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

Vol. 27, No. 2, June 2017, pp. 135–143; https://doi.org/10.17736/ijope.2017.jc690
http://www.isope.org/publications/publications.htm

A Comparative Study of the Generalized Wagner Model and a Free-Surface RANS Solver for Water Entry Problems

Charles Monroy, Sopheak Seng, Louis Diebold, Alexis Benhamou and Šime Malenica
Research Department, Bureau Veritas
Paris, France

Correct assessment of entry of a solid through a free surface is important in various hydrodynamic applications. It is especially crucial when dealing with ship motion behavior in high sea states where slamming impacts are likely to occur. There is a wide range of numerical methods designed to compute forces and pressures on the hull triggered by this phenomenon. However, from an industrial perspective, it is important to discriminate between them and find a compromise among CPU time, setup time (i.e., engineering time), and accuracy. This paper aims at comparing the merits of two different classes of methods: potential theory based on a Wagner model and computational fluid dynamics (CFD) based on a finite volume method with a volume-of-fluid (VOF) interface. The numerical results are compared against experimental data from a wave-induced loads on ships (WILS) campaign.

INTRODUCTION

Wave-induced loads on ships (WILS III) was a joint industrial project conducted by the Korea Research Institute of Ships and Ocean Engineering (KRISO) with participation of several academic and industrial partners, including Bureau Veritas. In the frame of this project (see Hong et al., 2014), an experimental campaign was run in order to measure loads on different 2-D sections impacting calm water. This experimental data set is very useful in validating different numerical tools designed to assess slamming loads on a ship. Since the pioneering work of Bishop and Price (1979), the standard practice in ship hydroelastic computations involving slamming events consists of cutting the bow of the ship in several 2-D sections. 3-D computations are too time consuming and there is no adequate simplified model. An example of such a method can be found in De Lauzon, Benhamou, and Malenica (2015), which compares hydroelastic behavior of a ship against an experiment.

Potential flow remains the standard theoretical framework when it comes to assessing slamming loads on a 2-D section of a ship and integrating them in a hydroelastic computation. In De Lauzon, Benhamou, and Malenica (2015), the slamming model is based on a generalized Wagner model (GWM), and elements of this model are shown for the WILS test cases. Several other potential flow models with different levels of complexity and robustness exist (e.g., see Korobkin and Malenica (2005) for a description of the modified Logvinovich model). All the models in this class of methods are very fast, but in our opinion, the GWM model offers a good compromise among accuracy, robustness, and CPU time.

With the constant evolution of hardware capabilities, it is natural to wonder whether it is possible for CFD to overtake potential flow theory for slamming load assessments in the future. It has already been proven possible to compute a full CFD hydroelastic computation (for example, Seng et al., 2014). However, due to CPU time, this kind of simulation has to be limited to a few wave periods. To ensure a converged result on a sea state of three hours, it is mandatory to reproduce ten times this duration, which makes approximately 30 hours of real-time simulation. It is difficult to expect classical CFD to perform this task. It is more likely that using CFD only for 2-D slamming load assessments (i.e., coupling CFD in the frame of hydroelastic software) still makes sense. To our knowledge, such a model has not yet been implemented, and this is certainly because the required CPU time still remains huge. Also, this coupling would be more difficult in practice because of the inherent difficulties of pre- and postprocessing tasks in CFD (e.g., meshing). However, while acknowledging the difficulties ahead, this kind of coupling is thought to be a reasonable goal. The first step is, of course, to check the gain in accuracy with CFD compared to potential flow theory. In this paper, the performance of open-source CFD software OpenFOAM is assessed. The OpenFOAM capabilities have already been discussed in Moirod et al. (2011) in the case of a wedge section. More recently, Southall et al. (2014) investigated the WILS wedge test cases with OpenFOAM, including some initial results on compressible effects. In the present paper, the incompressible solver interDyMFoam of OpenFOAM has been used.

In the frame of ISOPE-2016, a numerical benchmark on several WILS drop test cases was organized. This paper reflects the major part of the contribution of Bureau Veritas to the benchmark. Some preliminary results with the smoothed-particle hydrodynamics (SPH) method (with the collaboration of Ecole Centrale de Nantes and HydrOcean) were also shown in the conference paper (Monroy et al., 2016) but disregarded here.

EXPERIMENTAL CAMPAIGN

Test Cases and Setup Arrangement

During the WILS III experimental campaign, two series of drop tests were staged. The first series of tests was run on a simple 2-D wedge section, while the second one used a more realistic 2-D ship section and its variants.

Regarding the wedge section, two dead-rise angles (20 and 30 degrees), two drop heights (0.25 and 0.5 m), and different tilting angles (20, 10, 0, −10, and 20 degrees) were considered. In this paper, the focus has been put on test case Wedge 01, which is characterized by a dead-rise angle of 30 degrees, a drop height of 0.5 m, and a tilting angle of 0 degrees.

For the ship section, the test case Ship Section 11 has been chosen: it is characterized by the bulbous shape of experimental

Received August 31, 2016; updated and further revised manuscript received by the editors December 7, 2016. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-sixth International Ocean and Polar Engineering Conference (ISOPE-2016), Rhodes, Greece, June 26–July 1, 2016.
KEY WORDS: Water entry impact, slamming, generalized Wagner model, free-surface RANS solver, CFD.