Direct assessment of LNG cargo containment system under sloshing loads

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ABSTRACT

The direct assessment of sloshing capacities for a liquefied natural gas cargo containment system (LNG CCS) has been established in Chun et al. (2011). In this paper, the failure criterion is either the permanent deformation of LNG CCS or the crushing phenomenon of reinforced polyurethane foam (RPUF). However, those failure criteria are a little obscure to be defined objectively. To establish the exact failure criteria, in this paper, the tensile test has been carried out after the impact test. Through this result, the direct assessment secures the objective failure criterion.

KEY WORDS: Sloshing, structural capacity, dynamic behavior of RPUF, dynamic nonlinear FE analysis, direct assessment

INTRODUCTION

The structural capacity of LNG CCS under sloshing loads is one of the most critical aspects to design LNG CCS. The sloshing load, which is generated due to the resonance between the ship motion and the behavior of LNG in a tank, has very high peak pressure in the short duration time and it induces the severe damage of LNG CCS. In addition to the impact loads which are not simple to be specifically defined, it is complicated to evaluate the capacity of LNC CCS designed by RPUF due to its nonlinearity. Traditionally, the evaluation of the sloshing capacity has been performed using the static material property of components in LNG CCS (ABS. 2009). Furthermore, dynamic amplification factor (DAF) and the strain rate of RPUF are used to consider the dynamic effects of the external load and material property (DNV. 2006). However, it is short of reflecting the complicated dynamic behavior of LNG CCS. Therefore the direct assessment method was developed and presented years ago and has been improved since then.

For the direct assessment, the dry drop test has been carried out to study and quantify the dynamic behaviors of the insulation panel structure under various impact loads. Moreover, the dynamic behavioral characteristics of RPUF and the failure criteria of CCS have been obtained (Chun et al. 2009, Chun et al. 2011, Hwang et al. 2014). From a series of dry drop tests, it has been observed that there were several types of the failure modes such as foam crushing, permanent deformation, and delamination of glue joints. By this time, these were usually defined through the visual inspection and the global measurement of thickness changes, etc. Since these failure criteria have some limitation in an objective point of view, however, the more reasonable failure criteria have been studied in this study.

To establish obvious failure criteria, the tensile test was implemented to observe the mechanical material properties of the specimen after the dry drop test. Furthermore, the dynamic material properties were derived considering the material nonlinearity to estimate the change of RPUF property. These values can be used in the numerical simulation to evaluate the safe impact energy in the dry drop test.

ASSESSMENT PROCEDURE

The direct assessment procedure for the sloshing capacity evaluation has been developed for a few years (Chun et al. 2011, Hwang et al. 2014). In the existing procedure, the dry drop test has been performed to establish the failure criterion, maximum deformation, and to obtain the derived dynamic material property as well. Through the study in Hwang et al. (2014), it was found that the derived value was much more effective to demonstrate the dynamic behavior of LNG CCS than using the dynamic material property of RPUF directly in the numerical simulations. With the derived value, the sloshing capacity analysis was conducted under several sloshing loads defined by the peak pressure with the duration time. These loads were applied to the top surface of the top plywood on the various areas. Finally, the sloshing capacities were evaluated through the comparison with the sloshing loads.

The dry drop test is the most important process in this procedure. However, through the many experiences, it has been found that it is a little obscure to obviously determine the failure criteria. As mentioned above, there are two failure criteria of RPUF found in the dry drop. In the case of foam crushing, the surface irregularities of the test specimen in the manufacturing process can cause some visual errors and it is difficult to quantitify the crushing status. The measurement of the permanent deformation might include a measuring error as well. Hence, the tensile test for the sample specimen from the impact specimen was added to the existing procedure in order to secure more objective failure criterion. The failure criterion in the dry drop, the maximum deformation, can be determined based on the tensile test. The tensile strength after the impact should be satisfied with the criterion, which is the strength of RPUF specified in the material specification, since LNG CCS is continuously imposed by the operation loading due to the ship motion. In this paper, the partial tasks of the procedure were performed in the red dotted box as shown in Figure 1.