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# Experimental Study of Slosh-induced Loads on an LNG Fuel Tank of a Container Ship

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**The present paper reports an experimental study on the effect of sloshing impact pressure on a small-scale liquefied natural gas (LNG) fuel tank of a container ship. LNG has recently gained attention as a ship fuel because it conveniently satisfies the existing and upcoming requirements for the emission of sulfur oxides, nitrogen oxides, particulate matter, and carbon dioxide. In this study, three-dimensional tank tests were conducted for various filling and motion conditions. The main objective of these tests was to determine the dynamic pressure on the tank walls. The measured pressure data were statistically analyzed, and sloshing-induced pressure values of the two different tanks were compared with respect to different aspects. From this study, the characteristics of sloshing load with respect to the filling condition and tank shape were systematically investigated. Test results were also qualitatively compared with the existing sloshing test data of a conventional LNG carrier.**

## INTRODUCTION

For designing a liquefied natural gas (LNG) cargo containment system (CCS), a slosh-induced load is a critical concern owing to its potential to cause structural damage. Sloshing inside a ship's cargo may have strong nonlinear and stochastic characteristics under violent flows, resulting in large hydrodynamic impact loads. Thus, computational methods have limited capability in terms of actual application. Owing to such limitations of computational approaches, ship classification societies such as American Bureau of Shipping (2006), DNV GL (2014), and Lloyd's Register (2009) mainly recommend experimental analysis.

Techniques and recommendations for model-scale sloshing tests have been developed over the last few decades. The most common procedures adopt (1) a real-scale, five-hour experiment; (2) the sampling of peak values larger than a certain threshold value; (3) a statistical analysis for the sampled peaks; and (4) the estimation of extreme values based on the cumulative probability.

A large facility for conducting sloshing model tests was equipped to perform many fundamental and industrial experiments at Seoul National University (SNU) in 2010. Moreover, there have been several studies on the experimental methodology and a statistical method for dealing with the impact pressure (Mathiesen, 1976; Kim et al., 2010; Fillon et al., 2012; Malenica et al., 2017; Kim et al., 2017; Ahn et al., 2018). In addition, a set of hydrodynamic impact tests on the thermal and bubble effect was recently introduced (Yonghwan Kim et al., 2016).

Although many sloshing model tests have mainly focused on LNG CCS, in recent times, a growing number of experimental studies have been applied to LNG fuel tanks. According to Adamchak and Adede (2013), ship owners and operators are attempting to lower sulfur emissions while operating in emission control areas. The considerate substitution of conventional fuels with LNG could be viable solution to satisfy MARPOL Annex VI of the International Convention for the Prevention of Pollution from Ships. On the basis of such technical demand, Hyundai Heavy Industries designed an LNG-fueled container ship, and two types of LNG fuel tanks (a one-row tank and a two-row tank) were considered in this research. A two-row tank has almost a half breadth of a one-row tank in order to avoid the natural frequency of sloshing. Sloshing experiments were conducted on these two types of tanks at SNU.

The basic internal shape of an LNG fuel tank and an LNG CCS are similar, but there are two major differences: the tank length and the height of the lower chamfer. Therefore, the effect of the tank shape on sloshing impact can also be found by comparing the results from each tank. Kim et al. (2016) investigated the influence of lower chamfer height on sloshing load, but the tank considered in this former study did not have enough variance from conventional tank in terms of lower chamfer height compared with the LNG fuel tank.

This paper presents the sloshing model test results for LNG fuel tanks. In this experiment, 1/50 scale one-row and two-row model tanks for a large containership were tested under different filling conditions and excitation motions. A more practical design between these two types of LNG fuel tanks along with focus on motion excitation in the actual seaway conditions of a containership are the main objective of this study. An experiment was also carried out previously for the 1/50 scale of conventional

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KEY WORDS: Sloshing, LNG fuel tank, sloshing model test, one-row tank, two-row tank, container ship design.