ABSTRACT

Every effort was tried to demonstrate the procedure of the structural safety assessment of MARK III membrane type Cargo Containment System (CCS) with corrugated membrane under sloshing impact loading using local zooming analysis technique of LS-DYNA code in the last study. Big discrepancy was found in the pressure responses between local zooming analysis and full-scale 3D one layer global sloshing simulation. In this study, wet drop and shooting water impact analyses of Mark III membrane-type CCS with flat membrane were performed together with full-scale global sloshing ones with 70% filling level for the investigation of their big discrepancy, considering diverse constraint parameters of coupling algorithm and mesh size.

KEY WORDS: Structural safety assessment; cargo containment system (CCS); sloshing; local zooming analysis; LS-DYNA; fluid-structure interaction (FSI) analysis.

INTRODUCTION

As the cargo tank size and configuration of Liquefied Natural Gas carriers (LNGC) and LNG Floating Production Storage Offloading (LNG-FPSO) vessels grows in response to the global increase in demands for LNG and the necessities of economical transportation, impact loading from sloshing may become one of the most important factors in the structural safety of LNG Cargo Containment Systems (CCS). Guidance notes on the strength assessment have been suggested under the sloshing impact loads, involving the ultimate strength of MARK III membrane-type CCS component materials (ABS, 2006).

To ensure a reasonable and reliable safety assessment of CCS, its criteria should be established for the large deformation and strength of its components and their shock failure characteristics under impact loadings from sloshing, with consideration of their cryogenic material properties. To achieve a reasonable structural safety assessment of membrane-type CCS, it is necessary to develop the sloshing analysis techniques for more accurate and correct predictions of impact loading on the CCS, and to carry out full-scale sloshing analysis with fine-meshed CCS models. However, it is impossible to carry out full-scale sloshing simulations with fine-meshed CCS models in practice because of the Courant time step size criterion of the explicit hydrocodes involved, such as LS-DYNA (LSTC, 2011).

The local zooming analysis technique may prove useful in overcoming this limitation in the structural safety assessment of CCS. While Lagrangian interface segment could be handled in the structural analysis problem, Eulerian or ALE (Arbitrary Lagrangian Eulerian) interface parts should be treated in the Fluid-Structure Interaction (FSI) analysis problem. Contrary to the former case with interface history data of spatial and material points together at the same time, their material point history data of the latter case should be traced separately from the spatial point ones. After getting material histories of each ALE tracer particle, such as position, velocity and pressure etc., in the global sloshing simulation, its velocity can be applied to the ALE part in the local zooming analysis. Unfortunately, the material history position of each ALE part cannot be applied to the local zooming analysis model in LS-DYNA code.

FSI problems, such as sloshing and slamming etc., could be conveniently simulated by moving mesh algorithm and overlap capability of grid to structure mesh using the multi-material Arbitrary Lagrangian Eulerian (MMALE) formulation and the Euler–Lagrange coupling algorithm of LS-DYNA code, as shown in Fig. 1. VOF method is adopted for solving a broad range of nonlinear free surface problems and coupling algorithm is more suitable for the FSI problems with very complicated deformable structure, where fluid grid can overlap the structural mesh (Aquelet et al., 2003 and 2006; Souli et al., 2000).

![Fig. 1 Sketch of penalty coupling algorithm (Aquelet et al., 2006)](image-url)