A Study on Evaluation of Residual Stress Redistribution of Ultra-Thick YP47 FCA Butt Weld under Tensile Cyclic Load

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ABSTRACT
This study aims at evaluating the redistribution behavior of the residual stress in the multi-pass FCA butt weld of YP47 in an ultra large size containership under tensile cyclic loading. A H-slit type specimen was designed in order to simulate the restraint condition of the actual butt weld of the hatch coaming top plates. The temperature distribution of the multi-pass FCA butt weld was evaluated by heat transfer analysis. With this result, the distribution of the transverse residual stress in FCA butt weld was evaluated by thermo-mechanical analysis. And the validation of FE analysis was verified by comparing the predicted results with the experimental results obtained by both hole-drilling method and XRD. The effect of the tensile cyclic load on the redistribution of the residual stress in FCA butt weld was evaluated by using FEA. FEA results revealed that the maximum tensile transverse residual stress decreased with an increase of the applied tensile stress level. However, there was a little change in the mean transverse residual stress in FCA butt weld.

KEY WORDS: Residual stress redistribution; ultra large size containership; YP47; multi-pass FCA; restraint condition; tensile cyclic load; finite element analysis;

INTRODUCTION
The primary stress induced by the ship motion and the residual stress as a secondary stress caused by welding process have to be taken into account as the design load to evaluate the occurrence possibility on the unstable fracture in heavy thick butt weld. Especially, the evaluation of residual stress is important because the residual stress in the weld may cause the unstable fracture. According to BS7910 [BS7910, 2005], the transverse residual stress of the weld under restraint condition should be assumed to be the yield stress of the weld. However, although the maximum transverse residual stress corresponding to the yield strength of the weld presents after welding, the transverse residual stress may be redistributed and relaxed with the applied tensile loads under service life. It means that the redistribution of residual stress in the weld should be identified to prevent excessively conservative assessment.

The purpose of this study is to evaluate the redistribution behavior of the residual stress in the multi-pass FCA butt weld of YP47 in an ultra large size containership under the tensile cyclic load. In order to do it, an H-slit type specimen was designed to simulate the restraint condition of the ultra-thick FCA (flux cored arc) butt weld in the actual ship. The thermo-mechanical FE analysis was carried out to evaluate the residual stress of the H-slit type specimen. The validation of FE analysis procedures was verified by comparing with the measured results in the test specimen and actual welds obtained by hole-drilling method and XRD. After that, the effect of applied tensile stress on the redistribution of residual stress was evaluated by FEA. The applied tensile stress used as variables in this study, are set to be 70MPa, 175MPa and 280MPa considering the maximum design stress of YP47 butt weld.

RESIDUAL STRESS OF A THICK WELDMENT

Analysis Model and Procedure In order to evaluate the distribution of transverse residual stress of thick weldment with the restraint degree, the comprehensive FEA were employed. The thermo-mechanical FE model using commercial FE code was adopted. Heat transfer analysis was performed to evaluate temperature distribution of the multi pass FCA butt weld using 2D heat transfer model with a quasi-stationary condition [Satoh et al., 1976, Ueda et al., 1971]. A heat input model for FCA (flux cored arc) welding has been defined as the volume heat source distributed uniformly. Heat loss at all surfaces of the solution domain was assumed to be governed by natural convection. The effective thermal conductivity was adopted to prevent the excessive increases of temperature in the molten pool and the dependence of physical properties on temperature was also considered [The Strength Commission of KWJS, 2005]. Fig. 1 shows the thermal and mechanical properties as a function of temperature for both base metal and weld metal used in the FEA. Mesh design used for thermo-mechanical stress analysis consists of 4-nodes plane elements with generalized plane strain condition in order to control the excessive residual stress along the longitudinal direction. Mechanical properties of weldment were postulated to behave as an isotropic, elasto-plastic and kinematic strain-hardening continuum. A von-Mises criterion was used for yielding criterion of the weldment. Fig. 2 shows the analysis model and mesh design used for FEA. The symmetric condition was applied to the nodes on the symmetric axis. And in order to consider the restraint degrees in a thick weldment, spring elements were attached to