論　文　の　要　旨

固有ひずみ理論と弾性有限要素法を用いた船体構造の溶接プロセスの改善に関する研究
（Study on Improvement of Welding Process of Ship Grillage Structure using Elastic Finite Element Method with Inherent Strain Theory）

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The design concept of most merchant ships and offshore structures focuses on economic and safe sailing and building them with the reduction of the overall weight by incorporating lighter and thinner steel structures, which can reduce the fuel consumption .Thus, the improvement in accuracy management of products is one of the most crucial factors for heavy building industries to meet the trend of consumers. It is practically impossible to completely constrain welding distortion; however, with the accurate estimation and effective assembly process, it could be reduced as much as possible. The main factor that causes welding distortion is local shrinkage, as illustrated in Figure 1 (longitudinal shrinkage, transverse shrinkage, and angular distortion), which is mainly caused by the rapid change in welding temperature from heating to cooling along the welding line and is also regarded as an inherent deformation. In the study, elastic Finite Element Method (FEM) using inherent strain theory was introduced to numerically validate proposed methods reducing welding displacements.

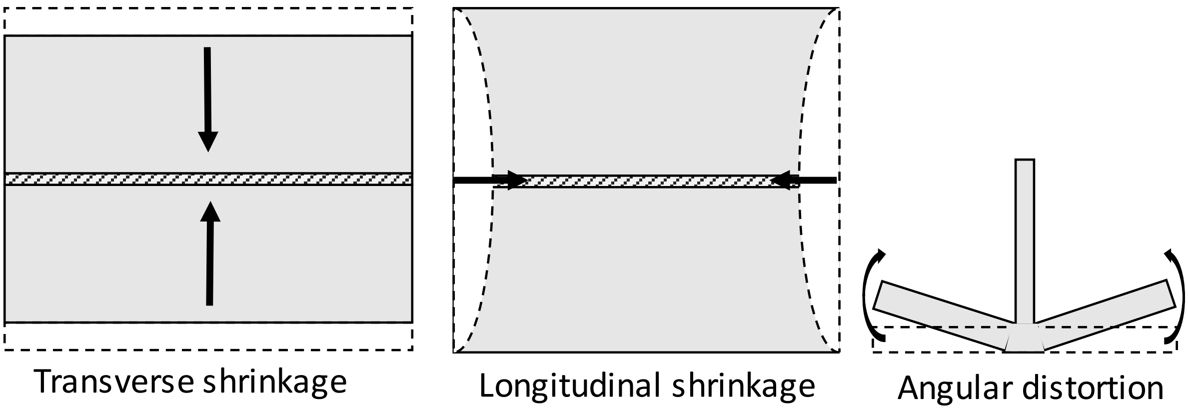


Figure 1 Classification of welding distortion

The optimization of the assembly sequence to obtain the lowest deformation for huge steel structures, such as ships and offshore structures, is crucial. The objective of the first study is to introduce an efficient method to systemically determine the optimal welding sequence for the lowest deformation of a general ship side panel, which is widely employed to design vessels and offshore structures. In this study, numerical simulation with a finite element method based on the inherent strain, interface element, and multipoint constraint function (MPC) is used as a precise computational approach to analyze the welding deformation. The employed numerical simulation obviously validated proposed systemic method to efficiently decide the optimal welding sequence for minimizing welding displacement.

Secondly, the optimal simultaneous welding to minimize welding deformation of a general ship grillage structure was studied. Most previous studies on the optimized welding sequence for the reducing welding displacements have focused on one welding line at each order. However, in heavy industries, several welders or robotic welding machines generally work together to efficiently spend work time. Herein, Inherent strain theory is introduced to calculate the complex mechanical behavior during a welding operation using the elastic FEM. MPC and the interface element theory are employed to consider the relationship of the different welded parts. The impact of the optimal simultaneous welding in the sequence on the reduction of welding displacement is validated by using proposed numerical method in the study.

The third study validated the effect of the gravity force on the numerical prediction of the optimal welding sequence of the general ship grillage structure with the introduction of the new boundary condition in which the structure is placed over rails. Additionally, the direction of the gravity force of welded structures could be changed at the final assembly process according to a production plan. The effect of the gravitational orientation on the final welding displacements was also investigated herein. The elastic FEM using inherent strain, interface element and MPC was introduced to analyze the welding deformation. This study validated the influence of the gravity force on the numerical prediction of welding displacements of the general ship grillage structure.

Lastly, the fourth study proposed the systematic method for positioning clamps and strongbacks based on their influence on welding displacements. To control welding displacements, mitigation methods such as clamps and strongbacks are widely used in heavy industries. It can be easily concluded that providing for as many clamps and strongbacks as feasible on welded structures to minimize welding displacements is common knowledge, but this may not always be feasible due to restrictive work environments as well as cost factors and interference from other portions of the structure. Currently there is not a distinct system to efficiently position clamps and strongbacks at welded structures. Based on understanding of how clamps and strongbacks effect on the reduction of welding displacements, a systematic method to efficiently position them will enable improvements to the welding process. In the study, several cases which have differently positioned clamps and strongbacks at welded structures were numerically simulated by the elastic FEM using inherent strain theory to investigate the influence of clamps and strongbacks on the reduction of welding distortions. According to the simulation data, the applicable systematic method for efficiently positioning clamps and strongbacks for minimizing welding deformations is proposed herein.