THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620
2017

STRUCTURAL 3D AND 1D MODELLING OF A BARGE HULL FOR STRENGTH ASSESSMENT ON HEAD WAVES CONDITION

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ABSTRACT

For the design of ship structures, the hull global strength in the case of head waves is one of the first analysis required by shipbuilding rules. For the strength analysis the 1D and 3D-FEM models can be used, according to the design level information. In both cases the head equivalent design waves (EDW) are used linked to a non-linear iterative algorithm for the wave-ship system balance. The balanced algorithm is directly implemented into the FEM program by user procedures for the 3D models. For the 1D models a program code has been developed. As numerical study we consider a prismatic closed section floating structure, pointing out the influence of the wave height on the stresses at the main panels and the vertical bending moments and shear forces.

Keywords: global strength, equivalent design wave, head wave condition.

1. INTRODUCTION

The design of the ship structures involves several criteria to be checked as the yielding stress limit, maximum bending moments and shear forces, buckling, fatigue, etc. In any design stage the global strength of the ship hull has to be assessed, using 1D models or 3D-FEM models, function to the existing data for the structure, according to the shipbuilding classification societies rules [2]. In the case of the 3D-FEM models the local strength can also be assessed, with the accuracy function to the mesh size of the model.

For the head wave global strength assessment by 1D models an iterative non-linear algorithm has been developed, with two convergence criteria on floating and longitudinal trim conditions for the balance between the ship and the equivalent quasi-static design waves (EDW) [7],[12],[14]. The theoretical details of the balance algorithm are presented in reference [4], with the own developed code P_ACASV.

The global and local strength assessment by 3D-FEM models in head EDW waves requires also an iterative procedure for the balance computation between the ship hull and the wave. For this case we have developed user procedures written in the commands files programming language of the FEM program [11], having as objective functions (to be minimized) the vertical reaction forces in two nodes, aft and fore, with simple support boundary condition. The user subroutines, press.geo, sin_shell, sin_shell2, are presented in detail in reference [11]. The use directly of the user subroutines for the balance algorithm is practical only for the case of head waves. In the case of oblique EDW waves the third equilibrium condition on roll angle slows up the iterative procedure on 3D-FEM models, so that the ship-wave equilibrium is obtained only by 1D models with specific codes [5]. The numerical study is developed for the same off-shore barge from reference [6], both 1D and 3D models, using codes and specific procedures for head wave EDW case [4].

2. THE TEST BARGE DATA

The test barge main data are:

-the barge characteristics (Table 1) [5],[6];

-the 3D-FEM model extended over the whole barge length (Figs.1.a,b) [6];

-the mass distribution is considered uniform and external shape is prismatic with rectangular transversal section over the whole barge length [6].

Table 1. The test barge characteristics [5],[6]

L [m]	97	ν	0.3
B [m]	33	ρ_m [t/m^3]	7.7
H [m]	4	N_{EL} (1D)	40
T [m]	2	Type (1D)	Beam
ρ [t/m^3]	1.025	δx [m] (1D)	2.425
g [m/s^2]	9.81	N_{EL} (3D)	239361
Δ [t]	6562.05	Type (3D)	Shell
x_G [m]	48.5	Size(3D)[m]	0.1÷0.3
y_G [m]	0	h_w [m]	0,2,4,7,10
z_{G1} [m]	4.3	EDW length	λ=L
E [N/m^2]	2.1e+11	EDW angle	head

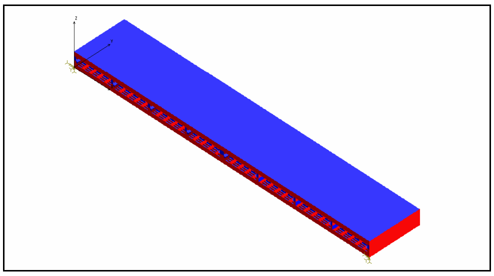


Fig.1.a 3D-FEM model [6]

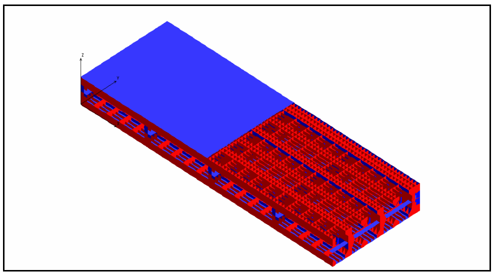


Fig.1.b 3D-FEM model detail [6]

The 3D-FEM model boundary conditions are: symmetry in the centre line (one sided model), aft and fore nodes (in base plane) vertical support (objective functions).

3. THE 3D-FEM HEAD EDW WAVE STRENGTH ANALYSIS

In the case 3D-FEM model for the test barge, using the iterative procedure and the user subroutines from reference [4], the next results are obtained:

-Figs.2.1-9 the water pressure on 3D model;

-Figs.3.1-9 the von Mises equivalent stress on the whole barge structure;

-Figs.4.1-9 deck normal stress distribution;

-Figs.5.1-9 bottom normal stress distribution;

-Figs.6.1-9 side tangential stress distribution;

-Figs.7.1-2 maximum deck normal stress;

-Figs.8.1-2 maximum deck von Mises stress;

-Figs.9.1-2 maximum bottom normal stress;

-Figs.10.1-2 maximum bott. von Mises stress;

-Figs.11.1-2 maximum side tangential stress;

-Figs.12.1-2 maximum side von Mises stress.

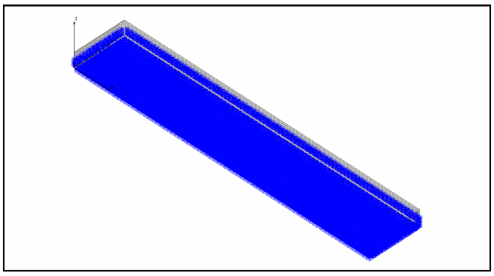


Fig.2.1 3D, water pressure, h_w=0, still water.

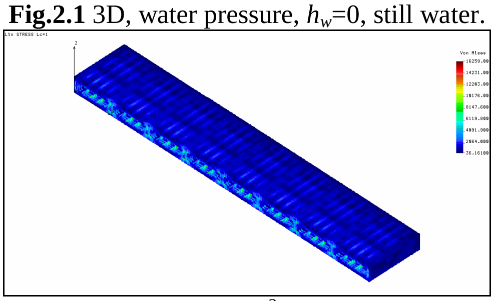


Fig.3.1 3D, σ_{vM} [N/mm^2], h_w=0, still water.

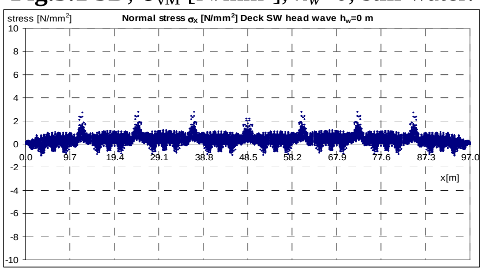


Fig.4.1 3D, deck σ_x [N/mm^2], h_w=0, sw.

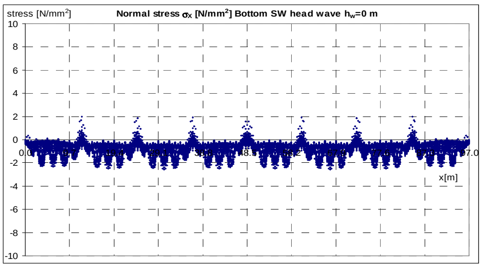


Fig.5.1 3D, bottom σ_x [N/mm^2], h_w=0, sw.

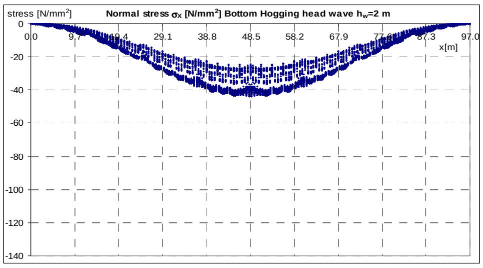


Fig.5.2 3D, bottom σ_x [N/mm^2], h_w=2, hogg.

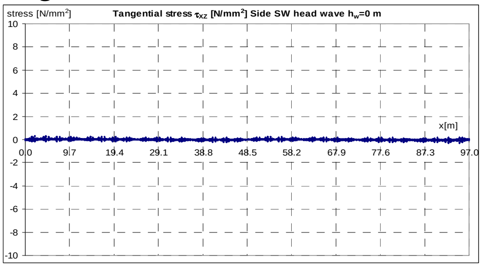


Fig.6.1 3D, side τ_{xz} [N/mm^2], h_w=0, sw.

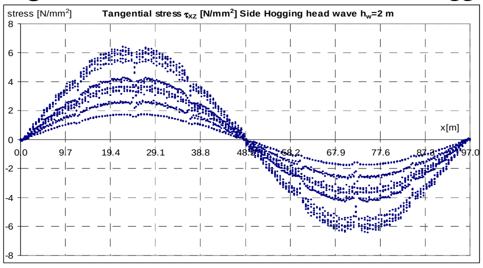


Fig.6.2 3D, side τ_{xz} [N/mm^2], h_w=2, hogg.

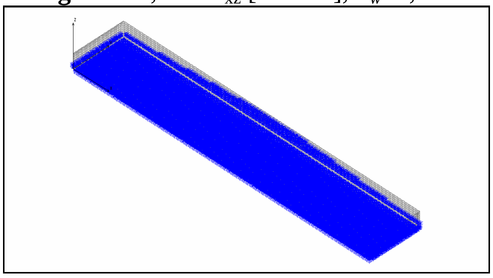


Fig.2.2 3D, water pressure, h_w=2, hogging.

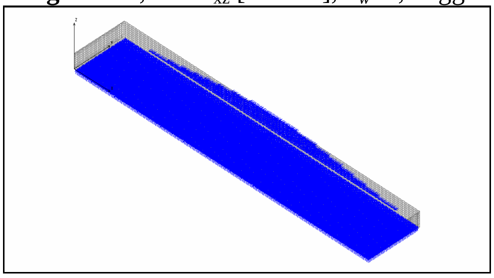


Fig.2.3 3D, water pressure, h_w=4, hogging.

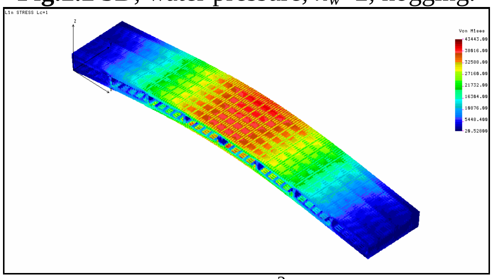


Fig.3.2 3D, σ_{vM} [N/mm^2], h_w=2, hogging.

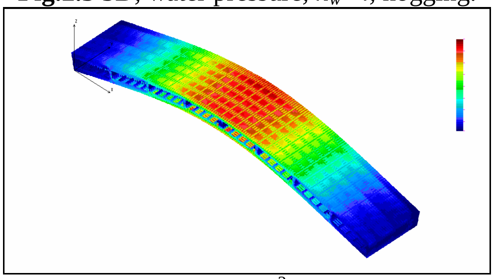


Fig.3.3 3D, σ_{vM} [N/mm^2], h_w=4, hogging.

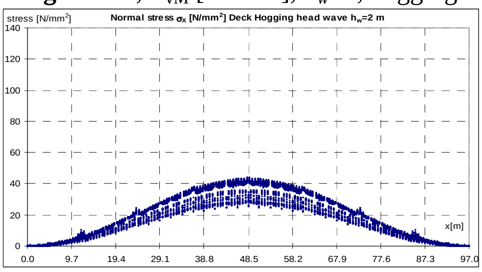


Fig.4.2 3D, deck σ_x [N/mm^2], h_w=2, hogg.

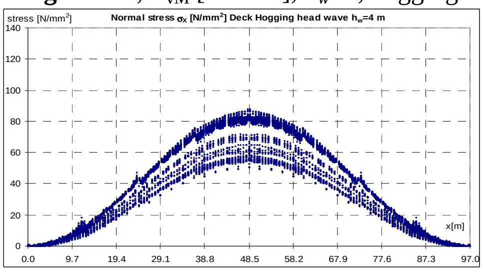


Fig.4.3 3D, deck σ_x [N/mm^2], h_w=4, hogg.

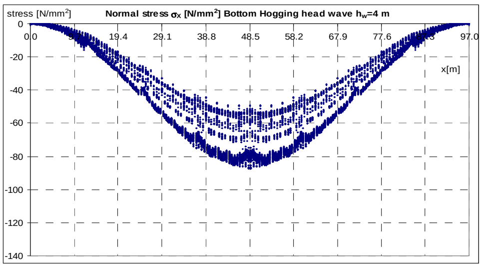


Fig.5.3 3D, bottom σ_x [N/mm^2], h_w=4, hogg.

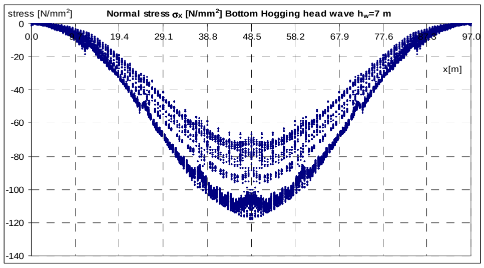


Fig.5.4 3D, bottom σ_x [N/mm^2], h_w=7, hogg.

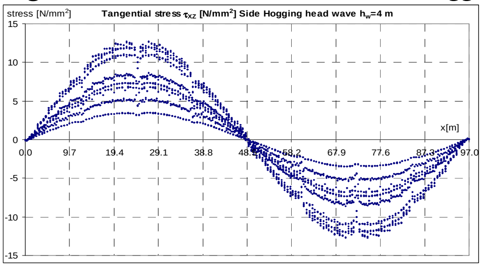


Fig.6.3 3D, side τ_{xz} [N/mm^2], h_w=4, hogg.

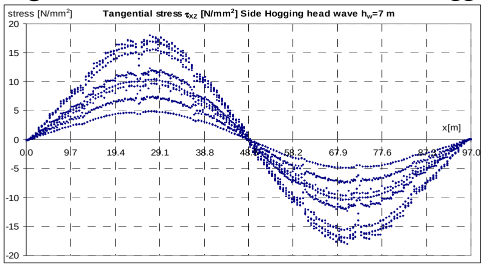


Fig.6.4 3D, side τ_{xz} [N/mm^2], h_w=7, hogg.

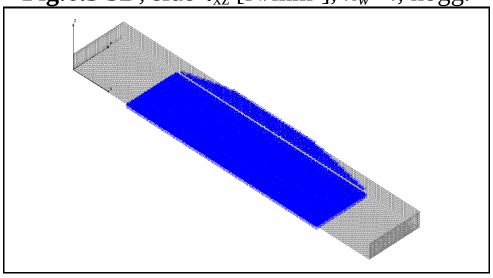


Fig.2.4 3D, water pressure, h_w=7, hogging.

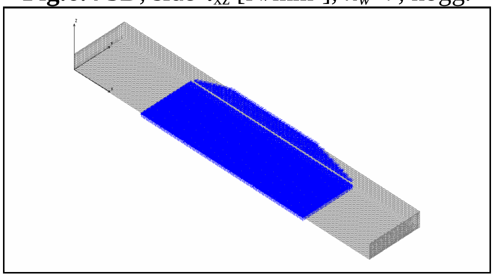


Fig.2.5 3D, water pressure, h_w=10, hogging.

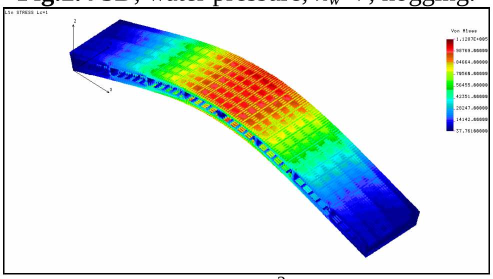


Fig.3.4 3D, σ_{vM} [N/mm^2], h_w=7, hogging.

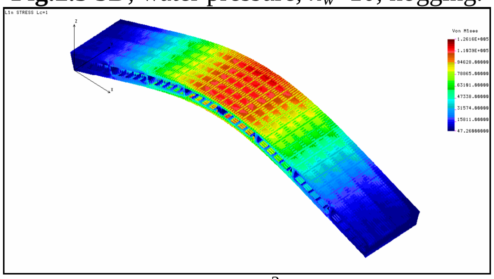


Fig.3.5 3D, σ_{vM} [N/mm^2], h_w=10, hogging.

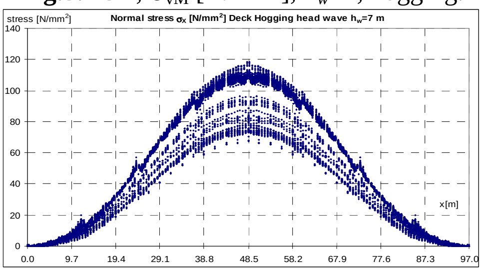


Fig.4.4 3D, deck σ_x [N/mm^2], h_w=7, hogg.

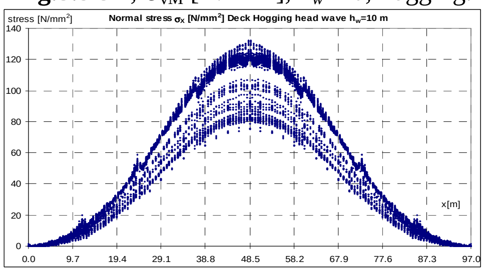


Fig.4.5 3D, deck σ_x [N/mm^2], h_w=10, hogg.

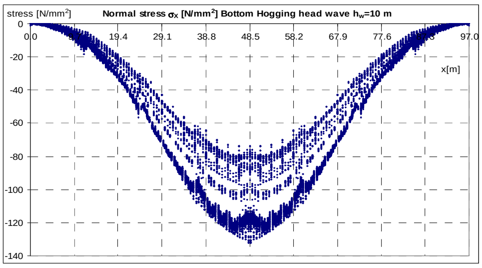


Fig.5.5 3D, bottom σ_x [N/mm^2],h_w=10, hogg.

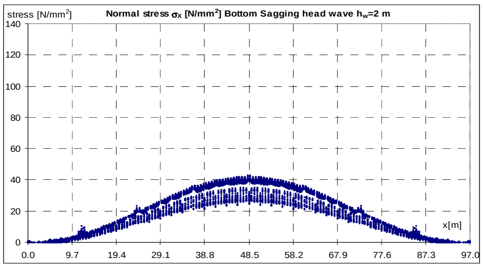


Fig.5.6 3D, bottom σ_x [N/mm^2], h_w=2, sagg.

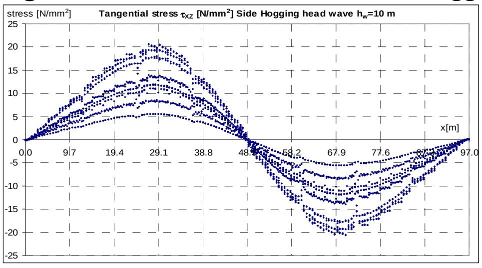


Fig.6.5 3D, side τ_{xz} [N/mm^2], h_w=10, hogg.

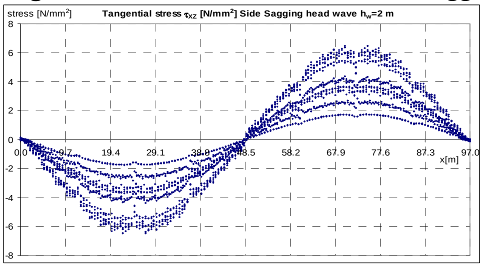


Fig.6.6 3D, side τ_{xz} [N/mm^2], h_w=2, sagg.

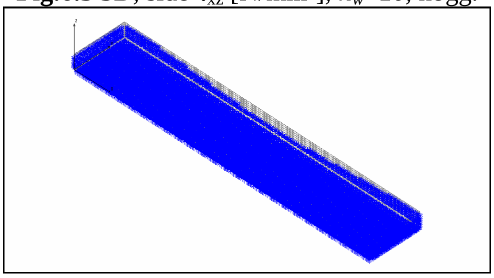


Fig.2.6 3D, water pressure, h_w=2, sagging.

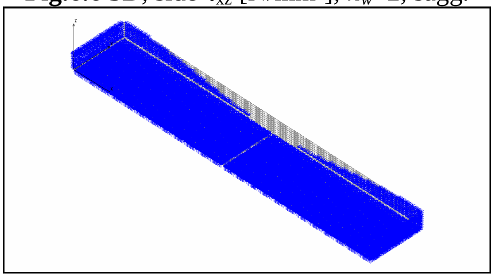


Fig.2.7 3D, water pressure, h_w=4, sagging.

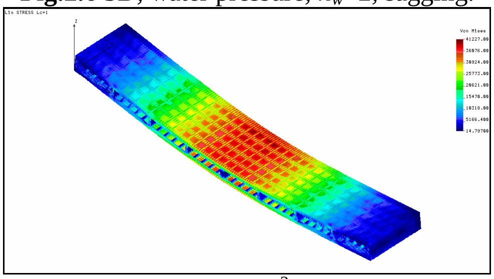
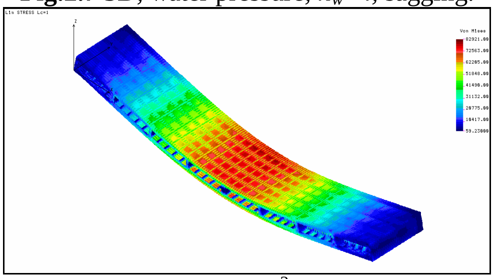


Fig.3.6 3D, σ_{vM} [N/mm^2], h_w=2, sagging.



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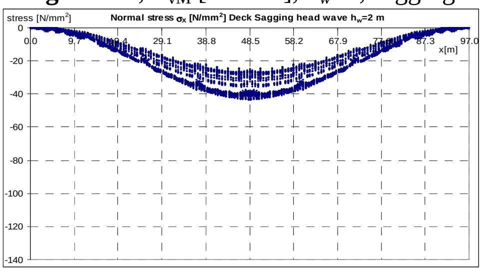

Fig.4.6 3D, deck σ_x [N/mm^2], h_w=2, sagg.

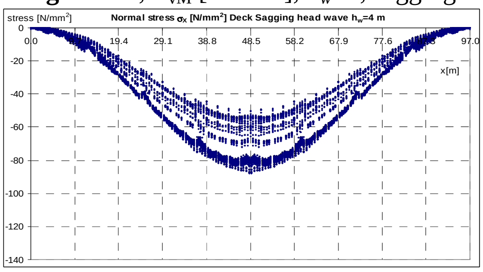

Fig.4.7 3D, deck σ_x [N/mm^2], h_w=4, sagg.

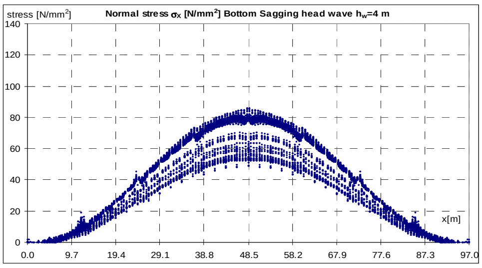

Fig.5.7 3D, bottom σ_x [N/mm^2], h_w=4, sagg.

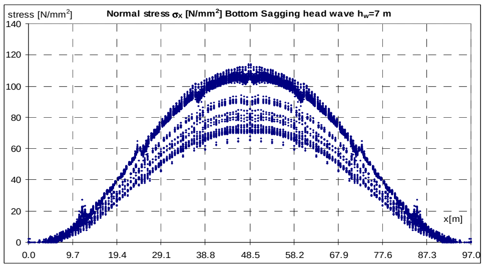

Fig.5.8 3D, bottom σ_x [N/mm^2], h_w=7, sagg.

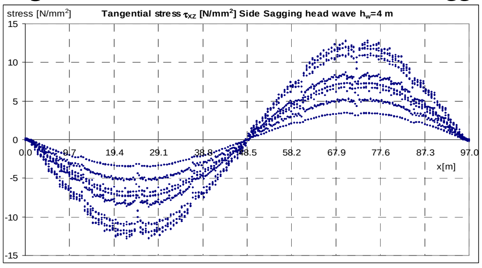

Fig.6.7 3D, side τ_{xz} [N/mm^2], h_w=4, sagg.

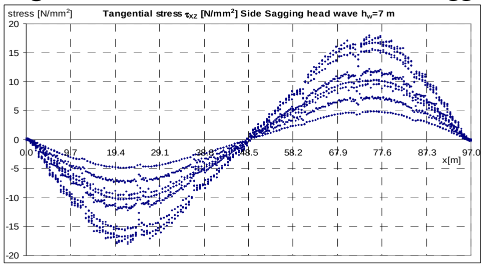

Fig.6.8 3D, side τ_{xz} [N/mm^2], h_w=7, sagg.

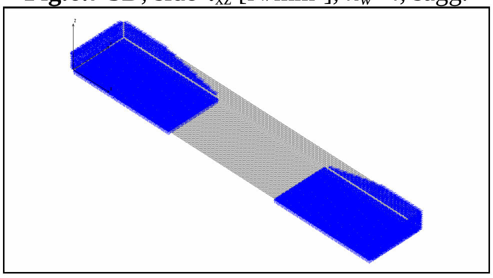

Fig.2.8 3D, water pressure, h_w=7, sagging.

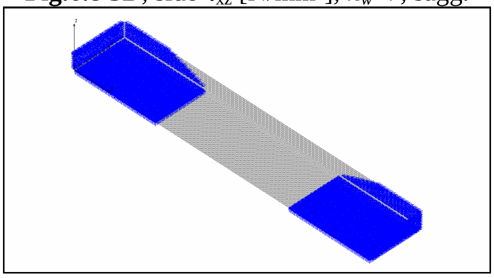

Fig.2.9 3D, water pressure, h_w=10, sagging.

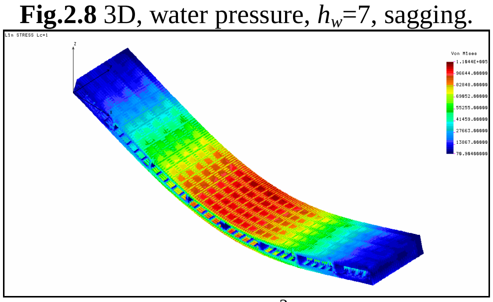

Fig.3.8 3D, σ_{vM} [N/mm^2], h_w=7, sagging.

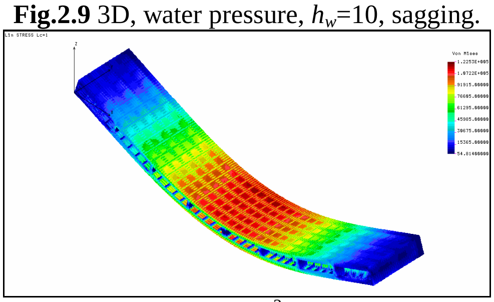

Fig.3.9 3D, σ_{vM} [N/mm^2], h_w=10, sagging.

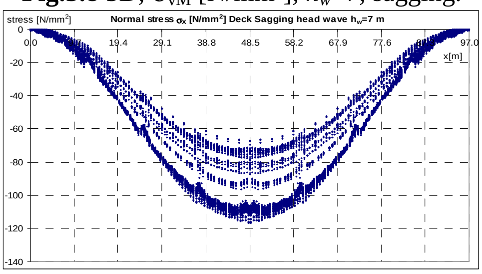

Fig.4.8 3D, deck σ_x [N/mm^2], h_w=7, sagg.

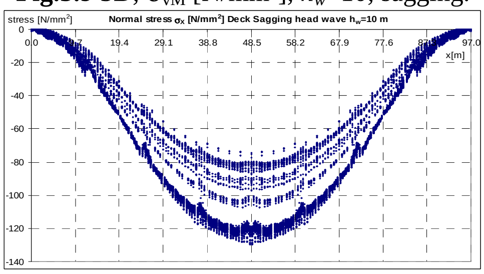

Fig.4.9 3D, deck σ_x [N/mm^2], h_w=10, sagg.

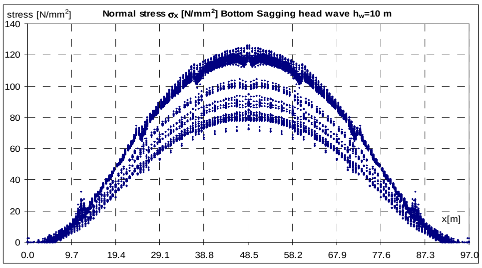

Fig.5.9 3D, bottom σ_x [N/mm^2], h_w=10, sagg.

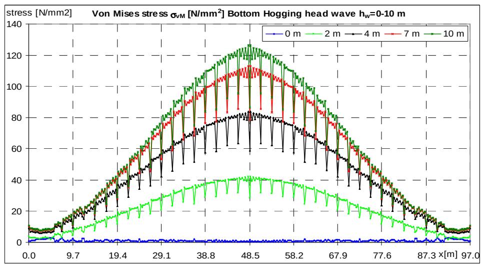

Fig.10.1 3D,bottom σ_{vM} [N/mm^2],max, hogg.

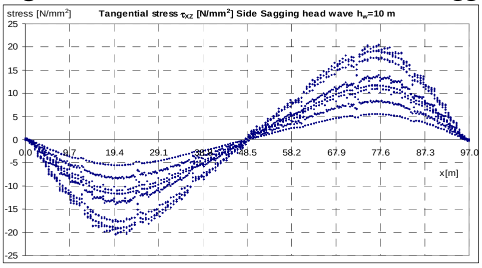

Fig.6.9 3D, side τ_{xz} [N/mm^2], h_w=10, sagg.

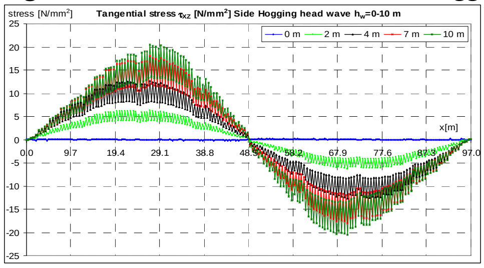

Fig.11.1 3D, side τ_{xz} [N/mm^2], max, hogg.

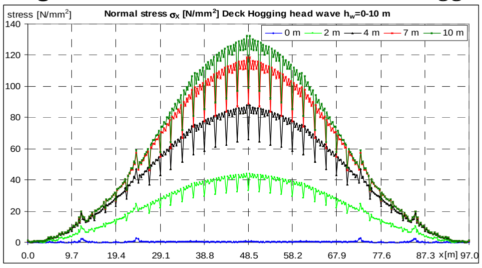

Fig.7.1 3D, deck σ_x [N/mm^2], max, hogg.

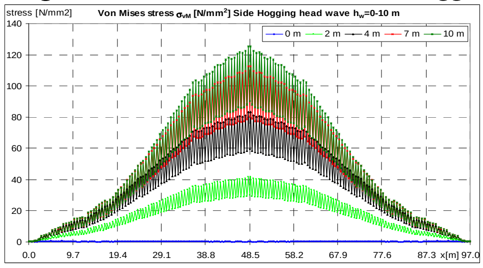

Fig.12.1 3D, side σ_{vM} [N/mm^2],max, hogg.

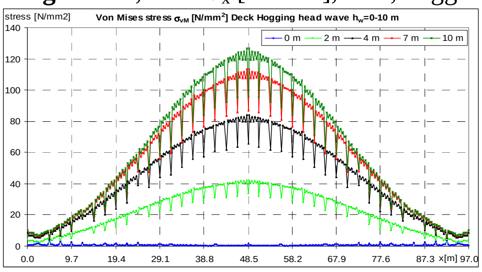

Fig.8.1 3D, deck σ_{vM} [N/mm^2], max, hogg.

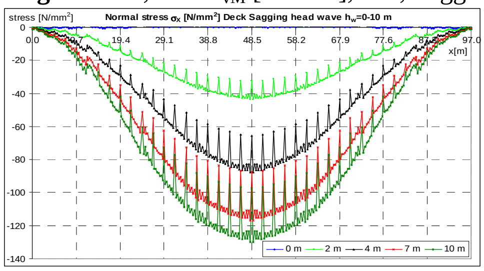

Fig.7.2 3D, deck σ_x [N/mm^2], max, sagg.

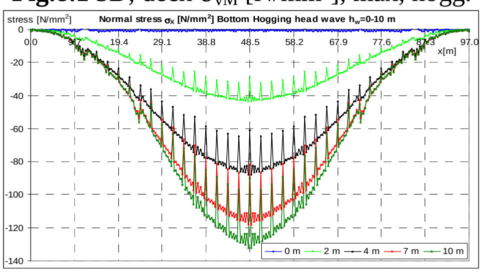

Fig.9.1 3D, bottom σ_x [N/mm^2], max, hogg.

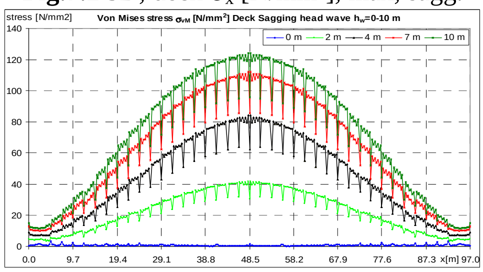

Fig.8.2 3D, deck σ_{vM} [N/mm^2], max, sagg.

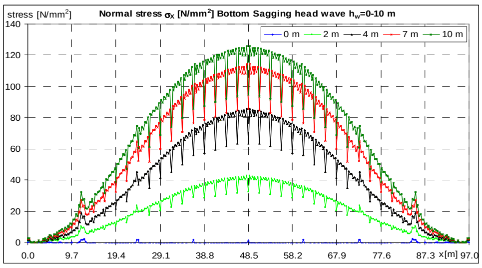

Fig.9.2 3D, bottom σ_x [N/mm^2], max, sagg.

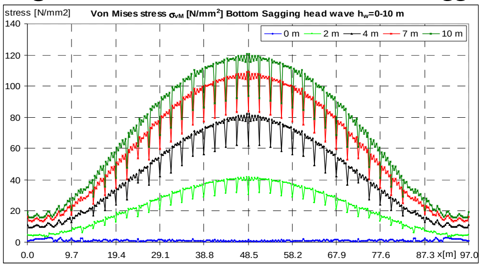

Fig.10.2 3D,bottom σ_{vM} [N/mm^2],max, sagg.

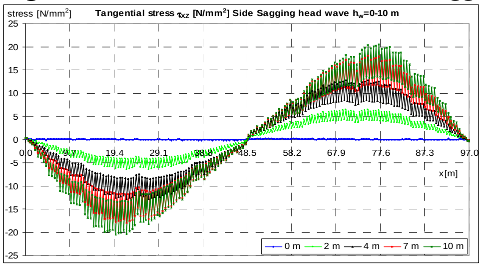

Fig.11.2 3D, side τ_{xz} [N/mm^2], max, sagg.

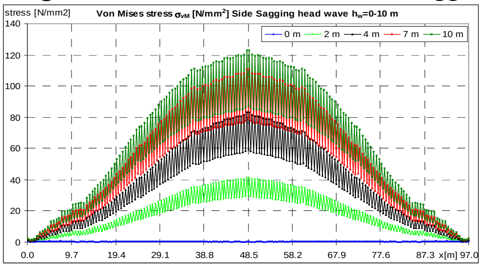

Fig.12.2 3D, side σ_{vM} [N/mm^2],max, sagg.

4. THE 1D MODEL HEAD EDW WAVE STRENGTH ANALYSIS

In the case 1D model for the test barge, using the iterative procedure from reference [4], the next results are obtained:

-Figs.13.1-2 the vertical bending moments, h_w=0-10m (step 0.5-1 m), EDW wave in hogging and sagging conditions;

-Figs.14.1-2 the vertical shear forces, h_w=0-10m (step 0.5-1 m), EDW wave in hogging and sagging conditions.

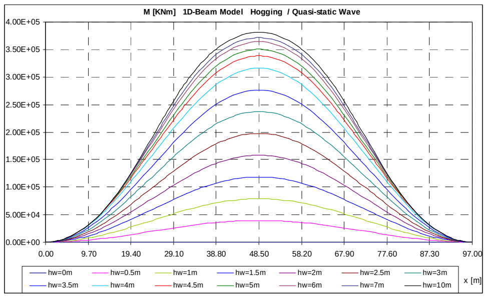

Fig.13.1 1D, VWBM [kNm], head, hogging.

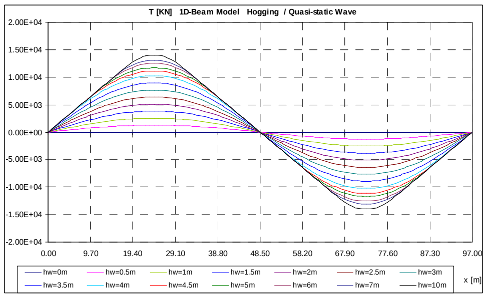

Fig.14.1 1D, VWSF [kN], head, hogging.

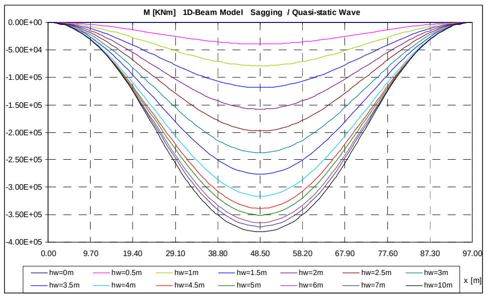

Fig.13.2 1D, VWBM [kNm], head, sagging.

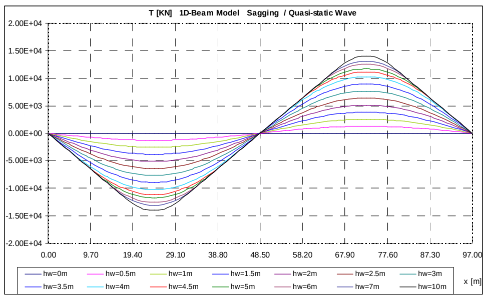

Fig.14.2 1D, VWSF [kN], head, sagging.

5. CONCLUSIONS

Table 2.a Maximum and admissible stresses by 3D-FEM model

No	h_w [m]	σ_x[N/mm^2] deck-max	σ_{vM}[N/mm^2] deck-max	σ_x[N/mm^2] bottom-max	σ_{vM}[N/mm^2] bottom-max
adm [2]		175	175	175	175
1	0-sw	2.81	3.13	-2.50	3.16
2	2-hog	44.07	42.24	-43.48	40.75
3	4-hog	87.86	84.18	-86.69	81.39
4	7-hog	118.40	113.40	-116.80	109.70
5	10-hog	132.20	126.70	-130.50	122.50
6	2-sag	-43.67	41.79	42.30	39.95
7	4-sag	-87,85	84.09	85.08	80.23
8	7-sag	-117.00	112.00	113.00	106.60
9	10-sag	-129.80	124.30	125.00	117.90

Table 2.b Maximum and admissible stresses by 3D-FEM model

No	h_w [m]	τ_{xz}[N/mm^2] side-max	σ_{vM}[N/mm^2] side-max
adm [2]		110	175
1	0-sw	±0.30	0.85
2	2-hog	±6.42	47.78
3	4-hog	±12.75	83.31
4	7-hog	±18.08	112.40
5	10-hog	±20.60	125.60
6	2-sag	±6.46	41.39
7	4-sag	±12.82	83.26
8	7-sag	±17.99	110.70
9	10-sag	±20.55	122.80

Table 3 Maximum and admissible bending moments and shear forces by 1D model

No	h_w [m]	M_{max}[kNm]	T_{max}[kN]
adm [2]		±4.64E+5	±1.28E+4
1	0-sw	0	0
2	2-hog	1.58E+5	±5.12E+3
3	4-hog	3.16E+5	±1.02E+4
4	7-hog	3.72E+5	±1.31E+4
5	10-hog	3.82E+5	±1.40E+4
6	2-sag	-1.58E+5	±5.12E+3
7	4-sag	-3.16E+5	±1.02E+4
8	7-sag	-3.72E+5	±1.31E+4
9	10-sag	-3.82E+5	±1.40E+4

From Figs.2-12, by 3D-FEM model, head EDW wave, the maximum stress values at the deck, bottom and side panels are selected in Tables 2.a.b, with the admissible values from rules [2].

From Figs.13-14, by 1D model, head EDW wave, the maximum bending moments and shear forces are selected in Table 3, with the admissible values from rules [2].

As the EDW waves exceed the base plane (z=0) and the deck plane (z=H), the relations between the structural response and the wave height become to be non-linear (Figs.2-14, Tables 2-3).

In the case of 3D-FEM model (Tables 2.a,b) the yielding stress limit criteria [2] is satisfied in all panels.

In the case of 1D model (Table 3) the global strength limit criteria [2] are satisfied on bending moment and for shear force the limit of the head equivalent design wave height EDW is h_w=6.69 m.

Acknowledgements

In this study the theoretical model and program code were developed in the frame of Research Centre of the Naval Architecture Faculty from "Dunarea de Jos" University of Galati.

The numerical analyses have been accomplished for the research project BVR C640/2014.

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Paper received on December 8th, 2017

