AN HP/SPECTRAL ELEMENT UNIFIED BOUSSINESQ FRAMEWORK FOR WAVE-FLOATING BODY INTERACTION

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This work is concerned with the development of a new efficient and accurate nonlinear tool for floating Wave Energy Converter (WEC) analysis. Floating WECs are structures that can harvest energy from the wave motion. Employed nearshore, they are gaining interest in the renewable energy community for the low ecological and landscape impact and the predictability of wave state [1]. The interactions between WECs and waves are traditionally modeled using linear radiation diffraction models [5]. Lately, Reynolds averaged Navier-Stokes (RaNS) models are being employed for research purposes aimed at maturing engineering practices through simulation tools that capture the nonlinear properties of waves [6]. However, the first fails in capturing viscous and higher orders nonlinear effects while the latter requires an impractical amount of computational power and time to evaluate the solution. We present a new medium fidelity model for nonlinear wave-structure interaction based on Boussinesq-type equations that have been a successful means to deliver fast industrial wave propagation tools for decades. These are based on vertically integrated dimensions, to obtain efficient models that take into account nonlinear effects and non-hydrostatic kinematics. We have considered a wave-body coupling inspired by the work of Jiang [2]. The resulting model closely resembles the coupling between two depth-averaged shallow water (or Boussinesq) models: a classical one for the outer free surface region and a variant based on pressure-velocity coupling for the inner region under the floating structure. We discuss the discretization of the problem: a high-order continuous spectral/hp element method is employed to discretize the equations in space as it combines the generality of the finite elements with the precision of the spectral technique described in [3]. The coupling fluxes between the inner and outer domains are described by numerical fluxes as suggested in [4] for discontinuous Galerkin spectral element method. The spectral method developed will present an exponential speed of convergence and thereby provide a basis for trade-off between accuracy and efficiency through the use of high-order numerical approximation. The work can be viewed as a concrete case within a general unified theoretical framework that allows for coupling different shallow water and Boussinesq-type models. A major advantage of this is that it is possible to demonstrate convergence to meet practical accuracy requirements and enable numerical analysis that can help qualify the fidelity needed from simulation tools. These results are employed to evaluate the benchmark for a one-dimensional freely heaving box case, reproducing the results presented the work of Lannes [7] and Rodriguez et al. [8] for nonlinear model and compared to VOF results for the Boussinesq model. The wave-body interaction is explored to allow the introduction of mooring in the form of a spring and power take-o_ unit in the form of a damper. Preliminary work on a proof-of-concept in a two-dimensional setting are presented. The continuation of this work is aiming at bridging these fundamental developments to applications of engineering relevance.

REFERENCES