Impact Analysis using CFD – A Comparative Study

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ABSTRACT

This paper presents results from part of a collaborative study carried out by Lloyd’s Register (LR) and Samsung Heavy Industries (SHI) on impact analysis using Computational Fluid Dynamics (CFD). Predictions of pressures, local and global forces are presented for a variety of 2D sections of a container ship using two CFD codes, namely OpenFOAM and Star-CCM+. In an attempt to justify the influence of hydrodynamic assumptions on dynamic response, the CFD studies are carried out independently and with differing numerical strategies in particular with regard to meshing and time-stepping. Differences in the two sets of results are discussed, and numerical results are compared against experiments.

KEY WORDS: impact loads, Computational Fluid Dynamics (CFD), dynamic response, model experiments.

INTRODUCTION

Prediction of slamming induced impact loads is currently a significant challenge for the Marine industry. For FLNG (Floating Liquefied Natural Gas) vessels, the effect of wave impacts and bottom slamming on the local hull structure is a concern. For container ships, the ongoing drive to increase container carrying capacity has resulted in rapid increase of ship size and the associated slenderness of these vessels makes them susceptible to whipping (vibrational response of the hull girder due to wave impact loads) (Hirdaris et al., 2014). Consequently there is an increasing need to develop practical tools to model impact flow phenomena and understand the influence of fluid-structure interactions on dynamic response.

Classic approaches for the prediction of impact loads such as those proposed by von Karman (1929), Wagner (1932) and Stavovy and Chuang (1970) are useful for preliminary analysis. However, because they are fully or semi-analytical they usually place limits on the range of section shapes that can be analysed, with reentrant forms such as bulbous bows particularly causing difficulties. On the other hand, Computational Fluid Dynamics (CFD) offers great advantages over these traditional methods; because they place no restriction on the shapes modelled, flow separation poses no significant problem and they offer the option of including effects such as compressibility and viscosity. The main drawback of CFD is the high computational demand for full three-dimensional analysis. However, coupling 2D CFD analysis with potential flow time domain ship motions codes may suggest an attractive medium term alternative.

During their participation in the WILS (Wave Induced Loads on Ships) JIP-III, Lloyd’s Register (LR) and Samsung Heavy Industries (SHI) instigated a collaborative study focused on CFD based slamming analysis. In this joint industrial project, CFD based slamming analyses were carried out to assess problems due to impact loads acting on a large container ship. The main objectives of the joint project were to compare analysis results from CFD slamming analysis and to determine equivalent impact loads for use in structural design assessment. The project considered impact of various sections with an undisturbed free surface. This paper focusses on the numerical predictions made for impact of 2D ship sections and their comparison against model experiments. It presents comparisons between two different CFD codes and experiments performed by KRISO for WILS JIP-III. LR performed simulations using the open-source CFD code OpenFOAM (OpenFOAM Foundation, 2012) and SHI used the commercial code STAR-CCM+.

Impact predictions are highly sensitive to fluctuations in the velocity of the impacting object. To provide a useful comparison of the two CFD codes without the results being affected by variations in the velocity when modelling a free drop, LR and SHI agreed that prescribed motions evaluated from the accelerometer measurements would be used in each CFD code. Parameters such as time step length, cell size and meshing strategy were decided independently.

EXPERIMENTS

A systematic series of 2D ship section drop tests were performed by KRISO (2014) as part of the WILS JIP-III.

The tests were performed for three ship sections. As shown in Fig. 1, Model III represents a typical profile ship section in way of Station 19 of the container ship; Model II is a simplified form of Model III, with the bulb replaced by a sharp wedge. This section was included in the tests to provide experimental data for validation of empirical impact methods (e.g. using Wagner theory) which do not allow re-entrant