A 3D high-order spectral element unified Boussinesq model for floating point absorber

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ABSTRACT

This work is focused on the development of a new nonlinear tool for floating Wave Energy Converter (WEC) analysis. In particular, we focus on point absorber WECs that convert wave motion into electricity. Point absorbers are buoys that operate in nearshore regions, preferably in resonance regime with the waves. These devices have smaller dimensions compared to the wave length in which they are employed and they are of interest to the renewable energy community for the low ecological and landscape impact [1].

In marine engineering, the analysis of wave-floating body interaction is commonly based either on linear radiation theory within the small oscillation assumption or on Reynolds averaged Navier Stokes (RANS) models to have a complete description of the body behaviours [2]. However, while the linear theory fails to capture the nonlinear characteristics of the problem, the RANS simulations require an impractical amount of computational power. Thus, we have considered a new medium fidelity model for nonlinear wave-structure interaction based on Boussinesq-type equations, which have been a successful mean to deliver fast industrial wave propagation tools for decades.

Boussinesq models are based on vertically integrated dimensions reducing the original problem to a lower dimension one ($\mathbb{R}^3 \to \mathbb{R}^2$), resulting in efficient models that take into account nonlinear effects and non-hydrostatic kinematics. We have considered a 3D 'unified' wave-body coupling where the flow is solved in the free surface region and in the body region with the same model. This was inspired by the approach proposed initially by Jiang [3] and recently analyzed in two-dimension by Lannes [4] and Bosi et al. [5]. The proposed model expands the previous results of [5] to a 3D domain. This model resembles the coupling between two depth-averaged shallow water (or Boussinesq) models: a classical one for the outer free surface region and congested flow model in the inner region under the floating structure [6]. The equations are discretized in space by a high-order two dimensional continuous spectral/*hp* element method is employed as it combines the generality of the finite elements with the precision of the spectral technique described in [7] while a discontinuous Galerkin method has been used to describe the coupling fluxes between the free surface domains and the congested flow domain, as suggested in [8]. The spectral method developed presents an exponential speed of convergence and thereby provides an efficient and accurate basis for an high-order numerical approximation.

The work can be viewed as a concrete case within a general unified theoretical framework that allows the coupling of different shallow water and Boussinesq-type models. Preliminary results on the interactions between waves and floating structures will be presented.

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