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A study on an efficient prediction of welding deformation for T-joint laser welding of sandwich panel Part II : Proposal of a method to use shell element model

Jae Woong Kim[1], Beom Seon Jang[2] and Sung Wook Kang[2]

[1]*Gas Technology R&D Group, Daewoo Shipbuilding & Marine Engineering Co., Ltd., Seoul, Korea*
[2]*RIMSE, Department of Naval Architecture and Ocean Engineering, Seoul National University, Seoul, Korea*

ABSTRACT: *I-core sandwich panel that has been used more widely is assembled using high power CO_2 laser welding. Kim et al. (2013) proposed a circular cone type heat source model for the T-joint laser welding between face plate and core. It can cover the negative defocus which is commonly adopted in T-joint laser welding to provide deeper penetration. In part I, a volumetric heat source model is proposed and it is verified thorough a comparison of melting zone on the cross section with experiment results. The proposed model can be used for heat transfer analysis and thermal elasto-plastic analysis to predict welding deformation that occurs during laser welding. In terms of computational time, since the thermal elasto-plastic analysis using 3D solid elements is quite time consuming, shell element model with multi-layers have been employed instead. However, the conventional layered approach is not appropriate for the application of heat load at T-Joint. This paper, Part II, suggests a new method to arrange different number of layers for face plate and core in order to impose heat load only to the face plate.*

KEY WORDS: Sandwich panel; Laser welding; Heat transfer analysis; Hetero-layered approach; Thermal elasto-plastic analysis.

INTRODUCTION

The research of steel sandwich panels has been extensively carried out for the past decades. Among the sandwich panel, I-core panels offer high strength to weight and stiffness to weight ratios, making them favorable in transport industry, especially shipping. Moreover, these panels are proved to be more resistant to impact and blast loads and space efficiency is good to fill different systems such as piping and wiring (Kujala et al., 2005; Yourlmaz et al., 2009). I-core sandwich panel is composed of two face sheet plates and web plates (called cores) welded perpendicular to the face sheet plates. CO_2 laser welding is adopted for T-joint welding between a core and a face plate due to its merits of narrow heat affected zone, small welding deformation, and deep penetration capability. CO_2 laser welding is known to induce less welding deformation than other conventional welding methods, however, the deformation level is still not ignorable in the sandwich panel since it consists of quite thin plates of 3-5*mm* thickness. (Kim et al., 2013). I-core sandwich panel is composed of two face sheet plates and web plates welded perpendicular to the face sheet plates as depicted in Fig. 1.

Corresponding author: *Beom Seon Jang*, e-mail: *seanjang@snu.ac.kr*

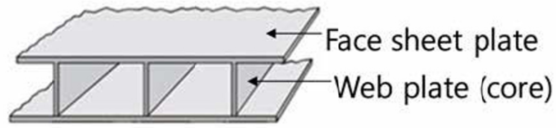

Fig. 1 Shape of I-core sandwich panel.

Kim et al. (2013) proposed a simple volumetric heat source model of laser welding for I-core sandwich including the defocus phenomenon. For a verification of the proposed model, heat transfer analysis and thermal elasto-plastic analysis are performed to investigate heat distribution in the thickness direction and the resultant welding deformation, respectively.

Table 2 summarizes a few researches on welding deformation induced by laser welding. Moraitis and Labeas (2008) used 3D Gaussian model for a butt weld of DH36 steel plate and a lap joint of aluminum alloy. Heat transfer analysis and thermal-elasto-plastic analysis was performed to simulate welding residual stress and deformation distortion using 3D solid element. An efficient keyhole model, which is independent of any empirical parameter, is introduced for the prediction of the keyhole size and shape required for the thermal analysis.

Tsirkas et al. (2003) simulated the laser welding process to predict laser welded panel distortions for butt joint specimen that consists of thick AH36 shipbuilding steel plates, using different welding parameters. Experimental testing was carried out to measure the distortion. Zain-ul-Abdeina et al. (2009) focused on the prediction of welding-induced distortions and residual stresses on thin sheets of 6056-T4 aluminum alloy. Cone-shaped volumetric heat source with Gaussian distribution and an upper hollow sphere is used to attain the required weld fusion zone size and temperature fields. From a comparative study of experimental and simulation results, a friction coefficient and a suction pressure to provide the best agreement in out-of-plane and in-plane displacements were found. Zain-ul-Abdeina et al. (2010) used a 3D volumetric conical heat source with Gaussian distribution without the hollow sphere for a fillet weld of T-joints made from 6056-T4 aluminum alloy. A comparative analysis of the experimental and simulation results showed a good agreement in temperature and displacement fields.

As an alternative to time-consuming thermal elasto-plastic analysis using 3D solid model, Sulaiman et al. (2011) developed a new linear elastic shrinkage method, named “Weld Planner”, to simulate welding deformation for GMAW process. Shell elements were used for the modeling of both plates and weld beads, which lead to more reduction in the computational time. It was employed to predict welding distortion induced in butt and T-joints of steel plates with thickness of 4*mm*. The simulation results were compared with experiment results and the difference was identified within 20%.

The above mentioned researches treated a butt weld or a conventional filet weld. Thus, deep penetration is not needed and the consideration of defocus has not been taken into account. However, T-joint of sandwich panel requiring a laser shooting on face plate requires a deep penetration into the upper part of core. This is enabled by the defocus of laser shooting and it should be incorporated into the heat source model.

In addition, those researches treated simple plates and the computational time is not significant. However, a sandwich panel consists of many core plates and the correct prediction of welding deformation can be made by accumulating the welding deformation for all T-joints. In this regard, thermal elasto-plastic FE analysis using solid model is quite time consuming. Thus, shell element model with virtual layers are employed to reduce the computational time. The heat load can be distributed through thickness by generating virtual layers and applying power densities to virtual nodes in this study.

This study focuses on a practical purpose how to make use of shell element model aiming at reducing the computational time without a deterioration of accuracy in the analysis results. Even if it is not based on robust theoretical background, the idea proposed in this study is expected to be directly applied to the actual engineering work and offer a concrete benefit.

This paper is unfolded as follows. First, volumetric heat source model to be used in this research is briefly defined. A new approach, named “Hetero-layered approach (HLA)” is proposed along with a simple illustrating example and a study on the number of layer of face plate. It is followed by a verification work to compare the temperature distribution on the cross section and welding deformations among the proposed method, a conventional method to use 3D solid elements and experiment results. The computational time of the proposed method as well as the welding deformation is also compared with the conventional method through four comparative studies. Finally, a conclusion is laid.