

A Study on Control of Bending Distortion By Induction Heating During Manufacturing of Built-up T Bar

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Introduction

This paper deals with the control method of bending distortion caused by twin tandem FCA welding at the Built-up T bar (BLT) by high frequency induction heating, which has practical importance to the shipbuilding industry. Although the correction method by flame torch or hydraulic pressure after welding is relatively easy to apply for a skilled and experienced worker, automatic control system during welding is difficult. It is because the system requires the quantitative prediction for bending distortion caused by welding and induction heating. The use of numerical and experimental method to solve this problem will result in a tool to predict the bending distortion of BLT. Such prediction capability can be most useful in the present effort to automate the manufacturing process of BLT.

Procedure of experiment and FEA

In order to control bending distortion of BLT during welding, heat input flow into work piece by induction heating and coil's location should be controlled to offset the shrinkage force caused by welding. To solve this problem, the shrinkage force caused by welding and induction heating process was calculated by FEA. Prior to thermal elasto-plastic analysis for shrinkage force by both processes, the electromagnetic fields of BLT induced by coil are calculated by FEA. Two different experiments for induction heating were performed to evaluate efficiency and temperature field by induction heating. Based on these results, heat input model for heat transfer analysis were developed. The variables used in this study are welding and induction heating parameters and geometric factors including heat input, gap between conductor and work piece and bending rigidity of BLT bar etc.

Results and discussion

In order to establish heat input model for induced current that produce heat for Joule effect, the current density at the coil of induction heating system was measured. The current density depends on the input power of induction heating system and defined as a function of effective coil voltage, frequency, inductance and cross-section area of coil. From this results, Heat input model was specified by a Gaussian distribution of which effective radius and the maximum heat flux was defined as a function of gap between conductor and work piece, input power and mean temperature of cross-section of work piece in the perpendicular direction of heating line by electromagnetic analysis. Herein,

Mean temperature is determined by input power of induction heating system. Effective radius of maximum heat flux for heat input model increased when mean temperature increase. The heat input model proposed by this study was verified by comparing with the temperature results measured with thermo-couples.

Shrinkage forces by both processes linearly increase according to the increase of the ratio heat intensity to bending rigidity of BLT. Here, heat intensity means power per unit length of heating line. Therefore, the predictive equations of shrinkage force caused by induction heating and welding was defined as a function of heat intensity and bending rigidity. Based on these results, the control method for bending distortion was proposed and verified by experiments with actual BLT (flange 15x 150x20000mm, Web 12x450x20000mm). The maximum bending distortion of BLT decreases to about 95% by induction heating and satisfies the design criteria of BLT for shipbuilding.

Conclusions

To control bending distortion of Built-up T bar manufactured by twin tandem FCA welding, shrinkage force by welding and induction heating was evaluated by FEA. The main results obtained are summarized as follow

1. Heat input model for induction heating was developed by electromagnetic analysis and verified by experiment. It is defined as a function of gap between conductor and work piece, input power and mean temperature of cross-section of work piece.
2. Shrinkage force by FCA welding and induction heating is defined as a function of heat input by both process and bending rigidity of BLT.