Structural Capacities of LNG Membrane Containment Systems

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ABSTRACT

This paper presents details of a methodology for generating the in-service structural capacities for both No.96 and MKIII Membrane Insulation Systems (MIS) within LNG tanks. The methodology includes testing and constitutive behavior of materials, physical testing of MIS components and panels, and nonlinear finite element models and analysis of in-service conditions. The calculated structural capacity distributions can be used in deterministic or reliability-based design assessments.

KEY WORDS: dynamic capacity; plywood; foam; cryogenic; LNG carrier; LNG

INTRODUCTION

This paper presents a methodology developed at ExxonMobil for generating the in-service structural capacities of the No.96 and MKIII Membrane Insulation Systems (MIS). These capacities are used in conjunction with LNG sloshing pressure predictions to assess the integrity of the LNG carriers MISs under either high-fill or partial-fill operating conditions. The ExxonMobil assessment methodology, known as EMPACT, is described in detail in a companion paper (Kuo et al., 2009). In the present paper, the first section presents an overview of the No.96 and MKIII MISs detailing the materials and components used in each system followed by a general section on the methodology. Next, two sections on physical testing of materials and components provide findings from an extensive experimental program. The subsequent two sections on nonlinear finite element modeling and validation of finite element models detail the development of numerical models. The next section presents details of the limit states for both systems, the response surface for idealized pressures, and the structural response to pressure time histories from physical sloshing tests. The final section of the paper provides conclusions and observations.

DESCRIPTION OF MEMBRANE INSULATION SYSTEMS

Illustrative overviews of the No.96 and MKIII systems are shown in Figure 1 and Figure 2, respectively.

No.96 Membrane Insulation System

The No.96 MIS is made of a primary barrier, a primary insulation box, a secondary barrier, a secondary insulation box, and hardware to connect the system to the ship. The primary and secondary barriers are 0.70mm invar, welded at short vertical fins. Invar has a high nickel content (36% Ni) and a low coefficient of thermal expansion that limits thermal stresses when the system is cooled. The invar barriers are connected to the ship hull through an invar tube at the bulkheads and to the plywood insulation boxes with a system of interlocking tabs and slots.