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Simplified welding distortion analysis for fillet welding using composite shell elements

Mingyu Kim, Minseok Kang and Hyun Chung

Division of Ocean Systems Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Korea

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ABSTRACT: *This paper presents the simplified welding distortion analysis method to predict the welding deformation of both plate and stiffener in fillet welds. Currently, the methods based on equivalent thermal strain like Strain as Direct Boundary (SDB) has been widely used due to effective prediction of welding deformation. Regarding the fillet welding, however, those methods cannot represent deformation of both members at once since the temperature degree of freedom is shared at the intersection nodes in both members. In this paper, we propose new approach to simulate deformation of both members. The method can simulate fillet weld deformations by employing composite shell element and using different thermal expansion coefficients according to thickness direction with fixed temperature at intersection nodes. For verification purpose, we compare of result from experiments, 3D thermo elastic plastic analysis, SDB method and proposed method. Compared of experiments results, the proposed method can effectively predict welding deformation for fillet welds.*

KEY WORDS: Prediction of welding distortion; Fillet welding; Inherent strain; Composite shell; Strain as direct boundary (SDB).

INTRODUCTION

Since welding is one of high productive joining method to assemble various parts, it is widely used in shipbuilding and offshore plants industries. Although welding affords many benefits such as flexibility of design, weight reduction and cost savings, residual stress and distortion are unavoidable (Wang et al., 2013). These distortions are caused by the heating and cooling cycle in welding process. In particular, welding distortion negatively affects the dimension accuracy, external appearance and various strengths of the structures. Avoiding these disadvantages, it requires such re-works, for example cutting, alignment and straightening, that schedule delay and additional costs are caused. However, by predicting magnitude of welding distortion in advance, we can not only efficiently construct structures maintaining same quality but also reduce reworks by means of reverse design and distortion margin. For these reasons, prediction of welding distortion became so crucial that many researches have been conducted in this field (Deng et al., 2007).

In order to predict welding distortion, some researchers introduced the 3D thermo elastic plastic finite element method to deeply look into interior phenomena as well as exterior (Teng et al., 2001; Deng et al., 2007; Perić et al., 2014). Even though thermal elastic plastic finite element method can be effectively used to predict welding residual stress and distortion for sample size structures, this method cannot be applied to large welded structures because of computation time and costs. Accordingly,

Corresponding author: *Hyun Chung*, e-mail: *hyunny92@kaist.edu*

simplified analysis methods have been frequently used for the prediction of welding distortion because those methods requires less computation time and resource compared to the 3D thermo elastic plastic analysis while maintaining reasonable prediction accuracy. Many simplified methods have used the inherent strain, which is regarded as the plastic strain equivalent to the distortion during welding process. If the inherent strain is known for each thermal process, deformation can be predicted using elastic analysis without the computationally expensive plastic stress analysis (Luo et al., 1997).

Recently, based on the long weld assumption, many researchers have proposed approaches, which use equivalent thermal strain and shell elements, to describe welding deformation (Jung and Tsai, 2004; Ha et al., 2008). It is more convenient for predicting welding distortion because of scalar parameters such as thermal expansion coefficient and artificial temperature as well as it is able to reduce modeling costs. In particular, the SDB method can describe the angular deformation of plates by introducing artificial temperatures of top and bottom surfaces in shell elements. Since temperatures at interior integration points are automatically assigned by linear interpolation of finite element methods, it can be easily depicted with a trapezoidal shapes of inherent strain region, which usually occur in butt joint. In this respects, the SDB method is the effective way to predict the welding deformation for butt joints without substantial efforts.

However, an important issue has not been considered in these methods. When it comes to fillet joints, which consist of a plate and a stiffener, it cannot predict deformation for both members. As you can see Fig. 1, since the nodes, which are located at intersections, share their degree of freedom such as a temperature, there is nothing but predicting deformation of either the plate or the stiffener.

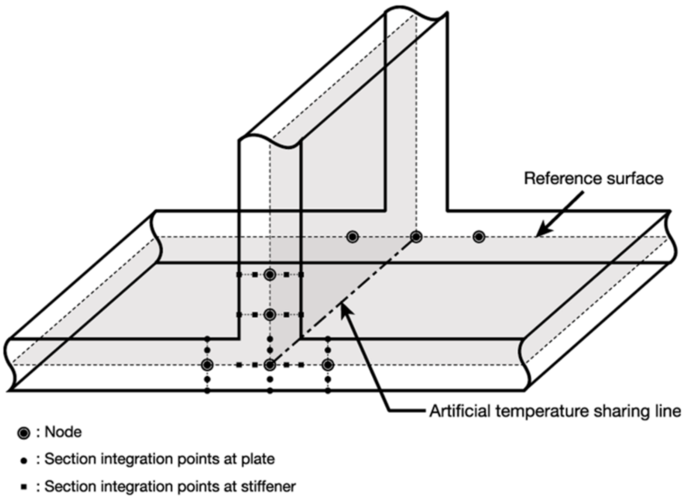

Fig. 1 Shell element in fillet welds.

For the ship production, previous methods didn’t consider the stiffener deformation because it is not the main issue to predict stiffener deformation. The former purpose of prediction of welding deformation was how much deformation occurs during fabricating hull forms, which is mostly affected by the plate deformation (Wang et al., 2013). In addition, since the plate deformation is relatively substantial than stiffener deformation, it was neglected. In the offshore structure, however, since all of the part should be under the control, the stiffener deformation must be also taken consideration in simplified analysis as well as the plate deformation.

In this paper, we suggest that new approach can predict both plate and stiffener deformation at once. In order to verify this method, we compare with results from experiments, 3D thermo elastic plastic analysis and previous simplified analysis.

BACKGROUNDS

Ueda et al. (1975) referred that the inherent strain, which is such incompatible strain produced by plastic strain, phase transformation or other means, was originally regarded to predict the residual stress. For seeking practical methods to predict the residual stress, Ueda and co-workers studied the characteristics of the inherent strain (Ueda et al., 1989; Ueda and Ma, 1994; Ma et al., 1995). They found where the inherent strain is uniform except starting and end regions of plates and inherent strain is