Appendix to report:

SBJ-33-C5-OON-22-RE-021

K12 - DESIGN OF MOORING AND ANCHORING

Appendix title:

APPENDIX E – PONTOON INTERFACE

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CONCEPT DEVELOPMENT FLOATING BRIDGE E39 BJØRNAFJORDEN

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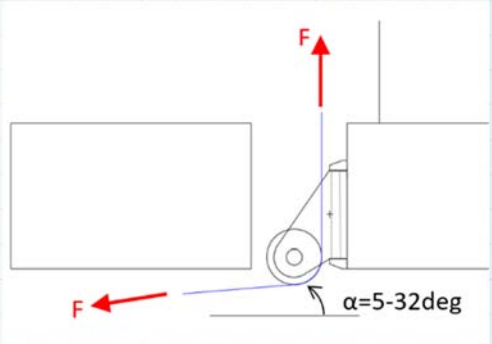
1 GENERAL

This appendix presents the overall assessment of the proposed fairlead solution.

A typical fairlead assembly is chosen to fit inside the moonpool in the pontoon. The following calculations shall ensure that the chosen geometry is feasible. Main loads and dimensions are assessed. However, this is not detail design of the fairlead. Fairlead supplier will ensure final integrity.

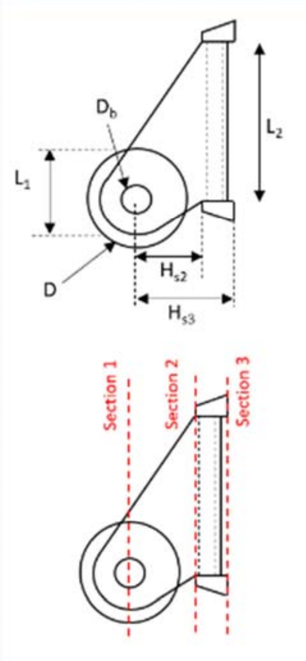


2 ASSESSMENT

INPUT

Geometry

Diameter wheel	$D := 3.4\ m$
Diameter axle	$D_b := 0.5\ m$
Length plate section 1	$L_1 := 2.5\ m$
Length plate section 2	$L_2 := 5.5\ m$
Height plate section 2	$H_{s2} := 2.2\ m$
Height plate section 3	$H_{s3} := 3.3\ m$
Mooring line angle	$\alpha := 0\ deg$
Wall thickness plates	$t := 40\ mm$
Wall thickness axle	$t_b := 60\ mm$
Distance between two plates	$d := 1\ m$
Width suport plates	$w := 3\ m$



Material

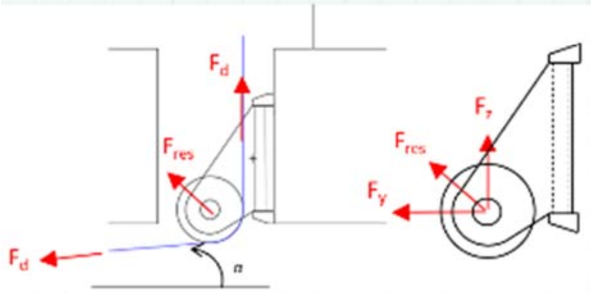
Specified minimum Yield Stress	$f_y := 355\ MPa$	
Specified minimum Tensile Strength	$f_u := 470\ MPa$	
Youngs modulus	$E := 210\ GPa$	
Plate material factor	$\gamma_{M1} := 1.15$	NORSOK N-004

Loads

Load factor	$\gamma_f := 1.25$	Ref. Lovdata, forskrift om posisjonerings- og ankringssystemer på flyttbare innretninger
Characteristic load in mooring line	$F_c := 10\ MN$	MBL anchor chain
Factor for out of plane load	$f := 0.1$	10% load in out of plane assumed

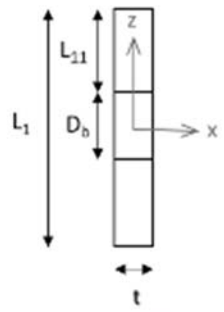
DESIGN CALCULATIONS

Design loads



Design load in mooring line	$F_d := F_c \cdot \gamma_f = 12.5\ MN$
Resultant force on wheel axis	$F_{res} := 2 \cdot F_d \cdot \cos(\alpha) = 25\ MN$
Vertical force on wheel axis	$F_y := F_{res} \cdot \cos\left(45\ deg - \frac{\alpha}{2}\right) = 17.7\ MN$
Horizontal force on whell axis	$F_z := F_{res} \cdot \sin\left(45\ deg - \frac{\alpha}{2}\right) = 17.7\ MN$
Out of plane load	$F_x := f \cdot F_d = 1.25\ MN$

Assessment section 1



$$L_{11} := \frac{L_1 - D_b}{2} = 1\ m$$

Cross section area $A_1 := 2 \cdot L_{11} \cdot t = 0.08\ m^2$

Normal stress per plate $\sigma_{n1} := \frac{F_y}{2\ A_1} = 110\ MPa$

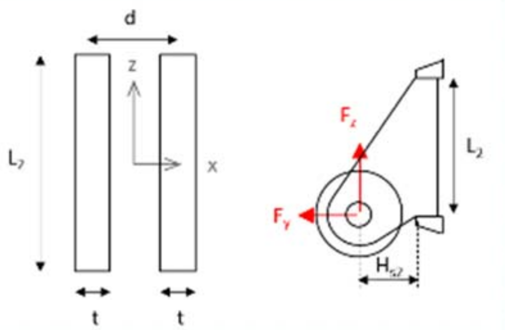
Shear stress per plate $\tau_1 := \frac{\sqrt{F_z^2 + F_x^2}}{2\ A_1} = 111\ MPa$

Von Mises stress $\sigma_{vm1} := \sqrt{\sigma_{n1}^2 + 3\left(\tau_1^2\right)} = 221\ MPa$

Utilisation $\eta_1 := \frac{\sigma_{vm1} \cdot \gamma_{M1}}{f_y}$ $\eta_1 = 0.72$

Bearing stress and shear out has not been checked in this preliminary assessment. However use of cheek plates can be considered if required.

Assessment section 2



$$M_{x2} := F_y \cdot \frac{L_2}{2} + F_z \cdot H_{s2} = 88\ MN \cdot m$$

$$M_{y2} := F_x \cdot \frac{L_2}{2} = 3\ MN \cdot m$$

$$M_{z2} := F_x \cdot H_{s2} = 3\ MN \cdot m$$

Moment of inertia

$$I_{xx2} := 2 \left[\frac{L_2^{\ 3} \cdot t}{12} \right] = [1.11]\ m^4$$

$$I_{zz2} := 2 \cdot \left[\left(\frac{L_2 \cdot t^3}{12} \right) + \left(\left(\frac{d}{2} \right)^2 \cdot (L_2 \cdot t) \right) \right] = [0.11]\ m^4$$

Polar moment of inertia

$$J_2 := I_{xx2} + I_{zz2} = [1.22]\ m^4$$

Cross section area

$$A_2 := 2 \cdot L_2 \cdot t = 0.44\ m^2$$

Section modulus

$$W_{xx2} := \frac{I_{xx2}}{\frac{L_2}{2}} = [0.4]\ m^3$$

$$W_{zz2} := \frac{I_{zz2}}{\frac{d}{2} + \frac{t}{2}} = [0.21]\ m^3$$

Normal stress plate

$$\sigma_{n2} := \frac{F_y}{A_2} + \frac{M_{x2}}{W_{xx2}} + \frac{M_{z2}}{W_{zz2}} = [270]\ MPa$$

Shear stress per plate

$$\tau_2 := \frac{\sqrt{F_z^{\ 2} + F_x^{\ 2}}}{A_2} + \frac{M_{y2}}{J_2} \cdot \frac{L_2}{2} = [48]\ MPa$$

Von Mises stress

$$\sigma_{vm2} := \sqrt{\sigma_{n2}^{\ 2} + 3\left(\tau_2^{\ 2}\right)} = [283]\ MPa$$

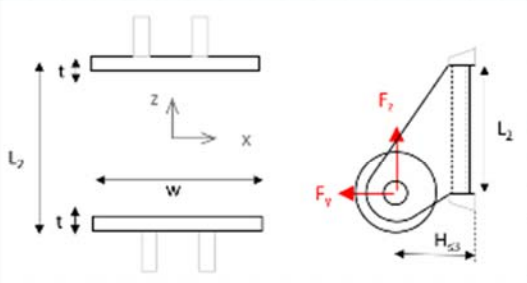
Utilisation

$$\eta_2 := \frac{\sigma_{vm2} \cdot \gamma_{M1}}{f_y} \qquad \eta_2 = [0.92]$$

The assessment of section 2 shows high utilisation. However, it is assumed that the section is fixed around the vertical axis. This is not necessary for the design and may be different for the supplier solution. In addition is possible to strengthen the section 2 with increased plate thickness or additional stiffeners. The utilisation is hence assumed acceptable in this feasibility assessment.

Assessment section 3

Section 3 transferes loads into the pontoon. Vertical shearforces shall be tranfered by vertical stiffener plates on top and below. The other loads thall be tranfered by horizontal plates.



$$M_{x3} := F_y \cdot \left(\frac{L_2}{2}\right) + F_z \cdot (H_{s3}) = 107\ MN \cdot m$$

$$M_{y3} := F_x \cdot \frac{L_2}{2} = 3\ MN \cdot m$$

$$M_{z3} := F_x \cdot (H_{s3}) = 4\ MN \cdot m$$

Moment of inertia

$$I_{xx3} := 2\left[\frac{w \cdot t^3}{12} + \left(\frac{L_2}{2} - \frac{t}{2}\right)^2 \cdot (t \cdot w)\right] = [1.79]\ m^4$$

$$I_{zz3} := 2 \cdot \left[\left(\frac{t \cdot w^3}{12}\right)\right] = [0.18]\ m^4$$

Polar moment of inertia

$$J_3 := I_{xx3} + I_{zz3} = [1.97]\ m^4$$

Cross section area

$$A_3 := 2 \cdot w \cdot t = 0.24\ m^2$$

Section modulus

$$W_{xx3} := \frac{I_{xx3}}{\frac{L_2}{2}} = [0.65]\ m^3$$

$$W_{zz3} := \frac{I_{zz3}}{\frac{w}{2}} = [0.12]\ m^3$$

Normal stress plate

$$\sigma_{n3} := \frac{F_y}{A_3} + \frac{M_{x3}}{W_{xx3}} + \frac{M_{z3}}{W_{zz3}} = [272]\ MPa$$

Shear stress per plate
(shear force Fz shall be taken y the vertical shear plates, see assessment below)

$$\tau_3 := \frac{F_x}{A_3} + \frac{M_{y3}}{J_3} \cdot \frac{L_2}{2} = [10]\ MPa$$

Von Mises stress $\sigma_{vm3} := \sqrt{\sigma_{n3}^{2} + 3\left(\tau_3^{2}\right)} = [273]\ MPa$

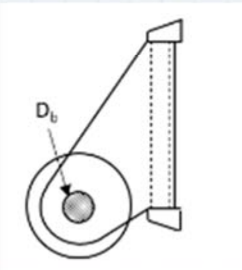
Utilisation $\eta_3 := \frac{\sigma_{vm3} \cdot \gamma_{M1}}{f_y}$ $\eta_3 = [0.88]$

Shear force Fz shall be transfered by vertical plates.

Total required length of shear plates $L_{s3} := \frac{\frac{F_z}{f_y} \cdot \sqrt{3} \cdot \gamma_{M1}}{t} = 2.5\ m$

Length per shear plate $l_{s3} := \frac{L_{s3}}{4} = 0.6\ m$

Assessment axle



Cross section area $A_b := \pi \cdot \left(\left(\frac{D_b}{2}\right)^2 - \left(\frac{D_b - 2\ t_b}{2}\right)^2\right) = 0.08\ m^2$

Shear stress in axle $\tau_b := \frac{F_{res}}{2\ A_b} = 151\ MPa$

Von Mises stress $\sigma_{vmb} := \sqrt{3} \cdot \tau_b = 261\ MPa$

Utilisation $\eta_b := \frac{\sigma_{vmb} \cdot \gamma_{M1}}{f_y}$ $\eta_b = 0.85$