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INFLUENCES OF MASS DISTRIBUTION ON SEAKEEPING PERFORMANCES OF AN OFFSHORE BARGE

Liviu Crudu
“Dunarea de Jos” University of Galaţi,
Faculty of Naval Architecture, Galaţi,
47, Domnească Street, 800008, România,
E-mail:liviu.crudu@ugal.ro

Octavian Neculeţ
NASDIS Consulting SRL,
6, Tecuci Street, Bl. V5, Et. 1, Galaţi,
800120, România,
E-mail:octav.neculet@nasdis.ro

Cristina Mihalache
“Dunarea de Jos” University of Galaţi,
Faculty of Naval Architecture, Galaţi,
47 Domneasca Street, 800008, România,
E-mail:cristina.mihalache12@yahoo.com

ABSTRACT

The information presented in this paper is based on the results obtained as an extension of a previous study when only a single loading case was taken into consideration in order to evaluate the behaviour and the hydrodynamic induced forces and moments due to waves for a pipe layer barge. The aim of the present paper is to compare and estimate the influence of the two additional operational loading cases. The importance of the evaluations of the environmental forces due to waves is mandatory because, on one hand, the designer has to be able to decide the value of the design wave on a given location and, on the other hand, to estimate the influences of the loading cases which clearly differ from the classical ones, specific to merchant ships, due to different specific restrictions as well as typical operations in offshore industry. It has to be underlined that both the motions and the structural responses are responsible in order to achieve good operational indexes which are of paramount importance during the lifetime of an offshore structure. In order to provide structural safety and comfort on board, an extensive evaluation has to be performed based on the identification of worst case scenarios and to find appropriate solutions having as target to avoid significant operational losses and physical damages.

Keywords: Offshore engineering, Seakeeping, Induced hydrodynamic loads, Loading cases

1. INTRODUCTION

As mentioned in a previous paper [4] the evaluation of the behaviour of an offshore floating structure consisting in the evaluation of RAO’s, accelerations and hydrodynamic induced forces and moments are practically mandatory as far as an important number of parameters have to be taken into account. The limitations related to the comfort on board and structural integrity could play an important role due to the limits imposed by different organizations and regulatory bodies. To this purpose, sometimes, a large volume of calculations has to be performed, taking into account the different types of operations which a floating body has to perform during its lifetime. One of the decisive factors to be considered is the mass distribution leading to a significant number of loading cases which have to be considered. An accurate enough evaluation is also required as far as the design wave is defined on this basis of the maximum allowable shear forces and bending moments provided by different classification societies.

The present paper is dedicated to the investigation of the forces and moments induced by the dynamic behaviour of a floating barge operating as pipe layer taking into account two additional loading cases as compared to the previous study [4]. The evaluations have been performed by using a computer code based on the well-known theory developed by Salvesen, Tuck and Faltinsen [1]. The computer code uses the “close fit source distribution technique” developed by Frank. Based on the calculation of the velocity potential (solving the classical boundary problem with initial conditions), the pressure distribution on the hull is obtained using Bernoulli's equation. Integrating the pressure on the wetted surface of the body the hydrodynamic diffraction forces and moments, induced by regular wave, are obtained. Then, together with the radiation forces and moments the evaluation of the amplitudes and phases for all six degrees of freedom [2], i.e. surge, sway, heave, roll, pitch and yaw motions become possible (see Fig. 1).

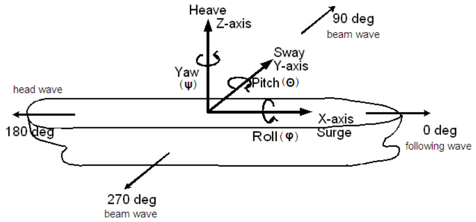

Fig. 1. Motions and coordinate system

The program also provides the structural forces and moments for a number of 18 cross sections along the ship [3]. The coordinate system is shown in Fig. 2.

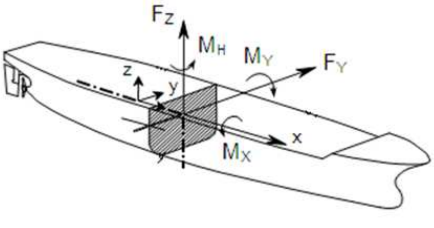

Fig. 2. Positive sign convention

2. GENERAL INPUT DATA

The general characteristics of the barge are presented in Table 1.

Table 1. Main dimensions of the barge

Length overall, L_{OA}	96.00 m
L_{PP}	92.40 m
Breath, B	33.00 m
Depth, D	4.00 m

The characteristics of loading case LC1 are:
Displacement = 3317 t
Draught = 1.07 m
KG (fluid) = 4.10 m
GM (fluid) = 81.73 m
Roll radius of gyration, K_{xx} = 8.935 m
Pitch radius of gyration, K_{YY} = 27.645 m
Yaw radius of gyration, K_{ZZ} = 27.431 m

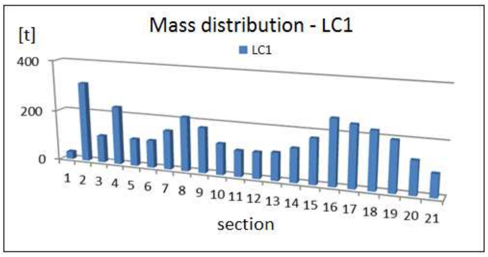

Fig. 3. Schematic representation of weight distribution, LC1

The characteristics of loading case LC2 are:
Displacement = 5976 t
Draught = 1.92 m
KG (fluid) = 3.62 m
GM (fluid) = 44.84 m
Roll radius of gyration, K_{xx} = 8.493 m
Pitch radius of gyration, K_{YY} = 25.477 m
Yaw radius of gyration, K_{ZZ} = 25.397 m

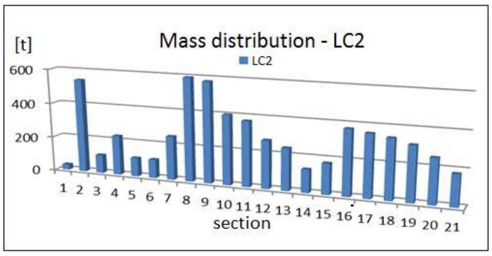

Fig. 4. Schematic representation of weight distribution, LC2

The characteristics of loading case LC3 are:
Displacement = 6716 t
Draught = 2.16 m
KG (fluid) = 4.00 m
GM (fluid) = 39.77 m
Roll radius of gyration, K_{xx} = 7.994 m
Pitch radius of gyration, K_{YY} = 23.739 m
Yaw radius of gyration, K_{ZZ} = 23.688 m

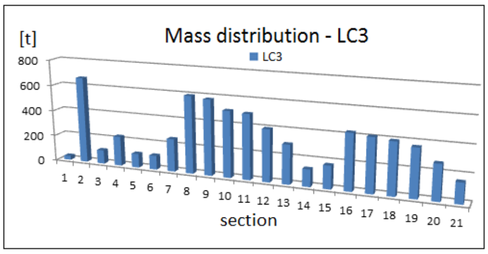

Fig. 5. Schematic representation of weight distribution, LC3

The above mentioned loading cases correspond to three different operational conditions which have been taken into account for mooring calculations too.

3. STILL WATER FORCES AND MOMENTS

As a first step, still water forces and moments have been evaluated based on the hydrostatic calculations and the mass distributions for each loading case. The calculations have been performed using NAPA software. The stability was also checked based on the evaluation of the windage area. The results are graphically presented in Fig. 6, Fig. 7 and Fig. 8 and numerically in Tab.2.

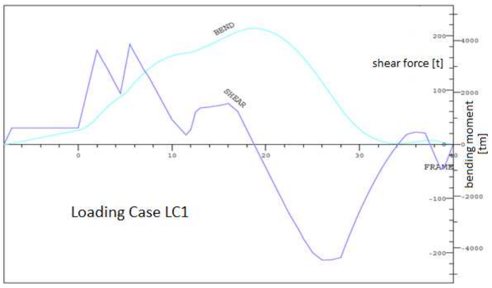

Fig. 6. Shear forces and bending moments, LC1

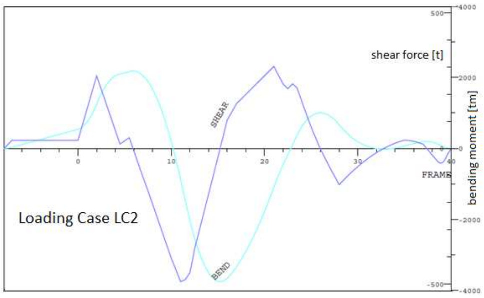

Fig. 7. Shear forces and bending moments, LC2

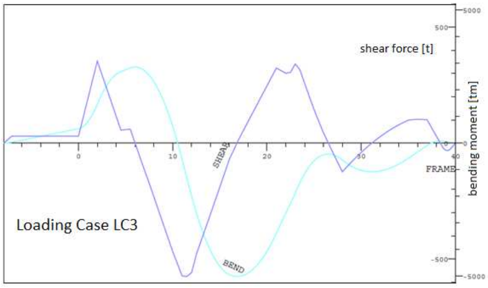

Fig. 8. Shear forces and bending moments, LC3

Table 2 Maximum shear forces, sagging and hogging moments

Still water forces and moments		Max shear force	Max Sagging moment	Max Hogging moment
LC1	Value	-213.4 t 184.3 t	0 t	4461.3 tm
	x, from AP*	62.7 m 13.2 m	0 m	44.9 m
LC2	Value	-491.0 t 302.1 t	-3752.4 tm	2182.9 tm
	x, from AP	26.4 m 50.4 m	36.6 m	14.1 m
LC3	Value	-575.7 t 353.7 t	-5015.6 tm	2862.3 tm
	x, from AP	27.6 m 4.8 m	40.3 m	14.4 m

AP* means Aft Perpendicular

These values are used latter in order to define the maximum total shear force and bending moment to be compared with the maximum design values given by the classification societies. Consequently, the evaluation of the design wave to be used can be identified.

4. EVALUATION OF MOTIONS

According to the above mentioned procedure, the motions of the floating barge were evaluated. The results are presented in comparative diagrams in order to identify the influences of mass distribution on the response amplitude operators (RAO's). The results for 0°, 45° and 90° heading angles are only depicted in the present paper.

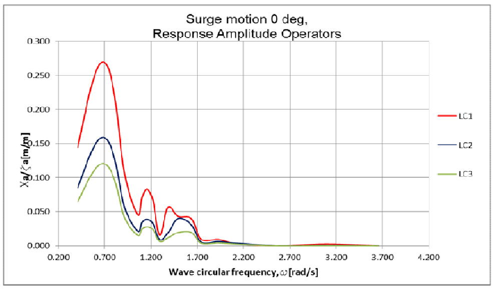

Fig. 9. RAO's surge motion; heading 0°

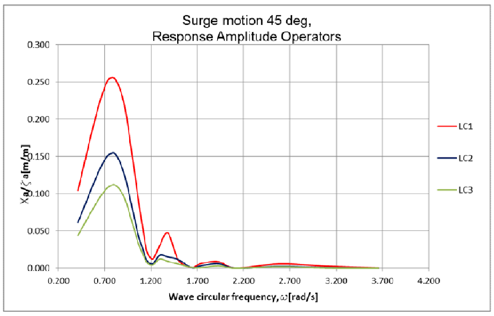

Fig. 10. RAO's surge motion; heading 45°

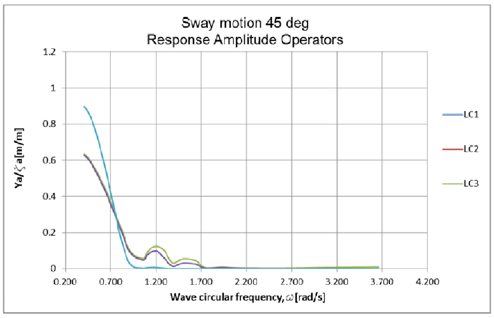

Fig. 11. RAO's sway motion; heading 45°

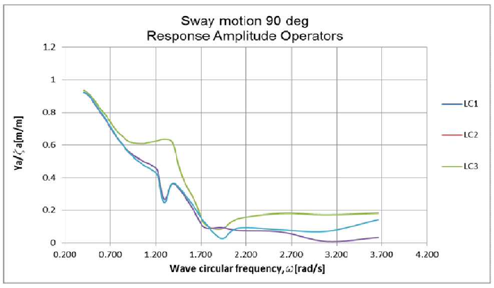

Fig. 12. RAO's sway motion; heading 90°

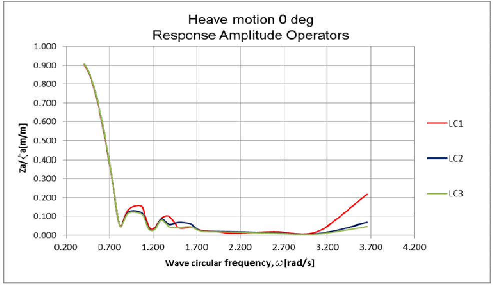

Fig.13. RAO's heave motion; heading 0°

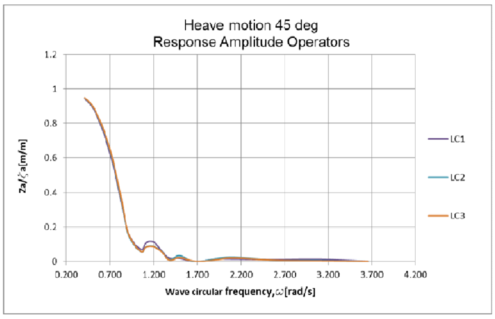

Fig.14. RAO's heave motion; heading 45°

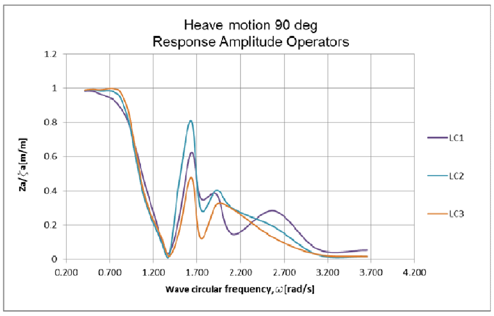

Fig.15. RAO's heave motion; heading 90°

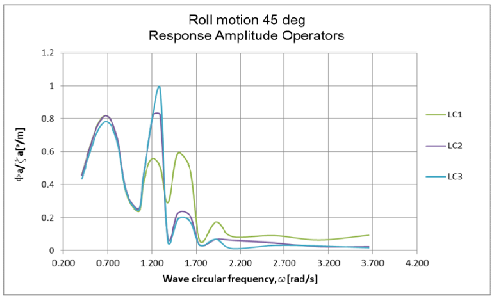

Fig. 16. RAO’s roll motion; heading 45°

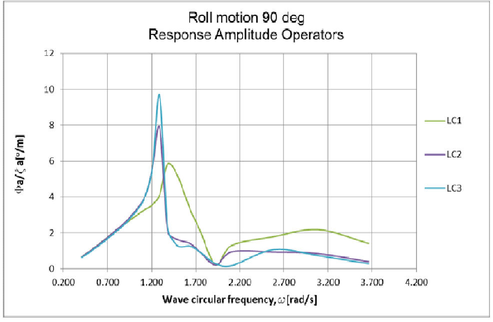

Fig. 17. RAO’s roll motion; heading 90°

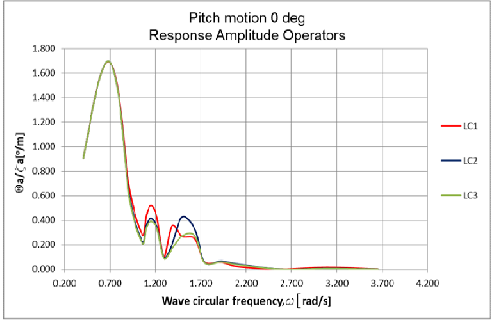

Fig. 18. RAO’s pitch motion; heading 0°

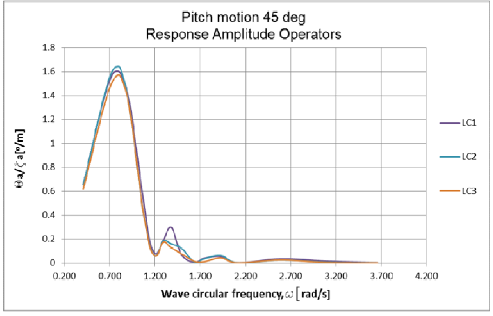

Fig. 19. RAO’s pitch motion heading 45°

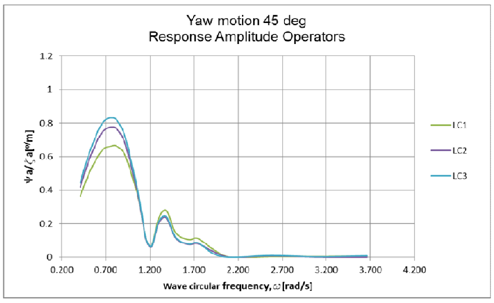

Fig. 20. RAO’s yaw motion; heading 45°

5. EVALUATION OF WAVE INDUCED FORCES AND MOMENTS

The calculations have been performed for the 3 loading cases already mentioned. The influences of the mass distribution can be identified based on the comparative diagrams. To this purpose, only relevant results have been selected, only for 0° and 45° heading angles. Mention should be made that the wave induced forces and moments and the still water ones ratio could lead to a “dynamic effect coefficient”. For a given mass distribution, also described by the radii of inertia of the motions (roll, pitch and yaw), the diagrams presented below can be looked at as response amplitude operators of the induced forces and moments [5].

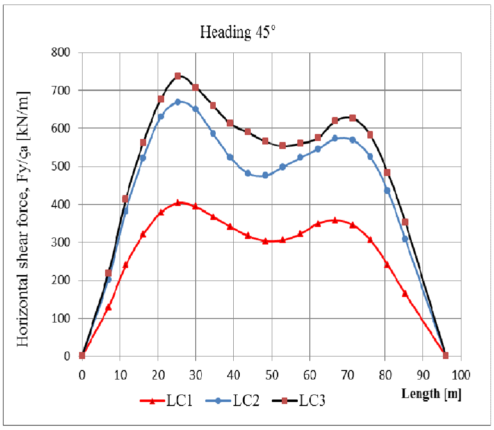

Fig. 21. Horizontal shear force, F_Y, along ship length (heading 45°)

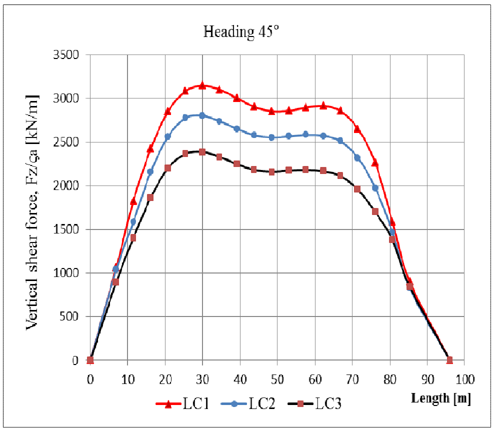

Fig. 22. Vertical shear force, F_Z, along ship length (heading 45°)

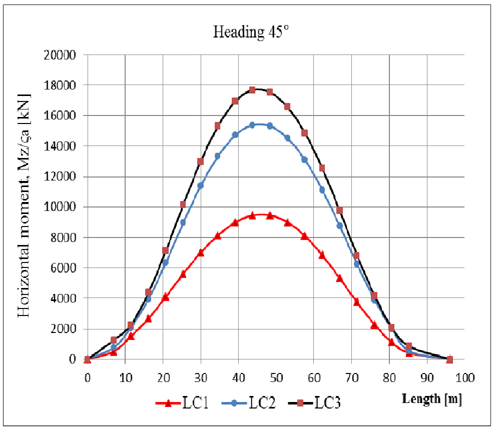

Fig. 25. Horizontal moment, M_H, along ship length (heading 45°)

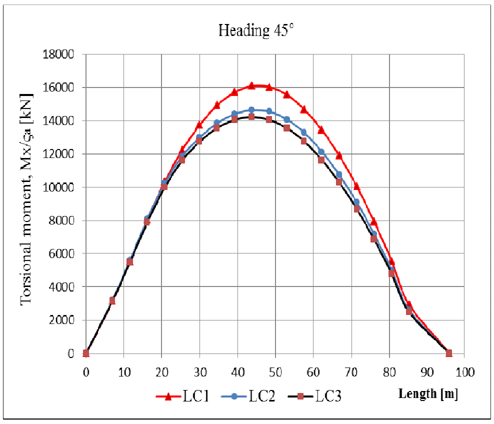

Fig. 23. Torsional moment, M_X, along ship length (heading 45°)

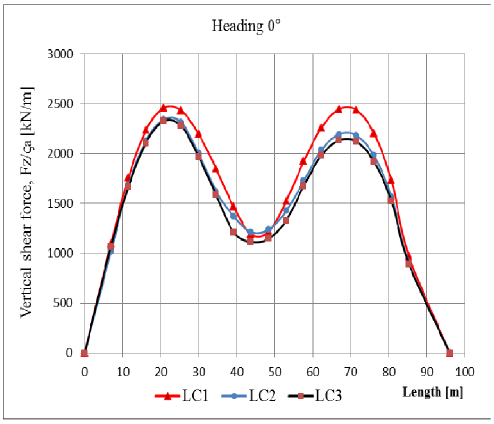

Fig. 26. Vertical shear force, F_Z, along ship length (heading 0°)

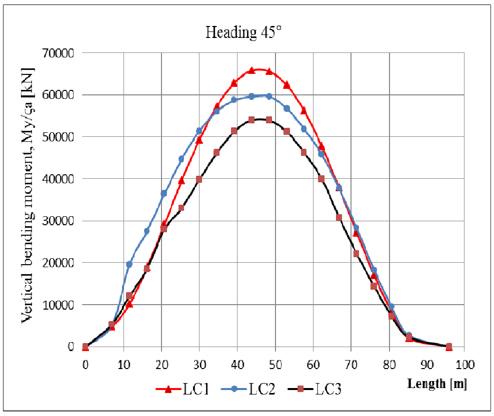

Fig. 24. Vertical bending moment, M_Y, along ship length (heading 45°)

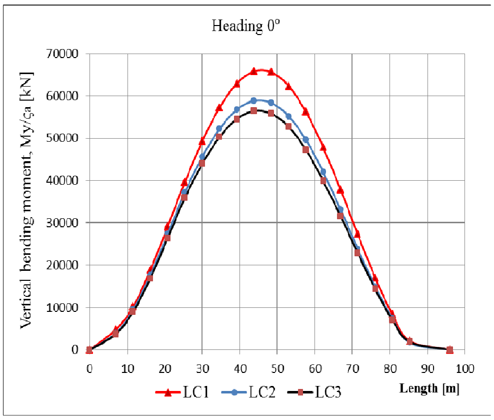

Fig. 27. Vertical bending moment, M_Y, along ship length (heading 0°)

The maximum values of the wave bending moments based on formulas provided by different classifications societies are presented in Fig. 28.

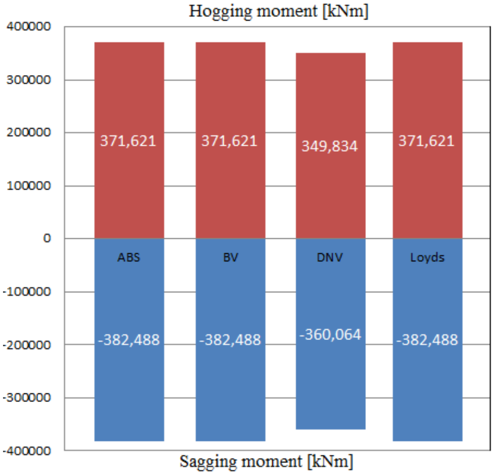

Fig. 28. Maximum wave bending moment, M_Y, using formulas provided by 4 classification societies

It can be observed that 3 of the results are practically the same. The lower value will lead to a smaller amplitude of the design wave if the procedure is based on these simple calculations. However, more detailed calculations have to be performed. As an example, using the maximum wave bending moment provided by BV MARS rule 2000, which is about 308,950 kNm for sagging (LC1 case), the maximum amplitude of the design wave could not reach higher values than $\varsigma_a = 4.5$ m which means a wave height of $H_{max} = 9$ m. On the other hand, if the value of the maximum bending moment is according to Fig. 28, then a significant higher amplitude of the design wave can be considered, leading to a wave height in the range of $H_{max} = 10$ m ÷10.5 m. This corresponds to a significant wave height of about $\varsigma_{1/3} = 4.5$ m and a sea state 7.

A stress analysis has been performed in a later stage using a mesh presented in Fig. 29. The von Mises stress results induced by waves are presented for all three loading cases in Fig. 29 ÷ Fig. 35.

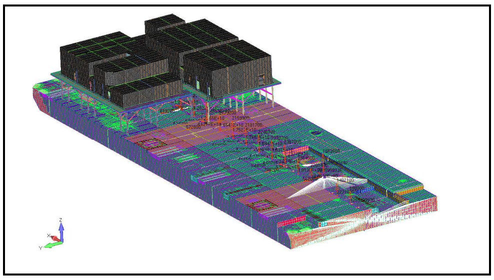

Fig. 29. The geometry and the mesh

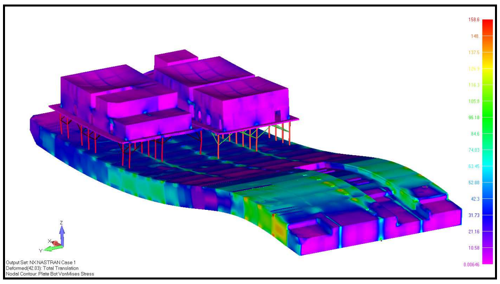

Fig. 30. Loading Case 1; heading 0°

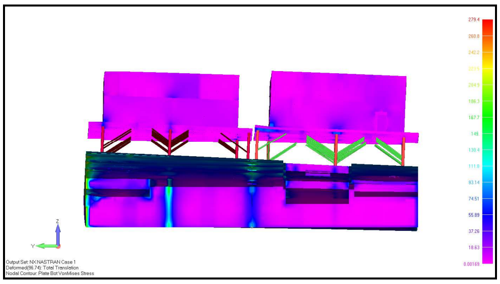

Fig. 31. Loading Case 1- aft view; heading 45°

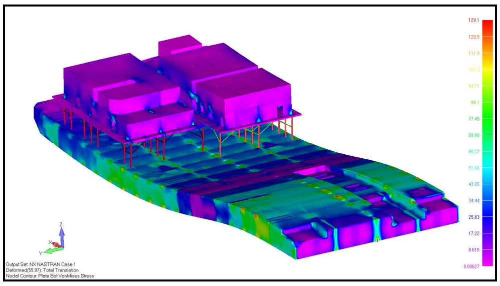

Fig. 32. Loading Case 2; heading 0°

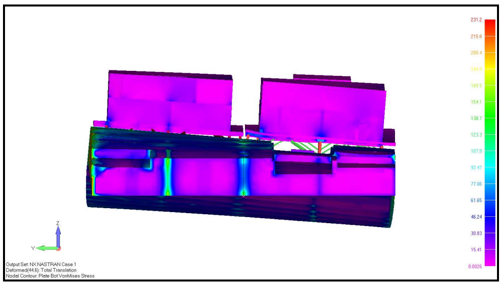

Fig. 33. Loading Case 2 - aft view; heading 45°

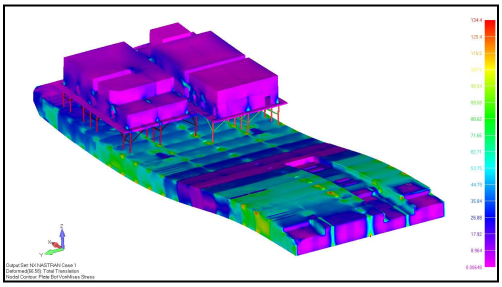

Fig. 34. Loading Case 3; heading 0°

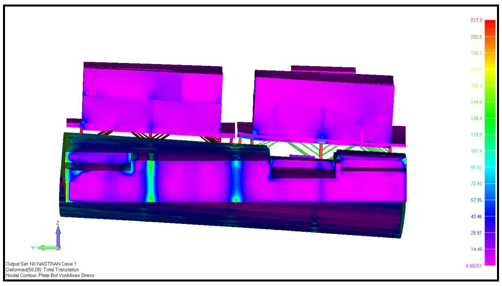

Fig. 35. Loading Case 3 - aft view; heading 45°

6. CONCLUDING REMARKS

The only motions affected by the mass and mass distributions are:

- surge motions are higher for LC 1 case, due to lower mass in this case (Fig. 9 and Fig. 10) but do not affect structural loads;
- heave motions are affected only for a heading angle of 90° (Fig. 15);
- roll motions which display local maximum values for a heading angle of 45° (Fig. 16). Despite the higher amplitudes of roll motions for LC 2 and LC 3 for 90° heading angle (Fig. 17), these do not have a significant impact on vertical shear forces and bending moments.

Except horizontal forces and moments (Fig. 21 and Fig. 25), other induced structural forces and moments show significant lower values for LC 2 and LC 3 than the LC 1 case.

Mention should be made that experimental tests on segmented model are mandatory to confirm the calculations [6].

The next stage of the research program is the evaluation of the influence of the length of the barge on induced structural forces and moments. A systematic evaluation is of paramount importance mainly in the early design stages.

REFERENCES

[1]. **Salvesen, N., Tuck, E. O., Faltinsen, O.,** “*Ship Motions and Sea Loads*”, Transactions of the Society of Naval Architects and Marine Engineers, 78, p., 250 – 287, 1970.

[2]. **Bhattacharyya, R.,** “*Dynamics of Marine Vehicles”*, John Wilwy & Sons Publishing House, New York, 1982.

[3]. **Faltinsen, O. M.,** “*Sea Loads on Ship and Offshore Structures*”, Cambridge University Press, Cambridge, UK, 1983.

[4]. **Crudu, L.,** “*Design wave principle and hydrodynamic induced loads for a pipe layer operating in specific area*”, Analele Universității „Dunarea de Jos” din Galati, Fascicula XI - Constructii Navale, Anul XXXI, pag. 73-78, Galati University Press, Galați, ISSN 1221-4620

[5]. **Hsu, T. H., Teng, H., “***Applied Offshore Structural Engineering”*, Gulf Publishing Company, Houston, Texas, 1984.

[6]. **Wereldsma, R.,** “*Towing tank experiments on ship girder loadings in oblique waves, a modal presentation of selected results*”, Delft University of technology, Ship Structure Laboratory, Report No. 239a, 1981.

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