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Rankine time-domain method with application to side-by-side gap flow modeling

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ABSTRACT

The performance of a time domain Rankine panel method applied to the seakeeping problem of two ships in side-by-side configuration is investigated in this article. Benchmark data for the numerical results are provided by fundamental seakeeping tests carried out in the towing tank of the CEHINAV-Technical University of Madrid. The multi-body system was composed by a barge and a prismatic geosim, which were subjected to regular head waves in two different gap distances. The motions of the geosim model were restricted to surge, heave and pitch, whereas the barge model was kept fixed. This set-up was adopted so as to guarantee that the gap width remained constant during the tests, providing a favorable situation for the numerical modeling of the system. Comparison between measurements and numerical results illustrates the limitation of potential flow solvers concerning the modeling of this hydrodynamic problem. Numerical wave resonance in the gap led to wave elevations and body motions much larger than those observed during the tests. In addition, the time domain method also presented convergence problems for a range of frequencies associated to the gap resonance phenomenon. In order to overcome these problems, an external damping factor was introduced in the time domain simulations, bringing a significant improvement to the numerical convergence of the method. Moreover, despite the simplicity of the damping model adopted, the results showed that this technique was indeed able to improve the computational predictions, leading to a closer agreement between the experiments and the numerical results.

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1. Introduction

The hydrodynamic interaction of two vessels in a side-by-side arrangement is currently receiving substantial attention due to its practical application in the offloading process involving the so-called FLNG (Floating Liquefied Natural Gas) units and LNG (Liquefied Natural Gas) carriers. As a result, much attention has been given to the analysis of multi-body interaction effects with regard to the prediction of risk of collision between the vessels [1]. In this regard, the correct modeling of the fully coupled dynamics of this multi-body problem and also the prediction of the vessels relative motions are important aspects when planning of such a complex operation [2]. Indeed, this analysis must also be taken into account in the design of a mooring system for this kind of operation [3].

Wave resonant effects in the gap is one of the challenging problems in the hydrodynamic modeling of two bodies arranged in a side-by-side configuration. These resonances create different mode shapes of wave elevation in the gap at each associated resonant frequency, which is a behavior quite similar to the one that takes place in moonpools [4]. The three basic modes are normally referred to as the piston mode, longitudinal and transversal sloshing. An approximation formula for the estimation of these frequencies in open boundaries may be found in [5]. A comprehensive numerical investigation with the purpose of studying the different resonant frequencies and modes is given by Sun et al. [6].

Occurrence of gap wave resonant effects in problems involving bodies arranged in side-by-side has already been observed by several authors (see for instance [7–9]). Although, in reality, resonant effects in the wave height may occur in the gap, they are largely dampened by viscous effects and, therefore, the conventional potential flow methods are known to over-estimate the hydrodynamic forces, the wave elevation in the gap and consequently the body motions. This occurs because these methods are unable to model the viscous effects, namely skin friction and flow separation on the hull side, that are deemed important, especially the latter, for the flow in the small gap between the hulls [10,11].

CFD applications for dealing with the viscous effects in this resonant problem are certainly envisaged, but, to this moment, the high computational effort they demand still renders these applications infeasible for practical engineering purposes. For this

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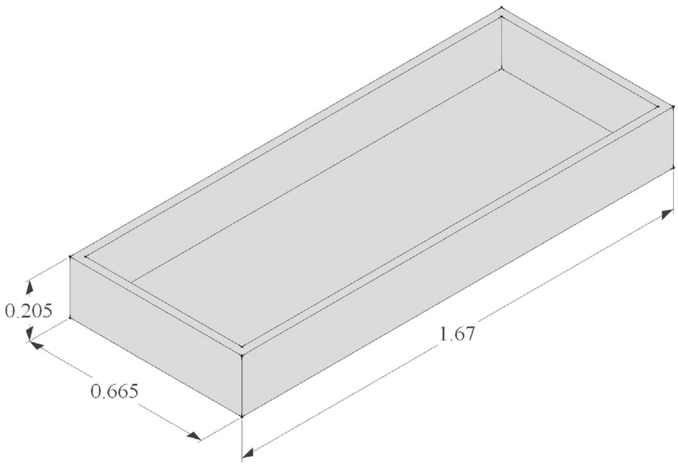

Fig. 1. Barge geometry and main dimensions in meters.

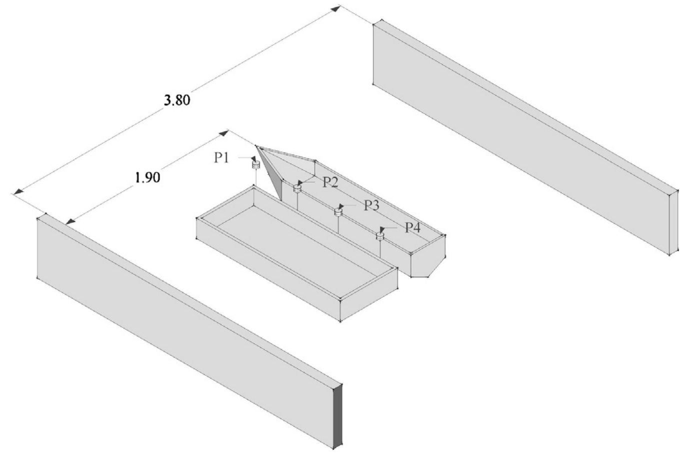

Fig. 4. Models positions in relation to the towing tank walls. Dimensions in meters.

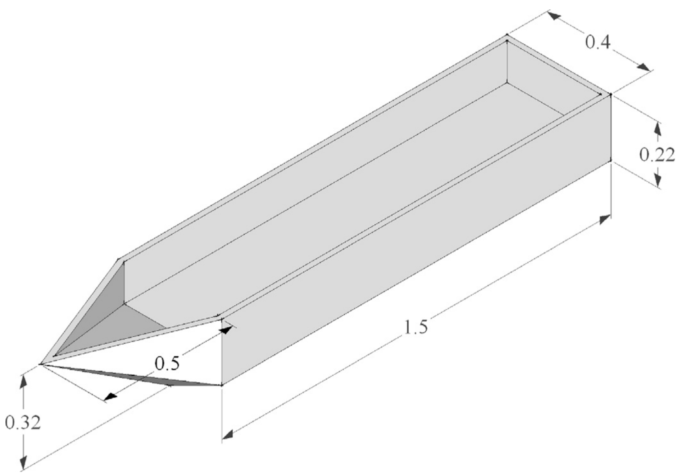

Fig. 2. Geosim geometry and main dimensions in meters.

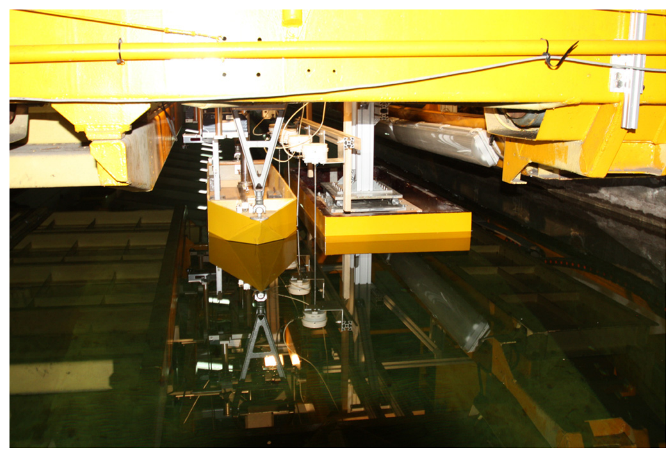

Fig. 5. General view of the models positioned in the tank.

reason, mixed approaches combining the benefits provided by viscous and potential flow solvers may be considered as a promising alternative to handle the problem. Kristiansen and Faltinsen [12] applied this methodology in a two-dimensional numerical wave tank with a floating body. Elie et al. [13] presented numerical results computed with their three-dimensional SWENSE (Spectral Wave Explicit Navier–Stokes Equations) numerical method for two side-by-side fixed barges in different regular waves incident angles.

However, for the time being, computational methods most often applied to model the side-by-side problem are based on the potential flow theory, in which suppression methods to deal with the resonant problems are used as an attempt to better reproduce the physics of the phenomenon. In the context of linear frequency domain diffraction/radiation codes, Huijsmans et al. [7] imposed a no flux vertical condition by applying a rigid lid along the gap

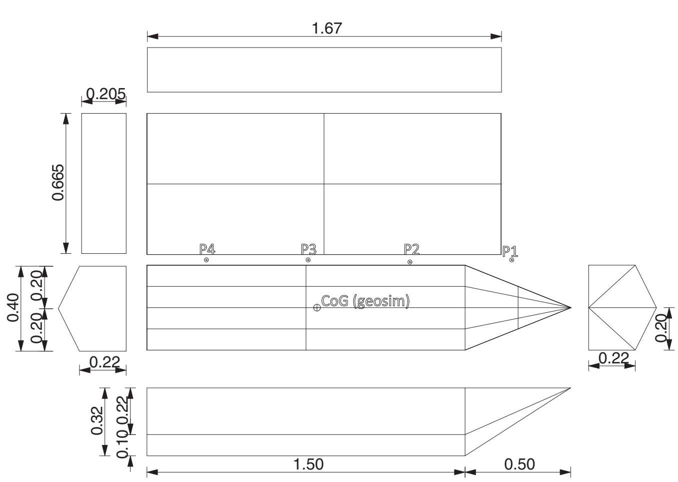

Fig. 3. Details of the geosim geometry and main dimensions in meters.

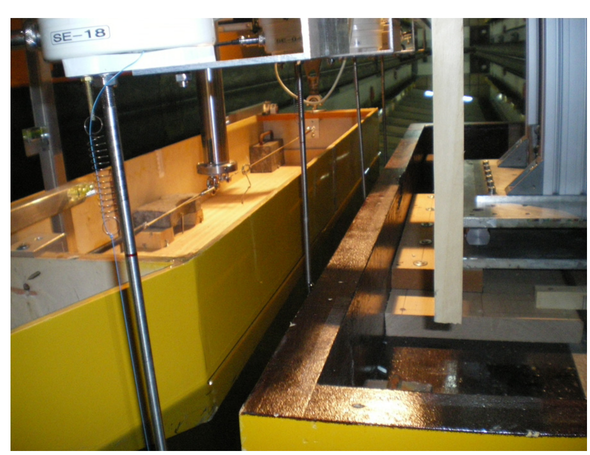

Fig. 6. Wave probes arranged along the gap centerline.

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