Parametric Investigation on the Simplified Triangular Impulse of Sloshing Pressure and Categorization of the Structural Response on the Mark III LNG CCS

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ABSTRACT

It has been well known the sloshing pressure has complex shape and various patterns. The pattern of sloshing pressure is variously characterized by the pressure amplitude, duration time and skewness. The structural response induced by the sloshing pressure is also affected by the pattern of sloshing pressure and the type of structural members. In order to understand the structural response by the perspective view of categorized pattern, it is more efficient to make simple sloshing pressure pattern than to reflect the complex pressure history. In this study, the sloshing pressures obtained by the small scale model test are simplified with respect to their duration and skewness. Dynamic analyses of Mark-III LNG CCS are then parametrically performed with the consideration of various types of sloshing impact. Meanwhile, the failure pressures given the duration and skewness are investigated after parametric calculations are conducted to investigate the effect of pressure parameters on the structural response.

KEY WORDS: Sloshing, Pressure pattern, Dynamic analysis, Impact, Structural response

INTRODUCTION

Liquefied natural gas (LNG) is effectively transported by insulated cargo containment outfitted with membrane tanks. To keep the LNG at cryogenic temperature of -163°C, a containment system is applied to the membrane tanks. In order to provide tightness against the LNG and gas, the insulation is assembled by a thin metal membrane, plywood and foam or perlite. The containment system needs also to withstand the various loads. A critical load on the LNG tank structure is caused by sloshing introduced by a violent motion of LNG at low filling state (Graczyk and Moan, 2011). As sloshing induced pressures may be extremely high, the structural strength of the containment system needs to be assessed during the design stage. There were many attempts made to develop a strength assessment procedure with the consideration of structural response to varying spatial and temporal characteristics of sloshing impact. Based on the structural response to sloshing impact, the strength assessment procedure is investigated independently by the scientific effort (Graczyk et al., 2006; Lee et al., 2011; Kim et al., 2010, Lee et al., 2006; Kim and Kim, 2007), classification societies (ABS, 2006; BV, 2006; LR, 2009; DnV, 2006) and industry (Kim et al., 2011; Nam et al., 2006; Ryu et al., 2009; Chun et al., 2011; Ito et al., 2008). Several studies on the dynamic structural analysis using numerical calculation and experimental measurement have been performed. Classification societies have suggested general procedure of pressure assessment and strength evaluation method of LNG CCS.

In spite of all the efforts which were made in order to assess the strength caused by sloshing impact, it is simple to mention that the actual design procedure based on comparative approaches or on simplified direct approaches are practically used. One of the direct approaches is that the structural response of the insulation system is analyzed with an assumption of simplified structural response. Based on the theoretical formulation of the fluid structure interaction of sloshing impact, it is, however, difficult to fully rely on such formulation because the complexity involved in the fluid structure interactions are enormous and no fully satisfactory method exists today. Furthermore, it is very difficult to apply impact pressure calculated by CFD to structural design directly (Lee et al, 2010). The aim of this paper is to investigate the characteristics of the structural response given the typical features of the sloshing pressures in order to assess the failure pressure. The structural response is investigated by the linear dynamic finite element analysis (FEA). By combining the structural response obtained by FEA and the failure criteria is investigated. The parametric FEA is also carried out in order to assess failure pressure and response surface governing the structural responses are discussed. This is done by analyzing the structural response to the various pressure patterns. This is also based on the premise that the pressure magnitude, duration and skewness is affecting on the failure.

Overall methodology

In this paper, it is suggested to use simplified procedures in combination with model test and linear dynamic structural analysis during the initial design of LNG carriers. The basic idea of the present approach is to suggest the simplified strength assessment method based on the linear dynamic analysis. Taking into account the pressures obtained by the model test, we have tried to identify the dangerous conditions from structural resistance point of view. In the analysis procedures for the direct assessment, the sloshing load is first determined based on model test. The measured sloshing load is