

## Static Response of an LNG Containment System of GTT No. 96 Type

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This paper focuses on the stress analysis of the load-carrying box structure of the LNG containment system (LCS) membrane type. The shell element model of LCS No. 96, which is recommended by classification societies, can predict neither the stresses associated with the failure mode which is related to shear through the thickness of the plywood plate, nor the stresses related to the crushing of primary and secondary bulkheads. Therefore, a comparative study of the finite element (FE) model of LCS No. 96 consisting of the shell, solid and model combining of solid and shell elements is conducted; it was found the latter model maintains the benefit of using the shell and solid model. A sensitivity study of the element type and size is carried out, and the effect of the inner steel hull flexibility on the response of LCS No. 96 is studied. Two global FE models of LCS No. 96 were created with rigid and flexible inner steel hull support. The studied responses are the elastic static stress distributions of LCS No. 96, eigen buckling modes and values, as well as their nonlinear geometrical behaviour of the LCS structure with imperfections introduced. It was found that the static stress distribution in the upper part of the primary box is not affected by the flexibility in the inner steel hull which supports LCS No. 96. The responses of the lower part of the primary box down to the mastic ropes are influenced by the response of the inner steel hull. The model of LCS No. 96 that accounts for the flexibility of the inner steel hull creates lower eigen buckling values than one with rigid support. Finally, the stress distributions before and after the LCS No. 96 loss of stiffness are studied.

### INTRODUCTION

An important component of membrane-type LNG carriers is the LNG cargo containment system (LCS). One of the relevant LCS is known as No. 96. This is supported by the ship's inner hull and prevents the inner hull from cryogenic temperatures. This system includes 2 identical metallic membranes and 2 independent insulation systems. The primary and secondary membranes are made of invar, a 36% nickel-steel alloy, and are 0.7 mm thick. The primary and secondary insulation layers consist of a load-bearing system made of prefabricated plywood boxes filled with expanded perlite. The primary layer is secured by means of the primary couplers, which are fixed to the secondary coupler assembly.

The secondary layer is laid and evenly supported by the inner hull through load-bearing resin ropes and fixed by means of the secondary coupler anchored to the inner hull as seen in Fig. 1 (GTT, 2005).

Here, the study of an LNG containment system of the GTT No. 96 system was based on the published information (DNV, 2006; ABS, 2006; and LR, 2009). The layout of the structure of LCS No. 96 was assumed. A rational design procedure should be based on direct calculation-based stress and strength assessments. The dynamic structural response of the containment system has been investigated using a direct calculation approach (Shin et al., 2006; Wang and Kim, 2007). The classification societies, such as DNV, ABS and LR, published notes on the strength assessment of membrane-type LNG containment systems under sloshing impact

loads (DNV, 2006; ABS, 2006; LR, 2009). Numerical analysis of the structural response using finite element (FE) methods is recommended by the classification societies. FE analysis gives an approximate solution to the real situation. One of the assumptions is the element type used on the numerical analyses. Most of the articles related to the structural response of LCS No. 96 use shell elements. The shell element has good bending performance, which is important for the bending of the cover plate and buckling of the bulkheads of LCS No. 96. However, the shell element model cannot predict the shear through the thickness, axial stress distribution over thickness, and the compressive stress on the region of plates, bulkheads, intersegments between primary and secondary bulkheads, respectively. The above-mentioned behaviour is important to represent in the strength assessment as it is mentioned as the failure modes of LCS No. 96 (DNV, 2006; ABS, 2006). Solid elements would be necessary to capture the relevant behaviour. Therefore, a comparative study of shell, solid and combination of

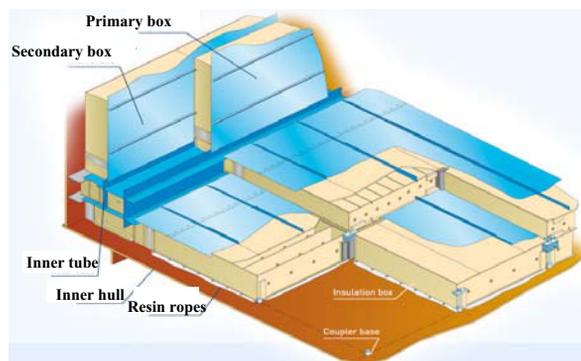


Fig. 1 Artist impression of LNG containment system No. 96

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