THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620, e-ISSN 2668-3156
2018

ON A RIVER BARGE TYPE EUROPE B2 1740T OPERATION LIMITS EVALUATION IN IRREGULAR WAVES

Elisabeta Burlacu
"Dunarea de Jos" University of Galati,
Faculty of Naval Architecture, Galati,
47 Domneasca Street, 800008, Romania,
E-mail: elisabeta.burlacu@ugal.ro

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

ABSTRACT

The barge type Europe B2 1740T is designed for operation on river routes. According to the cargo loading cases, on Danube River the significant wave height limits for operation in safety conditions have to be evaluated using the dynamic criteria in irregular waves. The study covers three main loading cases, using an eigen program package DYN-OSC for dynamic analysis. A full range of wave heading angles and three speeds are considered. The dynamic criteria are formulated for heave, roll and pitch motions plus accelerations, and results the barge reference operation limits.

Keywords: Europe B2 1740T barge, dynamic analysis, irregular waves.

1. INTRODUCTION

The operation limits in irregular waves navigation conditions, for each specific loading case of the Europe B2 1740T barge [4], have to be assessed by dynamic criteria [1,2].

For this study we use the eigen program package DYN-OSC [5], developed by a linear hydrodynamic and Lewis models [1], with ITTC wave power density spectrum (Fig.2).

The dynamic criteria are formulated in terms of most probable admissible amplitudes, *RMS* values, on motions and accelerations for ζ heave, φ roll and θ pitch [5].

$$\begin{aligned}
&RMS_{\zeta\max}\big|_{\beta} = H_{\beta} - f_s - T_{\beta} \geq RMS_{\zeta}\,;\ \beta = a,m,f \\
&RMSac_{\zeta\max} = 0.1g \geq RMS_{ac\zeta}\ ;\ f_s = 0.3m \\
&RMS_z = RMS_{\zeta} + \left(L/2 + \delta \cdot x_F\right) \cdot RMS_{\theta} + \\
&+B/2 \cdot RMS_{\varphi} + H_s/4\ ;\ \ \delta \in \{+1, 0, -1\} \\
&RMS_{\theta\max} = 2\ \deg \geq RMS_{\theta} \\
&RMSac_{\theta\max} = 0.1g/(L/2) \geq RMS_{ac\theta} \\
&RMS_{\varphi\max} = 4\ \deg \geq RMS_{\varphi} \\
&RMSac_{\varphi\max} = 0.1g/(B/2) \geq RMS_{ac\varphi}
\end{aligned} \tag{1}$$

where: *a, m, f* are the aft, mid and fore reference positions; *L, B, T* are the barge length, breadth and draught; x_F is the water plane centre longitudinal position [3].

Table 1 presents the Europe B2 1740T barge main characteristics [4], with offset lines in Fig.1 and dynamic criteria in Table 2.

Table 1. Barge main characteristics [4]

L [m]	B [m]	H_a [m]	H_m [m]	H_f [m]
76.5	10.96	3.20	3.20	3.90
$H_{s\ max}$[m]	μ [deg]	v[km/h]	Ns	N_P
0-2 (0.25)	0-360 (5)	0, 5, 10	405	21992
Case	Δ [t]	T_m[m]	x_F[m]	z_G[m]
Barge_1	405.95	0.55	-3.586	0.810
Barge_2	1540.95	2.00	-1.616	1.134
Barge_3	2108.40	2.70	-0.885	1.448
GM_{T0}[m]:	17.682	5.011	3.765	g[m/s^2]
J_x[tm^2]:	4152.36	16085.6	22578.9	9.81

Table 2. Dynamic criteria for barge analysis

Case	$RMS_{z\,a}$	RMS_{zm}	$RMS_{z\,f}$	RMS_{θ}	RMS_{φ}
Barge_1	2.35	2.35	3.05	0.0349	0.0698
Barge_2	0.90	0.90	1.60		
Barge_3	0.20	0.20	0.90		
$RMS_{ac\zeta}$	0.9810	$RMS_{ac\theta}$	0.0256	$RMS_{ac\varphi}$	0.1790

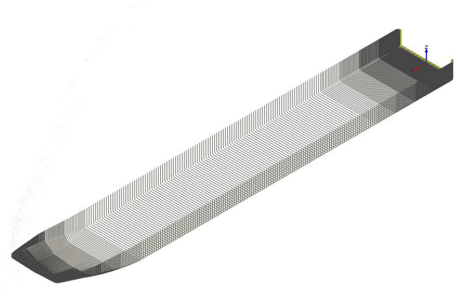

Fig.1 Barge Europe B2 1740T 3D lines [4]

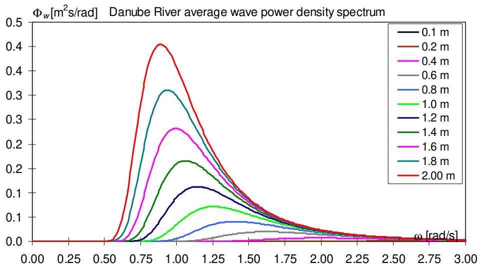

Fig.2 The ITTC wave spectra for $H_s \leq 2$m [1]

Table 3 presents the natural oscillation circular frequencies and Fig.3 presents the transversal stability diagrams for the three loading cases. Up to 10 deg. the transversal stability diagrams are linear, so that a non-linear roll model is not required.

Table 3. The natural oscillation frequencies for barge Europe B2 1740T, three cargo cases

Case	ω_ζ[rad/s]	ω_θ[rad/s]	ω_φ[rad/s]
Barge_1	1.603	1.507	3.999
Barge_2	1.365	1.341	1.176
Barge_3	1.251	1.244	1.433

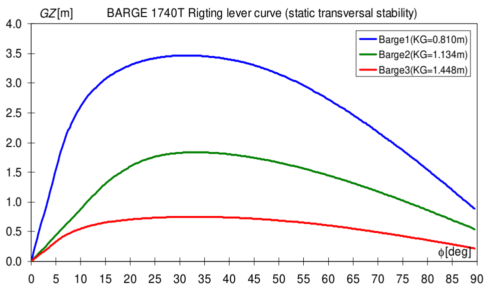

Fig.3 The transversal stability diagrams for barge Europe B2 1740T, three cargo cases

2. THE DYNAMIC ANALYSIS FOR LIGHT DISPLACEMENT CASE

In the case of light displacement, Barge_1 (Table 1) the following dynamic results are obtained:

-Figs.3.a-c the response amplitude operators, v=10km/h (F_n=0.102), for the main motions heave, roll and pitch, for case 1;

-Figs.4.a-h the maximum most probable amplitudes, *RMS* values, compared to the dynamic criteria (Table 2), for case 1;

-Figs.5.a,b the operation limits by dynamic criteria, in terms of limit significant wave height H_s and Beaufort sea state, speeds v=0, 5, 10 km/h and μ=0-360 deg., for case 1.

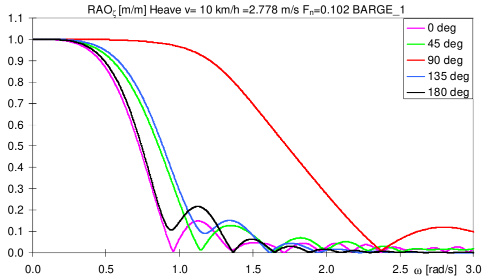

Fig.3.a Heave *RAO*, v=10km/h, case 1

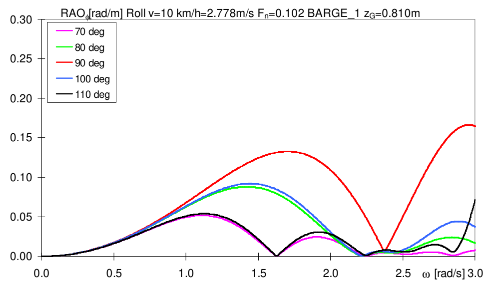

Fig.3.b Roll *RAO*, v=10km/h, case 1

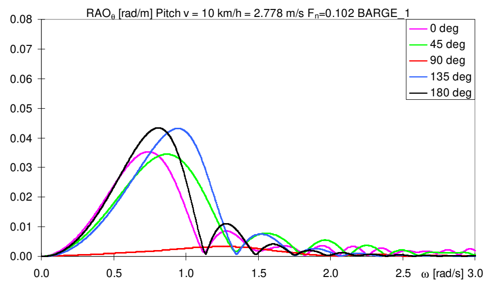

Fig.3.c Pitch *RAO*, v=10km/h, case 1

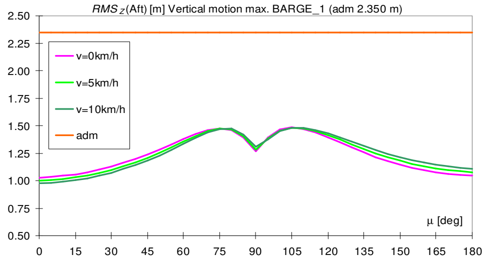

Fig.4.a Vertical *RMS* [m] aft max., case 1

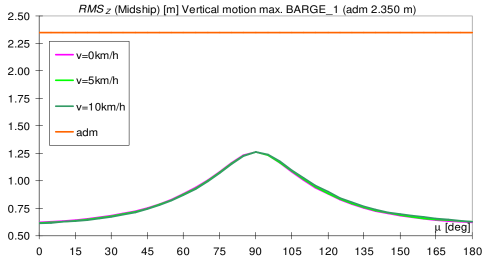

Fig.4.b Vertical *RMS* [m] mid max., case 1

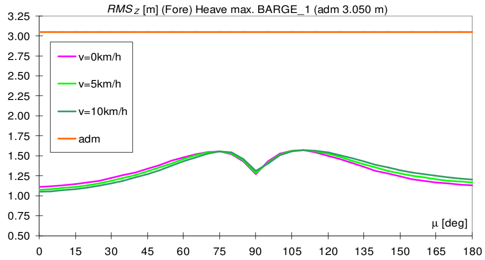

Fig.4.c Vertical *RMS* [m] fore max., case 1

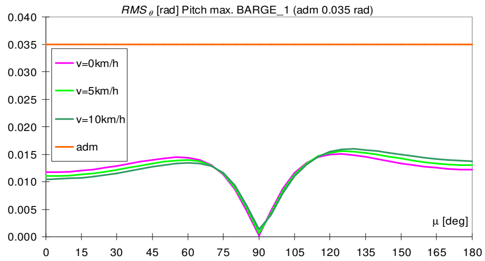

Fig.4.d Pitch *RMS* [rad] max., case 1

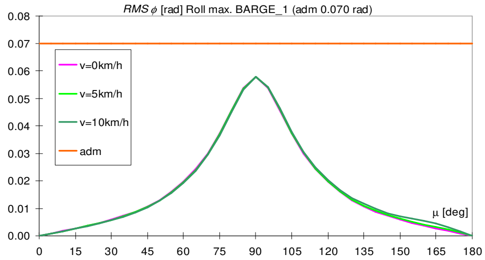

Fig.4.e Roll *RMS* [rad] max., case 1

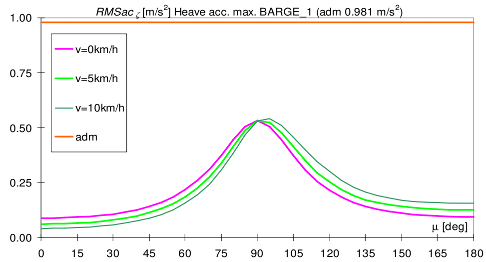

Fig.4.f Vertical acc. *RMS* [m/s^2] max., case 1

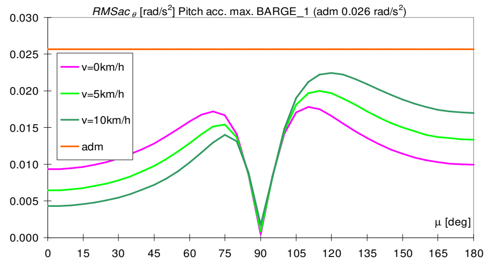

Fig.4.g Pitch acc. *RMS* [rad/s^2] max., case 1

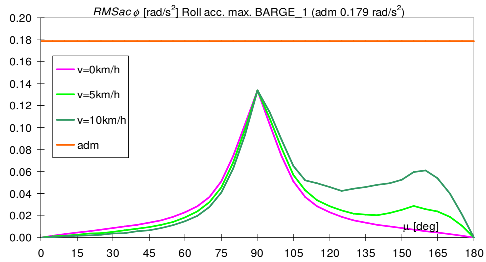

Fig.4.h Roll acc. *RMS* [rad/s^2] max., case 1

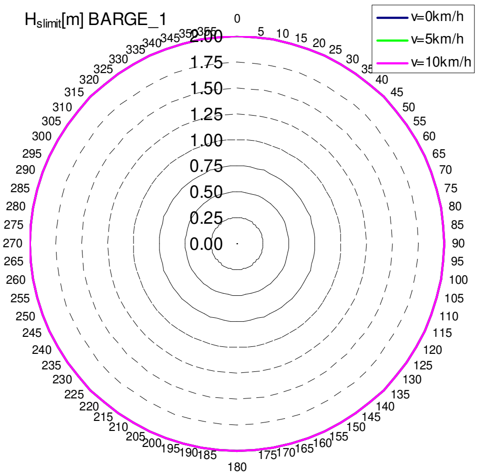

Fig.5.a The operation limits H_s [m], dynamic criteria, case 1

3. THE DYNAMIC ANALYSIS FOR COMMON CARGO LOAD CASE

In the case of common cargo load case, Barge_2 (Table 1) the following dynamic results are obtained:

-Figs.6.a-c the response amplitude operators, v=10km/h (F_n=0.102), for the main motions heave, roll and pitch, for case 2;

-Figs.7.a-h the maximum most probable amplitudes, *RMS* values, compared to the dynamic criteria (Table 2), for case 2;

-Figs.8.a,b the operation limits by dynamic criteria, in terms of limit significant wave height H_s and Beaufort sea state, speeds v=0, 5, 10 km/h and μ=0-360 deg., for case 2.

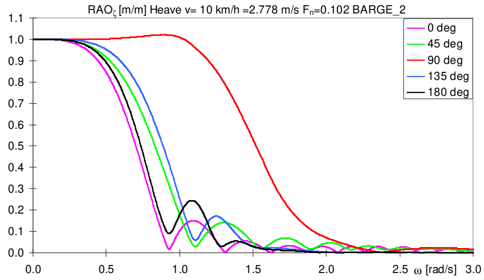

Fig.6.a Heave *RAO*, v=10km/h, case 2

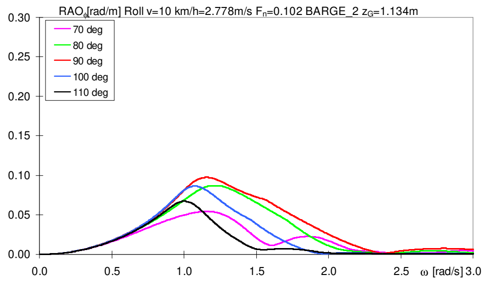

Fig.6.b Roll *RAO*, v=10km/h, case 2

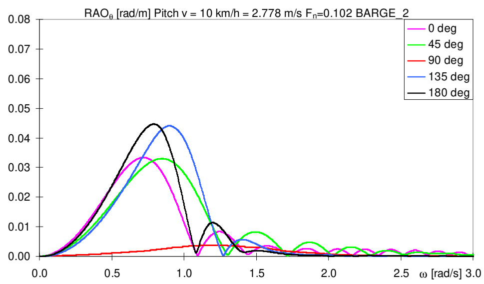

Fig.6.c Pitch *RAO*, v=10km/h, case 2

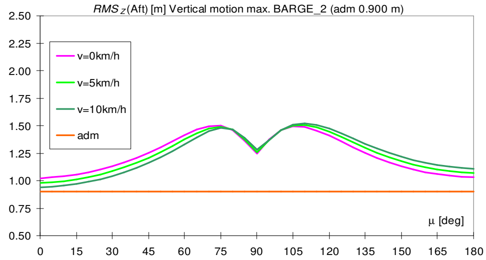

Fig.7.a Vertical *RMS* [m] aft max., case 2

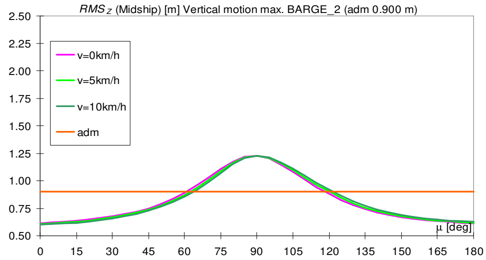

Fig.7.b Vertical *RMS* [m] mid max., case 2

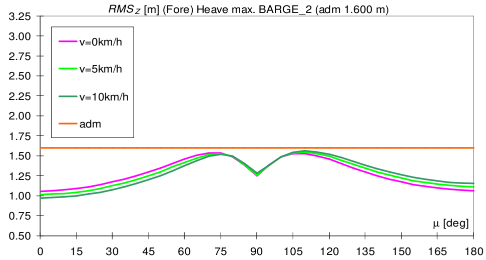

Fig.7.c Vertical *RMS* [m] fore max., case 2

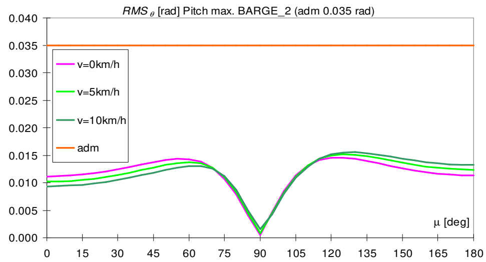

Fig.7.d Pitch *RMS* [rad] max., case 2

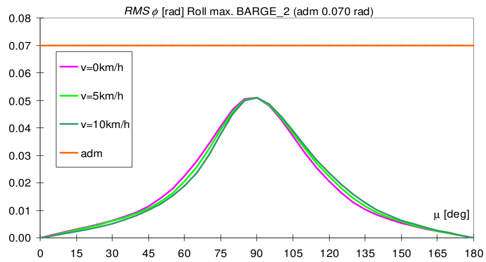

Fig.7.e Roll *RMS* [rad] max., case 2

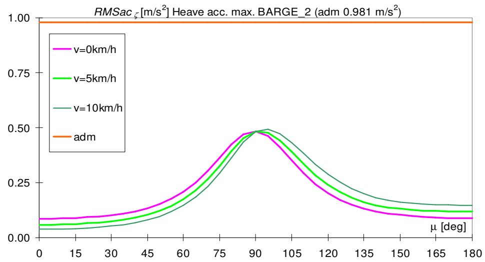

Fig.7.f Vertical acc. *RMS* [m/s^2] max., case 2

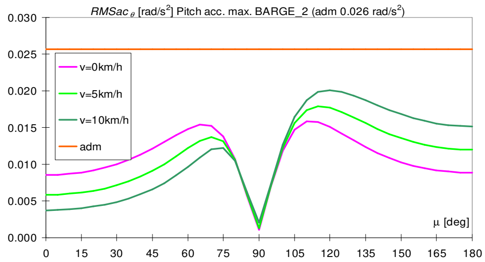

Fig.7.g Pitch acc. *RMS* [rad/s^2] max., case 2

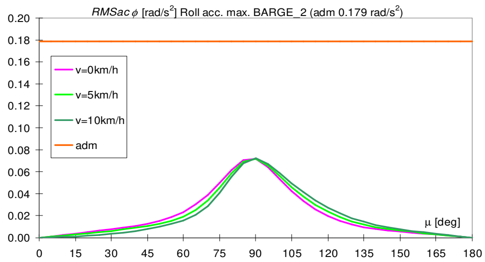

Fig.7.h Roll acc. *RMS* [rad/s^2] max., case 2

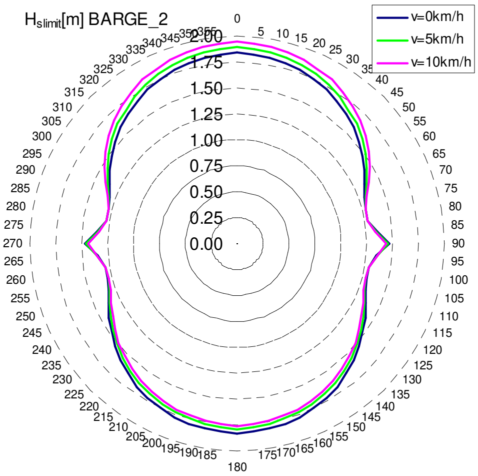

Fig.8.a The operation limits H_s [m], dynamic criteria, case 2

4. THE DYNAMIC ANALYSIS FOR FULL CARGO LOAD CASE

In the case of full cargo load case, Barge_3 (Table 1) the following dynamic results are obtained:

-Figs.9.a-c the response amplitude operators, v=10km/h (F_n=0.102), for the main motions heave, roll and pitch, for case 3;

-Figs.10.a-h the maximum most probable amplitudes, *RMS* values, compared to the dynamic criteria (Table 2), for case 3;

-Figs.11.a,b the operation limits by dynamic criteria, in terms of limit significant wave height H_s and Beaufort sea state, speeds v=0, 5, 10 km/h and μ=0-360 deg., for case 3.

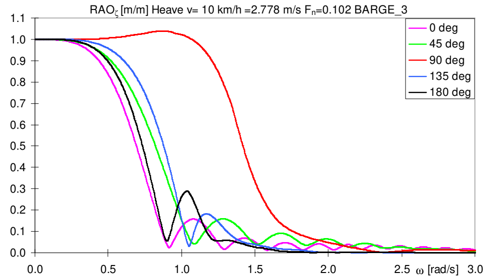

Fig.9.a Heave *RAO*, v=10km/h, case 3

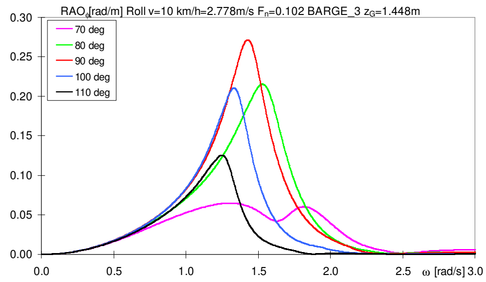

Fig.9.b Roll *RAO*, v=10km/h, case 3

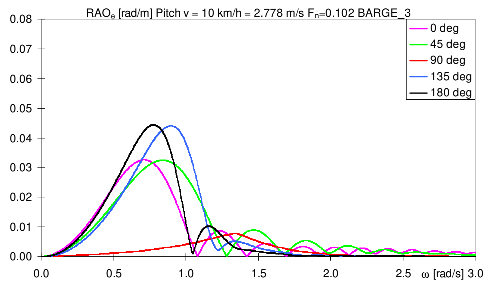

Fig.9.c Pitch *RAO*, v=10km/h, case 3

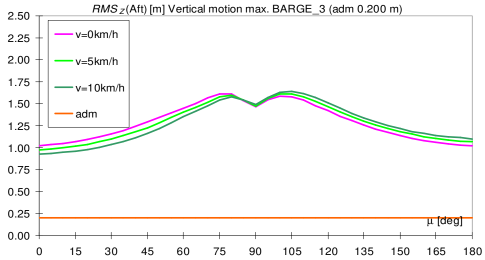

Fig.10.a Vertical *RMS* [m] aft max., case 3

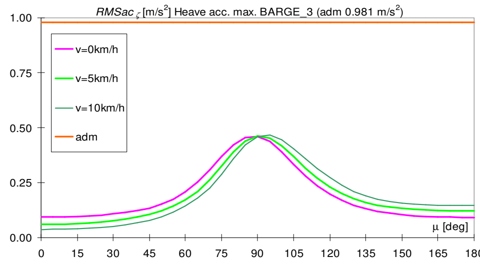

Fig.10.f Vertical acc.*RMS* [m/s^2] max.,case 3

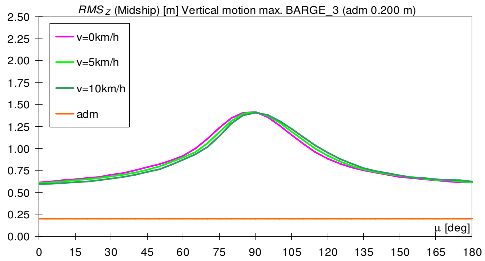

Fig.10.b Vertical *RMS* [m] mid max., case 3

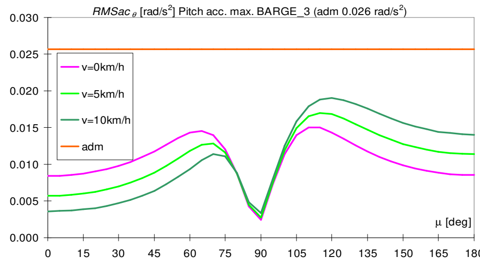

Fig.10.g Pitch acc. *RMS* [rad/s^2] max., case 3

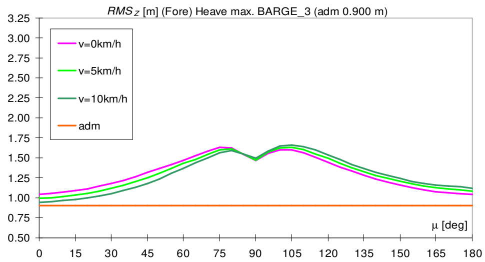

Fig.10.c Vertical *RMS* [m] fore max., case 3

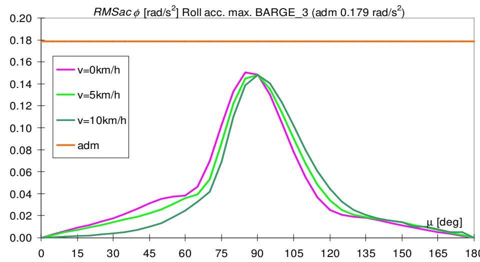

Fig.10.h Roll acc. *RMS* [rad/s^2] max., case 3

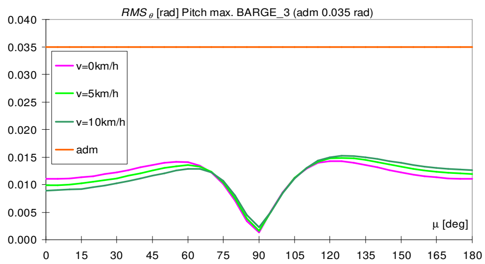

Fig.10.d Pitch *RMS* [rad] max., case 3

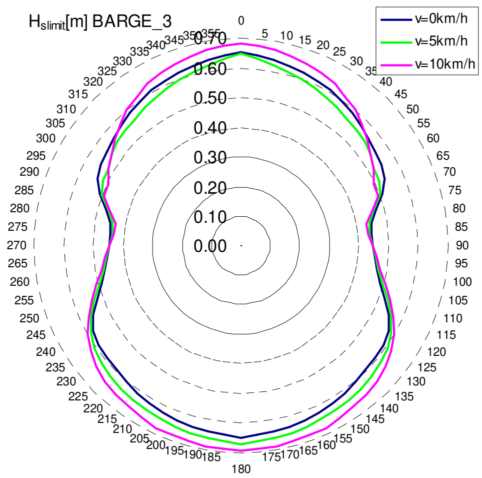

Fig.11.a The operation limits H_s [m], dynamic criteria, case 3

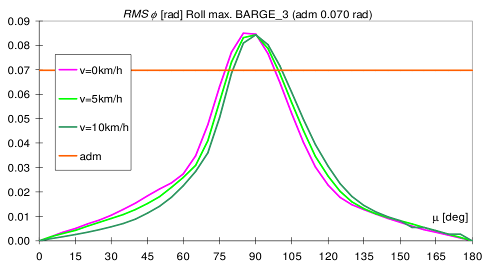

Fig.10.e Roll *RMS* [rad] max., case 3

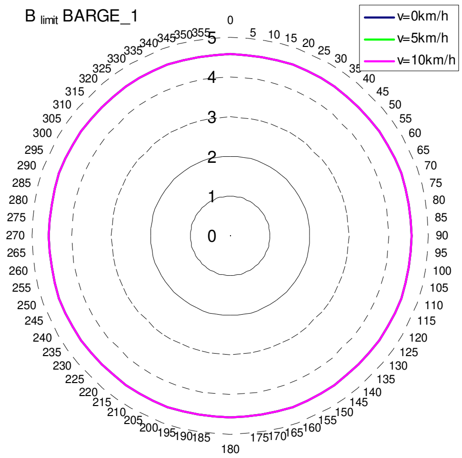

Fig.5.b Beaufort sea state limits, case 3

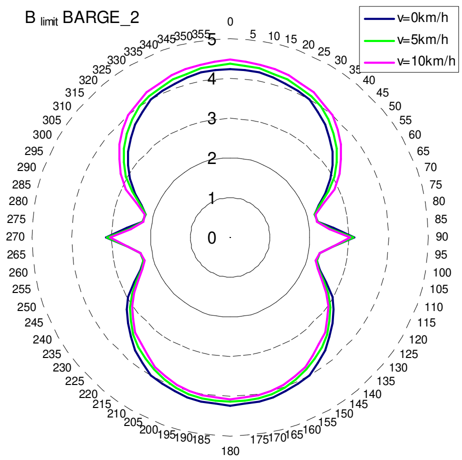

Fig.8.b Beaufort sea state limits, case 2

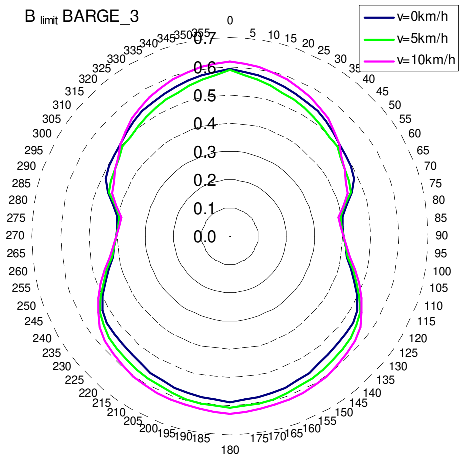

Fig.11.b Beaufort sea state limits, case 3

5. CONCLUSIONS

Tables 4.a,b,c include the maximum most probable amplitudes, *RMS* statistical values, for main motions and accelerations, compared to the dynamic criteria (Table 2).

Table 4.a. Maximum *RMS* amplitudes, for H_s[m]=2m, μ=0-360 deg., v=0 km/h, F_n=0

Criteria/Case	Barge_1	Barge_2	Barge_3
$RMS_{z\,max}$ aft	1.483	1.500	1.611
adm	2.35	0.90	0.20
%	-36.91%	**66.62%**	**>100%**
$RMS_{z\,max}$ mid	1.263	1.228	1.412
adm	2.35	0.90	0.20
%	-46.27%	**36.42%**	**>100%**
$RMS_{z\,max}$fore	1.567	1.537	1.629
adm	3.05	1.60	0.90
%	-48.63%	-3.95%	**81.03%**
$RMS_{\theta\,max}$	0.0150	0.0146	0.0143
adm	0.0349	0.0349	0.0349
%	-57.02%	-58.27%	-59.13%
$RMS_{\varphi\,max}$	0.0577	0.0510	0.0851
adm	0.0698	0.0698	0.0698
%	-17.31%	-27.01%	**21.90%**
$RMS_{\zeta\,max}$ acc	0.532	0.483	0.460
adm	0.9810	0.9810	0.9810
%	-45.77%	-50.73%	-53.10%
$RMS_{\theta\,max}$ acc	0.018	0.016	0.015
adm	0.0256	0.0256	0.0256
%	-30.53%	-38.34%	-41.48%
$RMS_{\varphi\,max}$ acc	0.134	0.072	0.151
adm	0.1790	0.1790	0.1790
%	-25.19%	-59.82%	-15.81%
H_s / B limit	**2.000/4.58**	**1.278/2.21**	**0.440/0.40**

Table 4.b. Maximum *RMS* amplitudes, for H_s[m]=2m,μ=0-360 deg.,v=5 km/h,F_n=0.051

Criteria/Case	Barge_1	Barge_2	Barge_3
$RMS_{z\,max}$ aft	1.481	1.507	1.611
adm	2.35	0.90	0.20
%	-36.97%	**67.40%**	**>100%**
$RMS_{z\,max}$ mid	1.262	1.228	1.411
adm	2.35	0.90	0.20
%	-46.28%	**36.40%**	**>100%**
$RMS_{z\,max}$fore	1.572	1.549	1.630
adm	3.05	1.60	0.90

%	-48.46%	-3.19%	**81.16%**
$RMS_{\theta max}$	0.0155	0.0152	0.0149
adm	0.0349	0.0349	0.0349
%	-55.47%	-56.55%	-57.44%
$RMS_{\varphi max}$	0.0577	0.0509	0.0844
adm	0.0698	0.0698	0.0698
%	-17.31%	-27.02%	**20.88%**
$RMS_{\zeta max}$ acc	0.531	0.483	0.461
adm	0.9810	0.9810	0.9810
%	-45.85%	-50.73%	-52.97%
$RMS_{\theta max}$ acc	0.020	0.018	0.017
adm	0.0256	0.0256	0.0256
%	-21.87%	-30.16%	-33.75%
$RMS_{\varphi max}$ acc	0.134	0.072	0.148
adm	0.1790	0.1790	0.1790
%	-25.19%	-59.80%	-17.27%
H_s / B limit	**2.000/4.58**	**1.280/2.22**	**0.435/0.39**

Table 4.c. Maximum *RMS* amplitudes, for H_s[m]=2m,μ=0-360deg.,v=10km/h,F_n=0.102

Criteria/Case	Barge_1	Barge_2	Barge_3
$RMS_{z\ max}$ aft	1.478	1.521	1.643
adm	2.35	0.90	0.20
%	-37.09%	**68.97%**	**>100%**
$RMS_{z\ max}$ mid	1.262	1.226	1.409
adm	2.35	0.90	0.20
%	-46.31%	**36.25%**	**>100%**
$RMS_{z\ max}$fore	1.573	1.563	1.662
adm	3.05	1.60	0.90
%	-48.44%	-2.33%	**84.71%**
$RMS_{\theta max}$	0.0159	0.0155	0.0152
adm	0.0349	0.0349	0.0349
%	-54.39%	-55.55%	-56.36%
$RMS_{\varphi max}$	0.0577	0.0509	0.0843
adm	0.0698	0.0698	0.0698
%	-17.31%	-27.03%	**20.71%**
$RMS_{\zeta max}$ acc	0.540	0.493	0.466
adm	0.9810	0.9810	0.9810
%	-44.92%	-49.71%	-52.49%
$RMS_{\theta max}$ acc	0.022	0.020	0.019
adm	0.0256	0.0256	0.0256
%	-12.51%	-21.60%	-25.87%
$RMS_{\varphi max}$ acc	0.134	0.072	0.148
adm	0.1790	0.1790	0.1790
%	-25.19%	-59.78%	-17.41%
H_s / B limit	**2.00/ 4.58**	**1.276/2.20**	**0.431/0.39**

From the dynamic analysis in irregular waves of the Europe B2 1740T barge results:

-In the case of light displacement there are no restrictions from the dynamic criteria, so the navigation class is IN(2.0).

-In the case of common cargo load the restrictions by dynamic criteria occur on vertical motions at aft and amidships, so the navigation class is IN(1.2).

-In the case of full cargo load the restrictions by dynamic criteria occur on vertical motions at aft, amidships and fore, plus on the roll motion, so the navigation class is IN(0.4).

If the freeboard safety condition f_s is reduced from 0.30m to 0.10m, then in this case the navigation class becomes IN(0.6), that has to be accepted by special approval.

-Because $F_{n\ max}$≈0.1 the speed influence is reduced on the dynamic responses in the three analyzed cargo loading cases.

Acknowledgements

In this study the program codes package were developed in the frame of Research Centre of the Naval Architecture Faculty from "Dunarea de Jos" University of Galati.

We express our thanks to NAVROM S.A. Galati for granting us the data for the barge type B1740T Europe 2B [4].

REFERENCES

[1]. **Bertram, V**, *"Practical ship hydrodynamics"*, Butterworth Heinemann, Oxford, 2000.

[2]. **BV**,*"Rules for the classification of steel ships"*, Bureau Veritas, Paris, 2017.

[3]. **Bidoae, R., Ionas, O.,***"Ship theory",* E.D.P. Publishing House, Bucharest, 2004.

[4]. **Pacuraru, F., Domnisoru, L., Popescu, G., Burlacu, E.,** *"Comparative analysis of the barge type B1740t Europe B2 numerical models on processing the draught survey data*", The Annals of "Dunarea de Jos" University of Galati, Fascicle XI Shipbuilding, pp.19-24, 2016.

[5]. **Domnisoru, L.,***"Ship dynamics. Oscillations and vibrations"*, Technical Publishing House, Bucharest 2001.

Paper received on December 20th, 2018