Characteristics of Dynamic Response of Mark III LNG Containment Subjected to Idealized Triangular Sloshing Impact

Mi-Ji Yoo(1), Sung-Je Lee(1), Sung-Chan Kim(3), Jang-Hyun Lee(2) and In-Sik Nho(4)

(1)Dept. of Naval Architecture and Ocean Engineering, Inha University Graduate School, Incheon, Korea
(2)Dept. of Naval Architecture and Ocean Engineering, Inha University, Incheon, Korea
(3)Dept. of Ship and Ocean System, Inha Technical College, Incheon, Korea
(4)Dept. of Naval Architecture and Ocean Engineering, Chungnam National University, Korea

Abstract

Dynamic response of LNG cargo containment subjected to sloshing impact is very complex because of high variability of sloshing load and insulation materials. During the structural strength assessment of the cargo containment in response to the sloshing impact, it requires careful investigations to the structural behavior of the containment. In this study, dynamic characteristics of Mark III type containment subjected to the sloshing impact are investigated with the variation of parameters in the pattern of sloshing load that are assumed from the pressure history. Characteristics of dynamic structural responses to various sloshing impacts are investigated in detail based on the results of implicit-transient finite element analysis. The dynamic behavior of containment are analyzed for the variation of duration time and skewness, and the peak pressure which represents the sloshing load assumed from the model test or computational fluid dynamic analysis.

An important observation is that although the maximum pressure and the impulse are similar, the dynamic response of the containment shows significant variations if the duration time and rising time is different.

Key words: Sloshing, Impact Pressure, Duration time, Skewness, Impulse, Transient Finite Element Analysis

Introduction

One of the important loads on the LNG tank cargo structure is caused by sloshing. Sloshing is an impact load of an internal fluid motion in a partially filled tank, which becomes critical when the LNG carrier is excited with a frequency similar to the natural frequency of LNG flow. In recent years, the size of LNG carrier cargo hold has been enlarged because of the market requirement. This tendency can lead the higher sloshing impact load than ever. Both strength assessment procedure of LNG cargo containment and sloshing load estimation has been required in order to support the guidance during the LNG CCS design.

Generally, two major approaches are provided for the sloshing assessment and LNG cargo containment design procedure by shipping registers. The first one is comparative approach, and the other is absolute approach. The comparative method is used for the standard size tank or conventional designs that are similar to proven LNG carriers presently operating with good experiences. The strength assessment of new design LNG carrier is to be compared with the previously designed LNG carriers. However, this approach is not reliable when a major design parameter changes significantly beyond the proven design range. In this case, the absolute approach may be selected.

Many attempts such as numerical, analytical, and model test approaches have been tried to develop the sloshing assessment by shipyards, shipping registers, and research scholars (Ito et al., 2008; Maguire et al., 2009; Graczyk and Moan 2009). Nevertheless, it is very difficult to expect the sloshing impact and structural response in realistic way because of the complexity of the sloshing, uncertainties relating to model test, scaling laws, local effects, and fluid-structure interactions. The most realistic analysis might be FSI (Fluid-Structure Interaction) analysis. Although the FSI analysis is expected to investigate the hydro-elastic effect and fluid motion in the LNG CCS, this approach still has some drawbacks. Due to limited knowledge of hydro-elastic analysis, it is difficult to obtain accurate solutions through the FSI analysis. The FSI method also require massive amount of computation time. Therefore, current shipyard and shipping registers practice for sloshing assessment for new LNG carrier is the combination of model tests (Kuo et al., 2009; Lloyd Register, 2009), stochastic post processing and the simplified absolute approach. Pressure time histories are obtained from small scale model tests. Thereafter, the measured pressure time histories are scaled into full scale of real LNG cargo hold. The FE analysis is directly performed with scaled sloshing load to assess the structural safety of LNG CCS (ABS, 2006; Lloyd Register, 2009). The simplified absolute procedure or direct assessment approach associated with model test can be applied to new design or partial filling operations at this moment. Once the numerical analysis is properly validated, numerical simulation based on direct approach is likely to become the preferred tool for LNG sloshing assessment, either in conjunction with model tests or eventually independently (Zheng et al., 2010).

To compensate the uncertainties and variability in the absolute assessment approach, optional levels of design procedures are introduced in current guidance (Lloyd’s Register, 2009; ABS, 2006). One of procedures is directed by linear dynamic structural analysis performed by finite element analysis. The linear dynamic analysis procedure is relatively simple for practical design guidance, but it