THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620, e-ISSN 2668-3156
2020

GLOBAL STRENGTH EVALUATION WITH DESIGN OBLIQUE WAVES CRITERIA FOR A 100000 TDW TANKER

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ABSTRACT

Among the preliminary ship’s evaluation steps, the global strength of the ship’s hull by design oblique wave’s criteria is required from the classification society’s construction rules. A 100000 tdw tanker is selected for evaluation, with two loading cases. The analysis is applied on a ship hull beam model, using own program software P_QSW, with three parameters non-linear equilibrium procedure. Significant oblique design waves are considered, corresponding to maritime operation cases. The global strength results at preliminary design steps are assessed by rules admissible values, so that the ship’s global strength design restrictions are obtained.

Keywords: global strength, design oblique waves, 100000 tdw tanker.

1. INTRODUCTION

In this study the preliminary global strength evaluation of a 100000 tdw tanker [3], [4] is analysed, in the case of design oblique waves. Table 1 presents the main ship’s characteristics, with two loading cases, full cargo and ballast. Fig.1 presents the ship’s offset lines [4].

Table 1. The 100000 tdw tank data [3], [4]

L_{OA}[m]	246.0	Loading:	TK1cargo	TK2ballast
L_{WL}[m]	240.0	Δ[t]	126457.1	81763.3
B[m]	42.0	LCG[m]	126.46	126.73
H[m]	21.3	T_{aft}[m]	15.0	10.5
ρ[t/m^3]	1.025	T_m[m]	15.0	10.0
g[m/s^2]	9.81	T_{fore}[m]	15.0	9.5
stations	41	μ [deg]	0 – 85 (step 5)	
points	1230	h_w[m]	0 – 12 (step 1)	

The global strength analyses for design oblique waves loads [5] are done with own P_QSW program [2], having implemented for wave-ship equilibrium computation a three parameters non-linear procedure (details [2]).

Table 2 presents the admissible sectional efforts from DNV-GL [1] rules for the global strength criteria formulation. This parametric study reveals the tanker global strength limits.

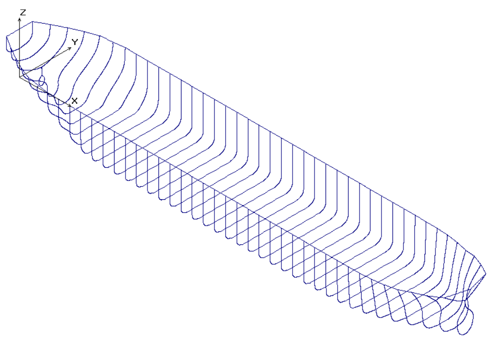

Fig.1.The offset-lines of 100000 tdw tanker [4]

Table 2. Admissible values, DNV-GL [1], vertical, horizontal and torsional efforts

VBM_{adm} [kNm] (bending)	6.31 10^6
VSF_{adm} [kN] (shearing)	9.43 10^4
HBM_{adm} [kNm] (bending)	2.25 10^6
HSF_{adm} [kN] (shearing)	2.93 10^4
MT_{adm} [kNm] (torsional)	7.70 10^5

2. GLOBAL STRENGTH OF 100000 TDW TANKER IN FULL CARGO

For the 100000 tdw tanker full cargo loading case, the following results on global strength evaluation are obtained:

-Tables 3.a,b present the equilibrium parameters wave-ship (sinkage, pitch and roll) for relevant design oblique waves, full cargo;

-Figs. 2.a,b present the design oblique wave, for h_w=10 m, μ= 45 and 75 deg, full cargo case;

-Figs.3.a-e present the efforts diagrams, for oblique wave μ=60 deg, hogging, full cargo;

-Tables 4.a,b present the maximum efforts, for relevant design oblique waves, full cargo case;

-Figs. 4.a-f present the global strength & free board criteria evaluation, full cargo case.

Table 3.a Eq. parameters, hogging, full cargo

Tanker 100000	μ[deg] / h_w[m]	0	45	60	75
T_m [m]	0	15.000	15.000	15.000	15.000
	5	14.680	14.756	14.895	15.359
	10	14.266	14.427	14.721	15.699
	12	14.082	14.277	14.632	15.833
θ [rad]	0	0.0000	0.0000	0.0000	0.0000
	5	0.0011	0.0009	0.0005	-0.0007
	10	0.0046	0.0040	0.0027	-0.0010
	12	0.0067	0.0058	0.0041	-0.0011
φ [rad]	0	0.0000	0.0000	0.0000	0.0000
	5	0.0000	0.0008	0.0010	0.0003
	10	0.0000	0.0029	0.0037	0.0005
	12	0.0000	0.0042	0.0053	0.0006

Table 3.b Eq. parameters, sagging, full cargo

Tanker 100000	μ[deg] / h_w[m]	0	45	60	75
T_m [m]	0	15.000	15.000	15.000	15.000
	5	15.243	15.180	15.064	14.627
	10	15.442	15.327	15.108	14.227
	12	15.511	15.380	15.122	14.060
θ [rad]	0	0.0000	0.0000	0.0000	0.0000
	5	0.0001	0.0001	0.0002	0.0009
	10	-0.0002	0.0000	0.0003	0.0022
	12	-0.0004	-0.0001	0.0003	0.0029
φ [rad]	0	0.0000	0.0000	0.0000	0.0000
	5	0.0000	-0.0001	-0.0003	-0.0011
	10	0.0000	-0.0003	-0.0005	-0.0035
	12	0.0000	-0.0004	-0.0007	-0.0049

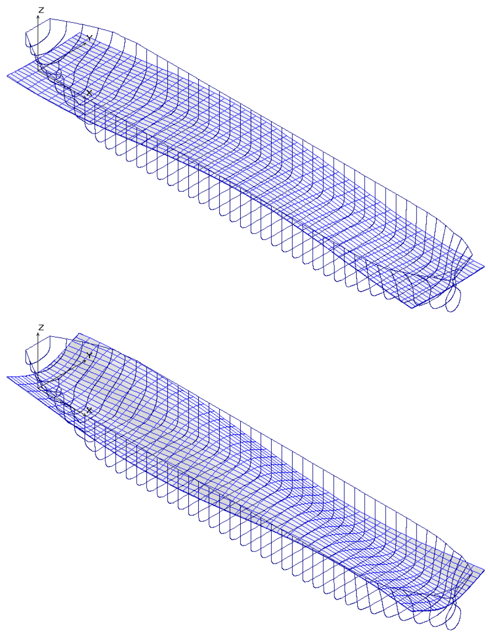

Fig.2.a Hogging design oblique wave, h_w=10 m, μ= 45 and 75 deg, 100000 tdw tanker, full cargo loading case

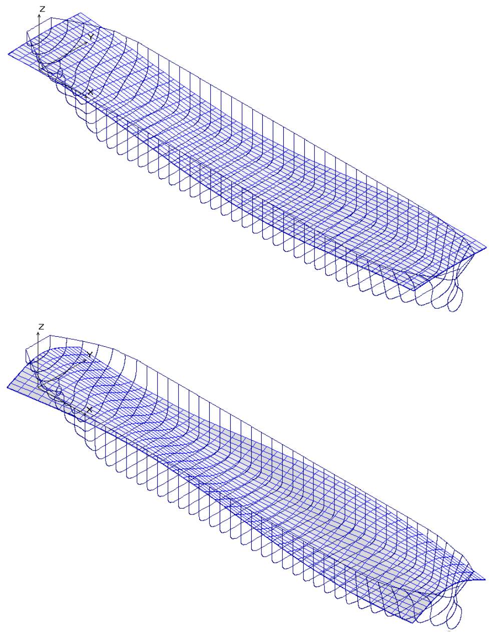

Fig.2.b Sagging design oblique wave, h_w=10 m, μ=45 and 75 deg, 100000 tdw tanker, full cargo loading case

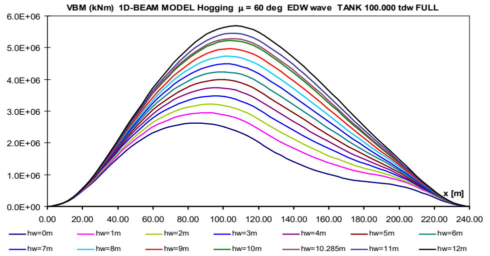

Fig.3.a *VBM* [kNm], μ=60deg, hogg, full cargo

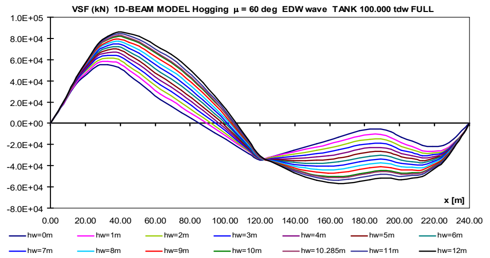

Fig.3.b *VSF* [kN], μ=60 deg, hogg, full cargo

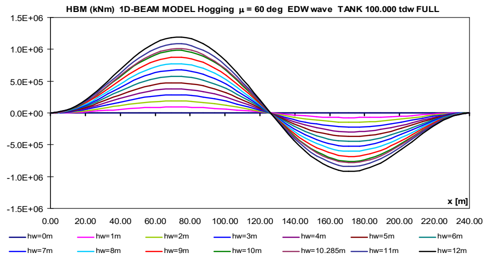

Fig.3.c *HBM* [kNm], μ=60deg, hogg, full cargo

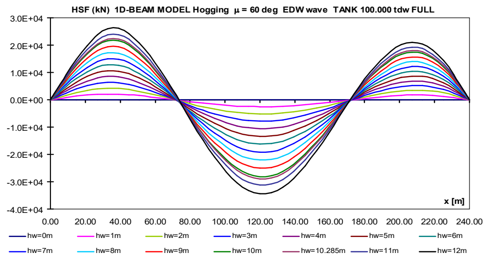

Fig.3.d *HSF* [kN], μ=60 deg, hogg, full cargo

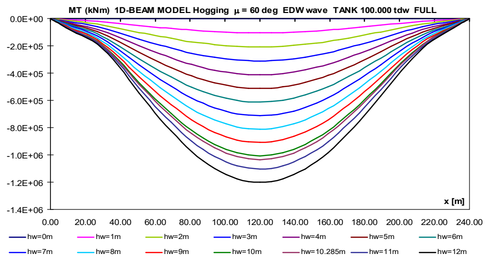

Fig.3.e *MT* [kNm], μ=60deg, hogg, full cargo

Table 4.a Max. efforts, hogging, full cargo

Tanker 100000	μ[deg] / h_w[m]	0	45	60	75
VBM [kNm]	0	2.6 10^{6}	2.6 10^{6}	2.6 10^{6}	2.6 10^{6}
	5	4.7 10^{6}	4.4 10^{6}	4.0 10^{6}	2.4 10^{6}
	10	6.6 10^{6}	6.1 10^{6}	5.2 10^{6}	2.1 10^{6}
	12	7.3 10^{6}	6.8 10^{6}	5.7 10^{6}	2.0 10^{6}
VSF [kN]	0	5.5 10^{4}	5.5 10^{4}	5.5 10^{4}	5.5 10^{4}
	5	7.6 10^{4}	7.4 10^{4}	7.0 10^{4}	5.6 10^{4}
	10	9.5 10^{4}	9.0 10^{4}	8.2 10^{4}	5.6 10^{4}
	12	1.0 10^{5}	9.7 10^{4}	8.6 10^{4}	5.6 10^{4}
HBM [kNm]	0	0.0	0.0	0.0	0.0
	5	0.0	3.1 10^{5}	4.7 10^{5}	5.0 10^{5}
	10	0.0	6.4 10^{5}	9.8 10^{5}	1.0 10^{6}
	12	0.0	7.7 10^{5}	1.2 10^{6}	1.2 10^{6}
HSF [kN]	0	0.0	0.0	0.0	0.0
	5	0.0	8.8 10^{3}	1.3 10^{4}	1.3 10^{4}
	10	0.0	1.9 10^{4}	2.8 10^{4}	2.6 10^{4}
	12	0.0	2.3 10^{4}	3.4 10^{4}	3.1 10^{4}
MT [kNm]	0	0.0	0.0	0.0	0.0
	5	0.0	3.2 10^{5}	5.1 10^{5}	6.6 10^{5}
	10	0.0	6.3 10^{5}	1.0 10^{6}	1.3 10^{6}
	12	0.0	7.4 10^{5}	1.3 10^{6}	1.6 10^{6}

Table 4.b Max. efforts, sagging, full cargo

Tanker 100000	μ[deg] / h_w[m]	0	45	60	75
VBM [kNm]	0	2.6 10^{6}	2.6 10^{6}	2.6 10^{6}	2.6 10^{6}
	5	4.7 10^{6}	1.4 10^{6}	1.6 10^{6}	3.1 10^{6}
	10	6.6 10^{6}	2.5 10^{6}	1.5 10^{6}	3.5 10^{6}
	12	7.3 10^{6}	3.4 10^{6}	2.1 10^{6}	3.6 10^{6}
VSF [kN]	0	5.5 10^{4}	5.5 10^{4}	5.5 10^{4}	5.5 10^{4}
	5	7.6 10^{4}	3.9 10^{4}	4.2 10^{4}	5.6 10^{4}
	10	9.5 10^{4}	5.4 10^{4}	3.7 10^{4}	5.7 10^{4}
	12	1.0 10^{5}	6.6 10^{4}	4.6 10^{4}	5.7 10^{4}
HBM [kNm]	0	0.0	0.0	0.0	0.0
	5	0.0	2.8 10^{5}	4.4 10^{5}	5.0 10^{5}
	10	0.0	5.4 10^{5}	8.5 10^{5}	9.9 10^{5}
	12	0.0	6.3 10^{5}	1.0 10^{6}	1.2 10^{6}
HSF [kN]	0	0.0	0.0	0.0	0.0
	5	0.0	7.4 10^{3}	1.2 10^{4}	1.4 10^{4}
	10	0.0	1.3 10^{4}	2.2 10^{4}	2.8 10^{4}
	12	0.0	1.5 10^{4}	2.6 10^{4}	3.4 10^{4}
MT [kNm]	0	0.0	0.0	0.0	0.0
	5	0.0	3.5 10^{5}	5.4 10^{5}	6.6 10^{5}
	10	0.0	7.3 10^{5}	1.1 10^{6}	1.3 10^{6}
	12	0.0	8.8 10^{5}	1.4 10^{6}	1.6 10^{6}

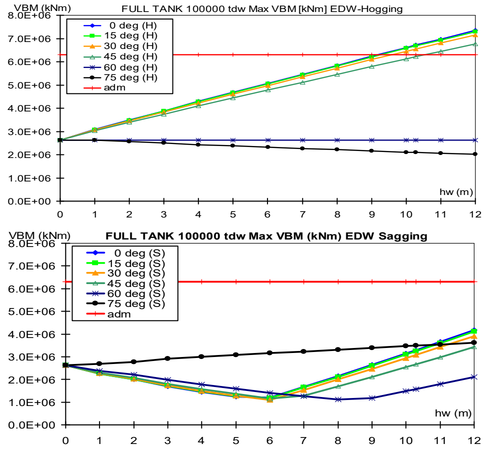

Fig.4.a VBM_{max} [kNm], TK 100000, full cargo

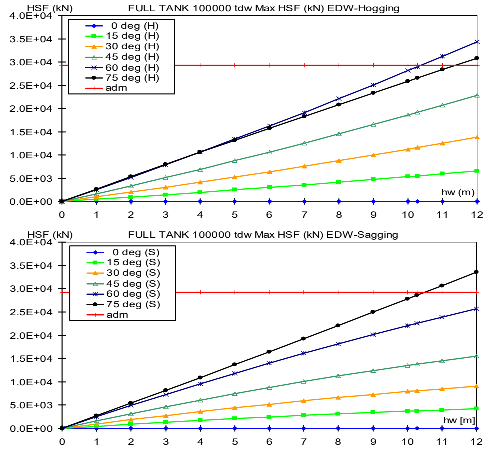

Fig.4.d HSF_{max} [kN], TK 100000, full cargo

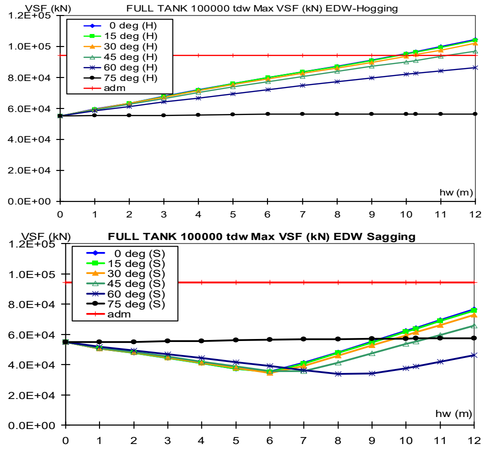

Fig.4.b VSF_{max} [kN], TK 100000, full cargo

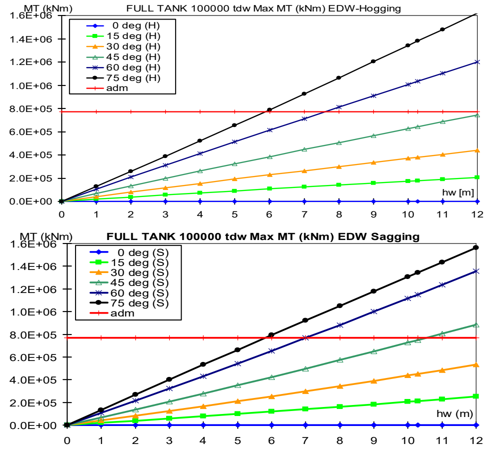

Fig.4.e MT_{max} [kNm], TK 100000, full cargo

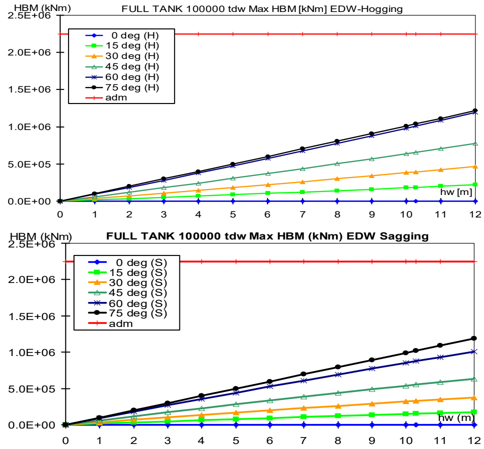

Fig.4.c HBM_{max} [kNm], TK 100000, full cargo

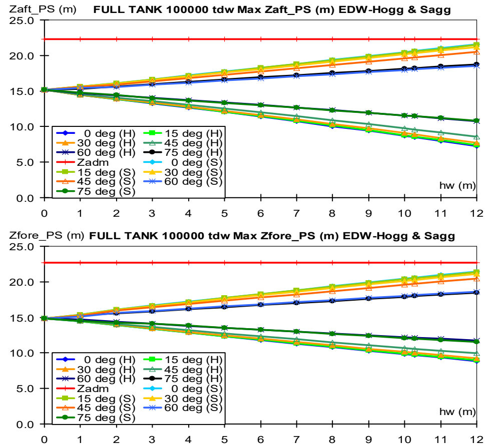

Fig.4.f Z_{max} [m], aft-fore, TK 100000, full cargo

3. GLOBAL STRENGTH OF 100000 TDW TANKER IN BALLAST

For the 100000 tdw tanker ballast loading case, the following results on global strength evaluation are obtained:

-Tables 5.a,b present the equilibrium parameters wave-ship (sinkage, pitch and roll) for relevant design oblique waves, ballast case;

-Figs. 5.a,b present the design oblique wave, for h_w=10 m, μ= 45 and 75 deg, ballast case;

-Figs. 6.a-e present the efforts diagrams, for oblique wave μ=60 deg, sagging, ballast case;

-Tables 6.a,b present the maximum efforts, for relevant design oblique waves, ballast case;

-Figs. 7.a-f present the global strength & free board criteria evaluation, ballast case.

Table 5.a Eq. parameters, hogging, ballast

Tanker 100000	μ[deg] / h_w[m]	0	45	60	75
T_m [m]	0	10.000	10.000	10.000	10.000
	5	9.547	9.639	9.809	10.421
	10	9.038	9.222	9.563	10.799
	12	8.826	9.048	9.457	10.947
θ [rad]	0	-0.0043	-0.0043	-0.0043	-0.0043
	5	0.0007	0.0002	-0.0009	-0.0049
	10	0.0074	0.0062	0.0041	-0.0044
	12	0.0102	0.0088	0.0062	-0.0042
φ [rad]	0	0.0000	0.0000	0.0000	0.0000
	5	0.0000	0.0024	0.0034	0.0023
	10	0.0000	0.0065	0.0090	0.0038
	12	0.0000	0.0085	0.0118	0.0042

Table 5.b Eq. parameters, sagging, ballast

Tanker 100000	μ[deg] / h_w[m]	0	45	60	75
T_m [m]	0	10.000	10.000	10.000	10.000
	5	10.387	10.303	10.145	9.557
	10	10.637	10.526	10.230	9.080
	12	10.782	10.554	10.209	8.845
θ [rad]	0	-0.0043	-0.0043	-0.0043	-0.0043
	5	-0.0070	-0.0068	-0.0062	-0.0031
	10	-0.0072	-0.0069	-0.0062	-0.0009
	12	-0.0069	-0.0081	-0.0073	-0.0002
φ [rad]	0	0.0000	0.0000	0.0000	0.0000
	5	0.0000	-0.0008	-0.0016	-0.0037
	10	0.0000	-0.0005	-0.0023	-0.0090
	12	0.0000	-0.0002	-0.0023	-0.0116

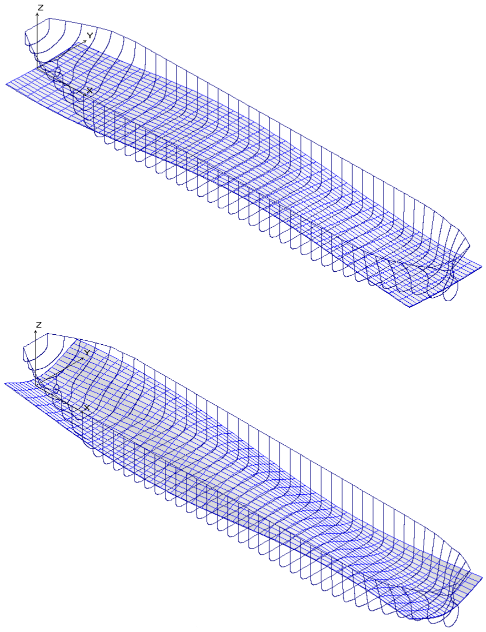

Fig.5.a Hogging design oblique wave, h_w=10 m, μ= 45 and 75 deg, 100000 tdw tanker, ballast loading case

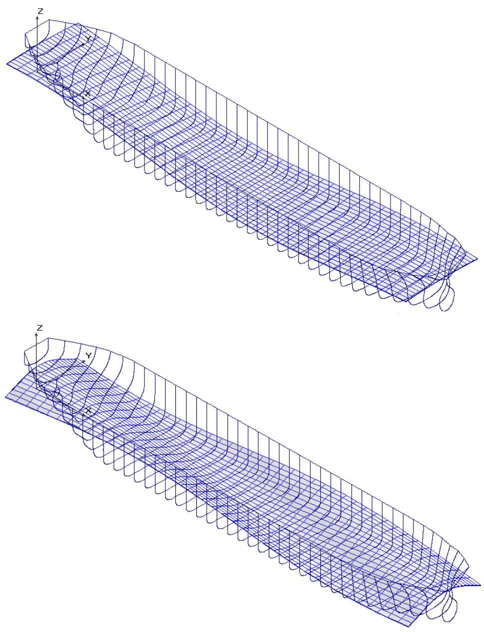

Fig.5.b Sagging design oblique wave, h_w=10 m, μ=45 and 75 deg, 100000 tdw tanker, ballast loading case

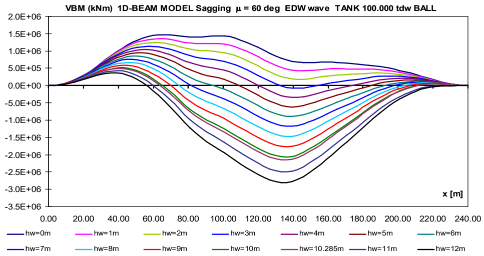

Fig.6.a *VBM* [kNm], μ=60deg, sagg, ballast

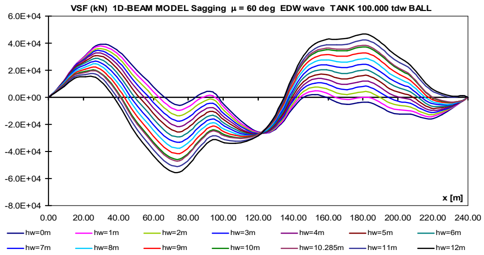

Fig.6.b *VSF* [kN], μ=60 deg, sagg, ballast

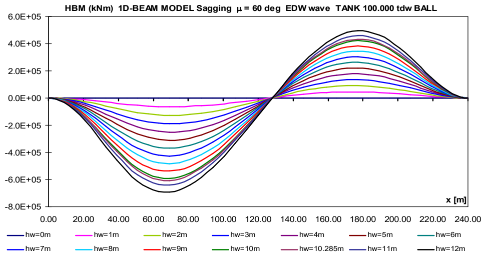

Fig.6.c *HBM* [kNm], μ=60deg, sagg, ballast

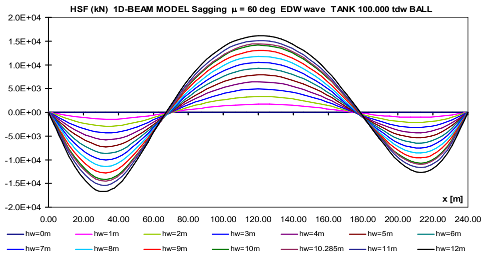

Fig.6.d *HSF* [kN], μ=60 deg, sagg, ballast

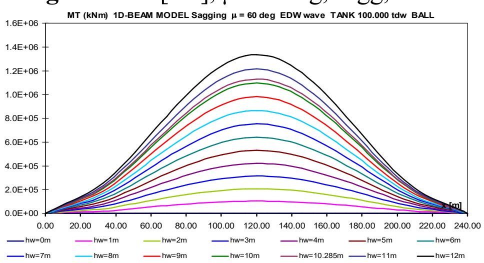

Fig.6.e *MT* [kNm], μ=60deg, sagg, ballast

Table 6.a Max. efforts, hogging, ballast

Tanker 100000	μ[deg] / h_w[m]	0	45	60	75
VBM [kNm]	0	$1.4\ 10^6$	$1.4\ 10^6$	$1.4\ 10^6$	$1.4\ 10^6$
	5	$3.2\ 10^6$	$3.0\ 10^6$	$2.6\ 10^6$	$1.4\ 10^6$
	10	$4.9\ 10^6$	$4.4\ 10^6$	$3.6\ 10^6$	$1.3\ 10^6$
	12	$5.6\ 10^6$	$5.0\ 10^6$	$4.1\ 10^6$	$1.2\ 10^6$
VSF [kN]	0	$3.9\ 10^4$	$3.9\ 10^4$	$3.9\ 10^4$	$3.9\ 10^4$
	5	$5.0\ 10^4$	$4.9\ 10^4$	$4.7\ 10^4$	$4.0\ 10^4$
	10	$6.4\ 10^4$	$6.0\ 10^4$	$5.4\ 10^4$	$3.9\ 10^4$
	12	$7.3\ 10^4$	$6.6\ 10^4$	$5.8\ 10^4$	$3.9\ 10^4$
HBM [kNm]	0	0.0	0.0	0.0	0.0
	5	0.0	$2.1\ 10^5$	$3.3\ 10^5$	$3.6\ 10^5$
	10	0.0	$4.4\ 10^5$	$6.9\ 10^5$	$7.4\ 10^5$
	12	0.0	$5.4\ 10^5$	$8.3\ 10^5$	$8.9\ 10^5$
HSF [kN]	0	0.0	0.0	0.0	0.0
	5	0.0	$6.0\ 10^3$	$9.1\ 10^3$	$9.0\ 10^3$
	10	0.0	$1.3\ 10^4$	$1.9\ 10^4$	$1.8\ 10^4$
	12	0.0	$1.6\ 10^4$	$2.4\ 10^4$	$2.2\ 10^4$
MT [kNm]	0	0.0	0.0	0.0	0.0
	5	0.0	$3.1\ 10^5$	$5.0\ 10^5$	$6.4\ 10^5$
	10	0.0	$6.0\ 10^5$	$9.7\ 10^5$	$1.3\ 10^6$
	12	0.0	$7.1\ 10^5$	$1.2\ 10^6$	$1.6\ 10^6$

Table 6.b Max. efforts, sagging, ballast

Tanker 100000	μ[deg] / h_w[m]	0	45	60	75
VBM [kNm]	0	$1.4\ 10^6$	$1.4\ 10^6$	$1.4\ 10^6$	$1.4\ 10^6$
	5	$1.3\ 10^6$	$1.1\ 10^6$	$9.4\ 10^5$	$1.8\ 10^6$
	10	$3.6\ 10^6$	$3.0\ 10^6$	$2.1\ 10^6$	$2.1\ 10^6$
	12	$4.5\ 10^6$	$4.0\ 10^6$	$2.8\ 10^6$	$2.2\ 10^6$
VSF [kN]	0	$3.9\ 10^4$	$3.9\ 10^4$	$3.9\ 10^4$	$3.9\ 10^4$
	5	$3.7\ 10^4$	$3.3\ 10^4$	$3.1\ 10^4$	$3.7\ 10^4$
	10	$6.9\ 10^4$	$6.0\ 10^4$	$4.6\ 10^4$	$3.5\ 10^4$
	12	$8.1\ 10^4$	$7.3\ 10^4$	$5.5\ 10^4$	$3.3\ 10^4$
HBM [kNm]	0	0.0	0.0	0.0	0.0
	5	0.0	$2.0\ 10^5$	$3.1\ 10^5$	$3.5\ 10^5$
	10	0.0	$3.7\ 10^5$	$5.9\ 10^5$	$6.9\ 10^5$
	12	0.0	$4.4\ 10^5$	$6.9\ 10^5$	$8.2\ 10^5$
HSF [kN]	0	0.0	0.0	0.0	0.0
	5	0.0	$4.9\ 10^3$	$7.8\ 10^3$	$9.3\ 10^3$
	10	0.0	$9.1\ 10^3$	$1.4\ 10^4$	$1.9\ 10^4$
	12	0.0	$1.1\ 10^4$	$1.7\ 10^4$	$2.3\ 10^4$
MT [kNm]	0	0.0	0.0	0.0	0.0
	5	0.0	$3.4\ 10^5$	$5.3\ 10^5$	$6.5\ 10^5$
	10	0.0	$7.2\ 10^5$	$1.1\ 10^6$	$1.3\ 10^6$
	12	0.0	$8.8\ 10^5$	$1.3\ 10^6$	$1.5\ 10^6$

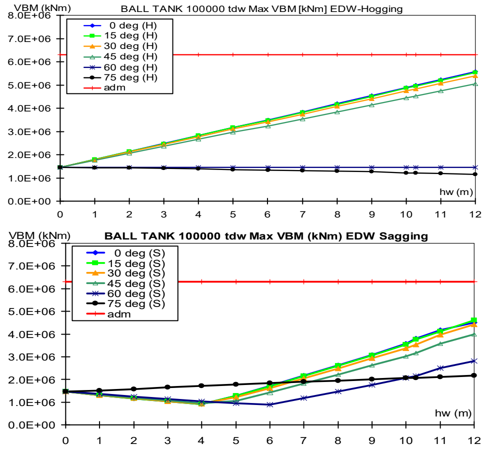

Fig.7.a *VBM$_{max}$* [kNm], TK 100000, ballast

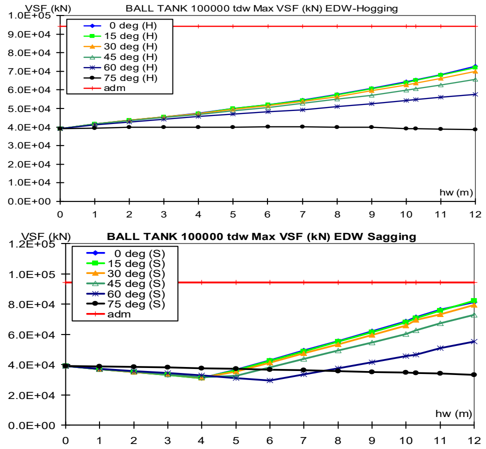

Fig.7.b *VSF$_{max}$* [kN], TK 100000, ballast

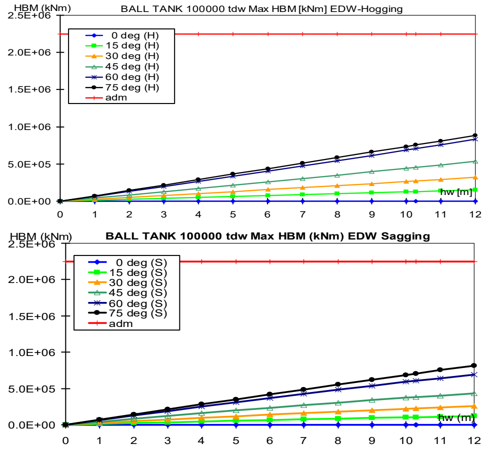

Fig.7.c *HBM$_{max}$* [kNm], TK 100000, ballast

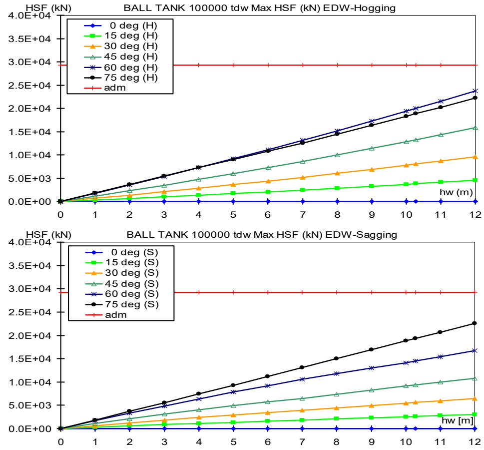

Fig.7.d *HSF$_{max}$* [kN], TK 100000, ballast

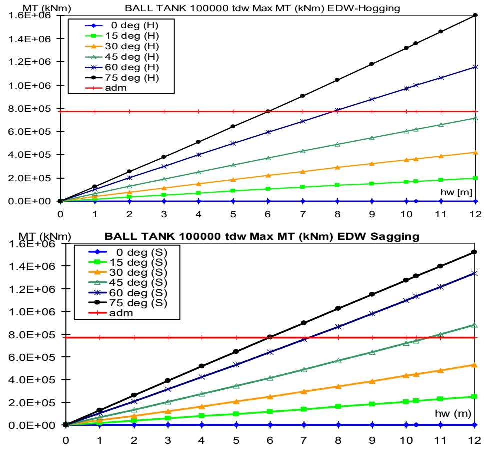

Fig.7.e *MT$_{max}$* [kNm], TK 100000, ballast

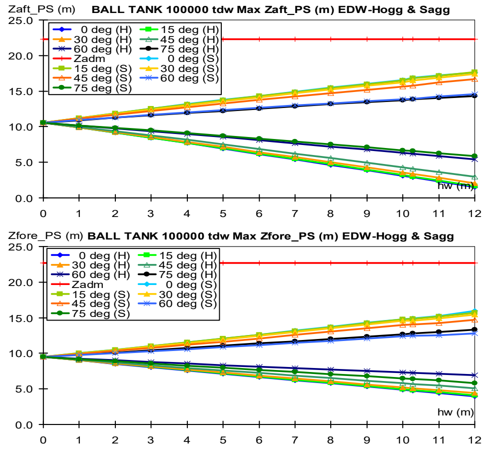

Fig.7.f *Z$_{max}$* [m], aft-fore, TK 100000, ballast

4. CONCLUSIONS

Fig. 8 and Table 7 present the resulting operation wave height h_w limits, by the preliminary global strength criteria (Tab.2) for the 100000 tdw tanker [4] (Table 1, Fig.1).

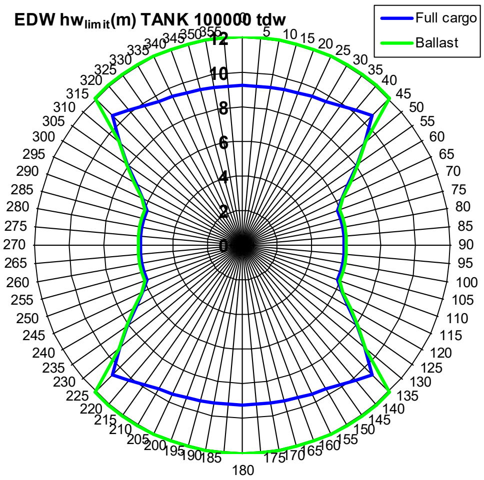

Fig.8 h_w[m] limits, TK 100000, polar diagram

Table 7. h_w[m] limits, TK 100000, both cases

μ	*VBM*	*VSF*	*HBM*	*HSF*	*MT*	*FB*
Full cargo case : Hogging oblique waves 90:**R4(57%)**						
0	**9.179**	**9.712**	12.0	12.0	12.0	12.0
15	**9.268**	**9.807**	12.0	12.0	12.0	12.0
30	**9.604**	**10.171**	12.0	12.0	12.0	12.0
45	**10.562**	**11.225**	12.0	12.0	12.0	12.0
60	12.0	12.0	12.0	**10.364**	**7.585**	12.0
75	12.0	12.0	12.0	**11.360**	**5.854**	12.0
Full cargo case : Sagging oblique waves 90:**R4(57%)**						
0	12.0	12.0	12.0	12.0	12.0	12.0
15	12.0	12.0	12.0	12.0	12.0	12.0
30	12.0	12.0	12.0	12.0	12.0	12.0
45	12.0	12.0	12.0	12.0	**10.554**	12.0
60	12.0	12.0	12.0	12.0	**7.019**	12.0
75	12.0	12.0	12.0	**10.506**	**5.830**	12.0
Ballast case : Hogging oblique waves 90:**R4(58%)**						
0	12.0	12.0	12.0	12.0	12.0	12.0
15	12.0	12.0	12.0	12.0	12.0	12.0
30	12.0	12.0	12.0	12.0	12.0	12.0
45	12.0	12.0	12.0	12.0	12.0	12.0
60	12.0	12.0	12.0	12.0	**7.872**	12.0
75	12.0	12.0	12.0	12.0	**5.975**	12.0
Ballast case : Sagging oblique waves 90:**R4(58%)**						
0	12.0	12.0	12.0	12.0	12.0	12.0
15	12.0	12.0	12.0	12.0	12.0	12.0
30	12.0	12.0	12.0	12.0	12.0	12.0
45	12.0	12.0	12.0	12.0	12.0	12.0
60	12.0	12.0	12.0	12.0	**7.155**	12.0
75	12.0	12.0	12.0	12.0	**5.983**	12.0

From the numerical data in sections 2 and 3 the next conclusions are formulated:

1. The wave height & ship-wave angle, combined with the geometric nonlinearities of the 1000 tdw tanker hull shape (Fig.1), lead to significant changes of the equilibrium parameters (sinkage, pitch, roll) (Tables 3.a,b & 5.a,b, Figs. 2.a,b, Figs.5.a,b) and also for the sectional efforts values (Figs.3.a-e, Figs.6.a-e).
2. In the case of full cargo, the main global strength restrictions occur in hogging wave condition (Figs.4.a-e, Table 4.a,b), for the heading angle whole range, and in sagging wave condition for μ > 30 deg.
3. In the case of ballast, the global strength restrictions are similar in hogging and sagging conditions and occur for heading angle μ > 45 deg (Figs.7.a-e, Table 6.a,b).
4. For both loading cases the free board criteria has no restriction (Fig.4.f, Fig.7.f).
5. The beam sea state (μ=75-105 deg.) is the most restrictive navigation case, h_{wlimit} = 5.830 – 5.975 m, R4(57-58%) [1] (Table 7, Fig.8).
6. Extended studies shall be coupled with 3D models and other relevant evaluation criteria.

Acknowledgements

This study and the program P_QSW [2] are developed at the Naval Architecture Research Centre, from University "Dunarea de Jos" of Galati.

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Paper received on October 16st, 2020

