THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620, e-ISSN 2668-3156
DOI: https://doi.org/10.35219/AnnUgalShipBuilding/2025.48.09
2025

THE AMIDSHIP CARGO HOLDS STRUCTURAL RESPONSE OF A 158500 DWT OIL TANKER, ON DESIGN WAVES

Nicoară Maria
"Dunarea de Jos" University of Galati,
Faculty of Naval Architecture, Galati,
47 Domneasca Street, 800008, Romania,
E-mail: nicoaramaria756@gmail.com

Leonard Domnișoru
"Dunarea de Jos" University of Galati,
Faculty of Naval Architecture, Galati,
47 Domneasca Street, 800008, Romania,
E-mail: leonard.domnisoru@ugal.ro

ABSTRACT

A strength analysis of the ships' structural parts under design equivalent waves became mandatory by rule requirements, providing the elements' structural response. The main objective is to evaluate the local combined with the global structural response of a 158500 tdw oil tanker. The strength analysis of partial extended FEM models has been conducted, including the amidships three oil cargo hold tanks. Considering the navigation restrictions, the study analyzes their impact on the amidships structural integrity of the oil tanker.

Keywords: oil tanker ship, partial extended FEM models, navigation restrictions.

1. INTRODUCTION

The structural response assessment is based on partial extended FEM models of the three amidships cargo holds of the 158500 tdw oil tanker "*Dimitrios*" JSEA [2], with reference data in Table 1. The three oil cargo hold FEM models (Fig. 1) utilize the Femap/ NX Nastran modules [4]. The initial oil-tanker design structure is developed according to the DNV-GL [3], [5] rules, and the numerical structural approach by eigen FEM procedures [1] (Figs. 1, 2).

Table 1. The 158500 tdw oil tanker data [2].

Data	Value	Unit
Loa	274.3	m
Lpp	264.3	m
B	48	m
D	23.15	m
d	17	m
Dw	158500	t
v	14.65	kn
No.ND	4030948	-
No.EL	4149940	-

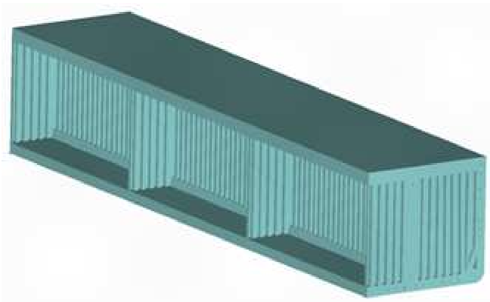

Fig.1 Oil tanker 158500 tdw, three amidships oil cargo holds FEM model

The constraints model the symmetry of the oil cargo holds structure at the center line, and using two master nodes, at aft and fore of the FEM model, linked by rigid elements to the end's transversal bulkheads, the effect of global loads is idealized [1] (Table 2).

Table 2. The 158500 tdw oil tanker constraints [1].

Nodes	Uz	Ux	Uy	Rz	Rx	Ry
CL(sym)	-	X	-	X	-	X
ND_{aft}	X	X	X	X	-	X
ND_{fore}	-	X	X	X	-	X

The partial extended FEM model includes the following load types: gravitational, cargo as nonstructural mass, global bending moment loads applied at the aft and fore master nodes, and quasi-static equivalent hydrostatic wave pressure on the bottom and side shells (Figs. 10-12). The design wave loads are considered under calm water, sagging, and hogging conditions, with reference wave heights according to DNV [3] (Tabel 3) navigation class restrictions: R0, R1, R2, R3, R4, and RE.

Table 3. The design wave height [3].

Navigation class	Wave height	Unit
R0 (100%)	10.54	m
R1 (90%)	9.48	m
R2 (80%)	8.43	m
R3 (70%)	6.32	m
R4 (60%)	5.27	m
RE (50%)	4.21	m
SW	0	m

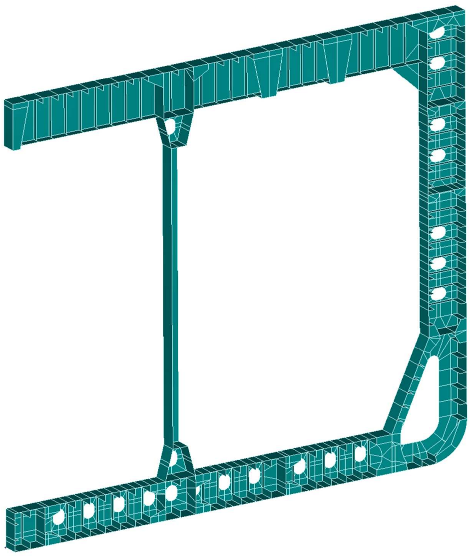

Fig.2 Oil tanker 158500 tdw, amidships section reference CAD model.

2. INITIAL DESIGN STRUCTURAL RESPONSE OF THE OIL TANKER

The initial 158500 tdw oil tanker [2] design structure is developed with Poseidon program conforming to the DNV-GL [3] local and global strength rules. Tables 4 and 5 present the maximum equivalent von Mises stresses and vertical deflections, by FEM analysis of the initial design structure.

Table 4. Initial oil-tanker design, maximum stresses

Navigation class	Max. stress Sagg.	Max. stress Hogg.	Unit
R0 (100%)	459	399	N/mm^2
R1 (90%)	416	357	N/mm^2
R2 (80%)	388	316	N/mm^2
R3 (70%)	350	244	N/mm^2
R4 (60%)	330	219	N/mm^2
RE (50%)	309	194	N/mm^2
SW	237	256	N/mm^2

Table 5. Initial oil-tanker design, maximum vertical deflections

Navigation class	Max.deflec. Sagg.	Max.deflec. Hogg.	Unit
R0 (100%)	247.36	214.19	mm
R1 (90%)	224.09	191.89	mm
R2 (80%)	200.92	169.68	mm
R3 (70%)	154.63	125.18	mm
R4 (60%)	131.53	103.83	mm
RE (50%)	108.33	82.778	mm
SW	114.85	115.13	mm

Following the structural assessment of the oil tanker initial structure, several areas were identified where the stress levels exceeded the allowable limit of the material (Figs. 5-9). For the initial design structure, the material is AH32 steel. The most critical case occurs under sagging conditions for navigation class R0 (no navigation restrictions) (Figs. 3, 4).

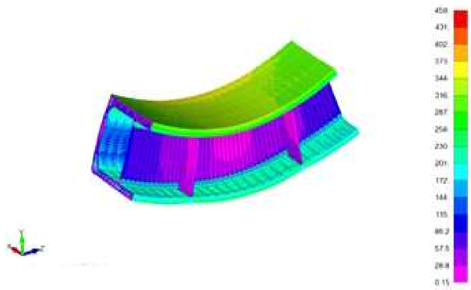

Fig.3 Oil tanker 158500 tdw initial design structure, R0 sagging, stress

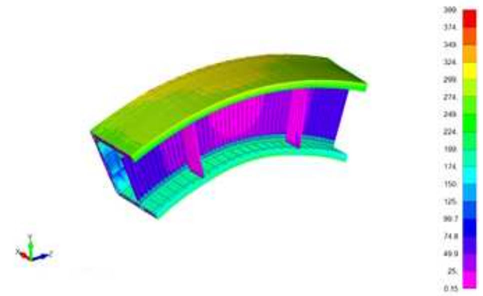

Fig.4 Oil tanker 158500 tdw initial design structure, R0 hogging, stress

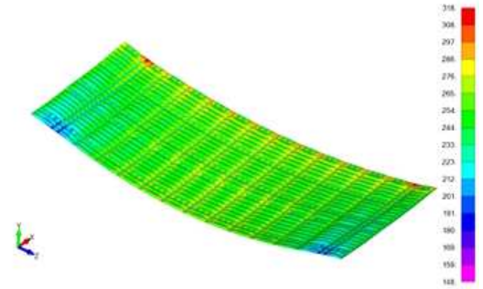

Fig.5 Oil tanker 158500 tdw initial design structure, R0 sagging, stress, bottom shell

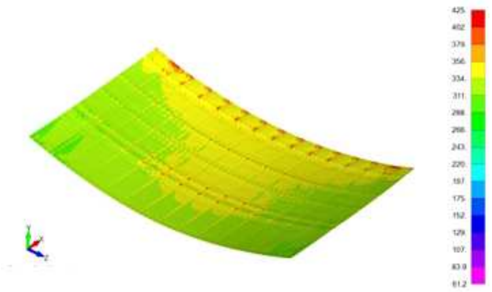

Fig.6 Oil tanker 158500 tdw initial design structure, R0 sagging, stress, deck shell

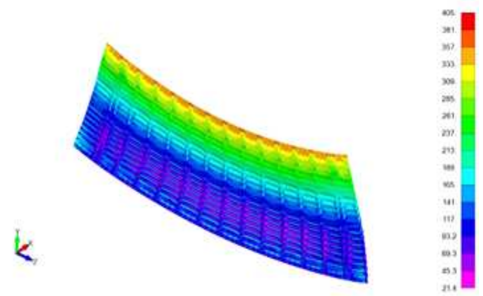

Fig.7 Oil tanker 158500 tdw initial design structure, R0 sagging, stress, double side shell

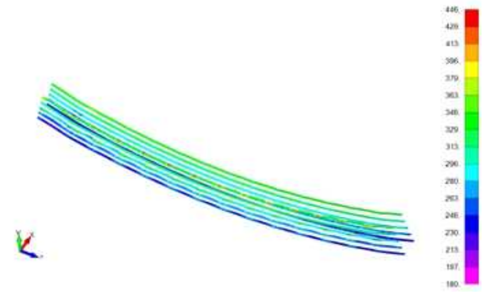

Fig.8 Oil tanker 158500 tdw initial design structure, R0 sagging, stress, double side long

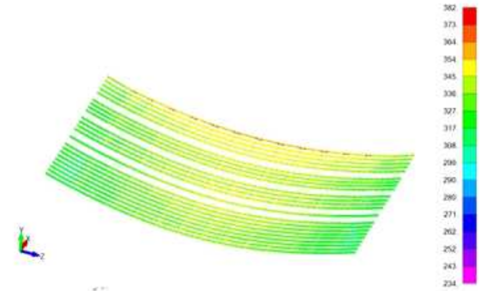

Fig.9 Oil tanker 158500 tdw initial design structure, R0 sagging, stress, deck longitudinals

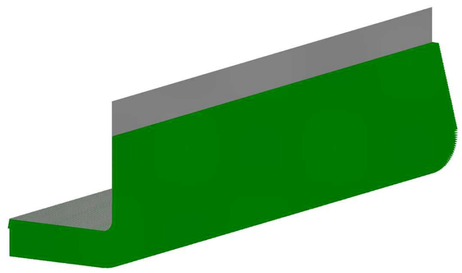

Fig.10 Oil tanker 158500 tdw, calm water, Hydrostatic wave pressure

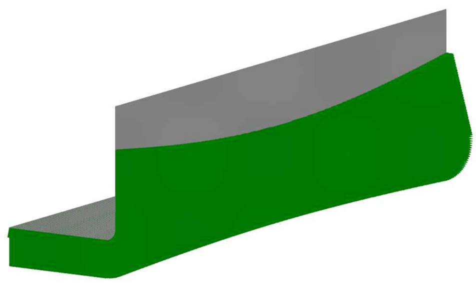

Fig.11 Oil tanker 158500 tdw, R0 sagging, design wave pressure

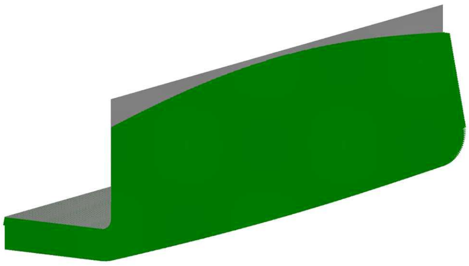

Fig.12 Oil tanker 158500 tdw, R0 hogging, design wave pressure

3. ENHANCED DESIGN STRUCTURAL RESPONSE OF THE OIL TANKER

The enhanced structural design has increased the thickness of the shell elements and switched the material grade from AH32 steel to AH36 and AH40. A uniform thickness increase is applied to all the structural elements to improve rigidity. Additionally, in areas subjected to maximum stress, localized reinforcement is implemented. Table 6 presents the elements' thicknesses changes for the enhanced design structure.

Table 6. Oil tanker main elements thickness, initial, and enhanced design structure

Structural element	Initial thickness [mm]	Enhanced thickness [mm]	Steel grade	Reinforcement type
Side shell	15	17	AH40	Localized
Double side shell	13	17	AH40	Localized
Deck stiffeners	16	18	AH40	Uniform
Deck shell	14	20	AH40	Uniform
Double bottom long.	13	15	AH36	Uniform
Double side longitudinals	14	19	AH40	Uniform
Deck longitudinals	12	16	AH40	Uniform
Flange of deck long.	35	48	AH40	Uniform
Flange of deck stiff.	16	21	AH40	Uniform
Flange of deck stiff.	16	27	AH40	Localized
Upper stool sheell	16	17	AH40	Uniform

Tables 7, 8 present the enhanced design structural response of the oil tanker, concerning the maximum equivalent von Mises stresses and vertical deflections. A noticeable attenuation in the distribution of stresses and deflections across the oil cargo holds FEM model is presented in the Figs. 13, 14.

The FEM analysis of the enhanced oil tanker design reveals that the structural response now complies with the material's admissible stress (400 N/mm^2) and deflection (225 mm) criteria (Figs. 15-21, structural details).

Table 7. Enhanced oil tanker design, maximum stresses

Navigation class	Max. stress Sagg.	Max. stress Hogg.	Unit
R0 (100%)	377	399	N/mm^2
R1 (90%)	347	312	N/mm^2
R2 (80%)	317	286	N/mm^2
R3 (70%)	255	236	N/mm^2
R4 (60%)	231	212	N/mm^2
RE (50%)	218	193	N/mm^2
SW	217	221	N/mm^2

Table 8. Enhanced oil tanker design, maximum vertical deflections

Navigation class	Max.deflec. Sagg.	Max.deflec. Hogg.	Unit
R0 (100%)	223.49	189.78	mm
R1 (90%)	202.7	169.82	mm
R2 (80%)	181.99	149.95	mm
R3 (70%)	140.6	110.14	mm
R4 (60%)	119.97	91.207	mm
RE (50%)	99.264	72.483	mm
SW	103	99.597	mm

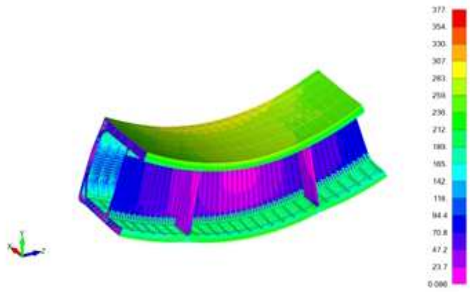

Fig.13 Oil tanker 158500 tdw enhanced design structure, R0 sagging, stress

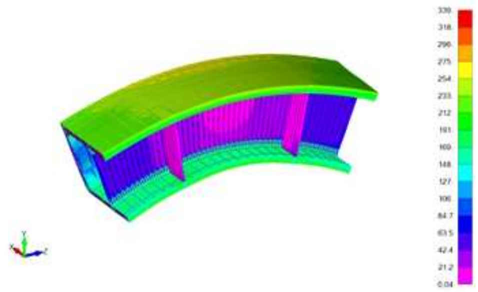

Fig.14 Oil tanker 158500 tdw enhanced design structure, R0 hogging, stress

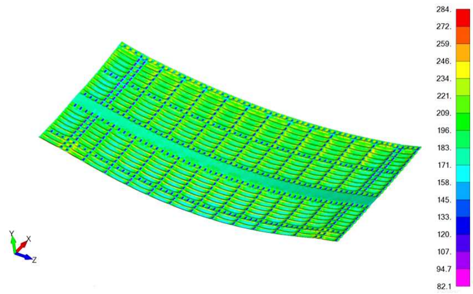

Fig.15 Oil tanker 158500 tdw enhanced design structure, R0 sagging, stress, double bottom shell

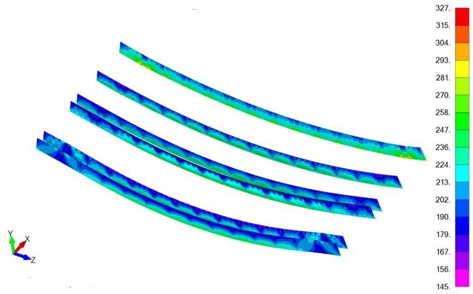

Fig.16 Oil tanker 158500 tdw enhanced design structure, R0 sagging, stress, bottom frames

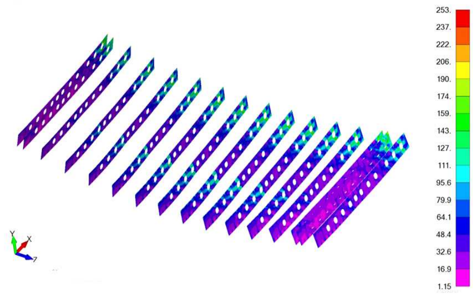

Fig.17 Oil tanker 158500 tdw enhanced design structure, R0 sagging, stress, bottom frames

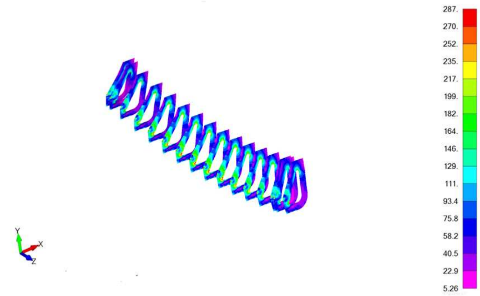

Fig.18 Oil tanker 158500 tdw enhanced design structure, R0 sagging, stress, bilge frames

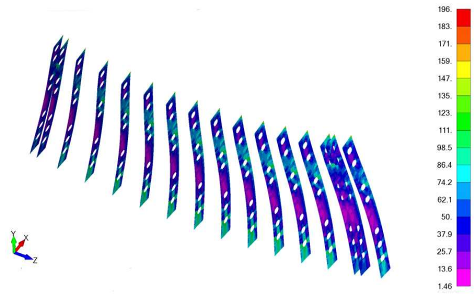

Fig.19 Oil tanker 158500 tdw enhanced design structure, R0 sagging, stress, side frames

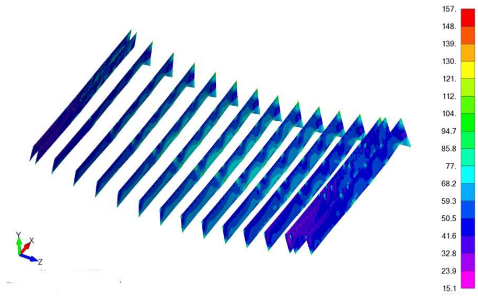

Fig.20 Oil tanker 158500 tdw enhanced design structure, R0 sagging, stress, deck frames

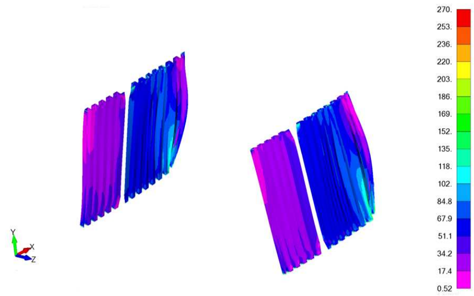

Fig.21 Oil tanker 158500 tdw enhanced design structure, R0 sagging, stress, bulkheads

4. CONCLUSIONS

Figs. 22-25 present the von Mises stress and vertical deflection values comparing the initial and enhanced design structural responses for the oil-tanker amidships cargo-holds FEM models, for each navigation class.

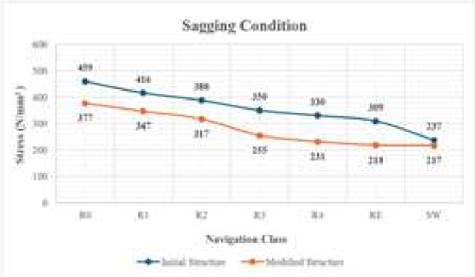

Fig.22 Oil tanker 158500 tdw, stress, sagging

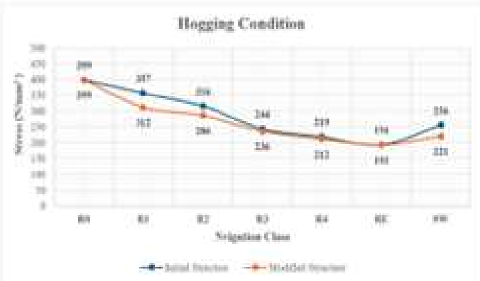

Fig.23 Oil tanker 158500 tdw, stress, hogging

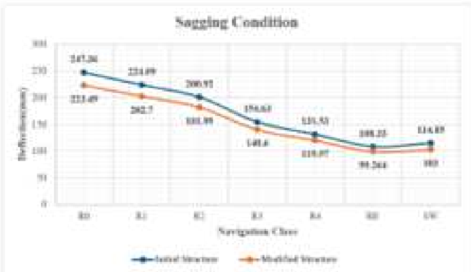

Fig.24 Oil tanker, vertical deflection, sagging

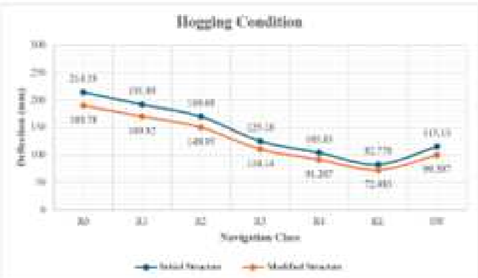

Fig.23 Oil tanker, vertical deflection, hogging

The analysis of stress and deflection states in this study is conducted based on 3D modeling of the amidships cargo hold compartments. The structural model is evaluated under calm water, sagging, and hogging design wave conditions for the DNV [3] navigation classes, resulting in various design wave heights (Table 3).

Following the assessment of the initial design structure, maximum stresses were recorded that exceeded the yielding stress limit of the material AH32, especially extreme for navigation class R0 under sagging conditions. This has a notable impact on the structural integrity of the longitudinal elements within the cargo hold compartments.

To reduce the hot-spot stresses, an enhanced design structure is considered, which consists of increasing the plate thickness, either uniformly across the structural components or locally, combined with the use of high-strength steel material AH40.

In conclusion, the enhanced design structure of the 158500 tdw oil tanker has improved rigidity in the amidships cargo-holds compartments in comparison to the initial design, satisfying the yielding stress limit and vertical deflection criteria under calm water and head design waves.

Acknowledgments

This study is developed at the "Naval Architecture Research Centre", "Dunarea de Jos" University of Galati.

REFERENCES

[1]. **Domnisoru, L.**, "*Finite Element Method in Ships' Construction*", Technical Publishing House, Bucharest, 2001.

[2]. **JSEA**, "*Shipbuilding and marine engineering in Japan Catalog*", Japan Ship Exporters Association, Tokyo, 2022.

[3]. **DNVGL,** *"Rules for Classification of Ships"*, Det Norske Veritas, Novik, 2025.

[4]. **FEMAP**, "*Femap/NX Nastran User Guide. Academic License*", Siemens PLM Soft., 2021-2025.

[5]. **Poseidon**, "*DNVGL Poseidon Users' Manual*", Det Norske Veritas – Germanischer Lloyd, Hamburg, 2023-2025.

Paper received on October 14th, 2025.

