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MODELLING OF WAVE-STRUCTURE INTERACTIONS USING NON-LINEAR NUMERICAL MODELS

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The accurate computation of wave loads is important in offshore engineering, for example, to optimally design oil and gas platforms or coastal defense structures. In recent years, there has also been an increased interest in offshore renewable-energy devices, which can be either mounted on the sea bed (fixed devices) or moored to it (floating devices). In this context, an accurate prediction of the wave loading is vital to ensure that offshore renewable-energy devices are economically viable and can withstand rough sea conditions. Numerical models can assist in the design of these devices by analysing several different configurations, while limiting expensive laboratory or onsite testing. The hydrodynamic behaviour is however complex due to: (i) the interactions between extreme waves and solid structures (for fixed and floating devices), and (ii) the mutual interactions between fluids and moving solids (for floating devices). The method developed in this work aims at tackling both aspects, although only fixed solids are considered in this study.

This study uses the computational fluid dynamics (CFD) model 'Fluidity-ICOM' [1], [2] to numerically solve the Navier–Stokes equations. Two approaches are compared to model waves interacting with solid structures. On the one hand, the Navier–Stokes equations are solved on a mesh surrounding the solid structures (defined-body method). This technique can give accurate results, when using appropriate discretisation schemes and sufficient spatial resolution, because the solid shape and boundary conditions are represented exactly. However, if the solid moves in the fluid domain, re-meshing is necessary. This is computationally expensive and might yield highly-distorted grids. In order to avoid this problem, another approach consists in meshing the entire domain (containing both fluids and solids) and model the effect of the solids through a body force. This methodology underpins the so-called immersed-body method. The latter uses two distinct meshes: one covering the entire domain (fluid mesh), and the other discretising solely the solids (solid mesh). The regions occupied by the solids are identified through a solid-concentration field, which is computed by projecting a unitary field from solid to fluid mesh. This method is a versatile way of modelling interactions between fluids and solids. Viré et al. [3] further presented a novel algorithm to ensure spatial conservation of the penalty force and solid-concentration field when projected from one mesh to the other.

The present study aims at validating the immersed-body approach in the context of wave-structure interactions. First, the propagation of waves is simulated in the inviscid regime, without solid structure. The results are shown to be in good agreement with linear wave theory. Second, a cylindrical pile is subjected to a regular train of small-amplitude gravity waves and linear diffraction theory is used for comparisons. Good overall agreements between the numerical and theoretical predictions is obtained for the free-surface elevation, using both defined- and immersed- body approaches. The immersed-body approach however tends to underestimate the water elevation in the vicinity of the structure, due to additional dissipation induced by the body force. The results will be shown for a wide range of wave conditions and recommendations will be made for future work.

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