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ANALYSIS OF THE INFLUENCE OF THE MESHING SIZE FOR AN OIL TANKER STRUCTURAL MODEL ON THE STRESS HOT SPOT VALUES

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ABSTRACT

The development of the shipbuilding industry leads to new requirements for the safety of ships. Stress hot spots are recorded on every floating structure and they influence negatively the hull strength. This analysis identifies the stress hot spots and the influence of the meshing size on their values for a 97235 tdw oil tanker, using the Femap/NX Nastran program. Structurally, two constructive options were considered for the central longitudinal bulkhead: corrugated and flat panels. The detailed local structural model is developed for three mesh sizes: coarse, medium, and fine. Quad and triangle shell elements are used for the FEM local models.

Keywords: stress hot spot, oil tank local structure, FEM analysis.

1. INTRODUCTION

The detailed evaluation of naval structures leads to the analysis of stress hot spots on numerical 3D-FEM models, representing the areas with the greatest potential for structural failure.

The present paper presents the analysis of stress hot spots at the midship section of a 97235 tdw oil tanker using 3D-FEM models developed with the Femap/NX Nastran program [1]. The analysis is performed for two structural models: a flat longitudinal bulkhead model (Fig.1.1) and a corrugated longitudinal bulkhead model (Fig.1.2). For both models, two types of mesh are used: triangular and quadrilateral finite elements. Three types of loading cases are considered: still water, equivalent design wave hogging and sagging.

For a precise structural analysis, 10 detail areas were chosen as reference, which are recording significant stress hot spot values.

The following table shows the number of CAD entities obtained for the structure in the midship section of the oil tanker 97235 tdw, the model being extended over a length of a frame distance of 3.2 m.

Table 1.1. Number of CAD objects.

Long.bulkhead	Points	Curves	Surfaces
Corrugated	13936	13936	3525
Flat	16111	15967	4020

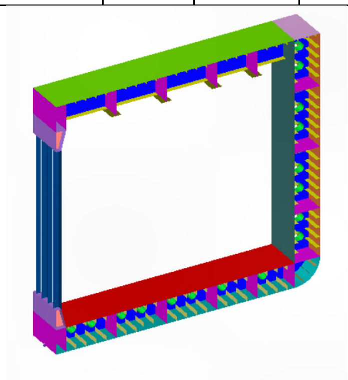

Fig. 1.1. 3D-CAD oil-tanker midship model with corrugated longitudinal bulkhead.

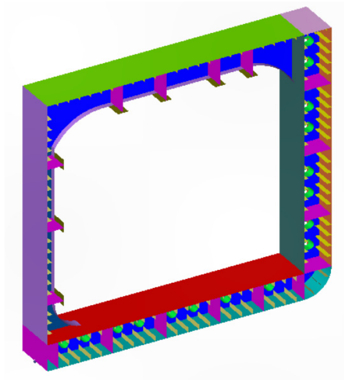

Fig. 1.2. 3D-CAD oil-tanker midship model with flat longitudinal bulkhead.

2. CHARACTERISTICS OF THE OIL TANKER MODEL

For the structural elements of the 3D-CAD model are assigned material and geometric properties during the meshing process for the generation of the 3D-FEM model. The material used is steel type grade A with the yielding stress of 235 MPa, and the geometric properties are shown in table 2.1 and table 2.2, respectively.

Table 2.1. The elements thickness of the model with a flat longitudinal bulkhead.

No.	Element name	Thickness [mm] / Profile
	Shell plates	
1.	Double bottom	18
2.	Bottom	20
3.	Bilge	17
4.	Shell	16
5.	Inner shell	12
6.	Deck	18
7.	Longitudinal bulkhead	14
	Functional elements	
8.	Floor	17
9.	Frame	12
10.	Transverse girder	15
11.	Vertical girder	12
12.	Longitudinal girder	12
13.	Side girder	12
14.	Deck girder	12
15.	Bulkhead girder	12
	Profiles	
16.	Bottom longitudinal	HP 370x13
17.	Double-bottom long.	HP 370x13
18.	Bilge longitudinal	HP 370x13
19.	Shell holland profile	HP 320x12
20.	Inner shell longitudinal	HP 300x11
21.	Deck longitudinal	HP 200x12
22.	Bulkhead longitudinal	HP 340x12
	Stiffeners	
23.	DB cut-hole flange	10
24.	DS cut-hole flange	10
25.	Deck long.girder flange	10
26.	Deck stiffeners	10
27.	Long. and vertical girder bulkhead flange	10

Table 2.2. The elements thicknesses of the model with corrugated longitudinal bulkhead, different to the flat long. bulkhead version.

No.	Element name	Thickness [mm] / Profile
	Shell plates	
1.	Deck	15
2.	Corrugated bulkhead	12
	Functional elements	
3.	Transverse girder	14
4.	Stool	14
5.	Bracket stool	14

The boundary conditions applied on the 3D-FEM model are as following:

-Boundary conditions applied to all nodes in the diametral plane, restraining the following degrees of freedom: transverse displacement, Tx, and rotations around the longitudinal, Rz, and vertical axes, Ry.

-Boundary conditions applied to all nodes at the intersection of the diametral plan and the base plane of the ship, with the following degrees of freedom restrained: displacement in the vertical direction, Ty;

-Boundary conditions applied to all nodes at the intersection of the diametral plane and the frame restraining the following degrees of freedom: displacement in the longitudinal direction, Tz.

On the FEM model, the local equivalent hydrostatic pressure is applied according to the DNV-GL rules [2], on the inner shell the pressure from the cargo, on the outer shell the pressure from the design equivalent quasi-static wave, hogging or sagging case (h_w =10.2 m, Figs.2.2, 2.3), and still water (h_w =0, Fig.2.1).

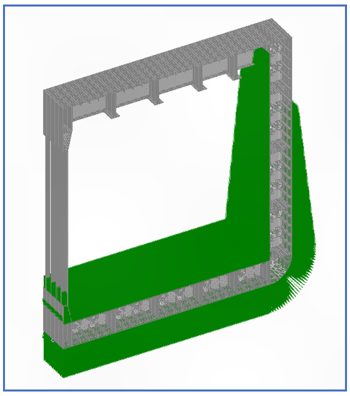

Fig. 2.1. 3D-FEM Model – cargo pressure and still water.

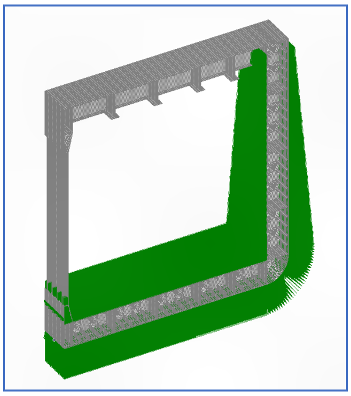

Fig. 2.2. 3D-FEM model – cargo pressure and equivalent wave, h_w = 10.2 m, hogging.

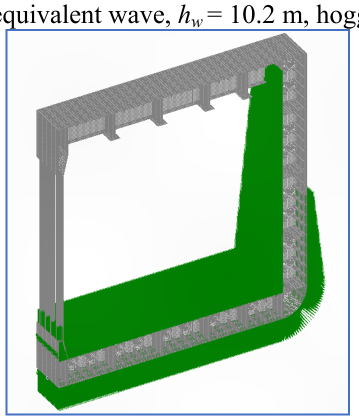

Fig. 2.3. 3D-FEM model – cargo pressure and equivalent wave, h_w = 10.2 m, sagging.

3. NUMERICAL RESULTS

The results of the structural analysis for the quasi-static equivalent loads are:
- *coarse mesh size* – still water, hogging, sagging- model with corrugated longitudinal bulkhead (mesh quad and triangle) (Figs. 3.1, 3.4, 3.7, 3.10, 3.13, 3.16; Tables 3.1, 3.2, 3.3, 3.4, 3.5, 3.6) and flat longitudinal bulkhead model (quad and triangle mesh) (Figs. 3.19, 3.22, 3.25, 3.28, 3.31, 3.34; Tables 3.7, 3.8, 3.9, 3.10, 3.11, 3.12);
- *medium mesh size* – still water, hogging, sagging – model with corrugated longitudinal bulkhead (mesh quad and triangle) (Figs. 3.2, 3.5, 3.8, 3.11, 3.14, 3.17; Tables 3.1, 3.2, 3.3, 3.4, 3.5, 3.6) and model with flat longitudinal bulkhead (quad and triangle mesh) (Figs. 3.20, 3.23, 3.26, 3.29, 3.32, 3.35; Tables 3.7, 3.8, 3.9, 3.10, 3.11, 3.12);
- fine mesh size – still water, hogging, sagging – model with corrugated longitudinal bulkhead (mesh quad and triangle) (Figs. 3.3, 3.6, 3.9, 3.12, 3.15, 3.18; Tables 3.1, 3.2, 3.3, 3.4, 3.5, 3.6) and model with flat longitudinal bulkhead (mesh quad and mesh triangle) (Figs. 3.21, 3.24, 3.27, 3.30, 3.33, 3.36; Tables 3.7, 3.8, 3.9, 3.10, 3.11, 3.12).

The following figures present the structural details where the stress hot spots have maximum stress values:
-corrugated longitudinal bulkhead model, still water load

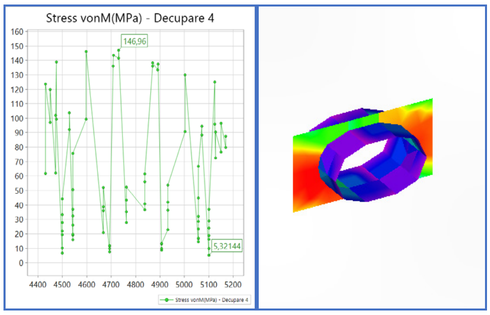

Fig. 3.1. 3D-FEM, Section 4, Stress von Misses – mesh quad 200.

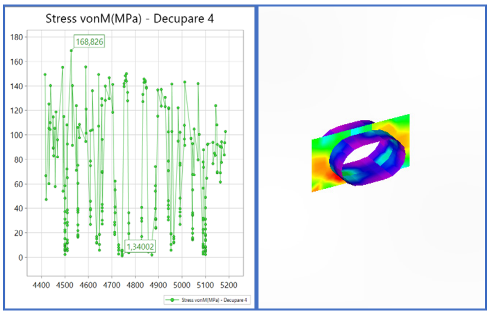

Fig. 3.2. Section 4, von Misses, mesh quad 100.

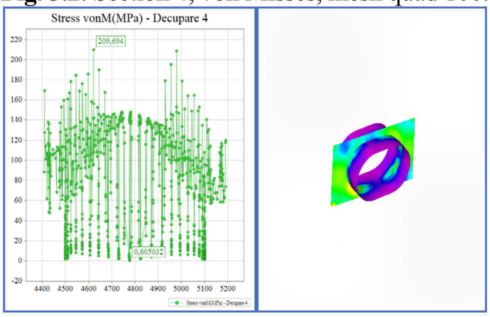

Fig. 3.3. Section 4, von Misses, mesh quad 50.

Table 3.1. Stress [MPa], corrugated longitudinal bulkhead, mesh quad, still water load.

Detail	MESH 200	MESH 100	MESH 50
Detail 1	60.466	92.113	113.234
Detail 2	61.583	86.742	101.013
Detail 3	81.181	111.083	128.749
Detail 4	146.960	168.826	209.694
Detail 5	66.339	68.581	82.473
Detail 6	73.597	79.323	112.349
Detail 7	17.408	15.911	24.385
Detail 8	98.068	95.135	103.133
Detail 9	46.522	54.978	60.867
Detail 10	66.563	50.875	54.688

-model with the corrugated longitudinal bulkhead, hogging wave load

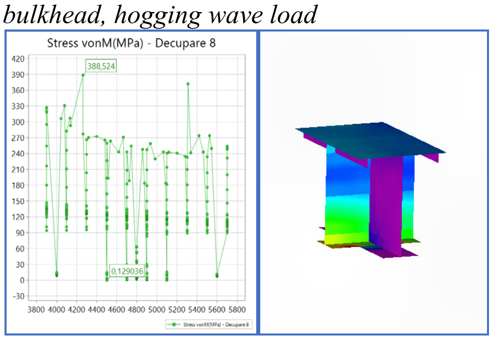

Fig. 3.4. Section 8, von Misses, mesh quad 200.

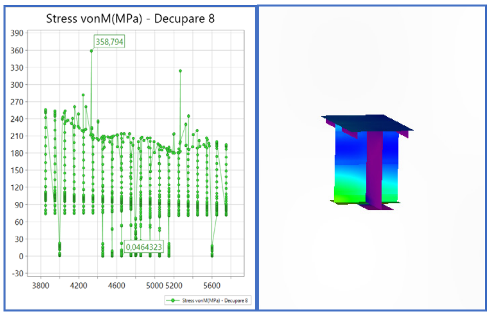

Fig. 3.5. Section 8, von Misses, mesh quad 100.

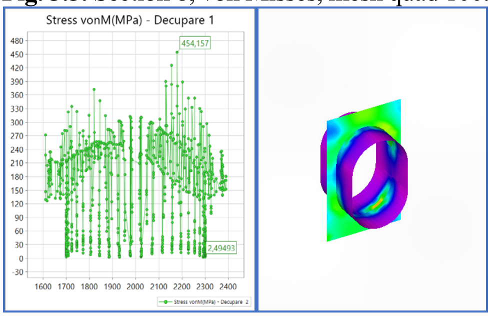

Fig. 3.6. Section 8, von Misses, mesh quad 50.

Table 3.2. Stress [MPa], corrugated longitudinal bulkhead, mesh quad, hogging wave load.

Detail	MESH 200	MESH 100	MESH 50
Detail 1	227.749	289.725	454.157
Detail 2	108.422	150.558	205.195
Detail 3	90.602	115.677	135.190
Detail 4	138.997	155.484	175.248
Detail 5	166.563	144.695	170.42
Detail 6	223.021	178.698	255.211
Detail 7	250.354	221.263	236.391
Detail 8	388.524	358.794	377.297
Detail 9	206.919	246.760	278.649
Detail 10	353.096	295.151	328.846

- model with the corrugated longitudinal bulkhead, sagging wave load

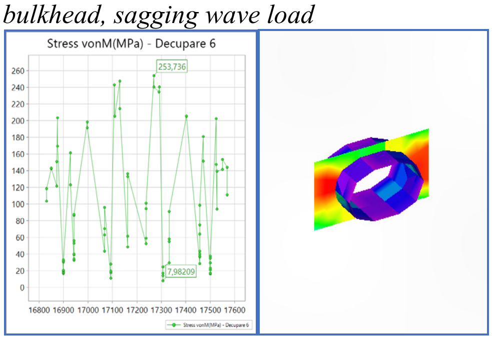

Fig. 3.7. Section 6, von Misses, mesh quad 200.

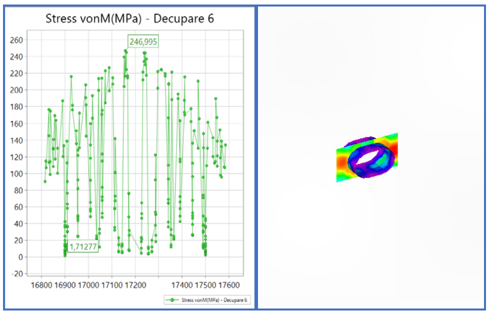

Fig. 3.8. Section 6, von Misses, mesh quad 100.

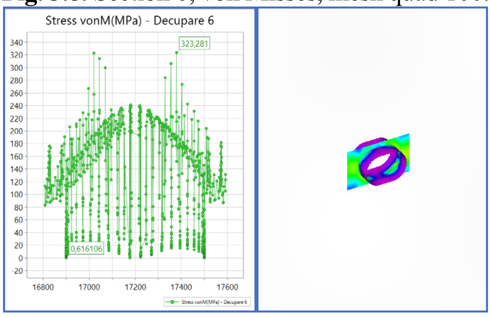

Fig. 3.9. Section 6, von Misses, mesh quad 50.

Table 3.3. Stress [MPa], corrugated longitudinal bulkhead, mesh quad, sagging wave load

Detail	MESH 200	MESH 100	MESH 50
Detail 1	198.367	241.755	361.806
Detail 2	57.013	77.721	96.446
Detail 3	113.276	103.416	127.692
Detail 4	136.77	174.866	156.632
Detail 5	104.765	89.845	86.711
Detail 6	235.736	246.995	323.281
Detail 7	215.656	205.048	229.704
Detail 8	203.171	178.269	181.324
Detail 9	116.278	137.035	154.974
Detail 10	229.153	200.385	237.519

- model with the corrugated longitudinal bulkhead, still water load

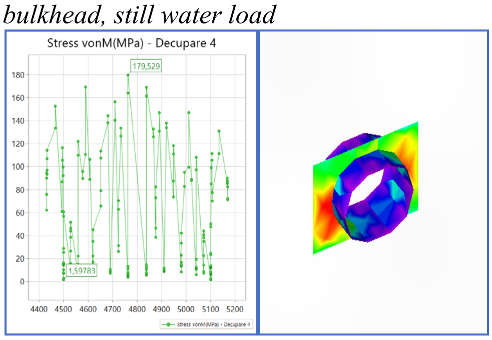

Fig. 3.10. Section 4, von Misses, mesh tri 200.

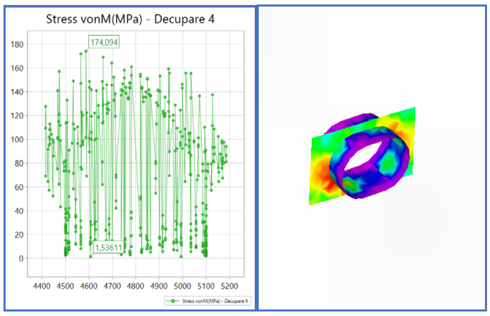

Fig. 3.11. Section 4, von Mises, mesh tri 100.

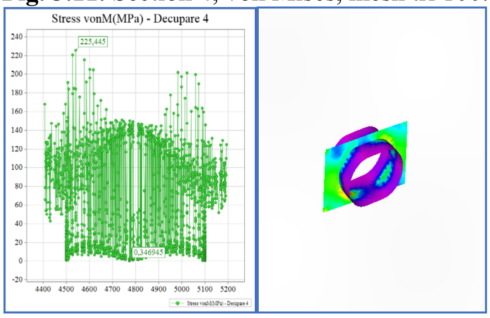

Fig. 3.12. Section 4, von Mises, mesh tri 50.

Table 3.4. Stress [MPa], corrugated longitudinal bulkhead, mesh tri, still water load.

Detail	MESH 200	MESH 100	MESH 50
Detail 1	60.730	83.088	104.718
Detail 2	60.940	83.000	117.167
Detail 3	81.601	103.647	148.358
Detail 4	179.529	174.094	225.445
Detail 5	66.211	67.834	81.185
Detail 6	83.255	86.694	109.624
Detail 7	17.513	17.688	28.261
Detail 8	106.36	103.392	111.346
Detail 9	69.577	74.590	76.864
Detail 10	80.333	59.054	56.806

-Model with the corrugated longitudinal bulkhead, hogging wave load

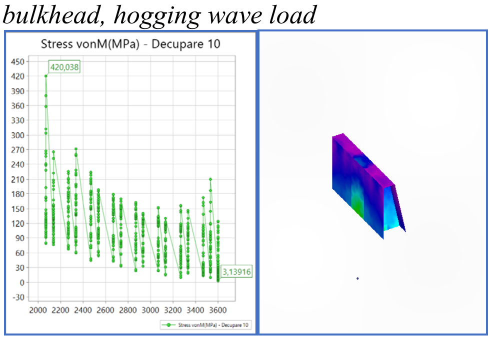

Fig. 3.13. Section 8, von Misses, mesh tri 200.

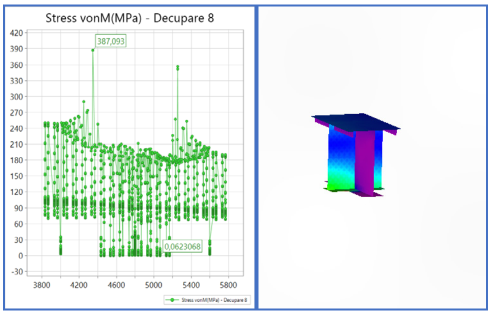

Fig. 3.14. Section 8, von Mises, mesh tri 100.

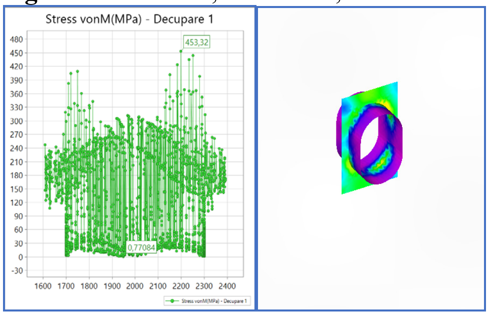

Fig. 3.15. Section 8, von Mises, mesh tri 50.

Table 3.5. Stress [MPa], corrugated longitudinal bulkhead, mesh tri, hogging wave load

Detail	MESH 200	MESH 100	MESH 50
Detail 1	235.339	328.738	453.320
Detail 2	121.086	184.910	265.217
Detail 3	91.753	101.403	140.722
Detail 4	164.229	147.510	175.418
Detail 5	212.713	161.022	172.829
Detail 6	246.254	227.645	236.815
Detail 7	258.952	246.915	257.119
Detail 8	419.525	387.093	403.353
Detail 9	313.685	335.674	352.872
Detail 10	420.038	373.986	367.139

-Model with the corrugated longitudinal bulkhead, sagging wave load

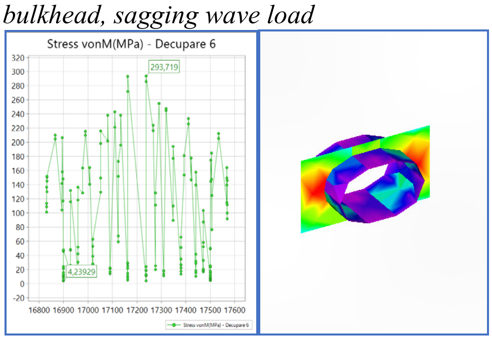

Fig. 3.16. Section 6, von Misses, mesh tri 200.

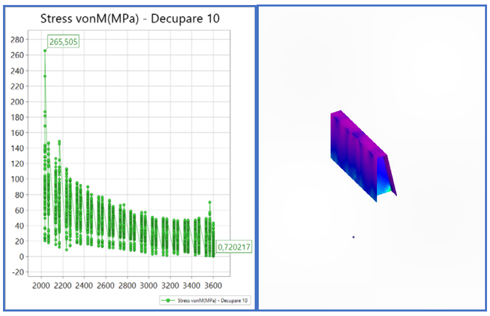

Fig. 3.17. Section 6, von Mises, mesh tri 100.

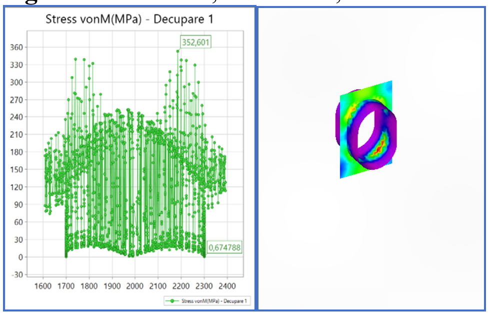

Fig. 3.18. Section 6, von Mises, mesh tri 50.

Table 3.6. Stress [MPa], corrugated longitudinal bulkhead, mesh tri, sagging wave load

Detail	MESH 200	MESH 100	MESH 50
Detail 1	211.633	264.160	352.601
Detail 2	59.730	84.455	123.206
Detail 3	121.044	116.898	147.913
Detail 4	164.473	179.074	246.107
Detail 5	121.651	98.069	107.770
Detail 6	293.719	262.023	309.299
Detail 7	223.277	229.927	252.107
Detail 8	218.395	191.007	191.924
Detail 9	176.984	186.362	196.084
Detail 10	270.270	265.505	266.050

-Model with the flat longitudinal bulkhead, still water load

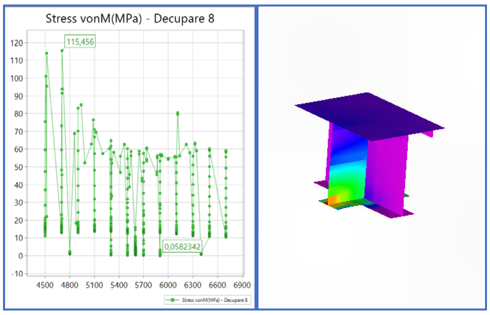

Fig. 3.19. Section 8, von Misses, mesh quad 200.

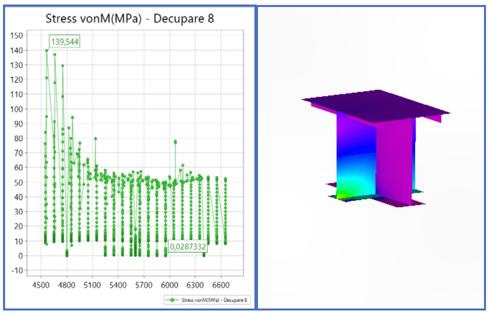

Fig. 3.20. Section 8, von Misses, mesh quad 100.

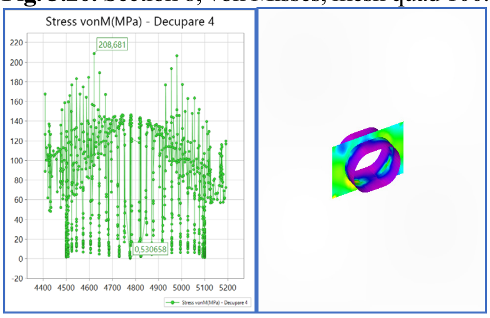

Fig. 3.21. Section 8, von Misses, mesh quad 50.

Table 3.7. Stress [MPa], flat longitudinal bulkhead, mesh quad, still water load.

Detail	MESH 200	MESH 100	MESH 50
Detail 1	81.588	93.769	107.187
Detail 2	61.026	86.245	100.562
Detail 3	79.828	109.953	127.325
Detail 4	144.179	167.787	208.681
Detail 5	54.960	67.764	82.473
Detail 6	92.367	92.570	112.268
Detail 7	15.755	22.847	44.222
Detail 8	115.456	139.544	155.823
Detail 9	45.213	33.854	31.365
Detail 10	54.469	32.224	14.763

- Model with the flat longitudinal bulkhead, hogging wave load

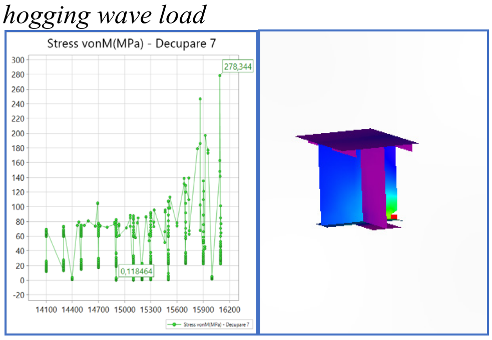

Fig. 3.22. Section 7, von Misses, mesh quad 200.

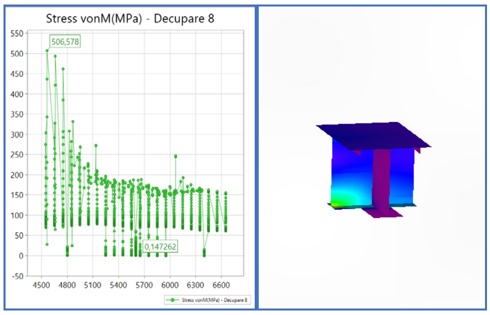

Fig. 3.23. Section 7, von Misses, mesh quad 100.

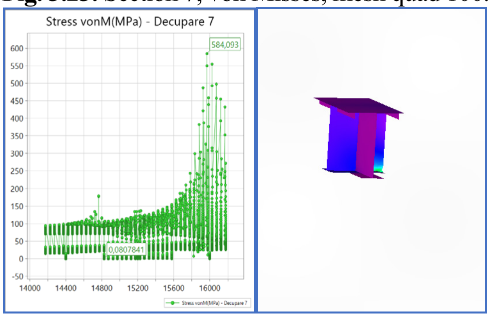

Fig. 3.24. Section 7, von Misses, mesh quad 50.

Table 3.8. Stress [MPa], flat longitudinal bulkhead mesh quad, hogging wave load.

Detail	MESH 200	MESH 100	MESH 50
Detail 1	141.282	225.602	271.051
Detail 2	81.107	137.002	229.742
Detail 3	75.118	108.895	125.474
Detail 4	112.645	146.358	172.150
Detail 5	103.961	147.272	185.440
Detail 6	122.074	175.911	169.765
Detail 7	278.344	479.846	584.093
Detail 8	277.143	506.578	555.741
Detail 9	135.377	164.572	203.071
Detail 10	171.173	188.151	108.891

-Model with the flat longitudinal bulkhead, sagging wave load

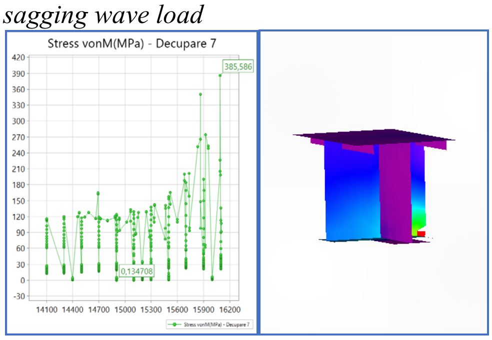

Fig. 3.25. Section 7, von Misses, mesh quad 200.

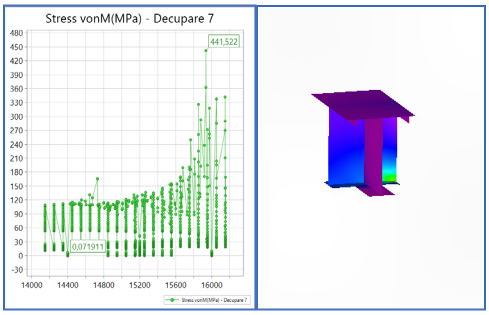

Fig. 3.26. Section 7, von Misses, mesh quad 100.

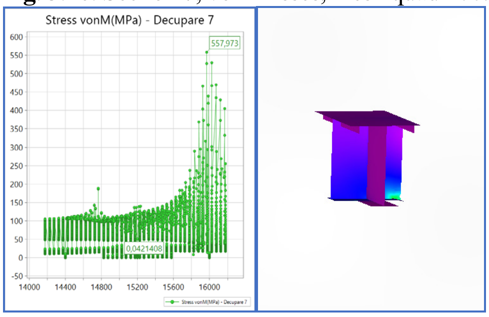

Fig. 3.27. Section 7, von Misses, mesh quad 50.

Table 3.9. Stress [MPa], flat longitudinal bulkhead, mesh quad, sagging wave load.

Detail	MESH 200	MESH 100	MESH 50
Detail 1	120.146	138.163	212.868
Detail 2	53.855	74.864	92.888
Detail 3	116.085	110.490	140.207
Detail 4	135.123	170.282	231.751
Detail 5	97.809	89.991	88.572
Detail 6	107.743	117.263	126.088
Detail 7	385.586	441.522	557.973
Detail 8	211.380	241.734	258.440
Detail 9	119.319	97.252	129.397
Detail 10	185.591	130.434	82.580

-Model with the flat longitudinal bulkhead, still water load

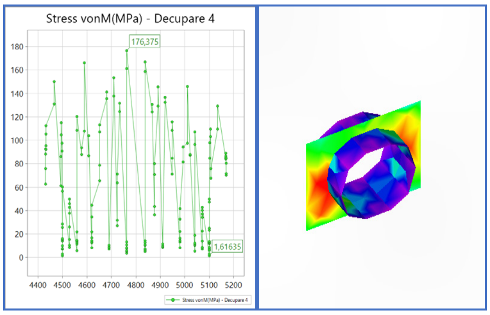

Fig. 3.28. Section 4, von Misses, mesh tri 200.

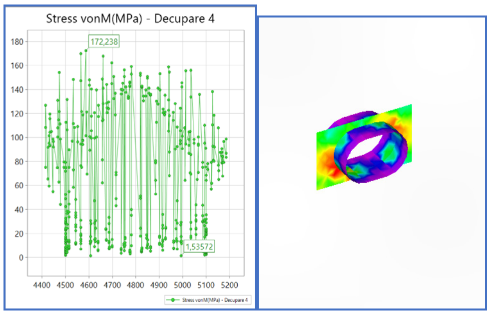

Fig. 3.29. Section 4, von Mises, mesh tri 100.

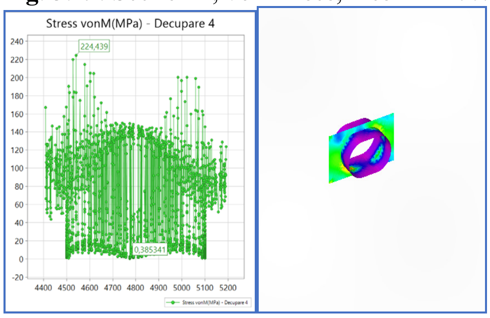

Fig. 3.30. Section 4, von Mises, mesh tri 50.

Table 3.10. Stress [MPa], flat longitudinal bulkhead, mesh triangle, still water load

Detail	MESH 200	MESH 100	MESH 50
Detail 1	81.981	84.765	102.518
Detail 2	60.315	81.048	114.967
Detail 3	79.527	102.010	146.162
Detail 4	176.375	172.238	224.439
Detail 5	63,884	68.790	80.461
Detail 6	108.548	99.622	108.795
Detail 7	15.951	26.155	46.615
Detail 8	130.800	142.355	156.810
Detail 9	45.688	37.393	35.804
Detail 10	50.791	28.995	14.090

-Model with the flat longitudinal bulkhead, hogging wave load

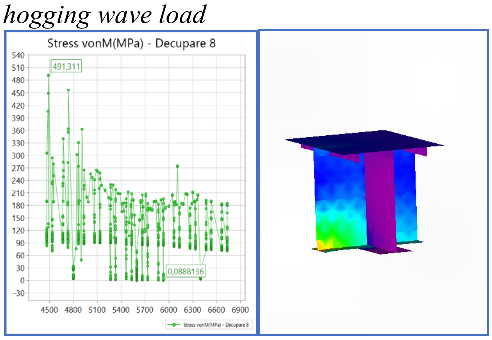

Fig. 3.31. Section 7, von Mises, mesh tri 200.

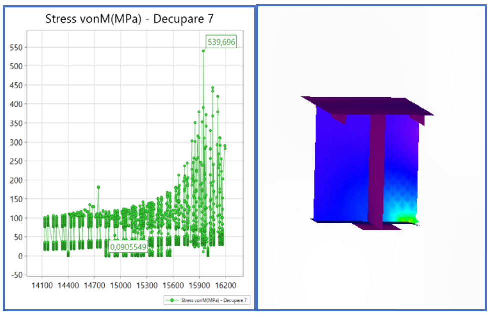

Fig. 3.32. Section 7, von Mises, mesh tri 100.

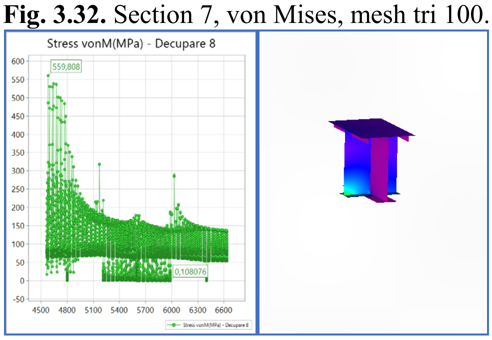

Fig. 3.33. Section 7, von Mises, mesh tri 50.

Table 3.11. Stress [MPa], flat longitudinal bulkhead, mesh tri, hogging wave load

Detail	MESH 200	MESH 100	MESH 50
Detail 1	226.274	236.230	333.441
Detail 2	110.739	168.294	240.999
Detail 3	83.638	102.021	129.623
Detail 4	151.941	146.176	173.647
Detail 5	205.795	164.080	181.607
Detail 6	204.907	184.361	206.759
Detail 7	451.959	539.696	607.136
Detail 8	491.311	516.011	559.808
Detail 9	213.999	188.055	232.414
Detail 10	264.150	171.089	205.192

-Model with the flat longitudinal bulkhead, sagging wave load

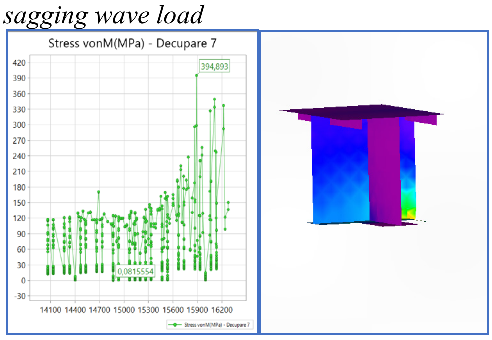

Fig. 3.34. Section 7, von Misses, mesh tri 200.

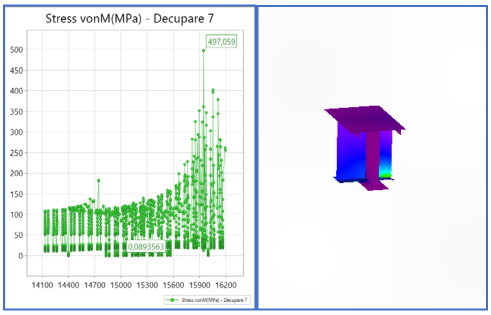

Fig. 3.35. Section 7, von Mises, mesh tri 100.

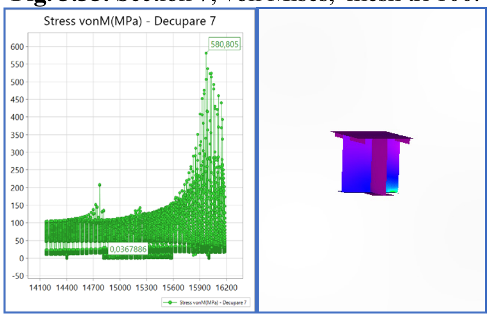

Fig. 3.36. Section 7, von Mises, mesh tri 50.

Table 3.12. Stress [MPa], flat longitudinal bulkhead, mesh tri, sagging wave load

Detail	MESH 200	MESH 100	MESH 50
Detail 1	131.545	151.590	207.178
Detail 2	54.289	74.011	108.442
Detail 3	123.771	128.104	163.339
Detail 4	165.878	173.049	237.989
Detail 5	116.615	98.197	111.519
Detail 6	121.737	127.065	156.145
Detail 7	394.893	497.059	580.805
Detail 8	244.282	245.586	260.398
Detail 9	121.770	118.196	148.157
Detail 10	172.860	119.192	80.085

4. CONCLUSIONS

From the analysis of all the structural cases of the midship section, under quasi-static equivalent wave loads, results that many details are recording stress hot spots.

To reduce the stress hot spots at the oil-tanker midship structure are recommended:
-use of flanges and stiffeners on webs;
- reconsidering the geometric angles of the structural details;
-selection of steel with higher yielding stress.

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