A Study on the Distortion and Residual Stress Caused by Groove Cutting with Flame

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Introduction

Flame cutting is widely used for groove cutting of flat bar for the hull structure and pressure vessel. However, groove cutting after flame cutting of both sides of flat bar induce the bending distortion. In welding assembly of these flat bar, the cutting induced-distortion often results in problems such as fit-up tolerance and dimensional instability. These problems could provoke the excessive distortion at the welded structure after welding. The aim of this study is to identify the mechanism of bending distortion caused by flame cutting for groove of flat bar with FEA and experiment. To do this, the redistribution of residual stress caused by flame cutting was also surveyed with the variables of the heat input, thickness and width of flat bar.

Procedure

The total heat input which flows into the work piece during flame cutting is determined by the sums of thermal energy by oxidization of Fe and preheating. In this study, to determine the amount of thermal energy for Fe-oxide, chemical experiment of slag by XRD and XRF was performed. It is a because of the fact that thermal energy depends on the types of Fe-oxide produced by flame cutting. Heat input by preheating was formulated as a function of flow rate and heating speed and specified by double Gaussian distribution with the effects of 1^{st} and 2^{nd} flame. Based on the results, the mechanism of bending distortion and residual stress at the caused by flame cutting at the flat bar with groove was investigated by FEA and verified by experiment. The variables used in this study are plate width and heat intensity defined as function of thermal energy per unit thickness and time. Here, the base metal is mild steel for shipbuilding.

Results and Discussion

The result of XRD experiment showed that the main compositions of slag were pure Fe such as α-Fe and Fe-oxide such as FeO, Fe_2O_3, and Fe_3O_4. Thermal energy for oxidization heat was calculated by the portion of Fe oxide with the reaction formula of Fe and O. Transient heat transfer analysis was carried out with the proposed heat input model. FEM result for HAZ size was coincident very well with experimental result. Prior to thermo-mechanical stress analysis for groove cutting, the initial residual stress distribution at the flat bar after gas cutting was investigated by FEA. The maximum initial tensile residual stress at the flat bar after gas cutting is yield stress of base metal and tensile residual stress zone appears symmetrically at the both sides and increases according to increase of width of flat bar. It means that the increase of width of flat bar cause increase of internal restraint. Base on these results, the initial residual stress distribution at the flat bar was defined as a function of heat intensity and cutting width. However, tensile residual stress was redistributed and bending distortion happened after flame cutting at the flat bar for groove. The redistribution of tensile residual stress after groove cutting induce the difference of shrinkage force at the both sides of flat bar which produce bending distortion. The difference shrinkage force increases according to the increase of heat intensity, but decreases according to increase of width of flat bar.

Conclusions

In order to identify the mechanism of bending distortion caused by flame cutting for groove of flat bar, FEA and comprehensive experiment was performed. The main results are summarized as follow

1. Heat input model for flame cutting is proposed and verified by comparison with the experimental result of HAZ size.

2. Residual stress at the flat bar after groove cutting with flame torch is redistributed and depends on the heat intensity and width of plate. Based on results, equivalent model to predict the distortion by groove cutting was established.