Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Fluid-structure interaction modeling, relating to membrane LNG ship cargo containment system

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ABSTRACT

Over the period 2006-07, a JDP (joint development project) for LNG cargo containment system (CCS) was carried out by HHI, ABS, BV, LR and PNU. The aim of the project was to develop "best current practice" for the analysis of fluid-structure interaction (FSI) events, in particular relating to sloshing impact loads in membrane type LNG CCS, which could lead to the improved evaluation of the structural safety of GTT Mark III type CCS.

KEY WORDS: Liquefied Natural Gas (LNG); Cargo Containment System (CCS); Fluid-Structure Interaction (FSI); Wet Drop Test

INTRODUCTION

In recent years, the needs for natural gas (NG) have been quickly and steadily increasing, due to the fast growth of world energy usage and NG's environment-friendly nature. The demand for building of LNG (liquefied natural gas) carriers with bigger cargo capacity has been also increasing to economically transport LNG. In cargo tanks of membrane type LNG carriers, because there is no internal supporting structure such as partial bulkheads, sloshing loads by LNG is one of the most important factors for the safety of insulation system and supporting hull structure. Therefore, to design a new-size LNG carrier safely, it is needed evaluating the sloshing impact load and assessing the structural response to that impact load. A dynamic structural analysis considering fluid-structure interaction (FSI) under sloshing impact load is the most essential for assessment of the structural safety of cargo containment system (CCS) in a membrane type LNG carrier (Nam et al., 2005 and 2006). Till now, however, a single method to predict the structural response of CCS on absolute basis has not been validated yet.

In early 2006, Hyundai Heavy Industries (HHI) commissioned Pusan National University (PNU) to carry out physical wet drop tests of Mark III type LNG tank insulation specimens, to clarify the impact pressure acting on the insulation membrane and the strains developed in the insulation system. In parallel, HHI proposed a joint development project (JDP) to major classification societies to carry out the numerical simulation of the wet drop test by each own manner. The main purpose of the JDP was to develop the best practice of analytical solution for the evaluation of structural safety of CCS in membrane type LNG carriers in consideration of FSI under sloshing impact loads. Three classification societies of American Bureau of Shipping (ABS), Bureau Veritas (BV) and Lloyd's Register Asia (LR) participated in the JDP of "Wet Drop Test Simulation" initiated by HHI.

This paper summarizes the simulation works carried out by four participants of HHI, ABS, BV and LR, including wet drop tests carried out by PNU.

WET DROP TEST

The tests were carried out at Slamming research laboratory in PNU. Figure 1 illustrates the test facility. The test specimen is guided by four linear motion (LM) sliders installed at main vertical columns. Transverse and rotational motions of the specimen are restrained for strict vertical drop maintaining the inclined (incident) angle. The test rig is placed on a water basin of 3 meter depth and the maximum drop height is 4.3 meter (Chung et al., 2006). The drop unit where the test specimen is to be attached is shown in Fig. 2. The drop unit consisted of steel housing for the test specimen, supporters and jigs connected to LM guide sliders.

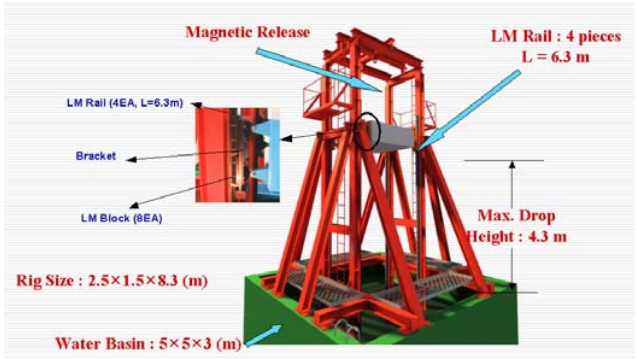

Fig. 1 Test rig for wet drop test

Total three types of specimens were tested; flat membrane (Flat), corrugated membrane (Light) and corrugated membrane with added weight (Heavy). The distinction of types comes mainly from shape of the membrane and weight of the specimen. Test specimens of Flat and Light are shown in Fig. 3. Both specimens consisted of plywood, reinforced poly-urethane foam (RPUF), rigid triplex, mastics and