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

Vol. 27, No. 2, June 2017, pp. 123–134; https://doi.org/10.17736/ijope.2017.jc699

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

Comparative Study of Water-Impact Problem for Ship Section and Wedge Drops

Sa Young Hong*, Kyong-Hwan Kim* and Sung Chul Hwang
Korea Research Institute of Ships and Ocean Engineering
Daejeon, Korea

A comparative study of a water-entry problem was conducted as a focused session of ISOPE-2016, Rhodes by the International Hydrodynamic Committee (IHC) of ISOPE. Thirteen institutions participated, and twenty different numerical results were investigated and compared with one another and with model test data. Some promising results were obtained even though there is still a long way to go to draw general conclusions. Four numerical cases were investigated, and several measures of comparison have been discussed.

INTRODUCTION

Nowadays, computational fluid dynamics (CFD) approaches based on the viscous flow model have been emerging as an alternative tool to traditional potential flow analysis methods and model tests in offshore hydrodynamics. Recent findings on vortex-induced motion (VIM) model tests and sea trials imply that the model test approach cannot predict full-scale VIM due to significant scale effects (KS Kim et al., 2016; Kyoung et al., 2015). Aside from VIM, several effects need CFD power due to their capability for inherent strong nonlinearity and viscous flow dominant physical phenomena, for example, sloshing, slamming and green water impacts, roll damping, and low-frequency motion damping. KS Kim et al. (2016) focused on CFD capability for the design and analysis of offshore platforms by virtue of the rapid increase in the computational power of parallel processing and the matured experience with computational methods in CFD.

Unlike VIM and roll damping that are solely governed by fluid viscosity, impact loads due to slamming are much more complicated because of strong nonlinearity such as wave breaking and splash, which are not strongly dependent on viscosity. Therefore, a more systematic validation study is needed for the application of CFD to impact load analysis. The water entry of a wedge problem is a basic and classical impact load problem, which has been studied by means of numerical and experimental approaches. Numerical study models are categorized by potential flow model and viscous flow model.

Von Karman (1929) and Wagner (1932) first derived analytic solutions. Dobrovol'skaya (1969) then gave a similarity analytic solution. Zhao et al. (1997), Mei et al. (1999), and Malleron and Scolan (2008) conducted a study based on a generalized Wagner model. Korobkin (2004) and Tassin et al. (2014) made improvements on a numerical scheme based on a modified Logvinovich model. Recently, Semenov and Iafrati (2006) and Xu et al. (2008) derived analytic solutions to asymmetric wedge problems. Numerical results based on analytic solutions are very useful for the validation and accuracy of model test results, while the application is very limited to simple wedge-shaped sections. Most of the impact problems encountered pertain to more complicated shapes and three-dimensional cases, so more flexible and general-purpose numerical approaches are necessary. CFD based on a Navier-Stokes (NS) equation has been emerging as an alternative to the potential flow approach by virtue of recent fast-increasing computational power and the development of numerical techniques of the NS solver.

Regarding CFD-based numerical studies of hydrodynamic impact problems, Sames et al. (1999) and Yang et al. (2008) conducted a Eulerian approach analysis with the Volume Of Fluid (VOF) free-surface model (Hirt and Nichols, 1981), while Oger et al. (2009) and Lee et al. (2010) implemented the Lagrangian approach, the particle method. They also compared their numerical results with model test results. Recently, Fluid Structure Interaction (FSI) and a variety of CFD studies have been performed (Peseux et al., 2005; Luo et al., 2011; Panciroli et al., 2012; Yamada et al., 2012; Hwang et al., 2015). The rapid expansion of commercial software and OpenFOAM CFD codes is accelerating the application of CFD to real engineering problems.

In this paper, a series of comparative studies of the water entry of a wedge and ship sections has been presented as a summary of a comparative study carried out as a focused session of the International Hydrodynamic Committee (IHC) at ISOPE-2016. Thanks to contributions of the Wave Induced Loads on Ships (WILS) project (Hong et al., 2014; Kim et al., 2014), a set of valuable model test data on the water-entry problem of a ship section and simple wedges was available. Thirteen groups from universities, classification societies, and research institutes participated in this study, and twenty different analysis results were compared, in which various levels of CFD methods were included as well as the potential flow approaches.

ANALYSIS METHODS

As mentioned previously, thirteen groups submitted their analysis results, but some of the participants provided results using different kinds of approaches, so a total of twenty different numerical methods were available in this comparative study.

The pressure and force signals were shared as well as the displacement and acceleration signals of the body measured from the model test. The drop velocity was also evaluated from the measured displacement and acceleration. The participants were requested to submit the numerical schemes, grid convergence index, pressures, and force signals. It should be noted that the specific numerical schemes were not applied for the body motion, the compressibility, the free-surface handling scheme, the grid size, and so on because each group had different numerical solvers with

*ISOPE Member.

Received October 13, 2016; revised manuscript received by the editors January 17, 2017. The original version was submitted directly to the Journal.

KEY WORDS: Water impact, wedge drop, ship-section drop, CFD, comparative study.