VALIDATION OF A BUOYANCY-MODIFIED TURBULENCE MODEL BY NUMERICAL SIMULATIONS OF BREAKING WAVES OVER A FIXED BAR

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INTRODUCTION

The surf zone dynamics are governed by important processes such as turbulence generation, nearshore sediment transport, wave run-up and wave overtopping at a coastal structure. During field observations, it is very challenging to measure and quantify wave breaking turbulence. Complementary to experimental laboratory studies in a more controlled environment, numerical simulations are highly suitable to understand and quantify surf zone processes more accurately.

In this study, wave propagation and wave breaking over a fixed barred beach profile is investigated using a two-phase Navier-Stokes flow solver. We show that accurate predictions of the turbulent two-phase flow field require special attention regarding turbulence modelling. The numerical wave flume is implemented in the open-source OpenFOAM library. The computed results (surface elevations, velocity profiles and turbulence levels) are compared against experimental measurements in a wave flume (van der A et al., 2017).

NUMERICAL MODEL

Numerical simulations are performed in a 2D numerical wave flume taking into account both water and air phases. The two-phase flow field is solved by using the incompressible Reynolds-Averaged Navier-Stokes (RANS) equations. The interface between the water and air phase is obtained by the Volume of Fluid (VoF) method in which a conservation equation is solved for the volume fraction. Boundary conditions for wave generation and absorption are adopted from the IHFOAM toolbox.

RANS turbulence modelling is applied by using a buoyancy-modified *k-ω* and *k-ω SST* model, which has been developed in previous work of the authors (Devolder et al., 2017, 2018). In general, such a buoyancy-modified turbulence model results in a stable wave propagation model and will predict the turbulence level in the flow field more accurately at the locations where wave breaking occurs. Furthermore, in the flow field prior to wave breaking (i.e. during wave propagation), low turbulence levels are expected and a laminar solution is acceptable. Therefore, the buoyancy term forces the solution of the flow field near the free water surface to a laminar solution in case of wave propagation. This approach also avoids wave damping over the length of the flume inherent in traditional RANS modelling. Subsequently in the surf zone where waves break, significant turbulence levels are expected. For this zone, the buoyancy term goes to zero and a fully turbulent flow field is resolved by the numerical model.

VALIDATION USING A TEST CASE

The performance of the numerical model, presented in the previous paragraph, is studied by performing simulations of breaking wave hydrodynamics over a fixed bar. The numerical results are validated using the large-scale laboratory study reported in van der A et al. (2017). An overview of the longitudinal cross section is shown in Figure 1. Regular waves are generated with wave height H = 0.85 m and wave period T = 4 s, first propagating and shoaling over an offshore slope (1:12) and subsequently breaking over a fixed bar with a height of 0.6 m. The validation study comprises surface elevations along the length of the wave flume, measured with resistive wave gauges (RWG) and pressure transducers (PT in Figure 1). In addition, velocity measurements and turbulence levels (e.g. TKE, Reynolds stresses, dissipation rates) along vertical profiles at particular locations in the surf zone are also compared to the experimental data.

By comparing our numerical simulations with the experimental dataset, we show that also for realistic situations, such as wave breaking over a bar, our buoyancy-modified turbulence model is able to accurately resolve the turbulent flow field, not only in terms of surface elevation and velocities, but also in terms of turbulent quantities.

REFERENCES

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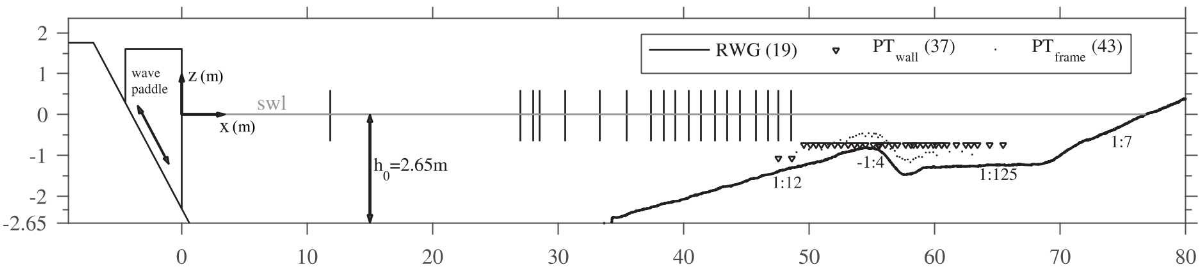

Figure 1 – A longitudinal cross section along the experimental wave flume used for the numerical simulations. Adopted from van der A et al. (2017).