Project title

Alexander L. Kielland

Document title

Simplified calculation of 8 vs 10 anchor lines

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1 Introduction

This report calculates the difference in anchor line forces and the corresponding stresses in the main members of the Alexander L. Kielland platform for the ideal 10 lines star anchoring and the actual anchoring pattern on the Edda field with only 8 anchors and in addition anchor angle deviations from the ideal 36 deg angles between the lines.
The two anchoring patterns are shown on plots given in section 5.1 and 5.2.

External force from wind, waves and current are equal for the two cases and taken to be 3080 kN.
The force is acting towards the C-column parallel to the rig center line, ref. plot in section 2.1.

The force of 3080 kN is taken from ref. /5/. Extract from this report is given in the plot below showing the different force components.

The main members of the rig are modeled and analysed by use of the structural analysis software Spaceclaim and ANSYS.
Some details are also checked by use of hand calculations.

2. DESIGNTILSTAND FOR EKOFISK-OMRÅDET.

Tabell 2.1 viser design-værtilstand for Ekofisk-området og resulterende krefter på plattformen. Værdataene er SD's anbefalte data for bruk i dette området. Strømhastigheten er funnet som summen av to komponenter:

Tidevann:	0.5 m/s
Vindindusert	2% av vindhastigheten

		Kraft fra siden (kN)	Kraft forfra (kN)
Vind	38 m/s	1630	1399
Strøm	1.26 m/s	1100	1029
Bølger	14 m/14 sek	350	350
Sum		3080	2778

Tabell 2.1 Værkrefter under design-værforhold for Ekofisk-området.

2 Conclusion and revision history

2.1 Conclusion

The calculations show that there is a difference in stress levels for the two anchor pattern configurations when the rig is exposed to a lateral force of 3080 kN.

For member D6, the maximum equivalent (von-Mises) stress increase from 3,4 MPa (10 line pattern) to 13,5 MPa (8 line pattern).

For member ED, the maximum equivalent (von-Mises) stress increase from 1,3 MPa (10 line pattern) to 11,0 MPa (8 line pattern).

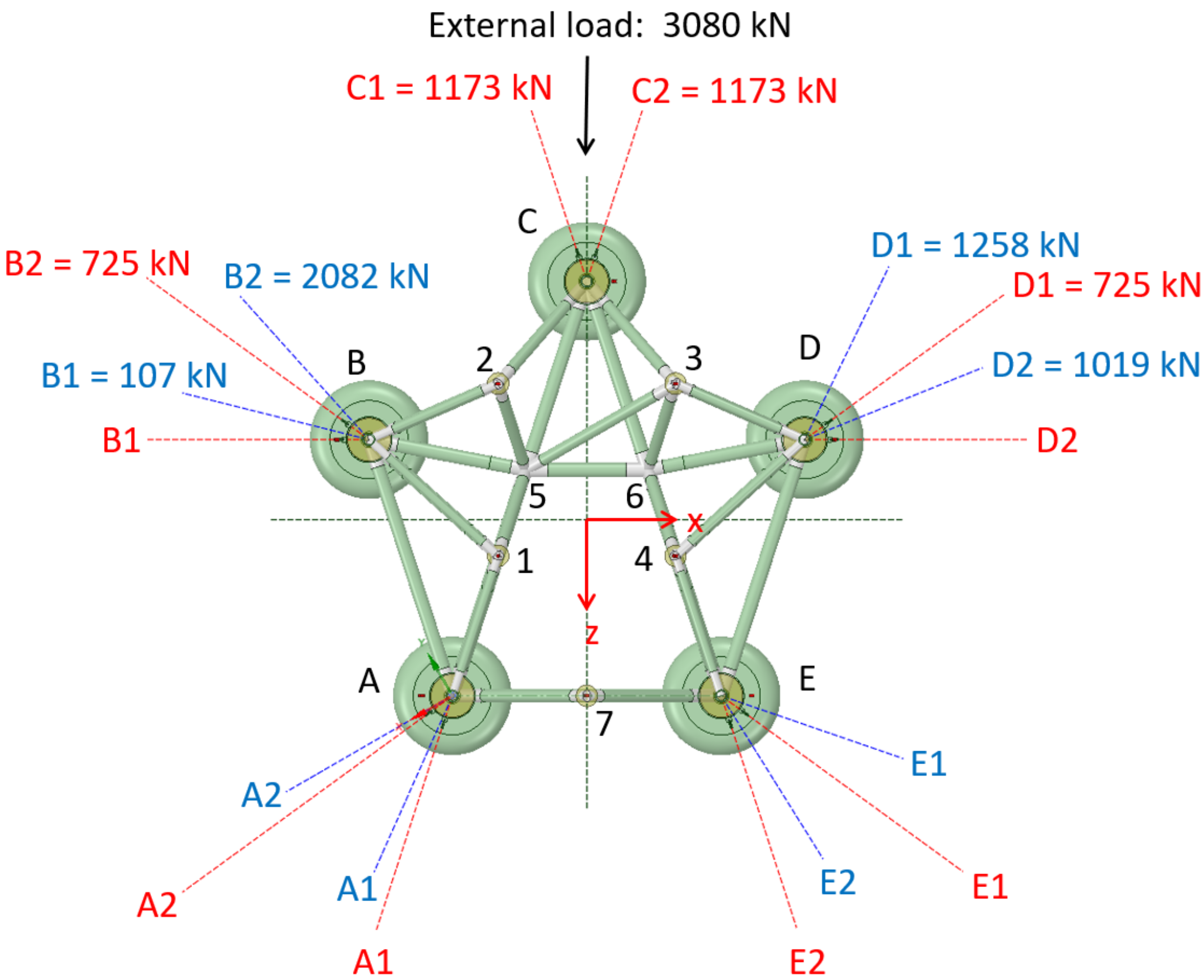
The maximum reported stress of 13,5 MPa in member DE is approximately 4% of the material yield strength (355 MPa).

The table below show the maximum equivalent (von-Mises) stress in each members for the two configurations.

		Equivalent stress [MPa]	
		10-Line	**8-Line**
Horizontal members (10 off). OD = 2.6 m	AB	1.3	8.2
	ED	1.3	11.0
	A5	3.9	1.4
	E6	3.8	2.0
	C5	5.6	2.1
	C6	5.7	2.4
	B5	3.4	8.2
	D6	3.4	13.5
	56	2.6	4.8
	AE	0.7	2.6
Diagonal bracing (15 off). OD = 2.2 m	A1	2.5	3.4
	E4	2.5	3.7
	B1	0.8	6.4
	D4	0.8	9.2
	C2	3.1	1.1
	C3	2.9	0.8
	B2	1.5	3.8
	D3	1.6	7.0
	51	3.7	1.8
	64	3.9	2.2
	52	2.7	0.8
	63	2.5	1.7
	A7	0.3	0.5
	E7	0.3	0.5
	53	0.8	0.9

The figure below show the anhor line forces for the two cases analysed, ref. also section 6.2 for details.

- 10 lines - Symmetric pattern - Red markings
- 8 lines - Unsymmetric pattern - EDDA 2/7C - Blue markings



2.2 Revision history

Revision	Description
01	First issue

3 References

/1/ NOU 1981:11. Alexander L. Kielland ulykken.

/2/ SINTEF. STF71 F80007. Global rammeanalyse. Rapport 1.

/3/ SINTEF. STF71 F80011. Global rammeanalyse. Rapport 2.

/4/ NSFI. 220 21280.28.01. Analyse av ankersystem.

/5/ NSFI. 220 21280.28.02. Analyse av ankersystem. Supplerende beregninger.

/6/ Riksarkivet - RA/S-1165: Justisdepartementet, Granskningskommisjonen ved Alexander Kielland-ulykken 27.3.1980:
https://media.digitalarkivet.no/db/browse?archives%5B%5D=no-a1450-01000000005772

/7/ https://media.digitalarkivet.no/db/contents/105513?archives%5B0%5D=no-a1450-01000000005772

E CFEM	E15 Structure - Detail colums
E CFEM	E16 Structure - Detail joints
E CFEM	E17 Structure - Detail bracings (mangler tegninger)
E CFEM	E18 Structure - Detail beams
E CFEM	E19 Fairled

/8/ https://media.digitalarkivet.no/db/contents/105516?archives%5B0%5D=no-a1450-01000000005772

D Forex Neptune	D9 Diverse listing. Tegninger av Alexander Kielland-plattformen
E CFEM	E12 General lay-out
E CFEM	E13 Structure. General Arrangement
E CFEM	E14 Structure. Details floats

4 Abbreviations and Units

4.1 Abbreviations

ABL - Above base line / bottom level
g - Gravity constant
Hs - Significant wave height
ID - Inner Diameter
OD - Outer Diameter
SE - Stavanger Engineering
TBA - To be addressed
m - meter
MSL - Mean sea level

4.2 Units

Units derived from SI units

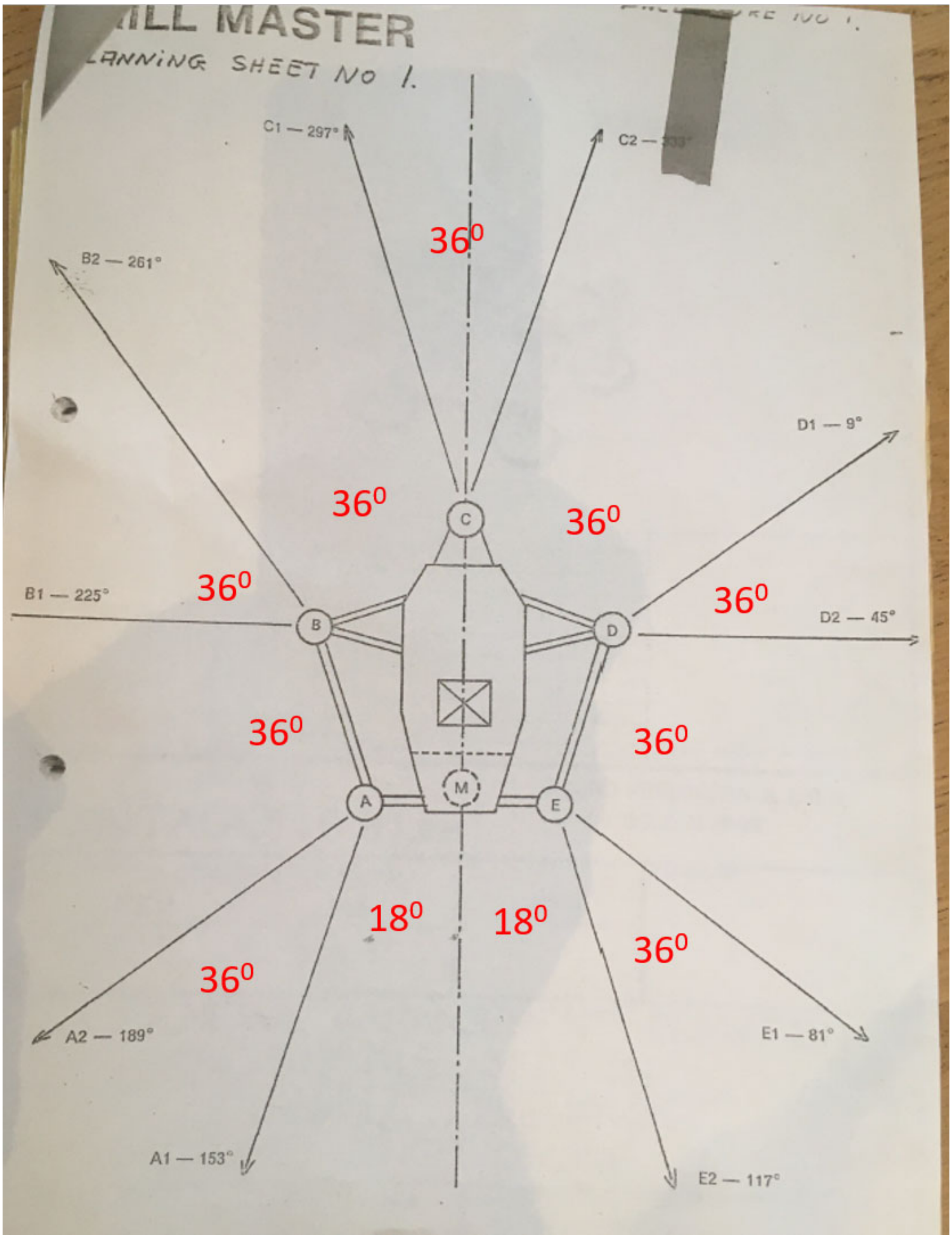
Metric tonne: $MT := 1000 \cdot kg$ $ton := 1000 \cdot kg$

Knots: $kn := 0.514 \cdot \frac{m}{s}$

5 Anchoring patterns

5.1 10 lines ideal anchoring pattern

The sketch below show the ideal 10 lines star anchoring pattern specified by the operating manual, from the sister rig Drill Master. Angle between the anchor lines are 36 deg.



5.2 8 lines anchoring pattern at the Edda 2/7C platform

The sketch below show the 8 lines anchoring pattern at the Edda 2/7C platform, taken from ref. /1/.
The two anhors on the C-column was not in use at Edda.
In addition there are deviations from the anchor line angles compared to the ideal 10 line pattern.

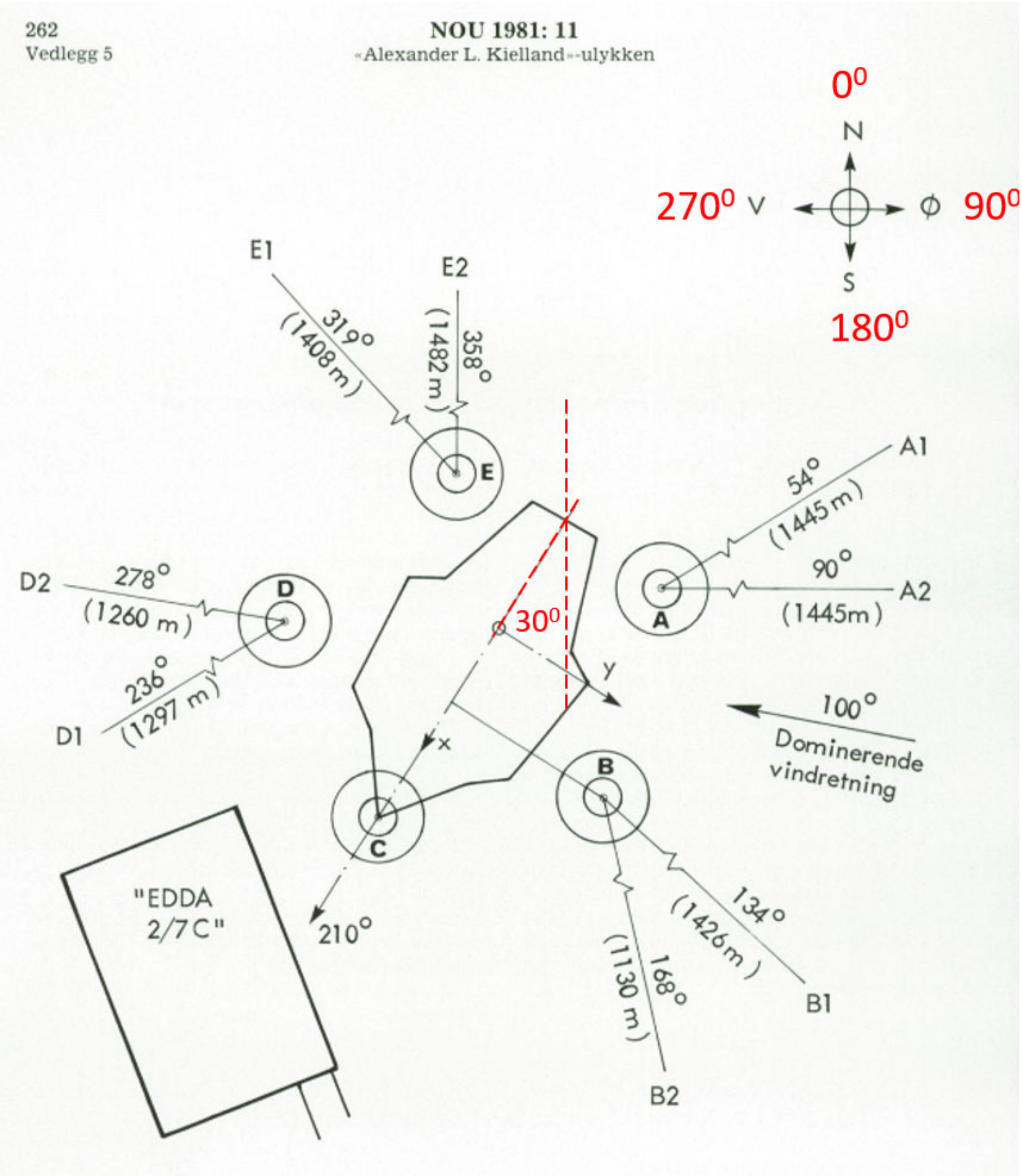
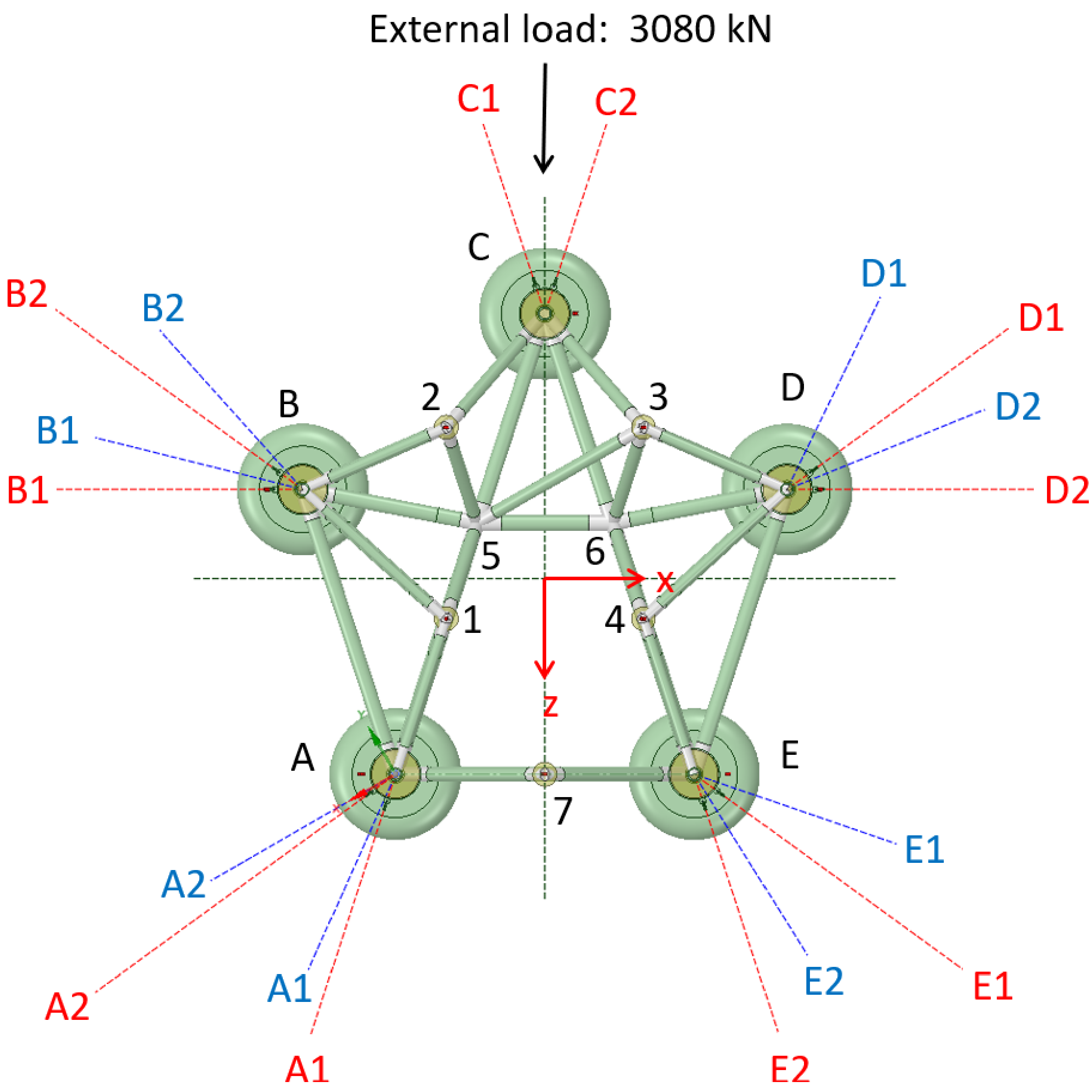


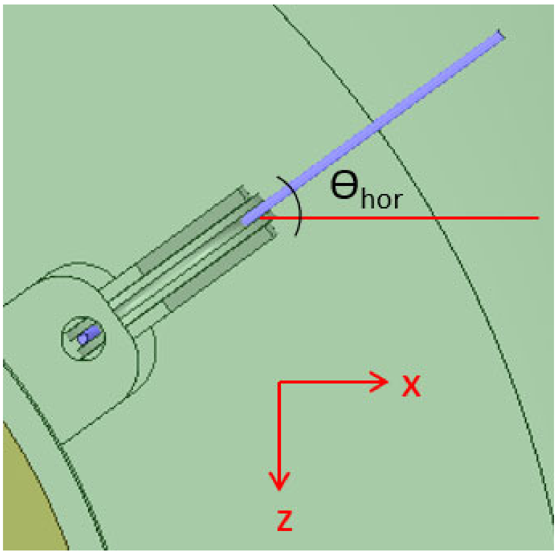
Fig. 5.1.1 Koordinatsystem og leggemønster for siste oppankring ved «Edda 2/7C».

5.3 10 and 8 lines anchoring pattern superimposed

The figure below show the two anchoring patterns superimposed on each other.
The red lines are the 10 line pattern while the blue lines are the 8 line pattern.
Anchor line angles with respect to the positive x-axis are given in the table on next page.
The absolute value of the angle deviation from the ideal 10 line pattern and the 8 line pattern for each anchor line are also given in the table.
We see that anchor line D1 and D2 have the largest angle deviation from the ideal pattern with 28 deg and 22 deg deviation respectively.
The external load of 3080 kN is also shown in the figure.



	10-Lines	8-Lines	
Line	Θ_{hor} [deg]	Θ_{hor} [deg]	Deviation [deg]
A1	252	246	6
A2	216	210	6
B1	180	166	14
B2	144	132	12
C1	108	0	NA
C2	72	0	NA
D1	36	64	28
D2	0	22	22
E1	324	341	17
E2	288	302	14



6 Calculations

6.1 Global FEM analysis of the rig

6.1.1 FEM analysis - General

The anchor line forces, deformation, stresses and strains in the main members due to the external load are calculated by use of a linear FEM analysis performed by means of the structural analysis software ANSYS. The following models are prepared and analysed:

- 10 line ideal anchor pattern with 3080 kN external load with direction towards the C-leg parallel to the rig centerline
- 8 line anchor pattern at Edda 2/7C with 3080 kN external load with direction towards the C-leg parallel to the rig centerline

Linear material is used and The Large Deflection option in Ansys is turned OFF.

The structure is calculated by use of a plate/shell model prepared using the geometric mid-surfaces of the members/pipes.

Actual plate thicknesses are applied to the various members/pipes. Ansys Spaceclaim Direct Modeler is used as a preprocessor for geometry modelling.

At the surface interfaces a conformal mesh is defined using the ''Shared Topology'' option in Spaceclaim.

The model is meshed with square SHELL 281 8-Node higher order Structural Shell with six degrees of freedom at each node.
However, some triangular filler elements are also generated by the automatic Mesher in order to mesh the geometry properly. In the critical areas however square SHELL 281 elements are used.

Note that no stiffeners are included in the model, only regular pipes. The main columns (A-E) with pontoons are modelled as infinite stiff. This also applies for the joints (1-7).
Some ''dummy members'' are modelled to represent the topside structure, indicated with blue colors in the following plots of the model.

An average element size of 500 mm is applied throughout the entire model.

The anchor lines are modelled by use of linear springs with the stiffnes based on nominal anhor wire diameter and wire modulus taken from ref. /1/. The horizontal length of the anchors are for the 10 line pattern taken to be 1400 m.

For the 8 line pattern the length are as given on the layout given in section 5.2.

Wire stiffness calculations are given in section 6.2.1 and 6.2.2.

Note that in agreement with client, no pretension are applied to the anchor wires for this study.
Anchor wire loads from the winches to the fairled are also included in the model.
An iteration process is performed where wires with compression loads has been deactivated in the analysis.

Vertically the model is restrained at bottom of each column/pontoon.

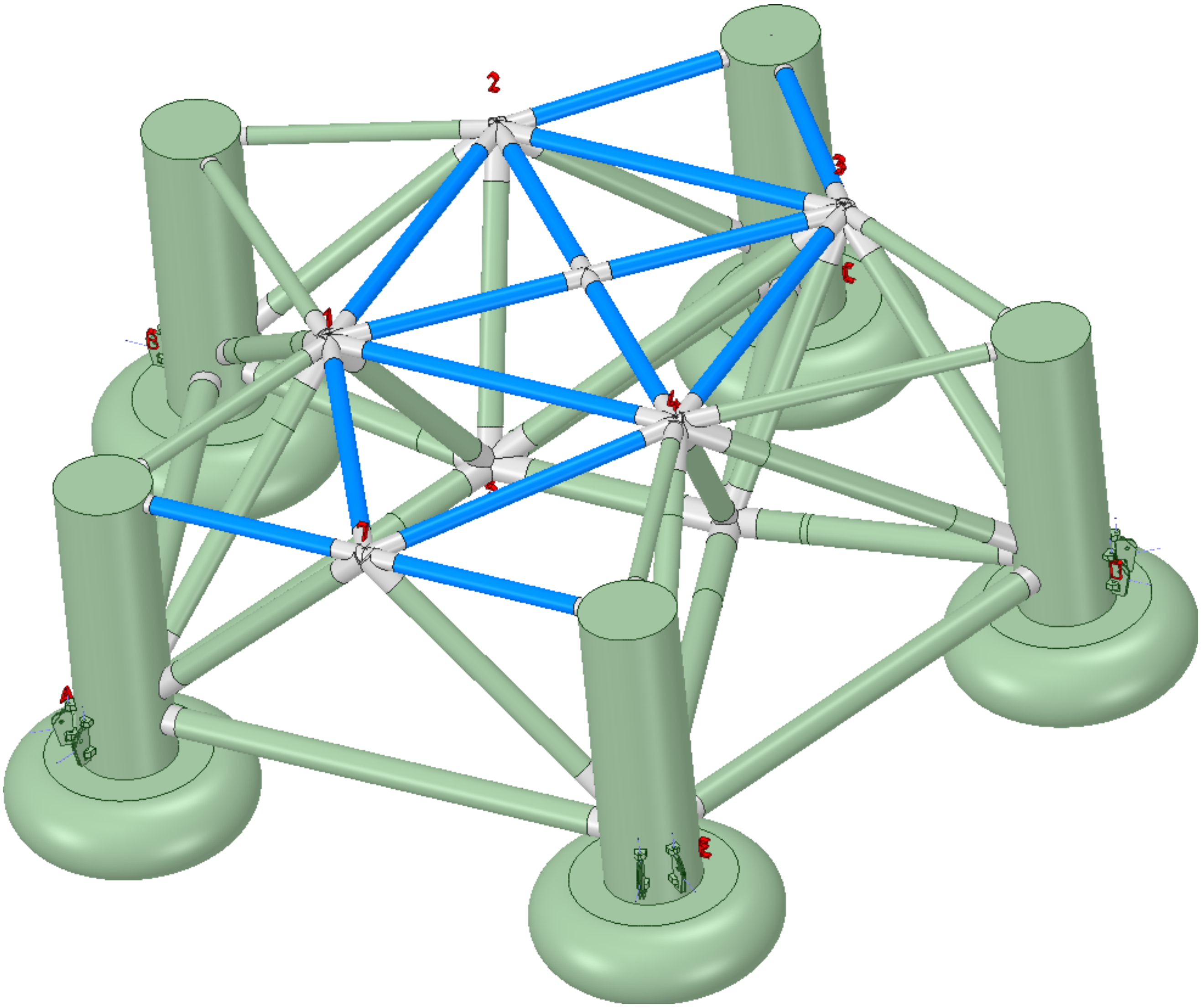
The following two tables show the thickness of the modelled main pipes, ref. /2/, /7/ and /8/.

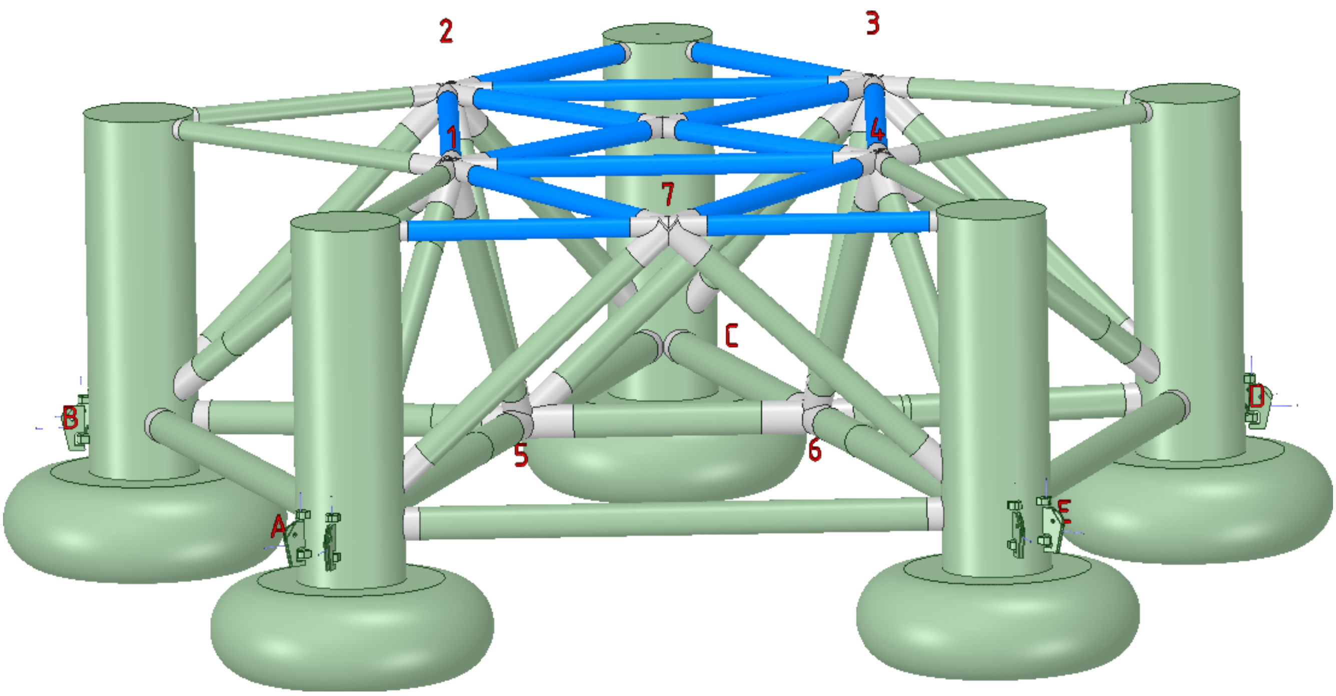
Member AB means that the member is going from column A to column B.

S = Start section of member
M = Mid section of member
E = End section of member

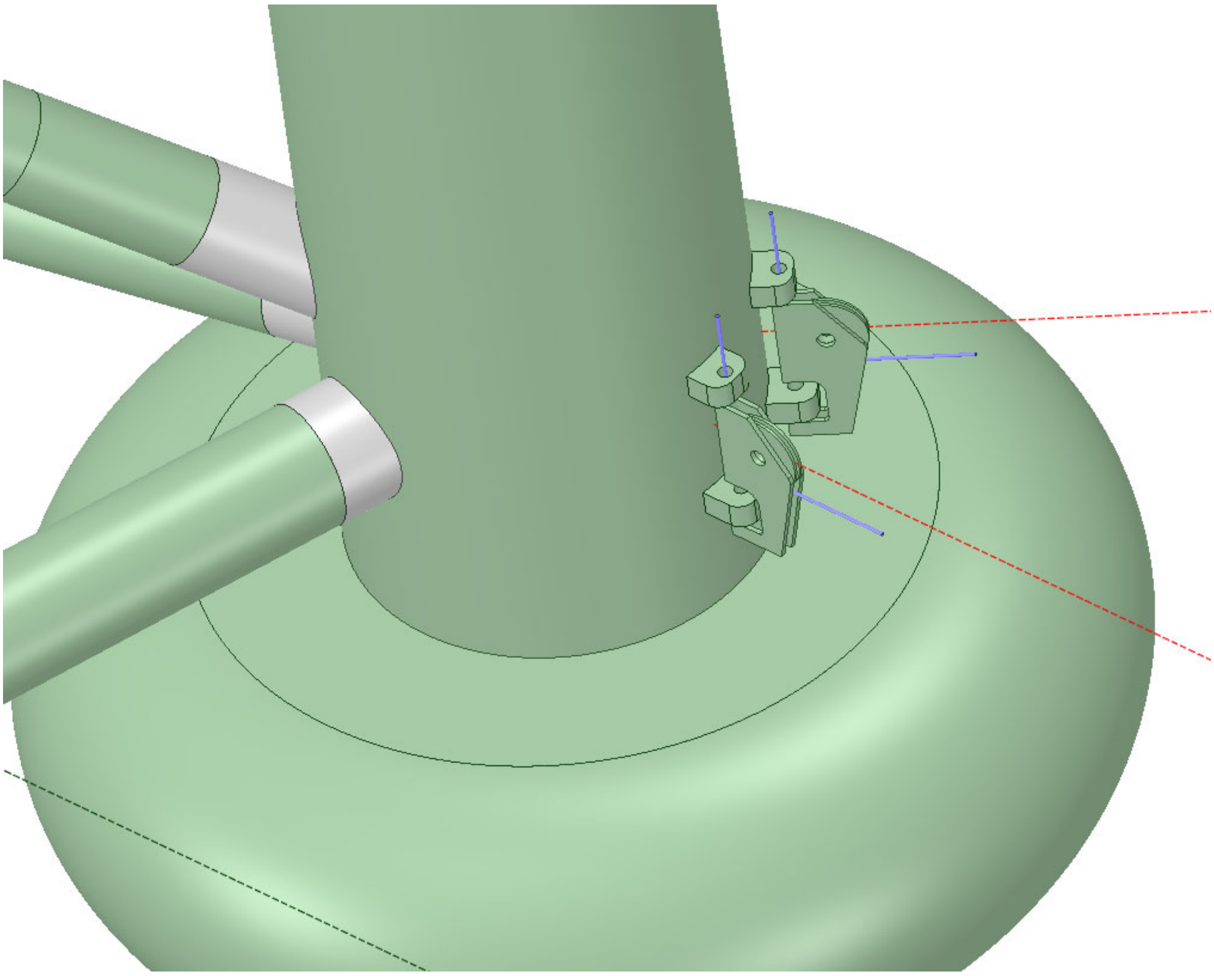
Horizontal members (10 off). OD = 2.6 m					
Member	**Section**	**Thickness [mm]**	**Member**	**Section**	**Thickness [mm]**
AB	S	24	ED	S	24
	M	22		M	22
	E	24		E	24
A5	S	30	E6	S	30
	M	26 & 28		M	26 & 28
	E	30		E	30
C5	S	24	C6	S	24
	M	24		M	24
	E	30		E	30
B5	S	28	D6	S	28
	M	26 & 30		M	26 & 30
	E	34		E	34
56	S	36			
	M	34			
	E	36			
AE	S	24			
	M	22			
	E	24			

Diagonal bracing (15 off). OD = 2.2 m					
Member	**Section**	**Thickness [mm]**	**Member**	**Section**	**Thickness [mm]**
A1	S	30	E4	S	30
	M	26 & 30		M	26 & 30
	E	32		E	32
B1	S	30	D4	S	30
	M	26, 24 & 28		M	26, 24 & 28
	E	28		E	28
C2	S	24	C3	S	24
	M	22		M	22
	E	24		E	24
B2	S	22	D3	S	22
	M	22		M	22
	E	22		E	22
51	S	20	64	S	20
	M	20		M	20
	E	20		E	20
52	S	20	63	S	20
	M	20		M	20
	E	20		E	20
A7	S	20	E7	S	20
	M	20		M	20
	E	20		E	20
53	S	22			
	M	22			
	E	22			


2
3
1
4
7
B
C
A
D
E

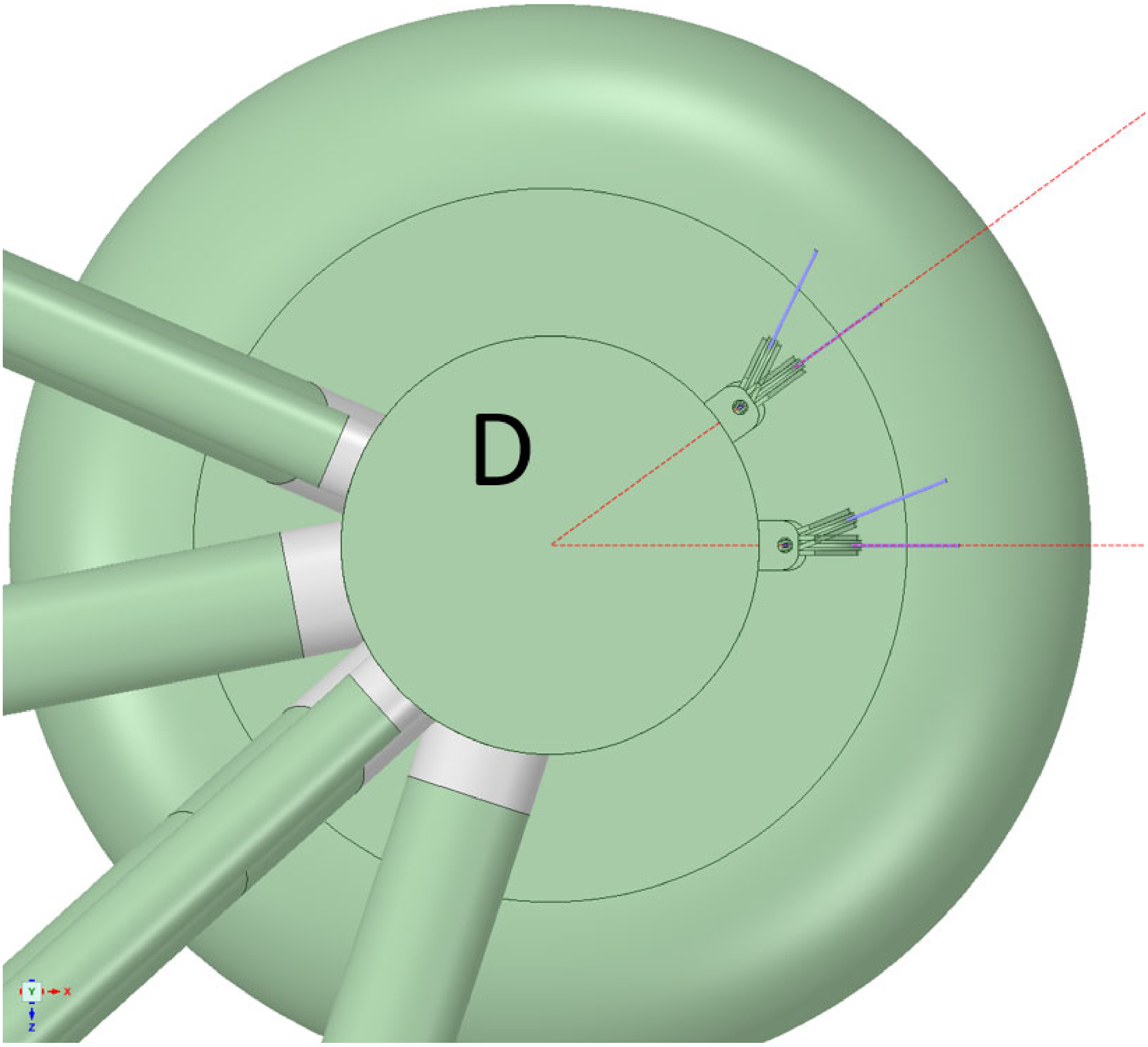

2
3
1
4
7
C
B
5
6
D
A
E

The figure below show the fairled assembly layout.

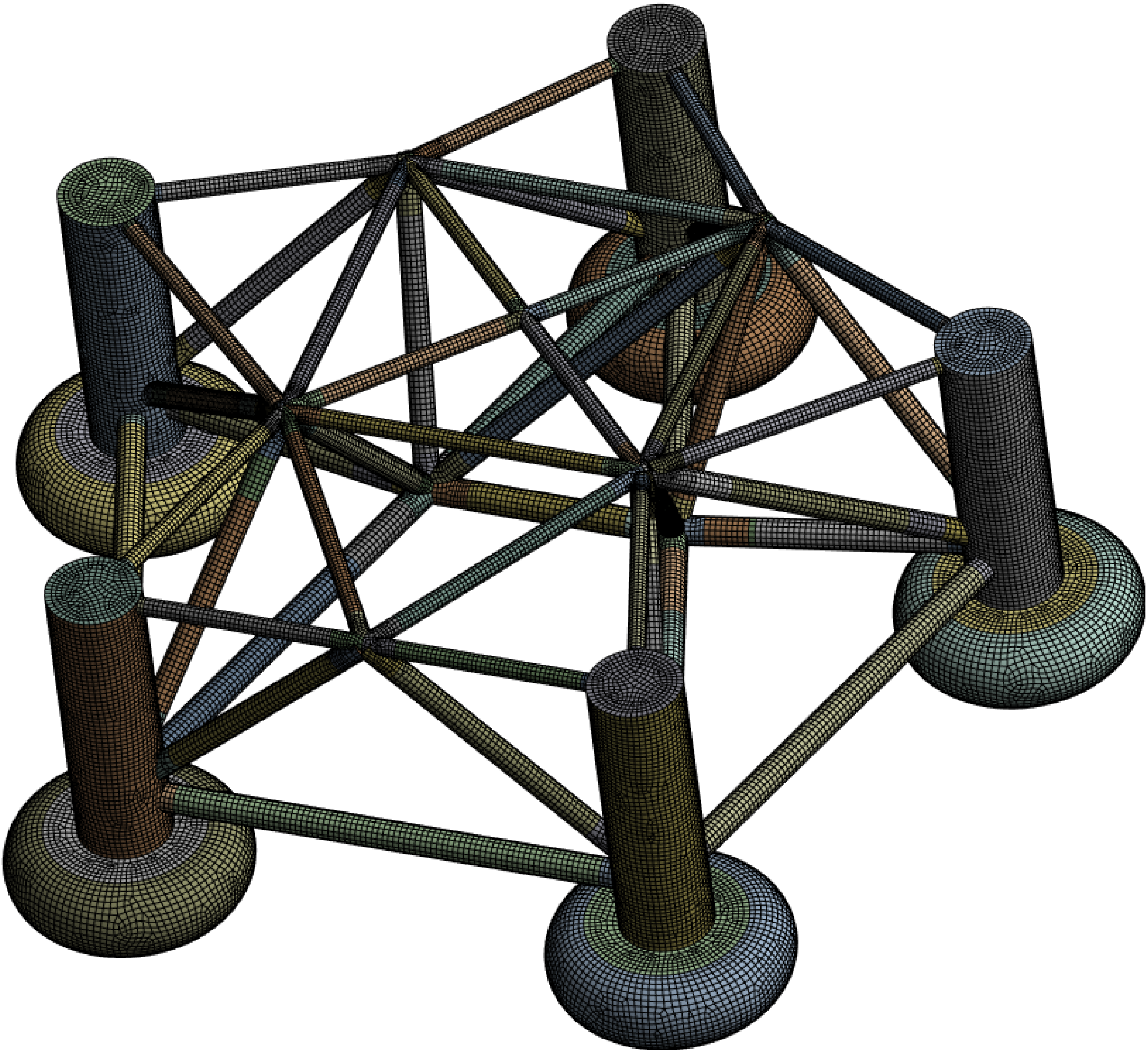


The figure below show the fairled orientation at D-leg for the two anchoring patterns. Note that for the ideal 10 line configuration the anchor forces do not give additional torque in the main column.

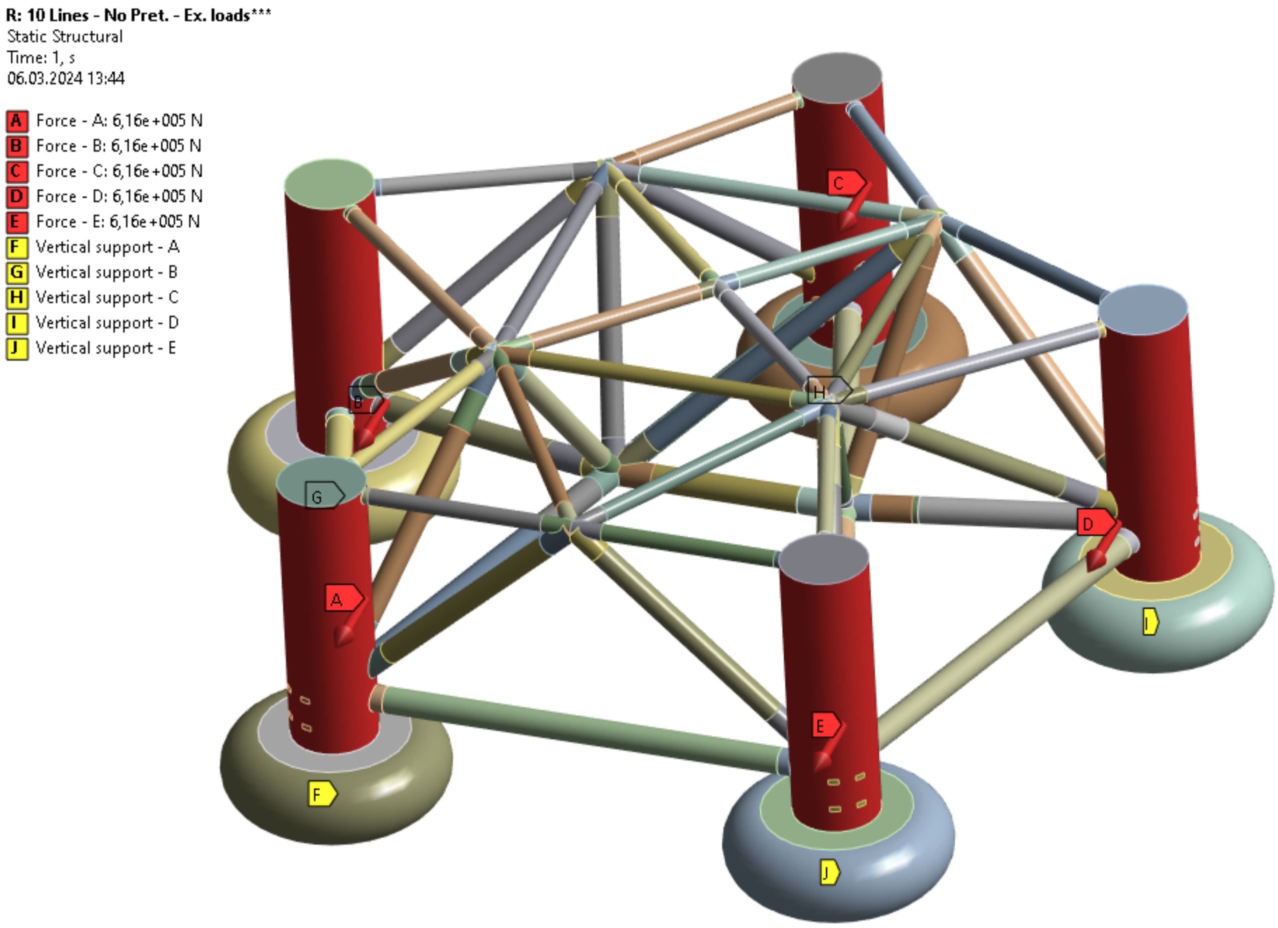
For the 8 line configuration we get additional torque in the column due to the offset with respect to column vertical centerline. This effect is included in the FEM model as the springs representing the anchor lines are attached to the main column at the fairled connection points by use of an Ansys ''Rigid remote attachment'' spring connection.



The figure below show the element model with the mesh.

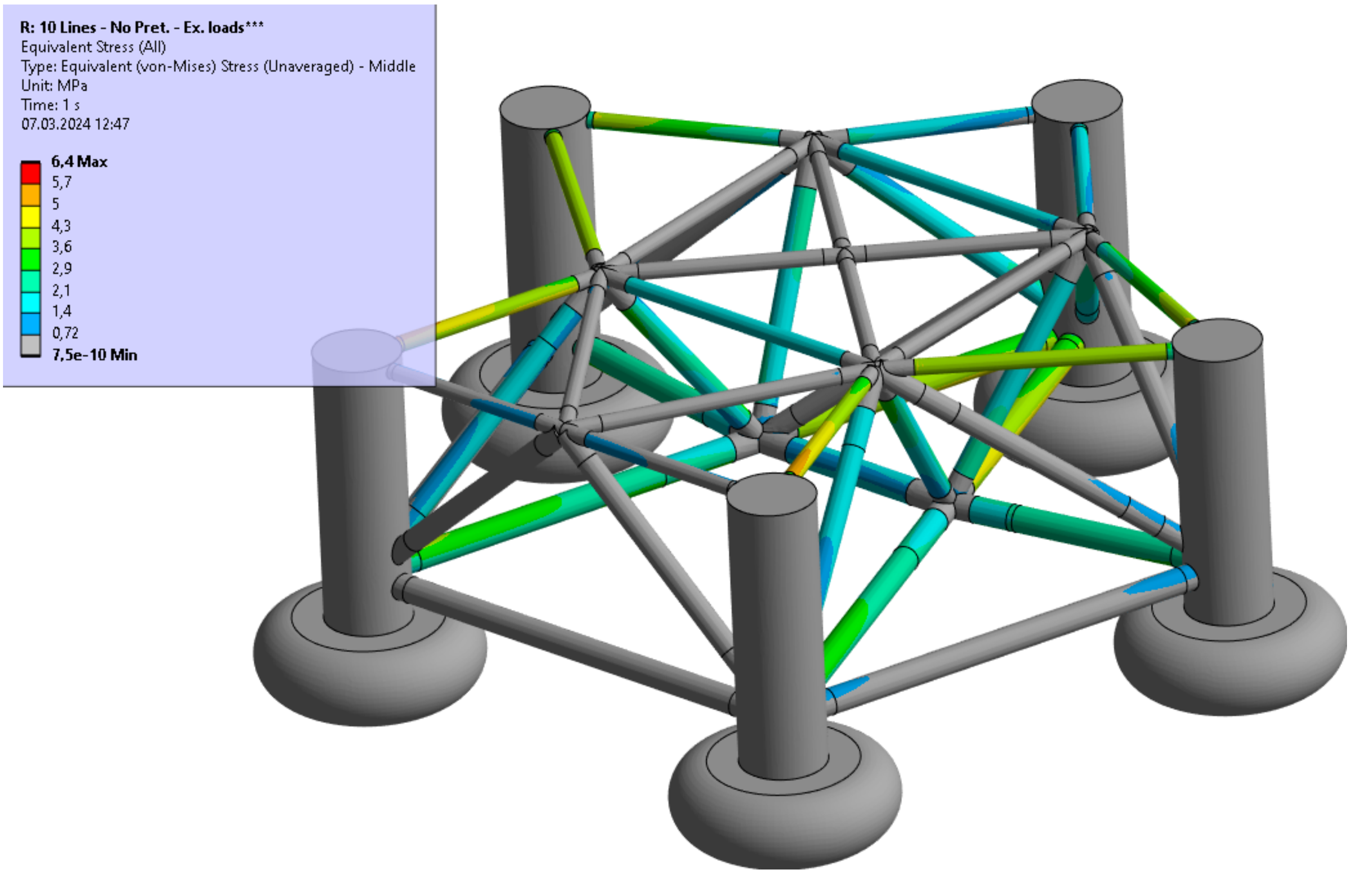


The figure below show the applied load of 3080 kN equally divided on the 5 columns, 616 kN on each. Direction is parallel to center line Fwd to Aft.

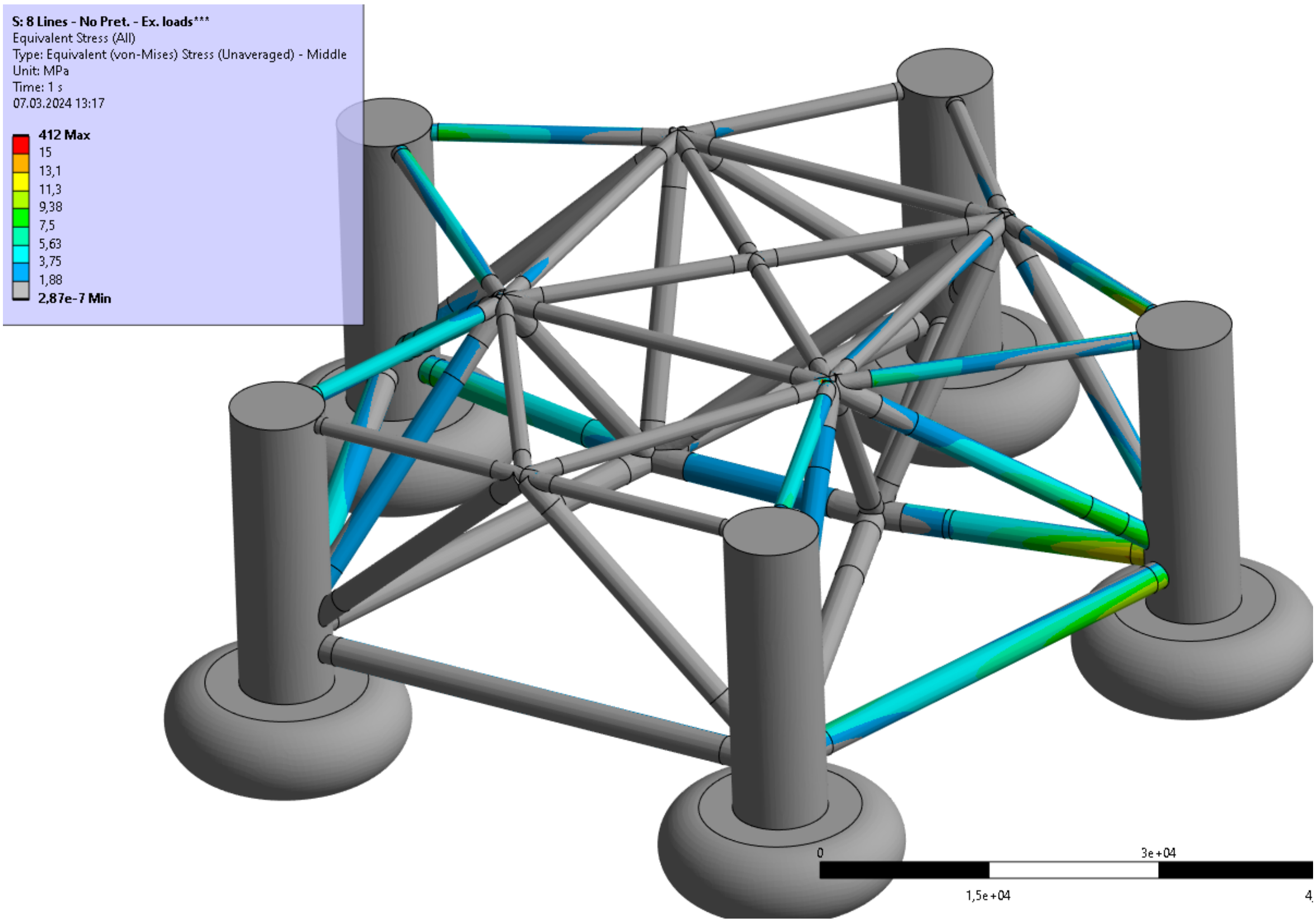


6.1.2 FEM analysis - Results

The following plot show the Equivalent (von-Mises) stress for the 10 line symmetric pattern.



The following plot show the Equivalent (von-Mises) stress for the 8 line un-symmetric pattern on Edda 2/7C.



Note that some high peak stresses occur in the stiff joints (1-7) which is due to the simplified model of these joints combined with some elements with poor quality in this area.
The simplification of the joints will however not influence the calculated stresses in the main members.

The following table give the maximum equivalent (von-Mises) stress for the main members for the two anchor line patterns taken from the Ansys analysis. Reported stress from Ansys is ''Unaveraged-Middle''.

Maximum stress is calculated to be 13,5 MPa for member D6 for the 8 line configuration.
This is approximately 4% of the material yield strengh (355 MPa).

	Equivalent stress [MPa]		
		10-Line	**8-Line**
Horizontal members (10 off). OD = 2.6 m	AB	1.3	8.2
	ED	1.3	11.0
	A5	3.9	1.4
	E6	3.8	2.0
	C5	5.6	2.1
	C6	5.7	2.4
	B5	3.4	8.2
	D6	3.4	13.5
	56	2.6	4.8
	AE	0.7	2.6
Diagonal bracing (15 off). OD = 2.2 m	A1	2.5	3.4
	E4	2.5	3.7
	B1	0.8	6.4
	D4	0.8	9.2
	C2	3.1	1.1
	C3	2.9	0.8
	B2	1.5	3.8
	D3	1.6	7.0
	51	3.7	1.8
	64	3.9	2.2
	52	2.7	0.8
	63	2.5	1.7
	A7	0.3	0.5
	E7	0.3	0.5
	53	0.8	0.9

6.2 Detail calculations

6.2.1 Anchor line stiffness - 10 lines - Symmetric pattern

Wire diameter: $\varnothing_{wire} := 70 \cdot mm$ from ref. /1/ section 5.1

Modulus of Elasticity: $E_{wire} := 5.12 \cdot 10^4 \cdot MPa$ from ref. /1/ section 5.1

Cross section area, nominal: $A_{wire} := \dfrac{\pi \cdot \varnothing_{wire}^{\ 2}}{4} = 3848\ mm^2$

Vertical distance from line at fairled to sea floor: $L_{vert} := 70.251 \cdot m$ 80 m water depth

Wire length: $L_{wire.symetric.hor} := 1400 \cdot m$ $L_{wire.symetric} := \sqrt{L_{wire.symetric.hor}^{\ 2} + L_{vert}^{\ 2}} = 1401.8\ m$

Axial stiffness: $k_{wire.symmetric} := \dfrac{E_{wire} \cdot A_{wire}}{L_{wire.symetric}}$ $k_{wire.symmetric} = 141\ \dfrac{N}{mm}$

Winch line from winch to fairled:

Wire length: $L_{wire.winch} := 23 \cdot m$

Axial stiffness: $k_{wire.winch} := \dfrac{E_{wire} \cdot A_{wire}}{L_{wire.winch}}$ $k_{wire.winch} = 8567\ \dfrac{N}{mm}$

6.2.2 Anchor line stiffness - 8 lines - Unsymmetric pattern - EDDA 2/7C

Wire length:

A1: $L_{wire.A1.hor} := 1445 \cdot m$ $L_{wire.A1} := \sqrt{L_{wire.A1.hor}^{\ 2} + L_{vert}^{\ 2}} = 1446.7\ m$

A2: $L_{wire.A2.hor} := 1445 \cdot m$ $L_{wire.A2} := \sqrt{L_{wire.A2.hor}^{\ 2} + L_{vert}^{\ 2}} = 1446.7\ m$

B1: $L_{wire.B1.hor} := 1426 \cdot m$ $L_{wire.B1} := \sqrt{L_{wire.B1.hor}^{\ 2} + L_{vert}^{\ 2}} = 1427.7\ m$

B2: $L_{wire.B2.hor} := 1130 \cdot m$ $L_{wire.B2} := \sqrt{L_{wire.B2.hor}^{\ 2} + L_{vert}^{\ 2}} = 1132.2\ m$

D1: $L_{wire.D1.hor} := 1297 \cdot m$ $L_{wire.D1} := \sqrt{L_{wire.D1.hor}^{\ 2} + L_{vert}^{\ 2}} = 1298.9\ m$

D2: $L_{wire.D2.hor} := 1260 \cdot m$ $L_{wire.D2} := \sqrt{L_{wire.D2.hor}^{\ 2} + L_{vert}^{\ 2}} = 1262.0\ m$

E1: $L_{wire.E1.hor} := 1408 \cdot m$ $L_{wire.E1} := \sqrt{L_{wire.E1.hor}^{\ 2} + L_{vert}^{\ 2}} = 1409.8\ m$

E2: $L_{wire.E2.hor} := 1482 \cdot m$ $L_{wire.E2} := \sqrt{L_{wire.E2.hor}^{\ 2} + L_{vert}^{\ 2}} = 1483.7\ m$

Axial stiffness:

$$k_{wire.A1} := \frac{E_{wire} \cdot A_{wire}}{L_{wire.A1}} \qquad k_{wire.A1} = 136 \ \frac{N}{mm}$$

$$k_{wire.A2} := \frac{E_{wire} \cdot A_{wire}}{L_{wire.A2}} \qquad k_{wire.A2} = 136 \ \frac{N}{mm}$$

$$k_{wire.B1} := \frac{E_{wire} \cdot A_{wire}}{L_{wire.B1}} \qquad k_{wire.B1} = 138 \ \frac{N}{mm}$$

$$k_{wire.B2} := \frac{E_{wire} \cdot A_{wire}}{L_{wire.B2}} \qquad k_{wire.B2} = 174 \ \frac{N}{mm}$$

$$k_{wire.D1} := \frac{E_{wire} \cdot A_{wire}}{L_{wire.D1}} \qquad k_{wire.D1} = 152 \ \frac{N}{mm}$$

$$k_{wire.D2} := \frac{E_{wire} \cdot A_{wire}}{L_{wire.D2}} \qquad k_{wire.D2} = 156 \ \frac{N}{mm}$$

$$k_{wire.E1} := \frac{E_{wire} \cdot A_{wire}}{L_{wire.E1}} \qquad k_{wire.E1} = 140 \ \frac{N}{mm}$$

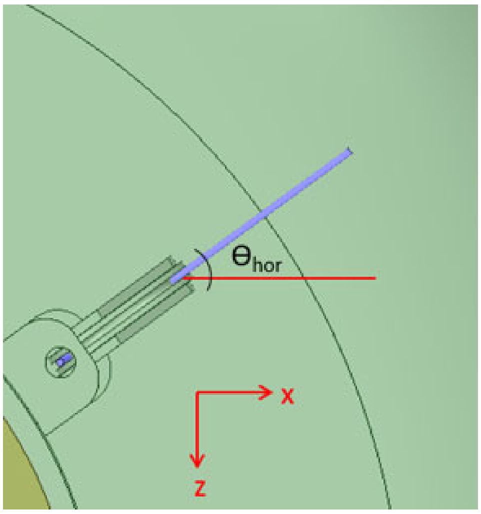
$$k_{wire.E2} := \frac{E_{wire} \cdot A_{wire}}{L_{wire.E2}} \qquad k_{wire.E2} = 133 \ \frac{N}{mm}$$

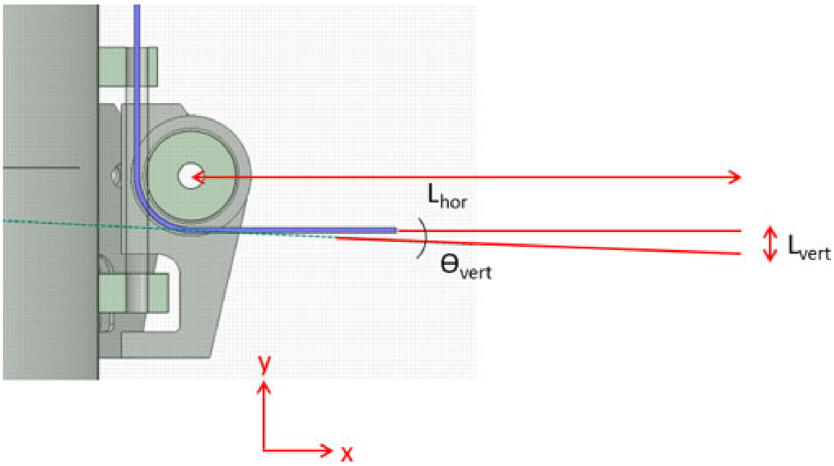
6.2.3 Anchor line force components - 10 lines - Symmetric pattern

The Excel spreadsheet below calculates the anchor line force components (x, y and z componets) base d on the anchor line forces calculated by Ansys. This will be a manual check that the force balance of th e model is correct.
From the results below we see that the total force in x-direction is zero, total vertical force is 190 kN while the total force in z-direction is 3080 kN which equals the applied external load.
From the table on next page we see that the total vertical reaction force in ansys is given to be 1 90 kN which equals the manually calulated anchor line total vertical force componet. There is no force in x dire ction which is correct.
Note that section 6.2.5 show detail calculations of the force components for anchor line D1 for the 8 line pattern. Similar Excel calculations for the 8 line pattern is given in section 6.2.4.

Water depth:		80	m
Waterline - EL:		20.7	m
Line @ Fairled - EL:		10.951	m
Vertical distance from line to seafloor:		70.251	m

Line	L_{hor} [m]	Θ_{hor} [deg]	F_{line} [kN]	Θ_{vert} [deg]	$F_{line.x}$ [kN]	$F_{line.y}$ [kN]	$F_{line.z}$ [kN]	$F_{line.hor}$ [kN]
A1	1400	252	0	2.87	0.00	0.00	0.00	0.00
A2	1400	216	0	2.87	0.00	0.00	0.00	0.00
B1	1400	180	0	2.87	0.00	0.00	0.00	0.00
B2	1400	144	725.1	2.87	-585.88	36.34	425.67	724.19
C1	1400	108	1173.2	2.87	-362.08	58.80	1 114.38	1 171.73
C2	1400	72	1173.2	2.87	362.08	58.80	1 114.38	1 171.73
D1	1400	36	725.1	2.87	585.88	36.34	425.67	724.19
D2	1400	0	0	2.87	0.00	0.00	0.00	0.00
E1	1400	324	0	2.87	0.00	0.00	0.00	0.00
E2	1400	288	0	2.87	0.00	0.00	0.00	0.00
					0.00	**190.27**	**3 080.09**	





Results from the Ansys calculations:

Probe: Springs	**Elastic Force**	**Units**
D2 - Seafloor	0	N
D2 - Winch	0	N
D1 - Seafloor	725 100	N
D1 - Winch	724 880	N
A1 - Seafloor	0	N
A1 - Winch	0	N
A2 - Winch	0	N
A2 - Seafloor	0	N
B1 - Winch	0	N
B2 - Winch	724 880	N
B1 - Seafloor	0	N
B2 - Seafloor	725 100	N
C1 - Winch	1 172 700	N
C2 - Winch	1 172 700	N
C1 - Seafloor	1 173 200	N
C2 - Seafloor	1 173 200	N
E1 - Winch	0	N
E2 - Winch	0	N
E1 - Seafloor	0	N
E2 - Seafloor	0	N

Probe: Reactions	**X Magnitude**	**Y Magnitude**	**Z Magnitude**	**Units**
Vertical support - A	0	212 430	0	N
Vertical support - B	0	33 996	0	N
Vertical support - C	0	-302 320	0	N
Vertical support - D	0	34 434	0	N
Vertical support - E	0	211 720	0	N
Total	**0**	**190 260**	**0**	N

6.2.4 Anchor line force components - 8 lines - Unsymmetric pattern - EDDA 2/7C

Water depth:		80	m
Waterline - EL:		20.7	m
Line @ Fairled - EL:		10.951	m
Vertical distance from line to seafloor:		70.251	m

Line	L_{hor} [m]	Θ_{hor} [deg]	F_{line} [kN]	Θ_{vert} [deg]	$F_{line.x}$ [kN]	$F_{line.y}$ [kN]	$F_{line.z}$ [kN]	$F_{line.hor}$ [kN]
A1	1445	246	0	2.78	0.00	0.00	0.00	0.00
A2	1445	210	0	2.78	0.00	0.00	0.00	0.00
B1	1426	166	107.07	2.82	-103.76	5.27	25.87	106.94
B2	1130	132	2081.5	3.56	-1 390.11	129.16	1 543.88	2 077.49
C1	0.0001	0	0	90.00	0.00	0.00	0.00	0.00
C2	0.0001	0	0	90.00	0.00	0.00	0.00	0.00
D1	1297	64	1258.2	3.10	550.75	68.05	1 129.21	1 256.36
D2	1260	22	1018.8	3.19	943.15	56.71	381.06	1 017.22
E1	1408	341	0	2.86	0.00	0.00	0.00	0.00
E2	1482	302	0	2.71	0.00	0.00	0.00	0.00
					0.03	**259.19**	**3 080.01**	

Results from the Ansys calculations:

Probe: Springs	**Elastic Force**	**Units**
D2 - Seafloor	0	N
D2 - Winch	1 018 700	N
D1 - Seafloor	0	N
D1 - Winch	1 257 700	N
A1 - Seafloor	0	N
A1 - Winch	0	N
A2 - Winch	0	N
A2 - Seafloor	0	N
B1 - Winch	106 750	N
B2 - Winch	2 081 700	N
B1 - Seafloor	0	N
B2 - Seafloor	0	N
C1 - Winch	0	N
C2 - Winch	0	N
C1 - Seafloor	0	N
C2 - Seafloor	0	N
E1 - Winch	0	N
E2 - Winch	0	N
E1 - Seafloor	0	N
E2 - Seafloor	0	N
A1 - Seafloor - EDDA	0	N
A2 - Seafloor - EDDA	0	N
B1 - Seafloor - EDDA	107 070	N
B2 - Seafloor - EDDA	2 081 500	N
D1 - Seafloor - EDDA	1 258 200	N
D2 - Seafloor - EDDA	1 018 800	N
E1 - Seafloor - EDDA	0	N
E2 - Seafloor - EDDA	0	N

Probe: Reactions	**X Magnitude**	**Y Magnitude**	**Z Magnitude**	**Units**
Vertical support - A	0	341 410	0	N
Vertical support - B	0	-182 730	0	N
Vertical support - C	0	-41 082	0	N
Vertical support - D	0	-178 780	0	N
Vertical support - E	0	320 300	0	N
Total	**0**	**259 118**	**0**	N

6.2.5 Anchor line force components - Detail calculation for line D1 - 8 line pattern

Horizontale line length: $L_{hor} := 1297 \cdot m$

Vertical distance from line at fairled to sea floor: $L_{vert} := 70.251 \cdot m$

Horizontal angle to line: $\theta_{hor} := 64 \cdot deg$

Line force: $F_{line} := 1258.2 \cdot kN$

Vertical line angle: $\theta_{vert} := \text{atan}\left(\frac{L_{vert}}{L_{hor}}\right) = 3.1\ deg$

Line components:

$F_{line.Y} := \sin\left(\theta_{vert}\right) \cdot F_{line}$ $\quad F_{line.Y} = 68.05\ kN$

$F_{line.hor} := \cos\left(\theta_{vert}\right) \cdot F_{line}$ $\quad F_{line.hor} = 1256.36\ kN$

$F_{line.X} := \cos\left(\theta_{hor}\right) \cdot F_{line.hor}$ $\quad F_{line.X} = 550.75\ kN$

$F_{line.Z} := \sin\left(\theta_{hor}\right) \cdot F_{line.hor}$ $\quad F_{line.Z} = 1129.21\ kN$

Control:

$F_{line} := \sqrt{F_{line.X}^2 + F_{line.Y}^2 + F_{line.Z}^2} = 1258.2\ kN$ OK

$F_{line.hor} := \sqrt{F_{line.X}^2 + F_{line.Z}^2} = 1256.36\ kN$ OK

Total line length: $L_{tot} := \sqrt{L_{hor}^2 + L_{vert}^2}$ $\quad L_{tot} = 1298.9\ m$

6.2.6 Summary of anchor line forces

The figure below show the anchor line forces for the two cases analysed:

- 10 lines - Symmetric pattern - Red markings
- 8 lines - Unsymmetric pattern - EDDA 2/7C - Blue markings