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CFD Simulations of Wave Impact Loads on a Truncated Circular Cylinder by Breaking Waves

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In this study, a numerical study was carried out on the wave impact problems between a truncated circular cylinder and breaking waves by using computational fluid dynamics (CFD) simulations. The target problem, which has been experimentally examined in the model test of Ha et al. (2018), is the wave impact problem between the cylinder and three different focusing waves (i.e., steep, spilling, and plunging waves). First, wave generation performance is checked by applying the present CFD simulation. In this case, the measured stroke signals of the wave maker in the test were directly used as input to the velocity boundary condition of the numerical calculation. Then, a series of CFD simulations were performed to estimate the local wave impact forces acting on the cylinder. For the validation, the numerical simulation results were directly compared with the model test data.

INTRODUCTION

The accurate estimation of wave impact force is significant for the survivability of the offshore platform under harsh environmental conditions. Moan (2005) reported accident rates for floating and fixed platforms in severe weather conditions. He explained that severe weather conditions would greatly affect structure damage of floating and fixed platforms. He also showed that the structural damages of various accidents cause a low fatigue life. Rosenthal et al. (2007) reported on the Draupner wave in the North Sea through the MaxWave Project. They showed the existence of high waves that were more than two times higher than the significant wave height—so-called rogue waves. It is known that severe sea conditions have caused the loss of more than 200 carriers.

Depending on the direction of the relative motion between the offshore platform and the incoming waves, the wave impact can be divided into two categories: vertical wave impact and horizontal wave impact. The vertical wave impact includes the bottom slamming of a ship-type structure and the wave-in-deck impact of a semi-submersible or tension-leg platform. In general, it is well known that the vertical wave impact load is a function of water entry velocity and the dead-rise angle between the platform and incoming wave. On the other hand, the horizontal wave impact includes the column or deck-box impact of the jacket platform or semisubmersible platform and the front bow impact of floating production storage and offloading units. The horizontal wave impact is a function of relative horizontal velocity including forward speed and wave speed. It is known that the large horizontal wave impact is generally caused by the breaking waves. The cylinder wave impact, which has been studied by many researchers for a long time, is a typical problem of this horizontal wave impact.

The breaking waves are usually categorized as spilling and plunging waves. The plunging wave has an especially dramatic wave shape as the overturning fluid of the wave crest and is an important topic on the wave impact force. To simulate the breaking wave numerically, many researchers introduced various numerical schemes. For example, Zelt (1991) generated a breaking wave on the beach. He used the Lagrangian finite-element Boussinesq wave model, and the numerical results were compared with the laboratory data. Hino et al. (1983) computed nonlinear shallow–water wave problems using the marker-and-cell (MAC) method. Results using the method showed a solitary wave approaching a beach and breaking waves. Lin and Liu (1998) treated the volume-of-fluid (VOF) model to capture the wave-breaking processes in two-dimensional flows. Also, this study showed that mean vorticity and turbulence intensity were very weak when close to the breaking wave front. Chen et al. (1999) performed the wave generations of a plunging breaker, including splashup. This study used the two-dimensional Navier–Stokes equation, and the results showed strong vorticities in breaking waves during the breaking process. Ghosh et al. (2007) performed the model tests and numerical simulations for generating breaking waves. Propagation characteristics of the breaking waves were directly measured using particle image velocimetry (PIV), and the numerical simulation results obtained by the level-set method (LSM) were compared with the results by PIV. Gotoh (2009) computed the process of wave breaking and run-up by using the moving particle semi-implicit (MPS) method. This study showed that

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KEY WORDS: CFD, focusing wave, wave impact, steep waves, spilling waves, plunging waves.