Sloshing Dynamics – Numerical Simulations in Support of the Sloshel Project

J R Maguire, S Whitworth, C N Oguibe, D Radosavljevic, E P Carden
Lloyd’s Register ODS
Technical Investigation & Analysis Consultancy
London, UK

ABSTRACT

This paper is one of a set related to the Sloshel project (which is overviewed in Brosset, Mravak, Kaminski, Collins & Finnigan, 2009). This particular paper considers numerical simulations of fluid loading and structural response, carried out by Lloyd’s Register, one of 5 Class societies involved in the Sloshel project. The section of Lloyd’s Register responsible for this work was Lloyd’s Register ODS, Technical Investigation and Analysis Consultancy. The experimental data was provided by MARIN.

The numerical work described will be in two main parts:
(i) computational fluid dynamics (CFD) simulation of fluid loading;
(ii) finite element analysis (FEA) simulation of structural response.

The CFD work will address 2D modelling, first order and second order discretisations, meshing and numerical setups, flow results, wall pressures, peak pressures and total load comparisons. The FEA work will address simulations of an individual NO96 box – static and dynamic – and simulations of the full scale wall – natural frequency and transient response. A selection of results will be given, focussing on the correlation between experimental and simulated pressures, loads and strains.

The simulations described follow the philosophy of a “decoupled” approach, separating the fluid loading from the structural response. However it is intended during subsequent stages of Sloshel to directly couple the fluid loading and structural response.

KEY WORDS: Sloshel, sloshing, numerical, simulation, CFD, FEA.

INTRODUCTION

In support of the Sloshel joint industry project Lloyd’s Register ODS undertook a range of numerical simulation work. The first part of this work related to the simulation of the waves generated in the Delta Flume operated by Deltares. One wave, named S074, was selected for careful comparison between experimental measurements and numerical simulation results because its particular breaking characteristics resulted in high pressures on the wall. The method of simulation of this wave is described in the first section and the numerical results in terms of pressures and loads on the wall are compared with the experimental measurements. Valuable lessons for future similar simulation work are presented at the end of the first section.

The second part of Lloyd’s Register’s numerical work focussed on the simulation of the reinforced NO96 box, the wall and its supporting structure. This work included reconciliation of the numerical model with static and modal tests of the NO96 test panel in isolation as well as with the measured strains and forces induced by the impact of the S074 wave in-situ. The influence of the flexibility of the supporting structure on the strains in the NO96 boxes is an important aspect of the containment system’s use in ships and thus the supporting structure was modelled and its dynamic properties reconciled with the measurements. The invar tongue slits on the cover plate of the NO96 test panel were important influences on the static measurement results and the developed method for modelling these connections is described.

The lessons learned from the numerical work are presented at the end of this paper and should be of value for the planning of any similar future testing paradigms.

CFD MODELLING OF THE BREAKING WAVE

Two-dimensional CFD analysis of the impact of the S074 breaking wave upon the wall containing the NO96 test panel was simulated. The wave was generated in a 145.16m long flume by an oscillating paddle at one end. The motion of the paddle was defined to produce many small waves that focused to form one large wave, which then broke near to, and impacted upon, the wall at the far end of the flume. The shape of the wave near to impact was recorded using a novel array of optical sensors, known as iCam, and pressure, force and strain measurements were taken on the wall and within its structure.

Work was carried out by Lloyd’s Register ODS using STAR-CD v4.04 and STAR-CCM+ v3.02. A boundary at atmospheric pressure was placed on the upper surface of the mesh, which allowed both air and water to leave the domain but only air to enter. In the initial setup, the remaining three boundaries were modelled as solid walls, with the boundary representing the paddle moved according to the profile shown in Fig. 1. The density of the air was defined as 1.2 kg/m³ and of water as 997.6 kg/m³.