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ON THE EVALUATION OF DIFFRACTION FORCES ON A FLOATING SEMISUBMERSIBLE UNIT

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ABSTRACT

The importance of the accurate evaluation of diffraction forces on offshore structures is of paramount importance in the determination of response amplitude operators of motions as well as of the accelerations in several points of interest which are directly linked to the comfort onboard and operational indexes. It is well known that the higher the sea state to operate the better the efficiency and operability characteristics of the floating structures. The purpose of the present paper is to show the significant differences between the evaluations carried out when Froude - Kryloff hypothesis is used and the results when the influence of structure geometry is considered. The calculations have been carried out for the ITTC semisubmersible, SR 192, using a 3D computer code based on Green functions method.

Dedicated to our Prof. Dr. Eng. Liviu Dan Stoicescu, member of the Romanian Academy of Technical Sciences, on the occasion of his 85th birthday.

Keywords: Offshore engineering, Diffraction forces, Froude-Kryloff forces, Seakeeping

1. INTRODUCTION

The wave exciting forces are practically dependent on the geometry of the offshore structure in correlation with wave characteristics. In fact, the L/λ ratio is providing a first evaluation of the preponderant type of excitation forces to be expected to act on the body. The calculations were performed for a semisubmersible which is compound of different types of elements which can be treated separately due to their geometry [1]. In the case of large volumes, like pontoons, the predominant forces are the potential ones while in case of thin elements, like bars, viscous forces have to be taken into considerations as the principal sources of excitations [7] (see Photo 1).

The geometry of the body is shown in Fig. 1 and Table 1, respectively.

In order to evaluate the potential forces a 3D method, based on Green functions theory, was used [2], [3]. The evaluation viscous forces were performed based on the Morison – O'Brian equation.

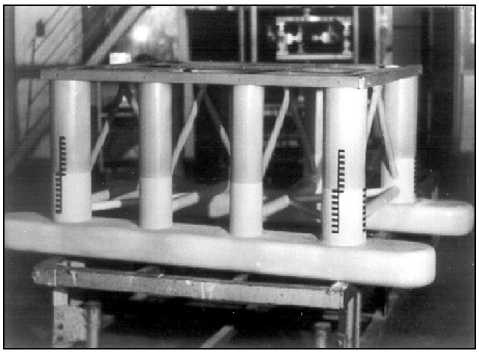

Photo 1. General view of the semisubmersible

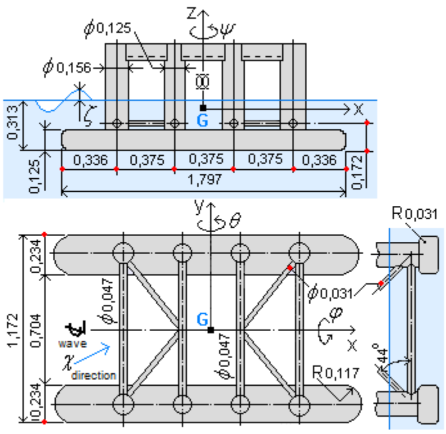

Fig. 1. The geometry of the semisubmersible model (scale 1:64)

Table 1. Main characteristics of the body

Lower body length	1,797 m
Width of lower bodies	1,172 m
Draught	0,313 m
Coordinates of centre of gravity (G)	x_G = 0 m, y_G = 0 m, z_G = 0,273 m (from BL)
Displacement in fresh water	130,3 kgf
Water depth	3,0 m
Wave direction	0^o, 45^o, 90^o
Wave height	0,046 m
Range of wave periods	1 s - 4 s

The present paper presents the results related to the evaluation of potential forces only. This is mainly due to the fact that, based on the investigation of the preponderance of the exciting forces, it was found that the calculation has to be performed in a domain where potential forces are of main interest. This aspect is graphically suggested in Fig. 2 (see the marked area).

It is important to underline that when fixed structures like jackets or gravitational structures are considered, only the diffraction forces have to be considered as far as the radiation problem is not anymore of interest.

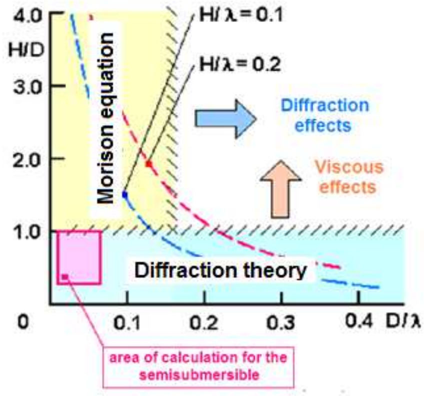

Fig. 2. Definition of calculation area for the SR 192 semisubmersible

As previously mentioned, the calculations were carried out based on a 3D theory [5], [8]. The general problem is a hydrodynamic boundary problem with initial conditions. Having double symmetry, the body surface was divided in 418 planar quadratic elements, 1672 ones for the whole structure. The mesh is shown in Fig. 3.,

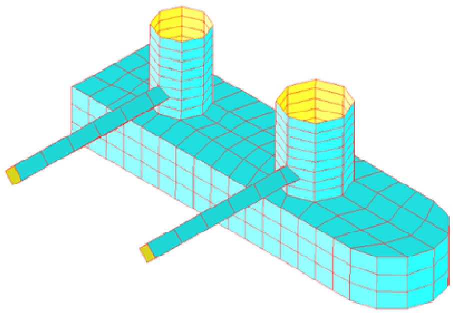

Fig. 3. The mesh used for computations

The velocity potential can be written as [5]

$$\Phi(x,y,z,t)=\varphi(x,y,z)\cdot e^{i\omega t}$$

where, the functions $\varphi(x,y,z)$ are the stationary part of functions $\Phi(x,y,z,t)$. Using the superposition principle, the velocity potential can be written as a sum of the following components:

$$\Phi(x,y,z,t)=\Phi_0(x,y,z,t)+\Phi_7(x,y,z,t)+\sum_{K=1}^{6}\Phi_K(x,y,z,t)$$

where,

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Φ_0 (x,y,z,t) is the potential of the incident wave (generating the Froude-Kryloff forces),
Φ_7 (x,y,z,t) is the diffraction potential due to the presence of the fixed body in waves and,
Φ_K (x,y,z,t) is the radiation potential due to body motions in initially calm water, as it is schematically observed in Fig. 4.

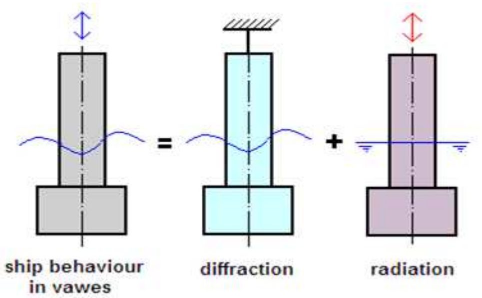

Fig. 4. Schematic representation of the general problem

Consequently, due to the importance of the exciting wave forces and moments on the behaviour of the structure and on the station keeping system, the evaluation was made taking into account:
- the potential of the incident wave (Froude – Kryloff forces);
- the influence of fix body diffraction and,
- the inter-influence between body motions and diffraction forces.

2. THEORETICAL RESULTS

The theoretical results, based on the above mentioned method, are graphically represented for a range of wave periods and heading angles, using the following formulae for the exciting forces and exciting moments, respectively [8].

$$F'_{x,y,z} = \frac{F_{x,y,z}\, L}{\Delta\zeta_a}$$

$$M'_{\varphi,\theta,\psi} = \frac{M_{\varphi,\theta,\psi}}{\Delta\zeta_a}$$

The results correspond to the model scale. If prototype data are required, the modelling scale has to be used (1:64). In the following figures, surge, sway and heave diffraction forces and roll, pitch and yaw diffraction moments are presented.

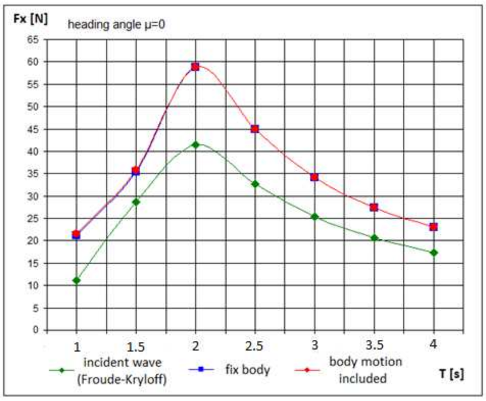

Fig. 5. Surge diffraction forces, heading angle μ = 0^o

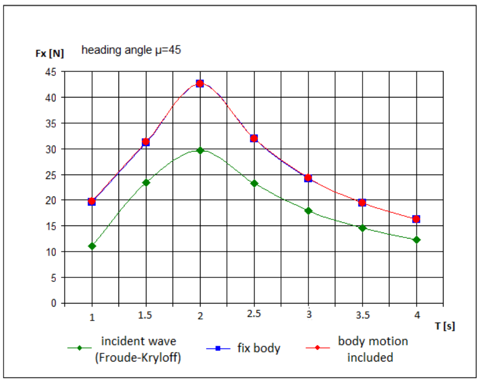

Fig. 6. Surge diffraction forces, heading angle μ = 45^o

Fig. 7. Sway diffraction forces, heading angle μ = 45^o

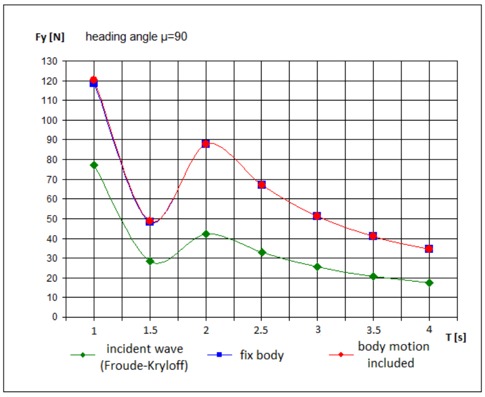

Fig. 8. Sway diffraction forces, heading angle $\mu = 90^o$

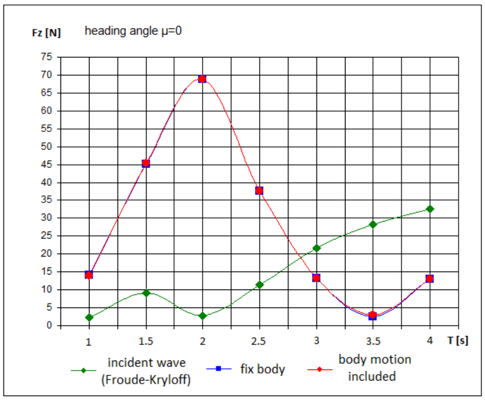

Fig. 9. Heave diffraction forces, heading angle $\mu = 0^o$

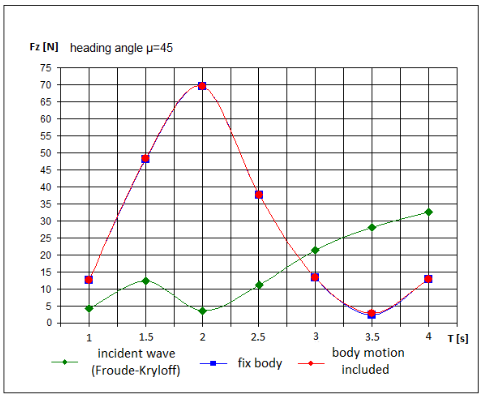

Fig. 10. Heave diffraction forces, heading angle $\mu = 45^o$

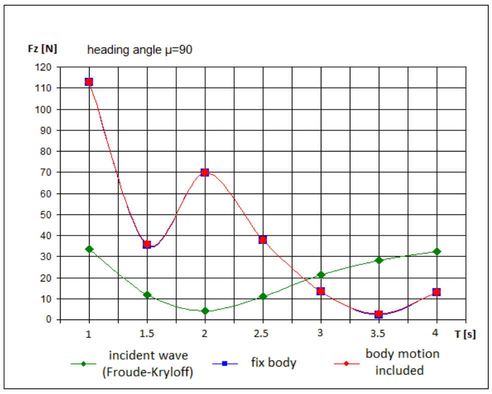

Fig. 11. Heave diffraction forces, heading angle $\mu = 90^o$

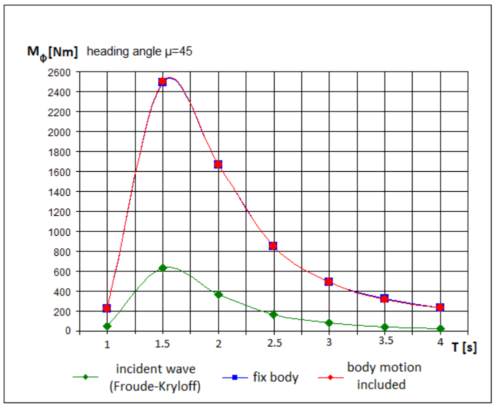

Fig. 12. Roll diffraction moments, heading angle $\mu = 45^o$

Fig. 13. Roll diffraction moments, heading angle $\mu = 90^o$

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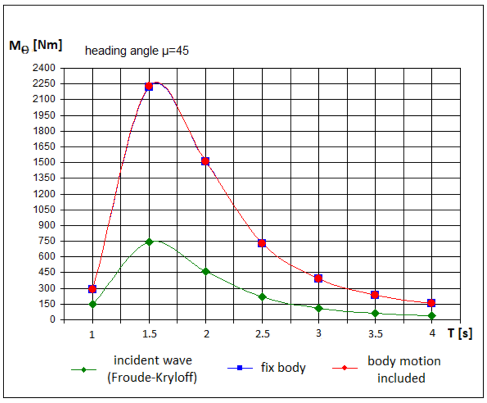

Fig. 14. Pitch diffraction moments, heading angle μ = 45°

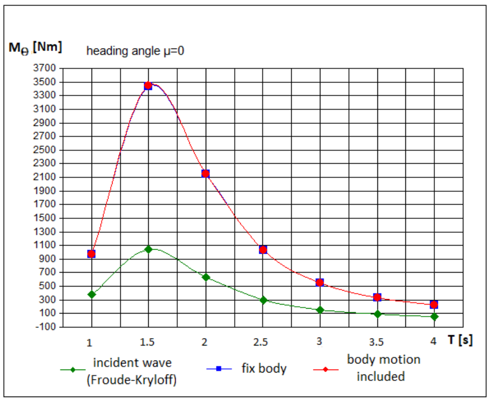

Fig. 15. Pitch diffraction moments, heading angle μ = 0°

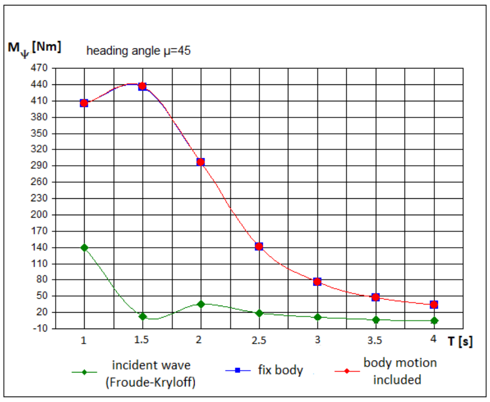

Fig. 16. Yaw diffraction moments, heading angle μ = 45°

3. EXPERIMENTAL RESULTS

The experimental results were obtained using a six components dynamometer (see Photo 2.) in order to obtain the six forces and moments which have been evaluated theoretically as presented in the above paragraph.

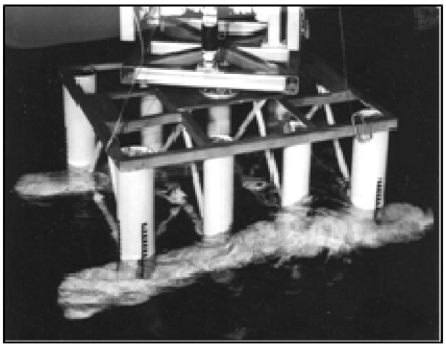

Photo 2. The semisubmersible model coupled to the six components dynamometer

The experiment was carried out [1] in order to have a direct comparison with already existing results, both theoretic and experimental ones, mentioned in the international literature. The possibility to check the results using different methods is given in the Fig. 17 where the own calculations are compared to the experimental ones and the calculations carried out by 26 organizations reported by ITTC [4], [6].

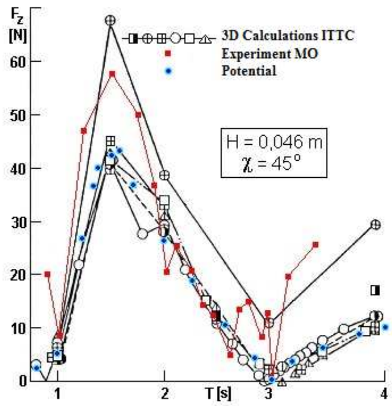

Fig. 17. Vertical diffraction forces Fz, comparative results, heading angle μ = 45°

4. CONCLUDING REMARKS

The first important conclusion refers to the fact that, at least for the semisubmersible case, the forces and moments calculated using the Froude – Kryloff hypothesis, i.e. using the wave velocity potential only, lead to significant low exciting forces and moments which will practically under evaluate the body motions. The differences are much larger in case of diffraction moments having as consequence a drastic decrease of roll and pitch amplitudes which could affect stability evaluations.

On the other hand, it is important to observe that the influences of body motions on the evaluation of diffraction forces and moments can be neglected.

The use of the 3-D potential theory leads to a very good agreement with the calculated values using other different theoretical approaches and more important, with the experimental ones as presented in the comparative diagram.

Acknowledgements

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