Interaction between wave impacts and corrugations of MarkIII Containment System for LNG carriers: findings from the Sloshel project

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ABSTRACT

The subject of this paper is the behavior of MarkIII corrugated primary membrane under breaking wave impacts. The study is based on the database of the large scale impact tests from the Sloshel project. Unidirectional breaking waves were generated in a flume tank in order to break onto an instrumented wall covered by a corrugated surface reproducing the MarkIII membrane at scale 1:6. Pressure sensors were positioned in between the corrugations. A special sensor was designed to measure the net force in the upward and downward direction on a horizontal corrugation. Special care was taken to observe the interaction between the wave impact and the corrugations by high speed cameras synchronized with the data acquisition system.

Four sources of impact loads on the corrugations were observed: the wave trough, the wave crest, the jet formed after wave impact or the entrapped air. This observation gave evidence that more mechanisms are involved during sloshing-corrugation interaction than those identified previously with wet drop tests. Moreover, the pressure measured upstream and downstream of a horizontal corrugation is correlated to the global vertical force, but this relation depends highly on the sensor position with regards to the corrugation, and the source of loading.

The paper describes the different kinds of corrugation loadings during breaking wave impacts. It emphasizes the need to take into account the sloshing corrugation interaction into a sloshing assessment methodology but shows that applying scaled corrugations in small scale tests (scale around 1:40 - 1:35) is not adequate.

KEY WORDS: sloshing, LNG carrier, membrane containment system, MarkIII, corrugation, impact pressure, model test, flume tank, breaking wave.

INTRODUCTION

MarkIII is one of the membrane Cargo Containment Systems (CCS) designed by GTT for LNG carriers. It is mainly composed of 3 m x 1 m panels of polyurethane foam covered by a stainless steel corrugated membrane in contact with the LNG at -162°C (see Figure 1). The panels are bonded to the double hull by resin ropes.

The membrane features large parallel corrugations crossing perpendicularly small parallel corrugations. The large and small corrugations are respectively 54 mm and 37.2 mm high. The distance between two large or two small corrugations is 340 mm. On the longitudinal walls of the MarkIII tanks the large corrugations are vertical whilst they are horizontal on the transverse bulkheads.

In 2008, some deformations of the membrane corrugations were observed for the first time on board several MarkIII ships during routine dry dock inspections. These deformations, without any leakage of the cargo, affected both large and small corrugations mainly in the corners of the ceiling and less frequently in the region covering a few meters above the chamfers of the longitudinal bulkheads. They had clearly been caused by sloshing impacts. Some corrugations were globally bent whereas some others were pinched almost symmetrically.

The design loads on the CCS of membrane ships are determined by producing the different deformations observed. It was concluded that, after the incidents some questions were raised:

- How to determine the loads on the corrugations?
- Could the presence of corrugations magnify the loads locally on the polyurethane foam?
- How to take this influence into account within the methodology?

Is it relevant to have scaled corrugations inside the model tanks?

After the incidents an investigation plan was launched by GTT. A reverse engineering process permitted to evaluate the loads capable of producing the different deformations observed. It was concluded that, with a static pressure up to 20 bar, both the corrugations and the insulation below remain sound, even though the corrugations may be significantly deformed.

The analysis presented in this paper was carried out based on experimental results from the Sloshel project (see Brosset et al., 2009). So-called large scale tests were carried out by MARIN in the Scheldt flume of Deltares (NL). Unidirectional breaking waves were generated in the flume in order to impact an instrumented rigid vertical wall. Two configurations of the wall were tested: a flat wall and a corrugated wall.