

Theoretical Prediction of Welding Distortion Considering Positioning and Gap Between Parts

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ABSTRACT

The welding distortion of a plate structure during the assembly process is influenced not only by the local shrinkage due to the welding thermal cycle, but also by root gap and misalignment. The former is governed by the heat input. The latter is strongly affected by the welding procedure, such as the welding sequence and the restraint on the parts to be welded. In this research, an elastic FEM is developed to precisely predict the distortion during the assembly process taking these factors into account. It employs the concept of inherent strain and the interface element to account for both the local shrinkage due to welding and the gap and misalignment in the weld joint. The proposed method is applied to study the influence of the welding sequence on structure distortion during the welding assembly.

INTRODUCTION

The assembly process in shipbuilding essentially involves the joining of large blocks. These blocks typically are all-welded, thin-plate structures. During the fabrication of these blocks, distortions occur due to a variety of causes, including cutting and welding. Even though it is practically impossible to eliminate distortion completely, it is necessary to produce blocks with a level of accuracy sufficient to avoid problems in the course of assembly.

Local shrinkage is produced as an unavoidable consequence of welding. While this shrinkage is the major cause of geometrical error in the welded structure, many other contributing factors cannot be ignored, such as initial geometrical error in the parts, the root gap of the groove, positioning and fixture prior to welding. The welding sequence is one of the major contributing factors to the root gap and misalignment, hence to geometrical inaccuracy.

Generally, there are 2 major causes of geometrical error in the welded structure. The first is the local shrinkage due to the thermal cycle experienced in the weld zone. The local distortion can be divided into 3 categories: longitudinal shrinkage, transverse shrinkage and angular distortion. All 3 types are strongly affected by heat input, shape of penetration, plate thickness and joint type. The gap and misalignment produced in the joint prior to welding are the second cause. Contributing factors to the gap and misalignment are the welding sequence, the positioning and the restraint, such as tack welding. For an accurate and reliable prediction of welding distortion during the assembly process, all these factors must be taken into account in addition to the local shrinkage.

In this research, a method is proposed to predict the distortion during welding while taking into account all the above factors.

Using this method, the local shrinkage due to the welding thermal cycle is considered through the inherent strains; the gap corrections are handled by interface elements. The proposed method is applied to study the welding distortion of thin-plate structures and to investigate the influence of the welding sequence.

THEORETICAL FORMULATION

Interface Potential

Fig. 1 schematically describes the process of welding parts A and B. At the beginning, both A and B are free parts. These parts are pulled together to their appropriate position, and tack welds are made. In this process, the root gap can differ, depending on how the misalignments are treated. After the positioning step, the actual welding is performed. These 3 stages—free, positioning and welding—can be modeled using the interface element (Murakawa et al., 1998).

The interface element is used to describe the interaction between the surfaces or the parts to be welded. In the initial free stage, the interaction is extremely weak, but after the last welding stage, the parts are strongly joined. The interaction during the second positioning stage is intermediate in strength, which nevertheless is sufficient to prevent penetration between parts. Such interaction between the surfaces can be described by the interface potential function ϕ . This research uses the Lennard-Jones type of potential function (Murakawa et al., 1998). The interface potential per unit area, ϕ , can be defined by the following equation:

$$\phi(\delta) = 2\gamma \left\{ \left(\frac{r_0}{r_0 - \delta_G + \delta} \right)^{2n} - 2 \left(\frac{r_0}{r_0 - \delta_G + \delta} \right)^n \right\} \quad (1)$$

where δ is the distance or the relative displacement between the parts to be welded, and δ_G is the root gap of the groove formed during the positioning stage. The parameters γ , r_0 and n are the surface energy, scale parameter and shape parameter, respectively; γ controls the bonding strength, r_0 determines the accuracy in positioning, and n changes the shape of the potential and is chosen to be 4 in our research. The derivative of ϕ with respect to the

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KEY WORDS: Interface element, welding distortion, welding sequence, gap, misalignment.