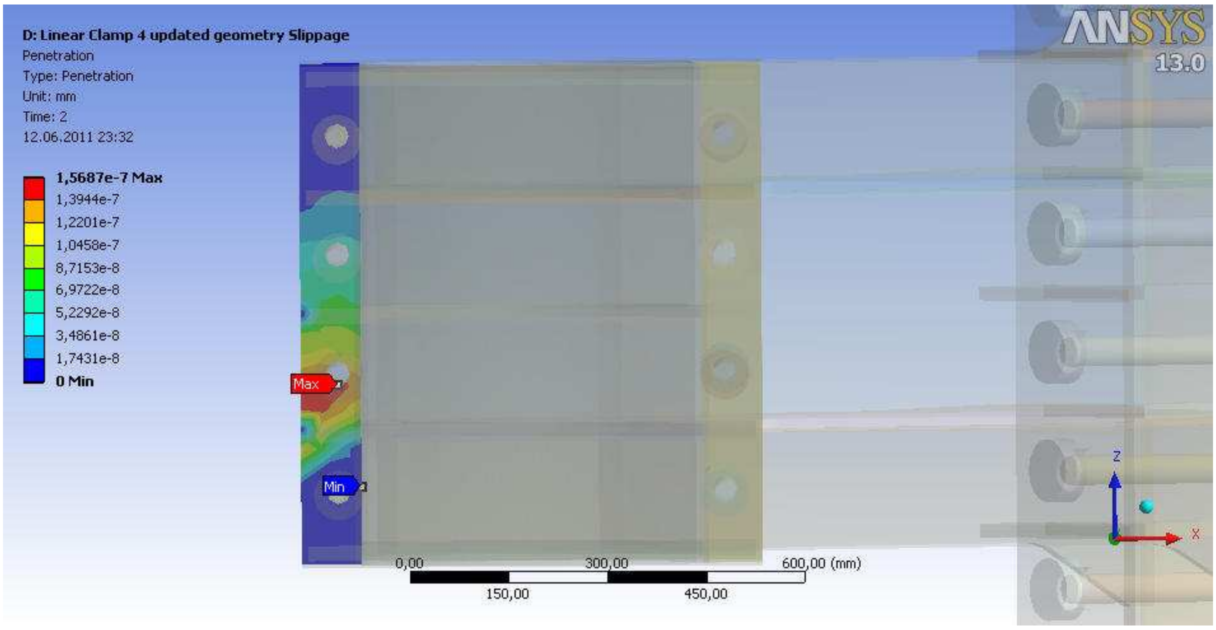


Figure 7.20 Penetration on riser guide

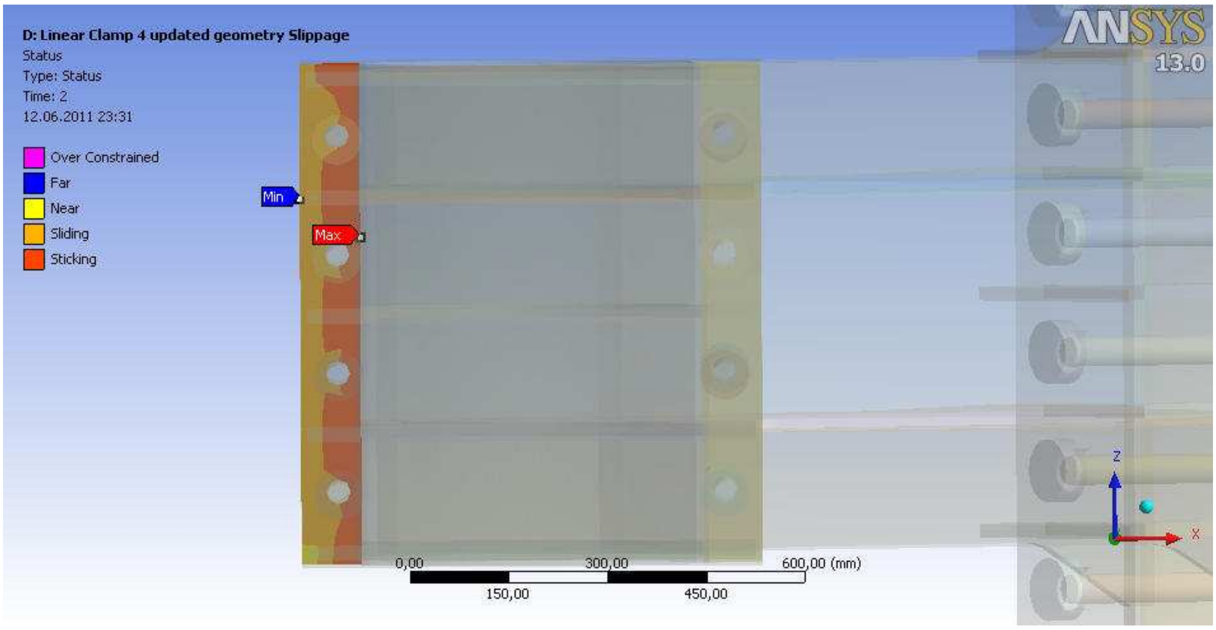


Figure 7.21 Status riser guide

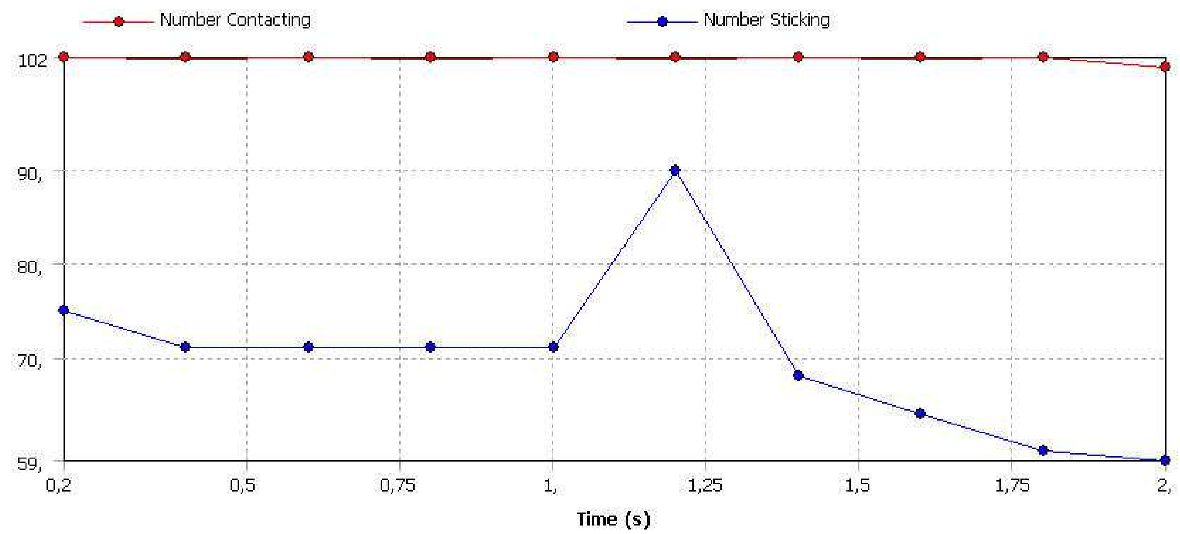


Figure 7.22 Element status for riser guide

7.4. New stresses in jacket leg

The pressure contribution from the clamping was taken from the ULS conditions of the clamp check (pre-tension with a factor of 1.3). The pressure from the back and front shell is shown in Figure 7.23 and Figure 7.24, respectively. The back shell has typically a pressure of 6-7 MPa and the front shell typically 4-5 MPa. Around the stiffer bracket the pressure are slightly higher, typically around 15 MPa.

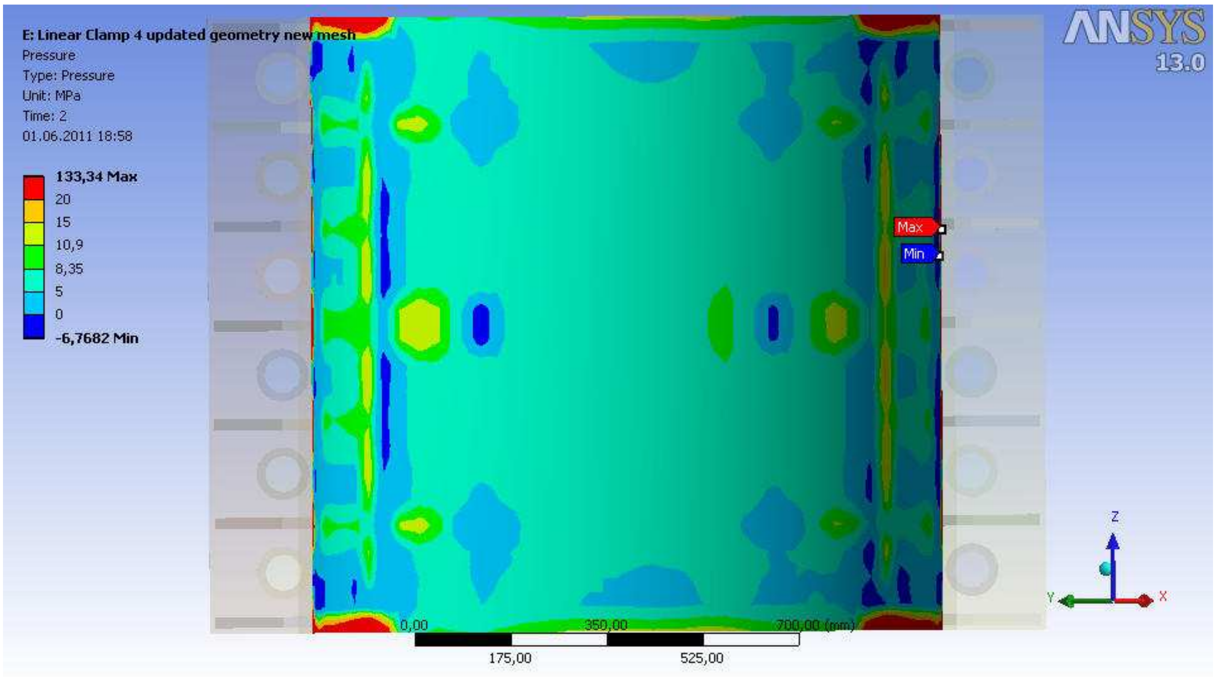


Figure 7.23 Pressure on back shell

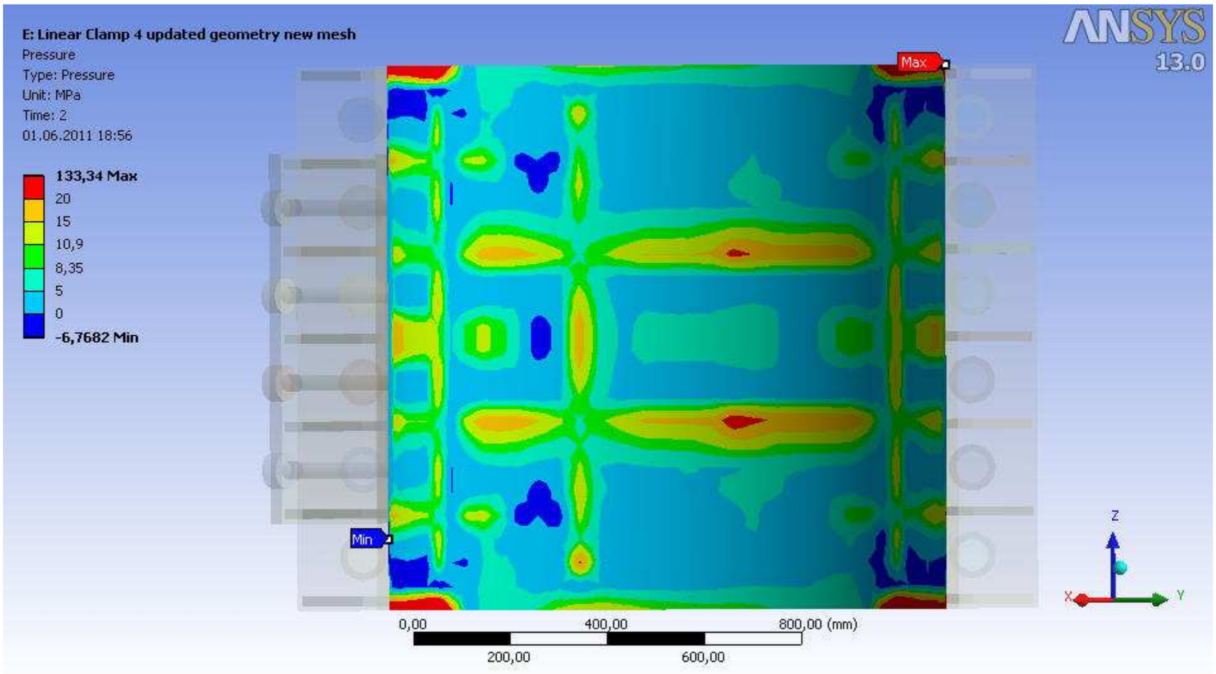


Figure 7.24 Pressure on front shell

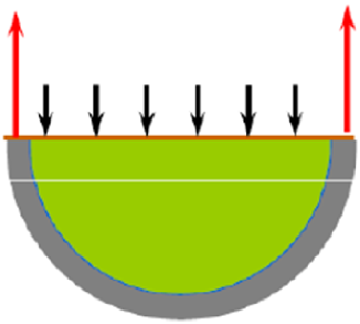


Figure 7.25 Half pipe (Karunakaran, 2010)

A simple calculation to find the pressure due to the clamping is to look at a half pipe as seen in Figure 7.25. The red arrows represents the pre-tension and the black arrows the contact pressure. The forces have to be in equilibrium. There are 12 bolts with pre-tension of 891.02 kN and dimensions as shown in Figure 7.26. This leads to:

$$F_b = \sigma_{pc} A$$

where,

F_b = pre-tension force
σ_{pc} = contact pressure
A = area

$$\sigma_{pc} = \frac{F_b}{A} = \frac{12 \cdot 891020}{1160 \cdot 1120} = 8{,}23\ MPa$$

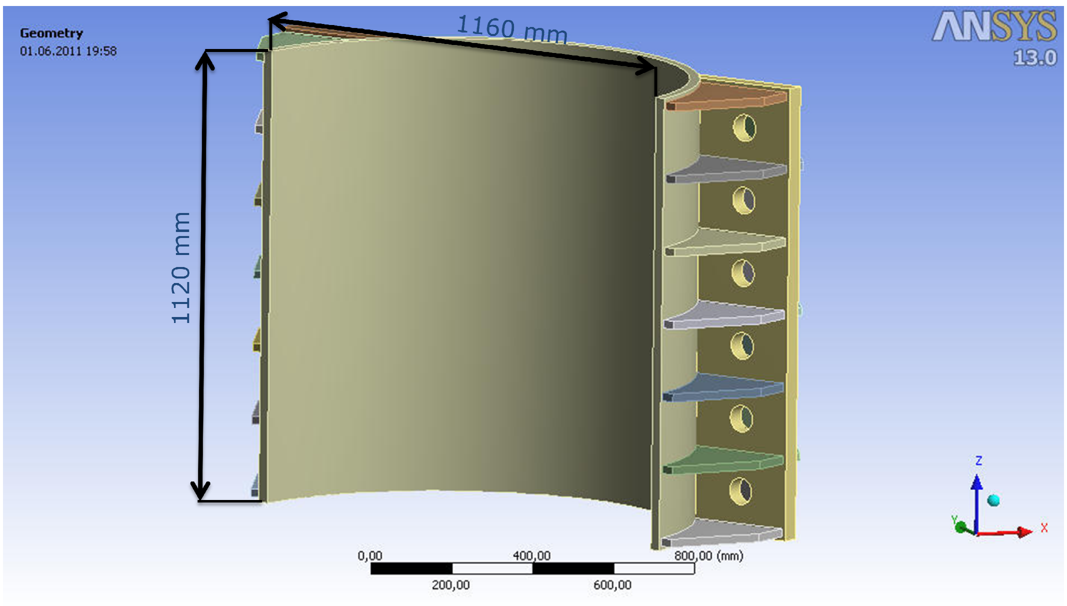


Figure 7.26 Clamp measures

7.5. Fatigue check

By checking the stresses in the clamp it can be seen that the jacket clamp and riser guide is fairly unaffected and that the cyclic loads have most influence on the riser arm (see Figure 7.27). The highest stresses are in the sharp corner near the riser guide and on the horizontal plate in the riser arm (see Figure 7.27 and Figure 7.28). Therefore these two areas and bolts including the weld near the sharp corner were checked for fatigue. In the fatigue calculations the correct principle stresses were used.

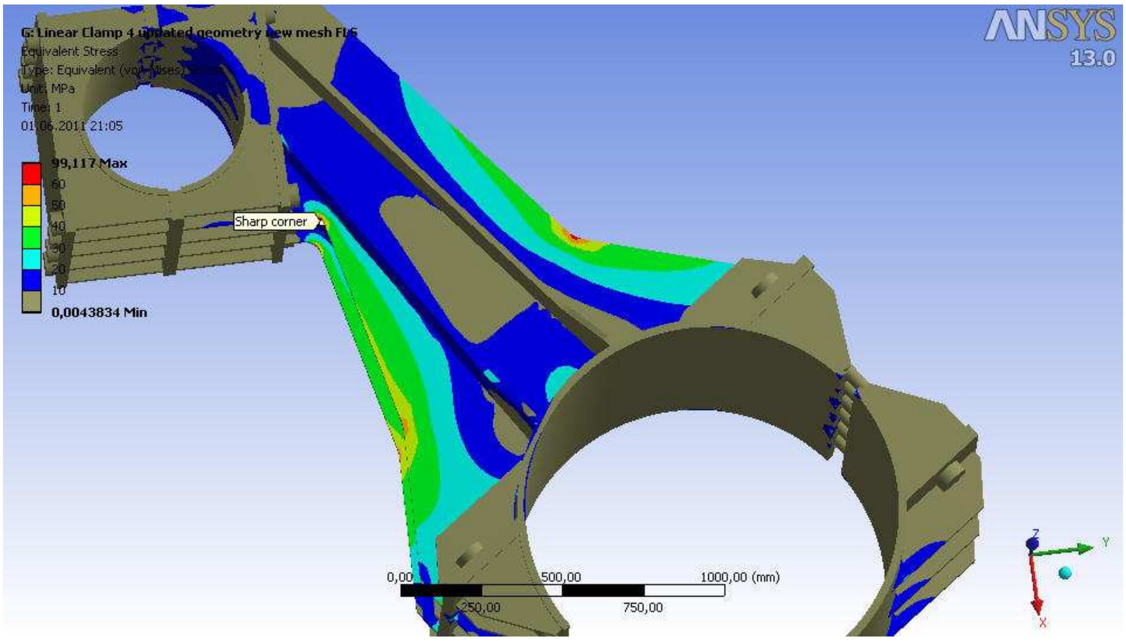


Figure 7.27 FLS von-Mises stress

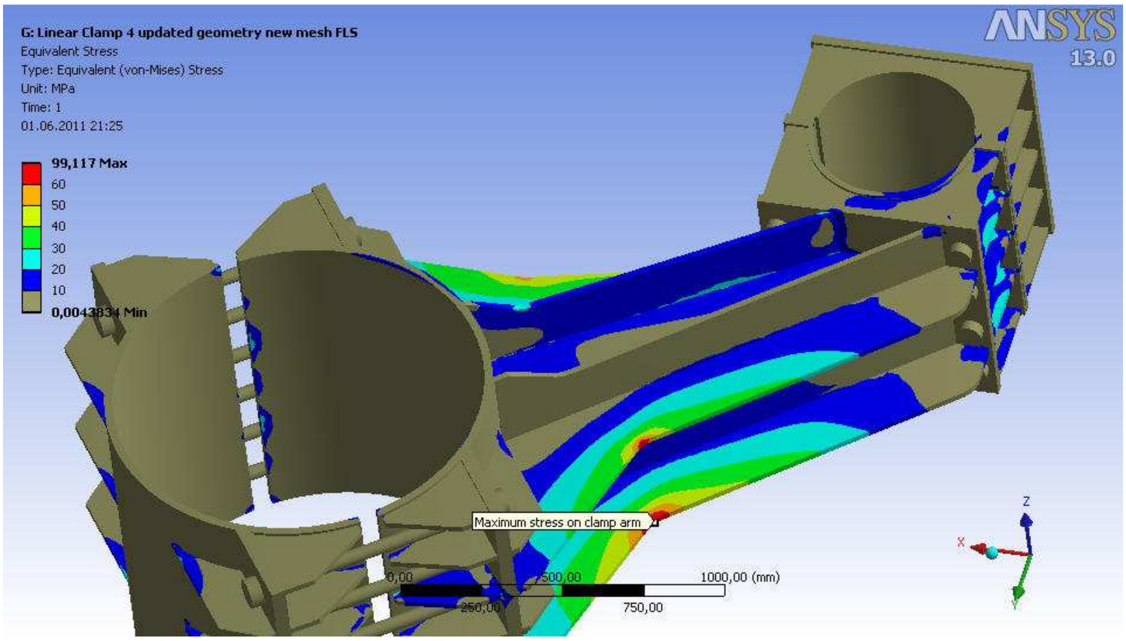


Figure 7.28 Maximum on clamp arm

7.5.1. Critical areas and bolts

In DNV-RP-C203 Appendix A, the corner and the plate on the clamp arm are classified as structural detail C. The bolts are classified as class W3 and the weld near the sharp corner as class G (thickness less than 150mm).

In Figure 7.29 the corner and weld is shown with maximum principal stress, i.e. tension. The corner and the weld on the top plate have maximum stresses of 68.2 MPa and 28.3 MPa, whereas the stresses in the corner and the weld on the bottom plate are 56.5 MPa and 23.6 MPa, respectively. Figure 7.30 presents the minimum principal stress, i.e. compression. Similarly for compression the corner and the weld on the top plate have maximum stress of 56.7 MPa and 26.3 MPa, while the stress in the corner and the weld on the bottom plate are 68.7 MPa and 28.5 MPa, respectively.

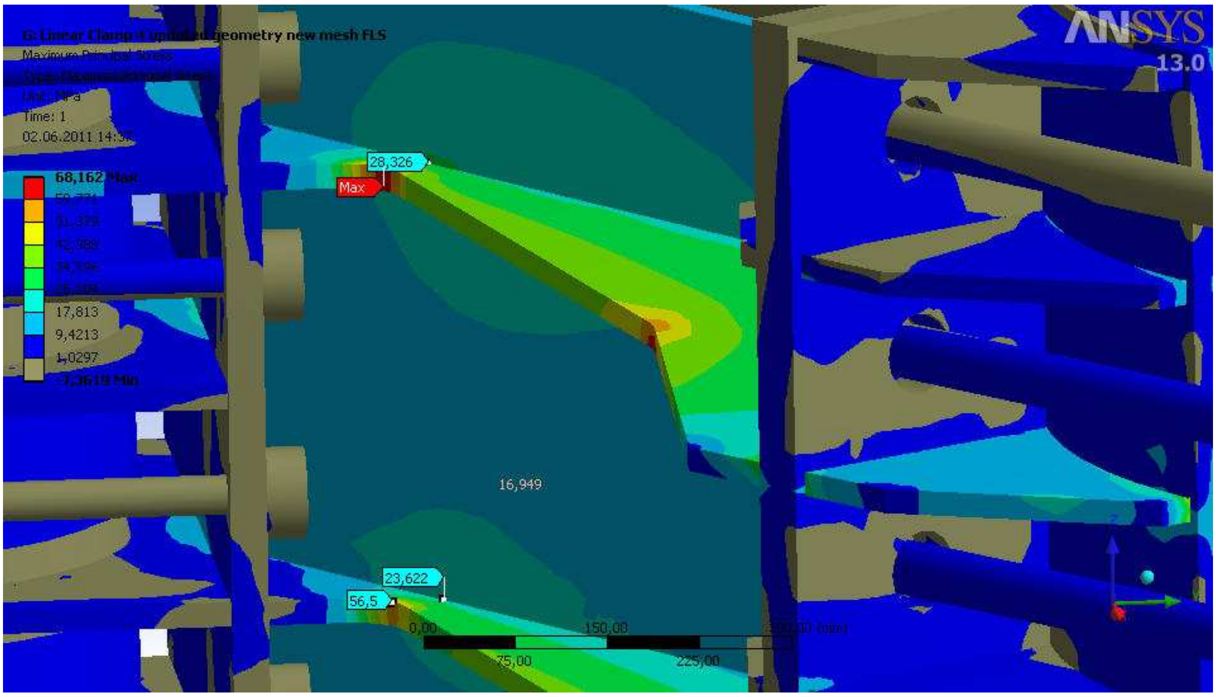


Figure 7.29 Maximum principal stress on corner and weld

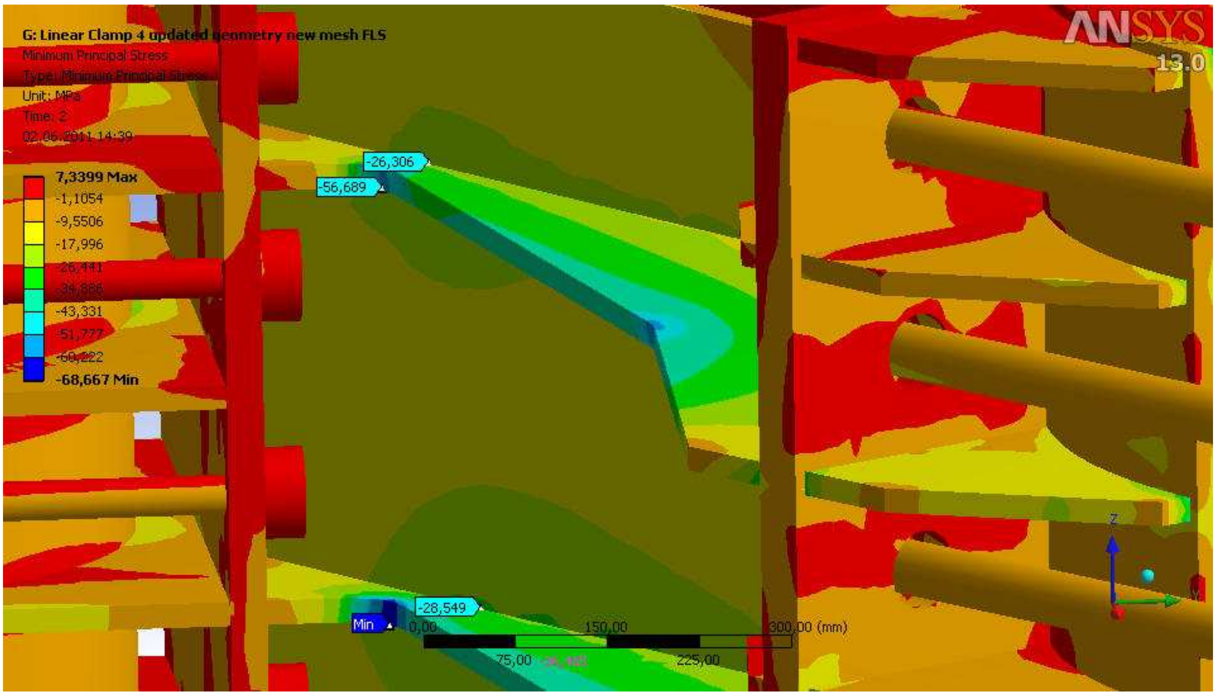


Figure 7.30 Minimum principal stress on corner and weld

For the top horizontal plate (see Figure 7.31 and Figure 7.32) the results shows maximum tension of 94.3 MPa and maximum compression of 69.5 MPa. The maximum stress for the bottom plate is 73.5 MPa for tension and 99.3 MPa for compression.

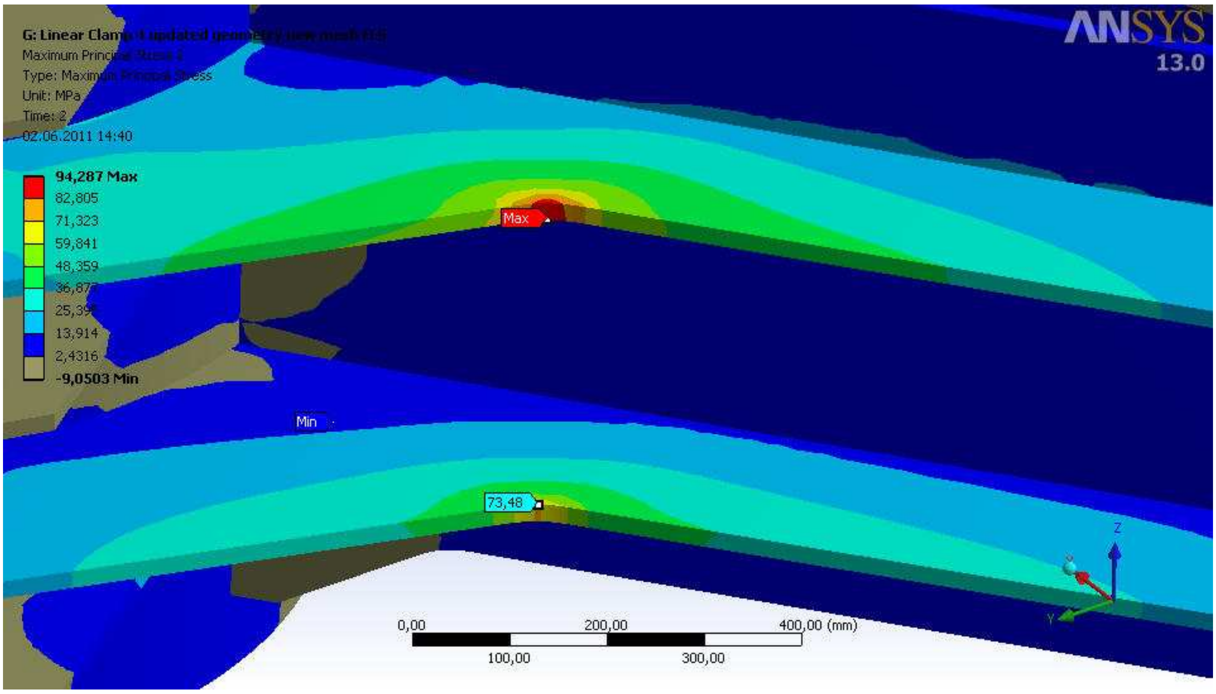


Figure 7.31 Maximum principal stress on horizontal plate

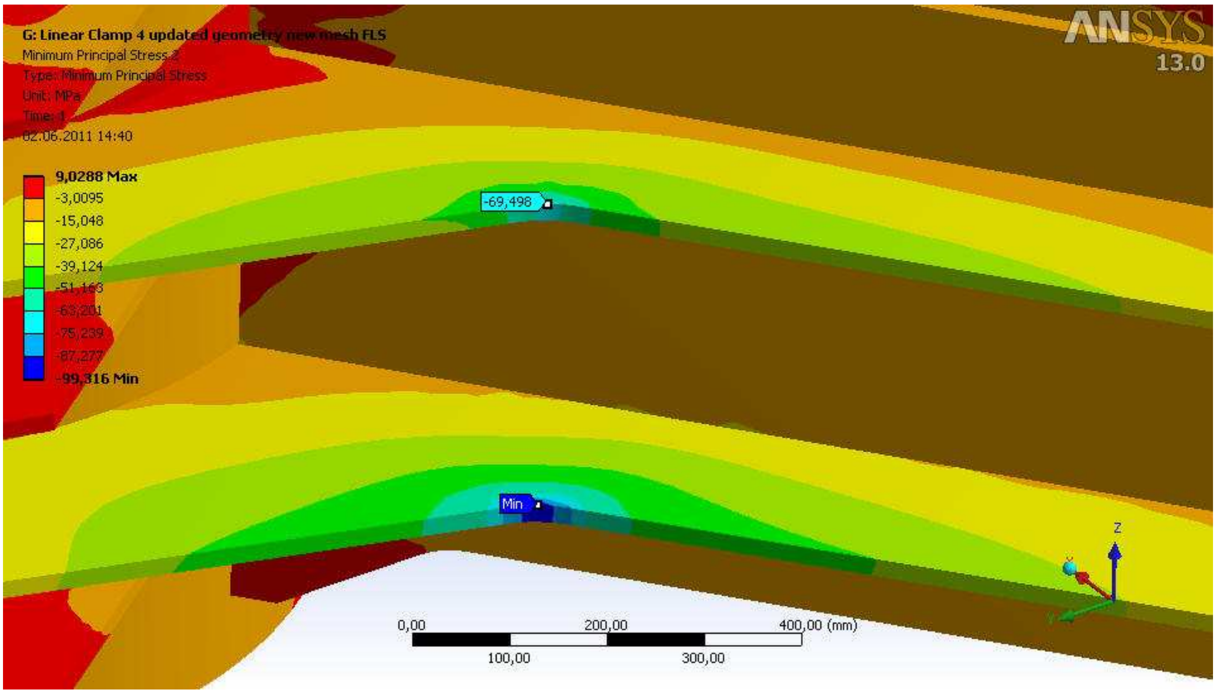


Figure 7.32 Minimum principal stress on horizontal plate

The stress ranges, $\Delta\sigma_O$, are found by adding the values for tension and compression. This results in a stress range of 124.9 MPa for the corner on the top plate and 125.2 MPa for the corner on the bottom plate. For the weld on the top plate the stress range is 54.6 MPa while for the weld on the bottom plate the stress range is 52.1 MPa. Similarly also for the top and bottom horizontal plates the stress ranges are 164 MPa and 172.8 MPa, respectively. Since the sharp corner and the horizontal plate are in the same structural class, only the one with the highest stress range needs to be checked, i.e. the bottom horizontal plate.

For the fatigue check the bolt with the highest equivalent stress was chosen. Figure 7.33 presents the stresses due to tension as 6.9 MPa and Figure 7.34 presents the stresses due to compression as 8.9 MPa. The resulting stress range for the bolt is 15.8 MPa.

In The North Sea the average wave period is approximately 8 seconds. This results in number of cycles over the 23 years to be:

$$n_0 = \frac{23 \cdot 365 \cdot 24 \cdot 60 \cdot 60}{8} = 9{,}0666 \cdot 10^7$$

To be conservative, the number of cycles until failure is assumed to be less than one million ($N \leq 10^6$ cycles). Table 7.4 gives values for m and $\log \bar{a}$ as listed below in Table 7.3:

S-N curve	m	$\log \bar{a}$
C	3,0	12,192
W3	3,0	10,998
G	3,0	10,570

Table 7.3 Values for 10^6 cycles

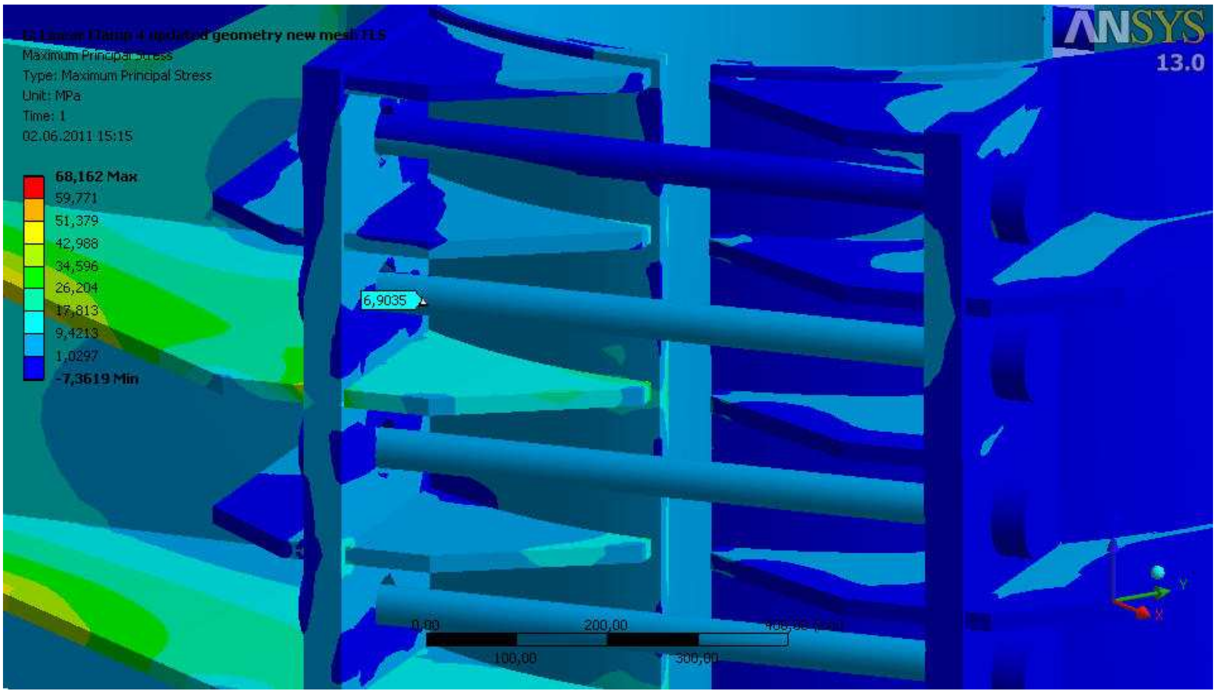


Figure 7.33 Maximum principal stress on bolts

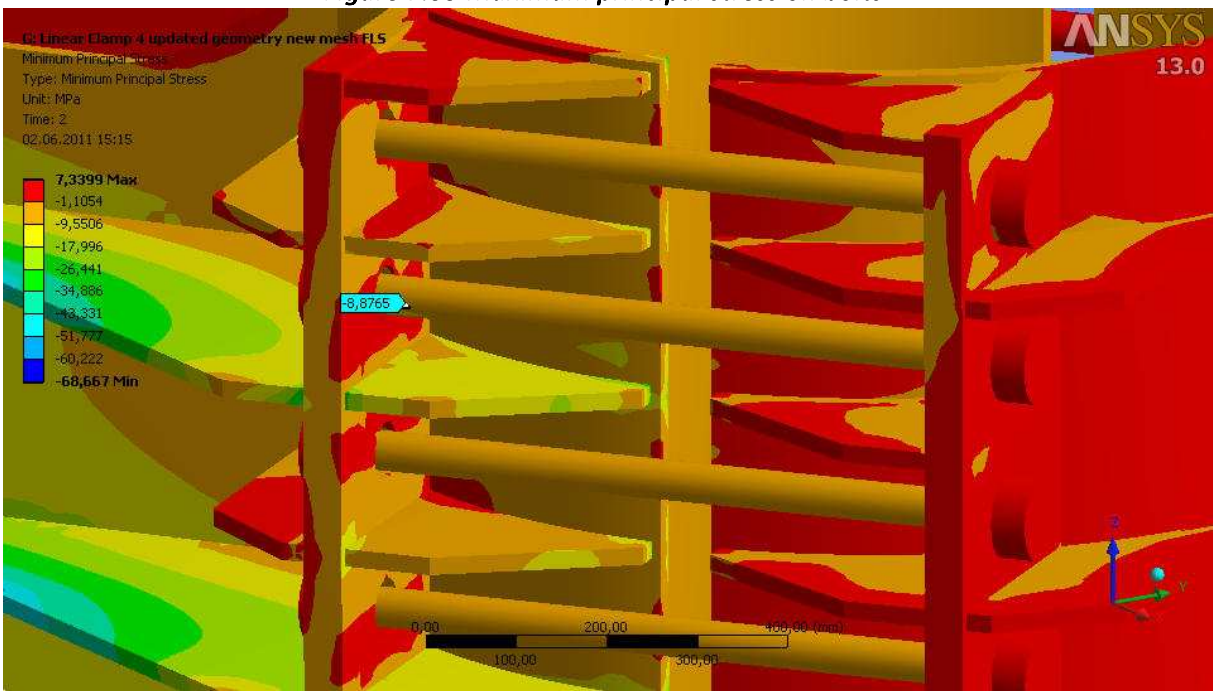


Figure 7.34 Minimum principal stress on bolts

By assuming a Weibull shape parameter, h, between 0.8 and 0.9 (i.e. 0.85) the gamma function can be found in Table 7.5 to be:

$$\Gamma\left(1+\frac{m}{h}\right) = 12{,}118$$

Table 2-2 S-N curves in seawater with cathodic protection						
S-N curve	$N \leq 10^6$ cycles		$N > 10^6$ cycles $\log \bar{a}_2$ $m_2 = 5.0$	Fatigue limit at 10^7 cycles*)	Thickness exponent k	Stress concentration in the S-N detail as derived by the hot spot method
	m_1	$\log \bar{a}_1$				
B1	4.0	14.917	17.146	106.97	0	
B2	4.0	14.685	16.856	93.59	0	
C	3.0	12.192	16.320	73.10	0.15	
C1	3.0	12.049	16.081	65.50	0.15	
C2	3.0	11.901	15.835	58.48	0.15	
D	3.0	11.764	15.606	52.63	0.20	1.00
E	3.0	11.610	15.350	46.78	0.20	1.13
F	3.0	11.455	15.091	41.52	0.25	1.27
F1	3.0	11.299	14.832	36.84	0.25	1.43
F3	3.0	11.146	14.576	32.75	0.25	1.61
G	3.0	10.998	14.330	29.24	0.25	1.80
W1	3.0	10.861	14.101	26.32	0.25	2.00
W2	3.0	10.707	13.845	23.39	0.25	2.25
W3	3.0	10.570	13.617	21.05	0.25	2.50
T	3.0	11.764	15.606	52.63	0.25 for SCF ≤ 10.0 0.30 for SCF >10.0	1.00

Table 7.4 S-N curves in seawater with cathodic protection (DNV-RP-C203)

Table 5-1 Numerical values for Γ (1+ m/h)					
h	m = 3.0	h	m = 3.0	h	m = 3.0
0.60	120.000	0.77	20.548	0.94	7.671
0.61	104.403	0.78	19.087	0.95	7.342
0.62	91.350	0.79	17.772	0.96	7.035
0,63	80.358	0.80	16.586	0.97	6.750
0.64	71.048	0.81	15.514	0.98	6.483
0.65	63.119	0.82	14.542	0.99	6.234
0.66	56.331	0.83	13.658	1.00	6.000
0.67	50.491	0.84	12.853	1.01	5.781
0.68	45.442	0.85	12.118	1.02	5.575
0.69	41.058	0.86	11.446	1.03	5.382
0.70	37.234	0.87	10.829	1.04	5.200
0.71	33.886	0.88	10.263	1.05	5.029
0.72	30.942	0.89	9.741	1.06	4.868
0.73	28.344	0.90	9.261	1.07	4.715
0,74	26.044	0.91	8.816	1.08	4.571
0.75	24.000	0.92	8.405	1.09	4.435
0.76	22.178	0.93	8.024	1.10	4.306

Table 7.5 Numerical values for the gamma function (DNV-RP-C203)

A summary of the results needed for the fatigue calculations are presented in Table 7.6.

Structure	S-N curve	m	$\log \bar{a}$	h	$\Gamma\left(1+\frac{m}{h}\right)$	$\Delta\sigma_o$
Horizontal plate	C	3,0	12,192	0.85	12,118	172.8 MPa
Bolts	W3	3,0	10,998	0.85	12,118	15.8 MPa
Weld on bracket	G	3,0	10,570	0.85	12,118	54.6 MPa

Table 7.6 Stress range results

The Weibull shape parameter is:

$$q = \frac{\Delta\sigma_o}{(\ln n_0)^{1/h}}$$

And the fatigue damage is:

$$D = \frac{\upsilon_0 T_d}{\bar{a}} q^m \Gamma\left(1+\frac{m}{h}\right) \leq \eta$$

Horizontal plate:

$$q = \frac{\Delta\sigma_o}{(\ln n_0)^{1/h}} = \frac{172,8}{(\ln(9,0666 \cdot 10^7))^{1/0,85}} = 5,645\ MPa$$

$$D = \frac{\upsilon_0 T_d}{\bar{a}} q^m \Gamma\left(1+\frac{m}{h}\right) = \frac{n_o}{10^{\log \bar{a}}} q^m \Gamma\left(1+\frac{m}{h}\right) = \frac{9,0666 \cdot 10^7}{10^{12,192}} \cdot 5,645^3 \cdot 12,118 = \underline{0,127}$$

Bolts:

$$q = \frac{\Delta\sigma_o}{(\ln n_0)^{1/h}} = \frac{15,8}{(\ln(9,0666 \cdot 10^7))^{1/0,85}} = 0,516\ MPa$$

$$D = \frac{n_o}{10^{\log \bar{a}}} q^m \Gamma\left(1+\frac{m}{h}\right) = \frac{9,0666 \cdot 10^7}{10^{10,998}} \cdot 0,516^3 \cdot 12,118 = \underline{0,00152}$$

Weld on bracket:

$$q = \frac{\Delta\sigma_o}{(\ln n_0)^{1/h}} = \frac{54,6}{(\ln(9,0666 \cdot 10^7))^{1/0,85}} = 1,784\ MPa$$

$$D = \frac{n_o}{10^{\log \bar{a}}} q^m \Gamma\left(1+\frac{m}{h}\right) = \frac{9,0666 \cdot 10^7}{10^{10,570}} \cdot 1,784^3 \cdot 12,118 = \underline{0,168}$$

8. Discussions and conclusions

8.1. ULS stress

Bolt check:
The results show that the M45 bolts have stresses between 360-450 MPa which are within the maximum allowable stress of 595 MPa. The results also show that the stresses in the M33 bolts are below the allowable stress with stresses around 420-430 MPa. The maximum stresses in Figure 7.2 may as mentioned be “unrealistic” and is probably due to geometrical discontinuities. But regardless of this the washer/nut knob is irrelevant for this analysis and the peak stresses can be disregarded. It is clear from the results that the bolts can withstand the maximum forces obtained in accordance with the ULS criteria.

Clamp check:
By comparing the results for action of pre-tension only and for all the loads applied the change in the stresses is relatively small, meaning that the pre-tension from the bolts contributes the largest stresses in the clamp. Since the stresses are roughly the same on the top and the bottom of the clamp it appears that the vertical loads are less critical than the horizontal loads. Further it looks like the maximum peak stress from the pre-tension only (load step 1) is due to discontinuity but is anyway structural irrelevant.

The results show that the stresses are in general within acceptable limits except for some hot spots. There are typically high stresses exceeding design yield in the end of many stiffener plates and on the bend of the horizontal plate in the bracket arm. As mentioned stress linearization technique is used to avoid peak stresses which do not cause structural failure. Even after stress linearization, the stresses obtained from the analysis exceeded design yield in certain transition regions of geometric discontinuity. For clear engineering judgment and better understanding on effects of secondary stresses due to discontinuities, a non-linear analysis was conducted.

The maximum equivalent plastic strain obtained from the results is 0.1% which is insignificant. The resulting total strain (elastic + plastic) is 0.3%. These strains are confined to local and do not cause any gross structural deformation of the clamp. Therefore the strains are considered to be disregarded. In summary it can be concluded that the clamp will withstand against peak forces from the environment and that the clamp meets the design criteria against the ULS stress check.

It can be discussed why not doing a non-linear analysis in the first place. The reason is that the results from the linear analysis within yield is conservative and takes less computational time. For example, with regarding to the computational time, the FE model took about 12.5 hours for linear analysis whereas for non-linear analysis it took about 19 hours. Hence the practice in the industry is to first do a linear analysis, and if the stresses still are outside allowable values, a non-linear analysis is conducted. It should be noted that the clamp geometry is complicated. A simpler geometry would probably not experience that many discontinuities.

8.2. Slippage

The results show that the penetration is low as expected since the contact algorithm used for the frictional contact is Normal Lagrange (see chapter 5.3). The penetration is well below the allowable value for both the jacket clamp and the riser guide. This means that the results are accurate enough.

The graph from Figure 7.19 shows that the back shell has the most sticking elements when all loads are applied. This means that the back shell is most active in preventing the clamp from sliding. That is logical because the front shell should be stiffer due to the bracket arm and this result in a smaller contact area than for the softer back shell. It is concluded that with a load factor of 2 and maximum relaxation, the jacket clamp has sufficient number of sticking elements to avoid slippage. The same applies for the riser guide.

8.3. New stresses in jacket leg

When disregarding the peak pressure, the contact pressure from the jacket clamp on the jacket leg was within the 10.9 MPa. It should be noted that this is only the contribution from the clamp. Since the jacket leg may already have residual stress the new stresses from the clamp have to be checked by the jacket owner.

8.4. Fatigue

There were three hot spots that were checked in the fatigue calculations. The hot spots include the bend in the horizontal plate, a weld on the bracket arm and the bolts. From the results it is shown that the largest fatigue damage is calculated to be on the weld even though the stress range is three times larger on the horizontal bracket plate. This shows that welds are more fragile for fatigue, which emphasizes the importance of good welding. Regardless the fatigue damage is less than the utilization factor of 0.306 for all areas; hence the clamp meets the requirements for the FLS check.

8.5. Summary and recommendations

The results from the analysis in the thesis and the Subsea 7 report are comparable. Even though the values are not identical the same conclusions are drawn. However there are several ways to do such analyses. The way the analysis is carried out is individual and may vary between users. The major differences in the analyses between the report and the thesis are probably the mesh, contact algorithms and the applied forces. The mesh in the previous Subsea 7 report shares the nodes whereas the mesh in the present thesis does not share the nodes. This leads to two completely different meshes which will result in somewhat different values. Mainly in the previous report Pure Penalty algorithm is used for the bounded contacts while in the present MPC algorithm is used to simulate the welds. This also leads to variation between the results. Regardless a non-linear analysis had to be conducted in the thesis to prove that the peak stresses was “fake”.

It should be noted that analysis was only performed on one clamp (clamp 4). For future work beyond this thesis, analysis for the other clamps should be performed as well. For experimental purposes other mesh and contact algorithms could be tested and compared. An analysis to see how corrosion and erosion affects the clamps over the design life, if loss of cathodic protection should occur, could also have been interesting. Analyzing the effect of thermal expansion of the riser and subsea pipeline, especially on the bottom clamp, could be another approach. The present clamps can also be compared against new design proposals.

9.References

ANSYS. (2005). ANSYS Workbench - Simulation Strctural Nonlinearities.

Chakrabarti, S. K. (2005). *Handbook of Offshore Engineering, Vol.1.* Illinois: Elsevier.

ConocoPhillips [Internal document]. (1993). *North Sea Design Premises.*

DNV-RP-C203. (2010, April). Fatigue design of offshore steel structures.

DNV-RP-C205. (2010, October). Environmental conditions and environmental loads.

Gelgele, H. L. (2008). *Dimensjonering av maskinelementer.* Stavanger: UiS.

Guo, B., Shanhong, S., Chacko, J., & Ghalambor, A. (2005). *Offshore Pipelines.* Amsterdam: GPP/Elsevier.

Hauber, F. R. (1973). *Patentnr. 3749429.* USA.

Hydratight. (2011). *Hydraulic Bolt Tensioners*. Retrieved April 5, 2001, from http://www.hydratight.com/en/products/tension

Karunakaran, D. (2010). MOK-160 Rørledninger og stigerør [Lecture notes], UiS.

NORSOK N-001. (2004, February). Structural design. *Rev.4*.

NORSOK N-003. (2007, September). Actions and action effects. *Edition 2*.

NORSOK N-004. (2004, October). Design of steel structures. *Rev.2*.

NS-EN-1993-1-8. (2005, November). Knutepunkter og forbindelse.

NTH. (1982). *Marin hydromekanikk.* Trondheim: Universitetet i Trondheim.

Scott, G. A. (1985). *Studbolting Experience in the Underwater Evironment of the North Sea.* Houston: OTC 5050.

Subsea 7 [Internal document]. (2006). *Clamp design report.* Stavanger.

Subsea 7 et al. (2007). *Bolts and nuts.*

Virginia Tech. (2004, September 23). *Introduction to Finite Element Analysis*. Retrieved April 2011, from Laboratory for Scientific Visual Analysis: http://www.sv.vt.edu/classes/MSE2094_NoteBook/97ClassProj/num/widas/history.html

Waløen, Å. Ø. (1976). *Maskindeler 2* (2. utg.). Trondheim: Tapir.

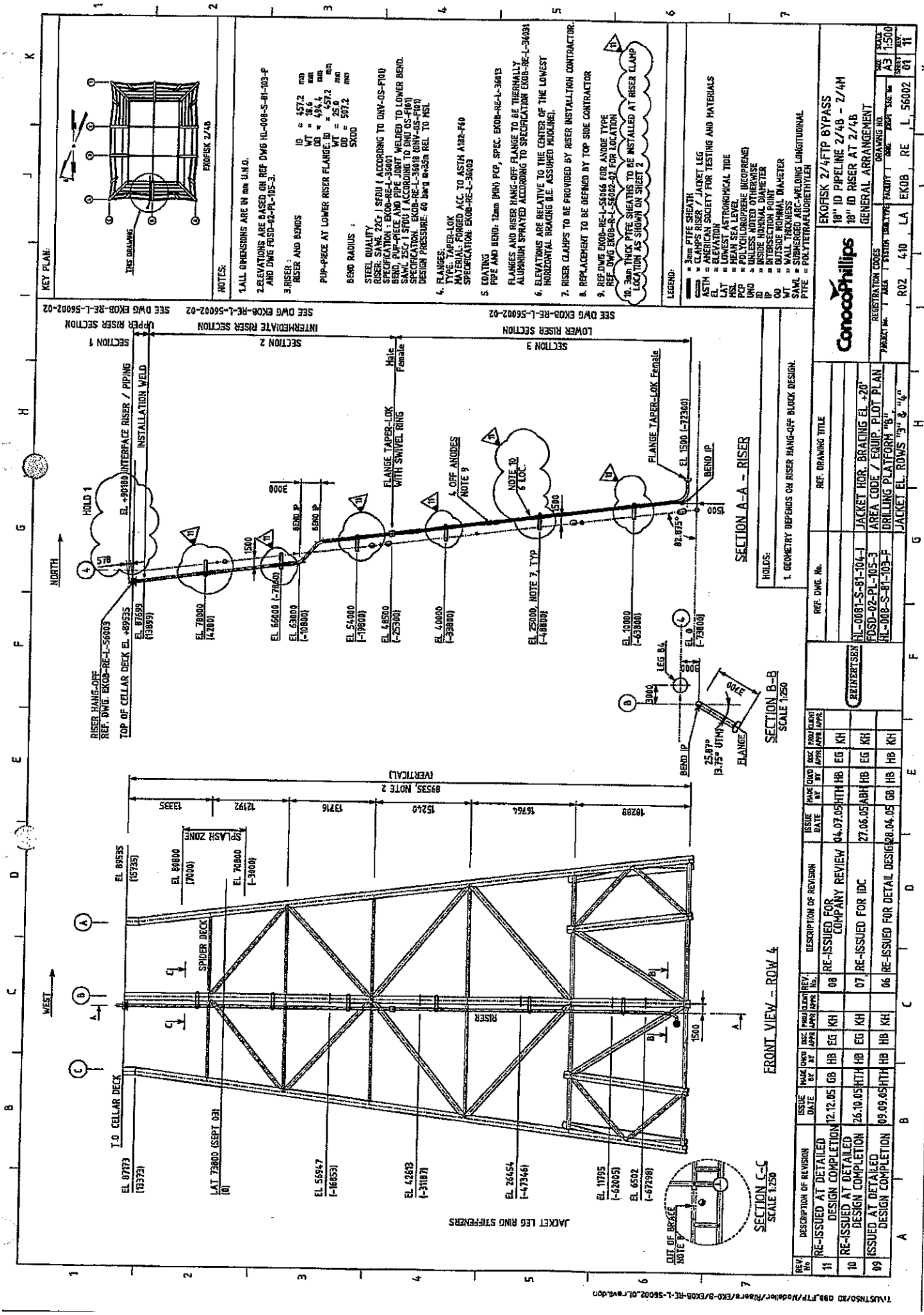
A

Appendix A

Drawings

(1 Pages)

A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FRONT VIEW – ROW 4
SECTION B–B
SCALE 1:250
SECTION C–C
SCALE 1:250
ConocoPhillips
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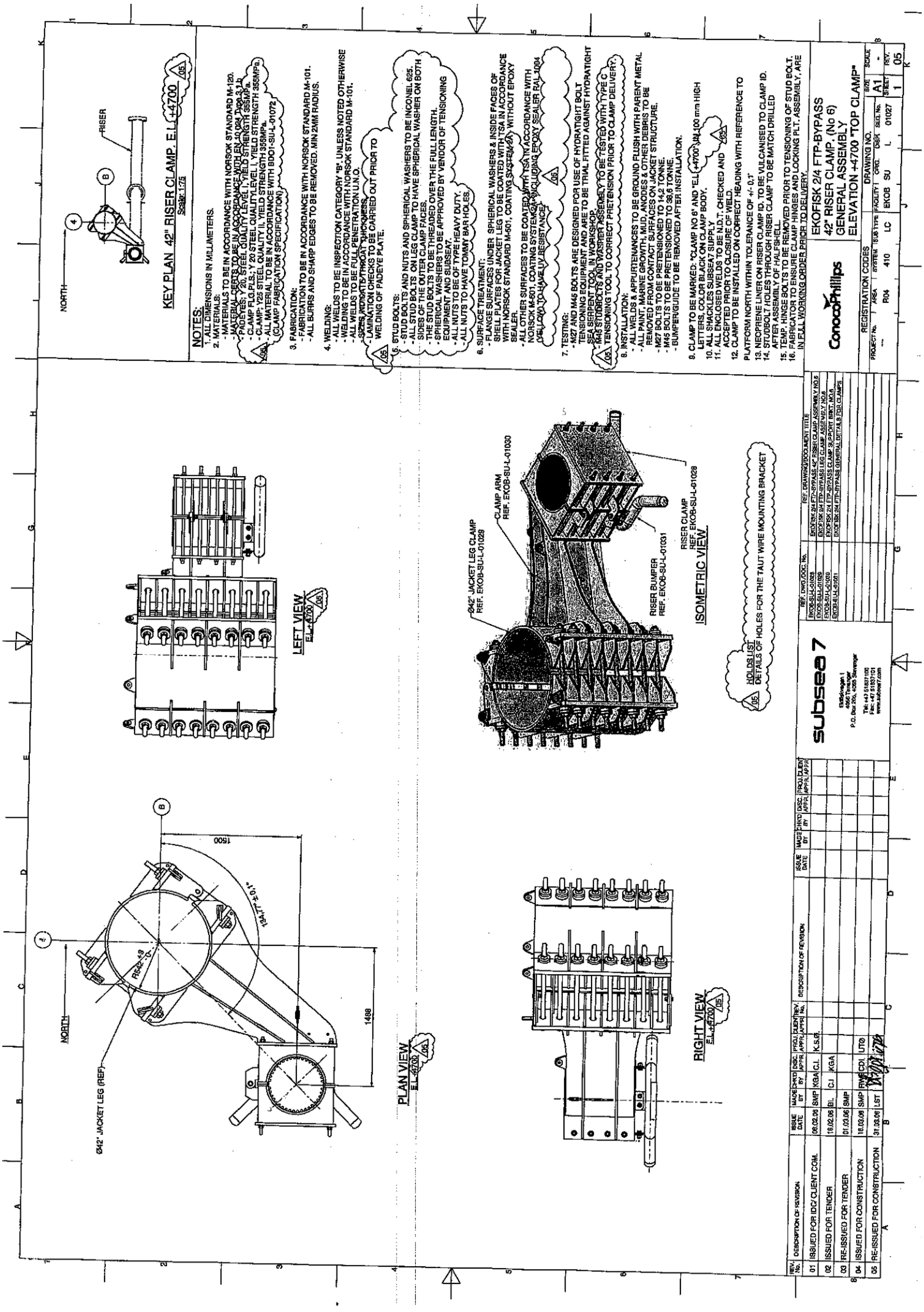
18" ID PIPELINE 2/4B - 2/4M
18" ID RISER AT 2/4B
GENERAL ARRANGEMENT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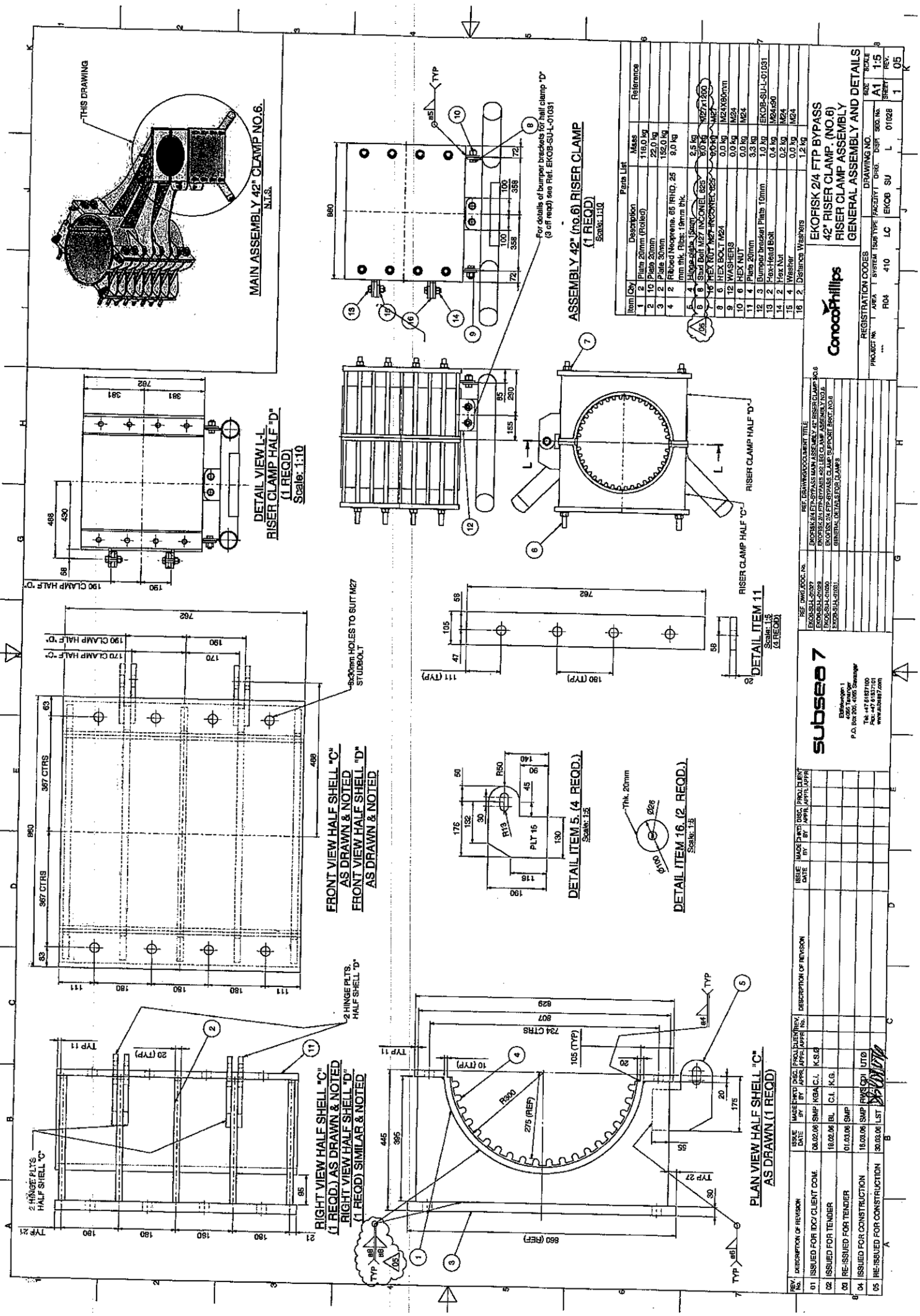
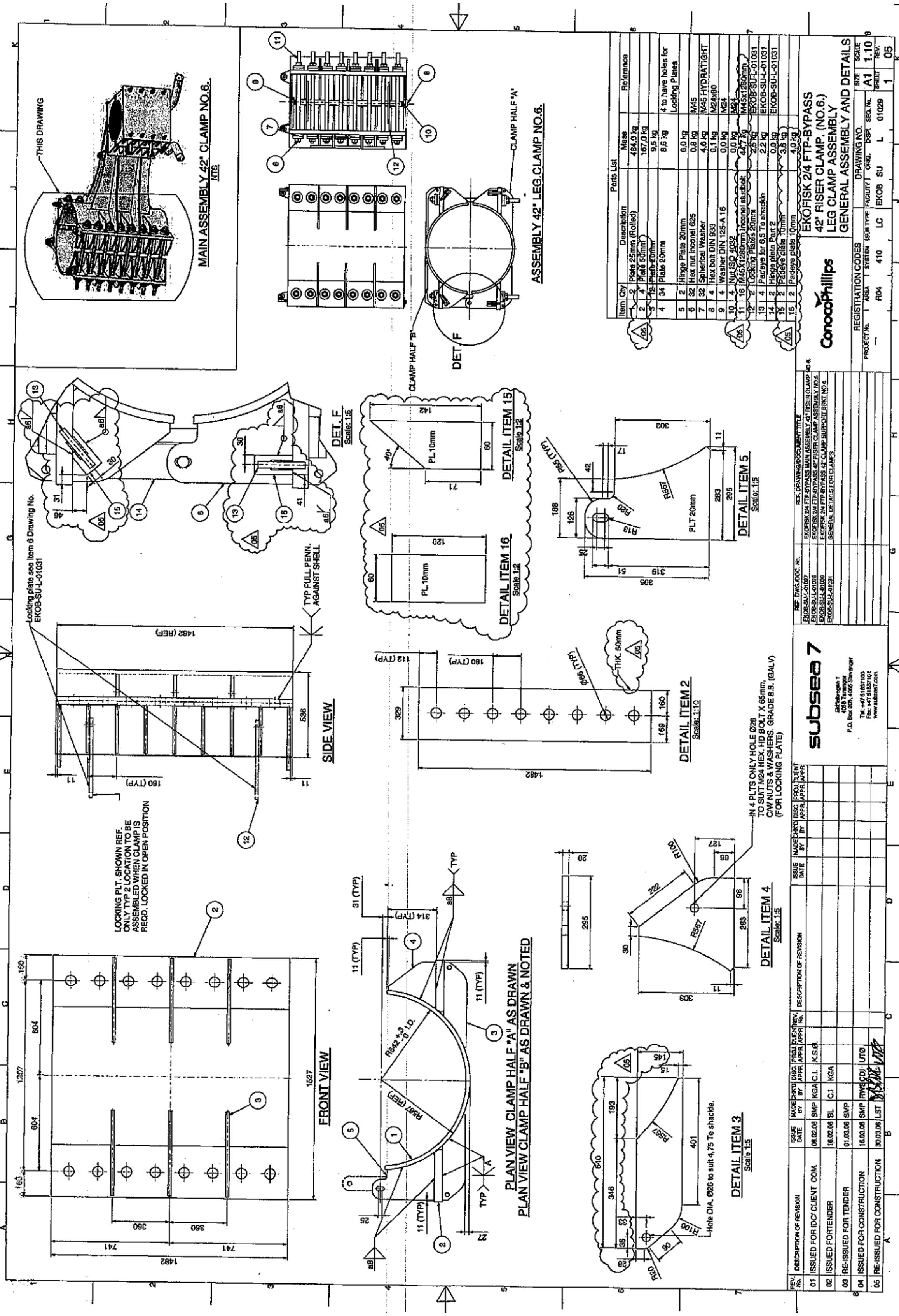
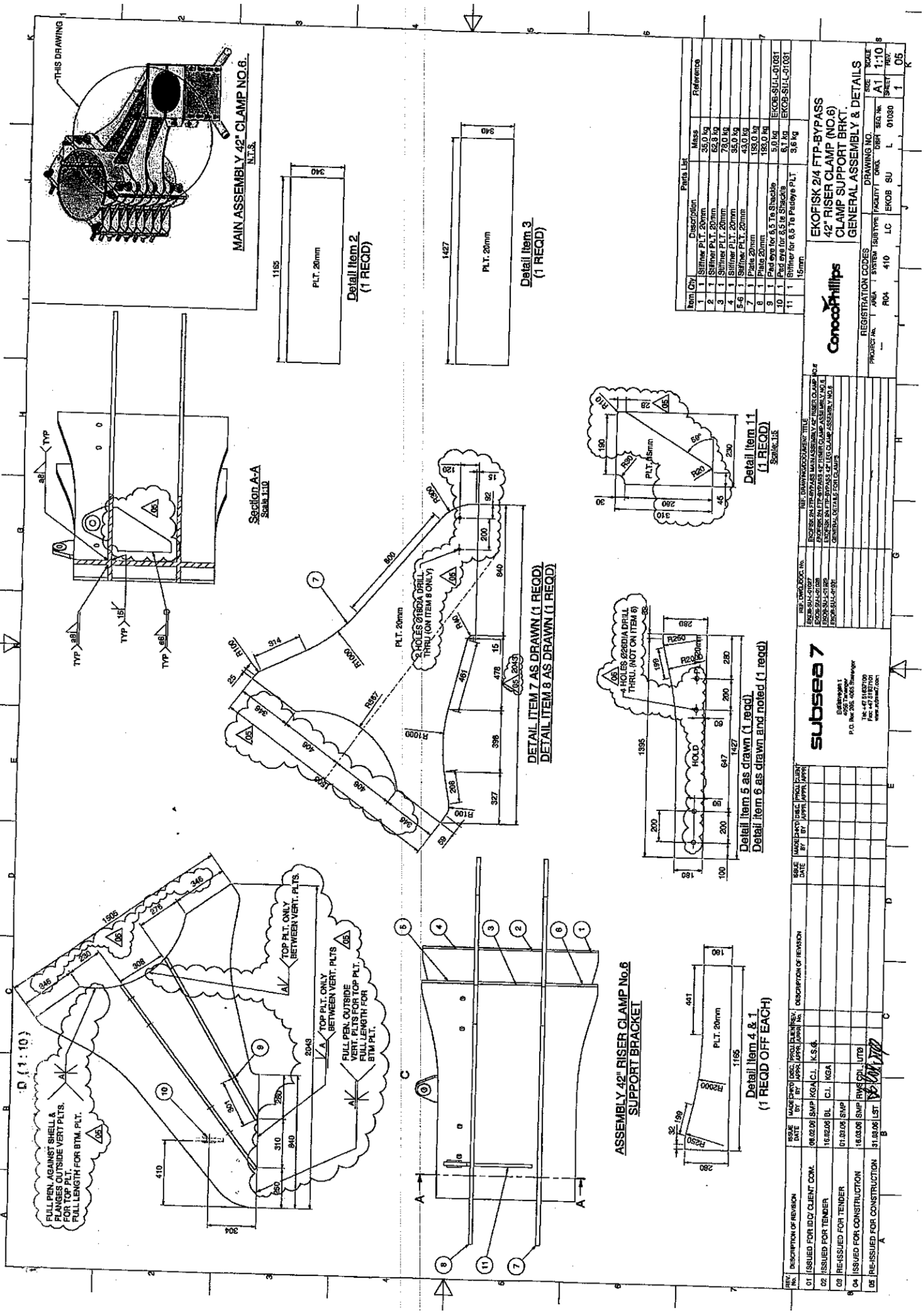
PLAN VIEW
LEFT VIEW
RIGHT VIEW
ISOMETRIC VIEW
EKOFISK 2/4 FTP-BYPASS
42" RISER CLAMP. (No 6)
GENERAL ASSEMBLY
ELEVATION +4700 "TOP CLAMP"
ConocoPhillips
subsea 7

A

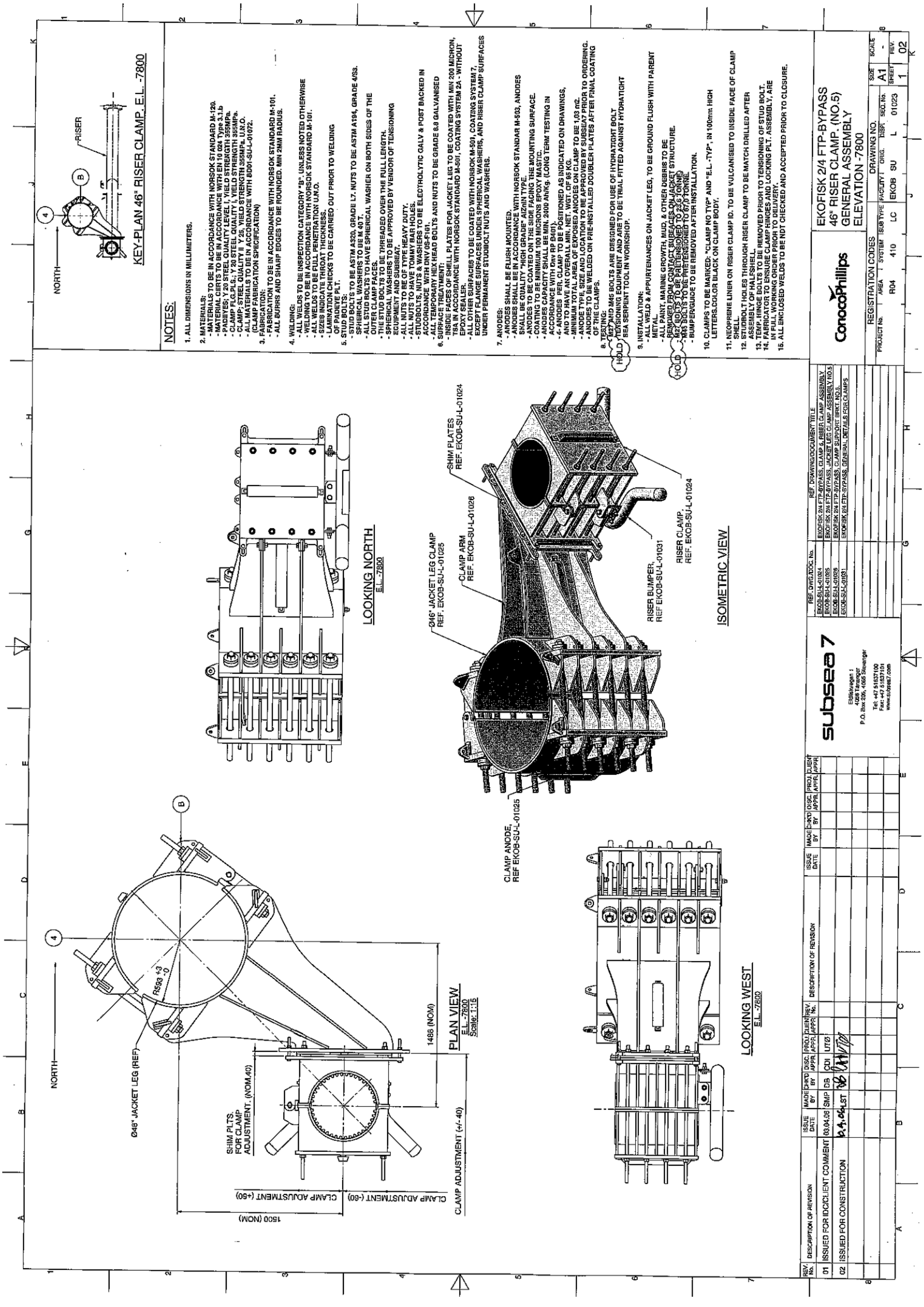

EKOFISK 2/4 FTP BYPASS
42" RISER CLAMP (NO.6)
RISER CLAMP ASSEMBLY
GENERAL ASSEMBLY AND DETAILS
MAIN ASSEMBLY 42" CLAMP NO.6.
ASSEMBLY 42" (no.6) RISER CLAMP
DETAIL VIEW L-L
RISER CLAMP HALF "D"
FRONT VIEW HALF SHELL "C" AS DRAWN & NOTED
FRONT VIEW HALF SHELL "D" AS DRAWN & NOTED
RIGHT VIEW HALF SHELL "C" (1 REQD.) AS DRAWN & NOTED
RIGHT VIEW HALF SHELL "D" (1 REQD) SIMILAR & NOTED
PLAN VIEW HALF SHELL "C" AS DRAWN (1 REQD)
DETAIL ITEM 5. (4 REQD.)
DETAIL ITEM 16. (2 REQD.)
DETAIL ITEM 11
Parts List
ConocoPhillips
subsea 7


MAIN ASSEMBLY 42" CLAMP NO.6.
ASSEMBLY 42" LEG CLAMP NO.6.
SIDE VIEW
FRONT VIEW
PLAN VIEW CLAMP HALF "A" AS DRAWN
PLAN VIEW CLAMP HALF "B" AS DRAWN & NOTED
DETAIL ITEM 2
DETAIL ITEM 3
DETAIL ITEM 4
DETAIL ITEM 5
DETAIL ITEM 15
DETAIL ITEM 16
DET. F
EKOFISK 2/4 FTP-BYPASS
42" RISER CLAMP, (NO.6.)
LEG CLAMP ASSEMBLY
GENERAL ASSEMBLY AND DETAILS
ConocoPhillips
subsea 7

A


MAIN ASSEMBLY 42" CLAMP NO.6
N.T.S.
THIS DRAWING
Detail Item 2
(1 REQD)
Detail Item 3
(1 REQD)
PLT. 20mm
Section A-A
Scale 1:10
DETAIL ITEM 7 AS DRAWN (1 REQD)
DETAIL ITEM 8 AS DRAWN (1 REQD)
Detail Item 11
(1 REQD)
Scale 1:5
Detail Item 5 as drawn (1 reqd)
Detail Item 6 as drawn and noted (1 reqd)
ASSEMBLY 42" RISER CLAMP No.6
SUPPORT BRACKET
Detail Item 4 & 1
(1 REQD OFF EACH)
FULL PEN. AGAINST SHELL & FLANGES OUTSIDE VERT PLTS. FOR TOP PLT. FULL LENGTH FOR BTM. PLT.
TOP PLT. ONLY BETWEEN VERT. PLTS.
FULL PEN. OUTSIDE VERT. PLTS FOR TOP PLT. FULL LENGTH FOR BTM PLT.
Parts List
ConocoPhillips
EKOFISK 2/4 FTP-BYPASS
42" RISER CLAMP (NO.6)
CLAMP SUPPORT BRKT.
GENERAL ASSEMBLY & DETAILS
subsea 7
01 ISSUED FOR IDC/ CLIENT COM.
02 ISSUED FOR TENDER
03 RE-ISSUED FOR TENDER
04 ISSUED FOR CONSTRUCTION
05 RE-ISSUED FOR CONSTRUCTION

A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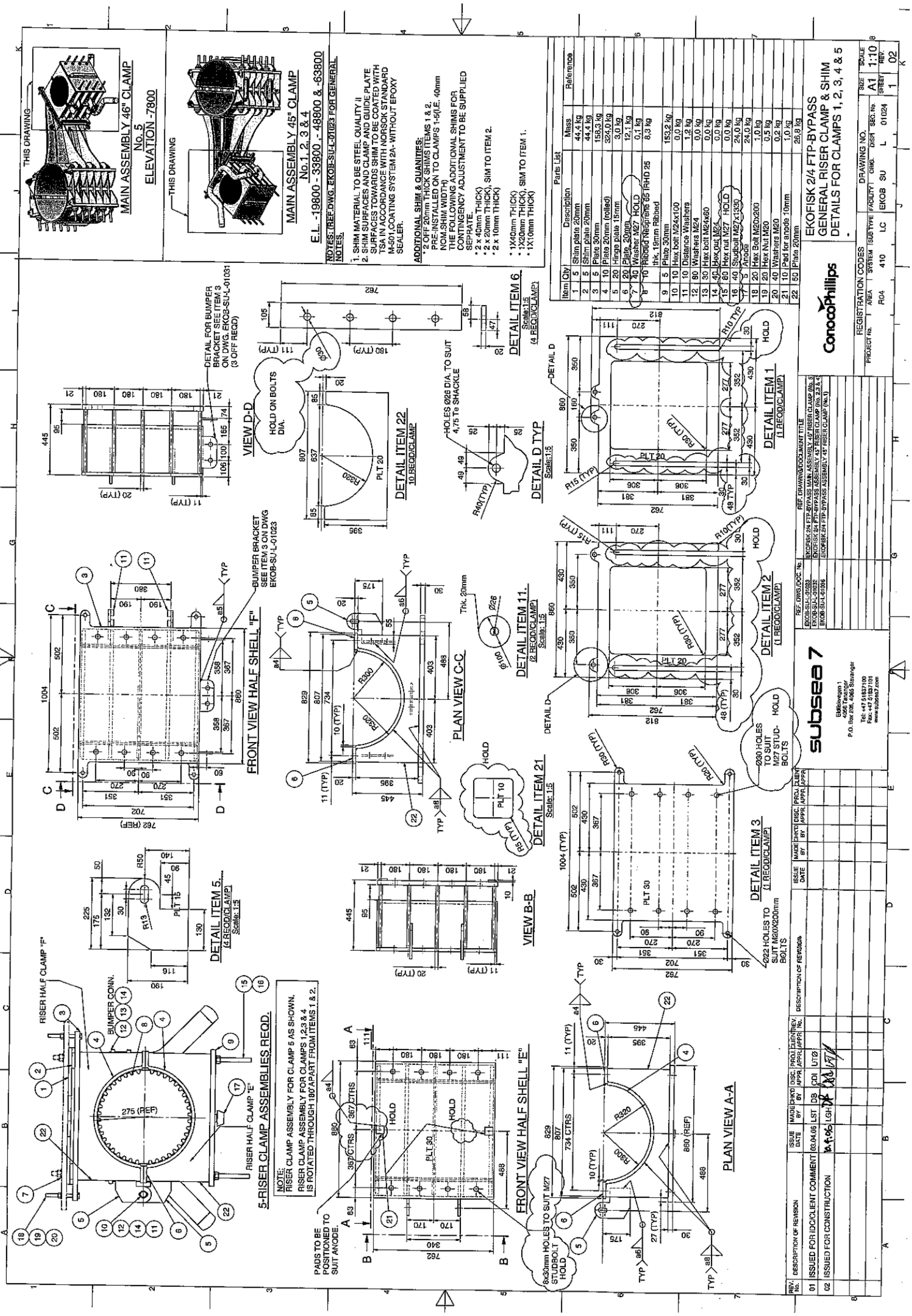
ISOMETRIC VIEW
PLAN VIEW
LOOKING WEST
EKOFISK 2/4 FTP-BYPASS
46" RISER CLAMP. (NO.5)
GENERAL ASSEMBLY
ELEVATION -7800
ConocoPhillips
subsea 7


EKOFISK 2/4 FTP-BYPASS
GENERAL RISER CLAMP & SHIM
DETAILS FOR CLAMPS 1, 2, 3, 4 & 5
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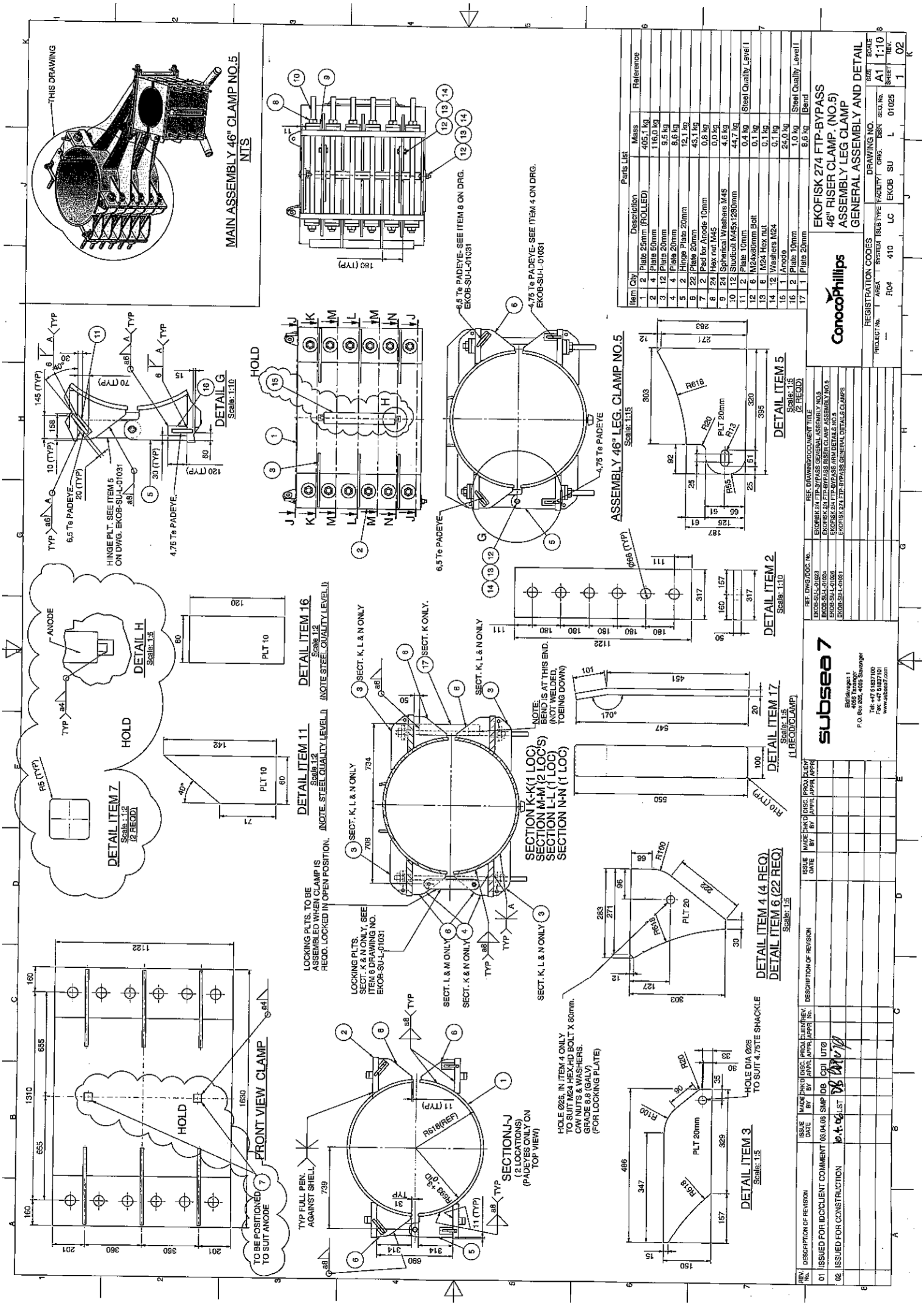
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NTS
ASSEMBLY 46" LEG CLAMP NO.5
FRONT VIEW CLAMP
EKOFISK 274 FTP-BYPASS
46" RISER CLAMP (NO.5)
ASSEMBLY LEG CLAMP
GENERAL ASSEMBLY AND DETAIL
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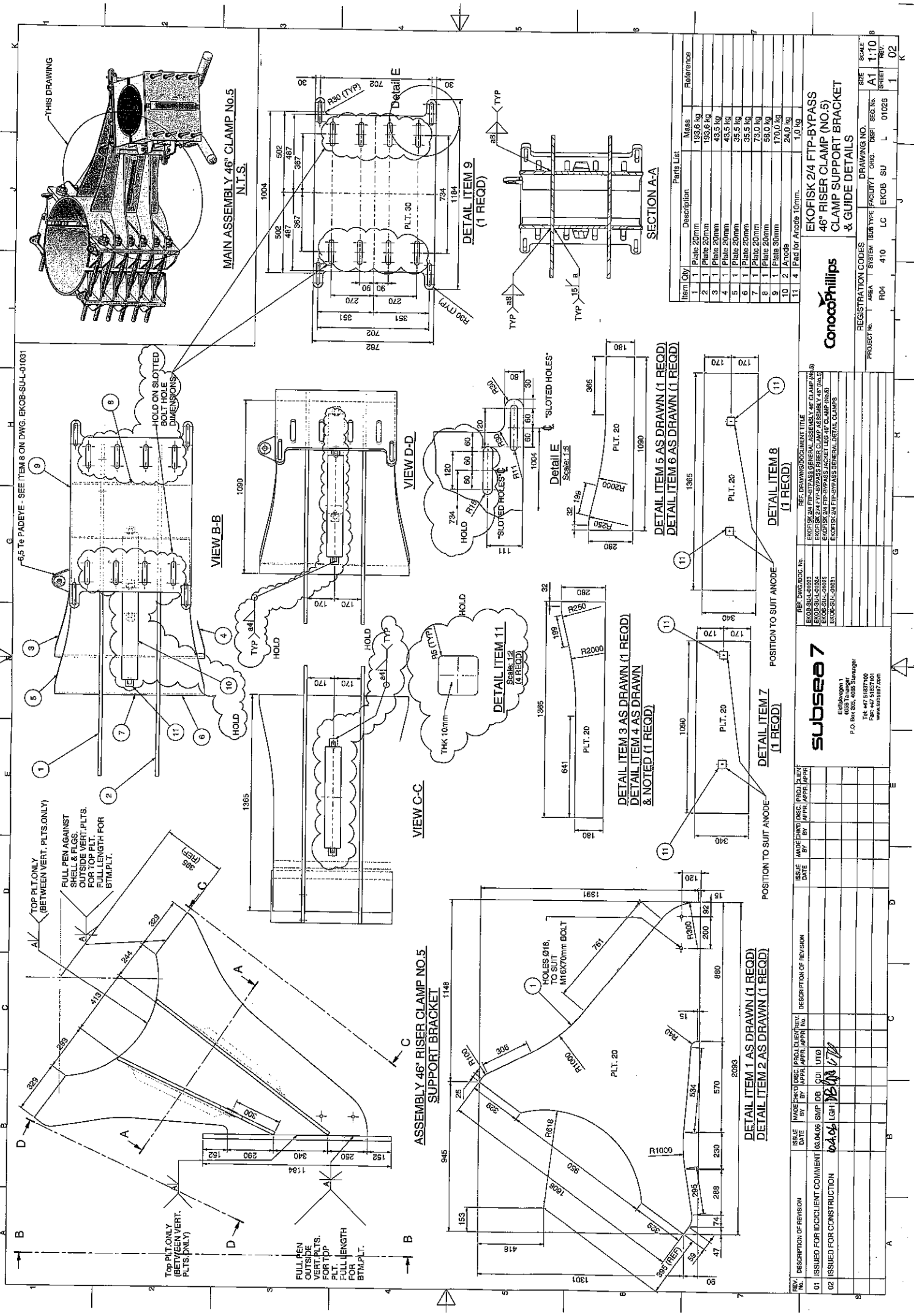
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N.T.S.
DETAIL ITEM 9
(1 REQD)
SECTION A-A
VIEW B-B
VIEW D-D
VIEW C-C
DETAIL ITEM 11
DETAIL ITEM 5 AS DRAWN (1 REQD)
DETAIL ITEM 6 AS DRAWN (1 REQD)
DETAIL ITEM 3 AS DRAWN (1 REQD)
DETAIL ITEM 4 AS DRAWN & NOTED (1 REQD)
DETAIL ITEM 8
(1 REQD)
DETAIL ITEM 7
(1 REQD)
ASSEMBLY 46" RISER CLAMP NO.5 SUPPORT BRACKET
DETAIL ITEM 1 AS DRAWN (1 REQD)
DETAIL ITEM 2 AS DRAWN (1 REQD)
POSITION TO SUIT ANODE
EKOFISK 2/4 FTP-BYPASS
46" RISER CLAMP (NO.5)
CLAMP SUPPORT BRACKET
& GUIDE DETAILS
ConocoPhillips
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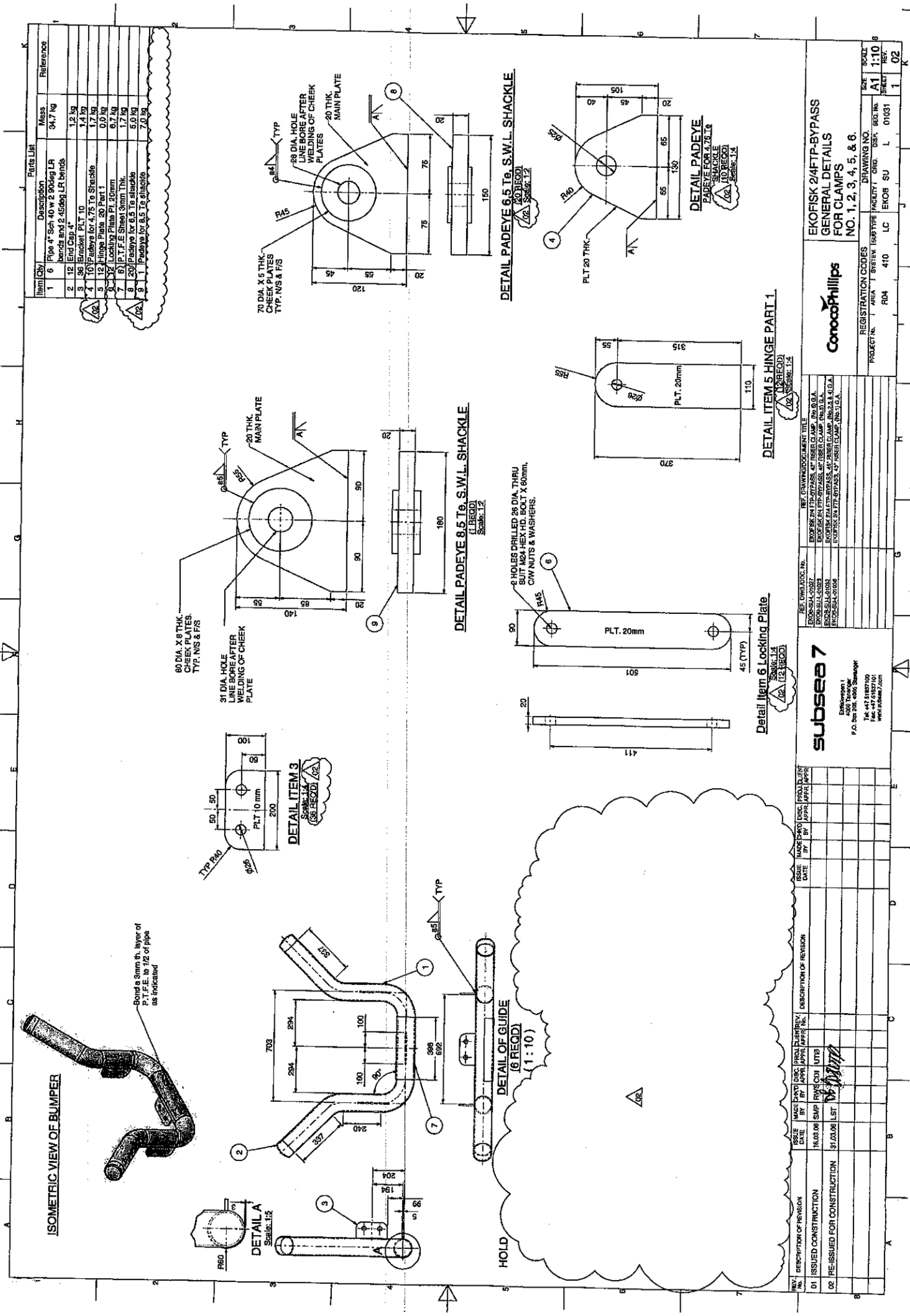
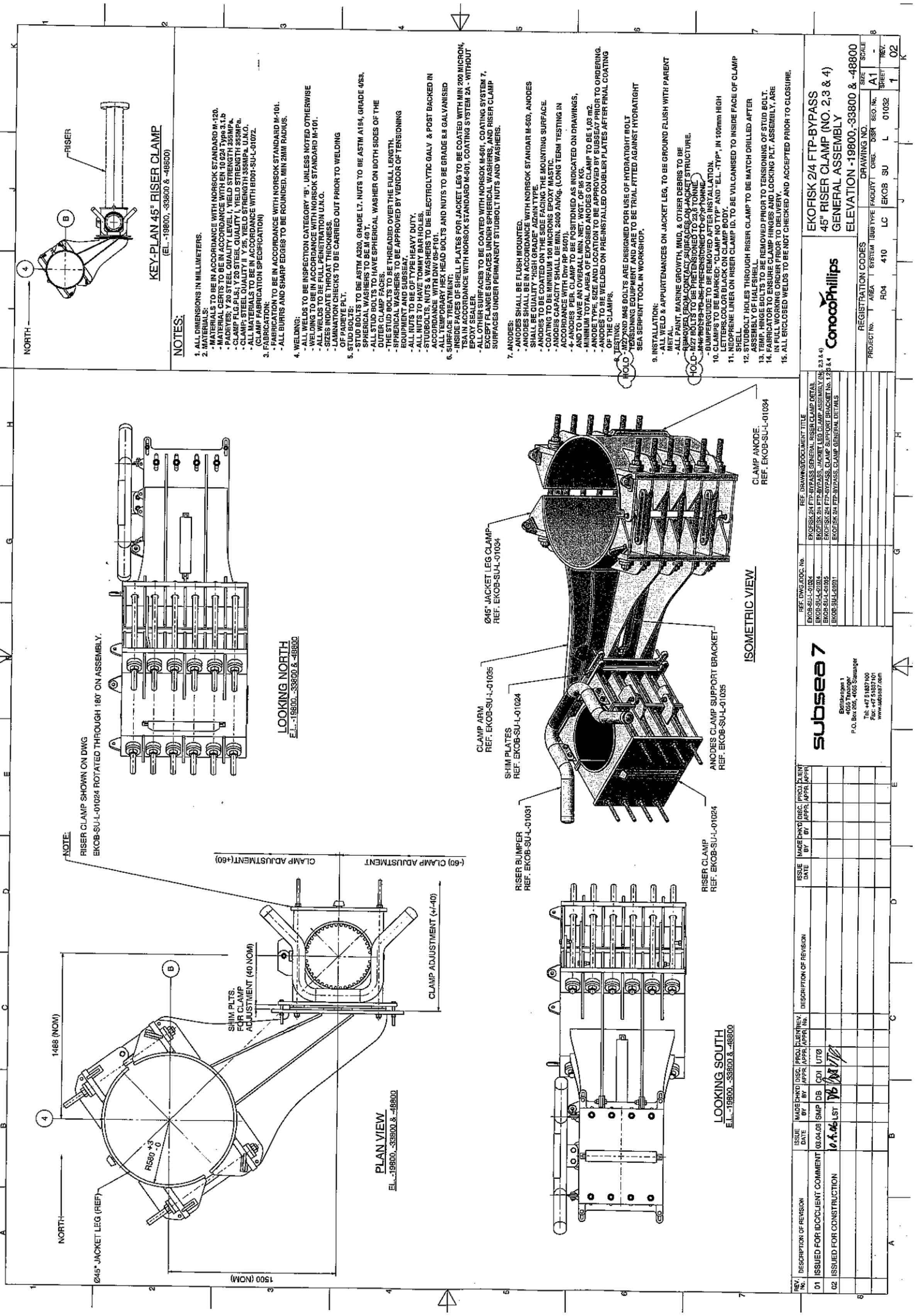

ISOMETRIC VIEW OF BUMPER
Bond a 3mm th. layer of P.T.F.E. to 1/2 of pipe as indicated
DETAIL A
Scale: 1:5
DETAIL OF GUIDE
(6 REQD)
(1 : 10)
DETAIL ITEM 3
Scale: 1:4
(36 REQD)
PLT 10 mm
TYP R40
DETAIL PADEYE 8,5 Te, S.W.L. SHACKLE
(1 REQD)
Scale: 1:2
60 DIA. X 8 THK. CHEEK PLATES TYP. N/S & F/S
31 DIA. HOLE LINE BORE AFTER WELDING OF CHEEK PLATE
20 THK. MAIN PLATE
DETAIL PADEYE 6,5 Te, S.W.L. SHACKLE
(20 REQD)
Scale: 1:2
70 DIA. X 5 THK. CHEEK PLATES TYP. N/S & F/S
28 DIA. HOLE LINE BORE AFTER WELDING OF CHEEK PLATES
20 THK. MAIN PLATE
DETAIL PADEYE FOR 4.75 Te SHACKLE
(10 REQD)
Scale: 1:4
PLT 20 THK.
Detail Item 6 Locking Plate
Scale: 1:4
(12 REQD)
2 HOLES DRILLED 26 DIA. THRU SUIT M24 HEX HD. BOLT X 60mm. C/W NUTS & WASHERS.
PLT. 20mm
DETAIL ITEM 5 HINGE PART 1
(12 REQD)
Scale: 1:4
HOLD
Parts List
Item
Qty
Description
Mass
Reference
Pipe 4" Sch 40 w 2 90deg LR bends and 2 45deg LR bends
End Cap 4"
Bracket PLT 10
Padeye for 4.75 Te Shackle
Hinge Plate 20 Part 1
Locking Plate PL 20mm
P.T.F.E Sheet 3mm Thk.
Padeye for 6.5 Te shackle
Padeye for 8.5 Te shackle
ConocoPhillips
EKOFISK 2/4FTP-BYPASS
GENERAL DETAILS
FOR CLAMPS
NO. 1, 2, 3, 4, 5, & 6.
ISSUED CONSTRUCTION
RE-ISSUED FOR CONSTRUCTION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(EL. -19800, -33800 & -48800)
NOTES:
PLAN VIEW
EL. -19800, -33800 & -48800
LOOKING NORTH
EL. -19800, -33800 & -48800
LOOKING SOUTH
EL. -19800, -33800 & -48800
ISOMETRIC VIEW
CLAMP ANODE.
REF. EKOB-SU-L-01034
EKOFISK 2/4 FTP-BYPASS
45° RISER CLAMP (NO. 2,3 & 4)
GENERAL ASSEMBLY
ELEVATION -19800,-33800 & -48800
ISSUED FOR IDC/CLIENT COMMENT
ISSUED FOR CONSTRUCTION

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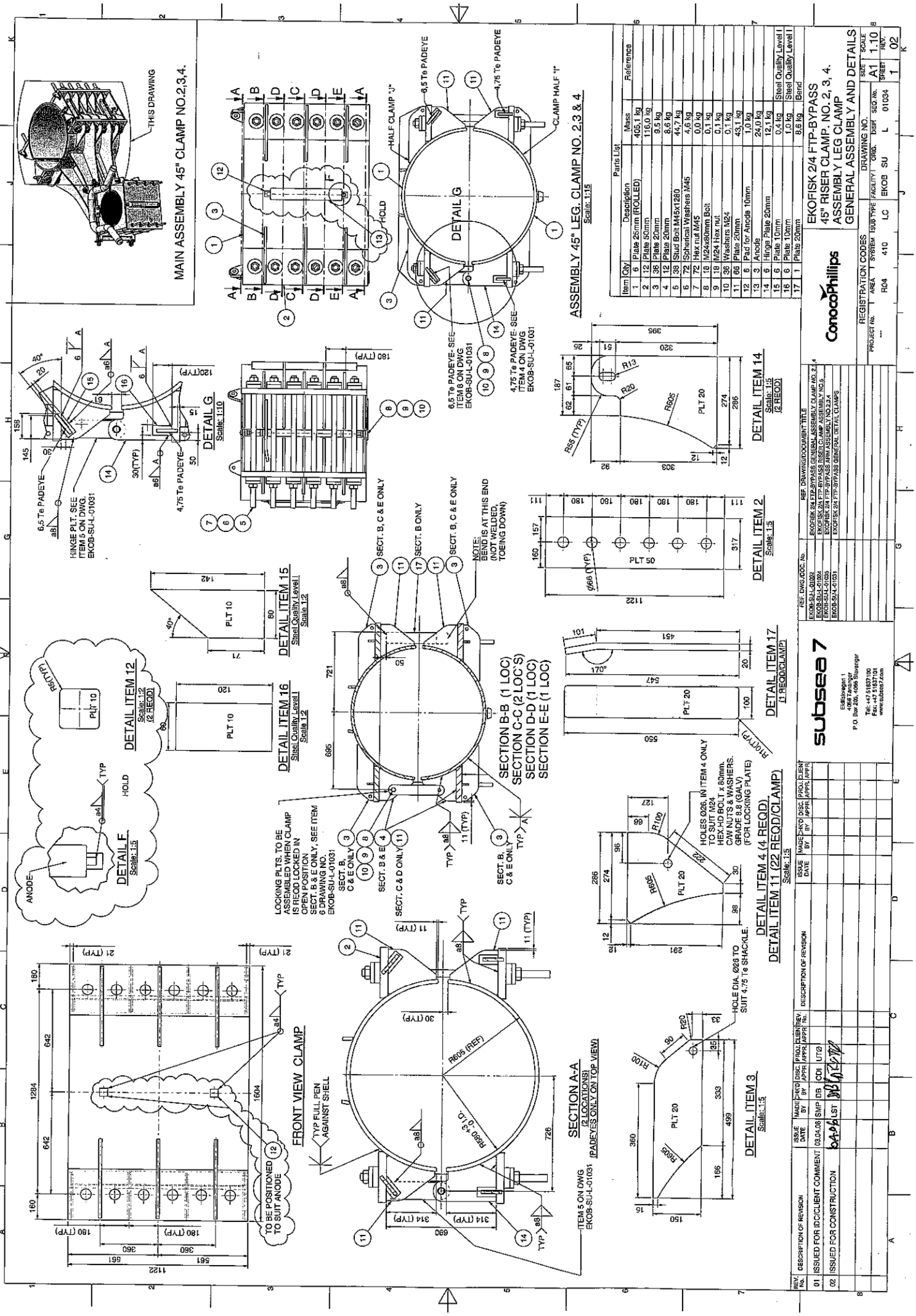
MAIN ASSEMBLY 45" CLAMP NO.2,3,4.
ASSEMBLY 45" LEG. CLAMP NO. 2,3 & 4
FRONT VIEW CLAMP
SECTION A-A
DETAIL G
DETAIL F
DETAIL ITEM 2
DETAIL ITEM 3
DETAIL ITEM 12
DETAIL ITEM 14
DETAIL ITEM 15
DETAIL ITEM 16
DETAIL ITEM 17
DETAIL ITEM 4 (4 REQD)
DETAIL ITEM 11 (22 REQD/CLAMP)
SECTION B-B (1 LOC)
SECTION C-C (2 LOC'S)
SECTION D-D (1 LOC)
SECTION E-E (1 LOC)
EKOFISK 2/4 FTP-BYPASS
45" RISER CLAMP. NO. 2, 3, 4.
ASSEMBLY LEG CLAMP
GENERAL ASSEMBLY AND DETAILS
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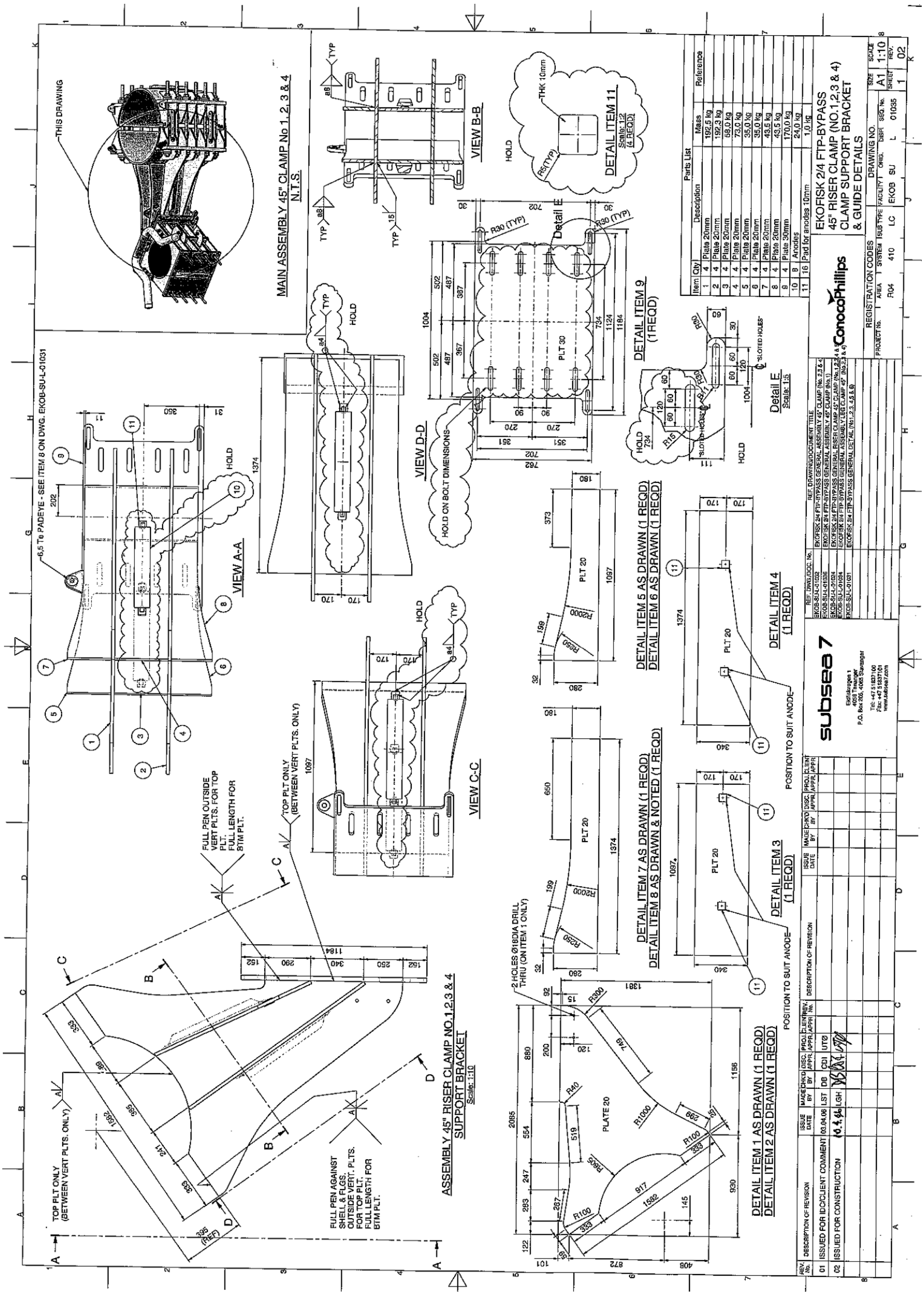
01 ISSUED FOR IDC/CLIENT COMMENT
02 ISSUED FOR CONSTRUCTION


EKOFISK 2/4 FTP-BYPASS
45" RISER CLAMP (NO.1,2,3 & 4)
CLAMP SUPPORT BRACKET
& GUIDE DETAILS
MAIN ASSEMBLY 45" CLAMP No 1, 2, 3 & 4
ASSEMBLY 45" RISER CLAMP NO.1,2,3 & 4 SUPPORT BRACKET
VIEW A-A
VIEW B-B
VIEW C-C
VIEW D-D
DETAIL ITEM 1 AS DRAWN (1 REQD)
DETAIL ITEM 2 AS DRAWN (1 REQD)
DETAIL ITEM 3 (1 REQD)
DETAIL ITEM 4 (1 REQD)
DETAIL ITEM 9 (1REQD)
DETAIL ITEM 11
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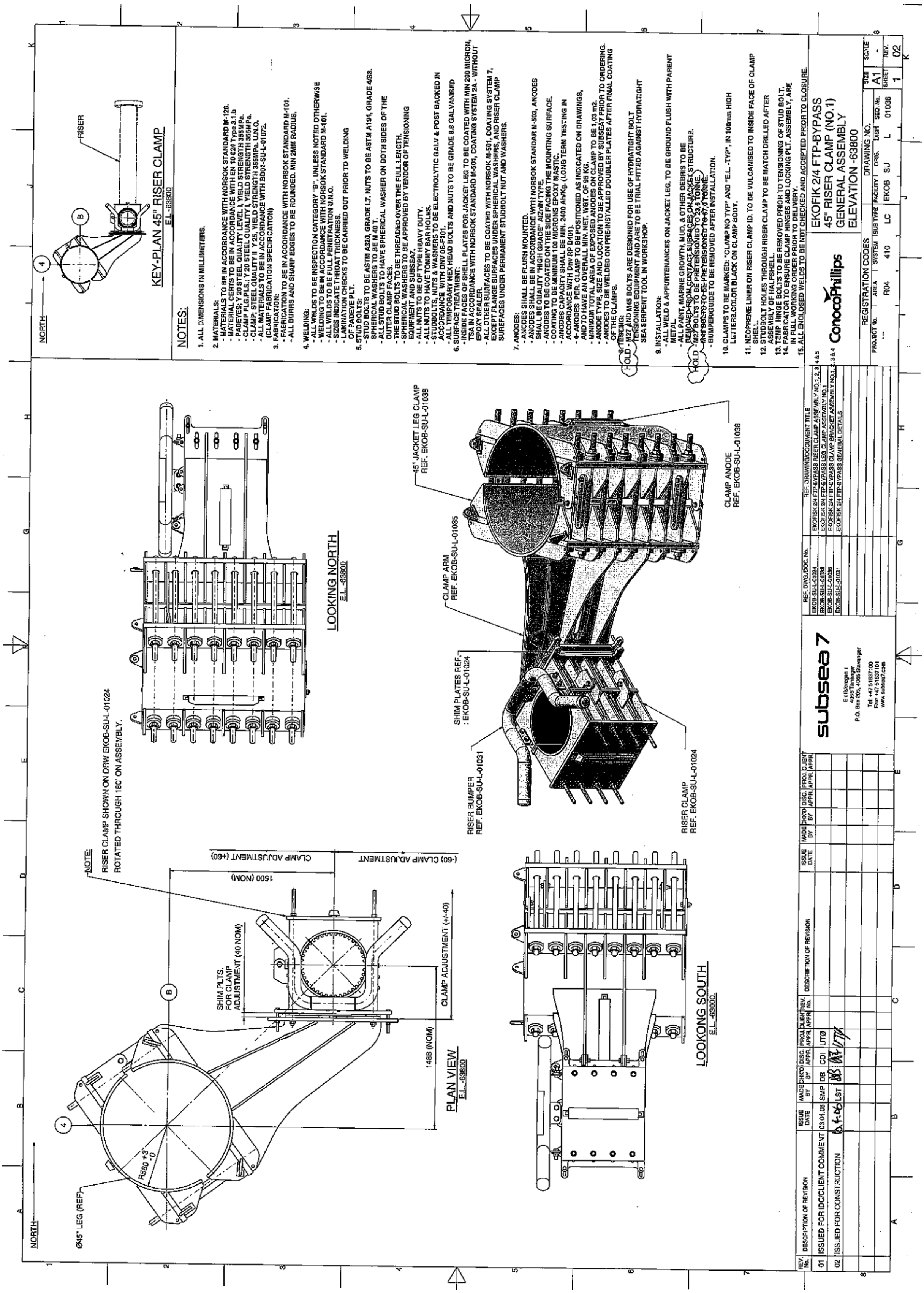
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45" RISER CLAMP (NO.1)
GENERAL ASSEMBLY
ELEVATION -63800
KEY-PLAN 45° RISER CLAMP
NOTES:
LOOKING NORTH
PLAN VIEW
LOOKONG SOUTH
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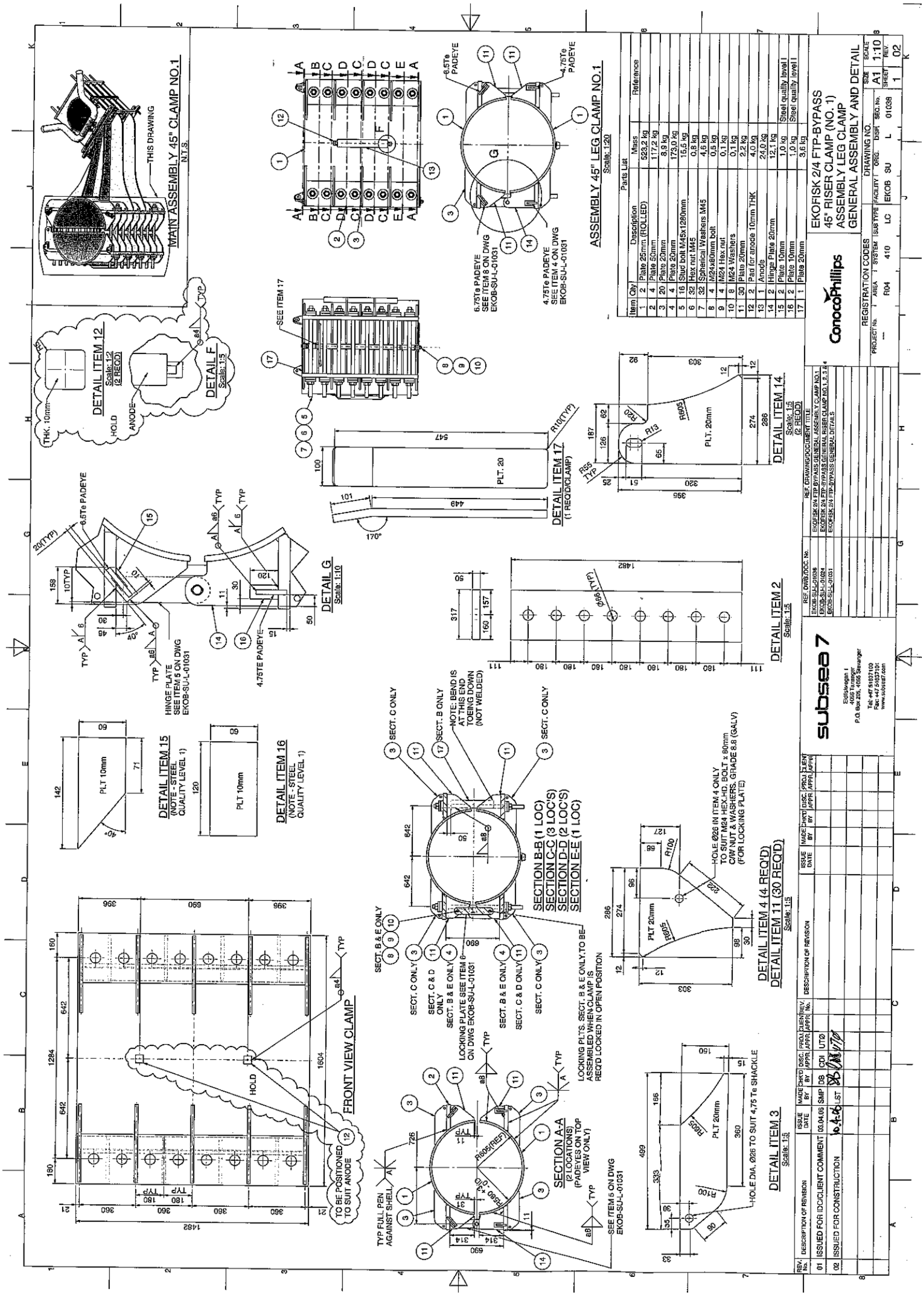
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N.T.S.
THIS DRAWING
ASSEMBLY 45° LEG CLAMP NO.1
Scale: 1:20
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DETAIL F
DETAIL G
Scale: 1:10
DETAIL ITEM 17
DETAIL ITEM 14
DETAIL ITEM 2
DETAIL ITEM 15
DETAIL ITEM 16
FRONT VIEW CLAMP
SECTION A-A
SECTION B-B (1 LOC)
SECTION C-C (3 LOC'S)
SECTION D-D (2 LOC'S)
SECTION E-E (1 LOC)
DETAIL ITEM 4 (4 REQ'D)
DETAIL ITEM 11 (30 REQ'D)
DETAIL ITEM 3
Parts List
ConocoPhillips
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EKOFISK 2/4 FTP-BYPASS
45° RISER CLAMP (NO. 1)
ASSEMBLY LEG CLAMP
GENERAL ASSEMBLY AND DETAIL
ISSUED FOR IDC/CLIENT COMMENT
ISSUED FOR CONSTRUCTION

B

Appendix B

"Bolts and Nuts"

(1 Pages)

B

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Introduction

Bolts
&
Nuts

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subsea 7

Content

- Joint Industry Project (JIP) – Bolts and Fasteners
- Material Selection
- Corrosion Protection
- Specification and Fabrication of fasteners
- Conclution

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Joint Industry Project (JIP) – Bolts and Fasteners

- Subsea 7 has been part of a Joint Industry project (JIP). The purpose was to create a guideline for the Specification, Design and Installation of Fasteners for the Offshore Oil and Gas Industry.
- The guideline is not a contractual document, and is intended for guidance only. Existing standards (e.g ISO, ASTM, NORSOK) should also be used for material selection of fasteners.
- The guideline covers the following topics:
  - Fastener Selection, Specification and Fabrication
  - Design of Bolted Connections
  - Controlled Assembly of Bolted Connections
- Fastener: A metallic screw, nut, bolt or stud having external or internal threads, with a nominal diameter of 6 mm or larger (1/4 inch or larger)

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Material Selection

Carbon Steel and Low alloy Materials

- Fasteners are generally made of carbon and low alloy steel. The majority of bolts used in the oil and gas industry are specified according to ASTM A 193 grade B7 or ASTM A320 grade L7.
- B7 bolts = ASTM A 194 Grade 2H (C-Mn steel) or Grade 7 (low alloy steel) nuts.
- L7 bolts = ASTM A 194 Grade 4 or Grade 7 nuts.
- ISO 10423 nut grade 2H and 2HM are also accepted With L7 bolts.

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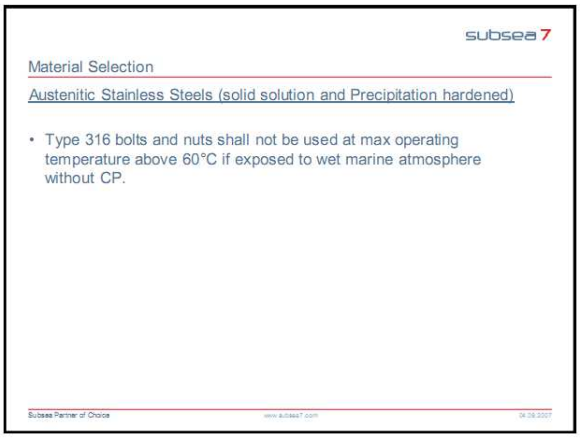
Material Selection

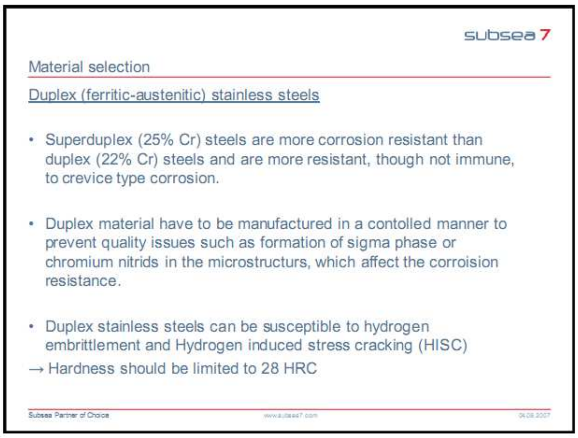
Corrosion Resistant Alloys (CRA)

- Elements to consider in material selection of CRA for fasteners

Requirements for a CRA fastener material	- Strength - Environmental exposure (e.g. topside, subsea, sour service) - Corrosion resistance requirements (e.g hydrogen embrittlement and HISC) - Toughness requirements (e.g. low temperature conditions)

- Pitting Resistance Equivalent Number (PREN):
- PREN = %Cr + 3.3%Mo + 16%N
- PREN ≥ 40 the metal is considered to be immune to pitting and crevice corrosion in seawater at ambient temperature.


subsea 7
Material Selection
Austenitic Stainless Steels (solid solution and Precipitation hardened)
• Type 316 bolts and nuts shall not be used at max operating temperature above 60°C if exposed to wet marine atmosphere without CP.


subsea 7
Material selection
Duplex (ferritic-austenitic) stainless steels
• Superduplex (25% Cr) steels are more corrosion resistant than duplex (22% Cr) steels and are more resistant, though not immune, to crevice type corrosion.
• Duplex material have to be manufactured in a contolled manner to prevent quality issues such as formation of sigma phase or chromium nitrids in the microstructurs, which affect the corroision resistance.
• Duplex stainless steels can be susceptible to hydrogen embrittlement and Hydrogen induced stress cracking (HISC)
→ Hardness should be limited to 28 HRC

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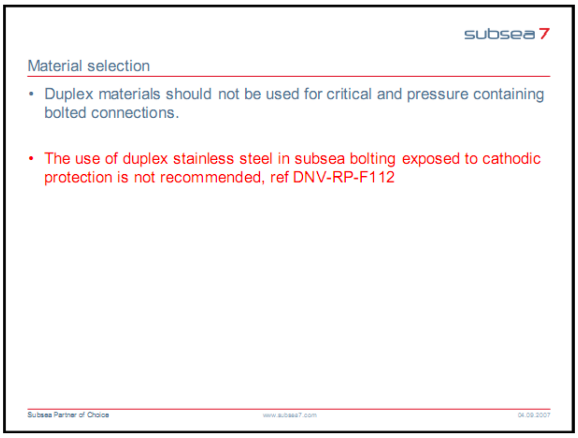
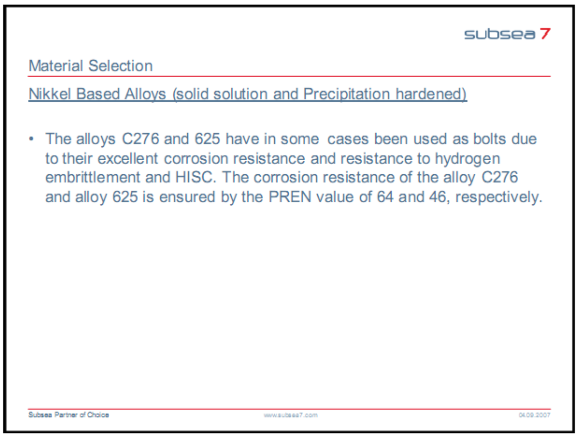
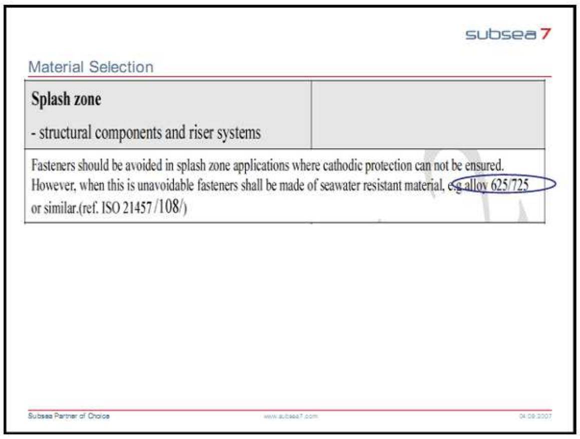
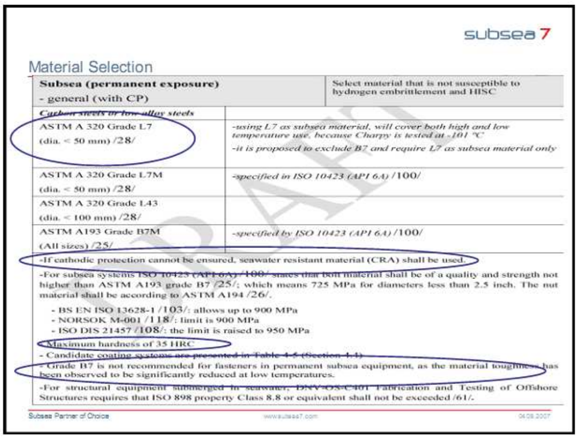

subsea 7
Material selection
• Duplex materials should not be used for critical and pressure containing bolted connections.
• The use of duplex stainless steel in subsea bolting exposed to cathodic protection is not recommended, ref DNV-RP-F112


subsea 7
Material Selection
Nikkel Based Alloys (solid solution and Precipitation hardened)
• The alloys C276 and 625 have in some cases been used as bolts due to their excellent corrosion resistance and resistance to hydrogen embrittlement and HISC. The corrosion resistance of the alloy C276 and alloy 625 is ensured by the PREN value of 64 and 46, respectively.


subsea 7
Material Selection
Splash zone
- structural components and riser systems
Fasteners should be avoided in splash zone applications where cathodic protection can not be ensured.
However, when this is unavoidable fasteners shall be made of seawater resistant material, e.g alloy 625/725 or similar.(ref. ISO 21457 /108/)


subsea 7
Material Selection
Subsea (permanent exposure)
- general (with CP)
Select material that is not susceptible to hydrogen embrittlement and HISC
Carbon steels or low alloy steels
ASTM A 320 Grade L7
(dia. < 50 mm) /28/
-using L7 as subsea material, will cover both high and low temperature use, because Charpy is tested at -101 °C
-it is proposed to exclude B7 and require L7 as subsea material only
ASTM A 320 Grade L7M
(dia. < 50 mm) /28/
-specified in ISO 10423 (API 6A) /100/
ASTM A 320 Grade L43
(dia. < 100 mm) /28/
ASTM A193 Grade B7M
(All sizes) /25/
-specified by ISO 10423 (API 6A) /100/
-If cathodic protection cannot be ensured, seawater resistant material (CRA) shall be used.
-For subsea systems ISO 10423 (API 6A) /100/ states that bolt material shall be of a quality and strength not higher than ASTM A193 grade B7 /25/; which means 725 MPa for diameters less than 2.5 inch. The nut material shall be according to ASTM A194 /26/.
- BS EN ISO 13628-1 /103/: allows up to 900 MPa
- NORSOK M-001 /118/: limit is 900 MPa
- ISO DIS 21457 /108/: the limit is raised to 950 MPa
- Maximum hardness of 35 HRC
- Candidate coating systems are presented in Table 4-5 (Section 4.4)
- Grade B7 is not recommended for fasteners in permanent subsea equipment, as the material toughness has been observed to be significantly reduced at low temperatures.
-For structural equipment submerged in seawater, DNV-OS-C401 Fabrication and Testing of Offshore Structures requires that ISO 898 property Class 8.8 or equivalent shall not be exceeded /61/.
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Material Selection

CRA	
ASTM A 193 Grade B8M /25/	*(All sizes)*
Alloy 718	*- Hardness max 35 HRC*
Alloy 625	*-solution treated condition. This means SMYS app. 300 MPa. Some cold work is required and acceptable for fasteners in this material.*
UNS S66286 ASTM A 453 Grade 660 /34/	*-precipitation hardened austenitic stainless steel* *- Hardness max. 35 HRC*
25Cr duplex	*-It is generally not recommended to use DSS as subsea fastener material exposed to CP due to susceptibility to HISC, ref. DNV RP-F112 /73/*
Guidance note: Martensitic, ferritic, duplex and precipitation hardened stainless steels are susceptible to HISC and should not be used for bolting in submerged service when they will be protected by cathodic protection. **End guidance note**	

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Material Selection

Subsea - H_2S environments (exposed)	Bolting will be deprived from atm. exposure by e.g.: - burial (anaerobic mud) - thermal insulation or flange protectors
Carbon steels or low alloy steels	
ASTM A 320 Grade L7M /28/	*-tempered and 100% hardness tested*
ASTM A 193 Grade B7M /25/	*-tempered and 100% hardness tested* *-hardness max 22 HRC* *-2M nuts*
-it must be remembered that use of lower strength bolting materials such as B7M may require pressure derating -material selection according to API and ISO 15156 /106/ for exposed bolting -ref. ISO 15156 for details regarding material and environmental limits -ISO 15156 defines bolting which is denied atmospheric exposure (e.g. under thermal insulation/in anaerobic mud) as exposed -candidate coating systems are presented in Table 4-5 (Section 4.4)	
CRA	
ASTM A453 Grade 660 /34/ UNS S66286	*-use Grade 660 nuts to be in accordance with ISO 15156 /106/*
Subsea - CP not ensured	A CRA with the required corrosion resistance shall be selected. Evaluate corrosion resistance in seawater without cathodic protection
CRA	
Alloy 625 (UNS N06625)	*- ambient temperature* **Guidance note** For subsea service without CP the general recommendation is to use the alloy 625 (UNS N06625) **End Guidance Note**

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Corrosion Protection

- Low alloy Steels require the following corrosion protection:
  - Coating for atmospheric service
  - Cathodic protection for subsea applications
- Corrosion resistant alloys (CRA) will require corrosion protection when used in subsea applications, mainly in the form of Cathodic protection

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Corrosion Protection

Cathodic Protection (i.e anodes)

- All subsea installations shall have Cathodic protection. This is a general requirement found in ISO/API documents for subsea.
- For fastener material such as low alloy steels, corrosion protection is required. To avoid HISC the low alloy material for fasteners used in conjunction with Cathodic protection shall comply with the following requirements:
  - The strength class shall not exceed the Property Class 8.8 according to ISO-898-1 for bolt
  - Property Class 8 for nuts according to ISO 898-2
  - Max bolt hardness shall be: 35HRC (ref. ISO 21457)

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Corrosion Protection

- In general the use of low alloy steel material is recommended for subsea bolting since the requirements to avoid HISC are well established.
- Fasteners of CRA may also be used. The selection of a CRA may be the result of a project specified need:
  - Cathodic protection cannot be ensured for the given bolt/bolted joint
  - Project-specific requirements indicate a need for a specific CRA-type material.
- If Cathodic protection can not be ensured Alloy 625 is recommended

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Corrosion Protection

Coating systems

- In addition to zinc and cadmium, metallic coating based on aluminium and with Zn-NI are used for fasteners.
- In addition, there is a range of potential organic coatings:
  - Fluoropolymer coating (PTFE type)
    - As single coating
    - As part of a duplex coating system (eg on Zinc or aluminium)
- Organic matrix with additions of metal or other particles
- Wax and oils (only for short term measures)

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Corrosion Protection

- In subsea applications the fasteners will have corrosion protection from the cathodic protection system. Consequently a coating on fasteners for subsea application should not be required.
- Corrosion protection alternatives for subsea bolting are specified in some standards, e.g. ISO 13628-1 and NORSOK M-001
- Note: The use of coatings represents a particular challange for bolting as the tolerance for the threads restricts the coating thickness. On the other hand a thin coating can be damaged due to the mechanical forces during bolting installation.

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Corrosion Protection

Subsea systems, ref ISO 13628-1 /104/ and NORSOK M-001 /119/

Coating system	*Typical properties and concerns*
Zine – hot dipped	- Thick coating is achieved - The possibility for dissolution of zinc leading to loss of pretension has been identified by some standards and recommend selection a thinner coating (e.g. phosphating or electroplating) - Fasteners harder than Rockwell 35 HRC shall not be hot galvanised
Zine – electrodeposited (electroplating)	- Avoid the risk of dissolution of a thick zinc coating leading to loss of bolt pretension - Will only provide corrosion protection during construction, storage and commissioning - Surface treatment and coating will introduce hydrogen in the bolt which may result in increased susceptibility to HISC. Post-process degassing is required by most standards to remove hydrogen. - Fasteners harder than Rockwell 35 HRC shall not be electroplated
Zine – thermo diffusion	- Thickness of 10 to 100 µm - Provides an even coating thickness.
Phosphating	- Avoid the risk of dissolution of a thick zinc coating leading to loss of bolt pretension - Will only provide corrosion protection during construction, storage and commissioning - Surface treatment and coating application will introduce hydrogen in the bolt which may result in increased susceptibility to HISC
Organic coatings - PTFE based coating [1]	- Low and consistent value for the friction coefficient (e.g. for torque based bolted joints) - Surface treatment (acid bath) will introduce hydrogen in the bolt which may result in increased susceptibility to hydrogen embrittlement and HISC - Necessary to ensure electrical continuity between the bolt and the structural item (required by all standards) - If continuity is not ensured separate strapping will be needed for each fastener **For more information, see "Topside – marine environments" above.**
Nickel – electroless	- Special equipment - Suitable in crude oil sour service systems

[1] EEMUA 194 does not recommend PTFE coating

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Specification and Fabrication of fasteners

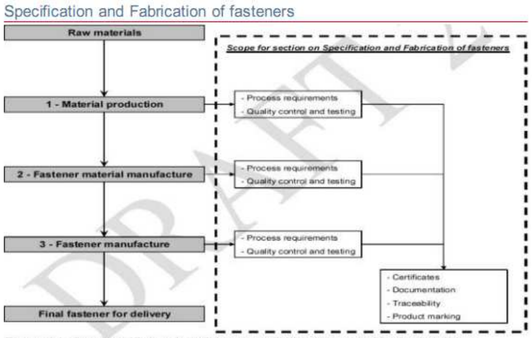

Figure 4-1: Overview illustration of the scope of this section – inside the dotted box.

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Specification and Fabrication of fasteners

- Appendix 1 in the guideline contains a: Guidance on prescription and Procurement of fasteners
- Appendix 2 in the guideline contains an: Example of Fastener Data Sheet. This data sheet should clerly define all relevant aspects of the end product and should be included in the specification.

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Specification and Fabrication of fasteners

FASTENER DATA SHEET	
Fastener specification	ISO 898-1:2009 and DNV RP** <This document>
Description	Stud bolt, M39 x 2.5 x 435, class 8.8, Xylan coated
End use	Low temperature piping application. Pre-stressed using bolt tensioner. Tensile loaded application.
Quality management system	ISO 9001 or equivalent.
Quality plan	To be submitted for prior approval detailing comprehensive manufacture, inspection and test details.
Manufacturer/s	Details of all manufacturer/s, from steel making to finished fastener, to be provided for prior approval. The right is reserved to assess any manufacturer before manufacture commences.
Threads	Rolled threads applied after completion of all heat treatment.
Mechanical testing	ISO 898-1 test series FF2 (feasible tests) plus machined Kv test specimens per ISO898-1 test series MP1 (property no. 17).
Test frequency	One bolt per 50 bolts (or part thereof) per cast per heat treatment batch to be submitted for testing (or more than one if necessary to fulfil specified testing scope).
Ductility	Minimum 14% on gauge length 5D.

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Specification and Fabrication of Fasteners

CVN	27J minimum average / 29 J minimum individual at minus 20 degrees C. Not more than one sample to be below minimum average.
Hardness testing	To be performed on each bolt, heat treated bolt blank or heat treated piece of fastener bar-stock. Method of testing to be submitted for prior approval.
NDT	Each finished (un-coated) stud to be 100% MPI tested to ASTM E709. All detected anomalies to be reported for prior approval.
Coating	Xylan 1040 blue.
Dimensional inspection	Each fastener to be inspected. Tolerances 6H/6g in accordance with ISO 965-1.
Marking	As per ISO 898 plus a fastener certificate number marked on each bolt. Clearly legible low stress dot stampings.
Certification	Minimum content as per RP**<This document>. EN 10204:2005 type 3.2 inspection certificate. Nominated body DNV. Certification shall be traceable to fasteners studs and vice versa from fastener certificate number.
Traceability	Each fasteners to be fully traceable through supplied certification to cast number steel maker heat treatment batch number / heat treater thread roller any other manufacturer involved in their production or inspection

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Conclusion

- For subsea with Cathodic Protection L7 bolts are recommended to be used.
- To avoid HISC the low alloy material for fasteners used in conjunction with Cathodic protection shall comply with the following requirements:
  - The strength class shall not exceed the Property Class 8.8 according to ISO-898-1 for bolt
  - Property Class 8 for nuts according to ISO 898-2
  - Max bolt hardness shall be: 35HRC (ref. ISO 21457)
- 625 bolts when Cathodic protection can not be ensured

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Conclusion

- Coating shall be used if components/structures have to be stored before deploying:
  - i.e. wax and oils for short tearm measures
  - Zinc Electrodepoited (Thickness 2-25 micron)
- Splash Zone: fastners should be avoided in splash zone applications where cathodic protection can not be ensured. If unavoidable fastners shall be Alloy 625
- Ordering of Fasteners:
  - Specification with data sheet included
  - Close follow-up required

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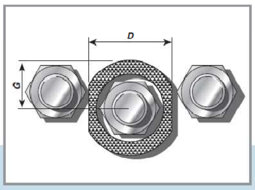
Appendix C

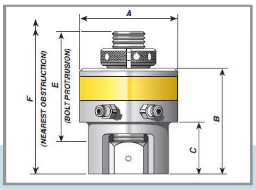
Hydratight – Aqua-jack data sheet

(1 Pages)

hydratight

SUBSEA BOLT TENSIONERS – AQUAJACK® DATA SHEET





C

- Unique reaction nut design allows rapid tool removal and application to long bolts and damaged threads
- 30mm (1.180") maximum piston stroke for tools AJ2 to AJ8. 20mm (0.78") maximum for tools AJ0 and AJ1. All tools incorporate visible piston stroke indicators
- Innovative tool design ensures maximum tool strokes can be used without overstroking the piston or oil spillage
- Maximum tool operating pressure 1500 bar (21,750 psi)

Tensioner Ref		Tool Hyd Area	Max Load	A	B	C	D	E	F	G
Bolt Dia.	Tool No.	in²	LBS	in	in	in	in	in	in	in
5/8"	AJ0	0.748	16,269	2.05	3.70	1.27	1.85	3.94	8.74	0.79
3/4"	AJ1	1.55	33,713	2.60	3.50	1.37	2.36	3.78	8.54	1.00
7/8"	AJ1	1.55	33,713	2.60	3.50	1.37	2.36	3.78	8.54	1.00
1"	AJ2 (M33)	2.56	55,680	[illegible] (377,4 kN)	[illegible]	1.97	2.95	4.92	11.37	1.20
1 1/8"	AJ2	2.56	55,680	3.23	4.72	1.97	2.95	4.92	11.37	1.20
1 1/4"	AJ3	3.90	84,825	3.86	5.16	2.28	3.62	5.12	12.09	1.50
1 3/8"	AJ3	3.90	84,825	3.86	5.16	2.28	3.62	5.12	12.09	1.50
1 1/2"	AJ4 (M45)	5.69	123,758	[illegible] (883,6 kN)	[illegible]	2.48	3.78	5.31	12.55	1.77
1 5/8"	AJ4	5.69	123,758	4.49	5.35	2.48	3.78	5.31	12.55	1.77
1 3/4"	AJ5	9.13	198,578	5.47	5.75	2.76	4.49	5.51	13.4	2.05
1 7/8"	AJ5	9.13	198,578	5.47	5.75	2.76	4.49	5.51	13.4	2.05
2"	AJ5	9.13	198,578	5.47	5.75	2.76	4.49	5.51	13.4	2.05
2 1/4"	AJ6	12.86	279,705	6.46	6.34	3.23	5.43	5.91	14.45	2.48
2 1/2"	AJ6	12.86	279,705	6.46	6.34	3.23	5.43	5.91	14.45	2.48
2 3/4"	AJ7	19.14	416,295	7.56	7.01	3.74	6.18	6.19	15.74	2.99
3"	AJ7	19.14	416,295	7.56	7.01	3.74	6.18	6.19	15.74	2.99
3 1/4"	AJ8	23.94	520,695	8.50	7.60	4.29	7.18	6.5	16.22	3.35
3 1/2"	AJ8	23.94	520,695	8.50	7.60	4.29	7.18	6.5	16.22	3.35

Further details can be obtained from your local Hydratight representative
or via the website **www.hydratight.com**

HT/TD-AJ/E/11-09

Appendix D

D

Horizontal and vertical wave forces on clamp

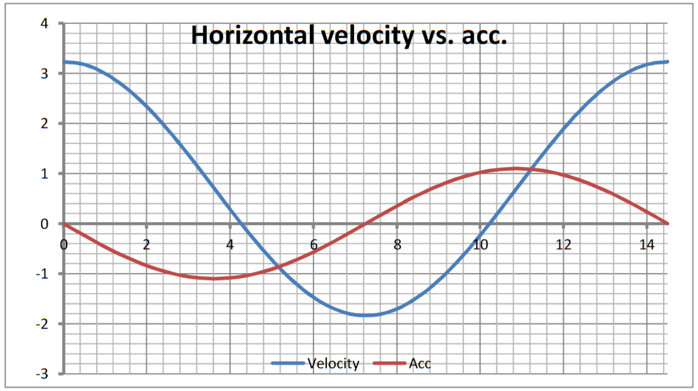
(1 Pages)

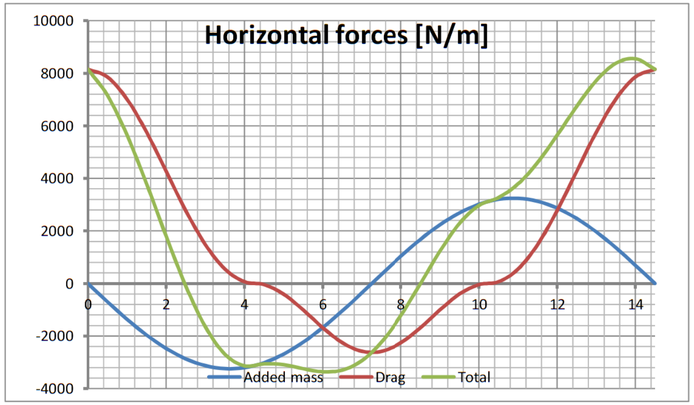
Horizontal force on clamp 1				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	-63,8	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	1,9		RP-C205 A-E
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$\frac{\pi H}{T}\frac{\cosh[k(z+d)]}{\sinh(kd)}\cos\theta$ $\frac{2\pi^2 H}{T^2}\frac{\cosh[k(z+d)]}{\sinh(kd)}\sin\theta$

t	u	u'	Added mass	Drag	Total	
0	3,235304	0	0	8153,940027	8153,94	
0,5	3,17603	-0,236167737	-697,5544744	7857,900342	7160,346	
1	3,000979	-0,461292533	-1362,492077	7015,577238	5653,085	
1,5	2,718338	-0,664847803	-1963,721064	5756,310629	3792,59	
2	2,341321	-0,837315528	-2473,128637	4270,308711	1797,18	
2,5	1,887558	-0,97063131	-2866,895463	2775,478487	-91,417	
3	1,378266	-1,058561451	-3126,609444	1479,80077	-1646,81	
3,5	0,837259	-1,096994435	-3240,126642	546,080483	-2694,05	
4	0,289834	-1,084133178	-3202,13912	65,43871067	-3136,7	
4,5	-0,23841	-1,020579059	-3014,423131	-44,27878777	-3058,7	
5	-0,72278	-0,909303797	-2685,756067	-406,9575851	-3092,71	
5,5	-1,14062	-0,7555105	-2231,506034	-1013,48796	-3244,99	
6	-1,47239	-0,566390372	-1672,91326	-1688,826148	-3361,74	
6,5	-1,70259	-0,35078646	-1036,09692	-2258,17086	-3294,27	
7	-1,82044	-0,118780163	-350,8338402	-2581,611488	-2932,45	
7,5	-1,82044	0,118780163	350,8338402	-2581,611488	-2230,78	
8	-1,70259	0,35078646	1036,09692	-2258,17086	-1222,07	
8,5	-1,47239	0,566390372	1672,91326	-1688,826148	-15,9129	
9	-1,14062	0,7555105	2231,506034	-1013,48796	1218,018	
9,5	-0,72278	0,909303797	2685,756067	-406,9575851	2278,798	
10	-0,23841	1,020579059	3014,423131	-44,27878777	2970,144	
10,5	0,289834	1,084133178	3202,13912	65,43871067	3267,578	
11	0,837259	1,096994435	3240,126642	546,080483	3786,207	
11,5	1,378266	1,058561451	3126,609444	1479,80077	4606,41	
12	1,887558	0,97063131	2866,895463	2775,478487	5642,374	
12,5	2,341321	0,837315528	2473,128637	4270,308711	6743,437	
13	2,718338	0,664847803	1963,721064	5756,310629	7720,032	
13,5	3,000979	0,461292533	1362,492077	7015,577238	8378,069	
14	3,17603	0,236167737	697,5544744	7857,900342	8555,455	
14,5	3,235304	2,69191E-16	7,95093E-13	8153,940027	8153,94	
Max value	3,235304	1,096994435	3240,126642	8153,940027	8555,455	[N/m]
				Max force	17110,91	[N]

(Projected lenght: 2m)





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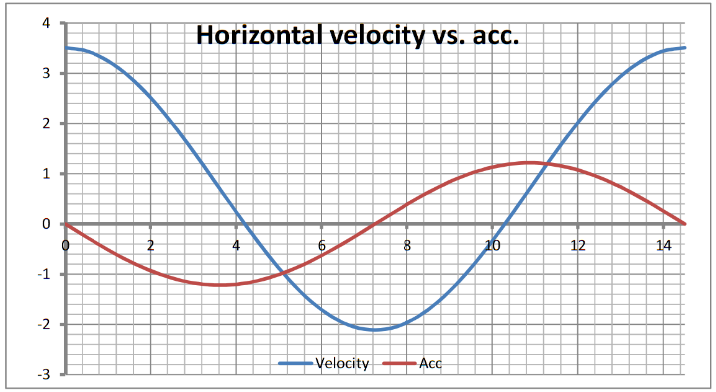
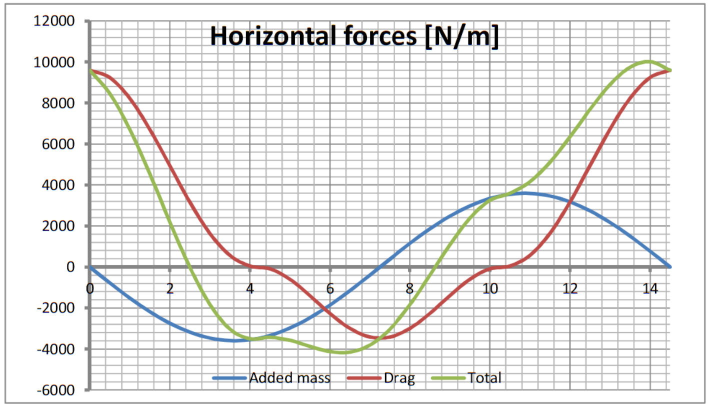
Horizontal force on clamp 2				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	-48,8	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	1,9		RP-C205 A-E
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$\frac{\pi H}{T}\frac{\cosh[k(z+d)]}{\sinh(kd)}\cos\theta$ $\frac{2\pi^2 H}{T^2}\frac{\cosh[k(z+d)]}{\sinh(kd)}\sin\theta$

t	u	u'	Added mass	Drag	Total	
0	3,509888	0	0	9596,742944	9596,743	
0,5	3,444194	-0,261745697	-773,1025614	9240,865588	8467,763	
1	3,250185	-0,511252457	-1510,055706	8229,123608	6719,068	
1,5	2,936932	-0,736853619	-2176,400325	6719,318654	4542,918	
2	2,519083	-0,928000326	-2740,978883	4943,360627	2202,382	
2,5	2,016175	-1,075754769	-3177,392315	3166,605248	-10,7871	
3	1,451725	-1,173208114	-3465,234413	1641,74574	-1823,49	
3,5	0,852124	-1,215803552	-3591,046002	565,6441528	-3025,4	
4	0,245411	-1,201549367	-3548,944271	46,91640634	-3502,03	
4,5	-0,34005	-1,131112069	-3340,89785	-90,07708286	-3430,97	
5	-0,87687	-1,007785227	-2976,634759	-598,9773545	-3575,61	
5,5	-1,33997	-0,837335469	-2473,187535	-1398,700773	-3871,89	
6	-1,70767	-0,627732835	-1854,09681	-2271,67673	-4125,77	
6,5	-1,9628	-0,388778111	-1148,31058	-3001,159274	-4149,47	
7	-2,09342	-0,131644555	-388,8306225	-3413,881796	-3802,71	
7,5	-2,09342	0,131644555	388,8306225	-3413,881796	-3025,05	
8	-1,9628	0,388778111	1148,31058	-3001,159274	-1852,85	
8,5	-1,70767	0,627732835	1854,09681	-2271,67673	-417,58	
9	-1,33997	0,837335469	2473,187535	-1398,700773	1074,487	
9,5	-0,87687	1,007785227	2976,634759	-598,9773545	2377,657	
10	-0,34005	1,131112069	3340,89785	-90,07708286	3250,821	
10,5	0,245411	1,201549367	3548,944271	46,91640634	3595,861	
11	0,852124	1,215803552	3591,046002	565,6441528	4156,69	
11,5	1,451725	1,173208114	3465,234413	1641,74574	5106,98	
12	2,016175	1,075754769	3177,392315	3166,605248	6343,998	
12,5	2,519083	0,928000326	2740,978883	4943,360627	7684,34	
13	2,936932	0,736853619	2176,400325	6719,318654	8895,719	
13,5	3,250185	0,511252457	1510,055706	8229,123608	9739,179	
14	3,444194	0,261745697	773,1025614	9240,865588	10013,97	
14,5	3,509888	2,98346E-16	8,81205E-13	9596,742944	9596,743	
Max value	3,509888	1,215803552	3591,046002	9596,742944	10013,97	[N/m]
				Max force	20027,94	[N]

(Projected lenght: 2m)





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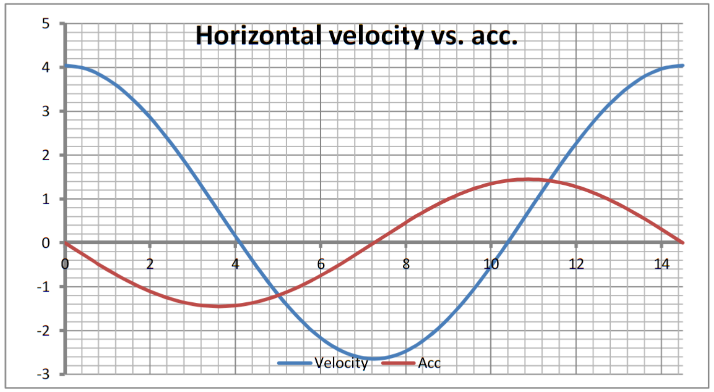
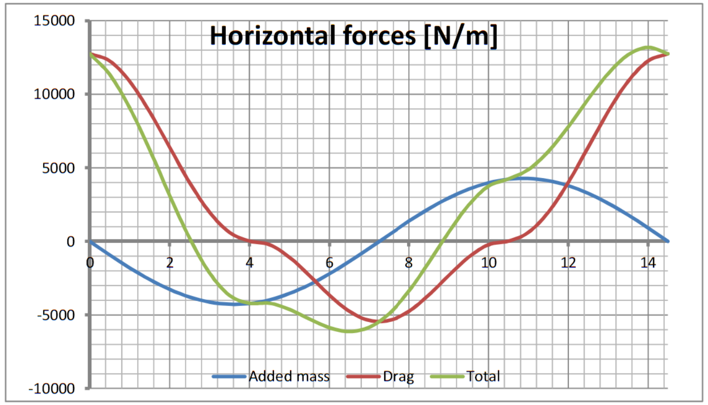
Horizontal force on clamp 3				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	-33,8	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	1,9		RP-C205 A-E
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$$\frac{\pi H}{T}\frac{\cosh[k(z+d)]}{\sinh(kd)}\cos\theta \qquad \frac{2\pi^2 H}{T^2}\frac{\cosh[k(z+d)]}{\sinh(kd)}\sin\theta$$

t	u	u'	Added mass	Drag	Total	
0	4,0462	0	0	12753,57949	12753,58	
0,5	3,967967	-0,31170407	-920,6616092	12265,17246	11344,51	
1	3,736929	-0,608833204	-1798,274105	10878,45114	9080,177	
1,5	3,363886	-0,877493974	-2591,801302	8814,955051	6223,154	
2	2,866284	-1,105124101	-3264,138751	6399,939096	3135,8	
2,5	2,267388	-1,281079854	-3783,848699	4004,877373	221,0287	
3	1,595203	-1,397133736	-4126,630088	1982,300602	-2144,33	
3,5	0,88116	-1,447859198	-4276,454841	604,848508	-3671,61	
4	0,158645	-1,430884372	-4226,317318	19,60608683	-4206,71	
4,5	-0,53856	-1,347002984	-3978,561894	-225,9433252	-4204,51	
5	-1,17784	-1,200137233	-3544,773338	-1080,719566	-4625,49	
5,5	-1,72933	-0,9971544	-2945,235121	-2329,652595	-5274,89	
6	-2,16722	-0,747545734	-2207,980983	-3658,824324	-5866,81	
6,5	-2,47104	-0,462982661	-1367,484107	-4756,591792	-6124,08	
7	-2,62658	-0,156771034	-463,0451954	-5374,277702	-5837,32	
7,5	-2,62658	0,156771034	463,0451954	-5374,277702	-4911,23	
8	-2,47104	0,462982661	1367,484107	-4756,591792	-3389,11	
8,5	-2,16722	0,747545734	2207,980983	-3658,824324	-1450,84	
9	-1,72933	0,9971544	2945,235121	-2329,652595	615,5825	
9,5	-1,17784	1,200137233	3544,773338	-1080,719566	2464,054	
10	-0,53856	1,347002984	3978,561894	-225,9433252	3752,619	
10,5	0,158645	1,430884372	4226,317318	19,60608683	4245,923	
11	0,88116	1,447859198	4276,454841	604,848508	4881,303	
11,5	1,595203	1,397133736	4126,630088	1982,300602	6108,931	
12	2,267388	1,281079854	3783,848699	4004,877373	7788,726	
12,5	2,866284	1,105124101	3264,138751	6399,939096	9664,078	
13	3,363886	0,877493974	2591,801302	8814,955051	11406,76	
13,5	3,736929	0,608833204	1798,274105	10878,45114	12676,73	
14	3,967967	0,31170407	920,6616092	12265,17246	13185,83	
14,5	4,0462	3,5529E-16	1,0494E-12	12753,57949	12753,58	
Max value	4,0462	1,447859198	4276,454841	12753,57949	13185,83	[N/m]
				Max force	26371,67	[N]

(Projected lenght: 2m)





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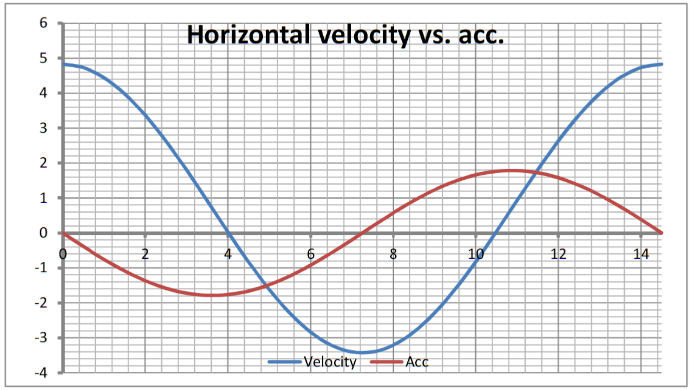
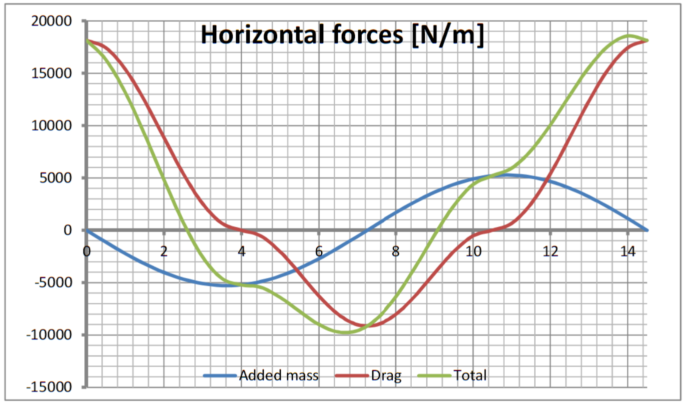
Horizontal force on clamp 4				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	-19,8	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	1,9		RP-C205 A-E
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$$\frac{\pi H}{T}\frac{\cosh[k(z+d)]}{\sinh(kd)}\cos\theta \qquad \frac{2\pi^2 H}{T^2}\frac{\cosh[k(z+d)]}{\sinh(kd)}\sin\theta$$

t	u	u'	Added mass	Drag	Total	
0	4,826557	0	0	18147,31069	18147,31	
0,5	4,73008	-0,384395614	-1135,366262	17429,07905	16293,71	
1	4,445161	-0,750817317	-2217,64406	15392,61916	13174,98	
1,5	3,985123	-1,082131636	-3196,227286	12371,45981	9175,233	
2	3,371476	-1,362846683	-4025,358477	8854,777434	4829,419	
2,5	2,632914	-1,579836534	-4666,268379	5400,211817	733,9434	
3	1,803971	-1,722954984	-5088,988758	2535,108123	-2553,88	
3,5	0,923407	-1,785509974	-5273,753679	664,2384934	-4609,52	
4	0,032397	-1,764576502	-5211,923739	0,817633079	-5211,11	
4,5	-0,8274	-1,661133394	-4906,390038	-533,2911339	-5439,68	
5	-1,61577	-1,480017535	-4371,438991	-2033,745741	-6405,18	
5,5	-2,29586	-1,2296977	-3632,084316	-4106,093546	-7738,18	
6	-2,83587	-0,921878568	-2722,897415	-6264,840195	-8987,74	
6,5	-3,21054	-0,570953419	-1686,390857	-8029,617278	-9716,01	
7	-3,40237	-0,193331122	-571,0305367	-9017,780737	-9588,81	
7,5	-3,40237	0,193331122	571,0305367	-9017,780737	-8446,75	
8	-3,21054	0,570953419	1686,390857	-8029,617278	-6343,23	
8,5	-2,83587	0,921878568	2722,897415	-6264,840195	-3541,94	
9	-2,29586	1,2296977	3632,084316	-4106,093546	-474,009	
9,5	-1,61577	1,480017535	4371,438991	-2033,745741	2337,693	
10	-0,8274	1,661133394	4906,390038	-533,2911339	4373,099	
10,5	0,032397	1,764576502	5211,923739	0,817633079	5212,741	
11	0,923407	1,785509974	5273,753679	664,2384934	5937,992	
11,5	1,803971	1,722954984	5088,988758	2535,108123	7624,097	
12	2,632914	1,579836534	4666,268379	5400,211817	10066,48	
12,5	3,371476	1,362846683	4025,358477	8854,777434	12880,14	
13	3,985123	1,082131636	3196,227286	12371,45981	15567,69	
13,5	4,445161	0,750817317	2217,64406	15392,61916	17610,26	
14	4,73008	0,384395614	1135,366262	17429,07905	18564,45	
14,5	4,826557	4,38146E-16	1,29412E-12	18147,31069	18147,31	
Max value	4,826557	1,785509974	5273,753679	18147,31069	18564,45	[N/m]
				Max force	37128,89	[N]

(Projected lenght: 2m)





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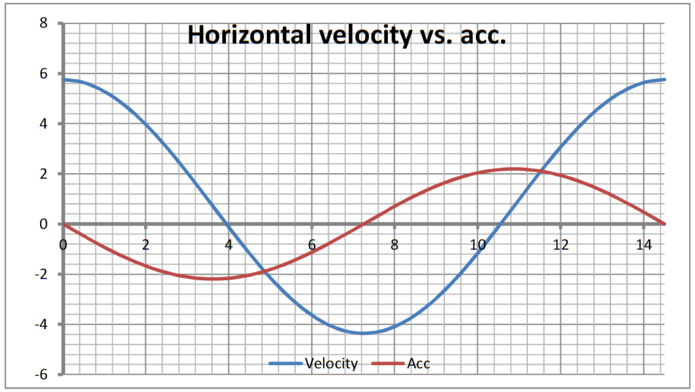
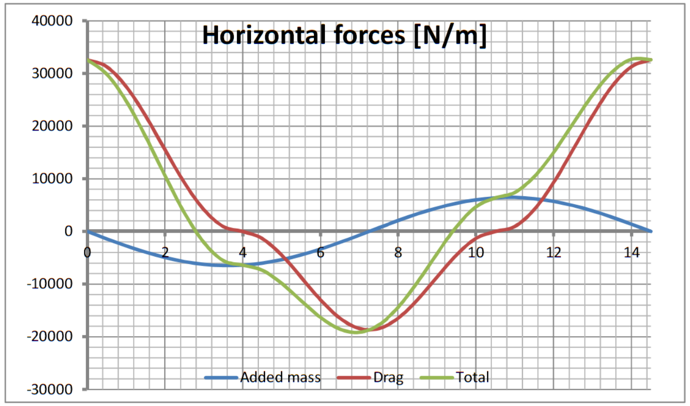
Horizontal force on clamp 5				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	-7,8	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	2,4		Assumed
	Cs	5,15		RP-C205 8.6.3.4
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$$\frac{\pi H}{T}\frac{\cosh[k(z+d)]}{\sinh(kd)}\cos\theta \qquad \frac{2\pi^2 H}{T^2}\frac{\cosh[k(z+d)]}{\sinh(kd)}\sin\theta$$

t	u	u'	Added mass	Drag	Total	
0	5,758575	0	0	32630,60418	32630,6	
0,5	5,640308	-0,471214649	-1391,798437	31304,06603	29912,27	
1	5,291038	-0,920395825	-2718,517926	27547,16281	24828,64	
1,5	4,727096	-1,326540315	-3918,122537	21987,91219	18069,79	
2	3,974852	-1,670657255	-4934,520094	15546,65655	10612,14	
2,5	3,069479	-1,936656118	-5720,184976	9270,954769	3550,77	
3	2,053312	-2,112099093	-6238,380365	4148,633119	-2089,75	
3,5	0,973866	-2,188782662	-6464,876022	933,2398014	-5531,64	
4	-0,11839	-2,163121187	-6389,081262	-13,79107614	-6402,87	
4,5	-1,17237	-2,036314569	-6014,540163	-1352,463713	-7367	
5	-2,13881	-1,814292145	-5358,76585	-4501,302265	-9860,07	
5,5	-2,9725	-1,507435436	-4452,421602	-8694,398549	-13146,8	
6	-3,63448	-1,130092722	-3337,887068	-12998,06566	-16336	
6,5	-4,09377	-0,699908129	-2067,276645	-16490,84502	-18558,1	
7	-4,32892	-0,236996609	-700,002664	-18439,72551	-19139,7	
7,5	-4,32892	0,236996609	700,002664	-18439,72551	-17739,7	
8	-4,09377	0,699908129	2067,276645	-16490,84502	-14423,6	
8,5	-3,63448	1,130092722	3337,887068	-12998,06566	-9660,18	
9	-2,9725	1,507435436	4452,421602	-8694,398549	-4241,98	
9,5	-2,13881	1,814292145	5358,76585	-4501,302265	857,4636	
10	-1,17237	2,036314569	6014,540163	-1352,463713	4662,076	
10,5	-0,11839	2,163121187	6389,081262	-13,79107614	6375,29	
11	0,973866	2,188782662	6464,876022	933,2398014	7398,116	
11,5	2,053312	2,112099093	6238,380365	4148,633119	10387,01	
12	3,069479	1,936656118	5720,184976	9270,954769	14991,14	
12,5	3,974852	1,670657255	4934,520094	15546,65655	20481,18	
13	4,727096	1,326540315	3918,122537	21987,91219	25906,03	
13,5	5,291038	0,920395825	2718,517926	27547,16281	30265,68	
14	5,640308	0,471214649	1391,798437	31304,06603	32695,86	
14,5	5,758575	5,37104E-16	1,58641E-12	32630,60418	32630,6	
Max value	5,758575	2,188782662	6464,876022	32630,60418	32695,86	[N/m]
				Max force	65391,73	[N]

(Projected lenght: 2m)





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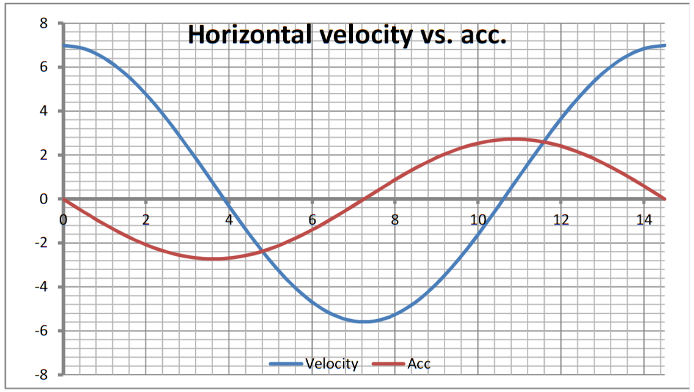
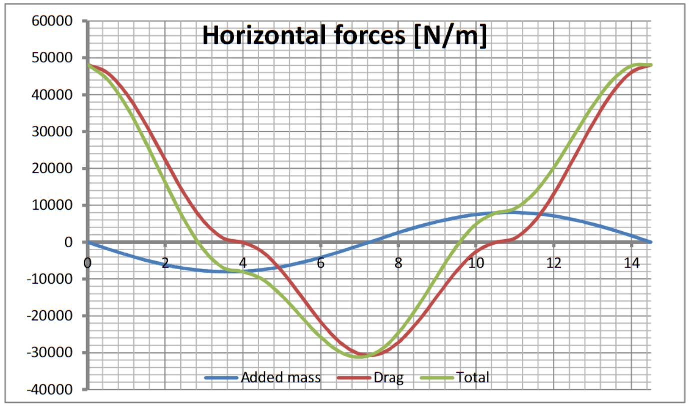
Horizontal force on clamp 6				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	4,2	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	2,4		Assumed
	Cs	5,15		RP-C205 8.6.3.4
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$\frac{\pi H}{T}\frac{\cosh[k(z+d)]}{\sinh(kd)}\cos\theta$ $\frac{2\pi^2 H}{T^2}\frac{\cosh[k(z+d)]}{\sinh(kd)}\sin\theta$

t	u	u'	Added mass	Drag	Total	
0	6,991316	0	0	48096,44347	48096,44	
0,5	6,844229	-0,586046547	-1730,970524	46093,96876	44363	
1	6,409844	-1,144690209	-3381,00279	40428,7195	37047,72	
1,5	5,708473	-1,649809429	-4872,943123	32065,27787	27192,33	
2	4,772912	-2,077785394	-6137,030052	22416,19506	16279,17	
2,5	3,646906	-2,408606423	-7114,156276	13087,12115	5972,965	
3	2,383105	-2,626803693	-7758,63246	5588,323899	-2170,31	
3,5	1,040605	-2,722174541	-8040,323613	1065,532989	-6974,79	
4	-0,31782	-2,690259534	-7946,05817	-99,39444033	-8045,45	
4,5	-1,62866	-2,532550981	-7480,243878	-2610,080361	-10090,3	
5	-2,83061	-2,256423158	-6664,661696	-7884,128392	-14548,8	
5,5	-3,86747	-1,874787496	-5537,447341	-14717,98461	-20255,4	
6	-4,69076	-1,405488855	-4151,308102	-21651,17092	-25802,5	
6,5	-5,26199	-0,870471117	-2571,058311	-27245,47618	-29816,5	
7	-5,55444	-0,294751117	-870,5886901	-30358,13156	-31228,7	
7,5	-5,55444	0,294751117	870,5886901	-30358,13156	-29487,5	
8	-5,26199	0,870471117	2571,058311	-27245,47618	-24674,4	
8,5	-4,69076	1,405488855	4151,308102	-21651,17092	-17499,9	
9	-3,86747	1,874787496	5537,447341	-14717,98461	-9180,54	
9,5	-2,83061	2,256423158	6664,661696	-7884,128392	-1219,47	
10	-1,62866	2,532550981	7480,243878	-2610,080361	4870,164	
10,5	-0,31782	2,690259534	7946,05817	-99,39444033	7846,664	
11	1,040605	2,722174541	8040,323613	1065,532989	9105,857	
11,5	2,383105	2,626803693	7758,63246	5588,323899	13346,96	
12	3,646906	2,408606423	7114,156276	13087,12115	20201,28	
12,5	4,772912	2,077785394	6137,030052	22416,19506	28553,23	
13	5,708473	1,649809429	4872,943123	32065,27787	36938,22	
13,5	6,409844	1,144690209	3381,00279	40428,7195	43809,72	
14	6,844229	0,586046547	1730,970524	46093,96876	47824,94	
14,5	6,991316	6,67993E-16	1,97301E-12	48096,44347	48096,44	
Max value	6,991316	2,722174541	8040,323613	48096,44347	48096,44	[N/m]
				Max force	96192,89	[N]

(Projected lenght: 2m)





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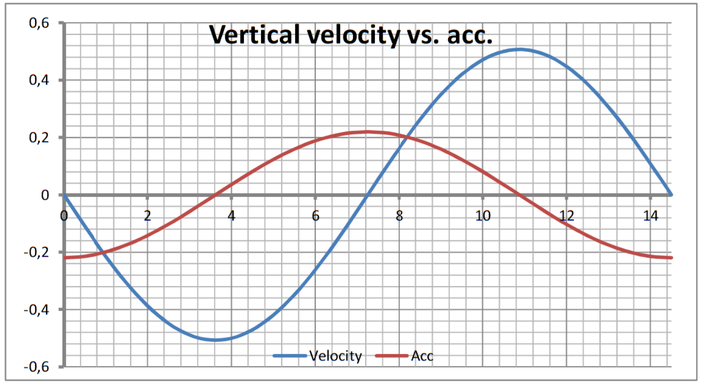
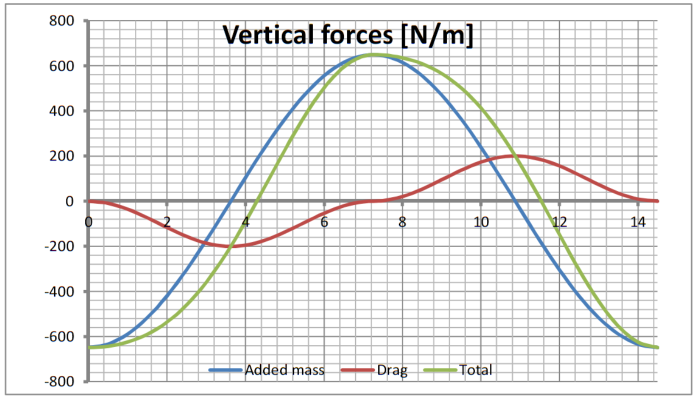
Vertical force on clamp 1				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	-63,8	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	1,9		RP-C205 A-E
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$$w = \frac{\pi H}{T}\frac{\sinh[k(z+d)]}{\sinh(kd)}\sin\theta \qquad w' = -\frac{2\pi^2 H}{T^2}\frac{\sinh[k(z+d)]}{\sinh(kd)}\cos\theta$$

t	w	w'	Added mass	Drag	Total	
0	0	-0,219669282	-648,8239792	0	-648,824	
0,5	-0,10898	-0,214533537	-633,6548351	-9,251451565	-642,906	
1	-0,21286	-0,199366441	-588,8566952	-35,29568321	-624,152	
1,5	-0,30679	-0,174877192	-516,5242707	-73,31844056	-589,843	
2	-0,38637	-0,142210881	-420,0397453	-116,2912488	-536,331	
2,5	-0,44789	-0,102894946	-303,9146284	-156,2706205	-460,185	
3	-0,48846	-0,058767758	-173,5788011	-185,8664023	-359,445	
3,5	-0,5062	-0,011892655	-35,1266221	-199,6078387	-234,734	
4	-0,50026	0,035538535	104,9680388	-194,9548369	-89,9868	
4,5	-0,47094	0,081307983	240,1545108	-172,7675001	67,38701	
5	-0,41959	0,12327556	364,1116248	-137,1471392	226,9645	
5,5	-0,34862	0,159478909	471,0432839	-94,67814778	376,3651	
6	-0,26136	0,188225201	555,9494826	-53,21088336	502,7386	
6,5	-0,16187	0,208170292	614,8601014	-20,41053494	594,4496	
7	-0,05481	0,218381572	645,0205452	-2,340219406	642,6803	
7,5	0,05481	0,218381572	645,0205452	2,340219406	647,3608	
8	0,161867	0,208170292	614,8601014	20,41053494	635,2706	
8,5	0,261355	0,188225201	555,9494826	53,21088336	609,1604	
9	0,348623	0,159478909	471,0432839	94,67814778	565,7214	
9,5	0,41959	0,12327556	364,1116248	137,1471392	501,2588	
10	0,470936	0,081307983	240,1545108	172,7675001	412,922	
10,5	0,500263	0,035538535	104,9680388	194,9548369	299,9229	
11	0,506198	-0,011892655	-35,1266221	199,6078387	164,4812	
11,5	0,488463	-0,058767758	-173,5788011	185,8664023	12,2876	
12	0,447889	-0,102894946	-303,9146284	156,2706205	-147,644	
12,5	0,386371	-0,142210881	-420,0397453	116,2912488	-303,748	
13	0,306788	-0,174877192	-516,5242707	73,31844056	-443,206	
13,5	0,212859	-0,199366441	-588,8566952	35,29568321	-553,561	
14	0,108977	-0,214533537	-633,6548351	9,251451565	-624,403	
14,5	1,24E-16	-0,219669282	-648,8239792	1,20196E-29	-648,824	
Max value	0,506198	0,218381572	645,0205452	199,6078387	647,3608	[N/m]
Min value	-0,5062	-0,219669282	-648,8239792	-199,6078387	-648,824	[N/m]
				Max force	-1297,65	[N]

(Projected lenght: 2m)





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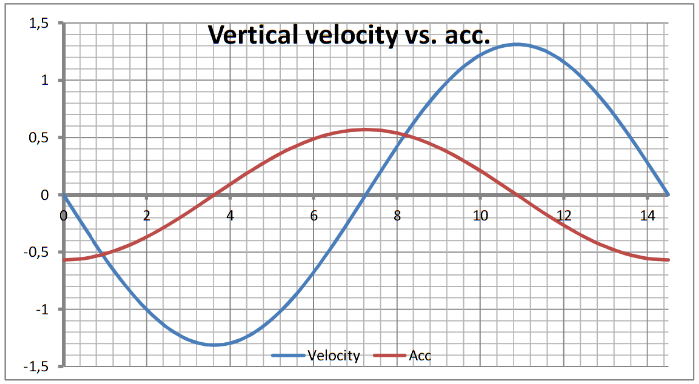
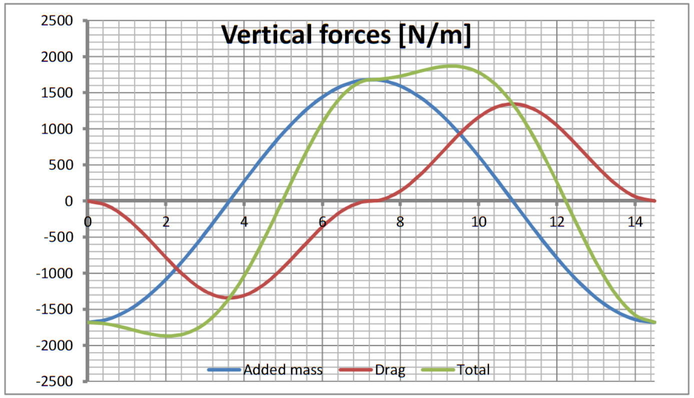
Vertical force on clamp 2				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	-48,8	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	1,9		RP-C205 A-E
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$\frac{\pi H}{T}\frac{\sinh[k(z+d)]}{\sinh(kd)}\sin\theta$ $-\frac{2\pi^2 H}{T^2}\frac{\sinh[k(z+d)]}{\sinh(kd)}\cos\theta$

t	w	w'	Added mass	Drag	Total	
0	0	-0,569072788	-1680,836149	0	-1680,84	
0,5	-0,28232	-0,555768182	-1641,539134	-62,08788337	-1703,63	
1	-0,55143	-0,516476474	-1525,485573	-236,8746404	-1762,36	
1,5	-0,79476	-0,4530349	-1338,102003	-492,0510856	-1830,15	
2	-1,00093	-0,368409918	-1088,15027	-780,4480675	-1868,6	
2,5	-1,1603	-0,266558497	-787,3178396	-1048,755646	-1836,07	
3	-1,26541	-0,152243097	-449,6713023	-1247,37739	-1697,05	
3,5	-1,31135	-0,03080898	-90,99863462	-1339,598238	-1430,6	
4	-1,29598	0,092065732	271,9290281	-1308,371242	-1036,44	
4,5	-1,22	0,210635552	622,1415916	-1159,468687	-537,327	
5	-1,08698	0,319356288	943,2635058	-920,4150854	22,84842	
5,5	-0,90314	0,413144279	1220,279467	-635,3992944	584,8802	
6	-0,67706	0,487614102	1440,236516	-357,106244	1083,13	
6,5	-0,41933	0,539283632	1592,849707	-136,9781709	1455,872	
7	-0,14199	0,565736859	1670,983015	-15,70556453	1655,277	
7,5	0,14199	0,565736859	1670,983015	15,70556453	1686,689	
8	0,419331	0,539283632	1592,849707	136,9781709	1729,828	
8,5	0,677064	0,487614102	1440,236516	357,106244	1797,343	
9	0,903139	0,413144279	1220,279467	635,3992944	1855,679	
9,5	1,086984	0,319356288	943,2635058	920,4150854	1863,679	
10	1,220003	0,210635552	622,1415916	1159,468687	1781,61	
10,5	1,295975	0,092065732	271,9290281	1308,371242	1580,3	
11	1,31135	-0,03080898	-90,99863462	1339,598238	1248,6	
11,5	1,265407	-0,152243097	-449,6713023	1247,37739	797,7061	
12	1,160295	-0,266558497	-787,3178396	1048,755646	261,4378	
12,5	1,000929	-0,368409918	-1088,15027	780,4480675	-307,702	
13	0,794761	-0,4530349	-1338,102003	492,0510856	-846,051	
13,5	0,55143	-0,516476474	-1525,485573	236,8746404	-1288,61	
14	0,282315	-0,555768182	-1641,539134	62,08788337	-1579,45	
14,5	3,22E-16	-0,569072788	-1680,836149	8,06653E-29	-1680,84	
Max value	1,31135	0,565736859	1670,983015	1339,598238	1863,679	[N/m]
Min value	-1,31135	-0,569072788	-1680,836149	-1339,598238	-1868,6	
				Max force	-3737,2	[N]

(Projected lenght: 2m)





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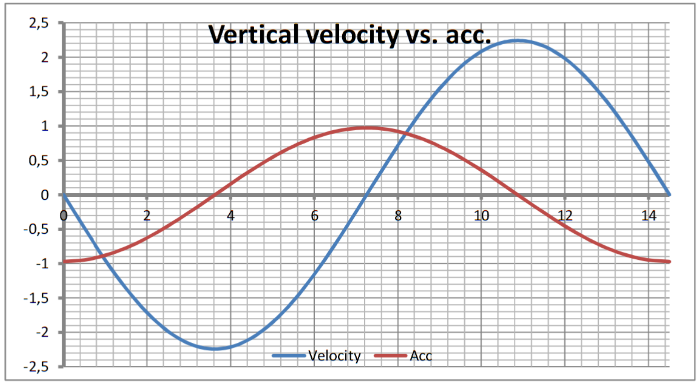
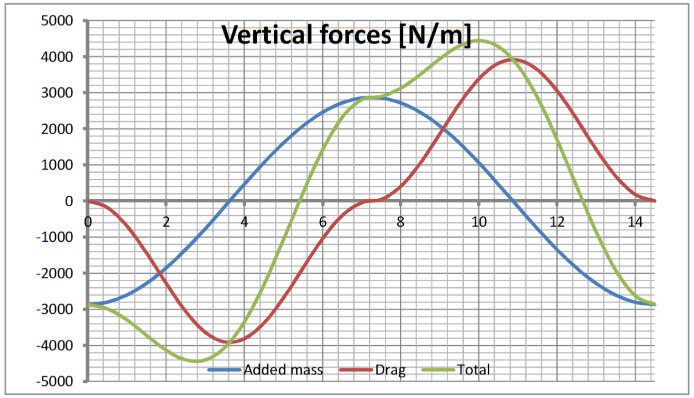
Vertical force on clamp 3				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	-33,8	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	1,9		RP-C205 A-E
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$\frac{\pi H}{T}\frac{\sinh[k(z+d)]}{\sinh(kd)}\sin\theta$ $\quad -\frac{2\pi^2 H}{T^2}\frac{\sinh[k(z+d)]}{\sinh(kd)}\cos\theta$

t	w	w'	Added mass	Drag	Total	
0	0	-0,971482816	-2869,410503	0	-2869,41	
0,5	-0,48195	-0,948770087	-2802,32528	-180,9428651	-2983,27	
1	-0,94136	-0,881693924	-2604,206442	-690,3243235	-3294,53	
1,5	-1,35676	-0,773390733	-2284,317804	-1433,98564	-3718,3	
2	-1,70872	-0,628924651	-1857,617005	-2274,461645	-4132,08	
2,5	-1,98078	-0,455050751	-1344,0561	-3056,391054	-4400,45	
3	-2,16022	-0,259899184	-767,6486246	-3635,234872	-4402,88	
3,5	-2,23865	-0,052595019	-155,3467529	-3903,994306	-4059,34	
4	-2,2124	0,15716843	464,2189602	-3812,989398	-3348,77	
4,5	-2,08271	0,359582857	1062,078311	-3379,042331	-2316,96	
5	-1,85563	0,54518359	1610,27606	-2682,367856	-1072,09	
5,5	-1,54178	0,705292145	2083,17909	-1851,745664	231,4334	
6	-1,15584	0,832422022	2458,674981	-1040,71557	1417,959	
6,5	-0,71585	0,920628771	2719,205963	-399,1958066	2320,01	
7	-0,2424	0,965787942	2852,589896	-45,77076378	2806,819	
7,5	0,242396	0,965787942	2852,589896	45,77076378	2898,361	
8	0,715854	0,920628771	2719,205963	399,1958066	3118,402	
8,5	1,155839	0,832422022	2458,674981	1040,71557	3499,391	
9	1,541778	0,705292145	2083,17909	1851,745664	3934,925	
9,5	1,855626	0,54518359	1610,27606	2682,367856	4292,644	
10	2,082707	0,359582857	1062,078311	3379,042331	4441,121	
10,5	2,212402	0,15716843	464,2189602	3812,989398	4277,208	
11	2,238648	-0,052595019	-155,3467529	3903,994306	3748,648	
11,5	2,160218	-0,259899184	-767,6486246	3635,234872	2867,586	
12	1,980778	-0,455050751	-1344,0561	3056,391054	1712,335	
12,5	1,708719	-0,628924651	-1857,617005	2274,461645	416,8446	
13	1,356762	-0,773390733	-2284,317804	1433,98564	-850,332	
13,5	0,941365	-0,881693924	-2604,206442	690,3243235	-1913,88	
14	0,48195	-0,948770087	-2802,32528	180,9428651	-2621,38	
14,5	5,49E-16	-0,971482816	-2869,410503	2,35083E-28	-2869,41	
Max value	2,238648	0,965787942	2852,589896	3903,994306	4441,121	[N/m]
Min value	-2,23865	-0,971482816	-2869,410503	-3903,994306	-4402,88	[N/m]
				Max force	8882,241	[N]

(Projected lenght: 2m)





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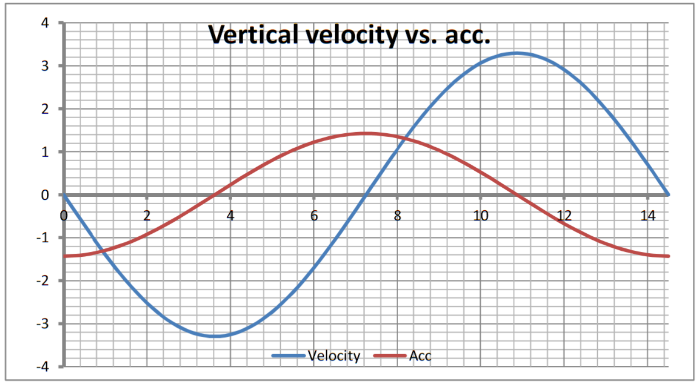
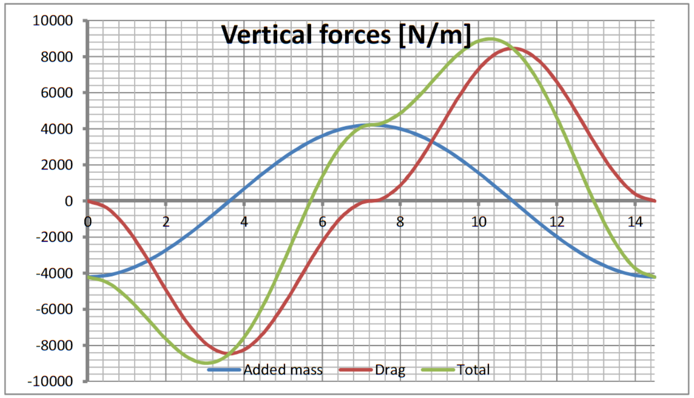
Vertical force on clamp 4				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	-19,8	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	1,9		RP-C205 A-E
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$$\frac{\pi H}{T}\frac{\sinh[k(z+d)]}{\sinh(kd)}\sin\theta \qquad -\frac{2\pi^2 H}{T^2}\frac{\sinh[k(z+d)]}{\sinh(kd)}\cos\theta$$

t	w	w'	Added mass	Drag	Total	
0	0	-1,427843766	-4217,33646	0	-4217,34	
0,5	-0,70835	-1,394461572	-4118,737477	-390,8702318	-4509,61	
1	-1,38358	-1,295875905	-3827,550908	-1491,228893	-5318,78	
1,5	-1,99411	-1,136696521	-3357,392312	-3097,675608	-6455,07	
2	-2,5114	-0,924366471	-2730,245783	-4913,260051	-7643,51	
2,5	-2,91126	-0,668814072	-1975,435995	-6602,372961	-8577,81	
3	-3,175	-0,38198867	-1128,257016	-7852,783234	-8981,04	
3,5	-3,29027	-0,077301903	-228,3219931	-8433,353581	-8661,68	
4	-3,25169	0,230999415	682,2891126	-8236,76606	-7554,48	
4,5	-3,06107	0,528499458	1560,997138	-7299,359711	-5738,36	
5	-2,72732	0,801287453	2366,714672	-5794,413309	-3427,7	
5,5	-2,26604	1,036608137	3061,767258	-4000,114934	-938,348	
6	-1,6988	1,223458177	3613,65501	-2248,139134	1365,516	
6,5	-1,05213	1,353100673	3996,57227	-862,3371659	3134,235	
7	-0,35626	1,419473684	4192,614253	-98,87336005	4093,741	
7,5	0,356263	1,419473684	4192,614253	98,87336005	4291,488	
8	1,052131	1,353100673	3996,57227	862,3371659	4858,909	
8,5	1,698802	1,223458177	3613,65501	2248,139134	5861,794	
9	2,26604	1,036608137	3061,767258	4000,114934	7061,882	
9,5	2,727319	0,801287453	2366,714672	5794,413309	8161,128	
10	3,061073	0,528499458	1560,997138	7299,359711	8860,357	
10,5	3,251694	0,230999415	682,2891126	8236,76606	8919,055	
11	3,290269	-0,077301903	-228,3219931	8433,353581	8205,032	
11,5	3,174995	-0,38198867	-1128,257016	7852,783234	6724,526	
12	2,911262	-0,668814072	-1975,435995	6602,372961	4626,937	
12,5	2,511401	-0,924366471	-2730,245783	4913,260051	2183,014	
13	1,994111	-1,136696521	-3357,392312	3097,675608	-259,717	
13,5	1,383577	-1,295875905	-3827,550908	1491,228893	-2336,32	
14	0,708349	-1,394461572	-4118,737477	390,8702318	-3727,87	
14,5	8,07E-16	-1,427843766	-4217,33646	5,07823E-28	-4217,34	
Max value	3,290269	1,419473684	4192,614253	8433,353581	8919,055	[N/m]
Min value	-3,29027	-1,427843766	-4217,33646	-8433,353581	-8981,04	[N/m]
				Max force	-17962,1	[N]

(Projected lenght: 2m)





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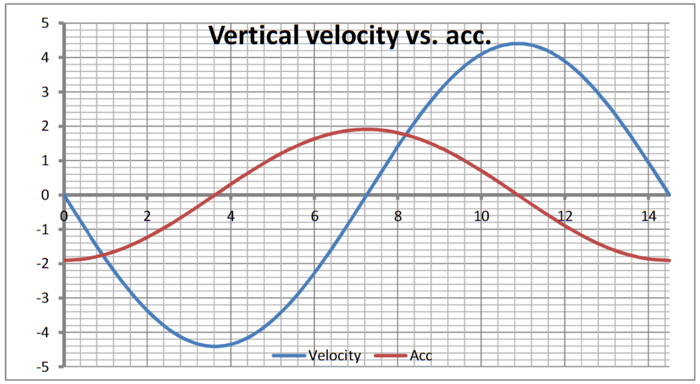
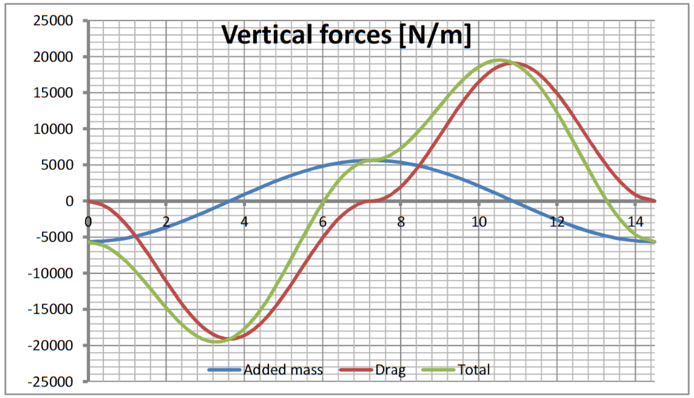
Vertical force on clamp 5				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	-7,8	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	2,4		Assumed
Slamming coefficient	Cs	5,15		RP-C205 8.6.1.2
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$$\frac{\pi H}{T}\frac{\sinh[k(z+d)]}{\sinh(kd)}\sin\theta \qquad -\frac{2\pi^2 H}{T^2}\frac{\sinh[k(z+d)]}{\sinh(kd)}\cos\theta$$

t	w	w'	Added mass	Drag	Total	
0	0	-1,909495463	-5639,962178	0	-5639,96	
0,5	-0,9473	-1,86485252	-5508,102997	-883,0110111	-6391,11	
1	-1,8503	-1,733011146	-5118,691041	-3368,8202	-8487,51	
1,5	-2,66678	-1,520136097	-4489,934781	-6997,927825	-11487,9	
2	-3,35857	-1,236181173	-3651,234161	-11099,49639	-14750,7	
2,5	-3,89331	-0,894423792	-2641,80589	-14915,35438	-17557,2	
3	-4,24601	-0,510844149	-1508,849711	-17740,14366	-19249	
3,5	-4,40017	-0,103378	-305,3413968	-19051,70429	-19357	
4	-4,34858	0,308921988	912,4443417	-18607,5954	-17695,2	
4,5	-4,09366	0,706777128	2087,565197	-16489,91014	-14402,3	
5	-3,64732	1,071584155	3165,073824	-13090,10085	-9925,03	
5,5	-3,03044	1,386285098	4094,587116	-9036,619433	-4942,03	
6	-2,27186	1,63616489	4832,642066	-5078,748517	-246,106	
6,5	-1,40704	1,809539431	5344,728044	-1948,097222	3396,631	
7	-0,47644	1,898301918	5606,900478	-223,3638137	5383,537	
7,5	0,476441	1,898301918	5606,900478	223,3638137	5830,264	
8	1,407044	1,809539431	5344,728044	1948,097222	7292,825	
8,5	2,271856	1,63616489	4832,642066	5078,748517	9911,391	
9	3,030438	1,386285098	4094,587116	9036,619433	13131,21	
9,5	3,647321	1,071584155	3165,073824	13090,10085	16255,17	
10	4,093658	0,706777128	2087,565197	16489,91014	18577,48	
10,5	4,348581	0,308921988	912,4443417	18607,5954	19520,04	
11	4,400169	-0,103378	-305,3413968	19051,70429	18746,36	
11,5	4,24601	-0,510844149	-1508,849711	17740,14366	16231,29	
12	3,893312	-0,894423792	-2641,80589	14915,35438	12273,55	
12,5	3,358568	-1,236181173	-3651,234161	11099,49639	7448,262	
13	2,66678	-1,520136097	-4489,934781	6997,927825	2507,993	
13,5	1,850297	-1,733011146	-5118,691041	3368,8202	-1749,87	
14	0,947296	-1,86485252	-5508,102997	883,0110111	-4625,09	
14,5	1,08E-15	-1,909495463	-5639,962178	1,14722E-27	-5639,96	
Max value	4,400169	1,898301918	5606,900478	19051,70429	19520,04	[N/m]
Min value	-4,40017	-1,909495463	-5639,962178	-19051,70429	-19357	[N/m]
				Max force	39040,08	[N]

(Projected lenght: 2m)





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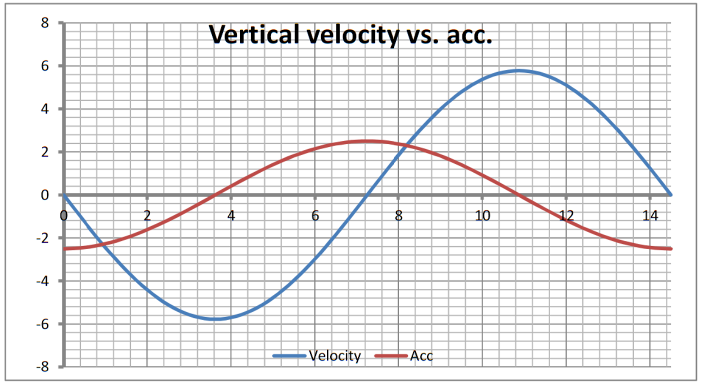
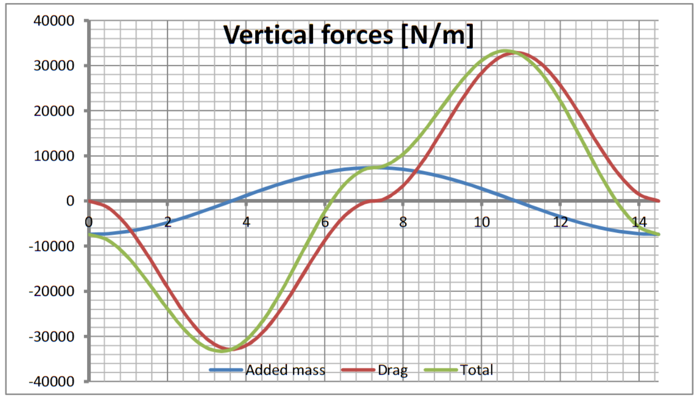
Vertical force on clamp 6				Comments
Trough-to-crest wave height	H	24,3	[m]	
Wave period	T	14,5	[s]	
Wave number	k	0,02026834	[1/m]	
Mean water depth	d	73,8	[m]	
Wave lenght	λ	310	[m]	RP-C205 Fig3-3
Distance from mean surface	z	4,2	[m]	
Distance from propagation	x	0	[m]	
Fluid desity	ρ	1025	[kg/m3]	
Added mass coefficient	Ca	0,801		RP-C205 A-D
Drag coefficient	Cd	2,4		Assumed
Slamming coefficient	Cs	5,15		RP-C205 8.6.1.2
Area	A	1,6	[m2]	(0,8*2)
Diameter	D	0,8	[m]	

$\frac{\pi H}{T}\frac{\sinh[k(z+d)]}{\sinh(kd)}\sin\theta$ $\quad -\frac{2\pi^2 H}{T^2}\frac{\sinh[k(z+d)]}{\sinh(kd)}\cos\theta$

t	w	w'	Added mass	Drag	Total	
0	0	-2,504663229	-7397,8735	0	-7397,87	
0,5	-1,24256	-2,446105595	-7224,915328	-1519,244027	-8744,16	
1	-2,42701	-2,273170781	-6714,128146	-5796,145126	-12510,3	
1,5	-3,49798	-1,993945029	-5889,395794	-12040,12172	-17929,5	
2	-4,40539	-1,621484622	-4789,28184	-19096,97997	-23886,3	
2,5	-5,10681	-1,173205398	-3465,22639	-25662,26556	-29127,5	
3	-5,56944	-0,670068392	-1979,140806	-30522,39095	-32501,5	
3,5	-5,77165	-0,135599734	-400,5127971	-32778,96605	-33179,5	
4	-5,70398	0,405209418	1196,842745	-32014,86484	-30818	
4,5	-5,3696	0,927071427	2738,235251	-28371,3308	-25633,1	
5	-4,78415	1,405584607	4151,590919	-22521,86812	-18370,3	
5,5	-3,97499	1,818374213	5370,822811	-15547,74508	-10176,9	
6	-2,97997	2,146138662	6338,920997	-8738,122462	-2399,2	
6,5	-1,8456	2,373552052	7010,618282	-3351,753299	3658,865	
7	-0,62494	2,489980786	7354,506848	-384,3034069	6970,203	
7,5	0,624942	2,489980786	7354,506848	384,3034069	7738,81	
8	1,845604	2,373552052	7010,618282	3351,753299	10362,37	
8,5	2,979967	2,146138662	6338,920997	8738,122462	15077,04	
9	3,974991	1,818374213	5370,822811	15547,74508	20918,57	
9,5	4,784149	1,405584607	4151,590919	22521,86812	26673,46	
10	5,369605	0,927071427	2738,235251	28371,3308	31109,57	
10,5	5,703984	0,405209418	1196,842745	32014,86484	33211,71	
11	5,771651	-0,135599734	-400,5127971	32778,96605	32378,45	
11,5	5,569443	-0,670068392	-1979,140806	30522,39095	28543,25	
12	5,106813	-1,173205398	-3465,22639	25662,26556	22197,04	
12,5	4,405394	-1,621484622	-4789,28184	19096,97997	14307,7	
13	3,497985	-1,993945029	-5889,395794	12040,12172	6150,726	
13,5	2,427013	-2,273170781	-6714,128146	5796,145126	-917,983	
14	1,242557	-2,446105595	-7224,915328	1519,244027	-5705,67	
14,5	1,42E-15	-2,504663229	-7397,8735	1,97382E-27	-7397,87	
Max value	5,771651	2,489980786	7354,506848	32778,96605	33211,71	[N/m]
Min value	-5,77165	-2,504663229	-7397,8735	-32778,96605	-33179,5	[N/m]
				Max force	66423,42	[N]

(Projected lenght: 2m)





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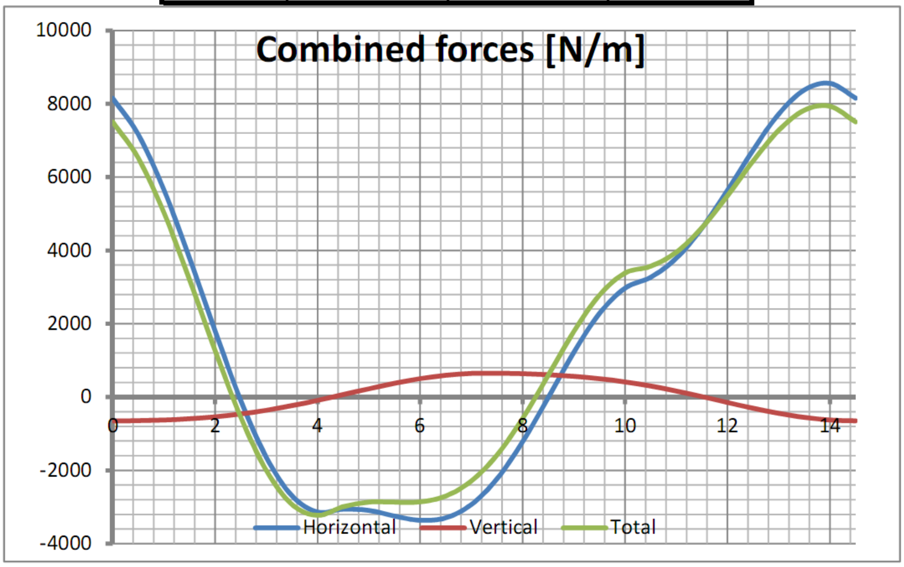
Combined force on clamp 1			
t	Horizontal	Vertical	Total
0	8153,940027	-648,8239792	7505,11605
0,5	7160,345868	-642,9062866	6517,43958
1	5653,085162	-624,1523784	5028,93278
1,5	3792,589565	-589,8427112	3202,74685
2	1797,180075	-536,3309942	1260,84908
2,5	-91,41697607	-460,1852489	-551,602225
3	-1646,808674	-359,4452034	-2006,25388
3,5	-2694,046159	-234,7344608	-2928,78062
4	-3136,700409	-89,9867981	-3226,68721
4,5	-3058,701919	67,38701064	-2991,31491
5	-3092,713652	226,9644856	-2865,74917
5,5	-3244,993994	376,3651361	-2868,62886
6	-3361,739408	502,7385993	-2859,00081
6,5	-3294,26778	594,4495664	-2699,81821
7	-2932,445328	642,6803258	-2289,765
7,5	-2230,777648	647,3607646	-1583,41688
8	-1222,07394	635,2706363	-586,803304
8,5	-15,91288856	609,160366	593,247477
9	1218,018074	565,7214317	1783,73951
9,5	2278,798482	501,258764	2780,05725
10	2970,144343	412,9220109	3383,06635
10,5	3267,577831	299,9228756	3567,50071
11	3786,207125	164,4812166	3950,68834
11,5	4606,410214	12,28760115	4618,69782
12	5642,37395	-147,6440078	5494,72994
12,5	6743,437348	-303,7484965	6439,68885
13	7720,031693	-443,2058301	7276,82586
13,5	8378,069315	-553,561012	7824,5083
14	8555,454816	-624,4033835	7931,05143
14,5	8153,940027	-648,8239792	7505,11605



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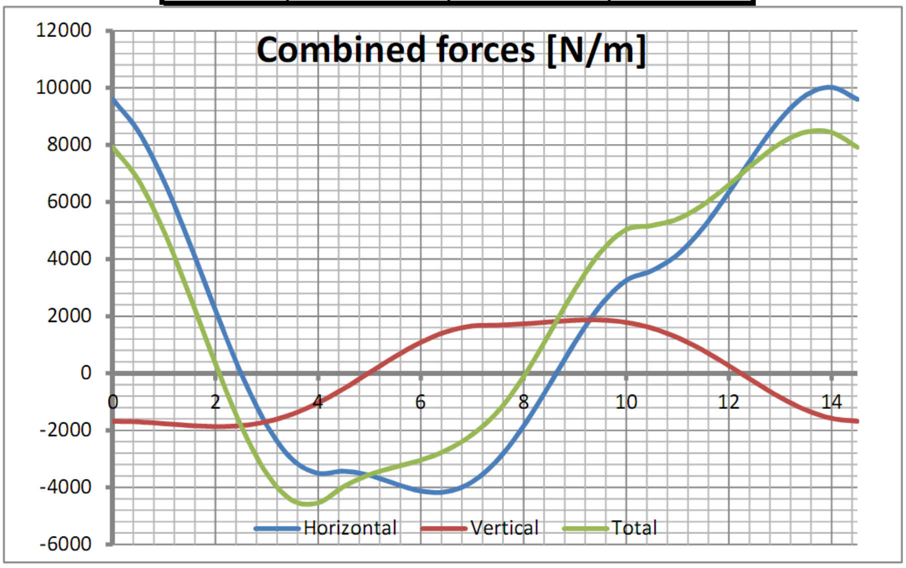
Combined force on clamp 2			
t	Horizontal	Vertical	Total
0	9596,742944	-1680,836149	7915,9068
0,5	8467,763026	-1703,627017	6764,13601
1	6719,067902	-1762,360214	4956,70769
1,5	4542,918329	-1830,153088	2712,76524
2	2202,381745	-1868,598337	333,783407
2,5	-10,78706682	-1836,073485	-1846,86055
3	-1823,488673	-1697,048692	-3520,53737
3,5	-3025,401849	-1430,596872	-4455,99872
4	-3502,027865	-1036,442214	-4538,47008
4,5	-3430,974933	-537,3270954	-3968,30203
5	-3575,612114	22,84842045	-3552,76369
5,5	-3871,888308	584,8801724	-3287,00814
6	-4125,77354	1083,130272	-3042,64327
6,5	-4149,469854	1455,871536	-2693,59832
7	-3802,712418	1655,277451	-2147,43497
7,5	-3025,051173	1686,68858	-1338,36259
8	-1852,848694	1729,827878	-123,020817
8,5	-417,5799191	1797,34276	1379,76284
9	1074,486762	1855,678761	2930,16552
9,5	2377,657405	1863,678591	4241,336
10	3250,820767	1781,610279	5032,43105
10,5	3595,860678	1580,30027	5176,16095
11	4156,690155	1248,599603	5405,28976
11,5	5106,980153	797,7060878	5904,68624
12	6343,997563	261,4378062	6605,43537
12,5	7684,33951	-307,7022023	7376,63731
13	8895,718978	-846,0509172	8049,66806
13,5	9739,179314	-1288,610933	8450,56838
14	10013,96815	-1579,451251	8434,5169
14,5	9596,742944	-1680,836149	7915,9068



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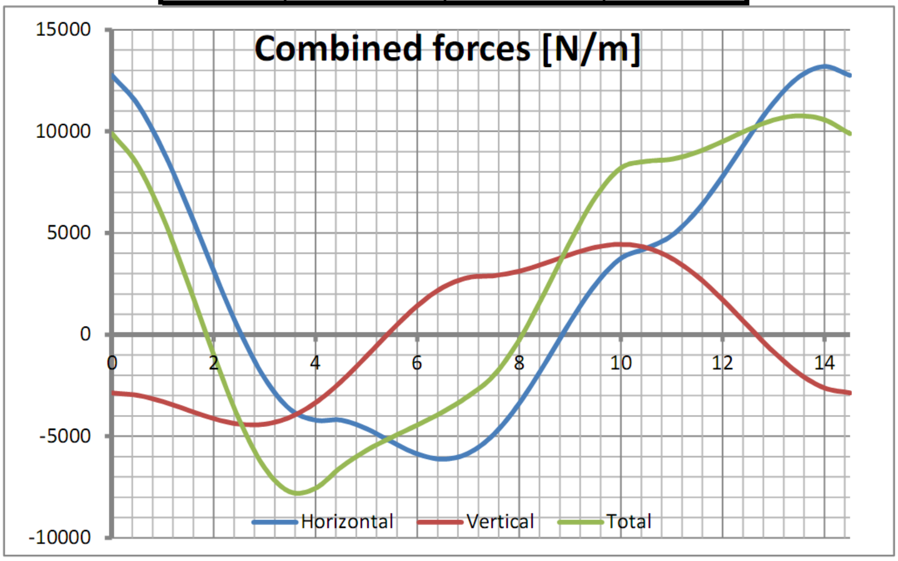
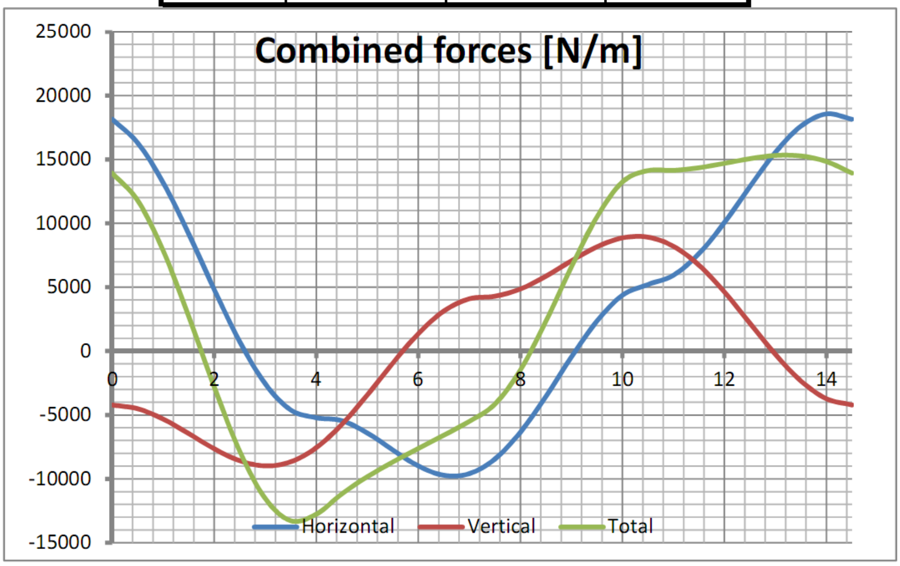
Combined force on clamp 3			
t	Horizontal	Vertical	Total
0	12753,57949	-2869,410503	9884,16898
0,5	11344,51085	-2983,268146	8361,24271
1	9080,177033	-3294,530765	5785,64627
1,5	6223,153749	-3718,303445	2504,8503
2	3135,800345	-4132,078651	-996,278305
2,5	221,0286737	-4400,447154	-4179,41848
3	-2144,329486	-4402,883497	-6547,21298
3,5	-3671,606333	-4059,341059	-7730,94739
4	-4206,711231	-3348,770438	-7555,48167
4,5	-4204,505219	-2316,964021	-6521,46924
5	-4625,492905	-1072,091796	-5697,5847
5,5	-5274,887716	231,4334264	-5043,45429
6	-5866,805306	1417,959411	-4448,84589
6,5	-6124,075899	2320,010156	-3804,06574
7	-5837,322898	2806,819132	-3030,50377
7,5	-4911,232507	2898,36066	-2012,87185
8	-3389,107685	3118,40177	-270,705915
8,5	-1450,843341	3499,390551	2048,54721
9	615,5825259	3934,924754	4550,50728
9,5	2464,053772	4292,643916	6756,69769
10	3752,618569	4441,120642	8193,73921
10,5	4245,923405	4277,208359	8523,13176
11	4881,303349	3748,647553	8629,9509
11,5	6108,93069	2867,586248	8976,51694
12	7788,726073	1712,334955	9501,06103
12,5	9664,077847	416,8446399	10080,9225
13	11406,75635	-850,3321641	10556,4242
13,5	12676,72524	-1913,882118	10762,8431
14	13185,83407	-2621,382415	10564,4517
14,5	12753,57949	-2869,410503	9884,16898



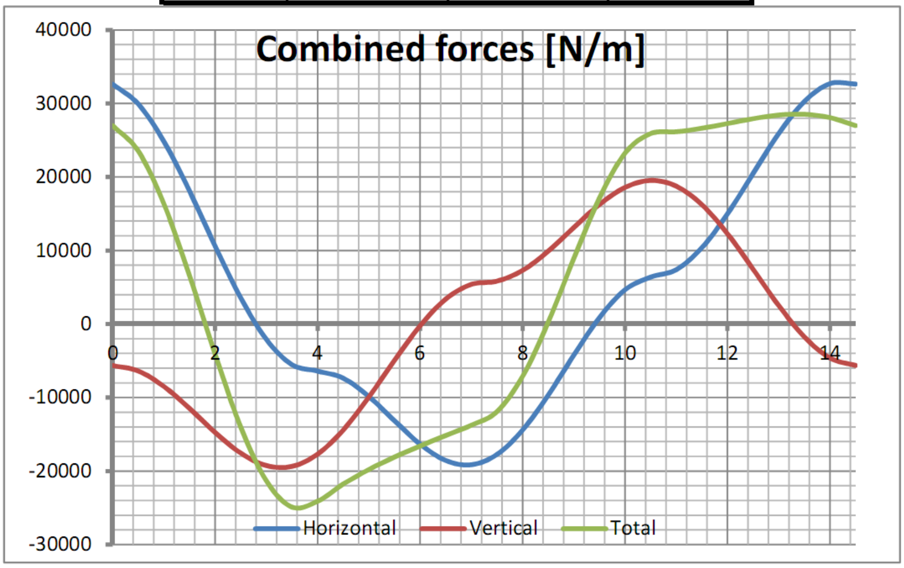
D

Combined force on clamp 4			
t	Horizontal	Vertical	Total
0	18147,31069	-4217,33646	13929,9742
0,5	16293,71279	-4509,607709	11784,1051
1	13174,9751	-5318,7798	7856,1953
1,5	9175,232524	-6455,06792	2720,1646
2	4829,418956	-7643,505833	-2814,08688
2,5	733,943438	-8577,808956	-7843,86552
3	-2553,880635	-8981,04025	-11534,9209
3,5	-4609,515186	-8661,675574	-13271,1908
4	-5211,106106	-7554,476948	-12765,5831
4,5	-5439,681171	-5738,362573	-11178,0437
5	-6405,184732	-3427,698637	-9832,88337
5,5	-7738,177861	-938,3476757	-8676,52554
6	-8987,737609	1365,515876	-7622,22173
6,5	-9716,008135	3134,235104	-6581,77303
7	-9588,811273	4093,740893	-5495,07038
7,5	-8446,7502	4291,487613	-4155,26259
8	-6343,226421	4858,909436	-1484,31698
8,5	-3541,94278	5861,794144	2319,85136
9	-474,00923	7061,882192	6587,87296
9,5	2337,69325	8161,12798	10498,8212
10	4373,098904	8860,356849	13233,4558
10,5	5212,741372	8919,055173	14131,7965
11	5937,992172	8205,031588	14143,0238
11,5	7624,096882	6724,526218	14348,6231
12	10066,4802	4626,936965	14693,4172
12,5	12880,13591	2183,014268	15063,1502
13	15567,6871	-259,7167035	15307,9704
13,5	17610,26322	-2336,322015	15273,9412
14	18564,44531	-3727,867246	14836,5781
14,5	18147,31069	-4217,33646	13929,9742



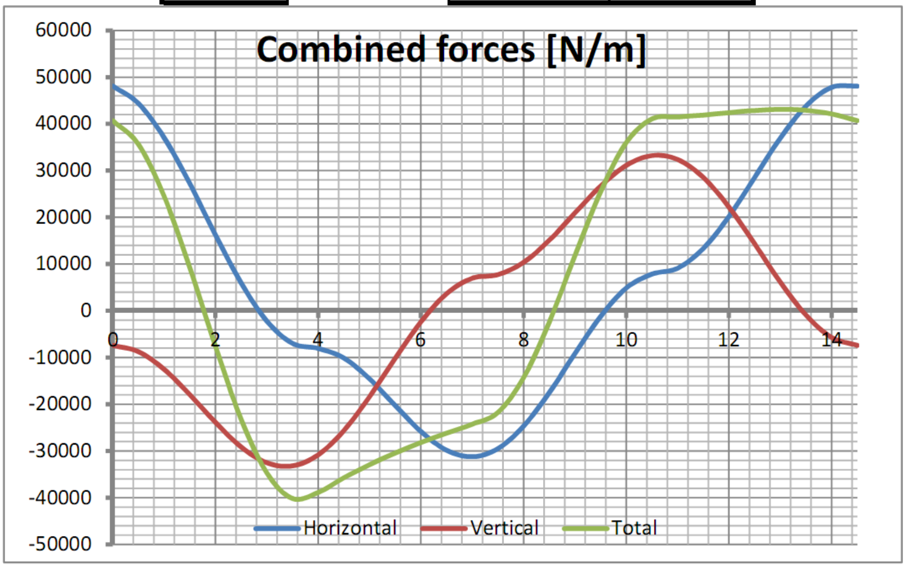
D

Combined force on clamp 5			
t	Horizontal	Vertical	Total
0	32630,60418	-5639,962178	26990,642
0,5	29912,2676	-6391,114008	23521,1536
1	24828,64489	-8487,511241	16341,1336
1,5	18069,78966	-11487,86261	6581,92705
2	10612,13646	-14750,73055	-4138,59409
2,5	3550,769793	-17557,16027	-14006,3905
3	-2089,747246	-19248,99337	-21338,7406
3,5	-5531,636221	-19357,04569	-24888,6819
4	-6402,872338	-17695,15106	-24098,0234
4,5	-7367,003876	-14402,34495	-21769,3488
5	-9860,068115	-9925,027031	-19785,0951
5,5	-13146,82015	-4942,032317	-18088,8525
6	-16335,95273	-246,1064513	-16582,0592
6,5	-18558,12166	3396,630821	-15161,4908
7	-19139,72818	5383,536665	-13756,1915
7,5	-17739,72285	5830,264292	-11909,4586
8	-14423,56837	7292,825266	-7130,74311
8,5	-9660,178593	9911,390583	251,21199
9	-4241,976947	13131,20655	8889,2296
9,5	857,4635849	16255,17468	17112,6383
10	4662,076449	18577,47534	23239,5518
10,5	6375,290186	19520,03974	25895,3299
11	7398,115824	18746,3629	26144,4787
11,5	10387,01348	16231,29395	26618,3074
12	14991,13974	12273,54849	27264,6882
12,5	20481,17665	7448,262227	27929,4389
13	25906,03473	2507,993044	28414,0278
13,5	30265,68074	-1749,870841	28515,8099
14	32695,86447	-4625,091986	28070,7725
14,5	32630,60418	-5639,962178	26990,642



D

Combined force on clamp 6			
t	Horizontal	Vertical	Total
0	48096,44347	-7397,8735	40698,57
0,5	44362,99824	-8744,159356	35618,8389
1	37047,71671	-12510,27327	24537,4434
1,5	27192,33474	-17929,51751	9262,81723
2	16279,16501	-23886,26181	-7607,0968
2,5	5972,964871	-29127,49195	-23154,5271
3	-2170,308561	-32501,53176	-34671,8403
3,5	-6974,790624	-33179,47885	-40154,2695
4	-8045,45261	-30818,0221	-38863,4747
4,5	-10090,32424	-25633,09555	-35723,4198
5	-14548,79009	-18370,2772	-32919,0673
5,5	-20255,43195	-10176,92227	-30432,3542
6	-25802,47903	-2399,201465	-28201,6805
6,5	-29816,53449	3658,864983	-26157,6695
7	-31228,72025	6970,203441	-24258,5168
7,5	-29487,54287	7738,810255	-21748,7326
8	-24674,41787	10362,37158	-14312,0463
8,5	-17499,86282	15077,04346	-2422,81936
9	-9180,537271	20918,56789	11738,0306
9,5	-1219,466695	26673,45904	25453,9923
10	4870,163517	31109,56605	35979,7296
10,5	7846,663729	33211,70759	41058,3713
11	9105,856602	32378,45325	41484,3099
11,5	13346,95636	28543,25015	41890,2065
12	20201,27742	22197,03917	42398,3166
12,5	28553,22511	14307,69813	42860,9232
13	36938,22099	6150,725923	43088,9469
13,5	43809,72229	-917,9830204	42891,7393
14	47824,93929	-5705,671301	42119,268
14,5	48096,44347	-7397,8735	40698,57



D

Appendix E

Horizontal and vertical load combinations

(1 Pages)

E

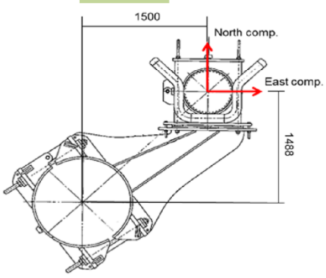
Elevation	Load	Riser loads [kN] F_Y (North)	F_X (East)	Use FY values are used and applyed on 45 deg. F_Y values	Combinded riser only 135° N component	135° E component	315° N component	315° E component
Elevation	Functional loads	-13	6					
78000	Installation loads	±6	±1	6	-4,24	4,24	4,24	-4,24
	Max. wave load	±131	±137	131	-92,63	92,63	92,63	-92,63
Elevation	Functional loads	29	-4					
66000	Installation loads	±19	±1	19	-13,44	13,44	13,44	-13,44
	Max. wave load	±166	±169	166	-117,38	117,38	117,38	-117,38
Elevation	Functional loads	-32	2					
54000	Installation loads	±27	±5	27	-19,09	19,09	19,09	-19,09
	Max. wave load	±151	±146	151	-106,77	106,77	106,77	-106,77
Elevation	Functional loads	-15	-5					
40000	Installation loads	±23	±13	23	-16,26	16,26	16,26	-16,26
	Max. wave load	±126	±118	126	-89,10	89,10	89,10	-89,10
Elevation	Functional loads	46	20					
25000	Installation loads	±14	±12	14	-9,90	9,90	9,90	-9,90
	Max. wave load	±89	±87	89	-62,93	62,93	62,93	-62,93
Elevation	Functional loads	-164	-72					
10000	Installation loads	±4	±4	4	-2,83	2,83	2,83	-2,83
	Max. wave load	±69	±66	69	-48,79	48,79	48,79	-48,79

ULS-a	
Functional	1,3
Environmental	0,7

ULS-a Riser only Elevation	135° N	135° E	315° N	315° E
78000	-87,26	78,16	53,46	-62,56
66000	-61,93	94,43	137,33	-104,83
54000	-141,16	102,16	57,96	-96,96
40000	-103,01	77,01	64,01	-90,01
25000	2,88	82,92	116,72	-30,92
10000	-251,03	-55,77	-175,37	-131,43

Moment arms [m]	
N-comp	1,5
E-comp	1,488

Pos. clockwise



Sum of moments ULS-a 135°	315°
247,2	-173,3
233,4	-362,0
363,8	-231,2
269,1	-229,9
119,1	-221,1
293,6	67,5

Riser loads only

ULS-b	
Functional	1
Environmental	1,3

ULS-b Riser only Elevation	135° N	135° E	315° N	315° E
78000	-137,66	130,66	111,66	-118,66
66000	-137,03	162,03	195,03	-170,03
54000	-189,90	159,90	125,90	-155,90
40000	-147,09	127,09	117,09	-137,09
25000	-45,71	111,71	137,71	-71,71
10000	-230,26	-5,74	-97,74	-138,26

Sum of moments ULS-b 135°	315°
400,9	-344,1
446,6	-545,5
522,8	-420,8
409,7	-379,6
234,8	-313,3
336,8	-59,1

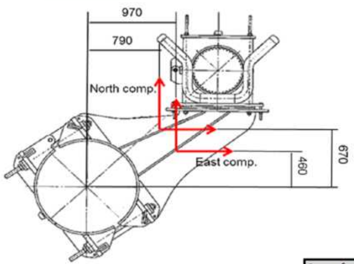
Elevation	Wave clamp loads [kN]	155° Comp from N	155° Comp from E	322° Comp from N	322° Comp from E
78000	96,2	-87,19	40,66	75,81	-59,23
66000	65,4	-59,27	27,64	51,54	-40,26
54000	37,1	-33,62	15,68	29,24	-22,84
40000	26,4	-23,93	11,16	20,80	-16,25
25000	20	-18,13	8,45	15,76	-12,31
10000	17,1	-15,50	7,23	13,47	-10,53

ULS-a	
Environ	0,7

ULS-a Clamp only Elevation	155° N	155° E	322° N	322° E
78000	-61,03	28,46	53,06	-41,46
66000	-41,49	19,35	36,08	-28,18
54000	-23,54	10,98	20,46	-15,99
40000	-16,75	7,81	14,56	-11,38
25000	-12,69	5,92	11,03	-8,62
10000	-10,85	5,06	9,43	-7,37

Moment arms		[m]
155	N-comp	0,97
	E-comp	0,46
322	N-comp	0,79
	E-comp	0,67

Pos. Clockwise



Sum of moments ULS-a 155°	322°
72,3	-14,1
49,1	-9,6
27,9	-5,5
19,8	-3,9
15,0	-2,9
12,9	-2,5

Clamp loads only

ULS-b	
Environ	1,3

ULS-b Clamp only Elevation	155° N	155° E	322° N	322° E
78000	-113,34	52,85	98,55	-76,99
66000	-77,05	35,93	67,00	-52,34
54000	-43,71	20,38	38,01	-29,69
40000	-31,10	14,50	27,04	-21,13
25000	-23,56	10,99	20,49	-16,01
10000	-20,15	9,39	17,52	-13,69

Sum of moments ULS-b 155°	322°
134,3	-26,3
91,3	-17,9
51,8	-10,1
36,8	-7,2
27,9	-5,5
23,9	-4,7

Sum of moments ULS-a 135°	315°
319,5	-187,4
282,6	-371,6
391,6	-236,7
288,9	-233,8
134,1	-224,0
306,4	65,0

Combined

Sum of moments ULS-b 135°	315°
535,2	-370,3
537,9	-563,4
574,5	-431,0
446,6	-386,8
262,7	-318,7
360,7	-63,8

E

Support Elevation	Load	Riser loads [kN] F_z (Vertical)	F_z values
Elevation	Functional loads	-2	
78000	Installation loads	±1	1
	Max. wave load	±16	16
Elevation	Functional loads	4	
66000	Installation loads	±3	3
	Max. wave load	±20	20
Elevation	Functional loads	-4	
54000	Installation loads	±4	4
	Max. wave load	±19	19
Elevation	Functional loads	-2	
40000	Installation loads	±3	3
	Max. wave load	±15	15
Elevation	Functional loads	6	
25000	Installation loads	±2	2
	Max. wave load	±11	11
Elevation	Functional loads	-21	
10000	Installation loads	0	0
	Max. wave load	±9	9

ULS-a	
Functional	1,3
Environmental	0,7

ULS-a Riser only (Vertical)			ULS-a Riser only (Parallel)		Sum of moments ULS-a	
Elevation	Up	Down	Up	Down	Up	Down
78000	9,9	-15,1	9,83	-14,99	20,76	-31,67
66000	23,1	-12,7	22,93	-12,61	48,45	-26,64
54000	13,3	-23,7	13,20	-23,52	27,89	-49,70
40000	11,8	-17	11,71	-16,87	24,75	-35,65
25000	18,1	-2,5	17,97	-2,48	37,96	-5,24
10000	-21	-33,6	-20,84	-33,35	-44,04	-70,47

Moment arm [m]
2,113

Riser only

ULS-b	
Functional	1
Environmental	1,3

ULS-b Riser only (Vertical)			ULS-b Riser only (Parallel)		Sum of moments ULS-b	
Elevation	Up	Down	Up	Down	Up	Down
78000	19,8	-23,8	19,65	-23,62	41,53	-49,91
66000	33	-25	32,75	-24,81	69,21	-52,43
54000	24,7	-32,7	24,52	-32,46	51,80	-68,58
40000	20,5	-24,5	20,35	-24,32	42,99	-51,38
25000	22,3	-10,3	22,13	-10,22	46,77	-21,60
10000	-9,3	-32,7	-9,23	-32,46	-19,50	-68,58

Moment arm [m]
2,113

E

Elevation	Wave clamp loads [kN]
78000	-66,4
66000	-39
54000	-18
40000	-8,9
25000	-3,7
10000	-1,3

ULS-a		ULS-a Wave clamp load (Parallel)		Moment arm [m]	Sum of moments ULS-a
Environmental	0,7	Elevation	Load [kN]	1,076	
		78000	-46,48		-50,01
		66000	-27,3		-29,37
		54000	-12,6		-13,56
		40000	-6,23		-6,70
		25000	-2,59		-2,79
		10000	-0,91		-0,98
					Clamp wave only

ULS-b		ULS-b Wave clamp load (Parallel)		Moment arm [m]	Sum of moments ULS-b
Environmental	1,3	Elevation	Load [kN]	1,076	
		78000	-86,32		-92,88
		66000	-50,7		-54,55
		54000	-23,4		-25,18
		40000	-11,57		-12,45
		25000	-4,81		-5,18
		10000	-1,69		-1,82

Elevation	Self-weight [kN]
78000	-36
66000	-31,5
54000	-31,5
40000	-31,5
25000	-31,5
10000	-36

ULS-a	ULS-a Self-weight (Vertical)	ULS-a Self-weight (Parallel)	Moment arm [m]	Sum of moments ULS-a

E

Functinal 1,3

Elevation	Load [kN]		Moment arm [m]	
			0,747	
78000	-46,8	-46,45		-34,70
66000	-40,95	-40,64		-30,36
54000	-40,95	-40,64		-30,36
40000	-40,95	-40,64		-30,36
25000	-40,95	-40,64		-30,36
10000	-46,8	-46,45		-34,70

Self-wight

ULS-b

Functinal 1

ULS-b Self-weight (Vertical)		ULS-b Self-weight (Parallel)	Moment arm [m]	Sum of moments ULS-b
Elevation	Load [kN]		0,747	
78000	-36	-35,73		-26,69
66000	-31,5	-31,27		-23,36
54000	-31,5	-31,27		-23,36
40000	-31,5	-31,27		-23,36
25000	-31,5	-31,27		-23,36
10000	-36	-35,73		-26,69

Elevation	Sum of moments ULS-a	
	Up	Down
78000	-63,95	-116,38
66000	-11,29	-86,37
54000	-16,03	-93,62
40000	-12,32	-72,72
25000	4,81	-38,39
10000	-79,72	-106,15

Combined

Elevation	Sum of moments ULS-b	
	Up	Down
78000	-78,05	-169,49
66000	-8,70	-130,34
54000	3,27	-117,11
40000	7,19	-87,19
25000	18,24	-50,13
10000	-48,01	-97,09

E

Appendix F

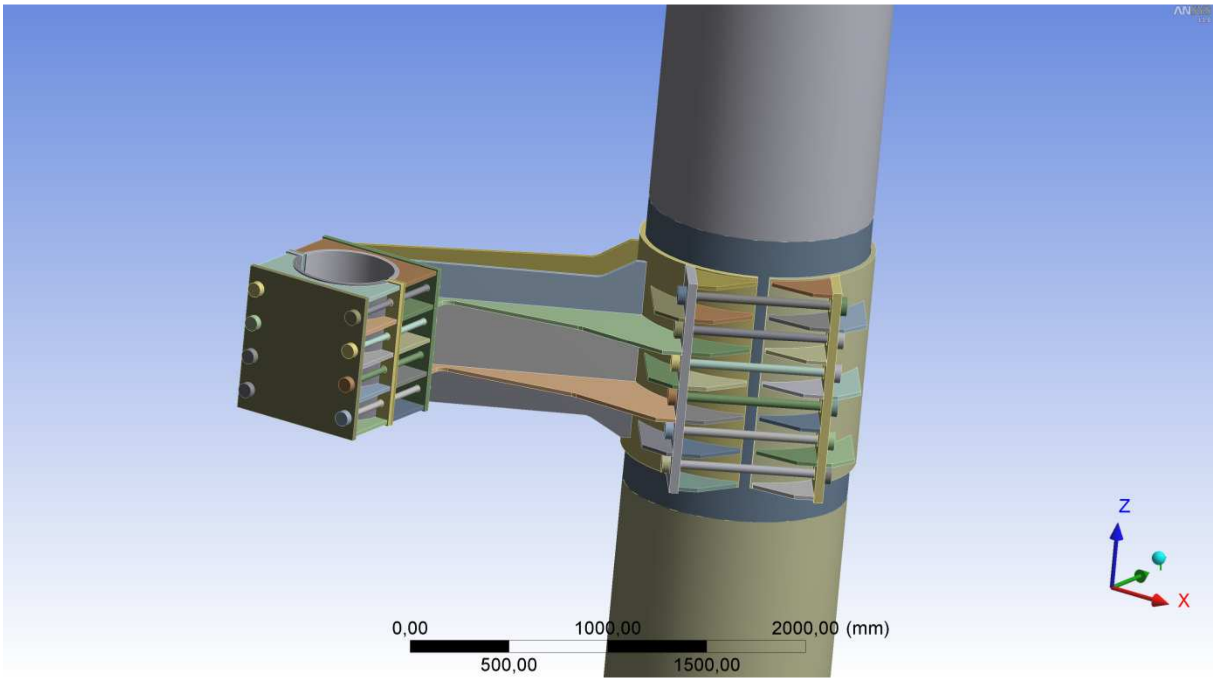
ANSYS print-outs

(1 Pages)

F

Bolt check

First Saved	Thursday, April 28, 2011
Last Saved	Saturday, May 21, 2011
Product Version	13.0 Release



F

Contents

F

Units

TABLE 1

Unit System	Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Bolt check (C4)

Geometry

TABLE 2
Bolt check (C4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Documents and Settings\SS7N0605\My Documents\ANSYS final\Analysis Clamp

	4_files\dp0\SYS-3\DM\SYS-3.agdb
Type	DesignModeler
Length Unit	Millimeters
Element Control	Program Controlled
Display Style	Part Color
Bounding Box	
Length X	2669,6 mm
Length Y	2739,6 mm
Length Z	7500, mm
Properties	
Volume	1,0542e+009 mm³
Mass	8275,2 kg
Scale Factor Value	1,
Statistics	
Bodies	135
Active Bodies	135
Nodes	227755
Elements	34990
Mesh Metric	Skewness
Min	1,34222502290619E-07
Max	0,701342273938782
Average	0,263600745331541
Standard Deviation	0,204632867506524
Preferences	
Parameter Processing	Yes
Personal Parameter Key	DS
CAD Attribute Transfer	No
Named Selection Processing	No
Material Properties Transfer	No
CAD Associativity	Yes
Import Coordinate Systems	No
Reader Save Part File	No
Import Using Instances	Yes
Do Smart Update	No
Attach File Via Temp File	Yes
Temporary Directory	C:\Documents and Settings\SS7N0605\Local Settings\Temp
Analysis Type	3-D
Enclosure and Symmetry Processing	Yes

TABLE 3
Bolt check (C4) > Geometry > Parts

Object Name	*Part 19*	*Part 20*	*Part 21*	*Part 22*	*Part 23*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	336,33 mm	235,48 mm		408,5 mm	235,48 mm
Length Y	290,6 mm	483,39 mm		324,69 mm	483,39 mm
Length Z	20, mm				
Properties					

F

Volume	9,1092e+005 mm³	1,0129e+006 mm³			
Mass	7,1508 kg	7,9516 kg			
Centroid X	564,14 mm	695,7 mm		61,271 mm	695,7 mm
Centroid Y	-379, mm	-161,62 mm		711,6 mm	-161,62 mm
Centroid Z	-540, mm	360, mm	-360, mm	-1,1288e-015 mm	1,5689e-015 mm
Moment of Inertia Ip1	22793 kg·mm²	95549 kg·mm²		12352 kg·mm²	95549 kg·mm²
Moment of Inertia Ip2	42679 kg·mm²	12352 kg·mm²		95549 kg·mm²	12352 kg·mm²
Moment of Inertia Ip3	64995 kg·mm²	1,0737e+005 kg·mm²			
Statistics					
Nodes	518	932			
Elements	65	117			
Mesh Metric	Skewness				
Min	0,014530416356964	4,21646506874607E-02		4,21644331178599E-02	4,21646506874607E-02
Max	0,512002193506522	0,701342273938782		0,701342177947464	0,701342273938782
Average	0,165039530216544	0,485150395565254		0,485150428159298	0,485150395565255
Standard Deviation	0,120344254612298	0,140667569688933		0,140667649270927	0,140667569688932

TABLE 4
Bolt check (C4) > Geometry > Parts

Object Name	*Part 24*	*Part 25*	*Part 26*	*Part 27*	*Part 28*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	929,21 mm	215,6 mm	327,63 mm		
Length Y	1068,6 mm	246,64 mm	302,57 mm		
Length Z	1120, mm		20, mm		
Properties					
Volume	5,0068e+007 mm³	1,3534e+007 mm³	9,1092e+005 mm³		
Mass	393,03 kg	106,24 kg	7,1508 kg		
Centroid X	-312,08 mm	65,168 mm	186,12 mm		
Centroid Y	-226,74 mm	-715,75 mm	-653,64 mm		
Centroid Z	4,7978e-013 mm	9,4673e-006 mm	-9,6753e-016 mm	-180, mm	-360, mm
Moment of Inertia Ip1	1,06e+008 kg·mm²	1,199e+007 kg·mm²	22793 kg·mm²		
Moment of Inertia Ip2	5,2331e+007 kg·mm²	1,1222e+007 kg·mm²	42679 kg·mm²		
Moment of Inertia Ip3	7,657e+007 kg·mm²	8,0408e+005 kg·mm²	64995 kg·mm²		
Statistics					
Nodes	10107	4357	518		
Elements	1748	724	65		
Mesh Metric	Skewness				
Min	2,71679800190106E-02	1,16506240940307E-02	1,45303156343443E-02	1,45303156343413E-02	
Max	5,86283932118858E-02	0,556331699641993	0,512002513503947		
Average	4,27387397704627E-	0,221742520621231	0,165039542186167	0,165039542186164	0,165039542186165

	02				
Standard Deviation	9,46938275428752E-03	0,128803220686873	0,120344267704764	0,120344267704762	

TABLE 5
Bolt check (C4) > Geometry > Parts

Object Name	*Part 29*	*Part 30*	*Part 31*	*Part 32*	*Part 33*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	327,63 mm				408,5 mm
Length Y	302,57 mm				324,69 mm
Length Z	20, mm				
Properties					
Volume	9,1092e+005 mm³				1,0129e+006 mm³
Mass	7,1508 kg				7,9516 kg
Centroid X	186,12 mm				-61,271 mm
Centroid Y	-653,64 mm				-711,6 mm
Centroid Z	180, mm	360, mm	-540, mm	540, mm	-360, mm
Moment of Inertia Ip1	22793 kg·mm²				12352 kg·mm²
Moment of Inertia Ip2	42679 kg·mm²				95549 kg·mm²
Moment of Inertia Ip3	64995 kg·mm²				1,0737e+005 kg·mm²
Statistics					
Nodes	518				932
Elements	65				117
Mesh Metric	Skewness				
Min	1,45303156343438E-02	1,45303156343455E-02	1,45303156343444E-02	1,45303156343455E-02	4,21644331178634E-02
Max	0,512002513503939	0,512002513503932	0,512002513503946	0,512002513503932	0,70134217794746
Average	0,165039542186167	0,165039542186166	0,165039542186164	0,165039542186166	0,485150428163655
Standard Deviation	0,120344267704763		0,120344267704762	0,120344267704763	0,14066764927183

TABLE 6
Bolt check (C4) > Geometry > Parts

Object Name	*Part 34*	*Part 35*	*Part 36*	*Part 37*	*Part 38*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				

Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	408,5 mm	195,11 mm	336,33 mm		
Length Y	324,69 mm	273,09 mm	290,6 mm		
Length Z	20, mm	1120, mm	20, mm		
Properties					
Volume	1,0129e+006 mm³	1,3534e+007 mm³	9,1092e+005 mm³		
Mass	7,9516 kg	106,24 kg	7,1508 kg		
Centroid X	-61,271 mm	-660,58 mm	-564,14 mm		
Centroid Y	-711,6 mm	283,16 mm	379, mm		
Centroid Z	360, mm	-2,4537e-006 mm	-2,9132e-015 mm	180, mm	360, mm
Moment of Inertia Ip1	12352 kg·mm²	1,199e+007 kg·mm²	22793 kg·mm²		
Moment of Inertia Ip2	95549 kg·mm²	1,1222e+007 kg·mm²	42679 kg·mm²		
Moment of Inertia Ip3	1,0737e+005 kg·mm²	8,0407e+005 kg·mm²	64995 kg·mm²		
Statistics					
Nodes	932	4357	518		
Elements	117	724	65		
Mesh Metric	Skewness				
Min	4,21644331178634E-02	0,01165068797102	1,45304163569723E-02	1,45304163569712E-02	1,45304163569723E-02
Max	0,701342177947461	0,556331711646928	0,512002193506532	0,512002193506526	
Average	0,485150428163655	0,221742552358315	0,165039530216549		
Standard Deviation	0,140667649271831	0,128803234299546	0,120344254612296	0,120344254612295	0,120344254612296

TABLE 7
Bolt check (C4) > Geometry > Parts

Object Name	*Part 39*	*Part 40*	*Part 41*	*Part 42*	*Part 43*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					

Length X	336,33 mm				235,48 mm
Length Y	290,6 mm				483,39 mm
Length Z	20, mm				
Properties					
Volume	9,1092e+005 mm³				1,0129e+006 mm³
Mass	7,1508 kg				7,9516 kg
Centroid X	-564,14 mm				-695,7 mm
Centroid Y	379, mm				161,62 mm
Centroid Z	-180, mm	-360, mm	540, mm	-540, mm	360, mm
Moment of Inertia Ip1	22793 kg·mm²				95549 kg·mm²
Moment of Inertia Ip2	42679 kg·mm²				12352 kg·mm²
Moment of Inertia Ip3	64995 kg·mm²				1,0737e+005 kg·mm²
Statistics					
Nodes	518				932
Elements	65				117
Mesh Metric	Skewness				
Min	1,45304163569674E-02	1,45304163569723E-02	1,45304163569712E-02	1,45304163569723E-02	4,21646506874514E-02
Max	0,512002193506529	0,512002193506526			0,701342273938776
Average	0,165039530216549				0,485150395565254
Standard Deviation	0,120344254612296	0,120344254612295		0,120344254612296	0,140667569688932

TABLE 8
Bolt check (C4) > Geometry > Parts

Object Name	*Part 44*	*Part 45*	*Part 46*	*Part 1*
State	Meshed			
Graphics Properties				
Visible	Yes			
Transparency	1			
Definition				
Suppressed	No			
Stiffness Behavior	Flexible			
Coordinate System	Default Coordinate System			
Reference Temperature	By Environment			
Material				
Assignment	Clamp steel			
Nonlinear Effects	Yes			
Thermal Strain Effects	Yes			
Bounding Box				
Length X	235,48 mm	408,5 mm	235,48 mm	929,21 mm
Length Y	483,39 mm	324,69 mm	483,39 mm	1068,6 mm
Length Z	20, mm			1120, mm
Properties				
Volume	1,0129e+006 mm³			5,0068e+007 mm³
Mass	7,9516 kg			393,03 kg
Centroid X	-695,7 mm	-61,271 mm	-695,7 mm	312,08 mm
Centroid Y	161,62 mm	-711,6 mm	161,62 mm	226,74 mm
Centroid Z	-360, mm	-4,7832e-016 mm	1,8368e-015 mm	1,1107e-013 mm
Moment of Inertia Ip1	95549 kg·mm²	12352 kg·mm²	95549 kg·mm²	1,06e+008 kg·mm²
Moment of Inertia Ip2	12352 kg·mm²	95549 kg·mm²	12352 kg·mm²	5,2331e+007 kg·mm²
Moment of Inertia Ip3	1,0737e+005 kg·mm²			7,657e+007 kg·mm²
Statistics				
Nodes	932			10107
Elements	117			1748
Mesh Metric	Skewness			
Min	4,21646506874514E-02	4,21644331178634E-02	4,21646506874514E-02	0,027167980019022
Max	0,701342273938782	0,701342177947461	0,701342273938776	5,86283932117944E-02
Average	0,485150395565254	0,485150428163655	0,485150395565254	0,042738738994393

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Standard Deviation	0,140667569688932	0,140667649271831	0,140667569688932	9,46938220017718E-03

TABLE 9
Bolt check (C4) > Geometry > Body Groups

Object Name	*Part 107*
State	Meshed
Graphics Properties	
Visible	Yes
Definition	
Suppressed	No
Assignment	Clamp steel
Coordinate System	Default Coordinate System
Bounding Box	
Length X	1143, mm
Length Y	1143, mm
Length Z	1500, mm
Properties	
Volume	1,3377e+008 mm³
Mass	1050,1 kg
Centroid X	8,8696e-002 mm
Centroid Y	5,9198e-014 mm
Centroid Z	1,4986e-013 mm
Moment of Inertia Ip1	3,5829e+008 kg·mm²
Moment of Inertia Ip2	3,5836e+008 kg·mm²
Moment of Inertia Ip3	3,2482e+008 kg·mm²
Statistics	
Nodes	15480
Elements	2160
Mesh Metric	Skewness
Min	2,77778071567026E-02
Max	2,77785598226894E-02
Average	2,77781025473718E-02
Standard Deviation	1,42767360555372E-07

TABLE 10
Bolt check (C4) > Geometry > Part 107 > Parts

Object Name	*Part 107*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Clamp steel
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	1143, mm
Length Y	1143, mm
Length Z	1500, mm
Properties	
Volume	1,3377e+008 mm³
Mass	1050,1 kg
Centroid X	8,8696e-002 mm
Centroid Y	5,9198e-014 mm
Centroid Z	1,4986e-013 mm
Moment of Inertia Ip1	3,5829e+008 kg·mm²

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Moment of Inertia Ip2	3,5836e+008 kg·mm²
Moment of Inertia Ip3	3,2482e+008 kg·mm²
Statistics	
Nodes	15480
Elements	2160
Mesh Metric	Skewness
Min	2,77778071567026E-02
Max	2,77785598226894E-02
Average	2,77781025473718E-02
Standard Deviation	1,42767360555372E-07

TABLE 11
Bolt check (C4) > Geometry > Parts

Object Name	*Part 110*	*Part 2*	*Part 3*	*Part 4*	*Part 5*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	700, mm	215,6 mm	327,63 mm		
Length Y	30, mm	246,64 mm	302,57 mm		
Length Z	760, mm	1120, mm	20, mm		
Properties					
Volume	1,5702e+007 mm³	1,3534e+007 mm³	9,1092e+005 mm³		
Mass	123,26 kg	106,24 kg	7,1508 kg		
Centroid X	-1500, mm	-65,168 mm	-186,12 mm		
Centroid Y	-1165,5 mm	715,75 mm	653,64 mm		
Centroid Z	2,5653e-012 mm	-4,8088e-006 mm	-2,2434e-015 mm	-180, mm	-360, mm
Moment of Inertia Ip1	5,9579e+006 kg·mm²	1,199e+007 kg·mm²	22793 kg·mm²		
Moment of Inertia Ip2	1,0891e+007 kg·mm²	1,1222e+007 kg·mm²	42679 kg·mm²		
Moment of Inertia Ip3	4,9515e+006 kg·mm²	8,0407e+005 kg·mm²	64995 kg·mm²		
Statistics					
Nodes	5624	4357	518		
Elements	978	724	65		
Mesh Metric	Skewness				
Min	9,3076260280272E-04	0,011650618861668	1,45303156343499E-02	1,45303156343448E-02	1,45303156343438E-02
Max	0,675486079914591	0,556331700654277	0,512002513503938		
Average	0,108166880821473	0,221742526456546	0,165039542186167		
Standard Deviation	0,129785120724642	0,128803227615819	0,120344267704764		

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TABLE 12
Bolt check (C4) > Geometry > Parts

Object Name	*Part 6*	*Part 7*	*Part 8*	*Part 9*	*Part 10*
State	Meshed				

Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	327,63 mm				408,5 mm
Length Y	302,57 mm				324,69 mm
Length Z	20, mm				
Properties					
Volume	9,1092e+005 mm³				1,0129e+006 mm³
Mass	7,1508 kg				7,9516 kg
Centroid X	-186,12 mm				61,271 mm
Centroid Y	653,64 mm				711,6 mm
Centroid Z	180, mm	360, mm	-540, mm	540, mm	-360, mm
Moment of Inertia Ip1	22793 kg·mm²				12352 kg·mm²
Moment of Inertia Ip2	42679 kg·mm²				95549 kg·mm²
Moment of Inertia Ip3	64995 kg·mm²				1,0737e+005 kg·mm²
Statistics					
Nodes	518				932
Elements	65				117
Mesh Metric	Skewness				
Min	1,45303156343506E-02		1,45303156343457E-02	1,45303156343511E-02	4,21644331178599E-02
Max	0,512002513503949	0,512002513503941	0,51200251350394	0,512002513503941	0,701342177947464
Average	0,165039542186167				0,485150428159298
Standard Deviation	0,120344267704764				0,140667649270926

TABLE 13
Bolt check (C4) > Geometry > Parts

Object Name	*Part 11*	*Part 12*	*Part 13*	*Part 14*	*Part 15*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				

Thermal Strain Effects	Yes				
Bounding Box					
Length X	408,5 mm	195,11 mm	336,33 mm		
Length Y	324,69 mm	273,09 mm	290,6 mm		
Length Z	20, mm	1120, mm	20, mm		
Properties					
Volume	1,0129e+006 mm³	1,3534e+007 mm³	9,1092e+005 mm³		
Mass	7,9516 kg	106,24 kg	7,1508 kg		
Centroid X	61,271 mm	660,58 mm	564,14 mm		
Centroid Y	711,6 mm	-283,16 mm	-379, mm		
Centroid Z	360, mm	-5,177e-006 mm	-3,5192e-015 mm	180, mm	360, mm
Moment of Inertia Ip1	12352 kg·mm²	1,199e+007 kg·mm²	22793 kg·mm²		
Moment of Inertia Ip2	95549 kg·mm²	1,1222e+007 kg·mm²	42679 kg·mm²		
Moment of Inertia Ip3	1,0737e+005 kg·mm²	8,0404e+005 kg·mm²	64995 kg·mm²		
Statistics					
Nodes	932	4357	518		
Elements	117	724	65		
Mesh Metric	Skewness				
Min	4,21644331178599E-02	1,16506503059919E-02	0,014530416356964	1,45304163569654E-02	1,45304163569653E-02
Max	0,701342177947464	0,5563317185945	0,512002193506519		
Average	0,485150428159297	0,2217425443135	0,165039530216544		
Standard Deviation	0,140667649270927	0,128803236805365	0,120344254612298		

TABLE 14
Bolt check (C4) > Geometry > Parts

Object Name	*Part 16*	*Part 17*	*Part 18*
State	Meshed		
Graphics Properties			
Visible	Yes		
Transparency	1		
Definition			
Suppressed	No		
Stiffness Behavior	Flexible		
Coordinate System	Default Coordinate System		
Reference Temperature	By Environment		
Material			
Assignment	Clamp steel		
Nonlinear Effects	Yes		
Thermal Strain Effects	Yes		
Bounding Box			
Length X	336,33 mm		
Length Y	290,6 mm		
Length Z	20, mm		
Properties			
Volume	9,1092e+005 mm³		
Mass	7,1508 kg		
Centroid X	564,14 mm		
Centroid Y	-379, mm		
Centroid Z	-180, mm	-360, mm	540, mm
Moment of Inertia Ip1	22793 kg·mm²		
Moment of Inertia Ip2	42679 kg·mm²		
Moment of Inertia Ip3	64995 kg·mm²		
Statistics			
Nodes	518		
Elements	65		
Mesh Metric	Skewness		

Min	1,45304163569657E-02	0,014530416356964	1,45304163569654E-02
Max	0,512002193506524	0,512002193506519	
Average	0,165039530216544		
Standard Deviation	0,120344254612298		

TABLE 15
Bolt check (C4) > Geometry > Body Groups

Object Name	*Part 167*	*Part 168*
State	Meshed	
Graphics Properties		
Visible	Yes	
Definition		
Suppressed	No	
Assignment	Clamp steel	
Coordinate System	Default Coordinate System	
Bounding Box		
Length X	1392,7 mm	1966,4 mm
Length Y	942,57 mm	1529,5 mm
Length Z	940, mm	380, mm
Properties		
Volume	3,9039e+007 mm³	4,5002e+007 mm³
Mass	306,46 kg	353,26 kg
Centroid X	-1002,7 mm	-878,93 mm
Centroid Y	-735,24 mm	-622,01 mm
Centroid Z	-4,7355e-009 mm	2,8422e-014 mm
Moment of Inertia Ip1	-2,5695e+007 kg·mm²	-1,6966e+007 kg·mm²
Moment of Inertia Ip2	7,4899e+007 kg·mm²	1,0256e+008 kg·mm²
Moment of Inertia Ip3	5,7134e+007 kg·mm²	1,0344e+008 kg·mm²
Statistics		
Nodes	20043	20548
Elements	2620	2866
Mesh Metric	Skewness	
Min	1,28570008830285E-02	1,34222502290619E-07
Max	0,635024754850647	0,630612494438596
Average	0,374806121704758	0,106056267466017
Standard Deviation	0,161278383303815	9,07650311926692E-02

TABLE 16
Bolt check (C4) > Geometry > Part 167 > Parts

Object Name	*Part 167:Body 2*	*Part 167:Body 1*	*Part 167:Body 3*	*Part 167:Body 4*	*Part 167:Body 5*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	1179,9 mm		1055,2 mm	1179,9 mm	1055,2 mm
Length Y	942,57 mm		670,02 mm	942,57 mm	670,02 mm
Length Z	340, mm	280, mm			340, mm

Properties					
Volume	1,0122e+007 mm³	5,6268e+006 mm³	4,6715e+006 mm³	5,6268e+006 mm³	8,3205e+006 mm³
Mass	79,46 kg	44,171 kg	36,671 kg	44,171 kg	65,316 kg
Centroid X	-1140, mm	-1115,2 mm	-840,34 mm	-1115,2 mm	-866,03 mm
Centroid Y	-684,09 mm	-664,15 mm	-802,05 mm	-664,15 mm	-818,62 mm
Centroid Z	2,3553e-013 mm	286,15 mm	-287,36 mm	-286,15 mm	3,6174e-013 mm
Moment of Inertia Ip1	7,6815e+005 kg·mm²	1,464e+005 kg·mm²	1,2495e+005 kg·mm²	1,464e+005 kg·mm²	6,3142e+005 kg·mm²
Moment of Inertia Ip2	1,5442e+007 kg·mm²	8,8149e+006 kg·mm²	5,0138e+006 kg·mm²	8,8149e+006 kg·mm²	8,7827e+006 kg·mm²
Moment of Inertia Ip3	1,4679e+007 kg·mm²	8,6714e+006 kg·mm²	4,8913e+006 kg·mm²	8,6714e+006 kg·mm²	8,1556e+006 kg·mm²
Statistics					
Nodes	4602	3154	2666	3154	3801
Elements	612	408	344	408	504
Mesh Metric	Skewness				
Min	1,28570008830285E-02	0,121940228772664	0,147043142256577	0,121940228773237	0,251582609432595
Max	0,56888569447759	0,56888569447732	0,635024754850643	0,568885694477314	0,635024754850484
Average	0,290302644765428	0,327842794622525	0,431158863841133	0,327842794622421	0,476527383998892
Standard Deviation	0,174997260051432	0,142869233338681	0,136697230319947	0,142869233338616	0,112863319428897

TABLE 17
Bolt check (C4) > Geometry > Part 167 > Parts

Object Name	*Part 167:Body 6*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Clamp steel
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	1055,2 mm
Length Y	670,02 mm
Length Z	280, mm
Properties	
Volume	4,6715e+006 mm³
Mass	36,671 kg
Centroid X	-840,34 mm
Centroid Y	-802,05 mm
Centroid Z	287,36 mm
Moment of Inertia Ip1	1,2495e+005 kg·mm²
Moment of Inertia Ip2	5,0138e+006 kg·mm²
Moment of Inertia Ip3	4,8913e+006 kg·mm²
Statistics	
Nodes	2666
Elements	344
Mesh Metric	Skewness
Min	0,147043142256505
Max	0,635024754850647
Average	0,431158863840972
Standard Deviation	0,136697230320043

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TABLE 18
Bolt check (C4) > Geometry > Part 168 > Parts

Object Name	*Part 168:Body 1*	*Part 168:Body 2*
State	Meshed	
Graphics Properties		
Visible	Yes	
Transparency	1	
Definition		
Suppressed	No	
Stiffness Behavior	Flexible	
Coordinate System	Default Coordinate System	
Reference Temperature	By Environment	
Material		
Assignment	Clamp steel	
Nonlinear Effects	Yes	
Thermal Strain Effects	Yes	
Bounding Box		
Length X	1966,4 mm	
Length Y	1529,5 mm	
Length Z	20, mm	
Properties		
Volume	2,2501e+007 mm³	
Mass	176,63 kg	
Centroid X	-878,93 mm	
Centroid Y	-622,01 mm	
Centroid Z	180, mm	-180, mm
Moment of Inertia Ip1	1,5073e+007 kg·mm²	
Moment of Inertia Ip2	3,6657e+007 kg·mm²	
Moment of Inertia Ip3	5,1718e+007 kg·mm²	
Statistics		
Nodes	9991	10557
Elements	1389	1477
Mesh Metric	Skewness	
Min	1,34222502290619E-07	
Max	0,579184356596601	0,630612494438596
Average	9,75164975073474E-02	0,114087235964726
Standard Deviation	8,66241219683841E-02	9,38161024265272E-02

TABLE 19
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Part 109*	*Part 111*	*Part 112*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	1143, mm		537,51 mm	680, mm	
Length Y	1143, mm		249,5 mm	299,5 mm	

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Length Z	3000, mm		760, mm	20, mm	
Properties					
Volume	2,6754e+008 mm³		1,1783e+007 mm³	2,0069e+006 mm³	
Mass	2100,2 kg		92,497 kg	15,754 kg	
Centroid X	6,6132e-014 mm	1,9257e-014 mm	-1500, mm		
Centroid Y	1,0519e-013 mm	9,9001e-014 mm	-1327,1 mm	-1284,5 mm	
Centroid Z	2250, mm	-2250, mm	-6,6222e-012 mm	2,4593e-014 mm	-180, mm
Moment of Inertia Ip1	1,8919e+009 kg·mm²		4,9266e+006 kg·mm²	1,0414e+005 kg·mm²	
Moment of Inertia Ip2	1,8919e+009 kg·mm²		7,3606e+006 kg·mm²	9,4954e+005 kg·mm²	
Moment of Inertia Ip3	6,4951e+008 kg·mm²		3,4268e+006 kg·mm²	1,0526e+006 kg·mm²	
Statistics					
Nodes	3480		2189	1031	
Elements	480		288	124	
Mesh Metric	Skewness				
Min	8,33332971479483E-02	8,33332971479644E-02	5,84098799933312E-02	2,12269373262377E-02	
Max	8,33337649077044E-02	8,33337649077013E-02	0,10380946899594	0,536835591001785	0,536835591001779
Average	8,33335459135925E-02	8,33335459136026E-02	8,11234012466018E-02	0,148645748660336	0,148645748660335
Standard Deviation	1,44899518002028E-07	1,44868802682552E-07	1,46773819037213E-02	0,110950983017304	0,110950983017305

TABLE 20
Bolt check (C4) > Geometry > Parts

Object Name	*Part 113*	*Part 114*	*Part 115*	*Part 116*	*Part 117*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	680, mm			91,303 mm	
Length Y	299,5 mm			20, mm	
Length Z	20, mm			760, mm	
Properties					
Volume	2,0069e+006 mm³			1,3018e+006 mm³	
Mass	15,754 kg			10,219 kg	
Centroid X	-1500, mm			-1805,1 mm	-1194,9 mm
Centroid Y	-1284,5 mm			-1490, mm	
Centroid Z	-360, mm	180, mm	360, mm	3,3542e-011 mm	-4,4782e-011 mm
Moment of Inertia Ip1	1,0414e+005 kg·mm²			4,9745e+005 kg·mm²	
Moment of Inertia Ip2	9,4954e+005 kg·mm²			5,0454e+005 kg·mm²	
Moment of Inertia Ip3	1,0526e+006 kg·mm²			7765,3 kg·mm²	

Statistics					
Nodes	1031			850	
Elements	124			102	
Mesh Metric	Skewness				
Min	2,12269373262377E-02	2,12269373262376E-02	2,12269373262377E-02	9,72112528705313E-03	9,86837835606333E-03
Max	0,536835591001794	0,53683559100177	0,536835591001789	0,658890449569679	0,658890373985007
Average	0,148645748660335	0,148645748660334	0,148645748660336	0,206164372933614	0,206158639887314
Standard Deviation	0,110950983017304	0,110950983017305		0,184451658814402	0,184459935982683

TABLE 21
Bolt check (C4) > Geometry > Parts

Object Name	*Part 118*	*Part 119*	*Part 120*	*Part 121*	*Part 122*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	Clamp steel				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	537,51 mm	700, mm	680, mm		
Length Y	249,5 mm	30, mm	299,5 mm		
Length Z	760, mm		20, mm		
Properties					
Volume	1,1783e+007 mm³	1,5702e+007 mm³	2,0069e+006 mm³		
Mass	92,497 kg	123,26 kg	15,754 kg		
Centroid X	-1500, mm				
Centroid Y	-1672,9 mm	-1834,5 mm	-1715,5 mm		
Centroid Z	-1,3631e-011 mm	1,9927e-013 mm	-9,8983e-015 mm	-180, mm	-360, mm
Moment of Inertia Ip1	4,9266e+006 kg·mm²	5,9579e+006 kg·mm²	1,0414e+005 kg·mm²		
Moment of Inertia Ip2	7,3606e+006 kg·mm²	1,0891e+007 kg·mm²	9,4954e+005 kg·mm²		
Moment of Inertia Ip3	3,4268e+006 kg·mm²	4,9515e+006 kg·mm²	1,0526e+006 kg·mm²		
Statistics					
Nodes	2189	5624	1031		
Elements	288	978	124		
Mesh Metric	Skewness				
Min	5,84098851592735E-02	9,30762602808091E-04	0,021226937326253		2,12269373262391E-02
Max	0,103809468995915	0,67548607991459	0,536835591001759	0,536835591001777	0,536835591001769
Average	8,11233961389966E-02	0,108166880821472	0,148645748660329	0,148645748660327	0,148645748660328
Standard Deviation	0,014677417570033	0,129785120724641	0,110950983017306	0,110950983017307	0,110950983017308

TABLE 22
Bolt check (C4) > Geometry > Parts

Object Name	*Part 123*	*Part 124*	*Part 125*	*Part 126*

State	Meshed			
Graphics Properties				
Visible	Yes			
Transparency	1			
Definition				
Suppressed	No			
Stiffness Behavior	Flexible			
Coordinate System	Default Coordinate System			
Reference Temperature	By Environment			
Material				
Assignment	Clamp steel			
Nonlinear Effects	Yes			
Thermal Strain Effects	Yes			
Bounding Box				
Length X	680, mm		91,303 mm	
Length Y	299,5 mm		20, mm	
Length Z	20, mm		760, mm	
Properties				
Volume	2,0069e+006 mm³		1,3018e+006 mm³	
Mass	15,754 kg		10,219 kg	
Centroid X	-1500, mm		-1194,9 mm	-1805,1 mm
Centroid Y	-1715,5 mm		-1510, mm	
Centroid Z	180, mm	360, mm	-6,5523e-011 mm	-1,1769e-011 mm
Moment of Inertia Ip1	1,0414e+005 kg·mm²		4,9745e+005 kg·mm²	
Moment of Inertia Ip2	9,4954e+005 kg·mm²		5,0454e+005 kg·mm²	
Moment of Inertia Ip3	1,0526e+006 kg·mm²		7765,3 kg·mm²	
Statistics				
Nodes	1031		850	
Elements	124		102	
Mesh Metric	Skewness			
Min	0,021226937326253	2,12269373262577E-02	9,72112544995619E-03	9,55231891611279E-03
Max	0,536835591001777	0,536835591001776	0,658890368375126	0,658890449569678
Average	0,148645748660329	0,148645748660328	0,206167038736625	0,206158948167862
Standard Deviation	0,110950983017308	0,110950983017307	0,184452193922543	0,184457535519197

TABLE 23
Bolt check (C4) > Geometry > Body Groups

Object Name	*Solid*	*Solid*
State	Meshed	
Graphics Properties		
Visible	Yes	
Definition		
Suppressed	No	
Assignment	A320	
Coordinate System	Default Coordinate System	
Bounding Box		
Length X	657,48 mm	33, mm
Length Y	494,88 mm	699, mm
Length Z	45, mm	33, mm
Properties		
Volume	1,2405e+006 mm³	5,9785e+005 mm³
Mass	9,7382 kg	4,6932 kg
Centroid X	-368,45 mm	-1793,4 mm
Centroid Y	507,13 mm	-1500, mm
Centroid Z	450, mm	270, mm
Moment of Inertia Ip1	7,2917e+005 kg·mm²	1,9044e+005 kg·mm²
Moment of Inertia Ip2	-5,2529e+005 kg·mm²	632,4 kg·mm²
Moment of Inertia Ip3	-70830 kg·mm²	1,9044e+005 kg·mm²
Statistics		
Nodes	2469	2955
Elements	450	540

Mesh Metric	Skewness	
Min	0,440138732486726	0,44011888500314
Max	0,551232086350019	0,551257731534364
Average	0,500000000065278	0,500000000065288
Standard Deviation	3,80711342255428E-02	3,80890151526413E-02

TABLE 24
Bolt check (C4) > Geometry > Solid > Parts

Object Name	*Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	A320
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	657,48 mm
Length Y	494,88 mm
Length Z	45, mm
Properties	
Volume	1,2405e+006 mm³
Mass	9,7382 kg
Centroid X	-368,45 mm
Centroid Y	507,13 mm
Centroid Z	450, mm
Moment of Inertia Ip1	2440,1 kg·mm²
Moment of Inertia Ip2	4,9244e+005 kg·mm²
Moment of Inertia Ip3	4,9244e+005 kg·mm²
Statistics	
Nodes	2469
Elements	450
Mesh Metric	Skewness
Min	0,440138732486726
Max	0,551232086350019
Average	0,500000000065278
Standard Deviation	3,80711342255428E-02

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TABLE 25
Bolt check (C4) > Geometry > Solid > Parts

Object Name	*Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	A320
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	

Length X	33, mm
Length Y	699, mm
Length Z	33, mm
Properties	
Volume	5,9785e+005 mm³
Mass	4,6932 kg
Centroid X	-1793,4 mm
Centroid Y	-1500, mm
Centroid Z	270, mm
Moment of Inertia Ip1	1,9044e+005 kg·mm²
Moment of Inertia Ip2	632,4 kg·mm²
Moment of Inertia Ip3	1,9044e+005 kg·mm²
Statistics	
Nodes	2955
Elements	540
Mesh Metric	Skewness
Min	0,44011888500314
Max	0,551257731534364
Average	0,500000000065288
Standard Deviation	3,80890151526413E-02

TABLE 26
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	88,788 mm	75, mm		33, mm	75, mm
Length Y	101,18 mm	35, mm		699, mm	35, mm
Length Z	96, mm	75, mm		33, mm	75, mm
Properties					
Volume	2,8953e+005 mm³	1,5463e+005 mm³		5,9785e+005 mm³	1,5463e+005 mm³
Mass	2,2728 kg	1,2138 kg		4,6932 kg	1,2138 kg
Centroid X	-700,15 mm	-1793,4 mm		-1206,6 mm	
Centroid Y	266,14 mm	-1867, mm	-1133, mm	-1500, mm	-1867, mm
Centroid Z	450, mm	270, mm			
Moment of Inertia Ip1	2591,8 kg·mm²	545,7 kg·mm²		1,9044e+005 kg·mm²	545,7 kg·mm²
Moment of Inertia Ip2	1597,4 kg·mm²	844,83 kg·mm²		632,4 kg·mm²	844,83 kg·mm²
Moment of Inertia Ip3	1597,3 kg·mm²	545,7 kg·mm²		1,9044e+005 kg·mm²	545,7 kg·mm²
Statistics					
Nodes	410	569		2955	569
Elements	62	88		540	88
Mesh Metric	Skewness				

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Min	5,26584940020604E-03	2,51621975414209E-02	2,51621969437135E-02	0,435521393777587	2,51621759087575E-02
Max	0,391125818314752	0,383604260619502	0,383604337010751	0,553019810894248	0,38360425277399
Average	0,192729337112471	0,169521137800938	0,169521111280568	0,500460391492182	0,169520833422492
Standard Deviation	0,134589805395133	0,124651328327566	0,124651385384051	4,46728240124611E-02	0,124651080812731

TABLE 27
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	75, mm	33, mm	75, mm		33, mm
Length Y	35, mm	699, mm	35, mm		699, mm
Length Z	75, mm	33, mm	75, mm		33, mm
Properties					
Volume	1,5463e+005 mm³	5,9785e+005 mm³	1,5463e+005 mm³		5,9785e+005 mm³
Mass	1,2138 kg	4,6932 kg	1,2138 kg		4,6932 kg
Centroid X	-1206,6 mm	-1793,4 mm			-1206,6 mm
Centroid Y	-1133, mm	-1500, mm	-1867, mm	-1133, mm	-1500, mm
Centroid Z	270, mm	90, mm			
Moment of Inertia Ip1	545,7 kg·mm²	1,9044e+005 kg·mm²	545,7 kg·mm²		1,9044e+005 kg·mm²
Moment of Inertia Ip2	844,83 kg·mm²	632,4 kg·mm²	844,83 kg·mm²		632,4 kg·mm²
Moment of Inertia Ip3	545,7 kg·mm²	1,9044e+005 kg·mm²	545,7 kg·mm²		1,9044e+005 kg·mm²
Statistics					
Nodes	569	2955	569		2955
Elements	88	540	88		540
Mesh Metric	Skewness				
Min	2,51621695420813E-02	0,44011888500314	2,51621975414209E-02	2,51621969437135E-02	0,435521393777587
Max	0,383604459761315	0,551257731534364	0,383604260619502	0,383604337010751	0,553019810894248
Average	0,169520988949984	0,500000000065288	0,169521137800938	0,169521111280568	0,500460391492182
Standard Deviation	0,124651452410631	3,80890151526413E-02	0,124651328327566	0,124651385384051	4,46728240124611E-02

TABLE 28
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparenc	1				

Transparency					
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	75, mm		33, mm	75, mm	
Length Y	35, mm		699, mm	35, mm	
Length Z	75, mm		33, mm	75, mm	
Properties					
Volume	1,5463e+005 mm³		5,9785e+005 mm³	1,5463e+005 mm³	
Mass	1,2138 kg		4,6932 kg	1,2138 kg	
Centroid X	-1206,6 mm		-1793,4 mm		
Centroid Y	-1867, mm	-1133, mm	-1500, mm	-1867, mm	-1133, mm
Centroid Z	90, mm		-90, mm		
Moment of Inertia Ip1	545,7 kg·mm²		1,9044e+005 kg·mm²	545,7 kg·mm²	
Moment of Inertia Ip2	844,83 kg·mm²		632,4 kg·mm²	844,83 kg·mm²	
Moment of Inertia Ip3	545,7 kg·mm²		1,9044e+005 kg·mm²	545,7 kg·mm²	
Statistics					
Nodes	569		2955	569	
Elements	88		540	88	
Mesh Metric	Skewness				
Min	2,51621759087575E-02	2,51621695420813E-02	0,44011888500314	2,51621975414209E-02	2,51621969437135E-02
Max	0,38360425277399	0,383604459761315	0,551257731534364	0,383604260619502	0,383604337010751
Average	0,169520833422492	0,169520988949984	0,500000000065288	0,169521137800938	0,169521111280568
Standard Deviation	0,124651080812731	0,124651452410631	3,80890151526413E-02	0,124651328327566	0,124651385384051

TABLE 29
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				

Bounding Box					
Length X	33, mm	75, mm		33, mm	75, mm
Length Y	699, mm	35, mm		699, mm	35, mm
Length Z	33, mm	75, mm		33, mm	75, mm
Properties					
Volume	5,9785e+005 mm³	1,5463e+005 mm³		5,9785e+005 mm³	1,5463e+005 mm³
Mass	4,6932 kg	1,2138 kg		4,6932 kg	1,2138 kg
Centroid X	-1206,6 mm			-1793,4 mm	
Centroid Y	-1500, mm	-1867, mm	-1133, mm	-1500, mm	-1867, mm
Centroid Z	-90, mm			-270, mm	
Moment of Inertia Ip1	1,9044e+005 kg·mm²	545,7 kg·mm²		1,9044e+005 kg·mm²	545,7 kg·mm²
Moment of Inertia Ip2	632,4 kg·mm²	844,83 kg·mm²		632,4 kg·mm²	844,83 kg·mm²
Moment of Inertia Ip3	1,9044e+005 kg·mm²	545,7 kg·mm²		1,9044e+005 kg·mm²	545,7 kg·mm²
Statistics					
Nodes	2955	569		2955	569
Elements	540	88		540	88
Mesh Metric	Skewness				
Min	0,435521393777587	2,51621759087575E-02	2,51621695420813E-02	0,44011888500314	2,51621975414209E-02
Max	0,553019810894248	0,38360425277399	0,383604459761315	0,551257731534364	0,383604260619502
Average	0,500460391492182	0,169520833422492	0,169520988949984	0,500000000065288	0,169521137800938
Standard Deviation	4,46728240124611E-02	0,124651080812731	0,124651452410631	3,80890151526426E-02	0,124651328327566

TABLE 30
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	75, mm	33, mm	75, mm		88,788 mm
Length Y	35, mm	699, mm	35, mm		101,18 mm
Length Z	75, mm	33, mm	75, mm		96, mm
Properties					
Volume	1,5463e+005 mm³	5,9785e+005 mm³	1,5463e+005 mm³		2,8953e+005 mm³
Mass	1,2138 kg	4,6932 kg	1,2138 kg		2,2728 kg
Centroid X	-1793,4 mm	-1206,6 mm			-36,758 mm
Centroid Y	-1133, mm	-1500, mm	-1867, mm	-1133, mm	748,13 mm
Centroid Z	-270, mm				450, mm
Moment of Inertia Ip1	545,7 kg·mm²	1,9044e+005 kg·mm²	545,7 kg·mm²		2591,8 kg·mm²
Moment of Inertia Ip2	844,83 kg·mm²	632,4 kg·mm²	844,83 kg·mm²		1597,4 kg·mm²

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Moment of Inertia Ip3	545,7 kg·mm²	1,9044e+005 kg·mm²	545,7 kg·mm²		1597,4 kg·mm²
Statistics					
Nodes	569	2955	569		377
Elements	88	540	88		56
Mesh Metric	Skewness				
Min	2,51621969437135E-02	0,435521393777587	2,51621759087575E-02	2,51621695420813E-02	7,67962448515975E-02
Max	0,383604337010751	0,553019810894248	0,383604252773993	0,383604459761315	0,382442778011599
Average	0,169521111280568	0,500460391492182	0,169520833422492	0,169520988949984	0,265142950721297
Standard Deviation	0,124651385384051	4,46728240124611E-02	0,124651080812731	0,124651452410631	9,51828443407145E-02

TABLE 31
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	657,48 mm	88,788 mm		657,48 mm	88,788 mm
Length Y	494,88 mm	101,18 mm		494,88 mm	101,18 mm
Length Z	45, mm	96, mm		45, mm	96, mm
Properties					
Volume	1,2405e+006 mm³	2,8953e+005 mm³		1,2405e+006 mm³	2,8953e+005 mm³
Mass	9,7382 kg	2,2728 kg		9,7382 kg	2,2728 kg
Centroid X	368,46 mm	36,76 mm	700,15 mm	-368,45 mm	-700,15 mm
Centroid Y	-507,14 mm	-748,13 mm	-266,15 mm	507,13 mm	266,14 mm
Centroid Z	450, mm			270, mm	
Moment of Inertia Ip1	2440,1 kg·mm²	2591,8 kg·mm²	2590,1 kg·mm²	2440,1 kg·mm²	2591,8 kg·mm²
Moment of Inertia Ip2	4,9244e+005 kg·mm²	1597,4 kg·mm²		4,9244e+005 kg·mm²	1597,4 kg·mm²
Moment of Inertia Ip3	4,9244e+005 kg·mm²	1597,4 kg·mm²	1595,7 kg·mm²	4,9244e+005 kg·mm²	1597,3 kg·mm²
Statistics					
Nodes	2469	377		2469	498
Elements	450	56		450	78
Mesh Metric	Skewness				
Min	0,440138732485638	5,99716297886576E-02	0,130115686410123	0,440138732486726	8,61703737395741E-02
Max	0,551232086355783	0,356001720473829	0,428612801636582	0,551232086350019	0,55610654203922
Average	0,500000000065292	0,260406958772791	0,306112068889663	0,500000000065278	0,273157987943119
Standard Deviation	3,80711342266405E-02	0,094434851504264	7,39375375836418E-02	3,80711342255428E-02	0,12152744702881

TABLE 32
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	88,788 mm	657,48 mm	88,788 mm		657,48 mm
Length Y	101,18 mm	494,88 mm	101,18 mm		494,88 mm
Length Z	96, mm	45, mm	96, mm		45, mm
Properties					
Volume	2,8953e+005 mm³	1,2405e+006 mm³	2,8953e+005 mm³		1,2405e+006 mm³
Mass	2,2728 kg	9,7382 kg	2,2728 kg		9,7382 kg
Centroid X	-36,758 mm	368,46 mm	36,76 mm	700,15 mm	-368,45 mm
Centroid Y	748,13 mm	-507,14 mm	-748,13 mm	-266,15 mm	507,13 mm
Centroid Z	270, mm				90, mm
Moment of Inertia Ip1	2591,8 kg·mm²	2440,1 kg·mm²	2591,8 kg·mm²	2590,1 kg·mm²	2440,1 kg·mm²
Moment of Inertia Ip2	1597,4 kg·mm²	4,9244e+005 kg·mm²	1597,4 kg·mm²		4,9244e+005 kg·mm²
Moment of Inertia Ip3	1597,4 kg·mm²	4,9244e+005 kg·mm²	1597,4 kg·mm²	1595,7 kg·mm²	4,9244e+005 kg·mm²
Statistics					
Nodes	377	2469	377		2469
Elements	56	450	56		450
Mesh Metric	Skewness				
Min	7,67962448515975E-02	0,440138732485638	5,99716297886576E-02	0,130115686410123	0,440138732486726
Max	0,382442778011599	0,551232086355783	0,356001720473829	0,428612801636582	0,551232086350019
Average	0,265142950721297	0,500000000065292	0,260406958772791	0,306112068889663	0,500000000065278
Standard Deviation	9,51828443407145E-02	3,80711342266405E-02	0,094434851504264	7,39375375836418E-02	3,80711342255428E-02

TABLE 33
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					

Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	88,788 mm		657,48 mm	88,788 mm	
Length Y	101,18 mm		494,88 mm	101,18 mm	
Length Z	96, mm		45, mm	96, mm	
Properties					
Volume	2,8953e+005 mm^3		1,2405e+006 mm^3	2,8953e+005 mm^3	
Mass	2,2728 kg		9,7382 kg	2,2728 kg	
Centroid X	-700,15 mm	-36,758 mm	368,46 mm	36,76 mm	700,15 mm
Centroid Y	266,14 mm	748,13 mm	-507,14 mm	-748,13 mm	-266,15 mm
Centroid Z	90, mm				
Moment of Inertia Ip1	2591,8 kg·mm^2		2440,1 kg·mm^2	2591,8 kg·mm^2	2590,1 kg·mm^2
Moment of Inertia Ip2	1597,4 kg·mm^2		4,9244e+005 kg·mm^2	1597,4 kg·mm^2	
Moment of Inertia Ip3	1597,3 kg·mm^2	1597,4 kg·mm^2	4,9244e+005 kg·mm^2	1597,4 kg·mm^2	1595,7 kg·mm^2
Statistics					
Nodes	498	377	2469	377	
Elements	78	56	450	56	
Mesh Metric	Skewness				
Min	8,61703737395741E-02	7,67962448515975E-02	0,440138732485638	5,99716297886576E-02	0,130115686410123
Max	0,55610654203922	0,382442778011599	0,551232086355783	0,356001720473829	0,428612801636582
Average	0,273157987943119	0,265142950721297	0,500000000065292	0,260406958772791	0,306112068889663
Standard Deviation	0,12152744702881	9,51828443407145E-02	3,80711342266405E-02	0,094434851504264	7,39375375836418E-02

TABLE 34
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	657,48 mm	88,788 mm		657,48 mm	88,788 mm
Length Y	494,88 mm	101,18 mm		494,88 mm	101,18 mm
Length Z	45, mm	96, mm		45, mm	96, mm
Properties					
Volume	1,2405e+006 mm^3	2,8953e+005 mm^3		1,2405e+006 mm^3	2,8953e+005 mm^3
Mass	9,7382 kg	2,2728 kg		9,7382 kg	2,2728 kg
Centroid X	-368,45 mm	-700,15 mm	-36,758 mm	368,46 mm	36,76 mm
Centroid Y	507,13 mm	266,14 mm	748,13 mm	-507,14 mm	-748,13 mm

F

Centroid Z	-90, mm				
Moment of Inertia Ip1	2440,1 kg·mm²	2591,8 kg·mm²		2440,1 kg·mm²	2591,8 kg·mm²
Moment of Inertia Ip2	4,9244e+005 kg·mm²	1597,4 kg·mm²		4,9244e+005 kg·mm²	1597,4 kg·mm²
Moment of Inertia Ip3	4,9244e+005 kg·mm²	1597,3 kg·mm²	1597,4 kg·mm²	4,9244e+005 kg·mm²	1597,4 kg·mm²
Statistics					
Nodes	2469	498	377	2469	377
Elements	450	78	56	450	56
Mesh Metric	Skewness				
Min	0,440138732486726	8,61703737395741E-02	7,67962448515975E-02	0,440138732485638	5,99716297886576E-02
Max	0,551232086350019	0,55610654203922	0,382442778011599	0,551232086355783	0,356001720473829
Average	0,500000000065278	0,273157987943119	0,265142950721297	0,500000000065292	0,260406958772791
Standard Deviation	3,80711342255428E-02	0,12152744702881	9,51828443407145E-02	3,80711342266405E-02	0,094434851504264

TABLE 35
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	88,788 mm	657,48 mm	88,788 mm		657,48 mm
Length Y	101,18 mm	494,88 mm	101,18 mm		494,88 mm
Length Z	96, mm	45, mm	96, mm		45, mm
Properties					
Volume	2,8953e+005 mm³	1,2405e+006 mm³	2,8953e+005 mm³		1,2405e+006 mm³
Mass	2,2728 kg	9,7382 kg	2,2728 kg		9,7382 kg
Centroid X	700,15 mm	-368,45 mm	-700,15 mm	-36,758 mm	368,46 mm
Centroid Y	-266,15 mm	507,13 mm	266,14 mm	748,13 mm	-507,14 mm
Centroid Z	-90, mm	-270, mm			
Moment of Inertia Ip1	2590,1 kg·mm²	2440,1 kg·mm²	2591,8 kg·mm²		2440,1 kg·mm²
Moment of Inertia Ip2	1597,4 kg·mm²	4,9244e+005 kg·mm²	1597,4 kg·mm²		4,9244e+005 kg·mm²
Moment of Inertia Ip3	1595,7 kg·mm²	4,9244e+005 kg·mm²	1597,3 kg·mm²	1597,4 kg·mm²	4,9244e+005 kg·mm²
Statistics					
Nodes	377	2469	498	377	2469
Elements	56	450	78	56	450
Mesh Metric	Skewness				
Min	0,130115686410123	0,440138732486726	8,61703737395741E-02	7,67962448515975E-02	0,440138732485638
Max	0,428612801636582	0,551232086350019	0,55610654203922	0,382442778011599	0,551232086355783
Average	0,306112068889663	0,500000000065278	0,273157987943119	0,265142950721297	0,500000000065292

F

Standard Deviation	7,39375375836418E-02	3,80711342255428E-02	0,12152744702881	9,51828443407144E-02	3,80711342266405E-02

TABLE 36
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*	*Solid*	*Solid*
State	Meshed				
Graphics Properties					
Visible	Yes				
Transparency	1				
Definition					
Suppressed	No				
Stiffness Behavior	Flexible				
Coordinate System	Default Coordinate System				
Reference Temperature	By Environment				
Material					
Assignment	A320				
Nonlinear Effects	Yes				
Thermal Strain Effects	Yes				
Bounding Box					
Length X	88,788 mm		657,48 mm	88,788 mm	
Length Y	101,18 mm		494,88 mm	101,18 mm	
Length Z	96, mm		45, mm	96, mm	
Properties					
Volume	2,8953e+005 mm³		1,2405e+006 mm³	2,8953e+005 mm³	
Mass	2,2728 kg		9,7382 kg	2,2728 kg	
Centroid X	36,76 mm	700,15 mm	-368,45 mm	-700,15 mm	-36,758 mm
Centroid Y	-748,13 mm	-266,15 mm	507,13 mm	266,14 mm	748,13 mm
Centroid Z	-270, mm		-450, mm		
Moment of Inertia Ip1	2591,8 kg·mm²	2590,1 kg·mm²	2440,1 kg·mm²	2591,8 kg·mm²	
Moment of Inertia Ip2	1597,4 kg·mm²		4,9244e+005 kg·mm²	1597,4 kg·mm²	
Moment of Inertia Ip3	1597,4 kg·mm²	1595,7 kg·mm²	4,9244e+005 kg·mm²	1597,3 kg·mm²	1597,4 kg·mm²
Statistics					
Nodes	377		2469	498	377
Elements	56		450	78	56
Mesh Metric	Skewness				
Min	5,99716297886575E-02	0,130115686410123	0,440138732486726	8,61703737395741E-02	7,67962448515975E-02
Max	0,356001720473829	0,428612801636582	0,551232086350019	0,55610654203922	0,382442778011599
Average	0,260406958772791	0,306112068889663	0,500000000065278	0,273157987943119	0,265142950721297
Standard Deviation	9,44348515042642E-02	7,39375375836418E-02	3,80711342255428E-02	0,12152744702881	9,51828443407144E-02

TABLE 37
Bolt check (C4) > Geometry > Parts

Object Name	*Solid*	*Solid*	*Solid*
State	Meshed		
Graphics Properties			
Visible	Yes		
Transparency	1		
Definition			
Suppressed	No		
Stiffness Behavior	Flexible		
Coordinate System	Default Coordinate System		

Reference Temperature	By Environment		
Material			
Assignment	A320		
Nonlinear Effects	Yes		
Thermal Strain Effects	Yes		
Bounding Box			
Length X	657,48 mm	88,788 mm	
Length Y	494,88 mm	101,18 mm	
Length Z	45, mm	96, mm	
Properties			
Volume	1,2405e+006 mm³	2,8953e+005 mm³	
Mass	9,7382 kg	2,2728 kg	
Centroid X	368,46 mm	36,76 mm	700,15 mm
Centroid Y	-507,14 mm	-748,13 mm	-266,15 mm
Centroid Z	-450, mm		
Moment of Inertia Ip1	2440,1 kg·mm²	2591,8 kg·mm²	2590,1 kg·mm²
Moment of Inertia Ip2	4,9244e+005 kg·mm²	1597,4 kg·mm²	
Moment of Inertia Ip3	4,9244e+005 kg·mm²	1597,4 kg·mm²	1595,7 kg·mm²
Statistics			
Nodes	2469	377	
Elements	450	56	
Mesh Metric	Skewness		
Min	0,440138732485637	5,99716297886575E-02	0,130115686410123
Max	0,551232086355783	0,356001720473829	0,428612801636582
Average	0,500000000065292	0,260406958772791	0,306112068889663
Standard Deviation	3,80711342266405E-02	9,44348515042642E-02	7,39375375836418E-02

TABLE 38
Bolt check (C4) > Construction Geometry

Object Name	*Construction Geometry*
State	Fully Defined
Display	
Show Mesh	No

F

TABLE 39
Bolt check (C4) > Construction Geometry > Paths

Object Name	*Path*
State	Fully Defined
Definition	
Path Type	Two Points
Path Coordinate System	Global Coordinate System
Number of Sampling Points	47,
Suppressed	No
Start	
Coordinate System	Global Coordinate System
Start X Coordinate	347,42 mm
Start Y Coordinate	-522,42 mm
Start Z Coordinate	472,5 mm
Location	Defined
End	
Coordinate System	Global Coordinate System
End X Coordinate	347,42 mm
End Y Coordinate	-522,42 mm
End Z Coordinate	427,5 mm
Location	Defined

Coordinate Systems

TABLE 40
Bolt check (C4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*

State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0,
Origin	
Origin X	0, mm
Origin Y	0, mm
Origin Z	0, mm
Directional Vectors	
X Axis Data	[1, 0, 0,]
Y Axis Data	[0, 1, 0,]
Z Axis Data	[0, 0, 1,]

Connections

TABLE 41
Bolt check (C4) > Connections

Object Name	*Connections*
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes

TABLE 42
Bolt check (C4) > Connections > Contacts

Object Name	*Contacts*
State	Fully Defined
Definition	
Connection Type	Contact
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Auto Detection	
Tolerance Type	Value
Tolerance Value	1, mm
Face/Face	Yes
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies

TABLE 43
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 110 To Part 111*	*Bonded - Part 110 To Part 112*	*Bonded - Part 110 To Part 113*	*Bonded - Part 110 To Part 114*	*Bonded - Part 110 To Part 115*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 110				
Target Bodies	Part 111	Part 112	Part 113	Part 114	Part 115
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					

F

Formulation	Pure Penalty
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled

TABLE 44
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 109 To Part 111*	*Bonded - Part 109 To Part 112*	*Bonded - Part 109 To Part 113*	*Bonded - Part 109 To Part 114*	*Bonded - Part 109 To Part 115*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 109				
Target Bodies	Part 111	Part 112	Part 113	Part 114	Part 115
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 45
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 109 To Part 116*	*Bonded - Part 109 To Part 117*	*Bonded - Part 111 To Part 116*	*Bonded - Part 111 To Part 117*	*Bonded - Part 112 To Part 116*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 109		Part 111		Part 112
Target Bodies	Part 116	Part 117	Part 116	Part 117	Part 116
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 46
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 112 To Part 117*	*Bonded - Part 113 To Part 116*	*Bonded - Part 113 To Part 117*	*Bonded - Part 114 To Part 116*	*Bonded - Part 114 To Part 117*

F

State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 112	Part 113		Part 114	
Target Bodies	Part 117	Part 116	Part 117	Part 116	Part 117
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 47
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 115 To Part 116*	*Bonded - Part 115 To Part 117*	*Bonded - Part 118 To Part 120*	*Bonded - Part 118 To Part 121*	*Bonded - Part 118 To Part 122*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 115		Part 118		
Target Bodies	Part 116	Part 117	Part 120	Part 121	Part 122
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 48
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 118 To Part 123*	*Bonded - Part 118 To Part 124*	*Bonded - Part 118 To Part 125*	*Bonded - Part 118 To Part 126*	*Bonded - Part 119 To Part 120*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 118				Part 119
Target Bodies	Part 123	Part 124	Part 125	Part 126	Part 120
Definition					
Type	Bonded				

Scope Mode	Automatic
Behavior	Symmetric
Suppressed	No
Advanced	
Formulation	Pure Penalty
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled

TABLE 49
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 119 To Part 121*	*Bonded - Part 119 To Part 122*	*Bonded - Part 119 To Part 123*	*Bonded - Part 119 To Part 124*	*Bonded - Part 120 To Part 125*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 119				Part 120
Target Bodies	Part 121	Part 122	Part 123	Part 124	Part 125
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 50
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 120 To Part 126*	*Bonded - Part 121 To Part 125*	*Bonded - Part 121 To Part 126*	*Bonded - Part 122 To Part 125*	*Bonded - Part 122 To Part 126*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 120	Part 121		Part 122	
Target Bodies	Part 126	Part 125	Part 126	Part 125	Part 126
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 51
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 123 To Part 125*	*Bonded - Part 123 To Part 126*	*Bonded - Part 124 To Part 125*	*Bonded - Part 124 To Part 126*	*Frictional - Part 116 To Part 126*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 123		Part 124		Part 116
Target Bodies	Part 125	Part 126	Part 125	Part 126	
Definition					
Type	Bonded				Frictional
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Friction Coefficient					0,21
Advanced					
Formulation	Pure Penalty				Normal Lagrange
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				Radius
Interface Treatment					Adjust to Touch
Pinball Radius					10, mm
Time Step Controls					None

TABLE 52
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Frictional - Part 117 To Part 125*	*Frictional - Part 24 To Part 107*	*Frictional - Part 1 To Part 107*	*Bonded - Part 19 To Part 1*	*Bonded - Part 19 To Part 12*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 117	Part 24	Part 1	Part 19	
Target Bodies	Part 125	Part 107		Part 1	Part 12
Definition					
Type	Frictional			Bonded	
Friction Coefficient	0,21				
Scope Mode	Automatic	Manual		Automatic	
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Normal Lagrange			Pure Penalty	
Interface Treatment	Adjust to Touch				
Pinball Region	Radius			Program Controlled	
Pinball Radius	10, mm	25, mm			
Time Step Controls	None				
Normal Stiffness				Program Controlled	
Update Stiffness				Never	

F

TABLE 53
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 20 To Part 1*	*Bonded - Part 20 To Part 12*	*Bonded - Part 21 To Part 1*	*Bonded - Part 21 To Part 12*	*Bonded - Part 22 To Part 1*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 20		Part 21		Part 22
Target Bodies	Part 1	Part 12	Part 1	Part 12	Part 1
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 54
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 22 To Part 2*	*Bonded - Part 23 To Part 1*	*Bonded - Part 23 To Part 12*	*Bonded - Part 24 To Part 25*	*Bonded - Part 24 To Part 26*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 22	Part 23		Part 24	
Target Bodies	Part 2	Part 1	Part 12	Part 25	Part 26
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 55
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 24 To Part 27*	*Bonded - Part 24 To Part 28*	*Bonded - Part 24 To Part 29*	*Bonded - Part 24 To Part 30*	*Bonded - Part 24 To Part 31*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 24				
Target Bodies	Part 27	Part 28	Part 29	Part 30	Part 31

Definition	
Type	Bonded
Scope Mode	Automatic
Behavior	Symmetric
Suppressed	No
Advanced	
Formulation	Pure Penalty
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled

TABLE 56
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 24 To Part 32*	*Bonded - Part 24 To Part 33*	*Bonded - Part 24 To Part 34*	*Bonded - Part 24 To Part 35*	*Bonded - Part 24 To Part 36*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 24				
Target Bodies	Part 32	Part 33	Part 34	Part 35	Part 36
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 57
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 24 To Part 37*	*Bonded - Part 24 To Part 38*	*Bonded - Part 24 To Part 39*	*Bonded - Part 24 To Part 40*	*Bonded - Part 24 To Part 41*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 24				
Target Bodies	Part 37	Part 38	Part 39	Part 40	Part 41
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				

Pinball Region	Program Controlled

TABLE 58
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 24 To Part 42*	*Bonded - Part 24 To Part 43*	*Bonded - Part 24 To Part 44*	*Bonded - Part 24 To Part 45*	*Bonded - Part 24 To Part 46*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 24				
Target Bodies	Part 42	Part 43	Part 44	Part 45	Part 46
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 59
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 24 To Part 167:Body 3*	*Bonded - Part 24 To Part 167:Body 5*	*Bonded - Part 24 To Part 167:Body 6*	*Bonded - Part 24 To Part 168:Body 1*	*Bonded - Part 24 To Part 168:Body 2*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 24				
Target Bodies	Part 167:Body 3	Part 167:Body 5	Part 167:Body 6	Part 168:Body 1	Part 168:Body 2
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 60
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 25 To Part 26*	*Bonded - Part 25 To Part 27*	*Bonded - Part 25 To Part 28*	*Bonded - Part 25 To Part 29*	*Bonded - Part 25 To Part 30*
State	Fully Defined				
Scope					
Scoping	Geometry Selection				

Method					
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 25				
Target Bodies	Part 26	Part 27	Part 28	Part 29	Part 30
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 61
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 25 To Part 31*	*Bonded - Part 25 To Part 32*	*Bonded - Part 25 To Part 33*	*Bonded - Part 25 To Part 34*	*Bonded - Part 25 To Part 45*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 25				
Target Bodies	Part 31	Part 32	Part 33	Part 34	Part 45
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 62
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 25 To Part 168:Body 1*	*Bonded - Part 25 To Part 168:Body 2*	*Bonded - Part 35 To Part 36*	*Bonded - Part 35 To Part 37*	*Bonded - Part 35 To Part 38*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 25		Part 35		
Target Bodies	Part 168:Body 1	Part 168:Body 2	Part 36	Part 37	Part 38
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				

F

Advanced	
Formulation	Pure Penalty
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled

TABLE 63
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 35 To Part 39*	*Bonded - Part 35 To Part 40*	*Bonded - Part 35 To Part 41*	*Bonded - Part 35 To Part 42*	*Bonded - Part 35 To Part 43*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 35				
Target Bodies	Part 39	Part 40	Part 41	Part 42	Part 43
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 64
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 35 To Part 44*	*Bonded - Part 35 To Part 46*	*Bonded - Part 35 To Part 168:Body 1*	*Bonded - Part 35 To Part 168:Body 2*	*Bonded - Part 35 To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 35				
Target Bodies	Part 44	Part 46	Part 168:Body 1	Part 168:Body 2	Solid
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 65
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 1 To Part 2*	*Bonded - Part 1 To Part 3*	*Bonded - Part 1 To Part 4*	*Bonded - Part 1 To Part 5*	*Bonded - Part 1 To Part 6*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 1				
Target Bodies	Part 2	Part 3	Part 4	Part 5	Part 6
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 66
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 1 To Part 7*	*Bonded - Part 1 To Part 8*	*Bonded - Part 1 To Part 9*	*Bonded - Part 1 To Part 10*	*Bonded - Part 1 To Part 11*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 1				
Target Bodies	Part 7	Part 8	Part 9	Part 10	Part 11
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 67
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 1 To Part 12*	*Bonded - Part 1 To Part 13*	*Bonded - Part 1 To Part 14*	*Bonded - Part 1 To Part 15*	*Bonded - Part 1 To Part 16*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 1				
Target Bodies	Part 12	Part 13	Part 14	Part 15	Part 16
Definition					

Type	Bonded
Scope Mode	Automatic
Behavior	Symmetric
Suppressed	No
Advanced	
Formulation	Pure Penalty
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled

TABLE 68
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 1 To Part 17*	*Bonded - Part 1 To Part 18*	*Bonded - Part 107 To Solid*	*Bonded - Part 107 To Solid*	*Bonded - Part 110 To Part 167:Body 2*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 1		Part 107		Part 110
Target Bodies	Part 17	Part 18	Solid		Part 167:Body 2
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 69
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 110 To Part 167:Body 1*	*Bonded - Part 110 To Part 167:Body 3*	*Bonded - Part 110 To Part 167:Body 4*	*Bonded - Part 110 To Part 167:Body 5*	*Bonded - Part 110 To Part 167:Body 6*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 110				
Target Bodies	Part 167:Body 1	Part 167:Body 3	Part 167:Body 4	Part 167:Body 5	Part 167:Body 6
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				

Pinball Region	Program Controlled

TABLE 70
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 110 To Part 168:Body 1*	*Bonded - Part 110 To Part 168:Body 2*	*Bonded - Part 110 To Solid*	*Bonded - Part 110 To Solid*	*Bonded - Part 110 To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 110				
Target Bodies	Part 168:Body 1	Part 168:Body 2	Solid		
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 71
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 110 To Solid*	*Bonded - Part 110 To Solid*	*Bonded - Part 110 To Solid*	*Bonded - Part 110 To Solid*	*Bonded - Part 110 To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 110				
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 72
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 2 To Part 3*	*Bonded - Part 2 To Part 4*	*Bonded - Part 2 To Part 5*	*Bonded - Part 2 To Part 6*	*Bonded - Part 2 To Part 7*
State	Fully Defined				
Scope					
Scoping	Geometry Selection				

Method					
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 2				
Target Bodies	Part 3	Part 4	Part 5	Part 6	Part 7
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 73
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 2 To Part 8*	*Bonded - Part 2 To Part 9*	*Bonded - Part 2 To Part 10*	*Bonded - Part 2 To Part 11*	*Bonded - Part 12 To Part 13*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 2				Part 12
Target Bodies	Part 8	Part 9	Part 10	Part 11	Part 13
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 74
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 12 To Part 14*	*Bonded - Part 12 To Part 15*	*Bonded - Part 12 To Part 16*	*Bonded - Part 12 To Part 17*	*Bonded - Part 12 To Part 18*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 12				
Target Bodies	Part 14	Part 15	Part 16	Part 17	Part 18
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					

F

Formulation	Pure Penalty
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled

TABLE 75
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 167:Body 2 To Part 168:Body 1*	*Bonded - Part 167:Body 2 To Part 168:Body 2*	*Bonded - Part 167:Body 1 To Part 168:Body 1*	*Bonded - Part 167:Body 3 To Part 168:Body 2*	*Bonded - Part 167:Body 4 To Part 168:Body 2*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 167:Body 2		Part 167:Body 1	Part 167:Body 3	Part 167:Body 4
Target Bodies	Part 168:Body 1	Part 168:Body 2	Part 168:Body 1	Part 168:Body 2	
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 76
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 167:Body 5 To Part 168:Body 1*	*Bonded - Part 167:Body 5 To Part 168:Body 2*	*Bonded - Part 167:Body 6 To Part 168:Body 1*	*Bonded - Part 119 To Solid*	*Bonded - Part 119 To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 167:Body 5		Part 167:Body 6	Part 119	
Target Bodies	Part 168:Body 1	Part 168:Body 2	Part 168:Body 1	Solid	
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 77
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 119 To Solid*	*Bonded - Part 119 To Solid*	*Bonded - Part 119 To Solid*	*Bonded - Part 119 To Solid*	*Bonded - Part 119 To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 119				
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 78
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 119 To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 119	Solid			
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 79
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Solid				
Target Bodies	Solid				

F

Definition	
Type	Bonded
Scope Mode	Automatic
Behavior	Symmetric
Suppressed	No
Advanced	
Formulation	Pure Penalty
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled

TABLE 80
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Solid				
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 81
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Part 25 To Solid*	*Bonded - Part 25 To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Solid			Part 25	
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 82
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 25 To Solid*	*Bonded - Part 25 To Solid*	*Bonded - Part 25 To Solid*	*Bonded - Part 25 To Solid*	*Bonded - Part 35 To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 25				Part 35
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 83
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 35 To Solid*	*Bonded - Part 35 To Solid*	*Bonded - Part 35 To Solid*	*Bonded - Part 35 To Solid*	*Bonded - Part 2 To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 35				Part 2
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 84
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 2 To Solid*	*Bonded - Part 2 To Solid*	*Bonded - Part 2 To Solid*	*Bonded - Part 2 To Solid*	*Bonded - Part 2 To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 2				
Target Bodies	Solid				
Definition					

Type	Bonded
Scope Mode	Automatic
Behavior	Symmetric
Suppressed	No
Advanced	
Formulation	Pure Penalty
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled

TABLE 85
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 12 To Solid*	*Bonded - Part 12 To Solid*	*Bonded - Part 12 To Solid*	*Bonded - Part 12 To Solid*	*Bonded - Part 12 To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 12				
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 86
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Part 12 To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Part 12	Solid			
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 87
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Solid				
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

TABLE 88
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Solid				
Target Bodies	Solid				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Symmetric				
Suppressed	No				
Advanced					
Formulation	Pure Penalty				
Normal Stiffness	Program Controlled				
Update Stiffness	Never				
Pinball Region	Program Controlled				

F

TABLE 89
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	1 Face				
Target	1 Face				
Contact Bodies	Solid				
Target Bodies	Solid				
Definition					

Type	Bonded
Scope Mode	Automatic
Behavior	Symmetric
Suppressed	No
Advanced	
Formulation	Pure Penalty
Normal Stiffness	Program Controlled
Update Stiffness	Never
Pinball Region	Program Controlled

TABLE 90
Bolt check (C4) > Connections > Contacts > Contact Regions

Object Name	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*	*Bonded - Solid To Solid*
State	Fully Defined			
Scope				
Scoping Method	Geometry Selection			
Contact	1 Face			
Target	1 Face			
Contact Bodies	Solid			
Target Bodies	Solid			
Definition				
Type	Bonded			
Scope Mode	Automatic			
Behavior	Symmetric			
Suppressed	No			
Advanced				
Formulation	Pure Penalty			
Normal Stiffness	Program Controlled			
Update Stiffness	Never			
Pinball Region	Program Controlled			

F

Mesh

TABLE 91
Bolt check (C4) > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	20,0 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0,272
Maximum Layers	5
Growth Rate	1,2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled

Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	227755
Elements	34990
Mesh Metric	Skewness
Min	1,34222502290619E-07
Max	0,701342273938782
Average	0,263600745331541
Standard Deviation	0,204632867506524

TABLE 92
Bolt check (C4) > Mesh > Mesh Controls

Object Name	*MultiZone*	*Body Sizing*	*MultiZone 2*	*Body Sizing 2*	*MultiZone 3*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Geometry	2 Bodies		3 Bodies		6 Bodies
Definition					
Suppressed	No				
Method	MultiZone		MultiZone		MultiZone
Mapped Mesh Type	Hexa		Hexa		Hexa/Prism
Free Mesh Type	Not Allowed		Not Allowed		Not Allowed
Element Midside Nodes	Use Global Setting		Use Global Setting		Use Global Setting
Src/Trg Selection	Automatic		Automatic		Automatic
Source	Program Controlled		Program Controlled		Program Controlled
Type		Element Size		Element Size	
Element Size		150, mm		50, mm	
Behavior		Soft		Soft	
Advanced					
Mesh Based Defeaturing	Off		Off		Off
Minimum Edge Length	3431,2 mm		20,06 mm		30, mm
Write ICEM CFD Files	No		No		No

TABLE 93
Bolt check (C4) > Mesh > Mesh Controls

Object Name	*Edge Sizing*	*Face Sizing*	*MultiZone 4*	*Body Sizing 3*	*Edge Sizing 2*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Geometry	6 Edges	6 Faces	2 Bodies		2 Edges
Definition					
Suppressed	No				
Type	Number of Divisions	Element Size		Element Size	Number of Divisions
Number of Divisions	2				2
Behavior	Soft			Soft	
Bias Type	No Bias				No Bias
Element Size		35, mm		50, mm	
Method			MultiZone		
Mapped Mesh Type			Hexa		
Free Mesh Type			Not Allowed		
Element Midside Nodes			Use Global Setting		
Src/Trg Selection			Automatic		

F

Source		Program Controlled	
Advanced			
Mesh Based Defeaturing		Off	
Minimum Edge Length		25,033 mm	
Write ICEM CFD Files		No	

TABLE 94
Bolt check (C4) > Mesh > Mesh Controls

Object Name	*MultiZone 5*	*Body Sizing 4*	*Sweep Method*	*Face Sizing 2*	*MultiZone 6*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Geometry	2 Bodies		6 Bodies	6 Faces	40 Bodies
Definition					
Suppressed	No				
Method	MultiZone		Sweep		MultiZone
Mapped Mesh Type	Hexa/Prism				Hexa/Prism
Free Mesh Type	Not Allowed				Not Allowed
Element Midside Nodes	Use Global Setting		Use Global Setting		Use Global Setting
Src/Trg Selection	Automatic		Automatic		Automatic
Source	Program Controlled		Program Controlled		Program Controlled
Type		Element Size			
Element Size		30, mm		30, mm	
Behavior		Soft		Soft	
Target			Program Controlled		
Free Face Mesh Type			Quad/Tri		
Sweep Element Size			30, mm		
Sweep Bias Type			No Bias		
Element Option			Solid		
Constrain Boundary			No		
Advanced					
Mesh Based Defeaturing	Off				Off
Minimum Edge Length	20, mm				20, mm
Write ICEM CFD Files	No				No

TABLE 95
Bolt check (C4) > Mesh > Mesh Controls

Object Name	*Body Sizing 5*	*MultiZone 7*	*Body Sizing 6*	*Patch Conforming Method*	*Body Sizing 7*
State	Fully Defined			Suppressed	
Scope					
Scoping Method	Geometry Selection				
Geometry	40 Bodies	14 Bodies		75 Bodies	2 Bodies
Definition					
Suppressed	No			Yes	
Type	Element Size		Element Size		Element Size
Element Size	30, mm		30, mm		75, mm
Behavior	Soft		Soft		Soft
Method		MultiZone		Tetrahedrons	
Mapped Mesh Type		Hexa/Prism			
Free Mesh Type		Not Allowed			
Element Midside Nodes		Use Global Setting		Use Global Setting	
Src/Trg Selection		Automatic			
Source		Program Controlled			
Active				No, Suppressed	
Algorithm				Patch Conforming	
Advanced					
Mesh Based Defeaturing		Off			
Minimum Edge Length		20, mm			
Write ICEM CFD Files		No			

F

TABLE 96
Bolt check (C4) > Mesh > Mesh Controls

Object Name	*MultiZone 8*	*Face Sizing 3*	*Automatic Method*	*Face Sizing 4*
State	Fully Defined			
Scope				
Scoping Method	Geometry Selection			
Geometry	17 Bodies	24 Faces	20 Bodies	16 Faces
Definition				
Suppressed	No			
Method	MultiZone		Automatic	
Mapped Mesh Type	Hexa			
Free Mesh Type	Not Allowed			
Element Midside Nodes	Use Global Setting		Use Global Setting	
Src/Trg Selection	Automatic			
Source	Program Controlled			
Type		Element Size		Element Size
Element Size		20, mm		17,5 mm
Behavior		Soft		Soft
Advanced				
Mesh Based Defeaturing	Off			
Minimum Edge Length	235,62 mm			
Write ICEM CFD Files	No			

Static Structural (C5)

TABLE 97
Bolt check (C4) > Analysis

Object Name	*Static Structural (C5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22, °C
Generate Input Only	No

F

TABLE 98
Bolt check (C4) > Static Structural (C5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	2,
Current Step Number	1,
Step End Time	1, s
Auto Time Stepping	On
Define By	Substeps
Initial Substeps	5,
Minimum Substeps	5,
Maximum Substeps	30,
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Nonlinear Controls	
Force Convergence	Program Controlled

Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Off
Output Controls	
Calculate Stress	Yes
Calculate Strain	Yes
Calculate Contact	No
Calculate Results At	All Time Points
Analysis Data Management	
Solver Files Directory	C:\Documents and Settings\SS7N0605\My Documents\ANSYS final\Analysis Clamp 4_files\dp0\SYS-5\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Delete Unneeded Files	Yes
Nonlinear Solution	Yes
Solver Units	Active System
Solver Unit System	nmm

TABLE 99
Bolt check (C4) > Static Structural (C5) > Analysis Settings
Step-Specific "Step Controls"

Step	Step End Time	Initial Substeps	Carry Over Time Step
1	1, s	5,	
2	2, s		On

TABLE 100
Bolt check (C4) > Static Structural (C5) > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
Coordinate System	Global Coordinate System
X Component	-0, mm/s² (ramped)
Y Component	-0, mm/s² (ramped)
Z Component	-9806,6 mm/s² (ramped)
Suppressed	No
Direction	-Z Direction

FIGURE 2
Bolt check (C4) > Static Structural (C5) > Standard Earth Gravity

F

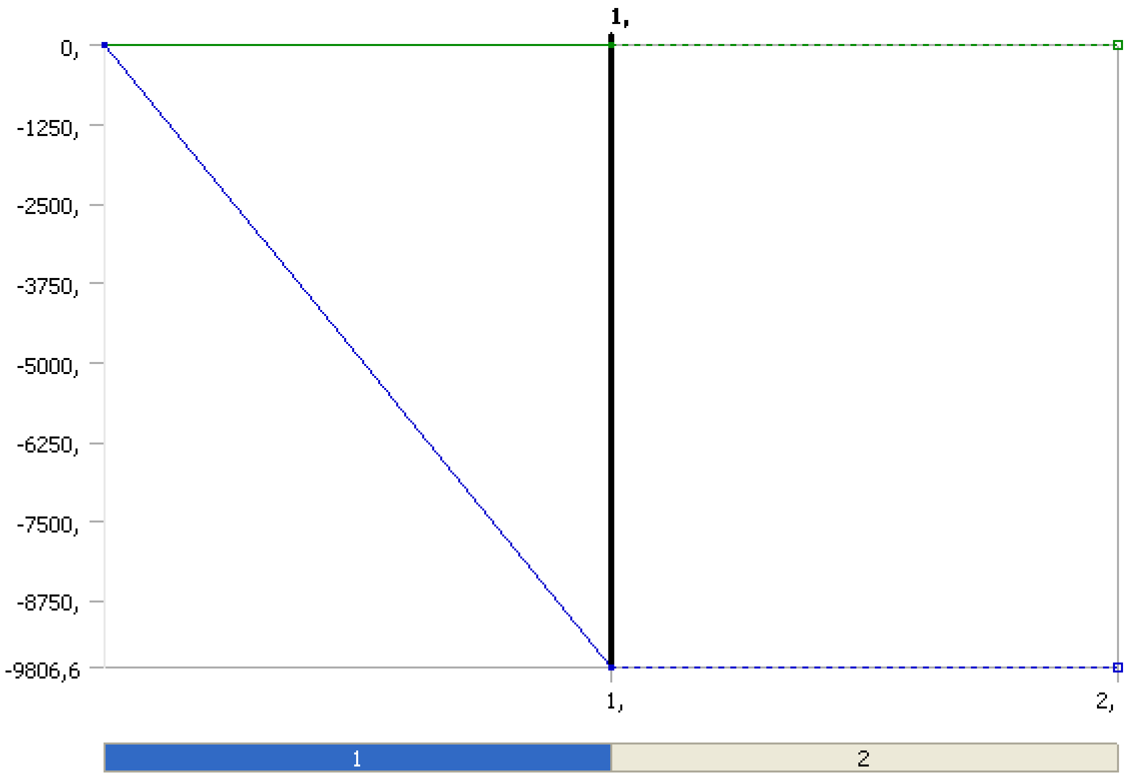

TABLE 101
Bolt check (C4) > Static Structural (C5) > Loads

Object Name	*Upper support*	*Lower support*	*Vert. wave on clamp*	*1/2 Hor. wave on clamp*	*1/4 Hor. wave on clamp 1*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Geometry	1 Face				
Definition					
Type	Fixed Support		Force		
Suppressed	No				
Define By			Vector		
Magnitude			Tabular Data		
Direction			Defined		

FIGURE 3
Bolt check (C4) > Static Structural (C5) > Vert. wave on clamp

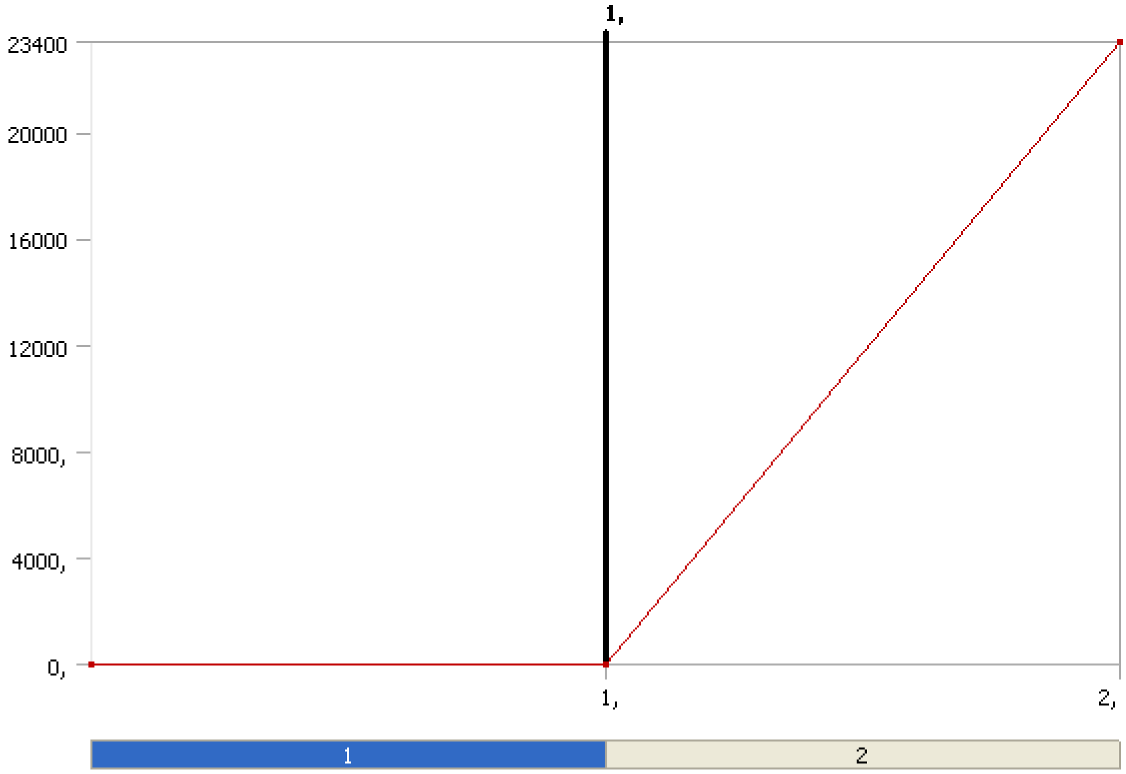

TABLE 102
Bolt check (C4) > Static Structural (C5) > Vert. wave on clamp

Steps	Time [s]	Force [N]
1	0,	0,
	1,	
2	2,	23400

FIGURE 4
Bolt check (C4) > Static Structural (C5) > 1/2 Hor. wave on clamp

F

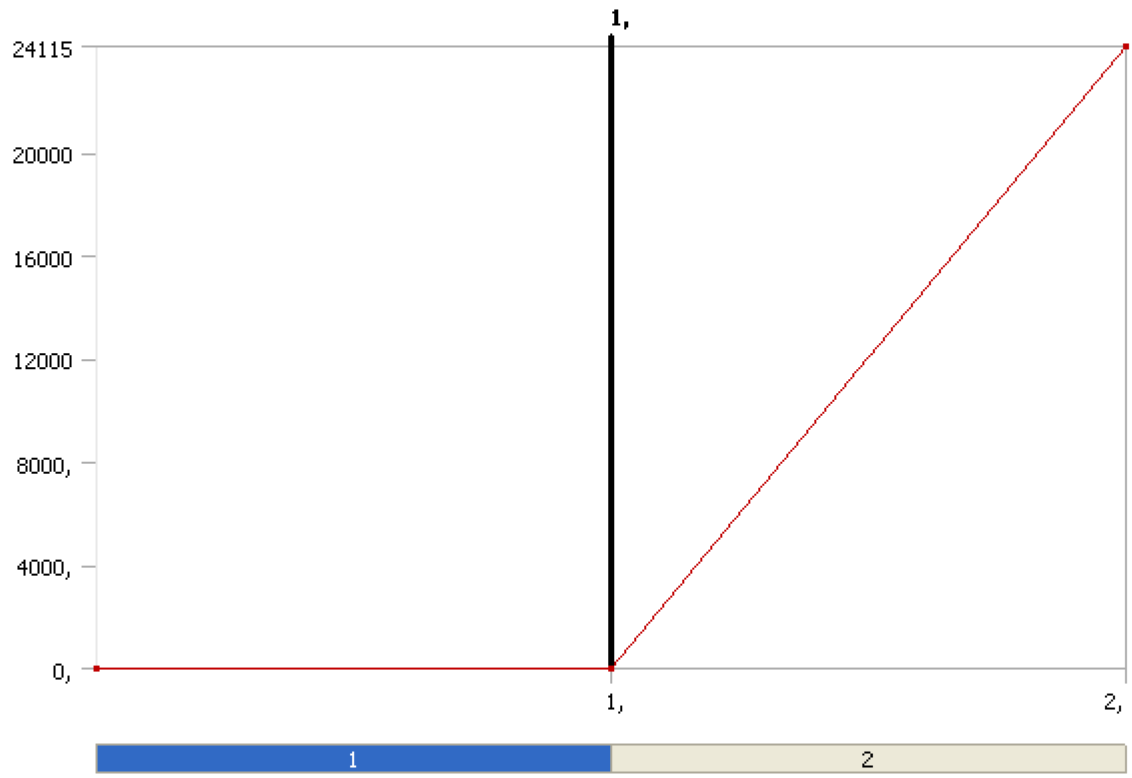

TABLE 103
Bolt check (C4) > Static Structural (C5) > 1/2 Hor. wave on clamp

Steps	Time [s]	Force [N]
1	0,	0,
	1,	
2	2,	24115

F

FIGURE 5
Bolt check (C4) > Static Structural (C5) > 1/4 Hor. wave on clamp 1

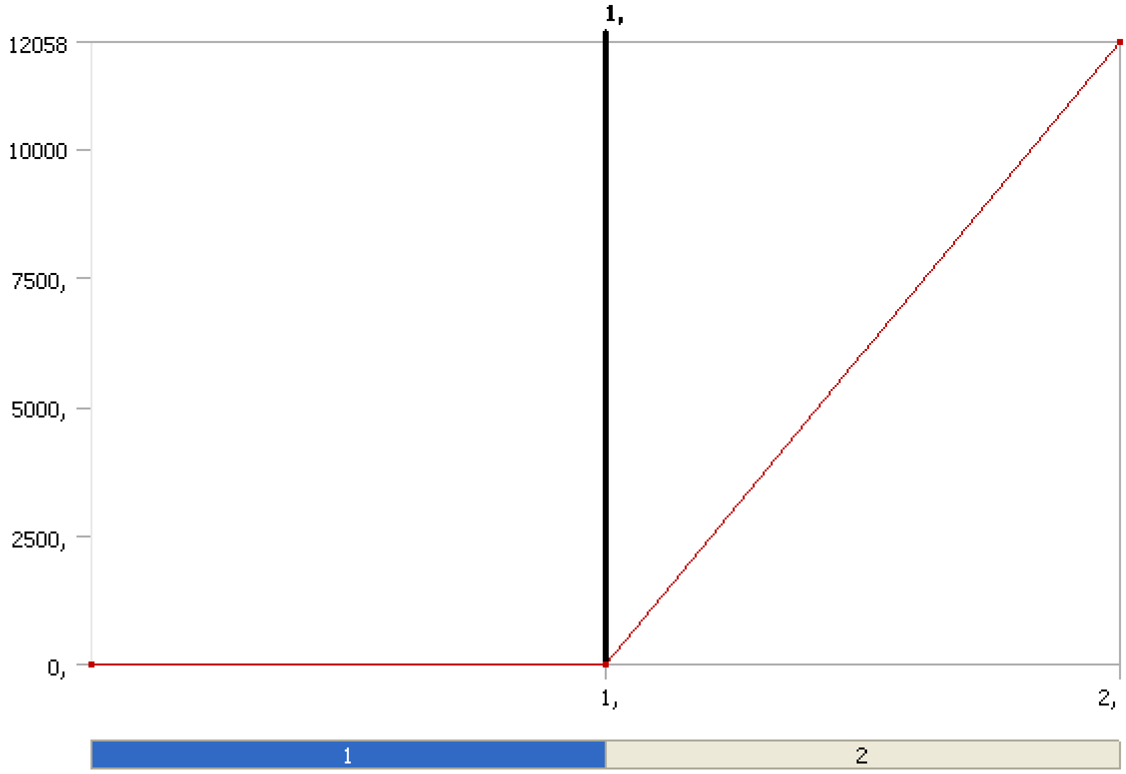

TABLE 104
Bolt check (C4) > Static Structural (C5) > 1/4 Hor. wave on clamp 1

Steps	Time [s]	Force [N]
1	0,	0,
	1,	
2	2,	12058

TABLE 105
Bolt check (C4) > Static Structural (C5) > Loads

Object Name	*1/4 Hor. wave on clamp 2*	*Riser south*	*1/2 Riser east 1*	*1/2 Riser east 2*	*Riser vertical*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Geometry	1 Face		1 Edge		1 Face
Definition					
Type	Force				
Define By	Vector	Components			Vector
Magnitude	Tabular Data				Tabular Data
Direction	Defined				Defined
Suppressed	No				
Coordinate System		Global Coordinate System			
X Component		Tabular Data			
Y Component		Tabular Data			
Z Component		Tabular Data			

FIGURE 6
Bolt check (C4) > Static Structural (C5) > 1/4 Hor. wave on clamp 2

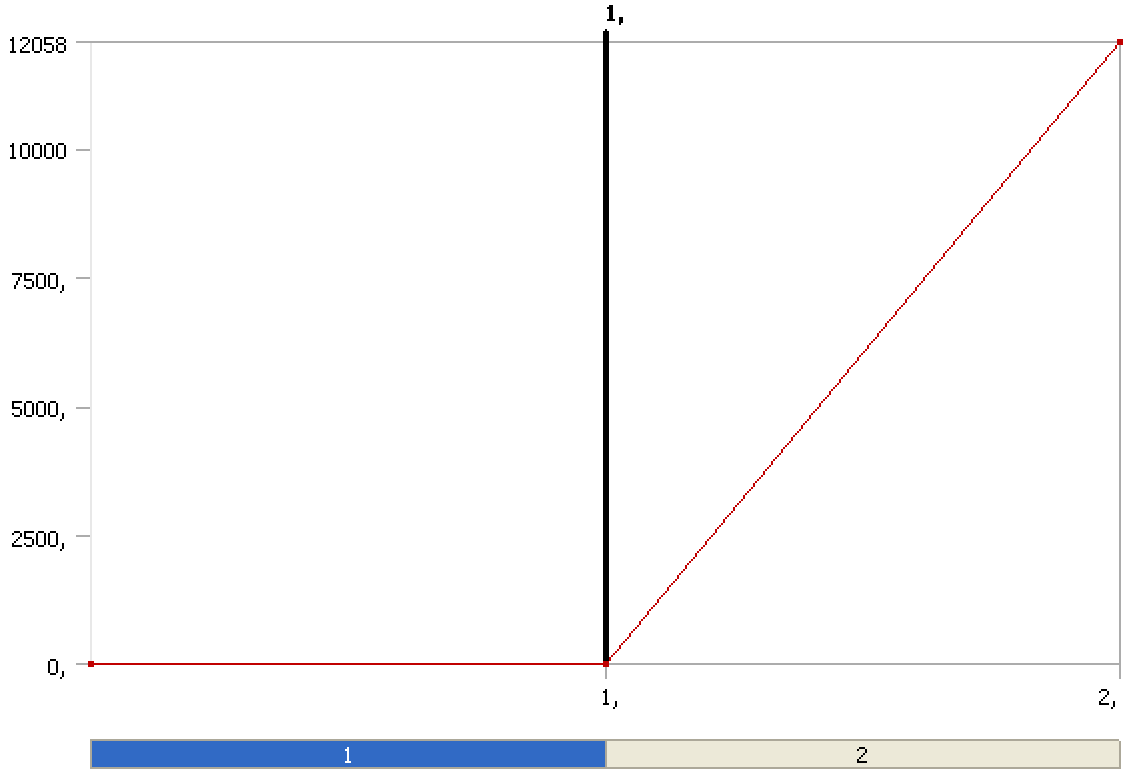

TABLE 106
Bolt check (C4) > Static Structural (C5) > 1/4 Hor. wave on clamp 2

Steps	Time [s]	Force [N]
1	0,	0,
	1,	
2	2,	12058

FIGURE 7
Bolt check (C4) > Static Structural (C5) > Riser south

F

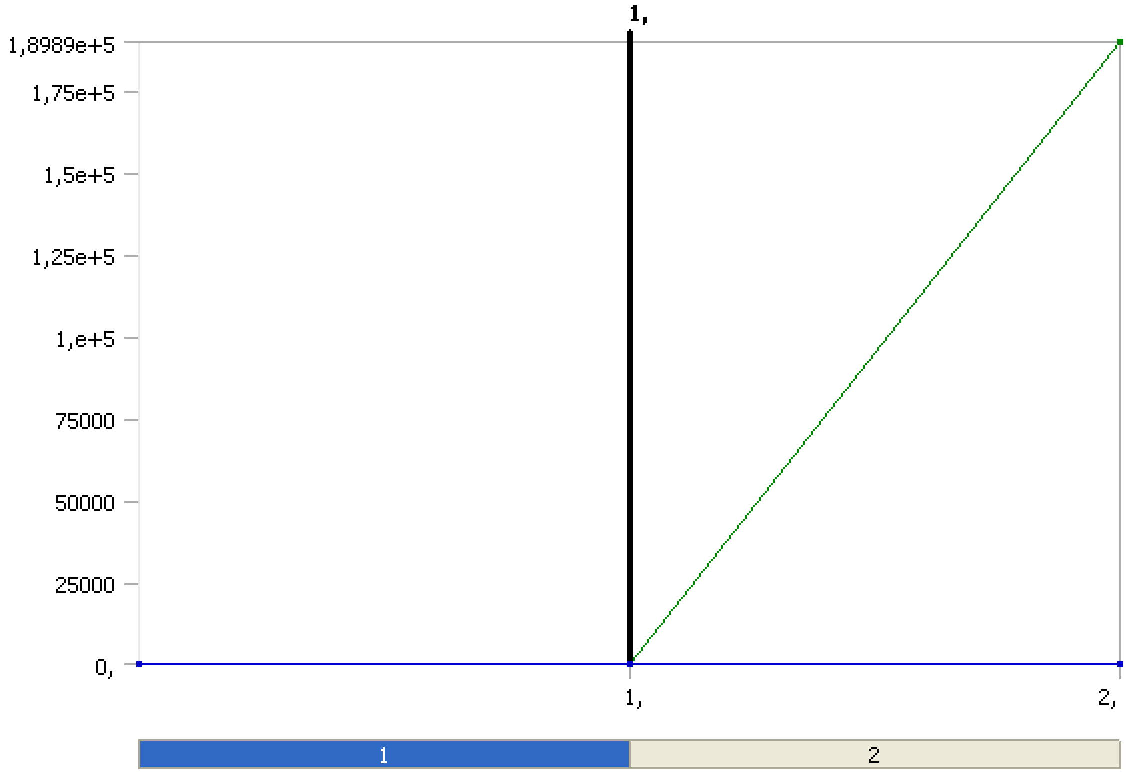

TABLE 107
Bolt check (C4) > Static Structural (C5) > Riser south

Steps	Time [s]	X [N]	Y [N]	Z [N]
1	0,	0,	0,	0,
	1,			
2	2,		1,8989e+005	

F

FIGURE 8
Bolt check (C4) > Static Structural (C5) > 1/2 Riser east 1

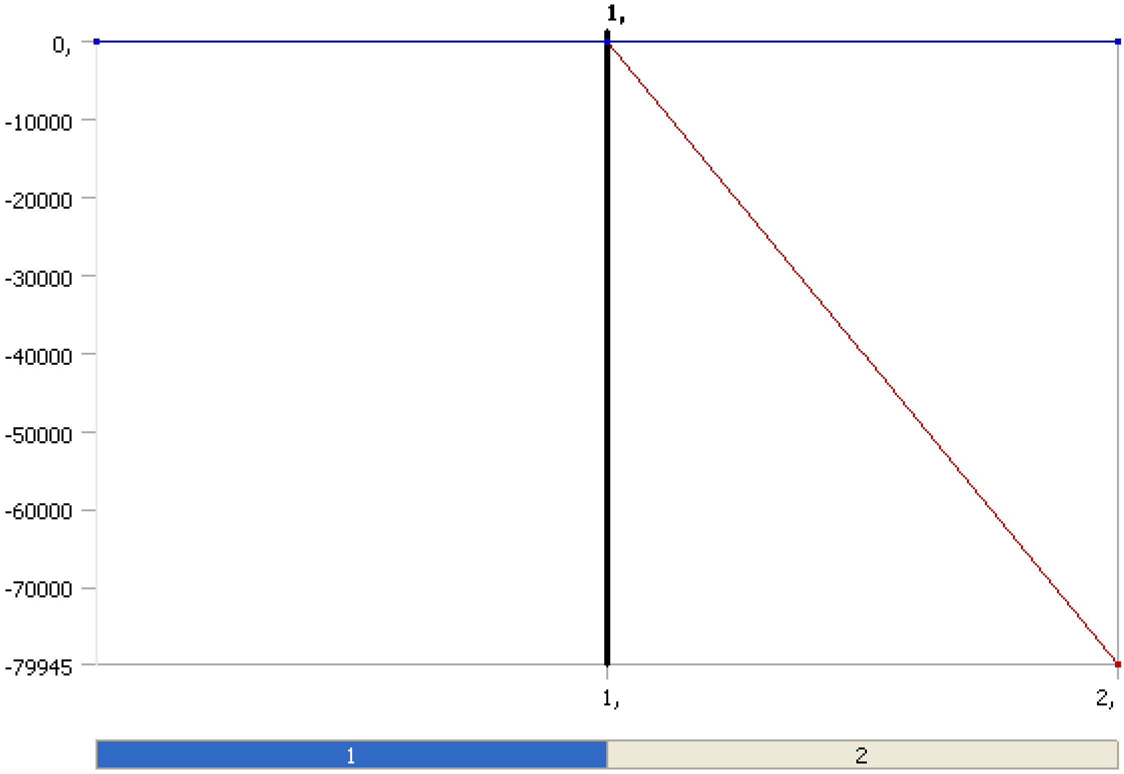

TABLE 108
Bolt check (C4) > Static Structural (C5) > 1/2 Riser east 1

Steps	Time [s]	X [N]	Y [N]	Z [N]
1	0,	0,	0,	0,
	1,			
2	2,	-79945		

FIGURE 9
Bolt check (C4) > Static Structural (C5) > 1/2 Riser east 2

F

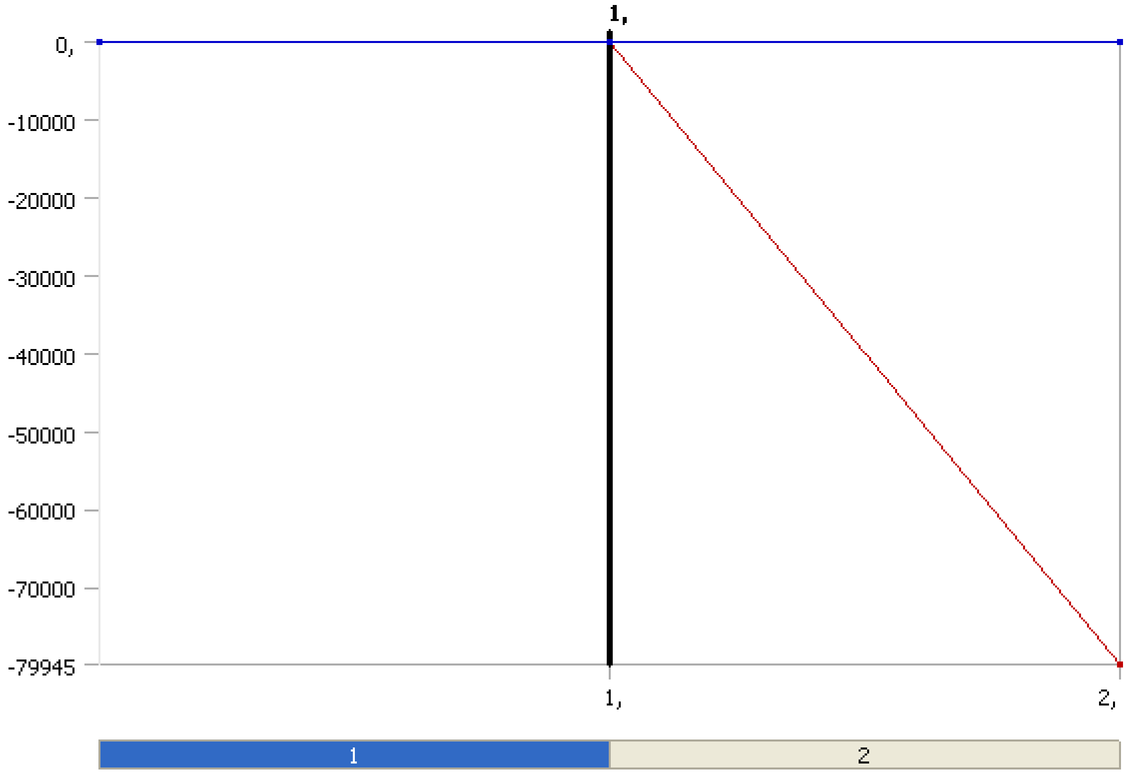

TABLE 109
Bolt check (C4) > Static Structural (C5) > 1/2 Riser east 2

Steps	Time [s]	X [N]	Y [N]	Z [N]
1	0,	0,	0,	0,
	1,			
2	2,	-79945		

FIGURE 10
Bolt check (C4) > Static Structural (C5) > Riser vertical

F

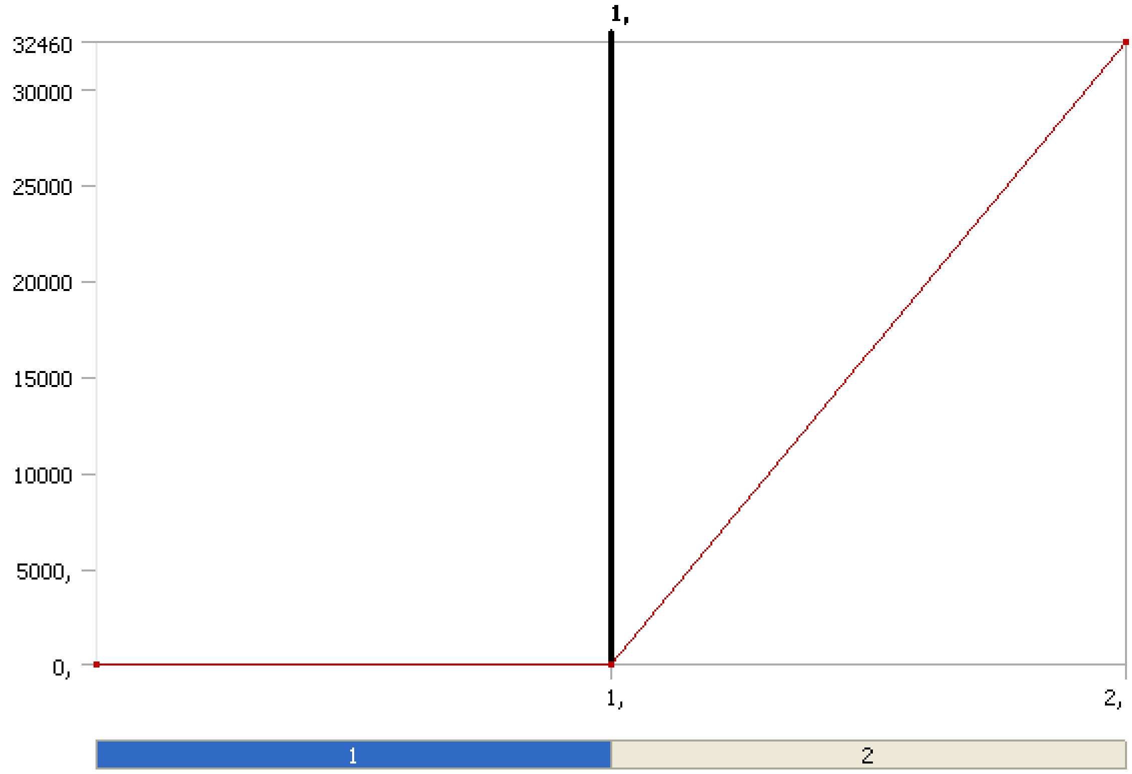

TABLE 110
Bolt check (C4) > Static Structural (C5) > Riser vertical

Steps	Time [s]	Force [N]
1	0,	0,
	1,	
2	2,	32460

TABLE 111
Bolt check (C4) > Static Structural (C5) > Loads

Object Name	*Pressure*	*Pressure 2*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	1 Face	
Definition		
Type	Pressure	
Define By	Normal To	
Magnitude	Tabular Data	
Suppressed	No	
Tabular Data		
Independent Variable	Time	

FIGURE 11
Bolt check (C4) > Static Structural (C5) > Pressure

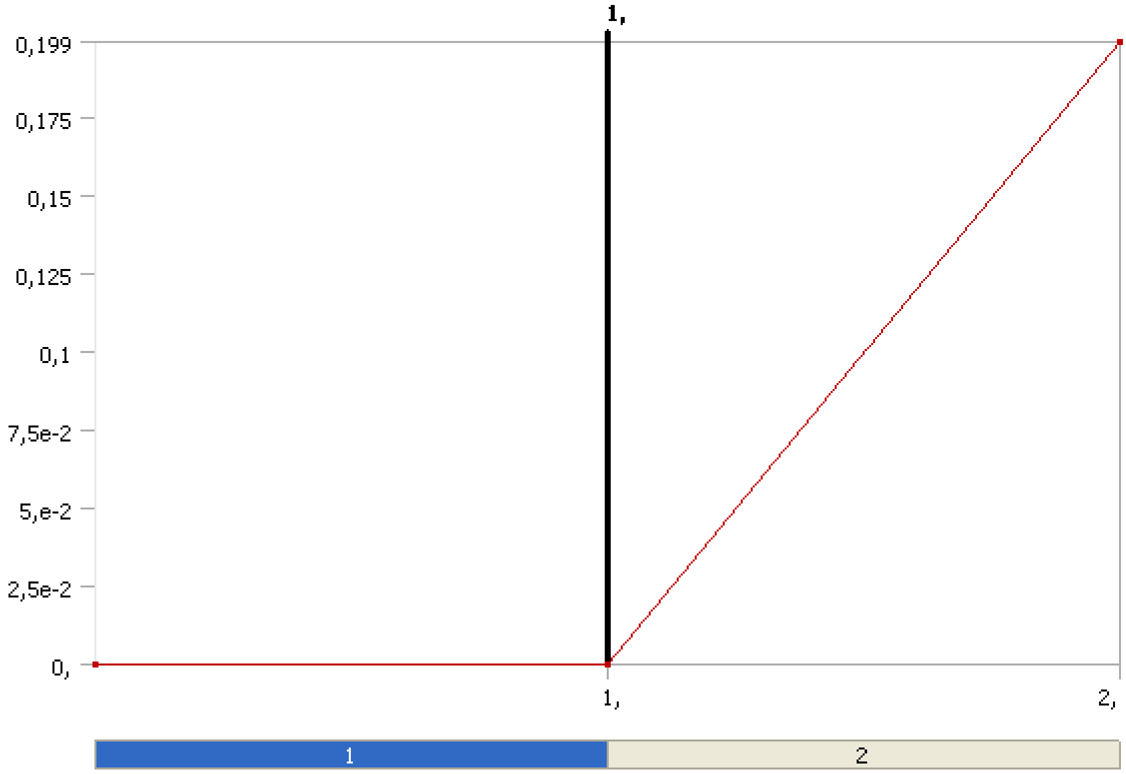

TABLE 112
Bolt check (C4) > Static Structural (C5) > Pressure

Steps	Time [s]	Pressure [MPa]
1	0,	0,
	1,	
2	2,	0,199

FIGURE 12
Bolt check (C4) > Static Structural (C5) > Pressure 2

F

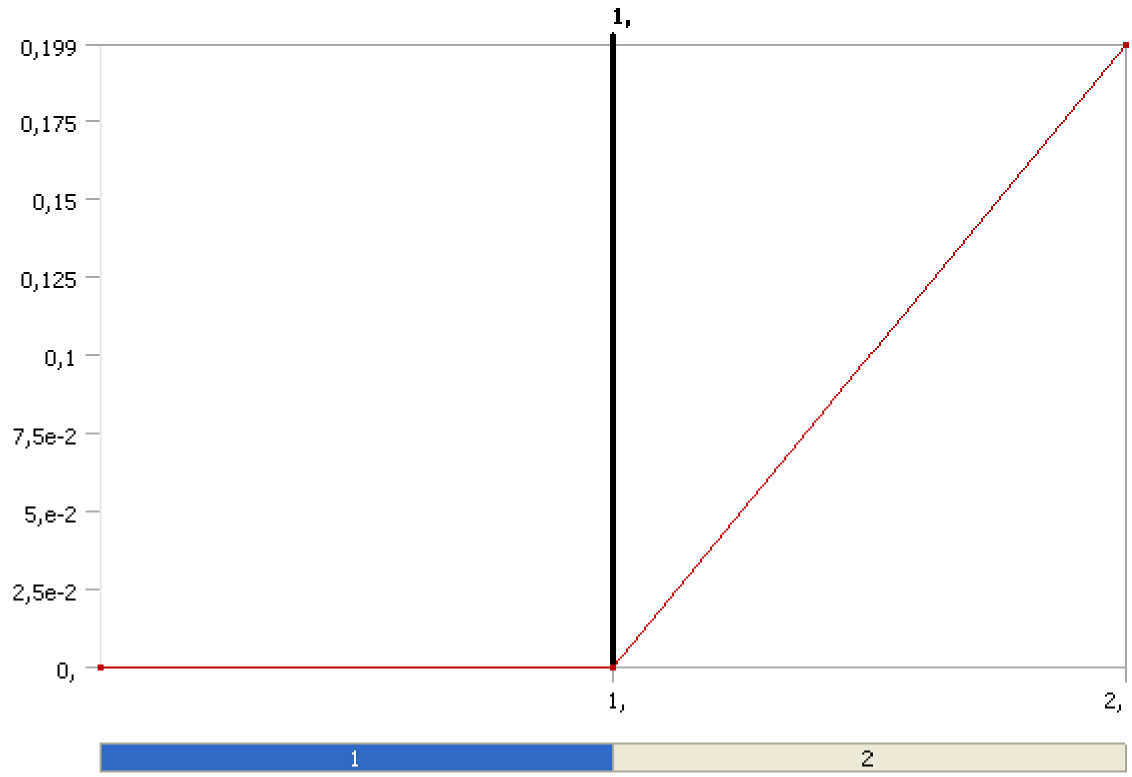

TABLE 113
Bolt check (C4) > Static Structural (C5) > Pressure 2

Steps	Time [s]	Pressure [MPa]
1	0,	0,
	1,	
2	2,	0,199

TABLE 114
Bolt check (C4) > Static Structural (C5) > Bolt Pretension

Object Name	*Bolt Pretension*	*Bolt Pretension 2*	*Bolt Pretension 3*	*Bolt Pretension 4*	*Bolt Pretension 5*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Geometry	1 Face				
Definition					
Type	Bolt Pretension				
Suppressed	No				
Define By	Load				
Preload	6,854e+005 N				

FIGURE 13
Bolt check (C4) > Static Structural (C5) > Bolt Pretension

F

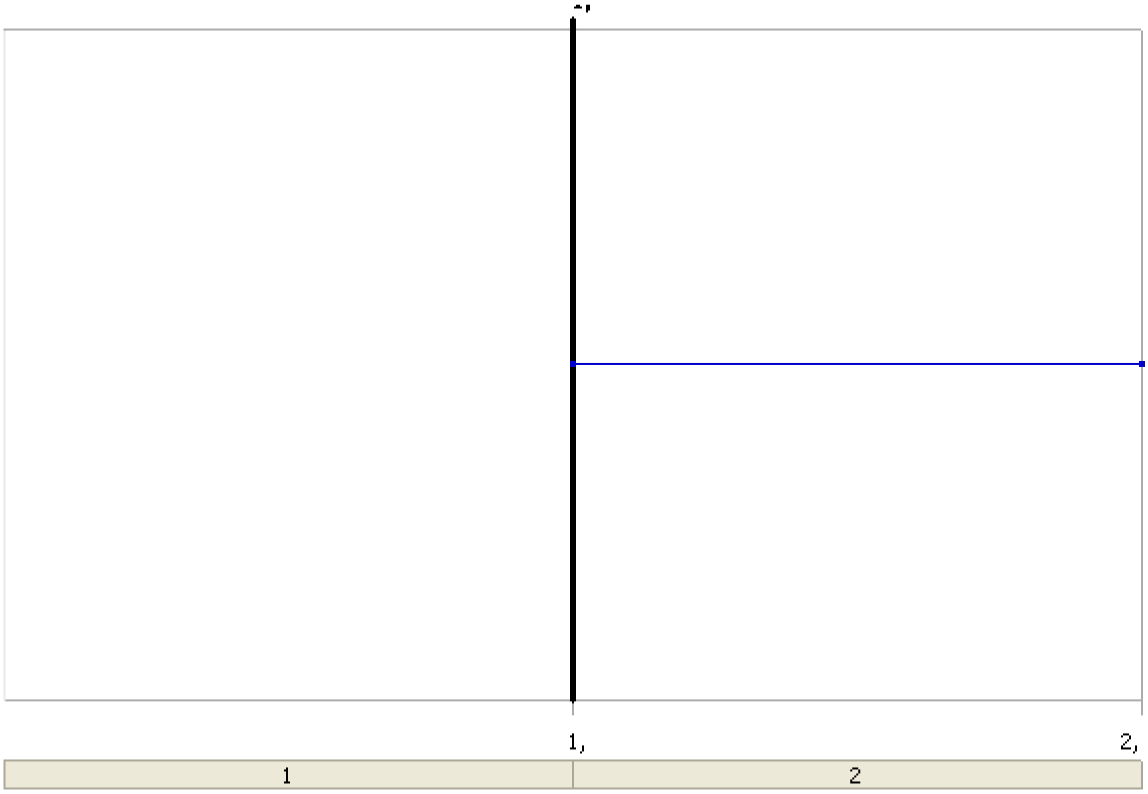

TABLE 115
Bolt check (C4) > Static Structural (C5) > Bolt Pretension

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

FIGURE 14
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 2

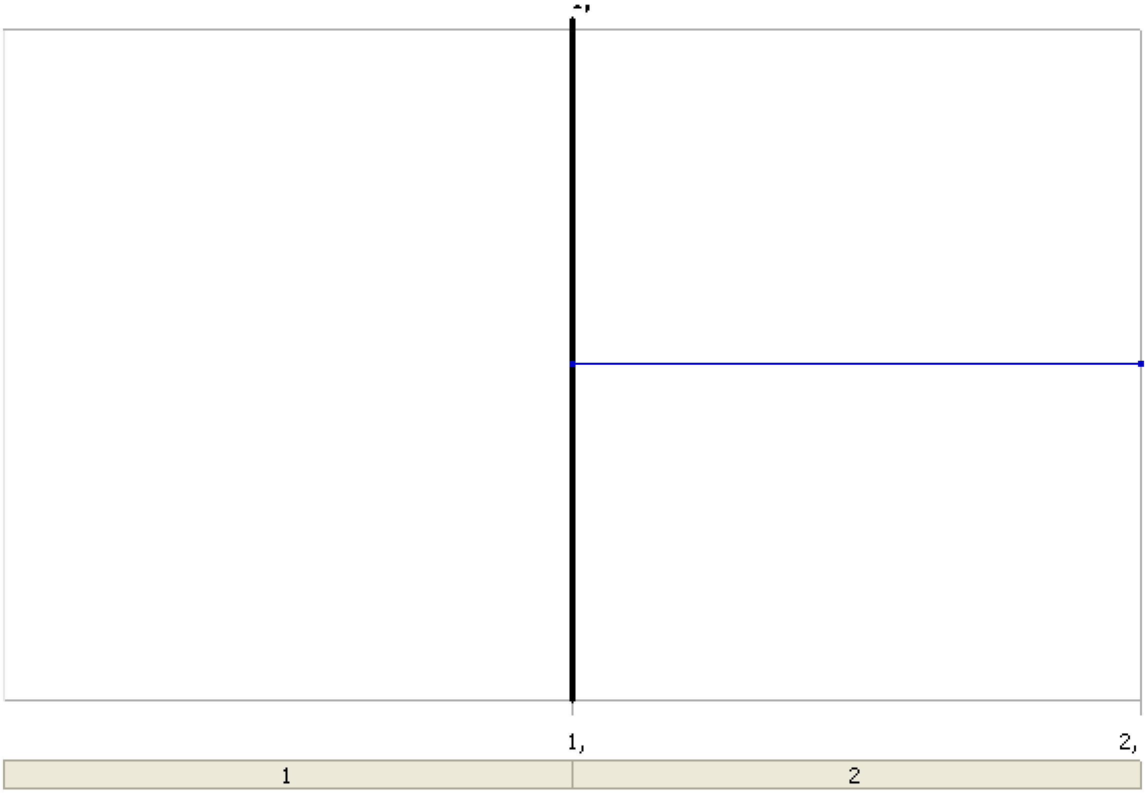

TABLE 116
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 2

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

F

FIGURE 15
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 3

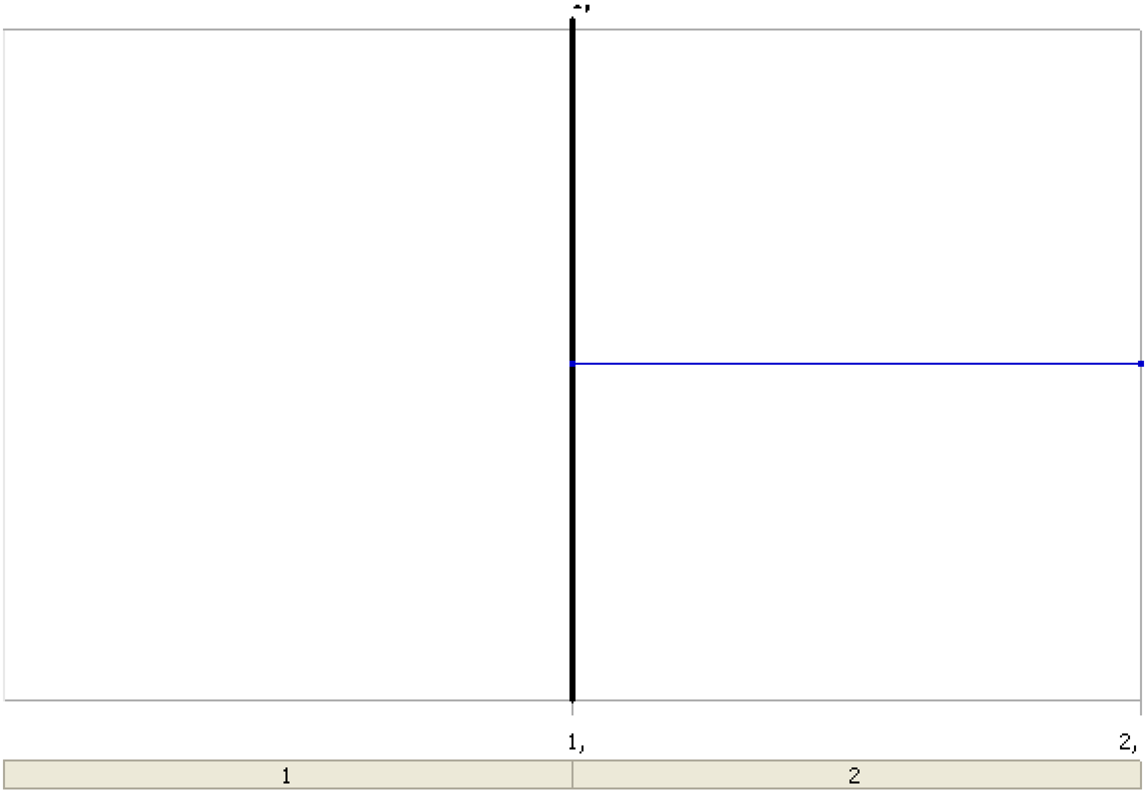

TABLE 117
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 3

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

FIGURE 16
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 4

F

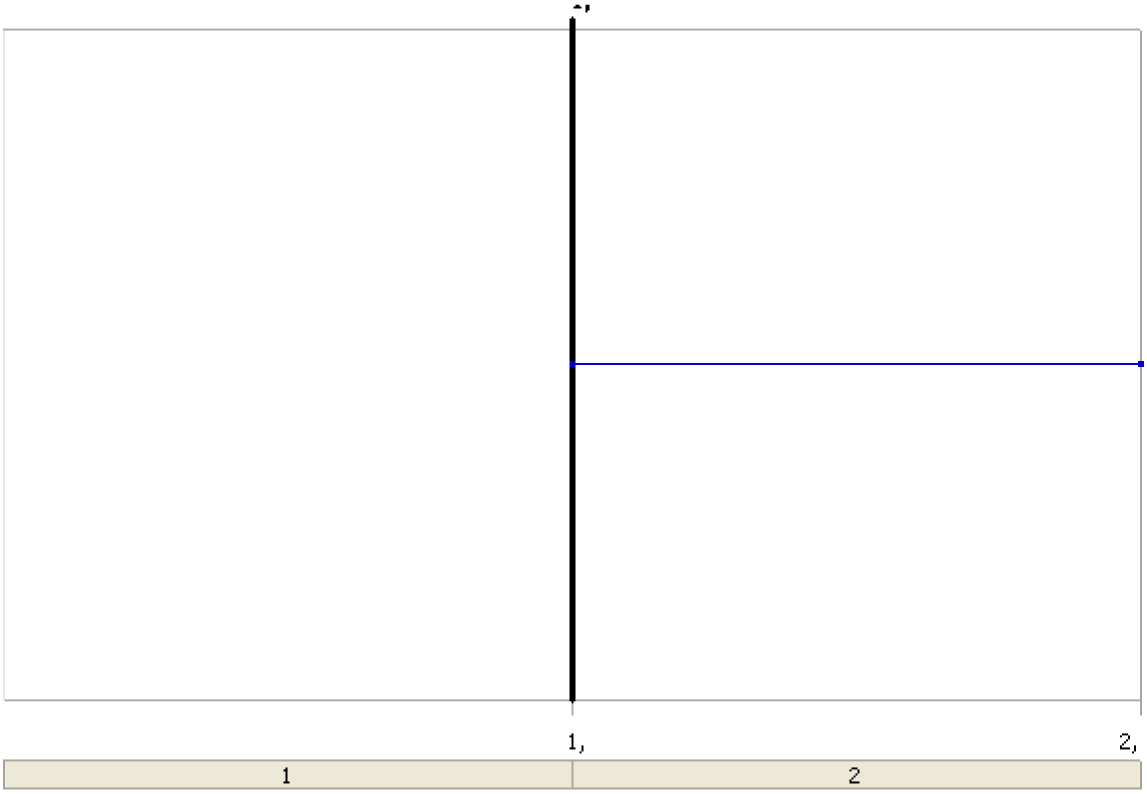

TABLE 118
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 4

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

F

FIGURE 17
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 5

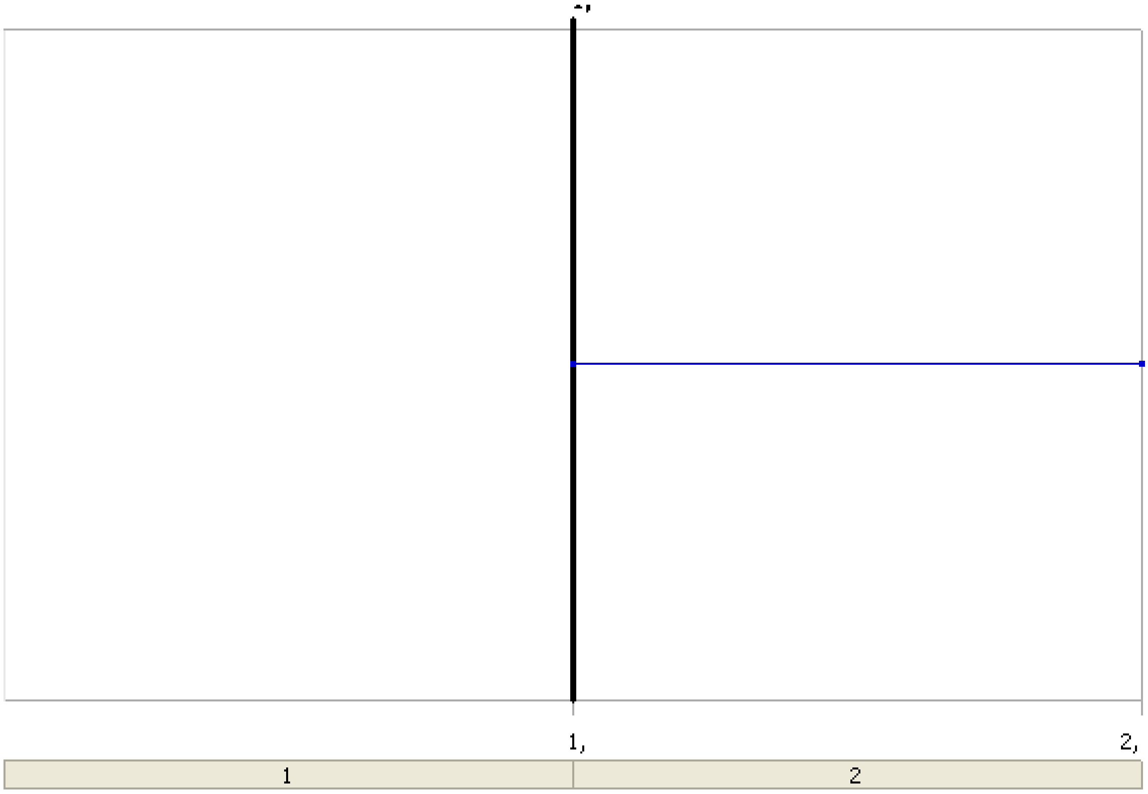

TABLE 119
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 5

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

TABLE 120
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 6

Object Name	*Bolt Pretension 6*	*Bolt Pretension 7*	*Bolt Pretension 8*	*Bolt Pretension 9*	*Bolt Pretension 10*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Geometry	1 Face				
Definition					
Type	Bolt Pretension				
Suppressed	No				
Define By	Load				
Preload	6,854e+005 N				

FIGURE 18
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 6

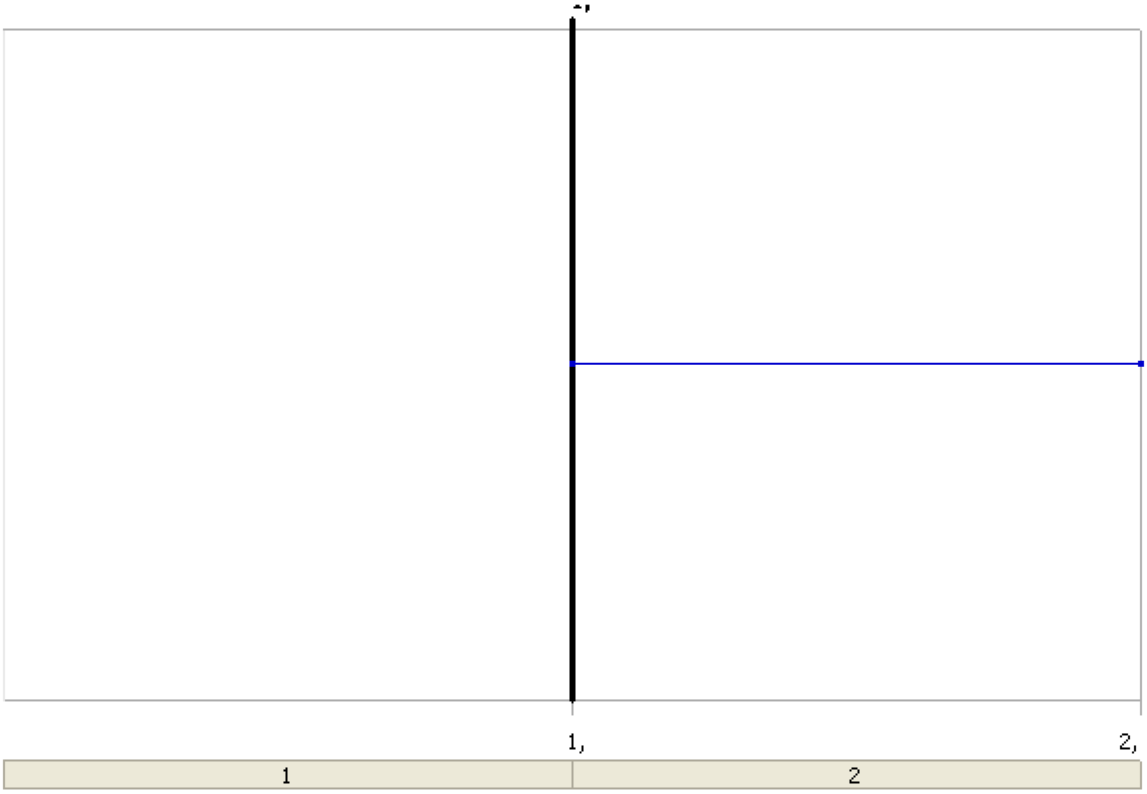

TABLE 121
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 6

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

FIGURE 19
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 7

F

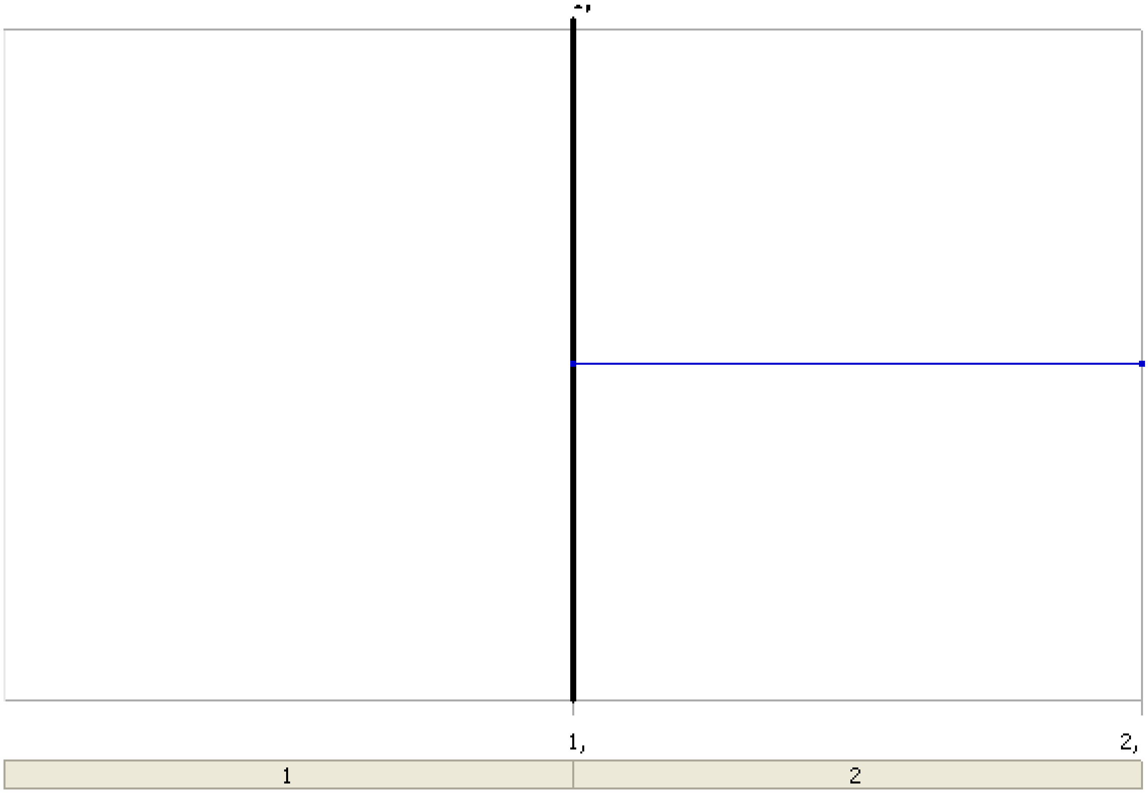

TABLE 122
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 7

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

FIGURE 20
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 8

F

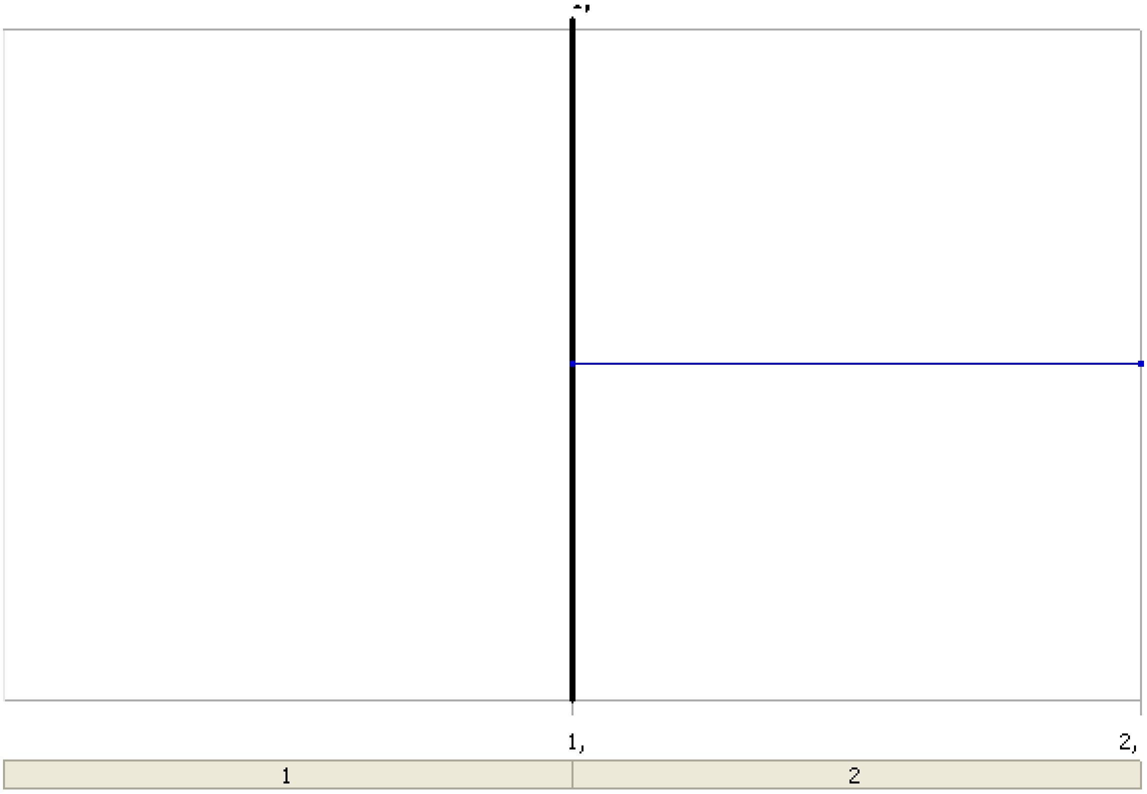

TABLE 123
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 8

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

FIGURE 21
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 9

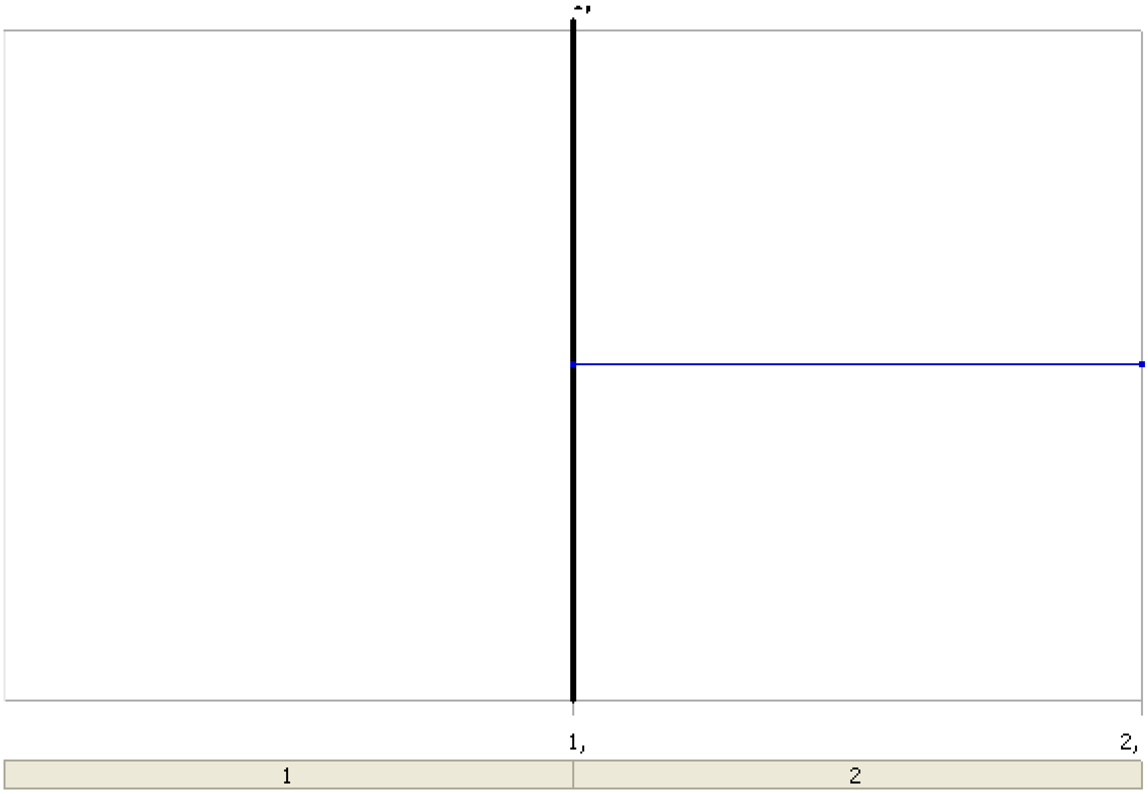

TABLE 124
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 9

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

F

FIGURE 22
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 10

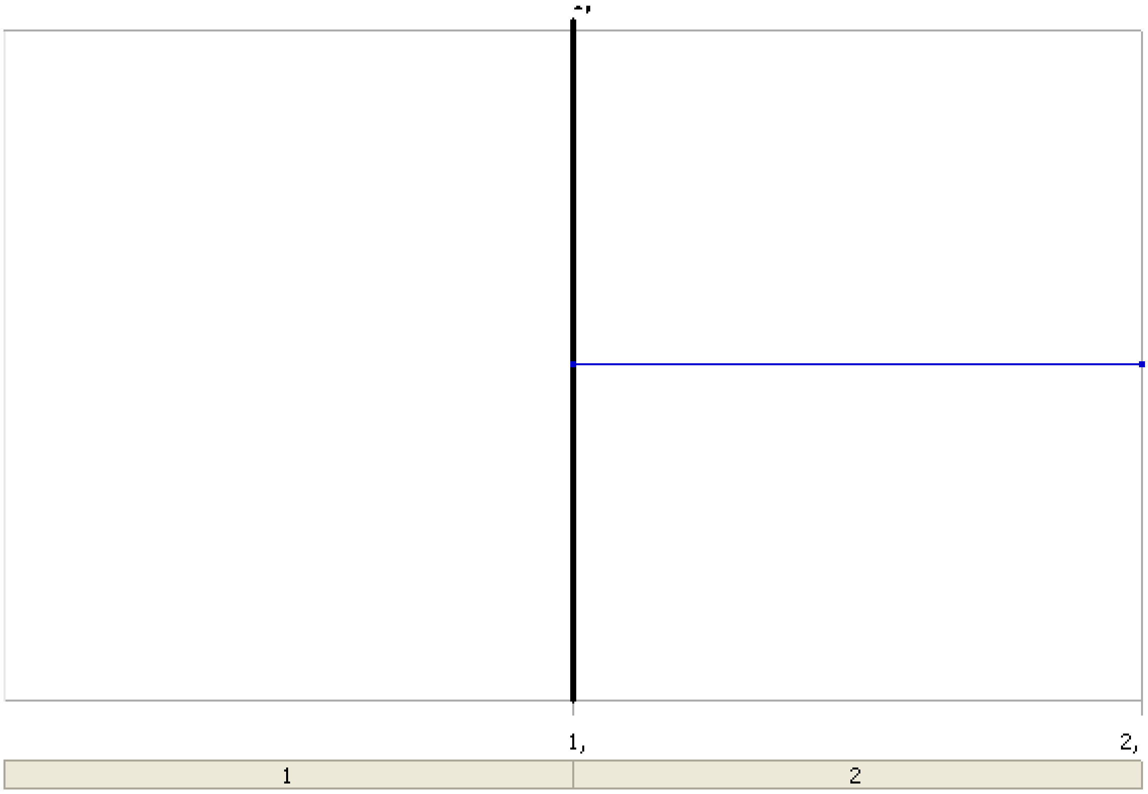

TABLE 125
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 10

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

TABLE 126
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 11

Object Name	*Bolt Pretension 11*	*Bolt Pretension 12*	*Bolt Pretension 13*	*Bolt Pretension 14*	*Bolt Pretension 15*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Geometry	1 Face				
Definition					
Type	Bolt Pretension				
Suppressed	No				
Define By	Load				
Preload	6,854e+005 N		3,76e+005 N		

FIGURE 23
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 11

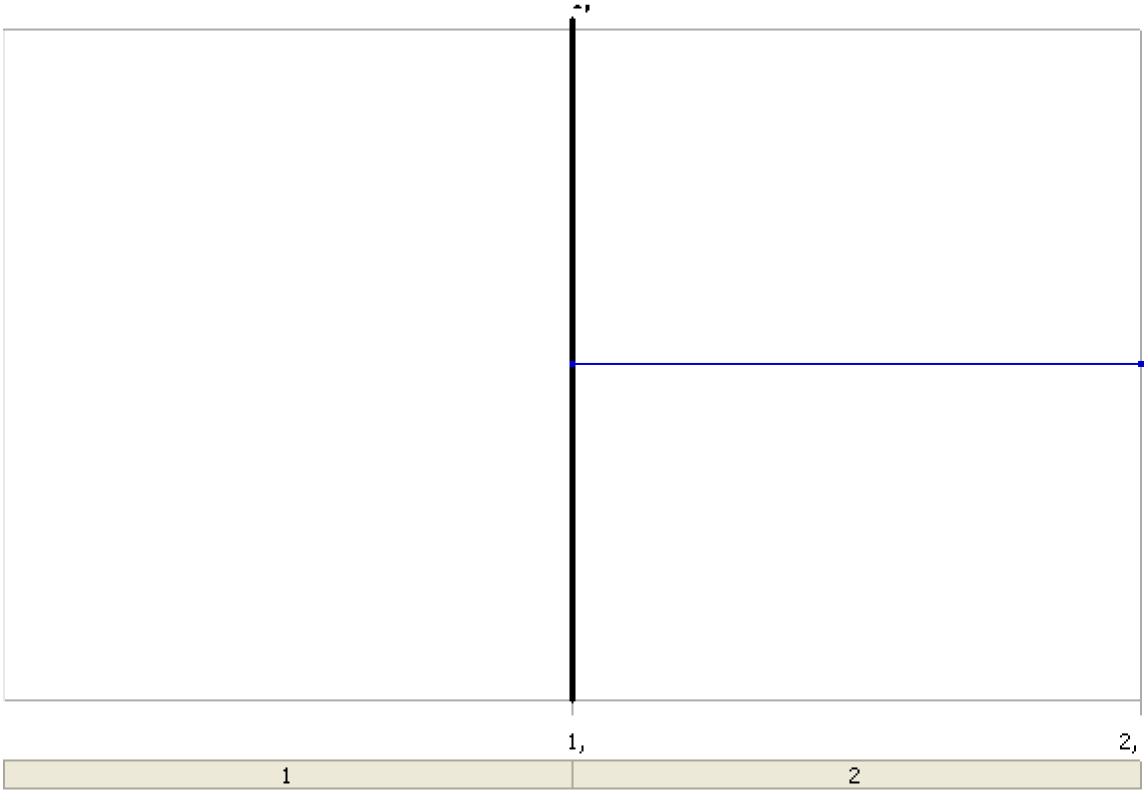

TABLE 127
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 11

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

FIGURE 24
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 12

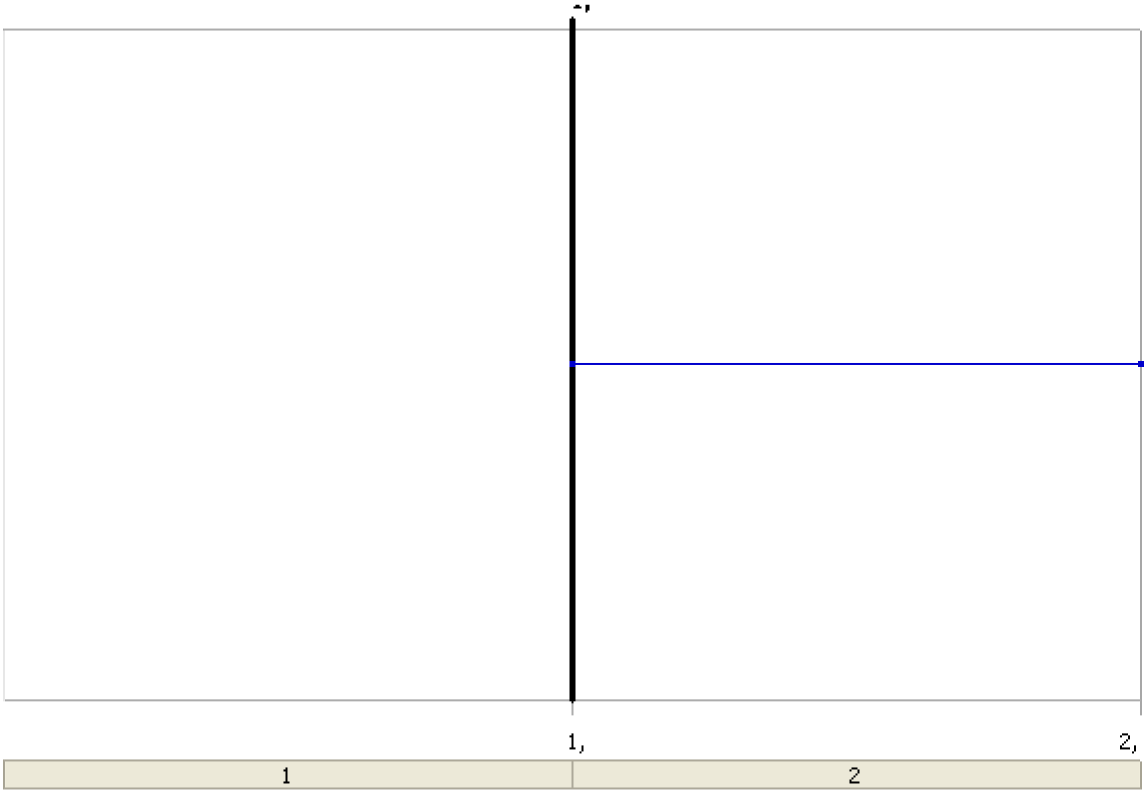

TABLE 128
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 12

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	6,854e+005	N/A
2,	Lock	N/A	

F

FIGURE 25
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 13

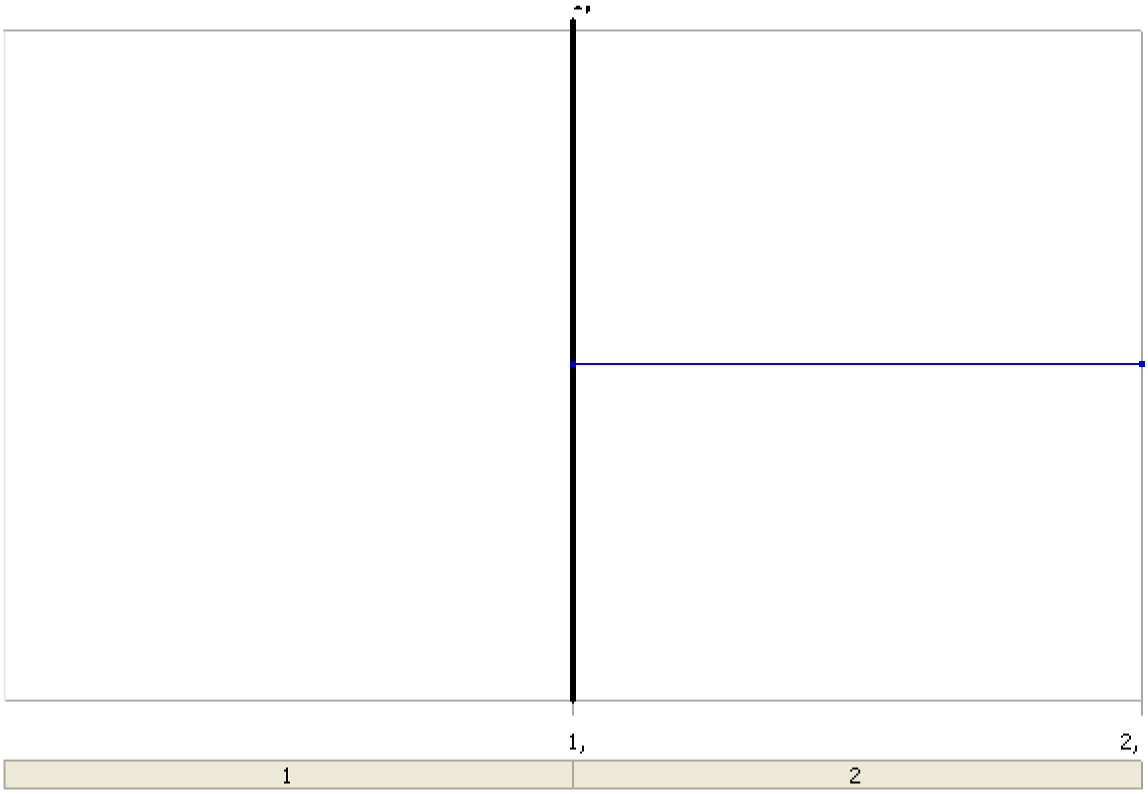

TABLE 129
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 13

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	3,76e+005	N/A
2,	Lock	N/A	

FIGURE 26
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 14

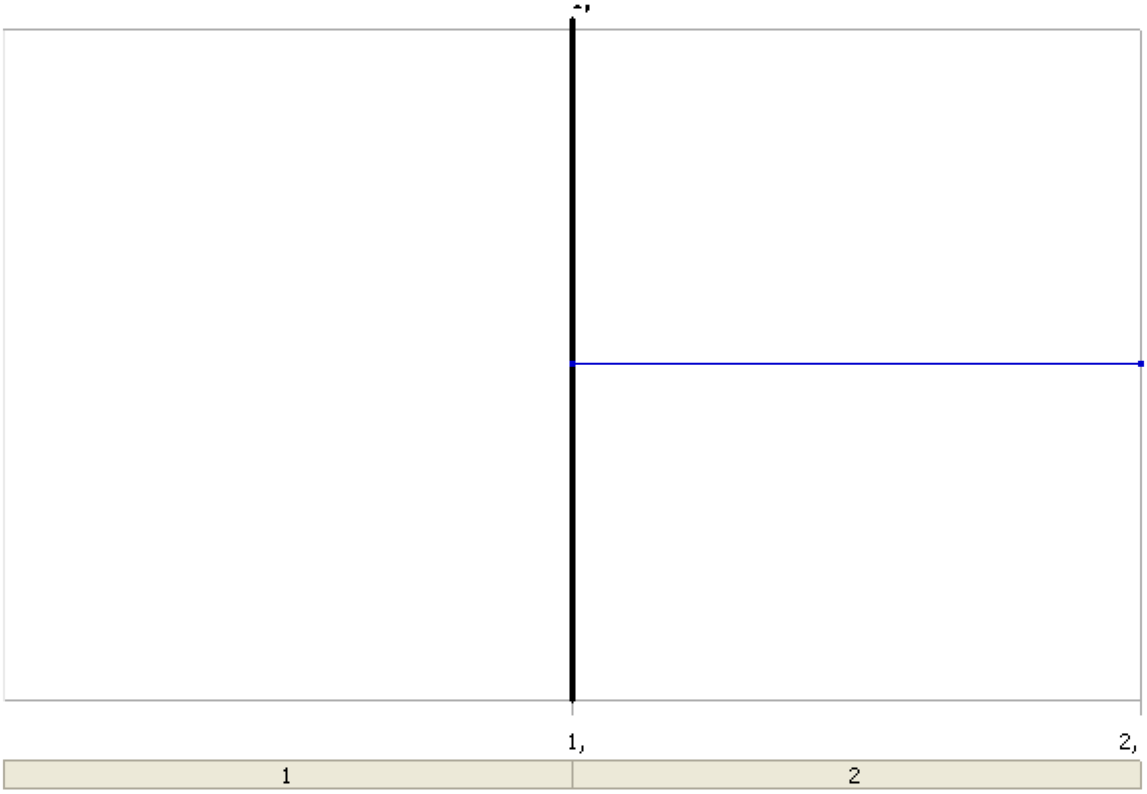

TABLE 130
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 14

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	3,76e+005	N/A
2,	Lock	N/A	

FIGURE 27
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 15

F

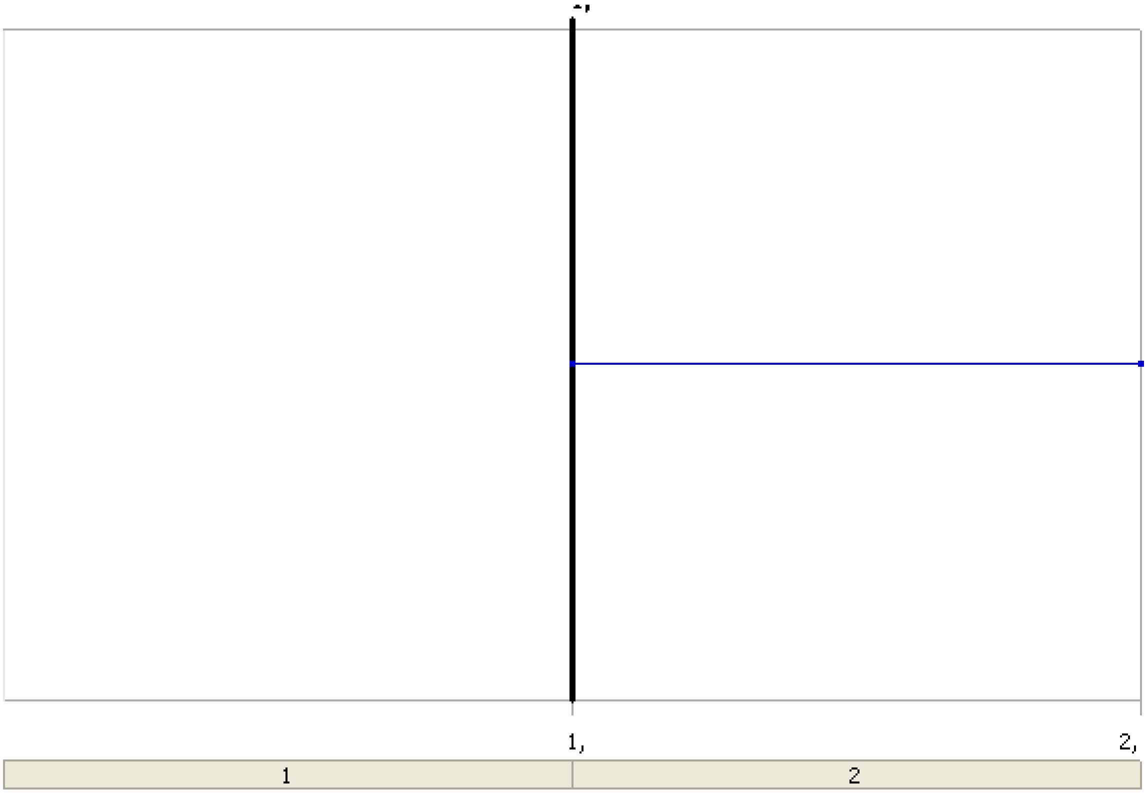

TABLE 131
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 15

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	3,76e+005	N/A
2,	Lock	N/A	

TABLE 132
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 16

Object Name	*Bolt Pretension 16*	*Bolt Pretension 17*	*Bolt Pretension 18*	*Bolt Pretension 19*	*Bolt Pretension 20*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Geometry	1 Face				
Definition					
Type	Bolt Pretension				
Suppressed	No				
Define By	Load				
Preload	3,76e+005 N				

FIGURE 28
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 16

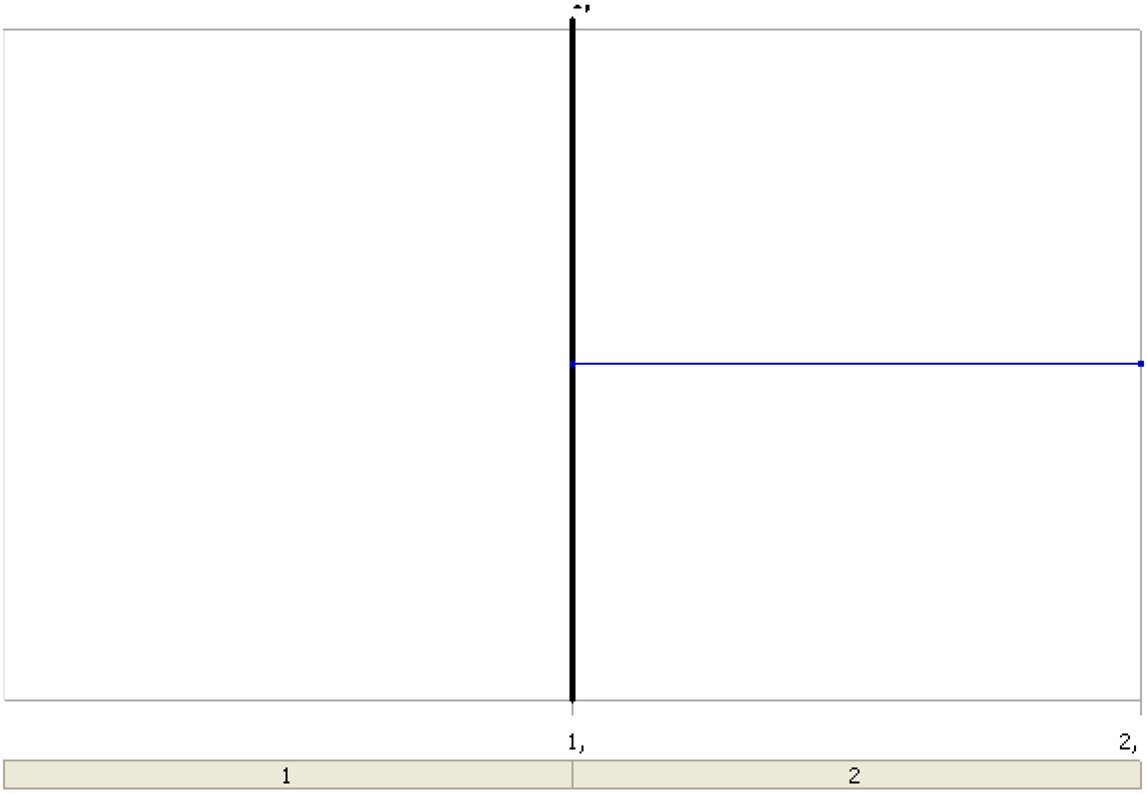

TABLE 133
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 16

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	3,76e+005	N/A
2,	Lock	N/A	

FIGURE 29
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 17

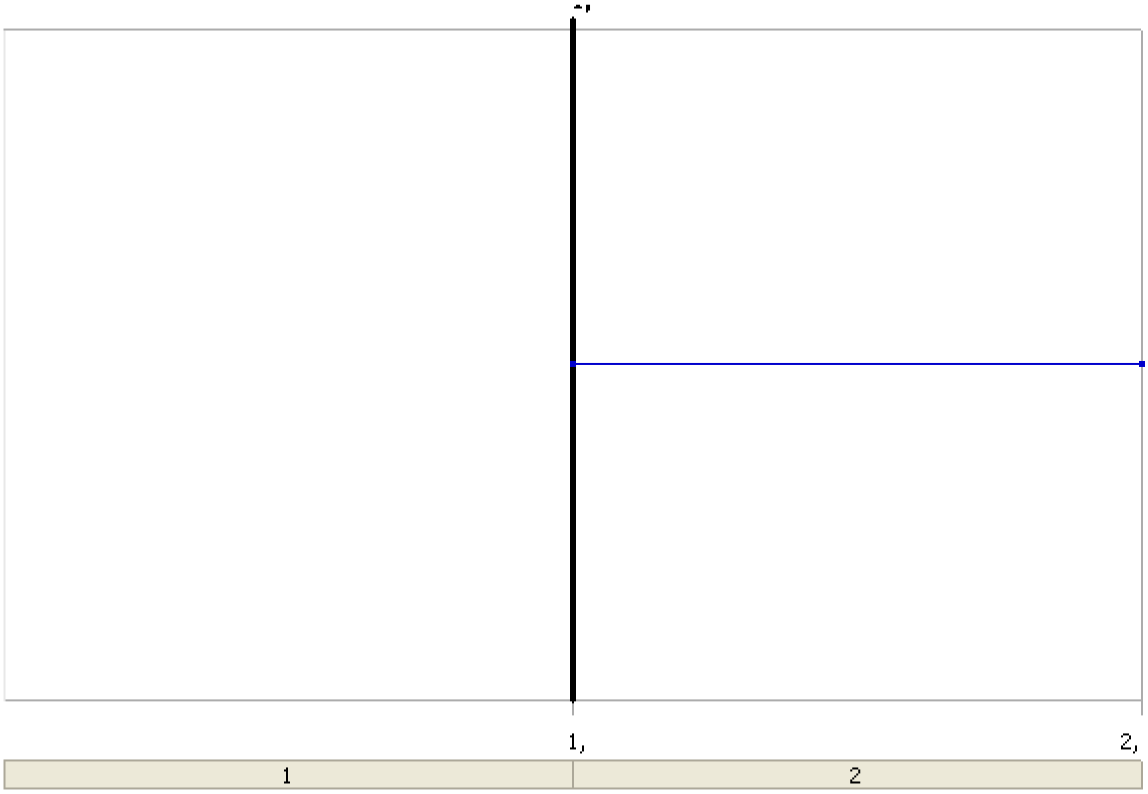

TABLE 134
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 17

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	3,76e+005	N/A
2,	Lock	N/A	

FIGURE 30
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 18

F

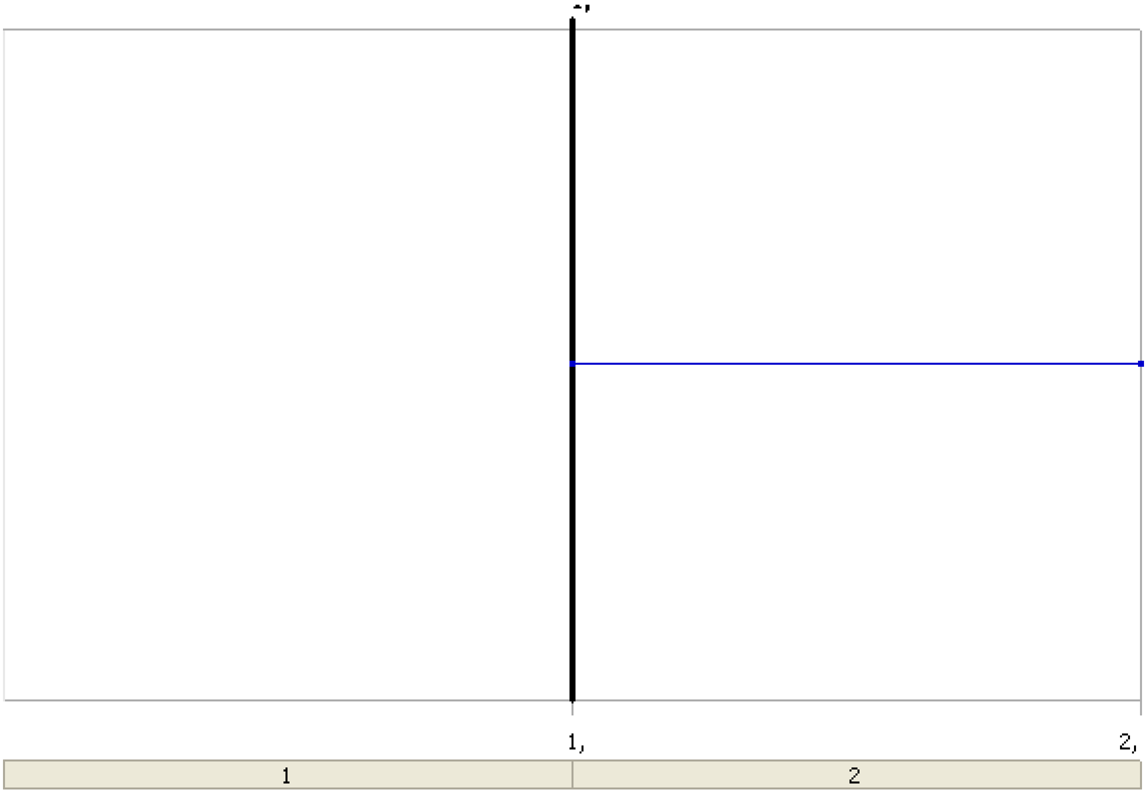

TABLE 135
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 18

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	3,76e+005	N/A
2,	Lock	N/A	

FIGURE 31
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 19

F

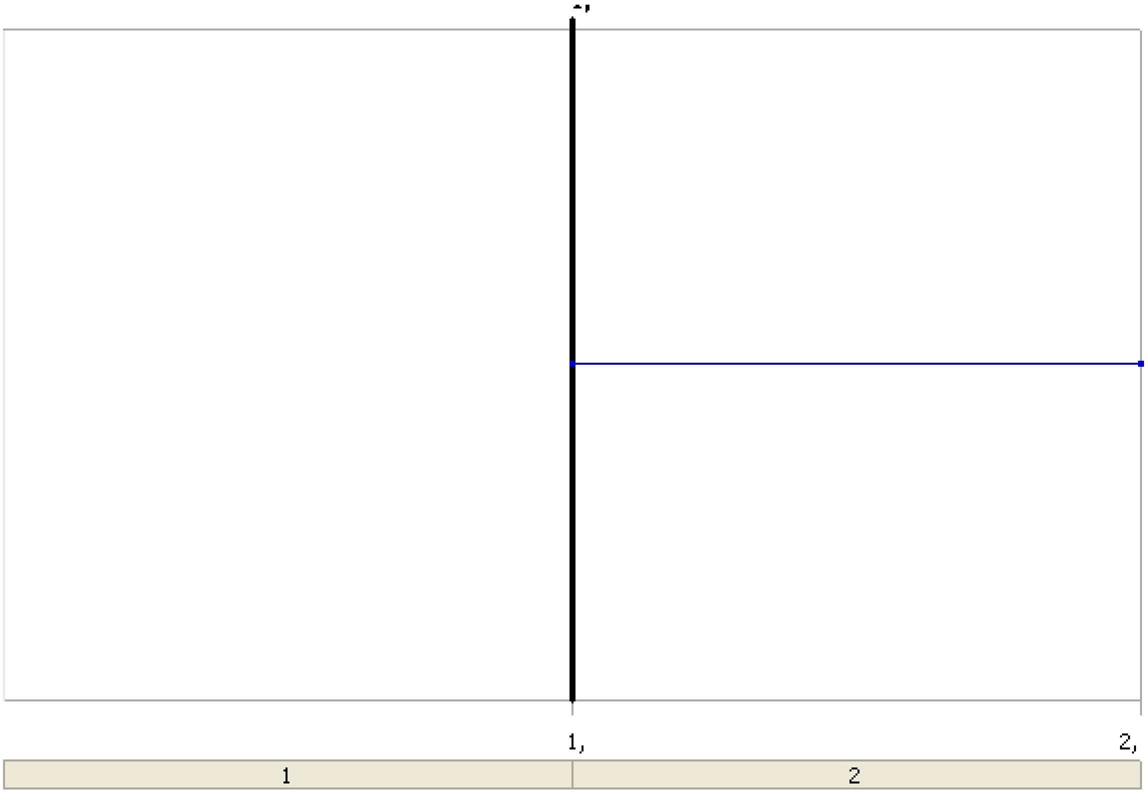

TABLE 136
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 19

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	3,76e+005	N/A
2,	Lock	N/A	

FIGURE 32
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 20

F

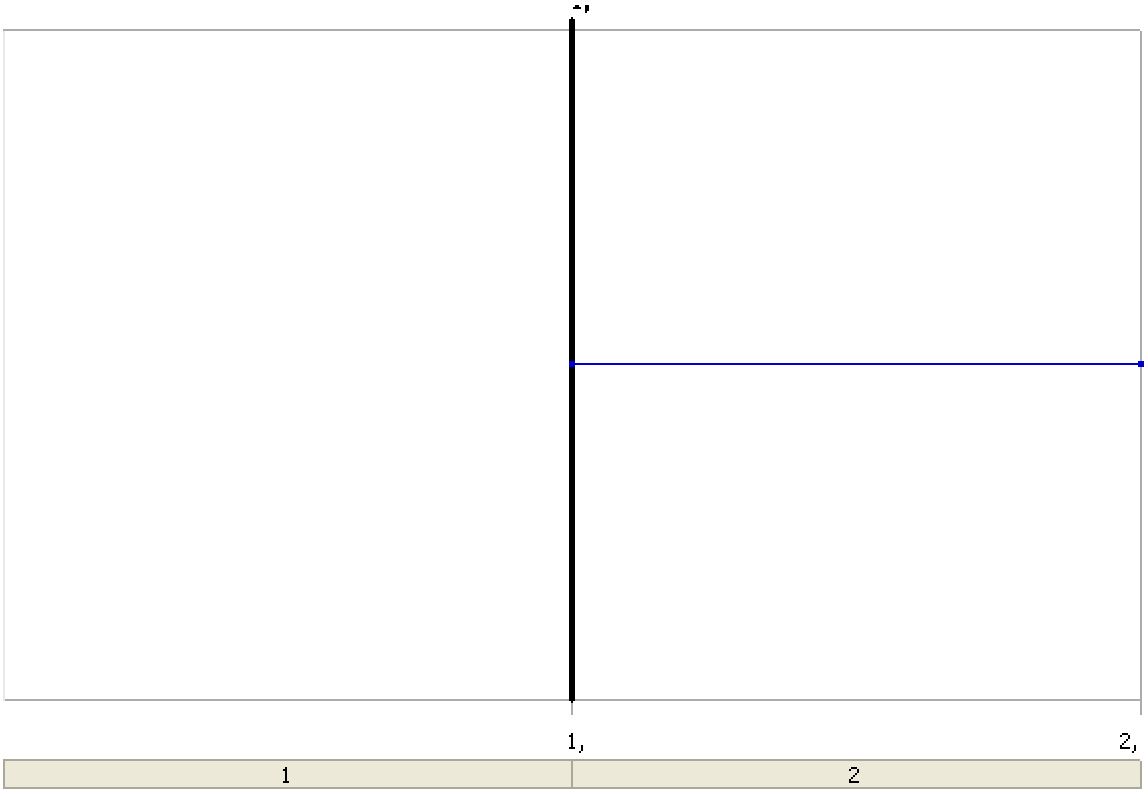

TABLE 137
Bolt check (C4) > Static Structural (C5) > Bolt Pretension 20

Steps	Define By	Preload [N]	Adjustment [mm]
1,	Load	3,76e+005	N/A
2,	Lock	N/A	

Solution (C6)

TABLE 138
Bolt check (C4) > Static Structural (C5) > Solution

Object Name	*Solution (C6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1,
Refinement Depth	2,
Information	
Status	Done

TABLE 139
Bolt check (C4) > Static Structural (C5) > Solution (C6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Force Convergence
Newton-Raphson Residuals	3
Update Interval	2, s
Display Points	All

FIGURE 33
Bolt check (C4) > Static Structural (C5) > Solution (C6) > Solution Information

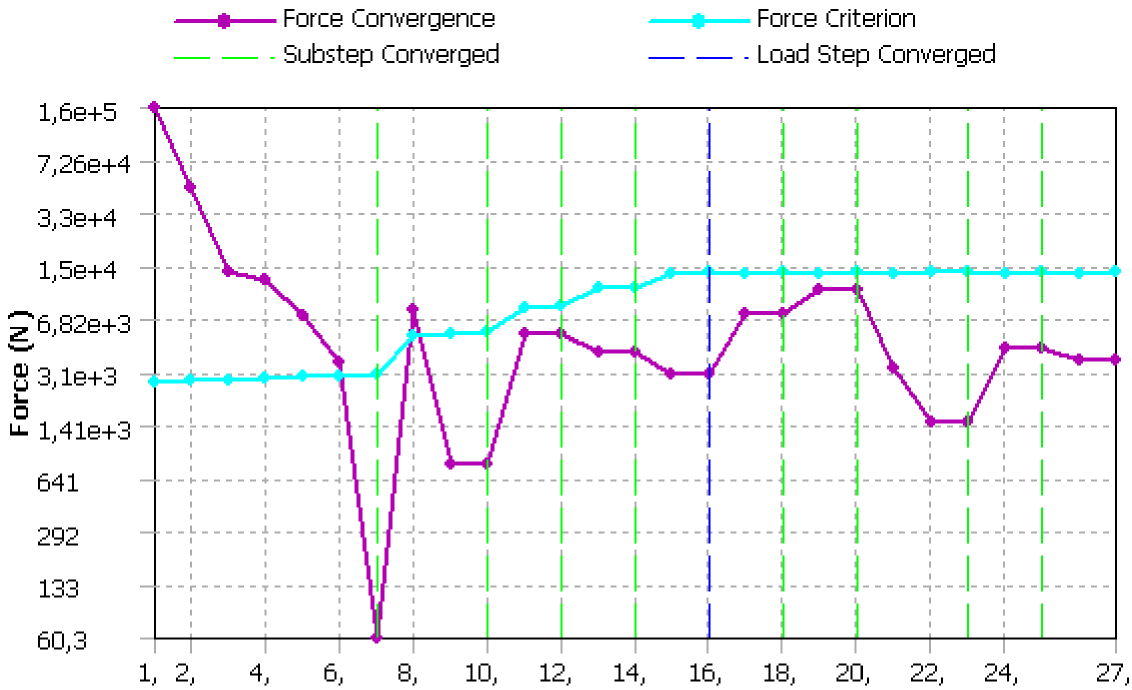

FIGURE 34
Bolt check (C4) > Static Structural (C5) > Solution (C6) > Solution Information

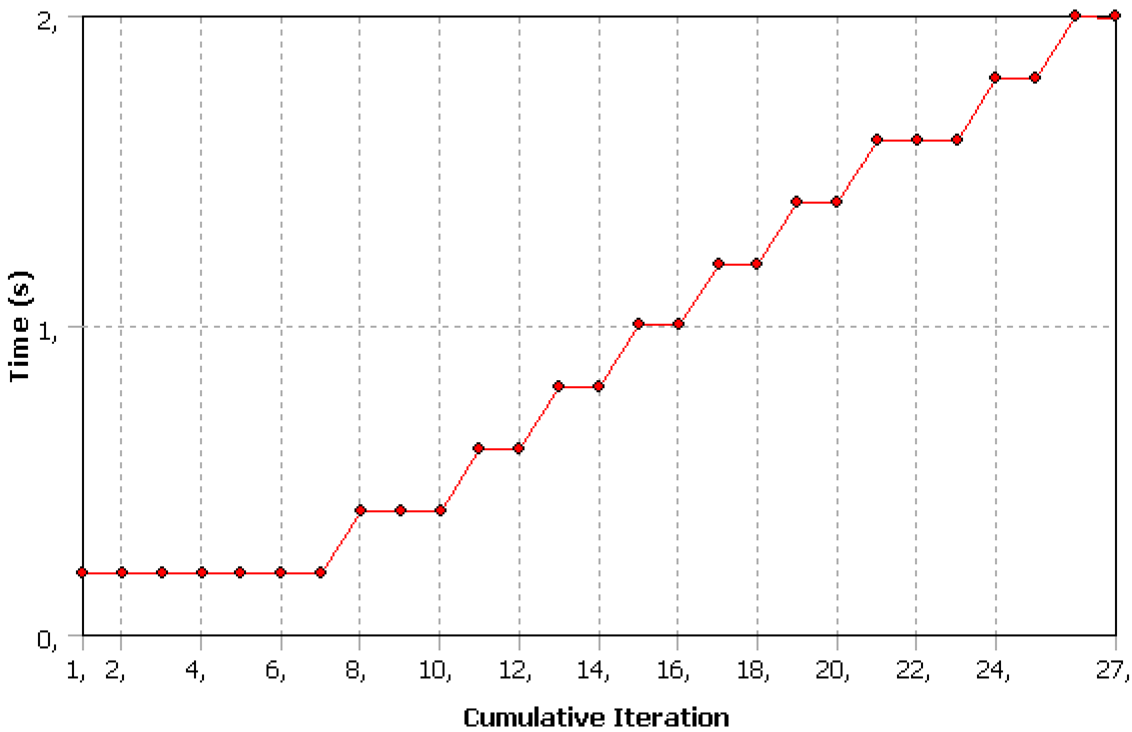

TABLE 142
Bolt check (C4) > Static Structural (C5) > Solution (C6) > Results

Object Name	*Equivalent Stress*	*Total Deformation*

State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Equivalent (von-Mises) Stress	Total Deformation
By	Time	
Display Time	2, s	Last
Calculate Time History	Yes	
Identifier		
Integration Point Results		
Display Option	Averaged	
Results		
Minimum	1,6414e-002 MPa	0, mm
Maximum	907,39 MPa	4,6196 mm
Minimum Occurs On	Part 167:Body 4	Solid
Maximum Occurs On	Solid	
Minimum Value Over Time		
Minimum	7,5986e-003 MPa	0, mm
Maximum	3,8271e-002 MPa	0, mm
Maximum Value Over Time		
Minimum	184,16 MPa	0,4705 mm
Maximum	920,43 MPa	4,6196 mm
Information		
Time	2, s	
Load Step	2	
Substep	5	
Iteration Number	27	

FIGURE 41
Bolt check (C4) > Static Structural (C5) > Solution (C6) > Equivalent Stress

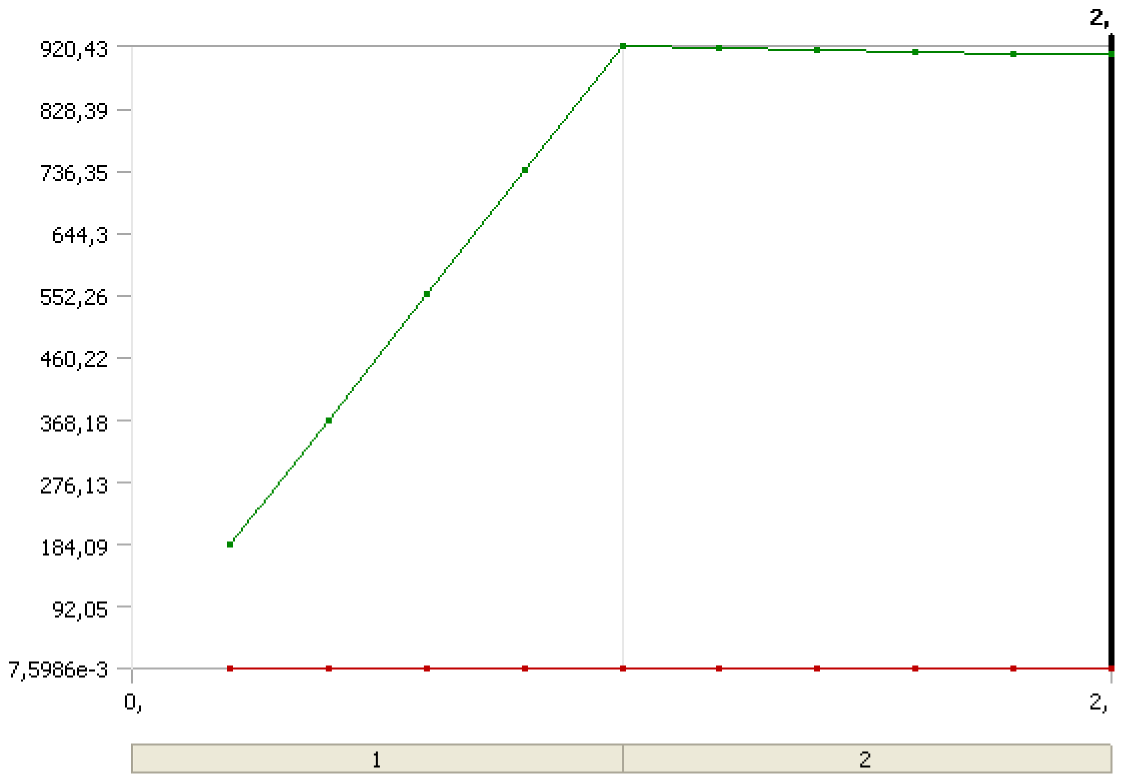

TABLE 143
Bolt check (C4) > Static Structural (C5) > Solution (C6) > Equivalent Stress

Time [s]	Minimum [MPa]	Maximum [MPa]
0,2	7,5986e-003	184,16
0,4	1,522e-002	368,27
0,6	2,2875e-002	552,36
0,8	3,056e-002	736,41
1,	3,8271e-002	920,43
1,2	3,8195e-002	917,81
1,4	3,5831e-002	915,2
1,6	2,5659e-002	912,6
1,8	1,9109e-002	909,99
2,	1,6414e-002	907,39

FIGURE 42
Bolt check (C4) > Static Structural (C5) > Solution (C6) > Total Deformation

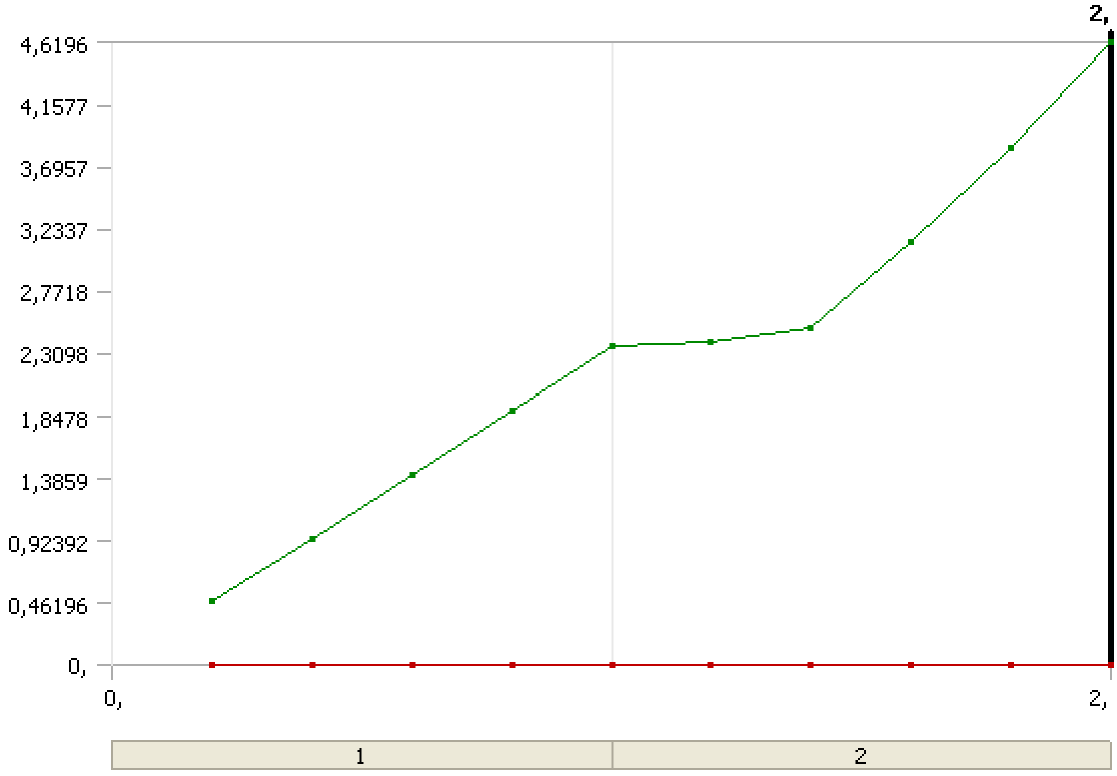

TABLE 144
Bolt check (C4) > Static Structural (C5) > Solution (C6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]
0,2	0,	0,4705
0,4		0,94253
0,6		1,4137
0,8		1,8845
1,		2,3564
1,2		2,3905
1,4		2,4972
1,6		3,1352
1,8		3,8278
2,		4,6196

Material Data

Clamp steel

TABLE 166
Clamp steel > Constants

Density	7.85e-006 kg mm^-3

TABLE 167
Clamp steel > Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.07e+005	0.3	1.725e+005	79615

TABLE 168
Clamp steel > Tensile Yield Strength

Tensile Yield Strength MPa
355

TABLE 169
Clamp steel > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
510

A320

TABLE 170
A320 > Constants

Density	7.85e-006 kg mm^-3

TABLE 171
A320 > Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.07e+005	0.3	1.725e+005	79615

TABLE 172
A320 > Tensile Yield Strength

Tensile Yield Strength MPa
730

TABLE 173
A320 > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
860

F