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ON LOCAL STRENGTH ANALYSIS IN CRITICAL CONDITIONS OF MOORING AND TOWING FOR A CHEMICAL TANKER

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ABSTRACT

Mooring and towing equipment ensure stability, control, and safety in stationary (mooring) and transit (towing) situations. Mooring equipment is responsible for securing a vessel in place at a dock, pier, or offshore structure. Proper mooring equipment and reinforcements ensure that the vessel remains safely secured despite the influence of environmental loads. Towing equipment is essential for moving a ship over short or long distances, either due to mechanical failures of the vessel or to relocate it. Towing is especially critical in rescue operations. The study involves a chemical tanker detailed strength check at mooring (at the pier) and towing (on relocation) cases. In both cases, the worst scenario was taken into consideration.

Keywords: mooring, towing, chemical tanker, critical conditions

1. INTRODUCTION

Mooring and towing operations involve the exertion of significant loads on localized areas of the ship's structure, such as mooring and towing points and the hull around the mooring and towing equipment. If these areas are not properly reinforced, high stresses could lead to structural damage, cracks, or even catastrophic failures.

Excessive stress at the bollards, rollers, or chocks can compromise the ship’s ability to remain securely moored, risking damage to the vessel or the port infrastructure.

The main goal of this research is to evaluate the local strength during mooring and towing operations in extreme conditions for a maritime chemical tanker by combined design forces [1].

For each fitting on the deck, the area of the ship's structure where the maximum stress was induced was determined. Due to the superior quality of the materials used for fittings, their strength is inherently designed to withstand significant overloading and is not factored in the evaluation.

2. ANALYSES OF FITTING ELEMENTS STRENGTH AT AFT

The structure (CAD) is created by Rhino [2], exported as a STEP file, and imported in Femap/NX Nastran [3] (Figs. 1, 2) for developing the 3D-FEM model. The used 3D-FEM mesh is a fine one (Fig. 3), with elements size between 50 mm and 70 mm, quad elements [4], with some exceptions where the use of triangular elements could not be avoided.

2.1. Model of the aft area

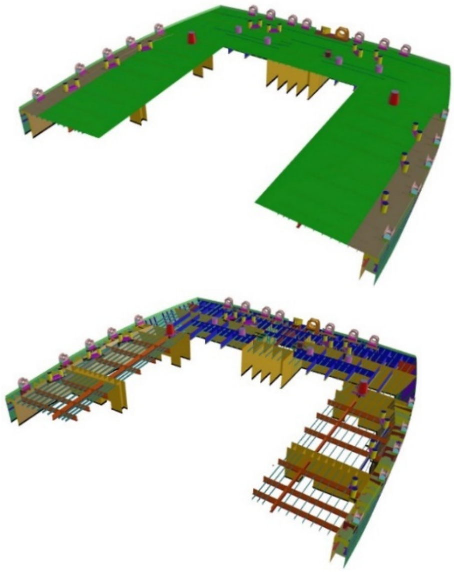


Fig. 1 Aft area of the ship (CAD)

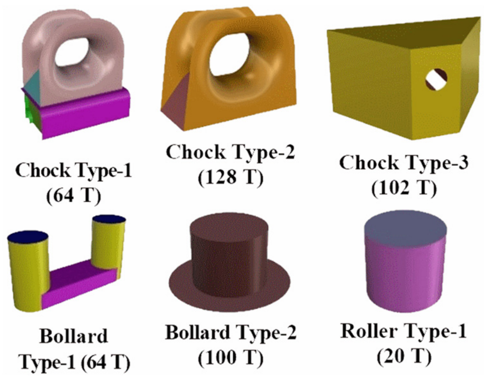


Fig. 2 Aft fittings elements (CAD)

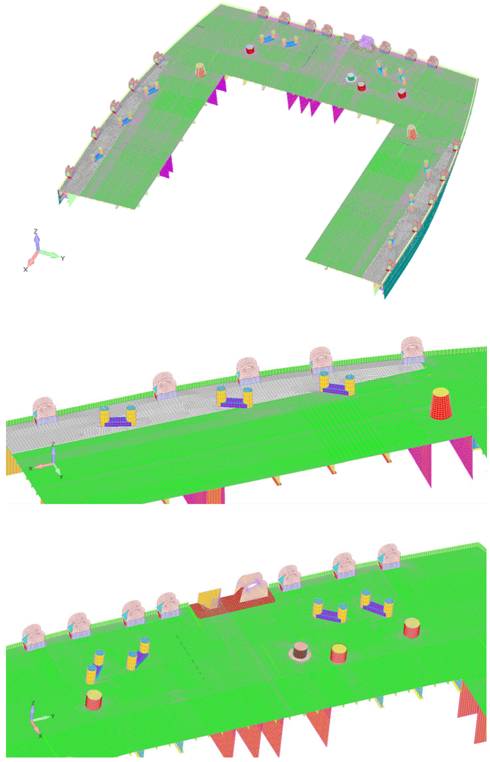


Fig. 3 Aft area of the ship (FEM)

2.2. Applied loads

The applied forces to the fittings are determined using the principle of composing forces (Fig. 4). In the direction of rope, the maximum safe working load (SWL) for each equipment and fleet angle is considered the minimum possible to obtain the maximum force that can occur. The resultant force is calculated using equation (1).

$$F_R = F_{SWL}\sqrt{2 + 2\cos(fleet\_angle)} \quad (1)$$

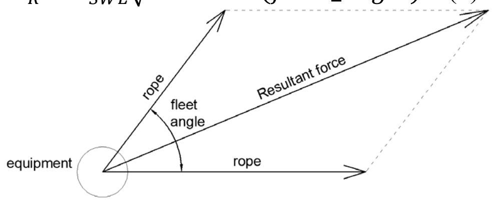


Fig. 4 Principle of determination of applied force on fittings

The applied loads to fittings have the values presented in Table 2 and Table 3 for mooring and towing operations. The loading force is applied in the direction of the resultant, which is presented in Fig. 5 and Fig. 6.

2.2.1. Mooring operation loads

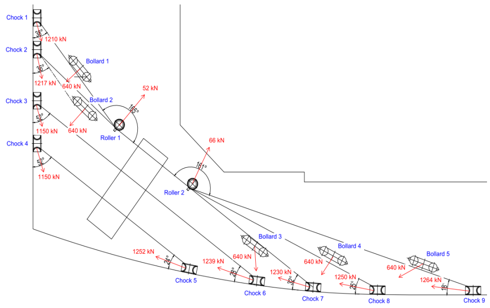


Fig. 5 Aft loads (mooring)

Table 2. Aft loads (mooring)

Element	Type	Load[kN]	Angle[deg]
Roller #1	1 (Fig.2)	52.23	165.11
Roller #2	1 (Fig.2)	66.51	151.15
Bollards#	1 (Fig.2)	640.15	0
Chock #1	1 (Fig.2)	1210.36	38.17
Chock #2	1 (Fig.2)	1218.72	36.05
Chock #3	1 (Fig.2)	1151.47	52.07
Chock #4	1 (Fig.2)	1151.47	52.07
Chock #5	1 (Fig.2)	1252.68	24.21
Chock #6	1 (Fig.2)	1239.34	29.08
Chock #7	1 (Fig.2)	1231.72	32.02
Chock #8	1 (Fig.2)	1250.16	25.04
Chock #9	1 (Fig.2)	1265.49	18.16

2.2.2. Towing operation loads

Table 3 Aft loads (towing)

Element	Type	Load[kN]	Angle[deg]
Roller #3	1 (Fig.2)	400.34	88.05
Roller #4	1 (Fig.2)	400.34	111.10
Bollard #6	2 (Fig.2)	1000.12	0
Chock #15	3 (Fig.2)	2041.31	90.00
Chock #16	2 (Fig.2)	2560.17	37.09

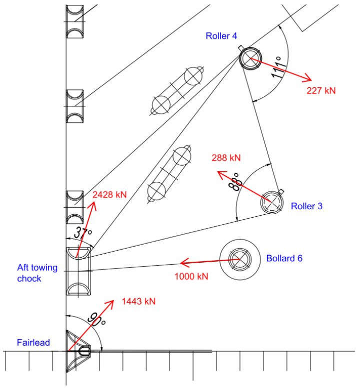


Fig. 6 Aft loads (towing)

2.3. Numerical results

2.3.1 Mooring operation

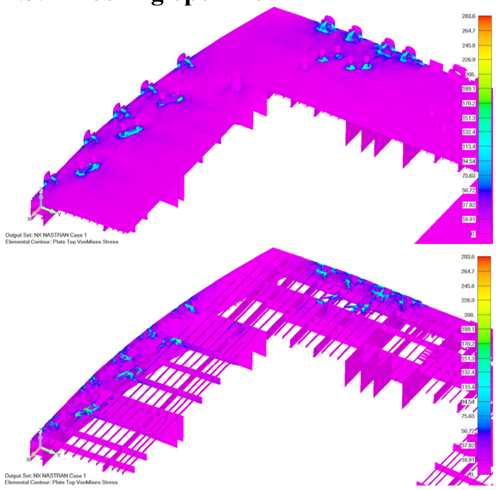


Fig. 7 Aft (mooring) – Von Misses stress[MPa]

The maximum values of Von Misses stress for each fitting are identified and centralized in Table 4.

Tab.4 Aft (mooring) – Von Misses stress

Element	Max. Von Mises stress [MPa]
Chock #1	233.81
Chock #2	256.73
Chock #3	187.72
Chock #4	178.74
Chock #5	180.81
Chock #6	172.15
Chock #7	193.72

Chock #8	164.91
Chock #9	157.31
Bollard #1	244.32
Bollard #2	177.65
Bollard #3	241.52
Bollard #4	204.63
Bollard #5	283.64
Roller #1	49.12
Roller #2	66.18

2.4.2 Towing operation

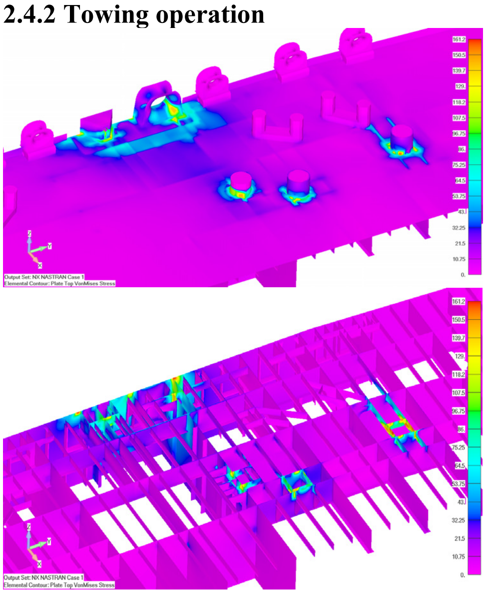


Fig. 8 Aft (towing) – Von Misses stress [MPa]

Table 5 presents the maximum values of Von Misses stress for towing case.

Tab.5 Aft (towing) – Von Misses stress

Element	Max. Von Mises stress [MPa]
Chock #15	155.13
Chock #16	157.91
Roller #3	145.59
Roller #4	161.21
Bollard #6	139.77

3. ANALYSIS OF FITTING ELEMENTS STRENGTH AT FORE

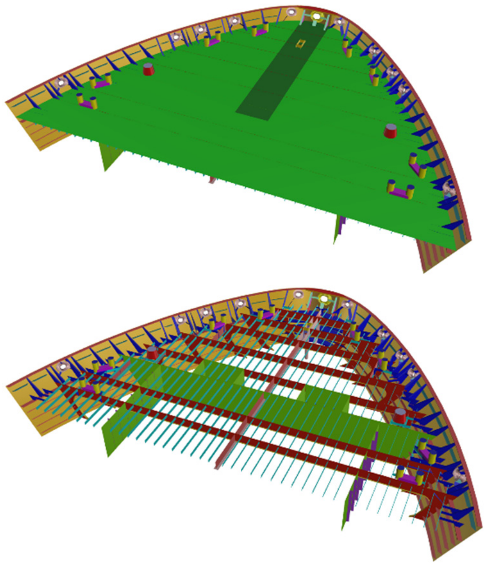


Fig. 9 Fore area of the ship (CAD)

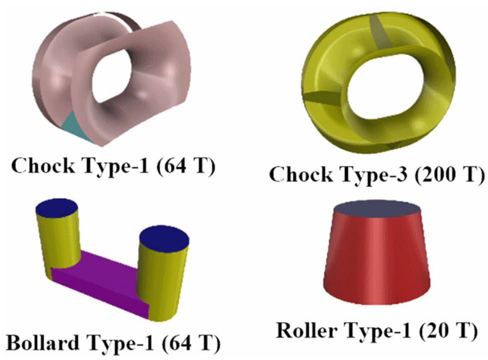
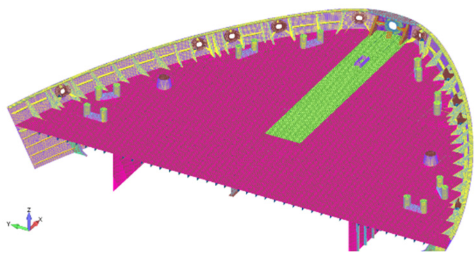


Fig. 10 Fore fittings elements (CAD)



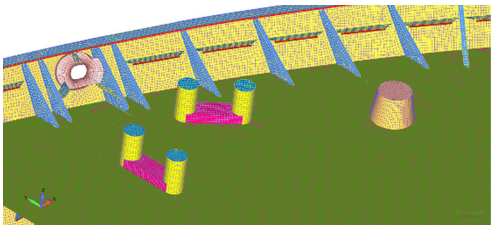


Fig. 11 Fore area of the ship (FEM)

3.1. Applied loads

The load values are applied according to Table 6 and Table 7. The direction of applied force (at fore) is presented in Fig.12 and Fig. 13.

3.1.1. Mooring operation

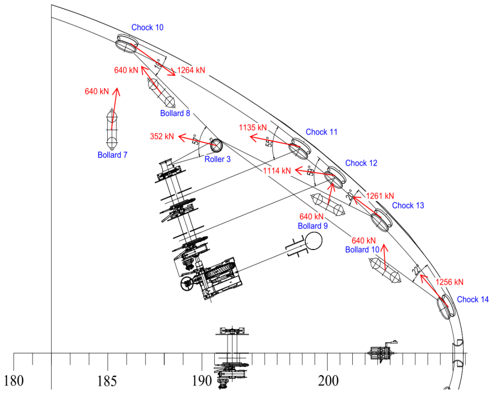


Fig. 12 Fore loads (mooring)

Tab 6. Fore loads (mooring)

Element	Type	Load[kN]	Angle[deg]
Roller #5	1 (Fig.10)	400.34	57.02
Bollards#	1 (Fig.10)	640.15	0
Chock #10	1 (Fig.10)	1280.27	19.01
Chock #11	1 (Fig.10)	1280.27	55.07
Chock #12	1 (Fig.10)	1280.27	59.04
Chock #13	1 (Fig.10)	1280.27	20.03
Chock #14	1 (Fig.10)	1280.27	22.06

3.1.2. Towing operation

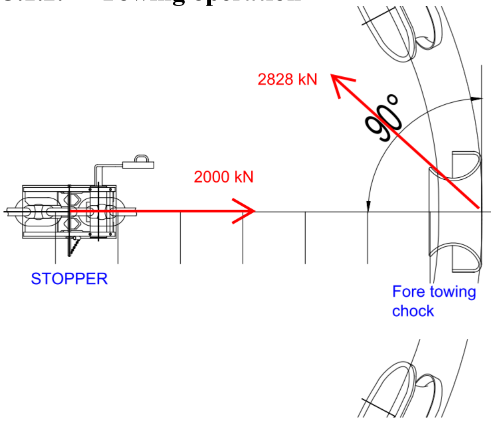


Fig. 13 Fore loads (towing)

Tab 7. Fore loads (towing)

Element	Type	Load[kN]	Angle[deg]
Chock #17	3 (Fig.10)	2828.54	90.00
Stopper #1	3 (Fig.10)	2000.78	0

3.2. Numerical results

3.2.1. Mooring operation

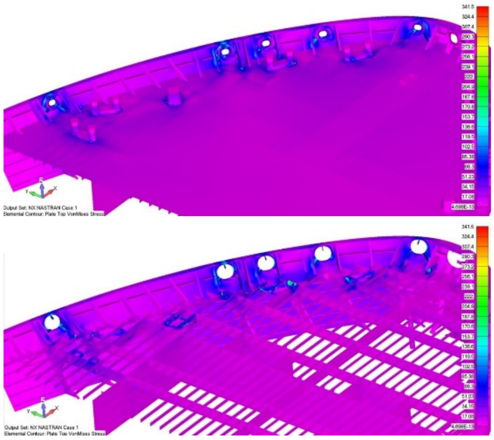


Fig. 14 Fore (mooring) – Von Misses stress[MPa]

The obtained values are higher in the fore area than the aft area which in some cases it is due to the smaller value of fleet angle and the increases of the resultant force.

Tab.8 Fore (mooring) – Von Misses stress

Element	Max. Von Mises stress [MPa]
Chock #10	261.61
Chock #11	309.43
Chock #12	227.45
Chock #13	197.12
Chock #14	274.47
Bollard #7	221.63
Bollard #8	273.95
Bollard #9	341.54
Bollard #10	310.23
Roller #5	172.28

3.2.2. Towing operation

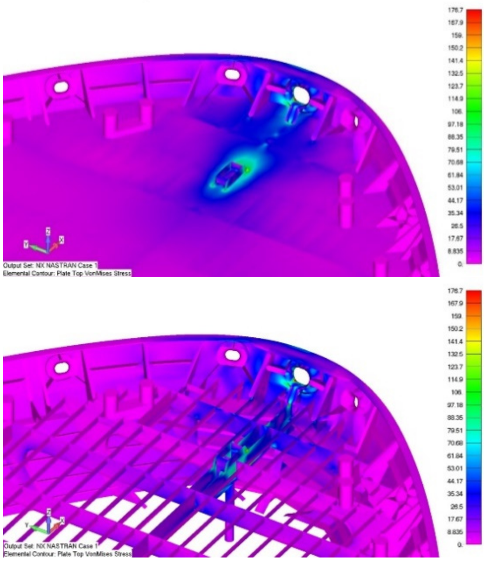


Fig. 15 Fore (towing) – Von Misses stress [MPa]

Tab.9 Fore (towing) – Von Misses stress

Element	Max. Von Mises stress [MPa]
Chock #17	157.91
Stopper #1	176.73

4. CONCLUSIONS

The results revealed the hot spot stress area on the ship's structure. As a solution to ensure safety on board the ship during mooring, superior quality steel can be chosen, or additional structural reinforcements can be added. For the mooring equipment that induces higher stress even than those admissible for AH36 steel, the addition of local profiles or the shell thickening becomes mandatory.

Figure 16 presents the maximum Von Misses stress for each fitting and is compared to admissible stress for different steel quality in the mooring cases.

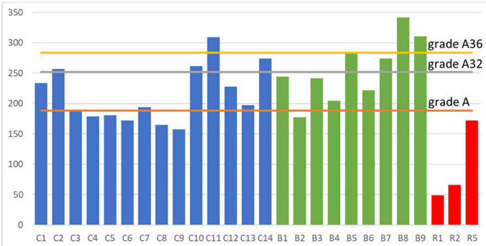


Fig. 16 Maximum Von Miss Stress [MPa] for mooring cases

For the towing cases, from the aft and fore areas, the results revealed that the stresses in the worst scenario are lower than the admissible ones of grade A steel (Fig. 17).

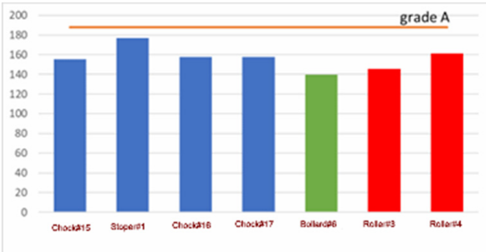


Fig. 17 Maximum Von Miss Stress [MPa] for towing cases

Acknowledgments

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