Image measurement of welding distortion of pipe joint in two-phase flow separator†

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KEY WORDS: (Welding distortion) (Image measurement) (3D measurement) (Stereo imaging technique) (Iterative substructure method) (Thermal elastic plastic analysis)

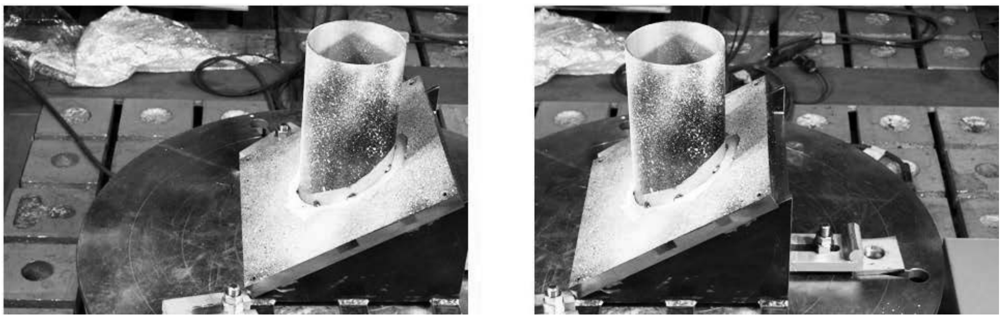
1. Introduction

The two-phase flow separator is connected to more than 300 pipes, which are attached by fillet welds. Although the welding causes deformation, it is quite difficult to correct this deformation to the shroud head to which the two-phase flow separator is attached because the shroud head material is very thick—more than 50 mm. Thus, it is necessary to clarify the mechanism of welding deformation so that it can be quantitatively predicted and controlled.

The objective of this paper is to investigate the influence of factors such as the inclination angle of the base plate, to which the pipes are connected, on welding deformation. In this study, the fillet welding experiments of pipe are performed with changing the angle of joint plane and a 3-dimentional measurement method by stereo imaging using two digital cameras is applied to measure the welding deformation. Furthermore, the measured results are compared with simulated results by Iterative Substructure Method (ISM) for 3-dimentional thermal elastic plastic FE analysis.

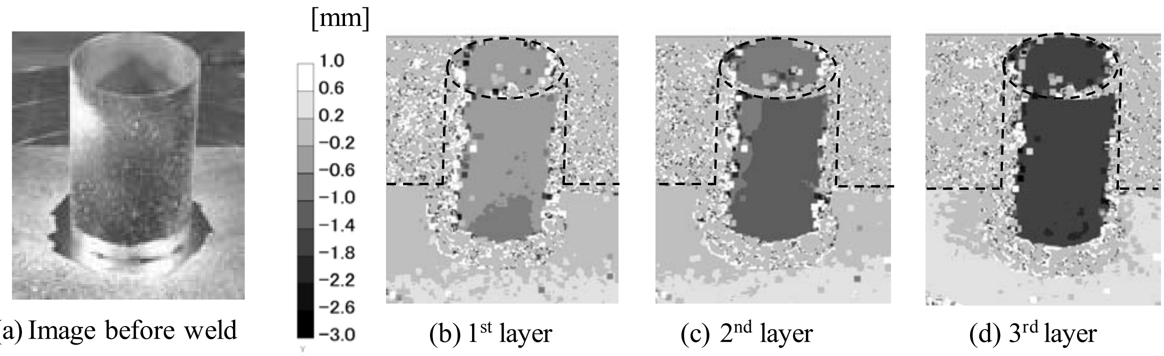
2. Three dimensional measurement based on stereo image processing and experiments

In this study, a measurement system using the stereo imaging technique based on the digital image correlation method is applied. This technique can eliminate the abovementioned errors by the out-of-plane displacement effect and both in-plane and out-of-plane deformation can



(a) Photo taken by left camera (b) Photo taken by right camera

Fig. 1 Photographs of specimen whose angle of joint plane is 30 degree.



(a) Image before weld (b) 1st layer (c) 2nd layer (d) 3rd layer

Fig. 2 Distribution of axial displacement measured by 3D measurement based on stereo imaging technique.

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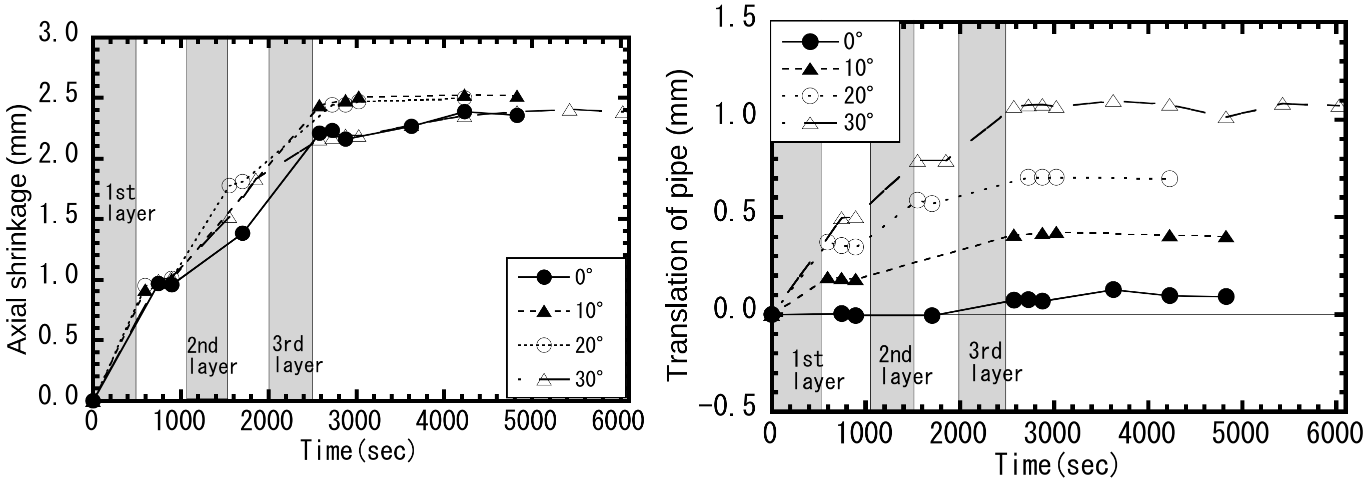
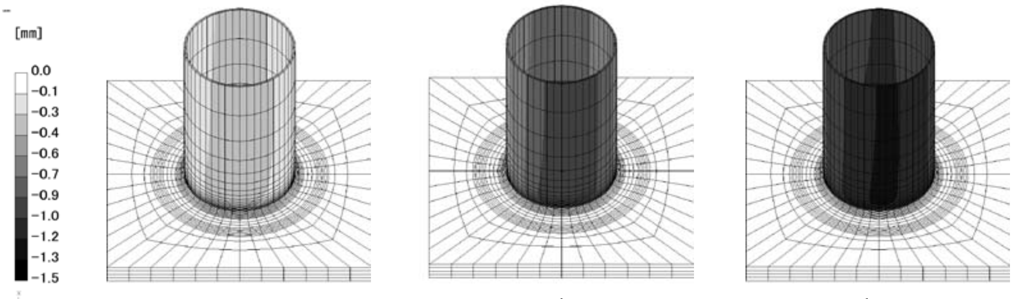


(a) Axial shrinkage (b) Translation of pipe

Fig. 3 Influence of inclination angle of joint plane on welding distortion.



(a) 1st layer (b) 2nd layer (c) 3rd layer

Fig. 4 Distribution of axial shrinkage simulated by Iterative substructure method.

be measured simultaneously with high accuracy.

To study the influence of the inclination angle of the joint plane on the welding deformation, four specimens with different inclination angles of welding plane, namely 0o, 10o, 20o and 30o are used. The diameter and thickness of pipe are 168.3mm and 3.4mm respectively. The thin base plate is 400x400x29 mm. Stainless steel SUS304 is used in both pipe and thick plate. The total welding passes and layers are ten and three. The first and second layers have four quarter circular passes, respectively. The third pass has two half circular passes. Measurement is carried out before welding, after each welding pass and after cooling by taking photographs by two digital cameras as shown in **Fig. 1**. Additionally, the specimens are sprayed to collate easier.

Figure 2 shows the axial displacement distribution of 0o model when the each layer is welded. It is seen that the axial shrinkage becomes larger when the layer increases. Furthermore, in the axial direction, the pipe is mainly deformed and the deformation of the thick plate is very small. In this measurement, it is difficult to use the imaging technique where the inclination angle to the camera is large or where the spray is not carried out such as the welding line. In these cases, the results are ignored.

The influences of the inclination angle of the welding plane on the axial and inclined direction are summarized in **Fig. 3.** The displacements of the top of the pipe when the welding of each layer is finished are plotted. This figure indicates that the influence of the inclination angle on the welding deformation in axial shrinkage is small. On the other hand, the deformation in inclined direction becomes large when the inclination angle of the weld plane becomes large.

3. Thermal elastic plastic FE analysis using Iterative Substructure Method (ISM)

The same models as the experimental specimens are used for the FE analyses. After the thermal conductive analysis using a moving heat source, the Iterative substructure method (ISM) as high-speed 3-dimensional thermal elastic plastic FE analysis developed by the authors is performed.

Figure 4 show the result of the welding deformation in the axial direction in case of the 0o model. From this figure, it is found that the axial shrinkage becomes larger when the layers increase. This tendency is the same as that of the experiment. The influence of the inclination angle of joint plane on the welding deformation in inclined direction is also the same as the experimental result.

4. Conclusions

The three-dimensional displacement measurement system based on the stereo imaging technique is applied to the welding deformation problem of weld joint model of two phase flow separator and serial computation are performed by Iterative substructure method as high-speed thermal elastic plastic FE analysis. The following conclusions are drawn.

(1) It is confirmed that the welding deformation distribution of pipe can be measured by measurement system using the stereo imaging technique based on the digital image correlation method and the displacements in axial and inclined direction can be calculated.

(2) When the inclination angle of the welding joint becomes lager, welding deformation in inclined direction becomes larger.