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Study of Water-entry Impact of Wedge and Ship-like Section Using Potential Theories and CFD

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This paper presents the results of potential-based methods and computational fluid dynamics (CFD) for the water-entry impact of a wedge and ship-like section. In the potential-based computation, a Generalized Wagner Model (GWM) and a Modified Logvinovich Model (MLM) were used. In the CFD computations, a constrained interpolation profile (CIP)-based method and commercial software were used for the prediction of fully nonlinear slamming phenomena. The grid convergence index for the peak pressure was analyzed for both CFD computations. The computational results were also compared with the experimental results obtained by the Korea Research Institute of Ships and Ocean Engineering (KRISO) as part of the Wave Induced Loads on Ships Joint Industry Project-III (WILS JIP-III). In the experiment, free drop tests were performed for 2-D wedges and ship sections of a containership. Accuracy was investigated in terms of the peak pressure, pressure distribution, local hydrodynamic force, and free-surface shape.

INTRODUCTION

When a water wave hits a ship or offshore structure, spatially and temporally localized impact pressure is created. An accurate prediction of the impact pressure on a structure is one of the essential elements to ensure safety in the design of ships or offshore structures (Faltinsen et al., 2004). In particular, the problem of a body falling into calm water at a constant speed has been tackled on the basis of the pioneering works of von Karman (1929) and Wagner (1932). Their methods are still used through the extension of the methods to solve the problem of an arbitrary body shape, and they are called the generalized von Karman and generalized Wagner methods (Kim et al., 2007).

In many papers studying the water-entry problem, the wedge model was commonly used because of its simple geometry and similarity to the shape of engineering structures such as a seaplane landing gear and the bottom of high-speed vessels. The wedge water-entry problems have been solved through the use of theoretical (Mei et al., 1999; Korobkin, 2004; Khabakhpasheva et al., 2014), experimental (Yettou et al., 2006; Tveitnes et al., 2008), and numerical methods (Oger et al., 2006; Kim et al., 2007; Johannessen, 2012; Yang and Qiu, 2012).

Recently, the Wave Induced Loads on Ships Joint Industry Project (WILS JIP) contributed to the investigation of the slamming and whipping phenomena and provided validation data for numerical analysis tools. Systematic model tests for testing the hydro-elasticity of ships were carried out by the Korea Research Institute of Ships and Ocean Engineering (KRISO) as part of the WILS JIP. The project focused on measuring local slamming forces and whipping responses due to waves. In the experiment, free-drop tests were also performed for 2-D wedges with dead-rise angles of 20° and 30°. Furthermore, the original and simplified ship sections of a containership were also tested with different falling heights (KRISO, 2014).

The present study provides the results of potential-based methods and computational fluid dynamics (CFD) computations for the water-entry impact of a wedge and a ship-like section. The test models were selected from the experimental cases of WILS JIP-III conducted by KRISO. In the potential-based computation, a Generalized Wagner Model (GWM) and a Modified Logvinovich Model (MLM) were used. In the CFD computations, a Cartesian-based in-house code, which is based on the constrained interpolation profile (CIP) method and commercial software, was used for the prediction of fully nonlinear slamming phenomena. The dependency of the grid size and time step was investigated for both CFD computations in terms of pressure-time histories. In addition, the uncertainty level of a fine-grid solution was calculated by following the procedure suggested by Celik et al. (2008). The computational results were compared with the experimental results, and the accuracy was investigated in terms of the peak pressure, pressure distribution, local hydrodynamic force, and free-surface shape. Finally, the computational efficiency was discussed in terms of the grid dependency and computational time.

POTENTIAL-BASED COMPUTATIONS

Two potential-based methods–GWM and MLM–are applied to the computations of the water-entry events of a wedge. The methods pertain to the flow of the surrounding fluid as a potential flow and the neglect of the flow separation. The velocity potential is determined by the solution of the Laplace equation under appropriate boundary conditions on the body and free surfaces. The gravity is ignored under the free-surface boundary condition, whereas a static pressure is added to the pressure obtained by the Bernoulli equation. Details of the two methods are described in the following sections.

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KEY WORDS: Water-entry impact, Generalized Wagner Method, Modified Logvinovich Model, CFD.