

A Study on the Saving Method of Plate Jigs in Hull Block Butt Welding

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Abstract. A large amount of plate jigs is used for alignment of welding line and control of welding deformations in hull block assembly stage. Besides material cost, the huge working man-hours required for working process of plate jigs is one of the obstacles in productivity growth of shipyard. In this study, analysis method was proposed to simulate the welding deformations of block butt joint with plate jigs setting. Using the proposed analysis method, an example simulation was performed for actual panel block joint to investigate the saving method of plate jigs. Results show that it is possible to achieve two objectives of quality accuracy of the hull block and saving the plate jig usage at the same time by deploying the plate jigs at the right places. And the proposed analysis method can be used in establishing guidelines for the proper use of plate jigs in block assembly stage.

1. Introduction

For the welding work of hull block joint, plate jigs are used to adjust the misalignment and to prevent welding deformation. At each shipyard, according to its scale, some hundreds thousands of plate jigs are used in a year, and the working time required for installation, removal, and finishing work is also huge. According to a survey, an around of 38,000 plate jigs are used for a 50K tanker [1]. Therefore, for the productivity improvement in the assembly and erection stages of hull blocks, the effort to reduce the usage of plate jigs as well as accuracy management through the control of welding deformation is very important.

Regarding the butt joint welding, there have been many analytical and experimental researches since the past. Recently, thanks to the development of the computer, there have been researches to precisely evaluate the deformation and residual stress of the welding joint using finite element method (FEM). However, most of the researches have been limited in a range of simple test specimen level [2, 3]. Simulation of welding deformation by FEM has a problem of generating a pretty large difference from the experimental results at the deformation point of view, in spite of a large calculation time for considering non-linearity of materials [4]. It is known that accuracy of the solution is largely relies on the adequate considerations of the melting zone of high temperature [5].

This study was performed with objectives of securing the quality accuracy of hull block and saving plan of plate jig usage. As research contents, the restraint effect of the plate jig on the deformation during butt welding was investigated quantitatively through a series of welding experiment. Further, a calculation method was established for the welding deformation of butt joint where plate jigs were attached by using a thermal elasto-plastic method based on FEM. The results were compared and verified with the experimental results. Lastly, an example simulation was performed for actual panel block joint to investigate the effect of deformation control according to the number of plate jigs installed. Results show that it is possible to achieve two objectives of quality accuracy of the hull block and saving the plate jig usage at the same time by deploying the plate jigs at the right places.



2. Experiment

Welding experiment was performed for the three specimens as shown in figure 1 to quantitatively compare the welding deformations by the butt welding according to the number of plate jigs installed. The size of base plate is 940 x 1100 x 15 (mm) and the size of plate jig is 200 x 100 x 8 (mm). The other conditions except the number of plate jigs are same in all the experiment cases. Flux cored arc welding was used and the details of welding condition are summarized in table 1. Welding experiment was performed in the order of butt welding, plate jig removal, and deformation measurement. It was confirmed that both the results of monitoring of welding conditions and appearance examination of welding beads were good.

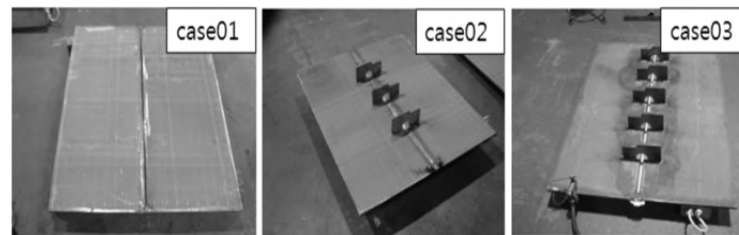


Figure 1. Specimens for welding experiment.

Table 1. Butt welding conditions.

Item	Value	Unit
Current	201 – 270	A
Voltage	27 – 31	V
Speed	15	cm / min
V-groove angle	35	Degree
Root gap	8	mm

Deflections due to welding were measured for total of 504 points marked in advance with a gap of 50mm (for the welding line, a gap of 20mm) for each specimen by using a contact type 3D measurement system after removing the plate jigs. Figure 2 shows the relative deflections obtained by fixing the end values of measure line to “0”. Deflections measured in transverse direction along center line are plotted in figure 2(a) and deflections measured in welding direction along edge line are plotted in figure 2(b).

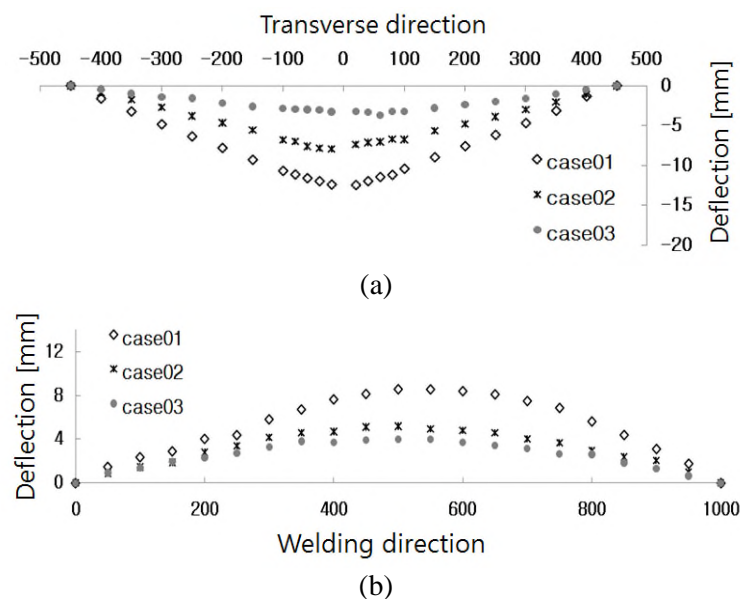


Figure 2. Deflections results of welding experiment.

The welding experiment as above yielded the data for the welding deformation according to the number of plate jigs installed. These results would be utilized for the comparison and verification to establish the welding deformation analysis method.

3. Analysis method for welding deformation

In this study, a thermal elasto-plastic analysis method based on FEM was used. As mentioned above, it is known that simulation of welding deformation by FEM has a problem of generating a pretty large difference from the experimental results at the deformation point of view, in spite of a large calculation time for considering non-linearity of materials. To improve the accuracy of deformation results by analysis, analysis parameters were decided based on the experiment results. The major items for analysis are listed as below;

(1) MSC MARC was used as an analysis code. Shell element having nine integral points was used to consider the temperature gradient in thickness direction.

(2) A half-model from the weld line was created as shown in figure 3. Symmetric boundary condition was applied along welding line and fix conditions were applied at the nodes of tag welding area to prevent rigid body motion.

(3) Temperature-dependent material properties were applied by referring to the research of Shin et al. [2]. Welding conditions for analysis were set as current of 248 (A), voltage of 26 (V), and welding speed of 15 (cm/min) by referring to the values in table 1.

(4) The moving heat source was used to simulate the 3D effect of welding deformation. The modeling technique where the welding beads of high temperature are gradually generated by elapse of time was implemented.

(5) Analysis was repeatedly carried out by changing the heat flux radius to find out heat input condition matching to deformation results of the experiment. At this time, experiment result of case 1 was used as the reference. Both angular deformation and longitudinal deformation showed the best similarities when the heat flux radius was 135mm.

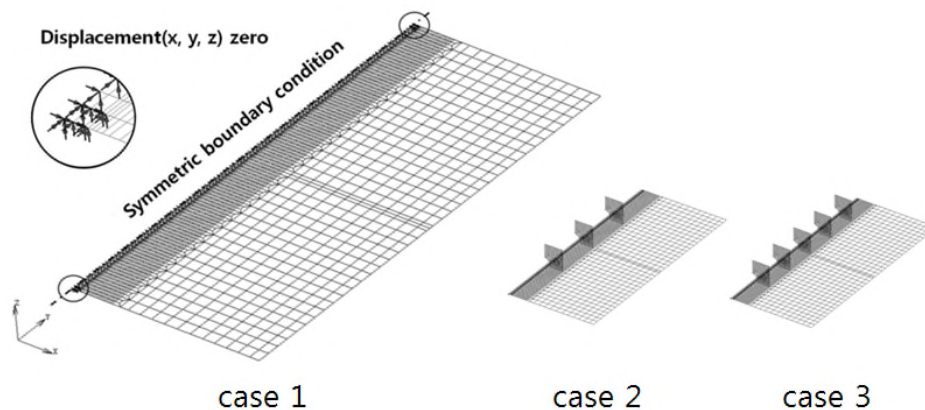


Figure 3. Finite element models and boundary conditions.

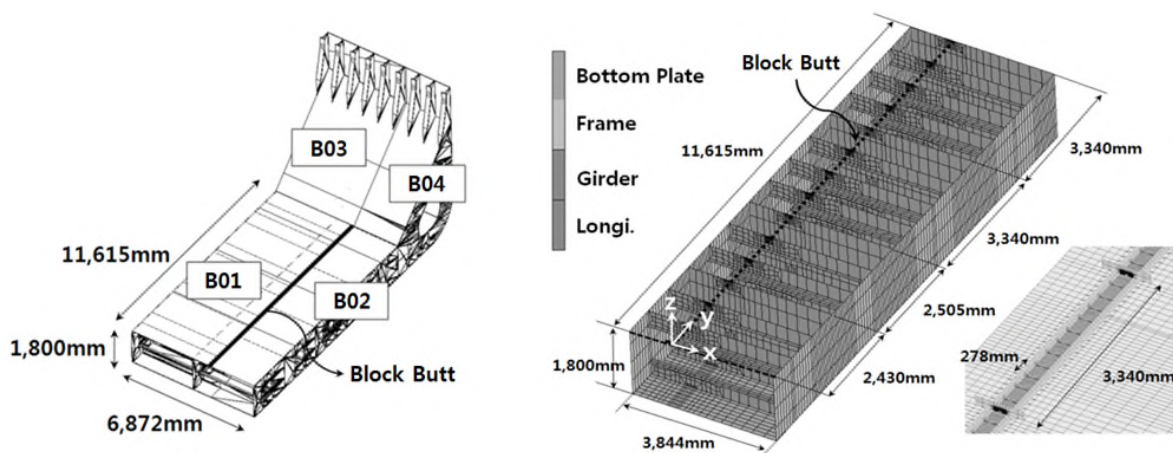
Similarities between experiments and analysis results are summarized in table 2. Match tolerance of 2mm was applied for the evaluation of similarities. Angular deformations were well matched in both experimental and analysis results for all the cases. The deflections along welding direction were also pretty similar in both experimental and analysis results except the case 3. For the difference of deflections along welding direction in case 3, it might be due to the analysis condition of heat flux radius determined from the case 1 where horizontal restraint does not exist. Fortunately, case 3 where the installation distance of plate jigs is 180mm is not the case of our interest since the installation distance of plate jigs at the site is normally more than 300mm.

Table 2. Similarity between experimental and analysis results [%].

Item	Case 1	Case 2	Case 3
Angular deformation	100	100	100
Deflection along welding direction	98	95	56

4. Welding deformation analysis of hull block joint

Using the proposed analysis method for welding deformation, an example simulation was performed for actual panel block joint to investigate the saving method of plate jigs. Figure 4 shows the panel block composed of 4 sub blocks B01~B04 and finite element model for welding deformation analysis. Analyses are conducted for 3 cases according to the number of plate jigs used as shown in table 3. Case 1 is selected to decide the deformation value for the lower limit, case 2 is the present method of construction in shipyard, and case 3 is an attempt to reduce the number of plate jigs.

**Figure 4.** Panel block and Finite element analysis model.**Table 3.** Analysis cases for panel block joint.

	Case 1	Case 2	Case 3
No. of plate jigs installed	0	39	20

Deflections along y-direction are plotted for all analysis cases as shown in figure 5. Result of case 3 is quite similar to that of case 2, but the plate jigs are need to be added at the location of $6,605 < y < 7,440$ and $9,945 < y < 10,780$ since the deflections exceed the values of case 1. Finally, it can be concluded that 22 plate jigs are sufficient for the butt joint welding of panel block and 17 plate jigs can be saved compared to the present method of construction in shipyard.

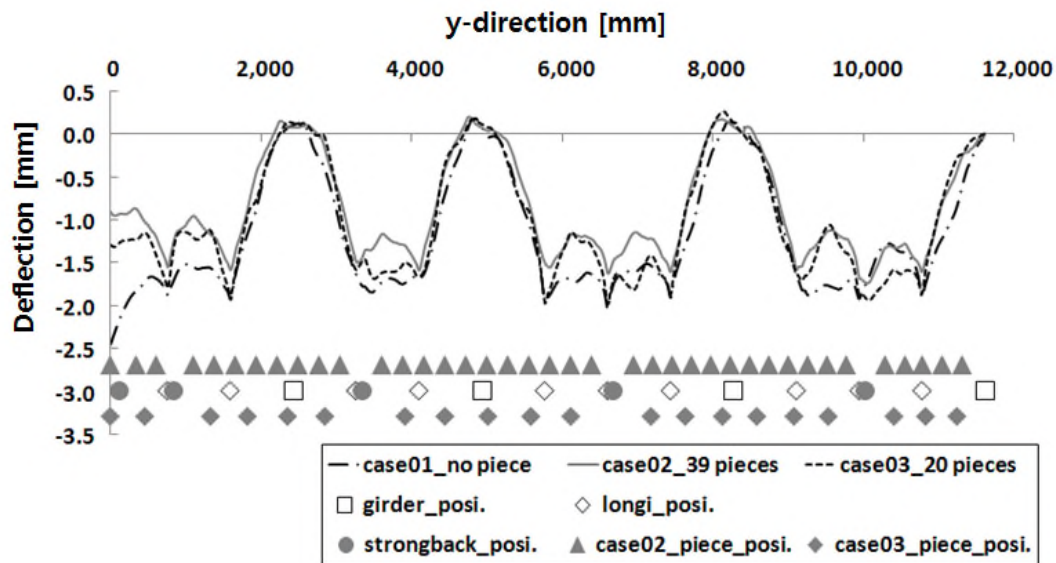


Figure 5. Analysis results for panel block joint.

5. Conclusions

This study was performed with the objectives of securing quality accuracy of block and of saving method of plate jigs used during butt welding of hull blocks. The major research results are as follows;

- (1) By carrying out a series of welding experiment, quantitative data were obtained to be utilized for the comparison and verification in establishing the welding deformation analysis method.
- (2) A deformation analysis method for the butt welding with plate jig setting was established using the thermal elasto-plastic analysis method based on FEM.
- (3) An example simulation was performed for actual panel block joint and the results show that it is possible to achieve two objectives of quality accuracy of the hull block and saving the plate jig usage at the same time by deploying the plate jigs at the right places.
- (4) The proposed analysis method is expected to be used as an analysis tool for the preparation of plate jig deployment drawing and its installation guide.

6. References

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