Repeatability and Two-Dimensionality of Model Scale Sloshing Impacts

A. Souto-Iglesias, E. Botia-Vera
Naval Architecture Department (ETSIN), Technical University of Madrid (UPM), Madrid, Spain
G. Bulian
Department of Mechanical Engineering and Naval Architecture, University of Trieste, Trieste, Italy

ABSTRACT

Canonical test cases for sloshing wave impact problems are presented and discussed. In these cases the experimental setup has been simplified seeking the highest feasible repeatability; a rectangular tank subjected to harmonic roll motion has been the tested configuration. Both lateral and roof impacts have been studied, since both cases are relevant in sloshing assessment and show specific dynamics. An analysis of the impact pressure of the first four impact events is provided in all cases. It has been found that not in all cases a Gaussian fitting of each individual peak is feasible. The tests have been conducted with both water and oil in order to obtain high and moderate Reynolds number data; the latter may be useful as simpler test cases to assess the capabilities of CFD codes in simulating sloshing impacts. The repeatability of impact pressure values increases dramatically when using oil. In addition, a study of the two-dimensionality of the problem using a tank configuration that can be adjusted to 4 different thicknesses has been carried out. Though the kinematics of the free surface does not change significantly in some of the cases, the impact pressure values of the first impact events changes substantially from the small to the large aspect ratios thus meaning that attention has to be paid to this issue when reference data is used for validation of 2D and 3D CFD codes.

KEY WORDS: Impact pressure, repeatability, two-dimensionality, statistical description.

INTRODUCTION

The state of the art sloshing assessment procedures for LNG vessels and floating production and storage units are based on risk assessment techniques (DNV, 2006; LRS, 2009; Gervaise et al., 2009; Kuo et al., 2009; Diebold, 2010). In such procedures, the statistical characterization of the sloshing loads relies on data obtained from experimental campaigns. Due to the extra costs that derive from these campaigns, a mid-term goal of designers is to characterize the sloshing loads using CFD technologies.

A widely known attempt to establish the current capabilities of CFD codes to achieve this target emerged from the Special 1st “Sloshing Dynamics” Symposium at ISOPE-2009 Conference, in which a benchmark test case was proposed to all participants (Kim et al., 2009). Contributions were presented using commercial codes (Godderidge et al., 2009) and meshless methods (Rafiee et al., 2009). Although this initiative was ground breaking, the outcomes have been limited, since as presented, the phenomena are yet too complex to be modeled with state of the art CFD technologies. Compared to that, the present test case aims at simplifying the setup significantly seeking the highest feasible repeatability. Repeatability in sloshing tests has not received, to our knowledge, much attention in the literature. Bogert et al. (2010) pay attention to wave heights and Kimmoun et al. (2010) to pressure records, with a limited repetitions number. An analysis of this issue, focusing on the first 4 impacts is provided in the paper. In addition, an exact description of the tank motion, data for a larger fluid viscosity and a study of the two-dimensionality of the problem using a tank configuration that can be adjusted to 4 different thicknesses are documented. As a significant drawback, the ullage pressure has not been controlled, it is therefore the atmospheric, and the pressure values shown correspond to relative pressures. Previous experimental campaigns using the same rig and similar geometrical configurations have been described in reference (Botia-Vera et al., 2010); they have been used for CFD validation in references (Delorme et al., 2009; Khayyer and Gotoh, 2009; Brizzolara et al., 2011; Cheng et al., 2009).

In the literature in general, a significant contribution is due to Lugni et al. (2006, 2010), who have described the extraordinary accelerations during wave impact events, though their work is not specifically arranged so as to be useful as reference for CFD validation attempts. Major contributions are due to Graczyk and Moan (2008); Graczyk et al. (2007) who provided statistical fitting for long series of sloshing impact pressure recordings. During ISOPE 2009 and 2010 relevant works have been presented covering aspects as crucial for industry as the scaling of impact pressures from models to prototypes. A significant contribution in these regards has been published as a journal paper (Yung et al., 2010).

The present paper is organized as follows: First the experimental setup is described, later lateral impacts for all conditions are discussed. Pressure peak values will be the monitored variables, leaving the analysis or rising times as in (Graczyk and Moan, 2008) for future studies. Subsequently, roof impacts are discussed. Some conclusions and future work threads are presented to close the paper.

EXPERIMENTAL SETUP

The used tank is rectangular, built with plexiglass. Its dimensions [mm] as well as the pressure sensor positions can be seen in Fig. 1. It is a 50 times scaled down longitudinal section of