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 ta	ınk data	[3],	[4]	l

$L_{OA}[\mathbf{m}]$	246.0	Loading:	TK1cargo	TK2ballast
$L_{WL}[m]$	240.0	$\Delta[t]$	126457.1	81763.3
<i>B</i> [m]	42.0	LCG[m]	126.46	126.73
<i>H</i> [m]	21.3	$T_{aft}[\mathbf{m}]$	15.0	10.5
$\rho[t/m^3]$	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]).

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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

vertical, nonzontal and to	isional eriorts
VBM _{adm} [kNm] (bending)	6.31 10 ⁶
VSF _{adm} [kN] (shearing)	9.43 10 ⁴
HBM _{adm} [kNm] (bending)	2.25 106
HSF _{adm} [kN] (shearing)	2.93 10 ⁴
MT_{adm} [kNm] (torsional)	7.70 105

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, $\mu=45$ 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, ful	l cargo

	Tanker	μ[deg]	0	15	60	75	
	100000	$h_w[m]$	0	43	00	15	
		0	15.000	15.000	15.000	15.000	
	T_m	5	14.680	14.756	14.895	15.359	
	[m]	10	14.266	14.427	14.721	15.699	
		12	14.082	14.277	14.632	15.833	
		0	0.0000	0.0000	0.0000	0.0000	
	0[mad]	5	0.0011	0.0009	0.0005	-0.0007	
	<i>e</i> [rad]	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 5	D LY.	parame	iers, sag	ging, iu	in cargo
Tanker 100000	μ [deg] h_w [m]	0	45	60	75
	0	15.000	15.000	15.000	15.000
T_m	5	15.243	15.180	15.064	14.627
[m]	10	15.442	15.327	15.108	14.227
	12	15.511	15.380	15.122	14.060
	0	0.0000	0.0000	0.0000	0.0000
0[mad]	5	0.0001	0.0001	0.0002	0.0009
[[[rad]	10	-0.0002	0.0000	0.0003	0.0022
	12	-0.0004	-0.0001	0.0003	0.0029
	0	0.0000	0.0000	0.0000	0.0000
φ [rad]	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

Table 3 h Eq. parameters sagging full cargo







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

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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 © *Galati University Press*, 2020

Table 4.a	a Max	. enort	s, noggi	ng, tull	cargo
Tanker	µ[deg]	0	45	60	75
100000	h _w [m]	0	75	00	15
	0	$2.6\ 10^{6}$	$2.6\ \overline{10^6}$	$2.6\ 10^{6}$	$2.6\ 10^{6}$
VBM	5	$4.7 \ 10^{6}$	$4.4 10^6$	$4.0\ 10^6$	$2.4\ 10^6$
[kNm]	10	6.6 10 ⁶	$6.1\ 10^{6}$	$5.2\ 10^{6}$	$2.1\ 10^{6}$
	12	7.3 106	$6.8\ 10^6$	$5.7\ 10^{6}$	$2.0\ 10^{6}$
	0	$5.5 \ 10^4$	$5.5 \ 10^4$	$5.5\ 10^4$	$5.5\ 10^4$
VSF	5	$7.6\ 10^4$	$7.4 \ 10^4$	$7.0\ 10^4$	$5.6\ 10^4$
[kN]	10	$9.5 \ 10^4$	$9.0\ 10^4$	$8.2\ 10^4$	$5.6\ 10^4$
	12	$1.0\ 10^5$	$9.7\ 10^4$	$8.6\ 10^4$	$5.6\ 10^4$
	0	0.0	0.0	0.0	0.0
HBM	5	0.0	3.1 10 ⁵	4.7 10 ⁵	5.0 10 ⁵
[kNm]	10	0.0	6.4 10 ⁵	9.8 10 ⁵	$1.0\ 10^{6}$
	12	0.0	$7.7 \ 10^5$	1.2 106	1.2 106
	0	0.0	0.0	0.0	0.0
HSF	5	0.0	$8.8\ 10^3$	$1.3\ 10^4$	$1.3\ 10^4$
[kN]	10	0.0	$1.9\ 10^4$	$2.8\ 10^4$	$2.6\ 10^4$
	12	0.0	$2.3\ 10^4$	$3.4\ 10^4$	$3.1\ 10^4$
	0	0.0	0.0	0.0	0.0
MT	5	0.0	3.2 105	5.1 10 ⁵	6.6 10 ⁵
[kNm]	10	0.0	6.3 10 ⁵	1.0 106	1.3 106
	12	0.0	7.4 10 ⁵	1.3 106	1.6 106
Table 4.b Max. efforts, sagging, full cargo					
			s, saggi	ng, tuli	cargo
Tanker	μ[deg]	0	s, saggi 45	ng, tuli 60	cargo 75
Tanker 100000	μ[deg] h _w [m]	0	45	60	75
Tanker 100000	μ [deg] h_w [m] 0	0 2.6 10 ⁶	45 2.6 10 ⁶	60 2.6 10 ⁶	cargo 75 2.6 10 ⁶
Tanker 100000 VBM	$\frac{\mu[\text{deg}]}{h_w[m]}$ $\frac{0}{5}$	$\begin{array}{c} 0 \\ 2.6 \ 10^6 \\ 4.7 \ 10^6 \end{array}$	45 2.6 10 ⁶ 1.4 10 ⁶	60 2.6 10 ⁶ 1.6 10 ⁶	$ \begin{array}{r} cargo \\ 75 \\ 2.6 \ 10^6 \\ 3.1 \ 10^6 \end{array} $
Tanker 100000 VBM [kNm]	$ \mu[deg] h_w[m] 0 5 10 $	$\begin{array}{c} 0 \\ 2.6 \ 10^6 \\ 4.7 \ 10^6 \\ 6.6 \ 10^6 \end{array}$	45 2.6 10 ⁶ 1.4 10 ⁶ 2.5 10 ⁶	60 2.6 10 ⁶ 1.6 10 ⁶ 1.5 10 ⁶	$ \begin{array}{r} cargo \\ 75 \\ \hline 2.6 \ 10^6 \\ \hline 3.1 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \end{array} $
Tanker 100000 <i>VBM</i> [kNm]	$ \frac{\mu[deg]}{h_w[m]} \\ 0 \\ 5 \\ 10 \\ 12 $	$\begin{array}{c} 0 \\ 2.6 \ 10^6 \\ 4.7 \ 10^6 \\ 6.6 \ 10^6 \\ 7.3 \ 10^6 \end{array}$	45 2.6 10 ⁶ 1.4 10 ⁶ 2.5 10 ⁶ 3.4 10 ⁶	$\begin{array}{c} \text{ng, full} \\ 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \end{array}$	$\begin{array}{c} \text{cargo} \\ 75 \\ \hline 2.6 \ 10^6 \\ \hline 3.1 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \hline 3.6 \ 10^6 \end{array}$
Tanker 100000 VBM [kNm]	μ [deg] h _w [m] 0 5 10 12 0	$\begin{array}{c} 0 \\ 2.6 \ 10^6 \\ 4.7 \ 10^6 \\ 6.6 \ 10^6 \\ \overline{7.3} \ 10^6 \\ 5.5 \ 10^4 \end{array}$	$\begin{array}{r} 45\\ \hline 2.6 \ 10^6\\ \hline 1.4 \ 10^6\\ \hline 2.5 \ 10^6\\ \hline 3.4 \ 10^6\\ \hline 5.5 \ 10^4\\ \end{array}$	$\begin{array}{c} \text{ng, full} \\ 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \end{array}$	$\begin{array}{r} \text{cargo} \\ \hline 75 \\ \hline 2.6 \ 10^6 \\ \hline 3.1 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \hline 3.6 \ 10^6 \\ \hline 5.5 \ 10^4 \end{array}$
Tanker 100000 VBM [kNm]	$ \frac{\mu[deg]}{h_w[m]} \\ \frac{0}{5} \\ \frac{10}{12} \\ 0 \\ 5 $	$\begin{array}{c} 0 \\ \hline 2.6 \ 10^6 \\ \hline 4.7 \ 10^6 \\ \hline 6.6 \ 10^6 \\ \hline 7.3 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 7.6 \ 10^4 \end{array}$	$\begin{array}{r} 45\\ \hline 2.6 \ 10^6\\ \hline 1.4 \ 10^6\\ \hline 2.5 \ 10^6\\ \hline 3.4 \ 10^6\\ \hline 5.5 \ 10^4\\ \hline 3.9 \ 10^4\end{array}$	$\begin{array}{c} \text{ng, full} \\ 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \end{array}$	$\begin{array}{r} \text{cargo} \\ \hline 75 \\ \hline 2.6 \ 10^6 \\ \hline 3.1 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \hline 3.6 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 5.6 \ 10^4 \end{array}$
VBM [kNm]	$\frac{\mu[deg]}{h_w[m]} = \frac{1}{0}$ $\frac{1}{12}$ $\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$ $\frac{1}{10}$	$\begin{array}{c} 0 \\ \hline 2.6 \ 10^6 \\ \hline 4.7 \ 10^6 \\ \hline 6.6 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 7.6 \ 10^4 \\ \hline 9.5 \ 10^4 \end{array}$	45 2.6 10 ⁶ 1.4 10 ⁶ 2.5 10 ⁶ 3.4 10 ⁶ 5.5 10 ⁴ 3.9 10 ⁴ 5.4 10 ⁴	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 3.7 \ 10^4 \end{array}$	cargo 75 2.6 10 ⁶ 3.1 10 ⁶ 3.5 10 ⁶ 3.5 10 ⁶ 5.5 10 ⁴ 5.6 10 ⁴ 5.7 10 ⁴
VBM [kNm]	$\begin{array}{c} \mu[deg] \\ h_w[m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12$	$\begin{array}{c} 0 \\ \hline 2.6 \ 10^6 \\ \hline 4.7 \ 10^6 \\ \hline 6.6 \ 10^6 \\ \hline 7.3 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 7.6 \ 10^4 \\ \hline 9.5 \ 10^4 \\ \hline 1.0 \ 10^5 \end{array}$	45 2.6 10 ⁶ 1.4 10 ⁶ 2.5 10 ⁶ 3.4 10 ⁶ 5.5 10 ⁴ 3.9 10 ⁴ 5.4 10 ⁴	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline \end{array}$	cargo 75 2.6 10 ⁶ 3.1 10 ⁶ 3.5 10 ⁶ 3.6 10 ⁶ 5.5 10 ⁴ 5.6 10 ⁴ 5.7 10 ⁴
Tanker 100000 VBM [kNm] VSF [kN]	$\begin{array}{c} \mu [deg] \\ h_w[m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 12 \\ 0 \\ - \end{array}$	$\begin{array}{c} 0 \\ \hline 2.6 \ 10^6 \\ \hline 4.7 \ 10^6 \\ \hline 6.6 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 7.6 \ 10^4 \\ \hline 9.5 \ 10^4 \\ \hline 1.0 \ 10^5 \\ \hline 0.0 \end{array}$	$\begin{array}{r} 45\\ \hline 45\\ \hline 2.6\ 10^6\\ \hline 1.4\ 10^6\\ \hline 2.5\ 10^6\\ \hline 3.4\ 10^6\\ \hline 5.5\ 10^4\\ \hline 3.9\ 10^4\\ \hline 5.4\ 10^4\\ \hline 6.6\ 10^4\\ \hline 0.0\\ \hline \end{array}$	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 3.7 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline 0.0 \end{array}$	cargo 75 2.6 10 ⁶ 3.1 10 ⁶ 3.5 10 ⁶ 3.6 10 ⁶ 5.5 10 ⁴ 5.7 10 ⁴ 5.7 10 ⁴
Tanker 100000 VBM [kNm] VSF [kN] HBM	$\begin{array}{c} \mu [deg] \\ h_w[m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 5 \\ 10 \\ 12 \\ 0 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 $	$\begin{array}{c} 0\\ \hline 0\\ \hline 2.6\ 10^6\\ \hline 4.7\ 10^6\\ \hline 6.6\ 10^6\\ \hline 7.3\ 10^6\\ \hline 5.5\ 10^4\\ \hline 7.6\ 10^4\\ \hline 9.5\ 10^4\\ \hline 1.0\ 10^5\\ \hline 0.0\\ \hline 0.0\\ \hline \end{array}$	45 2.6 10 ⁶ 1.4 10 ⁶ 2.5 10 ⁶ 3.4 10 ⁶ 5.5 10 ⁴ 3.9 10 ⁴ 5.4 10 ⁴ 6.6 10 ⁴ 0.0 0.8 10 ⁵	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 3.7 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline 0.0 \\ \hline 4.4 \ 10^5 \end{array}$	cargo 75 2.6 10 ⁶ 3.1 10 ⁶ 3.5 10 ⁶ 3.6 10 ⁴ 5.5 10 ⁴ 5.7 10 ⁴ 5.7 10 ⁴ 5.0 10 ⁵
Tanker 100000 VBM [kNm] VSF [kN] HBM [kNm]	$\begin{array}{c} \mu [deg] \\ h_w[m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\$	$\begin{array}{c} 0\\ \hline 0\\ \hline 2.6\ 10^6\\ \hline 4.7\ 10^6\\ \hline 6.6\ 10^6\\ \hline 7.3\ 10^6\\ \hline 5.5\ 10^4\\ \hline 7.6\ 10^4\\ \hline 9.5\ 10^4\\ \hline 1.0\ 10^5\\ \hline 0.0\\ \hline 0.0\\ \hline 0.0\\ \hline 0.0\\ \hline \end{array}$	$\begin{array}{r} 45\\ \hline 45\\ \hline 2.6 \ 10^6\\ \hline 1.4 \ 10^6\\ \hline 2.5 \ 10^6\\ \hline 3.4 \ 10^6\\ \hline 5.5 \ 10^4\\ \hline 3.9 \ 10^4\\ \hline 5.4 \ 10^4\\ \hline 6.6 \ 10^4\\ \hline 0.0\\ \hline 2.8 \ 10^5\\ \hline 5.4 \ 10^5\\ \hline \end{array}$	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline 0.0 \\ \hline 4.4 \ 10^5 \\ \hline 8.5 \ 10^5 \end{array}$	cargo 75 2.6 10 ⁶ 3.1 10 ⁶ 3.5 10 ⁶ 3.6 10 ⁶ 5.5 10 ⁴ 5.6 10 ⁴ 5.7 10 ⁴ 5.7 10 ⁴ 5.0 10 ⁵ 9.9 10 ⁵
Tanker 100000 <i>VBM</i> [kNm] <i>VSF</i> [kN] <i>HBM</i> [kNm]	$\begin{array}{c} \mu[deg] \\ h_w[m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 10 \\ 10 \\ 12 \\ 10 \\ 10 \\ 10$	$\begin{array}{c} 0\\ \hline \\2.6 \ 10^6\\ \hline \\4.7 \ 10^6\\ \hline \\6.6 \ 10^6\\ \hline \\7.3 \ 10^6\\ \hline \\5.5 \ 10^4\\ \hline \\9.5 \ 10^4\\ \hline \\1.0 \ 10^5\\ \hline \\0.0\\ \hline \\0.0\\ \hline \\0.0\\ \hline \\0.0\\ \hline \end{array}$	$\begin{array}{r} 45\\ \hline 45\\ \hline 2.6 \ 10^6\\ \hline 1.4 \ 10^6\\ \hline 2.5 \ 10^6\\ \hline 3.4 \ 10^6\\ \hline 5.5 \ 10^4\\ \hline 5.5 \ 10^4\\ \hline 5.4 \ 10^4\\ \hline 6.6 \ 10^4\\ \hline 0.0\\ \hline 2.8 \ 10^5\\ \hline 5.4 \ 10^5\\ \hline 6.3 \ 10^5\\ \hline \end{array}$	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 3.7 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline 0.0 \\ \hline 4.4 \ 10^5 \\ \hline 8.5 \ 10^5 \\ \hline 1.0 \ 10^6 \\ \hline \end{array}$	cargo 75 2.6 10 ⁶ 3.1 10 ⁶ 3.5 10 ⁶ 3.6 10 ⁶ 5.5 10 ⁴ 5.7 10 ⁴ 5.7 10 ⁴ 5.7 10 ⁴ 5.0 10 ⁵ 9.9 10 ⁵ 1.2 10 ⁶
Tanker 100000 <i>VBM</i> [kNm] <i>VSF</i> [kN] <i>HBM</i> [kNm]	$\begin{array}{c} \mu [deg] \\ h_w[m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 0 \\ - \end{array}$	$\begin{array}{c} 0\\ \hline 0\\ \hline 2.6 \ 10^6\\ \hline 4.7 \ 10^6\\ \hline 6.6 \ 10^6\\ \hline 7.3 \ 10^6\\ \hline 5.5 \ 10^4\\ \hline 7.6 \ 10^4\\ \hline 9.5 \ 10^4\\ \hline 1.0 \ 10^5\\ \hline 0.0\\ \hline \end{array}$	$\begin{array}{r} 45\\ \hline 45\\ \hline 2.6 \ 10^6\\ \hline 1.4 \ 10^6\\ \hline 2.5 \ 10^6\\ \hline 3.4 \ 10^6\\ \hline 5.5 \ 10^4\\ \hline 5.5 \ 10^4\\ \hline 5.4 \ 10^4\\ \hline 6.6 \ 10^4\\ \hline 0.0\\ \hline 2.8 \ 10^5\\ \hline 5.4 \ 10^5\\ \hline 6.3 \ 10^5\\ \hline 0.0\\ \hline \end{array}$	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline 0.0 \\ \hline 4.4 \ 10^5 \\ \hline 8.5 \ 10^5 \\ \hline 1.0 \ 10^6 \\ \hline 0.0 \\ \hline \end{array}$	cargo 75 2.6 10 ⁶ 3.1 10 ⁶ 3.5 10 ⁶ 3.6 10 ⁶ 5.5 10 ⁴ 5.7 10 ⁴ 5.7 10 ⁴ 5.0 10 ⁵ 9.9 10 ⁵ 1.2 10 ⁶ 0.0
Tanker 100000 VBM [kNm] VSF [kN] HBM [kNm]	$\begin{array}{c} \mu[deg] \\ \mu_w[m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 12 \\ 0 \\ 12 \\ 0 \\ 12 \\ 0 \\ 12 \\ 0 \\ 12 \\ 0 \\ 12 \\ 0 \\ 12 \\ 0 \\ 12 \\ 0 \\ 12 \\ 10 \\ 12 \\ 10 \\ 10$	$\begin{array}{c} 0\\ \hline 0\\ \hline 2.6\ 10^6\\ \hline 4.7\ 10^6\\ \hline 6.6\ 10^6\\ \hline 7.3\ 10^6\\ \hline 5.5\ 10^4\\ \hline 7.6\ 10^4\\ \hline 9.5\ 10^4\\ \hline 1.0\ 10^5\\ \hline 0.0\\ \hline $	$\begin{array}{r} 45\\ \hline 45\\ \hline 2.6\ 10^6\\ \hline 1.4\ 10^6\\ \hline 2.5\ 10^6\\ \hline 3.4\ 10^6\\ \hline 5.5\ 10^4\\ \hline 3.9\ 10^4\\ \hline 5.4\ 10^4\\ \hline 6.6\ 10^4\\ \hline 0.0\\ \hline 2.8\ 10^5\\ \hline 5.4\ 10^5\\ \hline 6.3\ 10^5\\ \hline 0.0\\ \hline 7.4\ 10^3\\ \hline 0.0\\ \hline \end{array}$	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline 0.0 \\ \hline 4.4 \ 10^5 \\ \hline 8.5 \ 10^5 \\ \hline 1.0 \ 10^6 \\ \hline 0.0 \\ \hline 1.2 \ 10^4 \end{array}$	cargo 75 2.6 10 ⁶ 3.1 10 ⁶ 3.5 10 ⁶ 3.6 10 ⁶ 5.5 10 ⁴ 5.6 10 ⁴ 5.7 10 ⁴ 5.7 10 ⁴ 9.9 10 ⁵ 1.2 10 ⁶ 0.0 1.4 10 ⁴
Tanker 100000 <i>VBM</i> [kNm] <i>VSF</i> [kN] <i>HBM</i> [kNm] <i>HSF</i> [kN]	$\begin{array}{c} \mu[deg] \\ \mu_{w}[m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 $	$\begin{array}{c} 0\\ \hline 0\\ \hline 2.6\ 10^6\\ \hline 4.7\ 10^6\\ \hline 6.6\ 10^6\\ \hline 7.3\ 10^6\\ \hline 5.5\ 10^4\\ \hline 7.6\ 10^4\\ \hline 9.5\ 10^4\\ \hline 1.0\ 10^5\\ \hline 0.0\\ \hline $	$\begin{array}{r} 45\\ \hline 45\\ \hline 2.6\ 10^6\\ \hline 1.4\ 10^6\\ \hline 2.5\ 10^6\\ \hline 3.4\ 10^6\\ \hline 5.5\ 10^4\\ \hline 3.9\ 10^4\\ \hline 5.4\ 10^4\\ \hline 6.6\ 10^4\\ \hline 0.0\\ \hline 2.8\ 10^5\\ \hline 5.4\ 10^5\\ \hline 6.3\ 10^5\\ \hline 6.3\ 10^5\\ \hline 0.0\\ \hline 7.4\ 10^3\\ \hline 1.3\ 10^4\\ \hline 0.0\\ \hline \end{array}$	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline 0.0 \\ \hline 4.4 \ 10^5 \\ \hline 8.5 \ 10^5 \\ \hline 1.0 \ 10^6 \\ \hline 0.0 \\ \hline 1.2 \ 10^4 \\ \hline 2.2 \ 10^4 \\ \hline \end{array}$	$\begin{array}{c} \text{cargo} \\ \hline 75 \\ \hline 2.6 \ 10^6 \\ \hline 3.1 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 5.7 \ 10^4 \\ \hline 5.7 \ 10^4 \\ \hline 5.7 \ 10^4 \\ \hline 0.0 \\ \hline 5.0 \ 10^5 \\ \hline 9.9 \ 10^5 \\ \hline 1.2 \ 10^6 \\ \hline 0.0 \\ \hline 1.4 \ 10^4 \\ \hline 2.8 \ 10^4 \\ \hline 0.0 \\ \hline $
Tanker 100000 <i>VBM</i> [kNm] <i>VSF</i> [kN] <i>HBM</i> [kNm] <i>HSF</i> [kN]	$\begin{array}{c} \mu[\text{deg}] \\ \mu[\text{deg}] \\ h_w[m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\$	$\begin{array}{c} 0\\ \hline 0\\ \hline 2.6\ 10^6\\ \hline 4.7\ 10^6\\ \hline 6.6\ 10^6\\ \hline 7.3\ 10^6\\ \hline 5.5\ 10^4\\ \hline 7.6\ 10^4\\ \hline 9.5\ 10^4\\ \hline 1.0\ 10^5\\ \hline 0.0\\ \hline $	$\begin{array}{r} 45\\ \hline 45\\ \hline 2.6\ 10^6\\ \hline 1.4\ 10^6\\ \hline 2.5\ 10^6\\ \hline 3.4\ 10^6\\ \hline 5.5\ 10^4\\ \hline 3.9\ 10^4\\ \hline 5.4\ 10^4\\ \hline 6.6\ 10^4\\ \hline 0.0\\ \hline 2.8\ 10^5\\ \hline 5.4\ 10^5\\ \hline 6.3\ 10^5\\ \hline 0.0\\ \hline 7.4\ 10^3\\ \hline 1.3\ 10^4\\ \hline 1.5\ 10^4\\ \hline 0.0\\ \hline 0.0\\$	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline 0.0 \\ \hline 4.4 \ 10^5 \\ \hline 8.5 \ 10^5 \\ \hline 1.0 \ 10^6 \\ \hline 0.0 \\ \hline 1.2 \ 10^4 \\ \hline 2.2 \ 10^4 \\ \hline 2.2 \ 10^4 \\ \hline 0.0 \\ $	cargo 75 2.6 10 ⁶ 3.1 10 ⁶ 3.5 10 ⁶ 3.6 10 ⁶ 5.5 10 ⁴ 5.7 10 ⁴ 0.0 5.7 10 ⁴ 0.0 5.0 10 ⁵ 9.9 10 ⁵ 1.2 10 ⁶ 0.0 1.4 10 ⁴ 2.8 10 ⁴ 3.4 10 ⁴
Tanker 100000 VBM [kNm] VSF [kN] HBM [kNm] HSF [kN]	$\begin{array}{c} \mu [deg] \\ \mu [deg] \\ h_w [m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\$	$\begin{array}{c} 0\\ \hline 0\\ \hline 2.6\ 10^6\\ \hline 4.7\ 10^6\\ \hline 6.6\ 10^6\\ \hline 7.3\ 10^6\\ \hline 5.5\ 10^4\\ \hline 7.6\ 10^4\\ \hline 9.5\ 10^4\\ \hline 1.0\ 10^5\\ \hline 0.0\\ \hline $	$\begin{array}{r} 45\\ \hline 45\\ \hline 2.6\ 10^6\\ \hline 1.4\ 10^6\\ \hline 2.5\ 10^6\\ \hline 3.4\ 10^6\\ \hline 5.5\ 10^4\\ \hline 3.9\ 10^4\\ \hline 5.4\ 10^4\\ \hline 6.6\ 10^4\\ \hline 0.0\\ \hline 2.8\ 10^5\\ \hline 5.4\ 10^5\\ \hline 6.3\ 10^5\\ \hline 0.0\\ \hline 7.4\ 10^3\\ \hline 1.3\ 10^4\\ \hline 1.5\ 10^4\\ \hline 0.0\\ \hline 0.0\\ \hline 2.5\ 10^5\\ \hline 0.0\\ \hline 7.4\ 10^3\\ \hline 0.0\\ \hline 0.0\\ \hline 7.4\ 10^3\\ \hline 0.0\\ \hline $	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 3.7 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 3.7 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline 0.0 \\ \hline 4.4 \ 10^5 \\ \hline 1.0 \ 10^6 \\ \hline 0.0 \\ \hline 1.2 \ 10^4 \\ \hline 2.2 \ 10^4 \\ \hline 2.6 \ 10^4 \\ \hline 0.0 \\ \hline 0.0 \\ \hline 1.2 \ 10^4 \\ \hline 0.0 \\ \hline 0.0 \\ \hline 1.2 \ 10^4 \\ \hline 0.0 \\ \hline 0.0 \\ \hline 1.2 \ 10^4 \\ \hline 0.0 \\ \hline 0.0 \\ \hline 1.2 \ 10^4 \\ \hline 0.0 \\ \hline 0.0$	$\begin{array}{c} \text{cargo} \\ \hline 75 \\ \hline 2.6 \ 10^6 \\ \hline 3.1 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 5.5 \ 10^4 \\ \hline 5.7 \ 10^4 \\ \hline 5.7 \ 10^4 \\ \hline 5.7 \ 10^4 \\ \hline 0.0 \\ \hline 5.0 \ 10^5 \\ \hline 1.2 \ 10^6 \\ \hline 0.0 \\ \hline 1.4 \ 10^4 \\ \hline 2.8 \ 10^4 \\ \hline 3.4 \ 10^4 \\ \hline 0.0 \\ \hline \end{array}$
Tanker 100000 VBM [kNm] VSF [kN] HBM [kNm] HSF [kN]	$\begin{array}{c} \mu [deg] \\ \mu [m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10 \\ 10$	$\begin{array}{c} 0\\ \hline 0\\ \hline 2.6\ 10^6\\ \hline 4.7\ 10^6\\ \hline 6.6\ 10^6\\ \hline 7.3\ 10^6\\ \hline 5.5\ 10^4\\ \hline 7.6\ 10^4\\ \hline 9.5\ 10^4\\ \hline 1.0\ 10^5\\ \hline 0.0\\ \hline $	$\begin{array}{r} 45\\ \hline 45\\ \hline 2.6 \ 10^6\\ \hline 1.4 \ 10^6\\ \hline 2.5 \ 10^6\\ \hline 3.4 \ 10^6\\ \hline 5.5 \ 10^4\\ \hline 3.9 \ 10^4\\ \hline 5.4 \ 10^4\\ \hline 6.6 \ 10^4\\ \hline 0.0\\ \hline 2.8 \ 10^5\\ \hline 5.4 \ 10^5\\ \hline 6.3 \ 10^5\\ \hline 0.0\\ \hline 7.4 \ 10^3\\ \hline 1.3 \ 10^4\\ \hline 1.5 \ 10^4\\ \hline 0.0\\ \hline 3.5 \ 10^5\\ \hline 0.0\\ \hline \end{array}$	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 6.0 \\ \hline 1.2 \ 10^6 \\ \hline 0.0 \\ \hline 1.2 \ 10^4 \\ \hline 2.2 \ 10^4 \\ \hline 2.2 \ 10^4 \\ \hline 2.6 \ 10^4 \\ \hline 0.0 \\ \hline 5.4 \ 10^5 \\ \hline 5.4 \ 10^5 \end{array}$	$\begin{array}{c} \text{cargo} \\ \hline 75 \\ \hline 2.6 \ 10^6 \\ \hline 3.1 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \hline 3.6 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 5.7 \ 10^4 \\ \hline 0.0 \\ \hline 5.0 \ 10^5 \\ \hline 9.9 \ 10^5 \\ \hline 1.2 \ 10^6 \\ \hline 0.0 \\ \hline 1.4 \ 10^4 \\ \hline 2.8 \ 10^4 \\ \hline 3.4 \ 10^4 \\ \hline 0.0 \\ \hline 6.6 \ 10^5 \end{array}$
Tanker 100000 <i>VBM</i> [kNm] <i>VSF</i> [kN] <i>HBM</i> [kNm] <i>HSF</i> [kN] <i>MT</i> [kNm]	$\begin{array}{c} \mu[deg] \\ \mu_{w}[m] \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 5 \\ 10 \\ 12 \\ 0 \\ 10 \\ 12 \\ 0 \\ 10 \\ 10 \\$	$\begin{array}{c} 0 \\ \hline 0 \\ \hline 2.6 \ 10^6 \\ \hline 4.7 \ 10^6 \\ \hline 6.6 \ 10^6 \\ \hline 7.3 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 7.6 \ 10^4 \\ \hline 7.6 \ 10^4 \\ \hline 1.0 \ 10^5 \\ \hline 0.0 \\ \hline 0.0$	$\begin{array}{r} 45\\ \hline 45\\ \hline 2.6\ 10^6\\ \hline 1.4\ 10^6\\ \hline 2.5\ 10^6\\ \hline 3.4\ 10^6\\ \hline 5.5\ 10^4\\ \hline 3.9\ 10^4\\ \hline 5.4\ 10^4\\ \hline 6.6\ 10^4\\ \hline 0.0\\ \hline 2.8\ 10^5\\ \hline 5.4\ 10^5\\ \hline 6.3\ 10^5\\ \hline 0.0\\ \hline 7.4\ 10^3\\ \hline 1.3\ 10^4\\ \hline 1.5\ 10^4\\ \hline 0.0\\ \hline 3.5\ 10^5\\ \hline 7.3\ 10^5\\ \hline 0.0 \\ \hline 0.0\\ $	$\begin{array}{c} \text{ng, full} \\ \hline 60 \\ \hline 2.6 \ 10^6 \\ \hline 1.6 \ 10^6 \\ \hline 1.5 \ 10^6 \\ \hline 2.1 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 4.2 \ 10^4 \\ \hline 4.6 \ 10^4 \\ \hline 0.0 \\ \hline 4.4 \ 10^5 \\ \hline 8.5 \ 10^5 \\ \hline 1.0 \ 10^6 \\ \hline 0.0 \\ \hline 1.2 \ 10^4 \\ \hline 2.2 \ 10^4 \\ \hline 2.2 \ 10^4 \\ \hline 2.6 \ 10^4 \\ \hline 0.0 \\ \hline 5.4 \ 10^5 \\ \hline 1.1 \ 10^6 \\ \hline 1.1 \ 10^6 \end{array}$	$\begin{array}{c} \text{cargo} \\ \hline 75 \\ \hline 2.6 \ 10^6 \\ \hline 3.1 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \hline 3.5 \ 10^6 \\ \hline 5.5 \ 10^4 \\ \hline 5.7 \ 10^4 \\ \hline 5.7 \ 10^4 \\ \hline 5.7 \ 10^4 \\ \hline 0.0 \\ \hline 5.0 \ 10^5 \\ \hline 9.9 \ 10^5 \\ \hline 1.2 \ 10^6 \\ \hline 0.0 \\ \hline 1.4 \ 10^4 \\ \hline 2.8 \ 10^4 \\ \hline 3.4 \ 10^4 \\ \hline 0.0 \\ \hline 6.6 \ 10^5 \\ \hline 1.3 \ 10^6 \\ \hline \end{array}$

Fascicle XI



Fig.4.a VBMmax [kNm], TK 100000, full cargo



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









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



Fig.4.e MT_{max} [kNm], 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 $h_w=10 \text{ m}, \mu=45 \text{ and } 75 \text{ deg}$, ballast case; -Figs. 6.a-e present the efforts diagrams, for oblique wave $\mu=60 \text{ deg}$, 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	µ[deg]	0	15	60	75	
100000	$h_w[m]$	0	43	00	15	
	0	10.000	10.000	10.000	10.000	
T_m	5	9.547	9.639	9.809	10.421	
[m]	10	9.038	9.222	9.563	10.799	
	12	8.826	9.048	9.457	10.947	
	0	-0.0043	-0.0043	-0.0043	-0.0043	
0[mad]	5	0.0007	0.0002	-0.0009	-0.0049	
[[[rad]	10	0.0074	0.0062	0.0041	-0.0044	
	12	0.0102	0.0088	0.0062	-0.0042	
	0	0.0000	0.0000	0.0000	0.0000	
φ [rad]	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 5.0 Eq		. parameters, sagging, banast			
Tanker 100000	$\mu[deg]$ $h_w[m]$	0	45	60	75
	0	10.000	10.000	10.000	10.000
T_m	5	10.387	10.303	10.145	9.557
[m]	10	10.637	10.526	10.230	9.080
	12	10.782	10.554	10.209	8.845
	0	-0.0043	-0.0043	-0.0043	-0.0043
0[mad]	5	-0.0070	-0.0068	-0.0062	-0.0031
[[[rad]	10	-0.0072	-0.0069	-0.0062	-0.0009
	12	-0.0069	-0.0081	-0.0073	-0.0002
	0	0.0000	0.0000	0.0000	0.0000
	5	0.0000	-0.0008	-0.0016	-0.0037
φ [lau]	10	0.0000	-0.0005	-0.0023	-0.0090
	12	0.0000	-0.0002	-0.0023	-0.0116

aina hallast

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Table 5 h Da







Fig.5.b Sagging design oblique wave, $h_w=10$ m, $\mu=45$ 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





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Table 6.a Max. efforts, hogging, ballast							
Tanker	µ[deg]	0	45	60	75		
100000	h _w [m]	0	43	00	75		
	0	1.4 106	1.4 106	1.4 106	1.4 106		
VBM	5	3.2 106	3.0 106	2.6 106	1.4 106		
[kNm]	10	4.9 106	$4.4 10^6$	3.6 106	1.3 106		
	12	5.6 106	5.0 106	$4.1\ 10^{6}$	1.2 106		
	0	3.9 104	3.9 104	3.9 104	3.9 10 ⁴		
VSF	5	5.0 104	4.9 10 ⁴	$4.7 \ 10^4$	4.0 104		
[kN]	10	6.4 10 ⁴	6.0 104	5.4 10 ⁴	3.9 10 ⁴		
	12	7.3 104	6.6 10 ⁴	5.8 10 ⁴	3.9 10 ⁴		
	0	0.0	0.0	0.0	0.0		
HBM	5	0.0	2.1 105	3.3 105	3.6 10 ⁵		
[kNm]	10	0.0	4.4 105	6.9 10 ⁵	7.4 105		
	12	0.0	5.4 10 ⁵	8.3 105	8.9 10 ⁵		
	0	0.0	0.0	0.0	0.0		
HSF	5	0.0	6.0 10 ³	9.1 10 ³	9.0 10 ³		
[kN]	10	0.0	1.3 104	1.9 104	1.8 104		
	12	0.0	1.6 104	2.4 104	2.2 10 ⁴		
	0	0.0	0.0	0.0	0.0		
MT	5	0.0	3.1 105	5.0 105	6.4 10 ⁵		
[kNm]	10	0.0	$6.0\ 10^{5}$	9.7 10 ⁵	1.3 106		
_	12	0.0	$7.1 \ 10^{5}$	1.2 106	1.6 106		
Table 6 b Max efforts sagging ballast							

 Table 6.b Max. efforts, sagging, ballast

Tanker	µ[deg]	0	15	60	75
100000	h _w [m]	0	43	00	15
	0	1.4 106	1.4 106	1.4 106	1.4 106
VBM	5	1.3 106	1.1 106	9.4 10 ⁵	1.8 106
[kNm]	10	3.6 106	3.0 106	2.1 106	$2.1\ 10^{6}$
	12	$4.5 \ 10^{6}$	$4.0\ 10^{6}$	$2.8\ 10^{6}$	$2.2\ 10^{6}$
	0	3.9 104	3.9 10 ⁴	3.9 10 ⁴	3.9 10 ⁴
VSF	5	3.7 104	3.3 104	3.1 104	3.7 10 ⁴
[kN]	10	6.9 10 ⁴	6.0 104	4.6 104	3.5 104
	12	8.1 104	7.3 104	5.5 104	3.3 104
	0	0.0	0.0	0.0	0.0
HBM	5	0.0	2.0 105	3.1 105	3.5 105
[kNm]	10	0.0	3.7 105	5.9 10 ⁵	6.9 10 ⁵
	12	0.0	4.4 105	6.9 10 ⁵	8.2 105
	0	0.0	0.0	0.0	0.0
HSF	5	0.0	4.9 10 ³	7.8 10 ³	9.3 10 ³
[kN]	10	0.0	9.1 10 ³	1.4 104	1.9 104
	12	0.0	1.1 104	1.7 104	2.3 10 ⁴
	0	0.0	0.0	0.0	0.0
MT	5	0.0	3.4 105	5.3 105	6.5 10 ⁵
[kNm]	10	0.0	$7.2 \ 10^{5}$	1.1 106	1.3 106
	12	0.0	8.8 105	1.3 106	1.5 106

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Fig.7.a VBMmax [kNm], TK 100000, ballast BALL TANK 100000 tdw Max VSF (kN) EDW-Hogging

> 5 6

4

8 9 10 11

hw (n

0.0

Zfore 25.0

20.0

15.0

10.0

5.0 0.0 2 з 4 5 6 7

← 0 deg (H) ← 15 deg (H)
 ← 30 deg (H) ← 45 deg (H)
 ← 75 deg (H)
 ← 75 deg (H)

PS (m) BALL TANK 100000 tdw Max Zfo

2 3 4 5 6 7 8

Fig.7.f Zmax [m], aft-fore, TK 100000, ballast

1

1

7

VSF (k 1.0E+05

9.0E+04

8.0E+04

7.0E+04 6.0E+04

5.0E+04

4.0E+04

3.0E+04

2.0E+04

1.0E+04 0.0E+00

VSF (k 1.2E+05

1.0E+0

8.0E+04

6.0E+04

4.0E+04

2.0E+04

0.0E+00

2 3

BALL TANK

3 4 5 6 7 8 9 10 11









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12

10 11

e_PS (m) EDW-Hogg & Sagg

9 10 11 12

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

Ta	able 7.	. <i>h</i> _w [m]	limits,	TK 100	000, bot	h cases
μ	VBM	VSF	HBM	HSF	MT	FB
Ful	l cargo	case : H	ogging o	blique wa	aves 90:1	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
Ful	l cargo	case : Sa	agging ol	olique wa	ves 90:1	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
Bal	last cas	e : Hog	ging obli	que wave	es 90: F	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
Bal	last cas	e : Sagg	ging oblic	que wave	s 90: F	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 $\mu > 30$ deg.

3. In the case of ballast, the global strength restrictions are similar in hogging and sagging conditions and occur for heading angle $\mu > 45$ 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).

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).
 Extended studies shall be coupled with 3D models and other relevant evaluation criteria.

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