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Prediction of extreme wave loads in focused wave groups

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ABSTRACT

The Volume of Fluid (VoF) method is a promising tool to predict extreme wave loads on fixed and floating offshore structures. The VoF method described in this paper has been validated step by step by means of model tests like dam break flow, sloshing in LNG tanks and loads on fixed structures in extreme regular waves. Until recently, there was no means to generate a realistic extreme irregular wave in the VoF method. Traditionally, these are generated in time-domain simulations by picking extreme events from long-duration simulations that apply a random phase model to generate waves. Due to the fact that the computational times in the VoF method are large such an approach is not feasible. Instead, an approach based on wave focusing can be applied. The focused wave is designed by choosing the phases of the linear harmonic components such that they are identical at a certain target location. By means of linear dispersion, the wave time trace at the wave generator is predicted and subsequently the required motions of the wave generator. This approach was applied in model tests designed to validate the VoF model in extreme irregular waves. A simplified box-shaped structure was placed in a shallow water basin in the path of the focused wave group and the wave loads were measured. This paper focuses on the ability of the VoF method to reproduce these focused wave groups and the subsequent wave loads on a typical fixed structure, using the motions of the wave generator. The VoF method contains too much numerical dissipation to properly compute wave propagation over long distances (from the wave generator to the target location). Therefore, a non-linear potential flow method is used to simulate the wave propagation from the wave generator to the boundary of the computational domain of the VoF method (close to the target location). At the boundary of the VoF domain the wave kinematics from the potential flow method are used as boundary conditions for the VoF method. The VoF method is then used to determine the focused wave around the target location and the impact on a structure which is located there.

KEY WORDS: VoF; wave focusing; nonlinear waves; model tests; wave loads;

INTRODUCTION

The 2004/2005 hurricanes Ivan, Katrina and Rita in the Gulf of Mexico have led to renewed attention to extreme waves and their consequences for offshore structures as described by D.J. Wisch and E.G. Ward (2007) and G. Forristal (2007). This also involves prediction tools for possible extreme loads associated with these extreme waves. Model tests are commonly used for this purpose. Although model tests are the accepted standard and very valuable, they are expensive and do not show large insight in flow details during wave impact. Therefore a lot of effort is put into making CFD suitable for the prediction of extreme wave loads. The main problem at the moment is the large computational effort involved in CFD time-domain simulations Traditionally, model tests or simple time-domain simulations (based on linear diffraction wave loads) focus on long-duration (3 hours or more) sea states in which statistical information is gathered on extreme wave loads and distribution functions. Due to the large computational time, this is not possible in CFD and therefore it has to focus on a few isolated extreme events. There are several challenging questions that need to be answered:

1. What does a realistic extreme irregular wave look like?
2. When is an extreme wave extreme to the structure?
3. How is this extreme wave generated in CFD?

This paper addresses the third question and describes a method to generate long-crested extreme waves measured in the model basin in a Volume of Fluid method, and the subsequent loads on a structure in the path of the wave. The measurements include a regular wave and several focused wave groups. For all these waves, the motions of the wave generator have been measured and this signal is used to generate the waves in the simulations. The propagation of the waves from the piston-type wave maker towards the location of the structure is simulated by means of a non-linear potential flow code. The interaction with and the wave loads on the structure in the path of the wave are simulated by means of the VoF method. The wave elevation and wave orbital velocities obtained with the potential flow code are used as boundary conditions in the VoF method. This split up using two codes is done because of to the following reasons: