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Reliability-based Methodology for Sloshing Assessment of Membrane LNG Vessels

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This paper describes the methods developed over the years by Gaztransport & Technigaz (GTT) in order to study sloshing and sloshing-induced loads in membrane-type liquefied natural gas (LNG) carriers. A large Research and Development program carried out over the past 4 years enables today the introduction of the most comprehensive evolution of GTT's method. This method is based on model testing using state-of-the-art assumptions, a long-term approach which combines all the conditions the vessel could experience during her lifetime, and the comparison of the sloshing loads to the strength of the Cargo Containment System for its different limit states via a reliability-based method. Aware that the model tests do not account for all the physics parameters, GTT considers it prudent to calibrate the method by comparison to actual experience at sea. The methodology thus remains comparative.

INTRODUCTION

As Cargo Containment System (CCS) designer of membrane insulation systems for LNG carriers, GTT has studied sloshing for many years using the most advanced tools and methods available.

In order to manage the risk of failure due to this phenomenon, 2 main approaches of engineering methods can be envisaged at the design stage:

• One could create an academic model allowing to track or to overestimate the maximum pressure that could occur. This model should not represent reality but should be able to cover the design.

• The other possibility would be to try to reflect as closely as possible the situations the ship is supposed to face. This ultimately leads to real-life reproduction.

Over the years, the main evolutions of the sloshing methods have consisted in moving from the first approach to the second. By including more physics in the modeling and by considering more representative assumptions, GTT is approaching a more direct or absolute way of assessing projects. This general trend, observed over the evolution of the method over the last 10 years, is described at the beginning of the paper; we then present the recent major update of the GTT method; abd finally we detail the method's calibration. Indeed, as the range of uncertainties is large and this model can not reflect 100% real life, GTT still considers it more reliable to build its new method based on experience at sea. This is performed by a comparative approach: The operational feedback GTT can acquire thanks to the large fleet of membrane ships that has been sailing for 40 years.

EVOLUTION OF METHODS

Azure Method

Basis of method. Earlier in this new century, LNG offshore applications were already the cause of a developing interest. The Azure R&D project set up by 9 European companies studied the full floating LNG chain: Floating Production and Storage Offshore units (FPSO) with liquefaction units, connecting arms with LNG carriers, Floating Storage and Regasification Units (FSRU) with regasification units.

Within this project, the LNG tanks were of the membrane type. Along with the design works for barges, safety studies have been carried out by classification societies—Bureau Veritas and the Royal Institute of Naval Architecture (RINA)—and attention has also been paid to the liquid motions inside tanks. A method has thus been developed jointly by GTT, SN Technigaz, Bureau Veritas and IRCN. (Spittael et al., 2000).

Fundamentals of method. Even if the aim of the Azure method were to reflect actual conditions at sea, several points made it quite close to an academic model:

• The selection of critical cases focused on the resonance period of the liquid on one hand and on maximum ship motions on the other. This selection was performed for both longitudinal and transverse motions.

• In line with the above, the proposed representation of ship motions was intended to occur via the combination of the 6 degrees of freedom, with each being defined by its zero up-crossing period and 1/10 spectral amplitude.

• The Azure method already relied on experimental model tests using water and air. Although the model tests were intended to occur with a reproduction of the 6 degrees of freedom, only 4 were simulated due to test apparatus technical limitations. The same limitations allowed only for very small-scale models; scale 1:70 is typical of the model tests performed based on this method.

From the model tests the pressure was recorded at several given locations. For a new project, the assessment was based on a wave contour approach that focused, as mentioned, on resonance and maximum motions. The pressure obtained was then compared to that recorded when the so-called reference vessel was tested by the same experimental protocol. At that time, the reference was defined by a 5-tank (with small upper chamfer), 130,000 m^3 LNG carrier which had encountered slight indentations on her tanks' ceiling while sailing in an intermediate sea state during her first laden voyage. At that time, the resonance had been found to be at fault (Gavory and de Sèze, 2009).

The project was validated through the comparison of the project design pressure load and insulation capacity with those of the

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KEY WORDS: Sloshing, method, long term, membrane insulation system; LNG carrier.