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Prediction and measurement of welding distortion of a spherical structure assembled from multi thin plates

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ABSTRACT

A spherical structure assembled from 14 thin bent plates and two circular polar plates was taken as the research object and its welding distortion was investigated in this study. Firstly, the welding distortion due to each welding line is measured by experiment. Then, the spherical structure was modeled by shell element and its welding distortion produced by each welding line was evaluated using the inherent deformation method proposed by authors. The computational process requires a short time when the inherent deformation method is employed. To determine the inherent deformation existing in the welding lines, a computed model with 3D solid element for a typical butt welded joint was applied and one case of the detail transient analysis by Thermal Elastic Plastic Finite Element Method was performed.

The computed and measured welding distortion show that the radial displacements on the welding lines and at the center of the top and the bottom polar plates are toward the inside of the spherical structure. The radial displacements at the positions between the welding lines are toward the outside of the spherical structure. The welding distortion at the measuring points changing with each welding line is well predicted using the inherent deformation method compared with the measured results.

1. Introduction

Welding technology which is a high productive and practical joining method is widely used in modern manufacturing industry such as shipbuilding, automobile, bridge, and pressure vessel industry. It is also well-known that the welding distortion always occurs during the welding process, caused by the non-uniform expansion and contraction of the weld and surrounding base material [1]. The welding distortion not only degrades the performance of a welded structure but also increases its production cost. Therefore, the prediction and control of welding distortion have become of critical importance in industries producing welded structures.

Up to now, a lot of studies of welding distortion were conducted by experimental measurement and empirical formulas for basic welding distortion such as longitudinal, transverse shrinkage and angular distortion were presented. Satoh and Terasaki [2] investigated the effect of welding conditions, such as weld heat input, physical and mechanical properties of materials, and size of weldments. on welding deformations for bead on plate and multi-pass welded butt joint. Masubuchi [3] proposed systematical methodologies for analyzing the welding distortion. The mechanism of welding distortion is clarified and formulas are applied to predict the fundamental welding distortion for the typical welded joint. Verhaeghe [4] investigated the welding distortion based on measured deformation available from literatures and reviewed approximate formulas considering various production factors. However, these formulas gave only the tendency of welding distortion and could not accurately predict the value of welding distortion.

With the development of advanced computer and numerical analysis technology, the computational approach especially the Finite Element Method (FEM) was applied to predict the welding distortion by many researchers in the welding field.

In the 1970s, Ueda and Yamakawa [5] firstly presented a computational approach to analyze the welding thermal stresses and resulting residual stresses during the welding process using the Thermal Elastic Plastic FEM. In this method, the change of mechanical properties depending on the temperature is considered. Butt and fillet welded joints are studied as examples. Later, some other investigators including Hibbitt [6], Friedman [7], and Lindgren and karlsson [8], etc. developed the Thermal Elastic Plastic FEM for the computation of temperatures, residual stresses and distortions with the progress of welding process. Now the Thermal Elastic Plastic FEM is widely accepted to analyze the welding problems for various welded joints and simple welded structures.

Although the current numerical methods based on the Finite Element Method show us good predictions on the welding distortion, requirements on memory capacity and computing time

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