ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620
2015

NAVIGATION SAFETY ASSESSMENT BASED ON SHORT TERM SEAKEEPING LIMIT CRITERIA FOR A FEEDER TYPE CONTAINER SHIP OF 1300 TEU

Carmen Gasparotti
"Dunarea de Jos" University of Galati,
Faculty of Naval Architecture, Galati,
47 Domneasca Street, 800008, Romania,
E-mail: carmen.gasparotti@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

This study presents the seakeeping behaviour of a feeder type container ship of 1300 TEU on three navigation scenario routes in the Black Sea. The routes are selected in order to cover the west costal route, the west - south coastal to north - east route, the west - south - east coastal route. The numerical analysis has two interlinked parts: the short term seakeeping analysis and the route scenarios analysis, taking into account the seakeeping limit criteria on heave, pitch and roll motions. The container ship is considered with the speed range of 10 - 20 knots, and the Black Sea state data is numerically predicted for a short term period of 3-5 days in several reference areas included in the scenario routes. The numerical analyses of the container ships dynamics are based on own in-house codes. The study results make possible to identify the navigation restrictions on the selected routes.

Keywords: feeder type container ship, short term seakeeping, Black Sea area, navigation sea routes.

1. INTRODUCTION

The navigation safety on the commercial sea routes is one of the main task for the ship's classification societies [1],[5]. According to the ship type and sea area, based on short term seakeeping analyses carried out for different ship heading angles, speed, sea state and position in specific areas, the extreme navigation conditions are modelled.

The short term seakeeping analyses are carried out for numerical wave spectra developed for the Black Sea area [8]. As study case, a feeder type container ship of 1300 TEU [6],[4] is considered.

Using the short term seakeeping response and imposing specific motions and accelerations limit criteria, several navigation route scenarios are analyzed. The navigation restrictions are obtained, in order to ensure safety on the sea routes.

2. THE FLOWCHART OF THE SEA ROUTES NUMERICAL ANALYSIS

The analysis from this study is based on the numerical method with the main flow chart presented in Figure 1. The numerical method includes the following steps:

- *input of ship data*: ship type and speed range u_s, mass diagram $m_x(x)$ $x=0\div L$ and CAD offset-lines $y_s(x,z)$, $z=0\div H(x)$, $x=0\div L$, correlated to the number of the stations over the ship's length L used for the numerical hull model;
- *input of wave data*: wave power density spectrum $S_{\zeta w}(\omega)$, $\omega=0\div\omega_{max}$ for the relevant sea states (H_s,T_m) and locations P_i, $i=1,n$ in the sea area;
- *input of navigation scenarios*: draw up of several navigation scenarios NS_j, $j=1,m$ specific to the sea area for the commercial ship;

- *response amplitude operators computation*: for the heave, pitch and roll motions the $RAO_\zeta(\omega_e)$, $RAO_\theta(\omega_e)$, $RAO_\varphi(\omega_e)$ $\omega_e=0\div\omega_{e\ max}$ function to the ship's heading angle $\mu=0\div360$ deg., speed $u_s=0\div u_{max}$ and loading case Δ are obtained based on own code DYN_OSC [3];
- *response spectra of ship motions*: based on the wave spectra [2] for a given sea state and location, with response amplitude operators and DYN_OSC [3] program, the response spectra result:

$$S_{\zeta,\theta,\varphi}(\omega_e)=RAO^2_{\zeta,\theta,\varphi}(\omega_e)\cdot S_{\zeta w}(\omega_e)\Big|_{Tm,Hs}$$
$$\omega_e=\omega-k\,u_s\cos\mu\ ;\ k=\omega^2/g \quad (1)$$

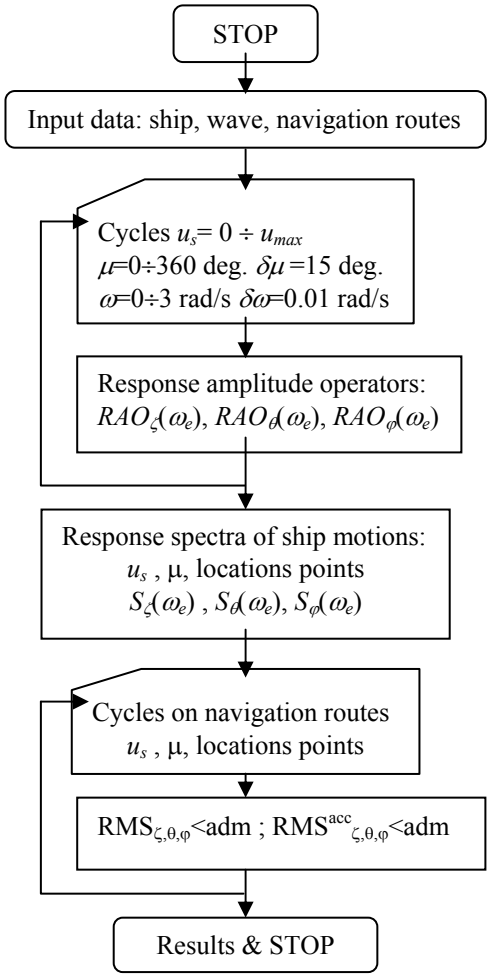

Fig.1 The flowchart of the numerical analysis.

- *navigation route scenarios evaluation*: for a selected route and considering the correlation between the reference locations, the seakeeping restrictions are evaluated by imposing the limit criteria on the statistical most probable values of motions and accelerations amplitudes, root mean square RMS values, using the NBS program code [7]: (2)

$$RMS_{\zeta,\theta,\varphi}=\left(\int_0^{\omega_{e\max}}S_{\zeta,\theta,\varphi}(\omega_e)d\omega_e\right)^{0.5}\le adm_{\zeta,\theta,\varphi}$$

$$RMS^{acc}_{\zeta,\theta,\varphi}=\left(\int_0^{\omega_{e\max}}\omega^4 S_{\zeta,\theta,\varphi}(\omega_e)d\omega_e\right)^{0.5}\le adm^{acc}_{\zeta,\theta,\varphi}$$

- *output results:* the locations on the navigation route where seakeeping restrictions occur.

3. THE NUMERICAL MODEL OF THE 1300 TEU CONTAINER SHIP

The study is carried out on a feeder type container ship of 1300 TEU with the CAD offset lines in Figure 2 and the main characteristics in Table 1.`

Figures 3÷5 present the response amplitude operators for heave, pitch and roll motions of the 1300 TEU container ship, for the reference maximum speed of 20 knots and heading angle $\mu=0\div180$ deg., $\delta\mu=15$ deg.

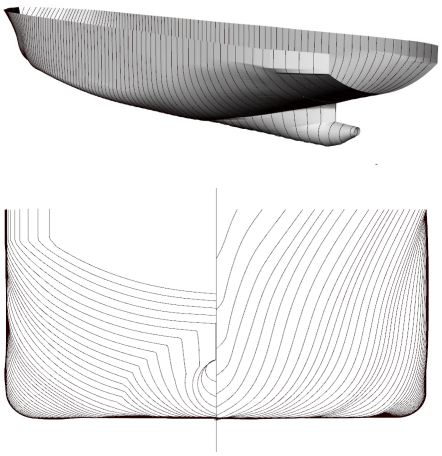

Fig.2 The offset lines of the feeder type container ship of 1300 TEU [6]

Table 1. The container ship main data

L[m]	149.5	μ [deg.]	0÷360
B [m]	23.6	$\delta\mu$ [deg.]	15
H [m]	13.5	N_e	51
T [m]	7.29	ω_ζ[rad/s]	0.851
u_s [knots]	0÷20	ω_θ[rad/s]	0.845
Δ [t]	18000	ω_φ[rad/s]	0.455
x_G [m]	71.43	Wave spectra	Back Sea

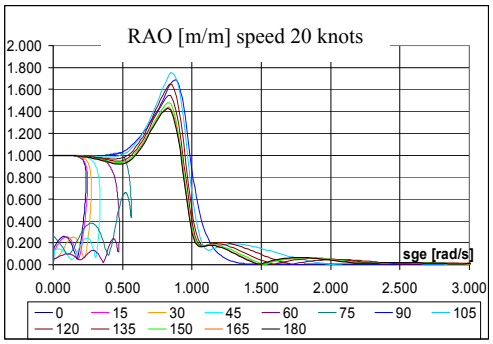

Fig.3. $RAO_\zeta(\omega_e)$ heave motion, container ship 1300 TEU, u_s=20 knots, μ=0÷180 deg.

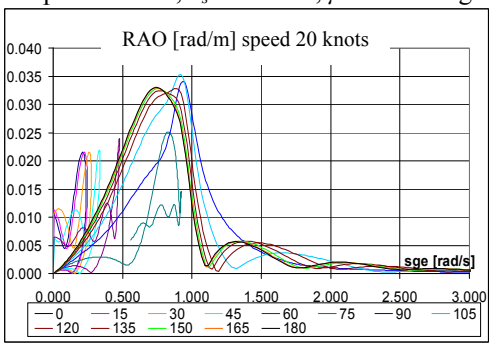

Fig.4. $RAO_\theta(\omega_e)$ pitch motion, container ship 1300 TEU, u_s=20 knots, μ=0÷180 deg.

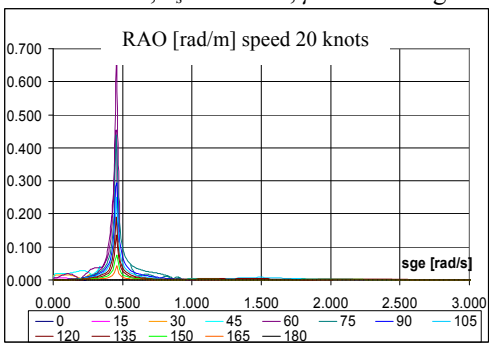

Fig.5. $RAO_\varphi(\omega_e)$ roll motion, container ship 1300 TEU, u_s=20 knots, μ=0÷180 deg.

In Figs. 6÷8 are presented some of the short term numerical wave spectra by WAMIT wave model [8] for different waves significant heights H_s[m] and average periods T_m[s], for the areas in the Black Sea that were selected on the navigation route scenarios (Figs.9÷11).

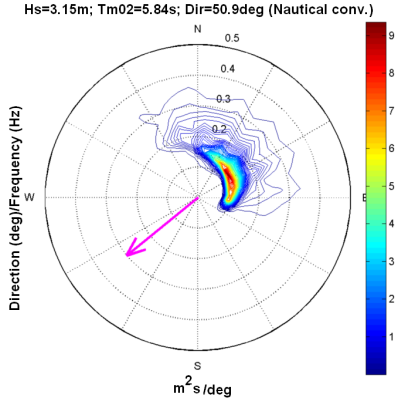

Fig.6 Black Sea spectra,H_s=3.15m,T_m=5.84s[8]

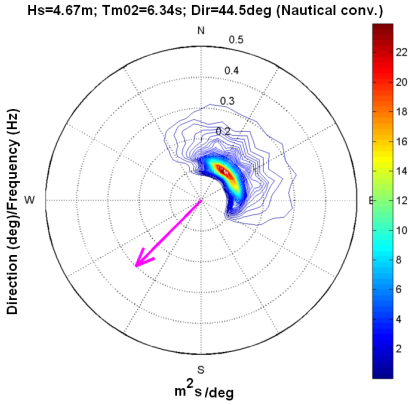

Fig.7 Black Sea spectra,H_s=4.67m,T_m=6.34s[8]

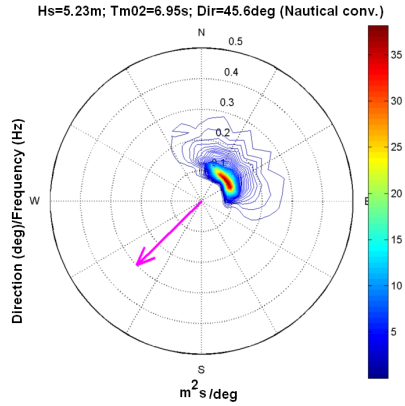

Fig.8 Black Sea spectra,H_s=5.23m,T_m=6.95s[8]

4. THE NAVIGATION ROUTE SCENARIOS EVALUATION FOR THE 1300 TEU CONTAINER SHIP

Taking into account the specific short term seakeeping limit criteria on the heave, pitch, roll motions and accelerations (2), three navigation route scenarios are assessed (Figs 9÷11), for the 1300 TEU container ship and the Back Sea numerical wave spectra (section 3).

The ship is considered at maximum speed of 20 knots over all the routes.

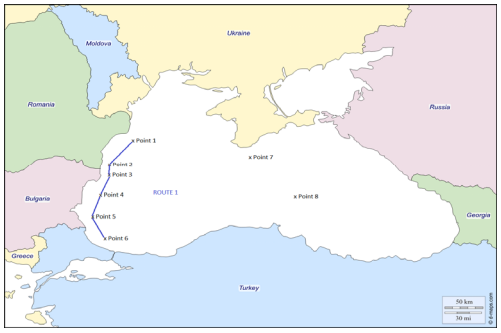

Fig.9 Scenario I - the west costal route, 1300 TEU container ship, B.S. map [9]

Table 2. Route scenario I assessment

Departure day & hour	*Restriction [km]zones distances*	*Heading angle μ [deg]*	*Restriction route segment*	*Not satisfied criteria*	*Not restricted route seg.*
D1: H00	94.8	65	P1-P2	roll	restricted
	24.2	70	P2-P3	roll	restricted
	55.9	75	P4-P5	roll	restricted
D1: H03	94.8	65	P1-P2	roll	restricted
	89.7	55	P3-P4	roll	restricted
	55.9	75	P4-P5	roll	restricted
D1: H06	94.8	65	P1-P2	roll	restricted
	89.7	55	P3-P4	roll	restricted
	55.9	65	P4-P5	roll	restricted
D1: H09	94.8	65	P1-P2	roll	restricted
	89.7	55	P3-P4	roll	restricted
	55.9	60	P4-P5	roll	restricted
D1: H12	94.8	65	P1-P2	roll	P1-P4-P5-P6
D1: H15	94.8	70	P1-P2	roll	P1-P4-P5-P6
D1: H18	94.8	70	P1-P2	roll	P1-P4-P5-P6
D1: H21	94.8	70	P1-P2	roll	P1-P4-P5-P6
D2: H00	94.8	65	P1-P2	roll	P1-P4-P5-P6
D2: H03	94.8	65	P1-P2	roll	P1-P4-P5-P6
D2: H06	94.8	65	P1-P2	roll	P1-P4-P5-P6
	24.2	70	P2-P3	roll	
D2: H09	94.8	55	P1-P2	roll	P1-P4-P5-P6
	24.2	65	P2-P3	roll	
D2: H12	94.8	55	P1-P2	roll	P1-P4-P5-P6
	24.2	60	P2-P3	roll	
D2: H15	94.8	55	P1-P2	roll	P1-P4-P5-P6
	24.2	60	P2-P3	roll	
D2: H18	94.8	55	P1-P2	roll	P1-P4-P5-P6
	24.2	65	P2-P3	roll	
D2: H21	94.8	65	P1-P2	roll	P1-P4-P6
	55.9	55	P4-P5	roll	
D3: H00	94.8	70	P1-P2	roll	P1-P5-P6
	55.9	60	P4-P5	roll	
D3: H03	94.8	70	P1-P2	roll	P1-P5-P6
	55.9	60	P4-P5	roll	
D3: H06	94.8	70	P1-P2	roll	P1-P5-P6
	55.9	60	P4-P5	roll	
D3: H09	94.8	70	P1-P2	roll	P1-P5-P6
	55.9	60	P4-P5	roll	
D3: H12	94.8	70	P1-P2	roll	P1-P5-P6
	55.9	55	P4-P5	roll	
D3: H15	94.8	70	P1-P2	roll	P1-P5-P6
D3: H18	94.8	70	P1-P2	roll	P1-P4-P5-P6
D3: H21	94.8	65	P1-P2	roll	P1-P4-P5-P6
D4: H00	94.8	60	P1-P2	roll	P1-P4-P5-P6
	24.2	70	P2-P3	roll	
D4: H03	94.8	60	P1-P2	roll	P1-P4-P5-P6
	24.2	65	P2-P3	roll	
D4: H06	94.8	60	P1-P2	roll	P1-P4-P5-P6
	24.2	65	P2-P3	roll	
D4: H09	94.8	60	P1-P2	roll	P1-P4-P5-P6
	24.2	70	P2-P3	roll	
D4: H12	94.8	60	P1-P2	roll	P1-P4-P5-P6
	24.2	70	P2-P3	roll	
D4: H15	94.8	60	P1-P2	roll	P1-P4-P5-P6
	24.2	70	P2-P3	roll	
D4: H18	94.8	60	P1-P2	roll	P1-P4-P5-P6
	24.2	65	P2-P3	roll	
D4: H21	94.8	55	P1-P2	roll	P1-P4-P5-P6
	24.2	65	P2-P3	roll	
D5: H00	94.8	55	P1-P2	roll	P1-P4-P5-P6
	24.2	60	P2-P3	roll	
D5: H03	94.8	55	P1-P2	roll	P1-P4-P5-P6
	24.2	65	P2-P3	roll	
D5: H06	94.8	60	P1-P2	roll	P1-P4-P5-P6
	24.2	65	P2-P3	roll	
D5: H09	94.8	65	P1-P2	roll	P1-P4-P6
	24.2	70	P2-P3	roll	
	55.9	55	P4-P5	roll	
D5: H12	94.8	70	P1-P2	roll	P1-P5-P6
	55.9	55	P4-P5	roll	
D5: H15	94.8	70	P1-P2	roll	P1-P3-P5-P6
	55.9	55	P4-P5	roll	
D5: H18	94.8	70	P1-P2	roll	P1-P4-P6
	55.9	55	P4-P5	roll	
D5: H21	94.8	65	P1-P2	roll	P1-P4-P5-P6

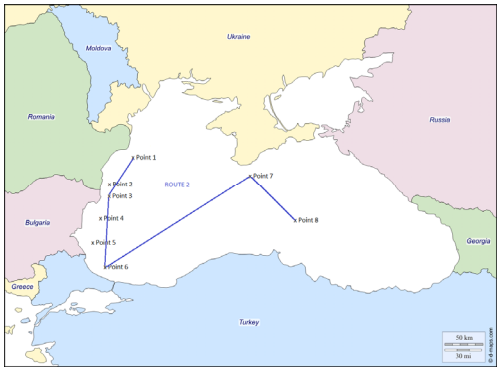

Fig.10 Scenario II - the west - south coastal to north - east route, 1300 TEU ship, B.S. map [9]

Table 3. Route scenario II assessment

Departure day & hour	*Restriction [km]zones distances*	*Heading angle μ [deg]*	*Restriction route segment*	*Not satisfied criteria*	*Not restricted route seg.*
D1: H00	117.5 219.7	65 55	P1-P3 P3-P6	roll roll	P1-P7-P8
D1: H03	117.5 219.7	65 55	P1-P3 P3-P6	roll roll	P1-P7-P8
D1: H06	117.5 219.7	65 55	P1-P3 P3-P6	roll roll	P1-P7-P8
D1: H09	117.5	65	P1-P3	roll	P1-P7-P8
D1: H12	117.5	65	P1-P3	roll	P1-P6-P7-P8
D1: H15	117.5	70	P1-P3	roll	P1-P6-P7-P8
D1: H18	117.5	70	P1-P3	roll	P1-P6-P7-P8
D1: H21	117.5	65	P1-P3	roll	P1-P6-P7-P8
D2: H00	117.5	65	P1-P3	roll	P1-P6-P7-P8
D2: H03	117.5	65	P1-P3	roll	P1-P6-P7-P8
D2: H06	117.5	65	P1-P3	roll	P1-P6-P7-P8
D2: H09	117.5 212.5	55 105	P1-P3 P7-P8	roll pitch	P1-P6-P7
D2: H12	117.5	55	P1-P3	roll	P1-P6-P7-P8
D2: H15	-	-	-	-	P1-P3-P6-P7-P8
D2: H18	117.5	60	P1-P3	roll	P1-P6-P7-P8
D2: H21	117.5 212.5	66 105	P1-P3 P7-P8	roll pitch	P1-P6-P7
D3: H00	117.5	70	P1-P3	roll	P1-P6-P7-P8
D3: H03	117.5	70	P1-P3	roll	P1-P6-P7-P8
D3: H06	117.5	70	P1-P3	roll	P1-P6-P7-P8
D3: H09	117.5	70	P1-P3	roll	P1-P6-P7-P8
D3: H12	117.5 212.5	70 105	P1-P3 P7-P8	roll pitch	P1-P6-P7
D3: H15	117.5	70	P1-P3	roll	P1-P6-P7-P8
D3: H18	117.5	70	P1-P3	roll	P1-P6-P7-P8
D3: H21	117.5	65	P1-P3	roll	P1-P6-P7-P8
D4: H00	117.5 212.5	60 105	P1-P3 P7-P8	roll pitch	P1-P6-P7
D4: H03	117.5 212.5	60 105	P1-P3 P7-P8	roll pitch	P1-P6-P7
D4: H06	117.5	60	P1-P3	roll	P1-P6-P7-P8
D4: H09	117.5	60	P1-P3	roll	P1-P6-P7-P8
D4: H12	117.5	60	P1-P3	roll	P1-P6-P7-P8
D4: H15	117.5	65	P1-P3	roll	P1-P6-P7-P8
D4: H18	117.5 212.5	60 105	P1-P3 P7-P8	roll pitch	P1-P6-P7
D4: H21	117.5 212.5	55 105	P1-P3 P7-P8	roll pitch	P1-P6-P7
D5: H00	117.5	55	P1-P3	roll	P1-P6-P7-P8
D5: H03	117.5	55	P1-P3	roll	P1-P6-P7-P8
D5: H06	117.5	60	P1-P3	roll	P1-P6-P7-P8
D5: H09	117.5	65	P1-P3	roll	P1-P6-P7-P8
D5: H12	117.5 212.5	70 105	P1-P3 P7-P8	roll pitch	P1-P6-P7
D5: H15	-	-	-	-	P1-P3-P6-P7-P8
D5: H18	117.5	70	P1-P3	roll	P1-P6-P7-P8
D5: H21	117.5	65	P1-P3	roll	P1-P6-P7-P8

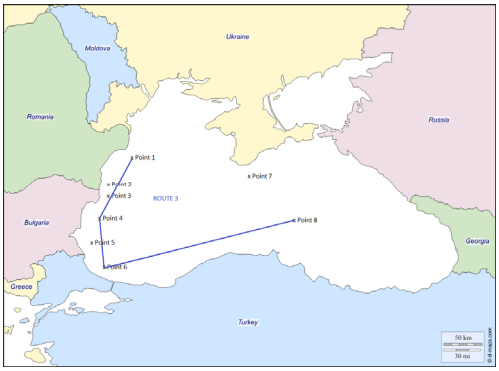

Fig.11 Scenario III - the west - south - east coastal route, 1300 TEU ship, B.S. map [9]

Table 4. Route scenario III assessment

Departure day & hour	*Restriction [km]zones distances*	*Heading angle μ [deg]*	*Restriction route segment*	*Not satisfied criteria*	*Not restricted route seg.*
D1: H00	206,2	60	P1-P4	roll	P1-P8
D1: H03	206,2	65	P1-P4	roll	P1-P8
D1: H06	206,2	65	P1-P4	roll	P1-P8
D1: H09	206,2	60	P1-P4	roll	P1-P8
D1: H12	206,2	55	P1-P4	roll	P1-P8
D1: H15	-	-	-	-	P1-P4-P6-P8
D1: H18	669	55	P6-P8	roll	P1-P4-P6
D1: H21	669	60	P6-P8	roll	P1-P4-P6
D2: H00	669	65	P6-P8	roll	P1-P8
D2: H03	669	70	P6-P8	roll	P1-P8
D2: H06	669	70	P6-P8	roll	P1-P8
D2: H09	669	65	P6-P8	roll	P1-P8
D2: H12	669	60	P6-P8	roll	P1-P8
D2: H15	669	60	P6-P8	roll	P1-P8
D2: H18	669	60	P6-P8	roll	P1-P8
D2: H21	669	65	P6-P8	roll	P1-P8
D3: H00	206,2	55	P1-P4	roll	P1-P8

	669	70	P6-P8	roll	
D3: H03	206,2 669	55 70	P1-P4 P6-P8	roll roll	P1-P8
D3: H06	206,2 669	55 70	P1-P4 P6-P8	roll roll	P1-P8
D3: H09	206,2 669	55 65	P1-P4 P6-P8	roll roll	P1-P8
D3: H12	206,2 669	55 65	P1-P4 P6-P8	roll roll	P1-P8
D3: H15	206,2 669	55 60	P1-P4 P6-P8	roll roll	P1-P8
D3: H18	669	55	P6-P8	roll	P1-P8
D3: H21	669	60	P6-P8	roll	P1-P8
D4: H00	669	65	P6-P8	roll	P1-P8
D4: H03	669	65	P6-P8	roll	P1-P8
D4: H06	669	60	P6-P8	roll	P1-P8
D4: H09	669	55	P6-P8	roll	P1-P8
D4: H12	-	-	-	-	P1-P4-P6-P8
D4: H15	669	55	P6-P8	roll	P1-P8
D4: H18	669	60	P6-P8	roll	P1-P8
D4: H21	669	65	P6-P8	roll	P1-P8
D5: H00	669	65	P6-P8	roll	P1-P8
D5: H03	669	70	P6-P8	roll	P1-P8
D5: H06	669	70	P6-P8	roll	P1-P8
D5: H09	669	70	P6-P8	roll	P1-P8
D5: H12	206,2 669	55 65	P1-P4 P6-P8	roll roll	P1-P8
D5: H15	206,2 669	55 65	P1-P4 P6-P8	roll roll	P1-P8
D5: H18	669	70	P6-P8	roll	P1-P8

5. CONCLUSIONS

Based on the navigation route scenarios assessment (sections 4) for the 1300 TEU container ship in the Black Sea area, the conclusions of this study are:

1. On the first navigation route (Fig.9), the west coastal route, restrictions are recorded frequently on P1-P2, P2-P3 and rarely on P4-P5 segments. The seakeeping restrictions occur on the roll motion amplitudes, for heading angles 55÷75 deg. The unrestricted route is P1-P4-P5-P6, valid for the most cases from the starting time in the 5-day reference.
2. On the second navigation route (Fig.10), west - south coastal to north - east, the restrictions occur on P1-P3 and on P3-P6 segments, due to the roll motions seakeeping limits. Also on P7-P8 segment, in some time intervals, the restrictions occur due to the pitch acceleration seakeeping limits. The roll restrictions occur for the heading angles 55÷70 deg. and the pitch restrictions occur for 105 deg. The unrestricted route is P1-P6-P7-P8, valid for the most cases from the starting time in the reference short time period.
3. On the third navigation route (Fig.11), west - south - east coastal route, the restrictions occur on P1-P4 or P6-P8 segments. The seakeeping restrictions occur on the roll motions amplitudes, most often on 60÷65 deg. ship's heading angle. P1-P8 is the route recorded as being most often unrestricted in the 3÷5-day reference time of the Black Sea navigation.
4. For all three Black Sea navigation routes scenarios, according to the sea state intensity (H_s,T_m), the ship's speed is usually decreased involuntarily by the waves and voluntarily by the onboard commands. The decrease of the ship's speed to 10÷18 knots will reduce the motions and accelerations amplitudes, so that the seakeeping criteria might be satisfied, but with the increase of the total navigation time.
5. Further studies will have to include other ship types, on several loading cases, with speed changes and more complex routes considered into the navigation scenarios.

Acknowledgements

This study was developed in the frame of UDJG Galati Research Centre of the Faculty of Naval Architecture .

REFERENCES

[1]. **BV,** Bureau Veritas, Paris, 2013.
[2]. **Domnisoru, L.,** "*Ship dynamics. Oscillations and Vibrations",* Technical Publishing House, Bucharest, 2001.
[3]. **Domnisoru, L., Rubanenco, I., Mirciu, I.**, *"DYN_OSC program for the ship's seakeeping analysis",* Galati University, 2013.
[4]. **Eyres, D.J.,** *"Ship construction",* Butterworth Heinemann, Boston, 2006.
[5]. **GL,** Germanischer Lloyd's, Hamburg, 2013.
[6]. **Gasparotti, C**., "*Studies for increase of the navigation safety in the Black Sea environment"*, PhD. Thesis, Galati University, 2014.
[7]. **Jagite G., Gasparotti C.,** *"NBS program for ship's navigation routes in the Black Sea assessment"*, Galati University, 2013.
[8]. **Rusu L., Ivan A.,** *"Modelling Wind Waves in the Romanian Coastal Environment"*, Environ Eng Manage J, 9(4), pp.547-552, 2010.
[9]. **xxx**, http://d-maps.com (Black Sea free maps).

Paper received on November 23rd, 2015