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ON THE INFLUENCES OF LOADING CASES AND INERTIAL CHARACTERISTICS ON THE BEHAVIOUR OF A FLOATING CRANE

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ABSTRACT

The evaluation of the dynamics of floating structures has to be investigated in order to define the operational index which is reflecting the ability to operate at certain sea state. The applications have been performed for a floating crane using a range of operational loading cases and sea states in the Black Sea coastal area. The influence of the way to evaluate the moments of inertia for the different loading cases is also systematically taken into account. The conclusions are formulated based on the comparative diagrams, incorporating the influences of the above mentioned parameters.

Keywords: Dynamics of floating structures, Seakeeping, Operational Index, Accelerations, Floating cranes.

1. INTRODUCTION

The ability to operate at relatively high sea states is practically defining the quality of the design of floating structures which a conceived to perform different operations at zero speed [8]. Among the parameters which have to be accurately considered are the mass distributions for all loading cases, the hydrodynamic “transparency” from the geometrical point of view, the characteristics of the location where the floating structure will operate, the wave theory to be used, etc.

The applications have been carried out for a floating crane operating in the coastal area of the Black Sea area. The sea spectrum was defined for the location called “Lebăda”. The systematic measurements have been performed by INMH Bucharest and the spectrum definition was developed in cooperation with ICEPRONAV Galati in 1988 [2], [3].

The main characteristics of the body are: L_{pp}=64.2 m, B=24 m, T=3.1 m, C_B =0.86 and a displacement of Δ= 4166 t. The body plan of the floating crane is presented in Figure 1 and a 3-D view in Figure 2.

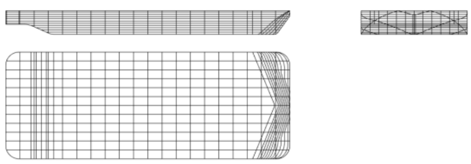


Fig. 1. The body plan of the floating crane

In order to evaluate the influence of the loading cases (LC) on the general behaviour of the floating body, 4 significant ones have been analysed. An example is presented in Fig. 3.

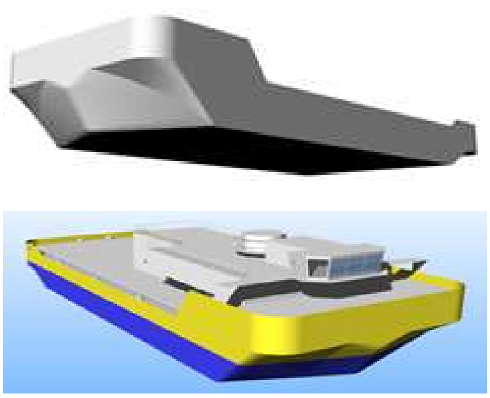
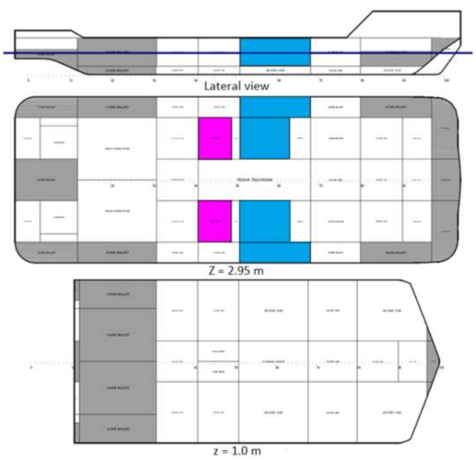


Fig. 2. The 3D views of the floating crane



Code	Tank type	Density t/m3
	WB	1.0250
	FW	1.0000
	FO	0.8500

Fig. 3. Typical description of a loading case (LC1 - 98% Bunker and WB)

The detailed characteristics of the loading cases are presented in Table 1. The displacements, the positions of the centre of gravity and the vertical coordinate of the centre of the buoyancy are presented for each loading cases.

Table 1. Main characteristics of the loading cases

Items	98% Bunker and WB	10% Bunker and WB	98% Bunker and WB+72	10% Bunker and WB+72
Deadweight [t]	2190.9	2145.3	2262.9	2217.3
Lightship [t]	2000.0	2000.0	2000.0	2000.0
Displacement [t]	4190.9	4145.3	4262.9	4217.3
X_G [m]	31.9	31.151	30.650	30.704
Y_G [m]	0.0	-0.007	0.136	0.130
Z_G [m]	5.745	5.779	5.834	5.868
Z_B [m]	1.620	1.605	1.648	1.632
Draft [m]	3.112	3.085	3.157	3.127
BMt [m]	16.988	17.152	16.678	16.853

As compared to the ship case, when simple formulas can be used for the evaluation of the moments of inertia, for floating structures these approximations could lead to significant errors.

Table 2. Radii of inertia for each loading case

Displacement and radii of inertia	98% Bunker and WB (LC1)	10% Bunker and WB (LC2)	98% Bunker and WB+72 (LC3)	10% Bunker and WB+72t (LC4)
Displacement [t]	4190.9	4145.3	4262.9	4217.3
r_{xx} [m]	8.185	8.143	8.410	8.192
r_{yy} [m]	25.866	22.234	25.616	22.387
r_{zz} [m]	26.276	22.750	25.987	22.908

2. INFLUENCE OF INERTIAL CHARACTERISTICS ON THE FLOATING CRAINE MOTIONS

The evaluation of influences of inertial characteristics on the Response Amplitude Operators has been performed for loading case LC1. When ship case is considered, different simple formulas are used. For roll radius of gyration a coefficient between 0.26 ÷ 0.30 B, where B is ship breadth, can be used and this is based on quite large statistic evidence. Similarly, simple evaluations can be used for pitch and yaw radii of gyrations when a coefficient of about 0.25 L (ship length) is commonly used. It can be observed that using such formulas there are no differences between the different loading cases. Constant values of about 7.20 m for roll radius of gyration and 20.0 m for pitch and yaw ones are enough far from the values presented in Table 2 and the influences have to be taken into account.

Consequently, due to totally unusual mass distributions, when offshore floating structures or even offshore ship shaped structures are considered, weights distributions are mandatory for accurate calculations.

The influences are presented in the following figures.

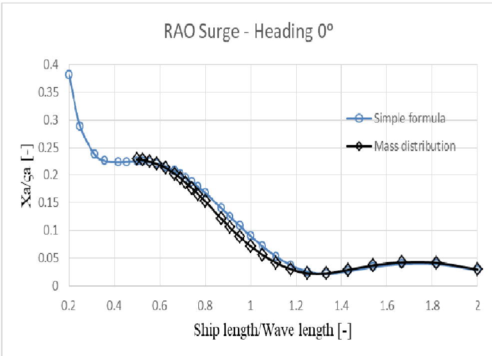


Fig. 4. RAO surge -comparative results (Heading 0^0)

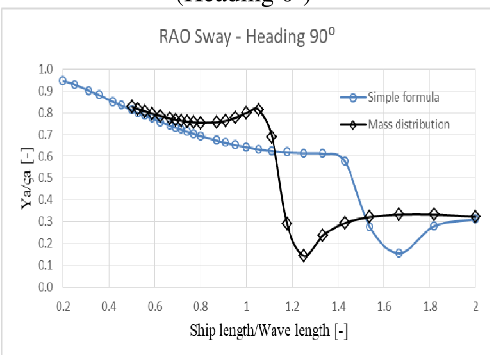


Fig. 5. RAO sway -comparative results (Heading 90^0)

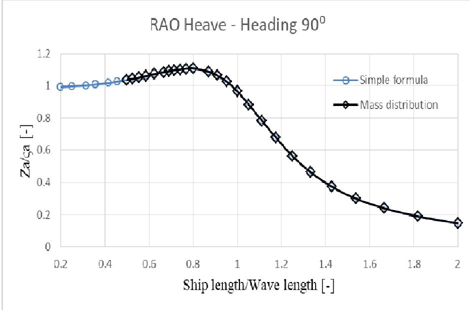


Fig. 6. RAO heave -comparative results (Heading 90^0)

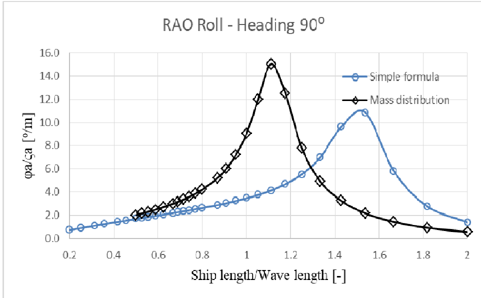


Fig. 7. RAO roll -comparative results (Heading 90^0)

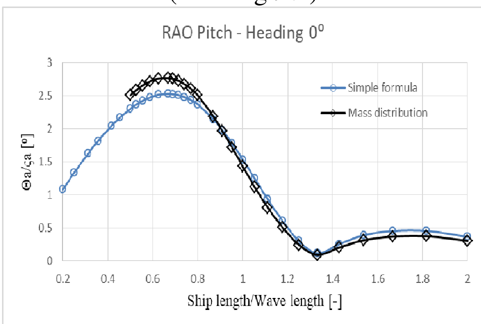


Fig. 8. RAO pitch -comparative results (Heading 0^0)

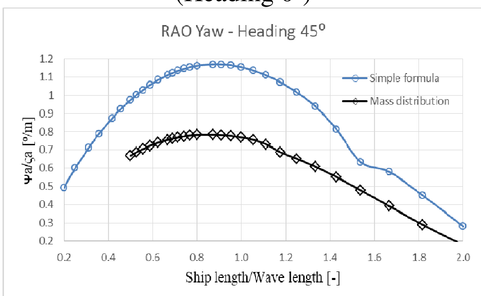


Fig. 9. RAO yaw -comparative results (Heading 45^0)

3. INFLUENCES OF LOADING CASES ON THE FLOATING CRAINE MOTIONS

The Response Amplitude Operators (RAO's) have been calculated for the above mentioned loading cases (LC) using the mass distributions as well as using the simple formulas for the moments of inertia. The results are presented in the following figures.

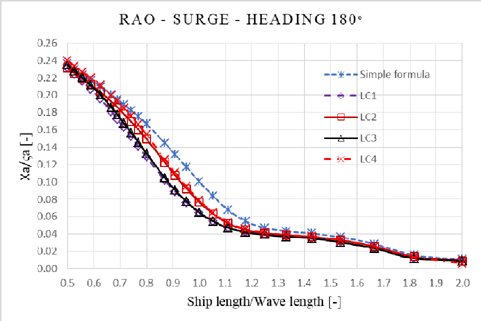


Fig. 10. RAO surge as a function of the loading cases, heading 180^0

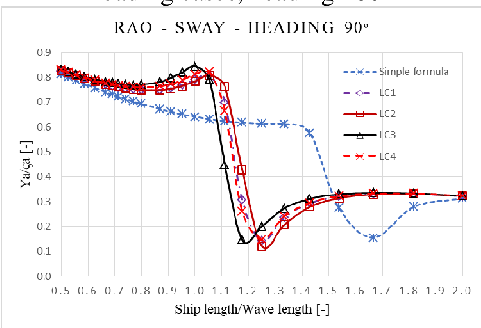


Fig. 11. RAO sway as a function of the loading cases, heading 90^0

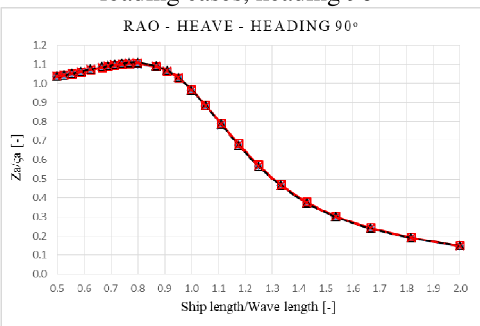


Fig. 12. RAO heave as a function of the loading cases, heading 90^0

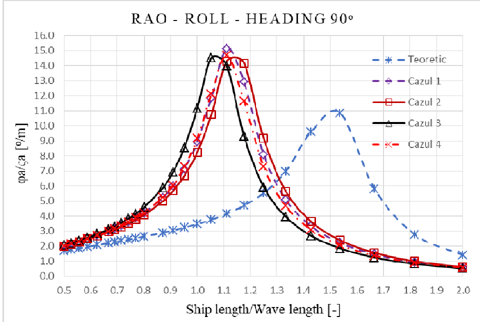


Fig. 13. RAO roll as a function of the loading cases, heading 90^0

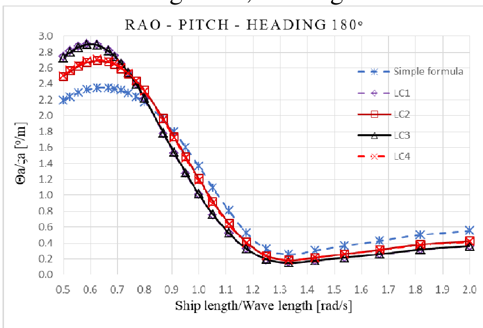


Fig. 14. RAO pitch as a function of the loading cases, heading 180^0

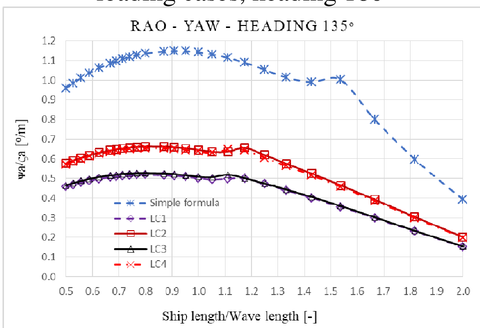


Fig. 15. RAO yaw as a function of the loading cases, heading 180^0

The calculations have been performed for a range of heading angles between $0^0 \div 180^0$ with a step of 15^0.

4. DEFINITION OF BLACK SEA SPECTRA FOR APPLICATIONS

The evaluations were made for a range of sea states defined based on wind speed in the coastal area of Black Sea, location

"Lebada". Four different wind speeds have been, from 10 m/s to 25 m/s with a step of 5 m/s. The results are graphically presented in Figure 14.

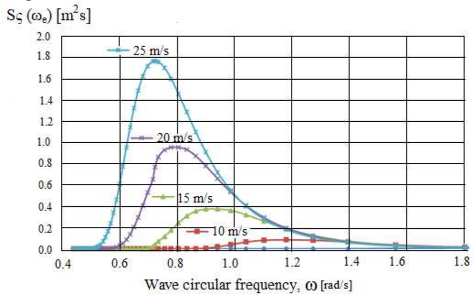


Fig. 16. The sea spectra used for applications

The main characteristics of the sea states are presented in Table 3.

Table 3. Wave characteristics of the sea states

	v=10m/s	v=15m/s	v=20m/s	v=25m/s
HMAXPROB=	1.551	2.812	4.079	5.206
HMAXP=	2.048	3.747	5.468	7.009
HMED=	0.494	0.887	1.285	1.643
H1/3=	0.788	1.415	2.052	2.623
H1/10=	1.003	1.801	2.611	3.338
H1/100=	1.315	2.360	3.422	4.374
PERMEDTZ=	4.336	5.555	6.500	7.245
T1/3=	5.283	5.993	6.487	6.851

The notations used refer to the wave characteristics consisting in probabilistic values like significant heights, significant 1/3 period in seconds and wave heights for a certain level of probability. The symbol SS1 to SS4 represents the sea state.

5. EVALUATION OF MOTIONS AND OPERATIONAL LIMITS

Based on RAO's calculations, as a next step the response spectra of motions and accelerations have been evaluated using the well-known expression [1]

$$S_x(\omega_e) = RAO^2(\omega_e) \cdot S_\zeta(\omega_e) \qquad (1)$$

where, $S_x(\omega)$ represents the generic response spectra which allow the determination of statistic values to be compared with the recommended ones [4], presented in Table 4.

Table 4. Recommended limits for different types of activities

RMS criteria			Type of activity
Vertical acceleration (a_z)	Lateral acceleration (a_y)	Roll motion (φ)	
0.20 g	0.10 g	6.0°	Light manual work
0.15 g	0.07 g	4.0°	Heavy manual work
0.10 g	0.05 g	3.0°	Intellectual work

The calculations have been performed for all loading cases, the already mentioned range of wave frequencies and for two distinct situations: Beam Sea and Head Sea [6].

a) The beam sea case

For beam sea the measuring point is marked in Fig. 15.

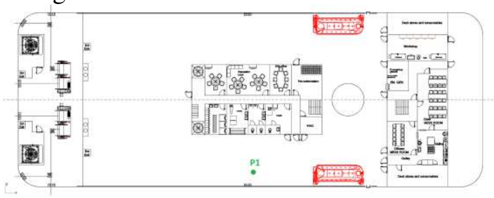


Fig. 17. The measuring point for the beam sea case

The results are presented in the following tables for the lateral accelerations (a_y), vertical accelerations (a_z) and roll motions.

It is important to underline that the values of the accelerations are practically parts of the gravitational acceleration.

Table 5. The results for the lateral accelerations

SS1	SS2	SS3	SS4	**a_y**
0.017	0.041	0.058	0.065	$ay_{1/3}$
0.022	0.052	0.074	0.083	$ay_{1/10}$
0.029	0.069	0.096	0.109	$ay_{1/100}$
0.009	**0.022**	**0.03**	**0.034**	**RMS**

Table 6. The results for the vertical accelerations

SS1	SS2	SS3	SS4	**a_z**
0.07	0.161	0.197	0.205	$az_{1/3}$
0.89	0.204	0.25	0.261	$az_{1/10}$
0.117	0.268	0.328	0.342	$az_{1/100}$
0.36	**0.082**	**0.1**	**0.105**	**RMS**

Table 7. The results for the roll motions

SS1	SS2	SS3	SS4	φ
0.806	1.89	2.442	2.65	$\varphi_{1/3}$
1.025	2.405	3.1	3.373	$\varphi_{1/10}$
1.343	3.152	4.072	4.42	$\varphi_{/100}$
0.408	**0.965**	**1.261**	**1.378**	**RMS**

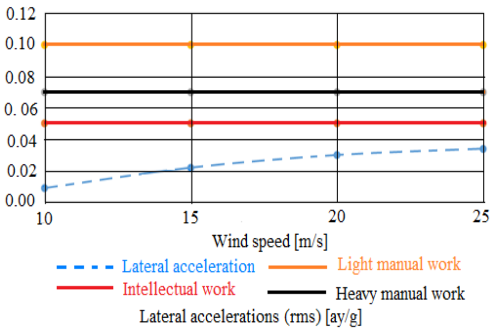


Fig. 18. Lateral accelerations according to Table 5

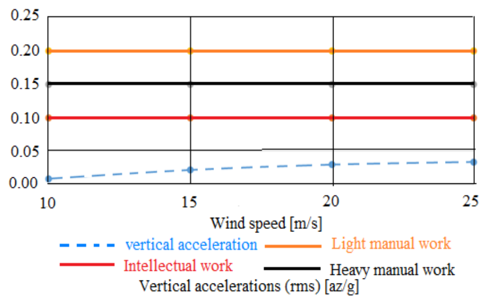


Fig. 19. Vertical accelerations according to Table 6

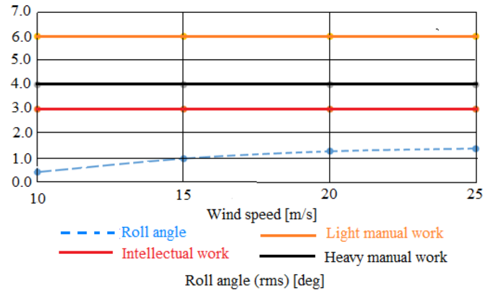


Fig. 20. Vertical accelerations according to Table 6

b) The following sea case

For the following sea case the measuring point is marked in Fig. 19.

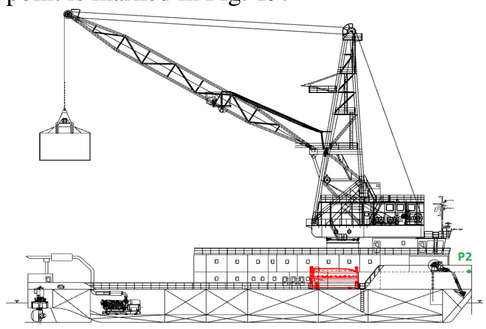


Fig. 21. The measuring point for the following sea case

The results are presented in the following tables in terms of vertical accelerations (a_x), vertical accelerations (a_z) and pitch motions.

Table 8. The results for the longitudinal accelerations

SS1	SS2	SS3	SS4	**a_x**
0.003	0.01	0.18	0.022	$ax_{1/3}$
0.003	0.013	0.023	0.028	$ax_{1/10}$
0.004	0.017	0.03	0.036	$ax_{1/100}$
0.001	**0.005**	**0.009**	**0.011**	**RMS**

Table 9. The results for the vertical accelerations

SS1	SS2	SS3	SS4	**a_z**
0.017	0.066	0.114	0.14	$az_{1/3}$
0.022	0.084	0.145	0.178	$az_{1/10}$
0.029	0.11	0.19	0.234	$az_{1/100}$
0.022	**0.034**	**0.056**	**0.072**	**RMS**

Table 10. The results for the pitch motions

SS1	SS2	SS3	SS4	θ [□]
0.23	0.858	1.49	1.848	$\theta_{1/3}$
0.293	1.092	1.897	2.351	$\theta_{1/10}$
0.384	1.431	2.486	3.082	$\theta_{/100}$
0.119	**0.445**	**0.77**	**0.952**	**RMS**

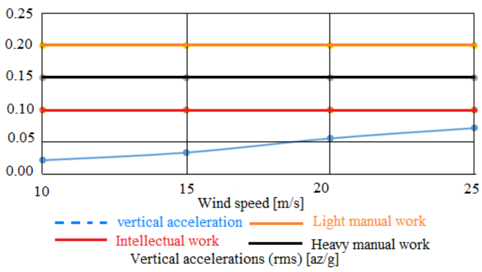


Fig. 22. Vertical accelerations according to Table 9

In both cases, i.e. beam and following sea respectively, the calculations have been performed for several points due to the necessity to evaluate the accelerations in sensitive areas where the dynamic effect has to be accurately known.

6. CONCLUDING REMARKS

The evaluation has been performed using a computer code based on the well-known theory developed by Salvesen, Tuck and Faltinsen [5]. The program is able to calculate the amplitudes and phases for all six degrees of freedom, i.e. surge, sway, heave, roll, pitch and yaw motions as well as the hydrodynamic loads for any heading angle in regular waves. The slender body theory is assumed and the three dimensional hydrodynamic quantities are expressed in terms of the solution to the sectional two-dimensional problem of a cylinder with the same shape as the individual cross-sections oscillating on the free surface. The program is using the "close fit source distribution technique" developed by Frank. The evaluation of the Response Amplitude Operators (RAO's) of motions is performed in the frequency domain.

The first important conclusion is the linked to the necessity to use the mass distributions information in order to have enough accurate evaluation of the inertial characteristics of the body. The only motion which is not affected is heave as it can be observed in Fig. 6. Less affected are and pitch motions while sway, roll and yaw motions are dramatically influenced as depicted in Fig. 5, Fig. 7 and Fig. 9.

As regarding the influences of the loading cases, the evaluations do not show large differences. However, some significant discrepancies are mainly displayed when sway, roll and yaw motions are considered.

The evaluation of the accelerations and motions, carried out in order to observe the capability to operate from the comfort point of view, lead to the idea that there are no situations to be avoided. It has to be underlined that coastal area of the Black Sea has been considered, specifically the location Lebăda.

Mention should be made that, from the operational point of view, the "rms" values were used which means to estimate the expected motions and accelerations for short time operations limited in time to about 6 hours. If higher operational periods are required then, different approaches have to be considered [7]. To this purpose, just to give a rough idea, some other statistical values have been shown, for example 1/3, 1/10 and 1/100.

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