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A Predictive Method for the Transverse Residual Stress Distribution at a Thick EH40 Weldment

Dong-Ju Lee, Gyung-Gyu Kim, Sang-Beom Shin and Joong-Geun Youn
Materials Research Dep't, Industrial Research Institute, R&D Division, Hyundai Heavy Industries Co. Ltd.
Ulsan, Korea

ABSTRACT

This study has been tried to establish the predictive equations for the level of transverse restraint stress and the distribution of transverse residual stress of a thick FCA weldment for the erection stage of a large container carrier using FEA and experiment. In order to do it, the restraint degree of a thick weldment of a large container carrier was evaluated using FEA. The validation of FE analysis procedure used for this study was verified by experiment using an H-slit type specimen for various restraint degrees. In experiment, the restraint stress and residual stress of test specimen were measured using uniaxial strain gages and XRD equipment, respectively. The effects of restraint degree, welding heat input, yield strength of the weldments and welding deposit sequence in a weld groove on the restraint stress and the residual stress were evaluated using FEA. Based on the FEA results, the predictive equations for the level of transverse restraint stress and the distribution of transverse residual stress at a thick weldment were established by dimensional analysis and multiple regression method.

KEY WORDS: Restraint degree; restraint stress; residual stress, thick weldment; finite element analysis; fracture; predictive equation

NOMENCLATURE

A : Section area of weldment
B : Thickness of weldment [mm]
E : Young's modulus [MPa]
F : Tension force per unit length [N/mm]
Ks : Restraint degree [MPa/mm]
K_{sp} : Spring stiffness [N/mm]
Ls : Restraint length [mm]
L_w : Weldment length [mm]
Q : Heat intensity [kJ/cm]
$\bar{u}$: Average displacement [mm]
σ_{Res} : Restraint stress [MPa]
σ_{Mean} : Mean restraint stress [MPa]

INTRODUCTION

Recently, with an increase in deck plate thickness of a container ship, the concern about the fracture safety of a thick butt weldment has increased more and more. This is mainly attributed to the change of fracture characteristics found at the thick weldment of over 60mm. Up to now, however, the design criteria of fracture properties such as CTOD (crack tip opening displacement) and crack arrestability to prevent the brittle fracture of a thick weldment are yet to be established. Brittle fracture is associated with the various uncertainties related to loading conditions, material strength, defects, initial imperfections such as distortion and residual stress and so on. Therefore, in order to establish the appropriate countermeasures for the brittle fracture of the thick weldment in the container carrier, first of all, the uncertainties described previously should be identified.

The purpose of this study is to establish how to predict the restraint stress caused by transverse shrinkage at the weldment and the distribution of transverse residual stress at the center and toe of a thick weldment using FEA and experiment. In order to do it, the restraint degree of the thick weldment in a large container carrier was evaluated using FEA in compliance with the welding sequence. From the results, the restraint degree for the thick weldment in an actual large container carrier was identified. The validation of FE analysis procedure used for this study was verified by experiment using an H-slit type specimen for various restraint degrees. In experiment, the restraint stress and residual stress of test specimen are measured using uniaxial strain gages and XRD equipment, respectively. The effects of restraint degree, welding heat input, yield strength of the weldments and welding deposit sequence in a weld groove on the restraint stress and the residual stress were evaluated using FEA. Based on the FEA results, the predictive equations for the level of transverse restraint stress and the distribution of transverse residual stress at a thick weldment were established by dimensional analysis and multiple regression method.

RESTRAINT DEGREE OF A THICK WELDMENT

FE Analysis Procedure In-plane restraint degree represents the resistance of weldment against the transverse shrinkage of weldment. It means that the restraint stress increases linearly with an increase in the restraint degree of weldment. In addition, the restraint degree of weldment strongly depends on the welding sequence. In this regard, in order to evaluate the level of restraint stress at a thick weldment, the restraint degree should be evaluated in consideration of welding sequence in the erection stage of the ship. The restraint degree (Ks) of weldment proposed first by Japanese researchers was defined as the transverse force (F) causing unit mean shrinkage($\bar{u}$) in the perpendicular direction of weldment as given in Eq. 1 [Satoh and Matsui, 1967].

$$Ks = \frac{\sigma_o}{\bar{u}} = \frac{FB}{L_w \bar{u}} \quad (1)$$