Recent progress on a complete and consistent second-order wave hydrodynamics model for floating structures

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Abstract

The second-order weakly nonlinear theory is commonly applied in the design and analysis of floating offshore structures. However, challenges and theoretical inconsistencies still exist in most of, if not all, the state-of-the-art models formulated in the Earth-fixed coordinate system, either in the time or frequency domain. The first challenge is related to the body boundary conditions involving second or higher derivatives, which are very difficult to numerically evaluated on structures with high curvature. In case of sharp edges, those high derivatives are non-integrable, leading to a theoretical inconsistency when Boundary Element Methods (BEMs) are used to solve the governing equation through the boundary-integral equations. Another theoretical inconsistency appear for moored floating structures with large horizontal motions. Those motions, often dominated by low-frequency slow-drift motions, could be comparable to or larger than the characteristic dimensions of the floating structures, e.g. diameter of the vertical columns of semi-submersible floaters. A traditional second-order wave hydrodynamic formulation assumes that the dynamic motions of the structure are asymptotically smaller than the characteristic dimensions of the structures, and that the second-order motions are smaller than the corresponding first-order ones. Those assumptions are often easily violated for moored structures in storm conditions.

In this presentation, some recent progresses on the development of a complete and consistent second-order wave hydrodynamics model, which were started by Shao and Faltinsen [1] and recently revisited by Shao et al. [2], will be presented. The model uses an alternative formulation in the body-fixed coordinate system, and can theoretically avoid the above mentioned challenges and inconsistencies. Some numerical examples will be given for demonstration purpose, including ship seakeeping and added resistance, and slow-drift motions of a deep-draft spar buoy. In the first case, we will show that one can avoid using soft springs in the time domain simulations. In the first case, we will show that one can avoid using soft springs in the time domain simulations thanks to the alternative formulation. In the second case, the importance of considering slow-drift motions and velocities will be discussed through comparisons between the consistent model and models that ignore either slow-drift motion or velocities.

Keywords: Second-order theory; Mooring; Floating structures; Slow-drift motions.

References

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