ABSTRACT

Membrane type Cargo Containment System (CCS) for Liquid Natural Gas Carrier (LNGC) is composed of two layers of insulation and membrane. In general, membrane is made of corrugated stainless steel 304L or flat invar (FeNi36) or flat composite material. In case of stainless steel membrane, corrugation should be made to reduce the thermal stress which is induced by very low temperature of Liquid Natural Gas (LNG). Typically, corrugated membrane is produced by bending or drawing process. During the bending or drawing process, the thickness reduction of original plate is inevitable and it will degrade the mechanical characteristics of corrugated membrane. Though range of Ni content of stainless steel is from 8% to 12%, typically 8% to 10% Ni content is used since more Ni content makes cost increase of stainless steel. In order to select the proper stainless steel based on economic and safety aspects, different studies of formability, weldability and mechanical characteristics have performed with 3 types of stainless steel. From the formability and mechanical properties studies, thickness reduction effect and strength characteristics are reviewed, respectively. Additionally, productivity was studied by weldability test. In this paper, characteristics of membrane in accordance with Ni contents of 8%, 9% and 10% of stainless steel 304L are introduced and its results are described.

KEY WORDS: LNGC; LNG; CCS; stainless steel; formability; weldability; mechanical characteristic

NOMENCLATURE

CCS: Cargo Containment System
LNGC: Liquid Natural Gas Carrier
LNG: Liquid Natural Gas
PUF: Poly-Urethane Foam
SOLIDUS: DSME newly developed membrane type CCS
MPa: Mega Pascal
FLD: Forming Limit Diagram
PAW: Plasma Arc Welding
GTAW: Gas Tungsten Arc Welding
NDT: Non Destructive Testing

ASTM: American Society for Testing and Materials
FLC: Forming Limit Curve

INTRODUCTION

LNG related business has rapidly grown due to the economic and environmental circumstances especially transport market of LNG. In general, transport of LNG is carried out by membrane type LNGC. The membrane type CCS is the most economical system for large LNGC due to lower material cost and excellent space efficiency.

To cope with the demand of the LNG market with flexibility, DSME has newly developed the membrane type CCS (SOLIDUS) and received an Approval In Principle from DNV, ABS and LR. The development for acquiring the General Approval for Ship Application is still ongoing with the object of finalization by 2017. The SOLIDUS is mainly composed of two layers of insulation and membrane. The insulation and membrane are made by Poly-Urethane Foam (PUF) and stainless steel (SUS304L) respectively. For those reasons, PUF and stainless steel occupy most of material cost.

In case of stainless steel, the cost of material is directly affected by Ni cost and content. There are efforts to reduce Ni content of stainless steel for decreasing cost. A study for new austenitic stainless steel with negligible nickel content was performed. (Fini, 2003) However due to the production difficulty of new stainless steel, this material is not available on the general stainless steel market. Stainless steel optimization was performed for various material contents. (Vitos, 2003) However a study was performed based on theory with no experiment.

The work described in this study is for formability, weldability and mechanical properties of membrane in accordance with Ni contents of 8%, 9% and 10% of stainless steel 304L. Based on those material studies, forming analysis, forming and measurement results are described for development of SOLIDUS.

SOLIDUS

The SOLIDUS shown in Fig. 1 is the corrugated membrane system which mainly consists of double metal membrane and insulation panel.