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A Comparative Study on the Nonlinear Interaction Between a Focusing Wave and Cylinder Using State-of-the-art Solvers: Part B

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In this paper, the comparative study carried out for focused wave interaction with a moving cylinder in ISOPE-2020 is reported. The fixed cylinder cases are reported in the companion paper as Part A (Sriram, Agarwal, Yan et al., 2021). The paper discusses qualitative and quantitative comparison between four different numerical solvers that participated in this comparative study. This is a challenging problem, as the cylinder moves over 40 m and interacts with the focusing waves. The performance of various solvers is compared for two different moving cylinder speeds. Both weakly coupled models and full Navier–Stokes (NS) solvers with different strategies for modeling the cylinder motion were adopted by the participants. In particular, different methods available for numerically simulating the forward speed problem emerge from this paper. The qualitative comparison based on the wave probe and pressure probe time histories between laminar and turbulent solvers is presented. Furthermore, the quantitative error analysis for individual solvers shows deviations up to 30% for moving wave probes and 50% for pressure time history. The reliability of each method is discussed based on all the wave probe and pressure probe discrepancies against experiments. The deviations for higher speed shown by all solvers indicate that further improvements in the modeling capabilities are required.

INTRODUCTION

Nonlinear wave current–structure interaction is a topic of great interest for offshore and coastal engineering as well as naval architecture. However, the problem is challenging and complex due to the nonlinear wave–current process and its subsequent interactions with structure. Traditionally, due to the complication of generating constant current in the laboratory, researchers resort to towing the structure (Koterayama, 1984; Sarpkaya and Storm, 1985; Teng and Nath, 1985; Vengatesan et al., 2000; Shafieefar and Massie, 2001). Modeling extreme scenarios of nonlinear focused waves (or steep waves) superposed with a current of higher intensity can be achieved by this method as generation of focused waves over a current in an experimental facility is challenging (Stagonas et al., 2018). Towing introduces a local current near the structure that is sufficient to evaluate combined wave-current loads on the structure. Nevertheless, a depth-uniform current never exists in practice (Beyer et al., 2017; Chen et al., 2019), and it is only of academic and fundamental interests to understand the physics of nonlinear wave-current loading on a structure. Furthermore, a depth-uniform current would naturally impart more load than the depth-varying current, and hence the towing approach is conservative in nature. By towing the structure, nonlinear wave-current interactions are physically excluded, which facilitates simulating interactions between the combined field and a structure by the numerical modeling community. However, numerical modeling is still challenging for larger towing speeds, where numerical stability and other complex physical processes in the wake region need to be modeled (Yan et al., 2015). This is particularly the case when a fixed reference frame-based simulation approach is adopted, which would require progressively larger domains with increasing towing speed.

The experimental measurements of the moving cylinder interacting with focused waves are released for the ISOPE-2020 participants. This paper discusses the performance of the recent numerical solvers for this complex problem of towing the structure with incoming waves. This benchmark case will be of particular interest to the forward speed problem in naval architecture, apart from studying the wave-current–cylinder interactions in other fields. In Part A (Sriram, Agarwal, Yan et al., 2021), we discussed the numerical performance based on 20 different solvers for wave–fixed-cylinder interactions. However, for a moving cylinder we had only four different solvers. The reason is the complexity of the problem; in particular, the cylinder needs to move over 40 m and then interact with the focusing waves. Herein, the focusing wave has to be fully developed whilst the cylinder should interact at the focusing locations with the same speed. Hence, the performance of the solvers or methodology adopted by the participants for this complex problem has been discussed, and the reliability of the approach in capturing: (a) the wave profile in the vicinity of the moving cylinder and propagation of waves in moving framework, and (b) the pressure time history at different probe locations above and below the still water level (SWL) for different towing speeds is analyzed. Finally, the methodology that provides the most robust solutions is identified and recommended for future studies.

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