International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 29, No. 3, September 2019, pp. 295–305; https://doi.org/10.17736/ijope.2019.ak34

http://www.isope.org/publications/publications.htm

Numerical Study of Focusing Wave Impact on a Fixed Cylinder

Seon Oh Yoo, Taeyoung Kim, Hyun Joe Kim and Dong Yeon Lee
Ship and Offshore Research Center, Samsung Heavy Industries
Daejeon, Korea

In recent years, interest has grown in studying impact loads by extreme waves when designing offshore structures. To date, the estimation of extreme wave and impact loads has been performed mostly through model tests. Since extreme waves are highly nonlinear, lengthy programs for model tests are required to properly estimate the level of impact load. In this sense, many attempts have been made to see results within relatively shorter durations. An example is numerical analysis based on computational fluid dynamics (CFD) as an alternative to a model test. However, the reliability of CFD simulation for extreme waves and induced impact load has not yet been properly proven. For better understanding of extreme waves, this paper studied the realization of focusing waves and associated impact loads on a fixed cylinder. CFD was used to consider the inherent nonlinearity in focusing waves. The focusing waves were generated by a numerical wavemaker, and the motion of the wavemaker was reconstructed from time series in model tests. A numerical scheme was calibrated with a combination of mesh size and time step to properly generate the focusing wave. Impact loads on a fixed cylinder were then calculated with calibrated parameters. Comparison was made for three different types of focusing waves: plunging, spilling, and steep waves. The effect on the sensor's mesh and air compressibility were also discussed.

INTRODUCTION

Most offshore structures are required to operate for more than 20 years in the harsh environmental conditions on site, requiring a complete structural integrity that can be achieved by predicting the extreme wave loads of these conditions. Thus, designing offshore structures presents a significant challenge. In order to properly predict design loads, irregular sea states need to be considered in long-term statistics. This requires a great amount of computation time and cost. Hence, as an alternative approach, the focusing wave is being widely employed on the basis of nonlinear wave–wave interaction.

The focusing wave is highly nonlinear, making it reliable in experiments for a large number of researchers. Additionally, computational fluid dynamics (CFD) is widely utilized since it can take into account the nonlinear interactions of waves and structures. Yang et al. (2011) and Chen et al. (2014) generated focusing waves by using open source software, OpenFOAM. A linear wave theory was applied to a wavemaker or to flux on a wall. The global trend showed in the adequate agreement between numerical and experimental waves, but discrepancy was observed at the highest peak.

When focusing waves include breaking phenomena, it is more difficult to generate them. In this sense, modification was considered for initially generated waves. Bunnik et al. (2015) conducted the model tests and numerical simulations using a ComFLOW program. Measured waves were reconstructed by second-order wave theory, and those were used for the numerical simulation. The amplitude and phase were iteratively modified until the shapes matched appropriately. Pakozdi et al. (2016) carried out a CFD simulation to obtain wave impact loads during green water events on a tension leg platform. In their study, linear superposition of regular waves was assumed, and scaling factors were introduced in order to generate a desired wave height.

In the work of Östman et al. (2015), numerical simulation started near the breaking event since using full lengths of experimental data has a high computational cost. Truncated simulation reasonably generated a global pattern of waves, but peak amplitude was underestimated. Duz et al. (2017) compared the numerical solution with test results using particle image velocimetry (PIV). The shape was well matched when wave components were corrected by iteration. Scharnke et al. (2017) also used PIV results and showed that wave loads can be predicted properly if wave parameters are known at the location of impact. However, such parameters would not be easy to know since even Stokes' fifth-order theory underestimates horizontal particle velocity. Deng et al. (2016) also found that the wave stretching model is restricted to the prediction of particle velocity and induced loads. Recently, the Korea Research Institute of Ship and Offshore Engineering (KRISO) conducted a series of experiments about impact loads acting on a fixed cylinder from three different types of focusing waves: plunging, spilling, and steep waves (Ha et al., 2018). Relevant numerical simulations have shown that wave kinematics is also dependent on the shape of meshes (Hong et al., 2018; Liu et al., 2018).

The previous studies commonly showed that the shape of focusing waves was not easily generated, especially near focusing points. In this regard, several researchers employed iteration or scaling factors to achieve a better agreement. However, published results so far are highly dependent on computational parameters. It is obvious that thorough analysis is required to seek efficient and appropriate ways to generate focusing waves. Our primary concern is establishing the procedure and methodology to appropriately predict the impact loads by focusing waves. Despite active research on this topic, correspondence between experimental and numerical results is still not mature. Therefore, this paper focuses on how the focusing waves can be generated with adjusting computational parameters.

In this paper, the realization of focusing waves and associated impact loads on a fixed cylinder was investigated using CFD. The numerical solution was compared to the results of model tests by KRISO (Ha et al., 2018). In the CFD simulation, the motion of

Received October 24, 2018; updated and further revised manuscript received by the editors January 15, 2019. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-eighth International Ocean and Polar Engineering Conference (ISOPE-2018), Sapporo, Japan, June 10–15, 2018.

KEY WORDS: Computational fluid dynamics, piston-type numerical wavemaker, plunging wave, spilling wave, steep wave, wave impact.