Development of a New Reduction Device of Sloshing Load in Tank

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ABSTRACT

This paper presents the results of an experimental study to develop a new device for reduction of the sloshing load in tank. This study suggests a method of sloshing reduction using membrane material, which can deform flexibly near the free surface to restrain the fluid motion, and cause no damage to tank plate. The model tank tests were conducted to investigate the effect of this device by measuring water pressure and fluid motion due to sloshing with and without the device. Comparison of the data measured in each condition shows the effectiveness of proposed device. Finally, the design method of this device to give high performance is discussed.

KEY WORDS: Sloshing; Model tank test; Reduction device; Membrane material; Mooring rope

INTRODUCTION

In step with the global movement of reduction of GHG, demands for natural gas, whose amounts of CO₂ emissions are lower than oil or coal, are increasing rapidly. As a result, global energy markets require large gas carrier in order to reduce the transport cost, or LNG chain cost. The carrying capacities of LNG vessels, which have been 130,000 m³ in the late 1970s, have increased dramatically after 2005. Now we can observe that larger LNG vessels whose size is over 250,000 m³ are designed and constructed.

At the same time, markets expect the relaxation of stowage restriction assuming the case like piling up small volume of LNG from two or more producer. It can be considered that such enlargement of tank size and operation with partially-loaded state will cause increase of sloshing load. However, because installed insulation structure should be the same regardless of tank size, the strength of the insulation will be the constraint condition for design in LNG tank, which cannot be restraint sloshing pressure by inner structural member. Therefore, to satisfy the market demands, it is effective to develop sloshing-reduction device which is applicable to various stowage condition.

In the field of architecture, considerable degree of seismic damage of floating roofs on cylindrical oil storage tank at Tokachioki earthquake in 2003 led to development of study on sloshing. As sloshing-reduction system to cylindrical tank like the oil storage tank, various ideas such as the use of bubble (Hara and Shibata, 1987), the reversed U-tube (Hayama and Iwabuchi, 1985), the use of wire-rope (Kobayashi and Matsudaira, 1980), various types of bulkhead (Kobayashi, Mieda, Jitsu, Shibata, 1996) and the buffer made of rubber with floating roof (Ida et al, 2007) are reported. On the other hand, as sloshing-reduction system to vessel, we can observe examples of researches such as U-tube, wire mesh screen, and swash bulkhead (Warnitchai and Pinkaew, 1998) (Faltinsen and Timokha, 2008). However, it has problem that it cost much to change the design to apply these system to vessel.

This study suggests a method of sloshing reduction using membrane material, which can deform flexibly near the free surface to restrain the fluid motion, and cause no damage to tank plate. This device is applicable to not only membrane LNG tank, but also general cargo tank and ballast tank. The result of test shows proposed device work effectively in any case such as various motion patterns, frequencies of vibration, and filling level of fluid. This device will contribute to the expansion of design flexibility such as tank size and tank arrangement.

TEST METHOD

Test Equipment

Figure 1 shows the appearance of experimental setup. This equipment is designed to be able to simulate three dimensional ship motions by giving motions of four degrees of freedom with four actuators. However sloshing tests were conducted with only two actuators in this study. The maximum amplitude of each actuator is ± 150 mm in translational direction. The maximum angle of rotation is ± 20 degrees. Center of rotation corresponds to tank center. Each actuator is controlled individually by PC. This system can generate not only regular motion but also irregular motion by external input signal. It was confirmed that the minimum oscillation period which did not generate superfluous vibration was about one second by operation tests.