

Numerical Simulation of Extreme Free Surface Waves

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ABSTRACT

In traditional coastal and offshore engineering design, physical experiments and potential flow solvers are commonly used to investigate wave loading on structures. However, most potential flow models cannot deal with extreme free surface problems including wave breaking or splashing over the structure. Further, physical experiments easily become very complex and scaling issues arise. In these cases, an approach that includes the viscous effects models both water and air and fully couples the wave and structure is needed. This paper deals with the generation of waves close to the breaking point using two commercial software packages. These may be used to generate an extreme design wave to investigate the survivability of offshore wave energy converters or other devices operating in such a challenging environment. Regular and focused wave results are presented and compared with physical experiments and potential flow calculations.

KEY WORDS: NewWave; CFD; focused waves; free surface; 1st order; 2nd order

INTRODUCTION

One of the largest renewable energy resources is provided by the oceans covering more than 70% of our planet. Powered by the sun, the moon and the wind, waves result from the huge amount of energy generated by these phenomena. During the past 30 years large effort has been undertaken to transfer the wave energy into electricity by using many different techniques and approaches. One thing is similar in all wave energy devices, either floating on the surface or fixed on the sea bed: they have to operate in one of the most challenging environments. Apart from corrosion due to the elements, the subject the devices are designed for - the waves - put the largest stresses on them. The range of wave shape varies from small ripples over long periodic oscillations to extreme high and steep waves appearing almost suddenly by wave interaction of comparatively small ones. In traditional offshore design, physical experiments and potential flow calculations are the state of the art. However, when considering the highly turbulent processes of wave breaking and run-up at the wave energy converters (WEC), with overtopping, splashing and mixing, both of these procedures reach their limits. The calculations cannot be used for all

physical possibilities and the physical experiments are often very expensive and the received data set might be small. Hence other methods have to be used which can handle viscosity effects in field and laboratory scale and model both air and water to simulate these green water effects. With increasing computational power, design tools like Computational Fluid Dynamics (CFD) become attractive. Using fully nonlinear Reynolds-Averaged-Navier-Stokes (RANS) implementation, state of the art interface capturing schemes and turbulence methods, they fulfil the requirements for the described cases.

The EPSRC project “Extreme Wave Loading on Offshore Wave Energy Devices using CFD” deals with the topics just described. The programme of work starts with the modelling of the waves, regular and focused, which is described in this paper. Simulation data shall be compared with experimental data from appropriate physical tests and further numerical results generated from other work packages in the project. The waves are generated by applying the horizontal and vertical velocity components at the left hand boundary of the domain. For the NewWave simulations several linear wave components taken from a measured wave spectrum are superposed to focus at a given location and time in the numerical wave tank.

EXPERIMENTAL SETUP

In this work, we follow the wave tank geometry and set up used in physical experiments described by Ning *et al.* (2007). They used a wave tank with the dimensions 69 m x 3 m and the water depth in the experiment was set to 0.5 m. The waves were generated by a piston wavemaker and wave reflections were absorbed by a 4 m foam layer placed at the downstream end of the flume. Wave gauges (WG) were used to measure the surface elevation around the point of the maximum wave elevation. Additionally an Acoustic Doppler Velocimeter (ADV) was used to measure the horizontal water velocities in a depth of 0.15 m below still water level at the focus point. In the study by Ning *et al.* (2007), four NewWave cases are investigated with different input amplitudes; here we reproduce numerically cases 2, 3 and 4.

The NewWave theory describes the surface elevation and wave velocity components of a focused wave group of N waves taken from a measured or theoretical spectrum, e.g. JONSWAP or Pierson-