A Mark III Panel Subjected to a Flip-through Wave Impact: Results from the Sloshel Project

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ABSTRACT

Within the Sloshel Joint Industrial Project, a new full scale wave impact test campaign has been carried out in April 2010. Unidirectional focused waves were generated in a flume in order to impact a rigid wall in which an instrumented Mark III LNG containment system panel had been embedded. The wall was entirely covered with the Mark III corrugated membrane in the same way as on board a LNG carrier. During one of the last tests of the campaign a flip-through type of impact was generated and very high local pressures were measured. The horizontal small corrugations of the membrane were significantly deformed but no permanent deformation of the foam was observed by initial visual inspection. After removing the Mark III panel and cutting it into small blocks, no discernible cracking, no discernible permanent deformation and no discernible change of the initial properties were observed.

This paper describes the main lessons obtained from this flip-through impact, through measurements related to the hydrodynamic loads, and through the structural response of the different components of the Mark III panel.

KEY WORDS: Sloshing, LNG carrier, Mark III, Corrugation, Containment System, Flip-Through, impact pressure, Sloshel

INTRODUCTION

The aim of the Sloshel full scale Mark III tests was to study some key issues related to sloshing impacts in tanks of Mark III LNG vessels through impact tests of breaking waves in a flume. Although obviously not identical to the real conditions, the conditions induced by impacts of breaking waves in a flume with water and air on a real Mark III containment system are considered to be relevant for studying fluid-structure interactions, scaling effects by comparison with a previous test campaign at scale 1:6 and wave–corrugation interactions. These tests also enabled the building of a reference data base for validation of numerical simulations.

As the loads generated by the water are almost twice as large as those generated by LNG for similar waves due to the ratio of densities, caution was taken in order to not damage the membrane or the containment system before having stored enough data. The wooden-wedge-reinforced version of the membrane was used and only large air-pocket type or slosh type of impacts (inducing large but not extreme loads) were generated at first. These types of impacts, described in Brosset et al (2009), are believed to be the most representative of sloshing impacts for low and partial fill levels in tanks of LNG carriers.

After 139 tests with such waves, without any discernible deformation of the corrugations, it was decided to generate intentionally a flip-through type of impact, less likely to occur onboard a ship but potentially capable to deform the corrugations and to damage the foam or the plywood plates of the Mark III panel.

During test 140 a real flip-through impact was created, inducing a maximum measured pressure of 56 bar, the highest ever measured during the different campaigns of the Sloshel project. The horizontal corrugations of the membrane were significantly deformed with a maximum deflection of 5 mm. No permanent deformation of the foam was observed by initial visual inspection. After two subsequent tests generating moderate impacts, it was decided to end the campaign in order to allow a careful check of the Mark III panel, including search for cracks after cutting the panel into small blocks and material tests. No residual deformation of the foam and no discernible change of the initial mechanical properties were observed.

This paper describes in detail test 140, through the numerous measurements (pressures, strains, forces) and high speed videos recorded, related to both the loads and the response of the containment system including the corrugations. Reasons are proposed to explain why the foam was not crushed after the panel withstood a maximum pressure of 30 bar while its notional capacity is only 14 bar at ambient temperature in static conditions.

TEST SET-UP

The full scale Mark III tests were carried out in the outdoor Delta flume operated by Deltares in The Netherlands. The flume is 240 m long, 7 m high and 5 m wide. At one end it features a piston-type second order wave making system. Details of the set-up are given by Kaminski and Bogaert (2010). For the sake of simplicity, only the elements that are relevant to the present paper are described in the section below.

General set-up

A transverse concrete test wall was placed 145 m from the wave maker. A horizontal steel test panel was embedded into the test wall, enabling the mounting of two instrumented blocks at a height in between 5.0 m and 6.0 m above the bottom of the flume as indicated in Figure 1. The two blocks were 1.2 m wide and 1.0 m high. The first one, on the left in Figure 1, was a thick block of aluminium. The second one, on the right in Figure 1, was a Mark III panel cut in order to fit within the opening (1.2 m wide instead of 3 m originally). The panel was assembled from...