Modelling Wave-Structure Interaction of Submerged Flexible Plates

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ABSTRACT

The interaction between water waves and submerged flexible plates has gained significant interest for applications in wave energy harvesting [1]. This study focuses on characterizing the coupled dynamic response of a flexible submerged plate clamped at one edge, subjected to wave forcing; see the schematic representation in Fig. 1. We employ two-way coupled fluid-structure interaction simulations to capture the intricate interaction between the waves and the flexible plate. The incompressible flow is simulated using a finite volume approach-based Navier Stokes solver in OpenFOAM. The structural counterpart is simulated using the Finite Element Method-based solver CalculiX. To facilitate the two-way coupling between the structural and the fluid solver, preCICE is used to aid in data exchange between the employed solvers. Strong coupling is achieved through the parallel implicit scheme with the IQN-ILS acceleration method.

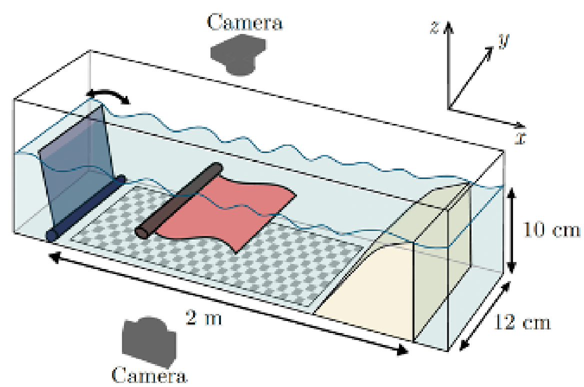

Figure 1: Schematic diagram of the water tank: the wave maker, the thin elastic plate and the wave absorber. The checkerboard pattern on the bottom is used to reconstruct the water height map using the top view camera. The side view camera is used to track the deformation of the plate.

We build on experimental results where a flexible polypropylene plate, submerged at a fixed depth and clamped at one edge, was subjected to waves of varying frequencies and amplitudes [2]. The motion of the plate is found to be crucial in wave reflection, with the flexible plate exhibiting significant wave attenuation capabilities. For low-amplitude waves, the plate reflects and transmits wave energy depending on the wave-to-plate length ratio. At higher wave amplitudes, the plate's ability to change its mean position allows it to act as an efficient wave absorber, dissipating incoming wave energy. Key parameters influencing the wave-structure interaction, such as wave characteristics (amplitude, frequency), plate material properties and flexibility, and geometric configurations, are systematically investigated under varying wave conditions, facilitating the optimization of design parameters for enhanced performance and durability. The findings suggest that the plate's flexibility induces nonlinear behaviour, enhancing its potential for applications like coastal protection and wave energy conversion. The study also explores the role of the plate's resonant frequencies and deformation modes in modulating wave reflection and transmission. This research provides insights into the hydrodynamic performance of flexible submerged plates, offering valuable contributions to the design and optimization of marine structures aimed at sustainable wave energy utilization.

References

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