FE Computation on Accuracy Fabrication of Ship and Offshore Structure Based on Processing Mechanics

Hong ZHOU · Jiangchao WANG

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Hong ZHOU
School of Naval Arcitecture and Ocean Engineering
Jiangsu University of Science and Technology
Zhenjiang, Jiangsu, China

Jiangchao WANG
School of Naval Arcitecture and Ocean Engineering
Huazhong University of Science and Technology
Wuhan, Hubei, China

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Preface

The construction of ship and offshore structures is a complicated process involving a series of thermal processing technologies, such as flame welding, plate bending with induction heating, and welding. The dimensional accuracy of ship and offshore structures, as well as their fabrication cost and schedule, can be significantly influenced by fabrication deformations caused by the elastic-plastic mechanical response during individual thermal processing. Two fabrication deformations typically occur, namely, in-plane shrinkage and out-of-plane bending deformation.

Owing to complex physical behaviors resulting from individual thermal processing, the engineering solution to these mechanical responses during the construction of ship and offshore structures is generally determined by experimental measurements and fabrication experience. With the fast increase of labor cost and requirement of production efficiency, it is of great significance to solve such mechanical problems holistically with scientific investigation through advanced computational approaches. This will enhance the technological level and construction quality of ship and offshore structures.

To address actual engineering problems during the construction of ship and offshore structures, advanced computational approaches such as thermal elastic-plastic and elastic finite element (FE) computations were developed and employed to examine physical behaviors. In addition, the generation mechanism of the mechanical response was also clarified. Thus, computational analysis was carried out not only for fabrication deformation prediction due to thermal processing, but also for reduction of deformation tolerance and guarantee of fabrication accuracy. Therefore, appropriate construction processing based on theoretical analysis and computational modeling is desired and provided for actual engineering applications to improve the construction quality.

Focused on processing mechanics, the target of this monograph was to examine various typical thermal processing approaches employed during the construction of ship and offshore structures. The book is organized as follows:

Chapter 1 introduces the background of fabrication processing during the construction of ship and offshore structures. It also summarizes the progress of fabrication processing mechanics for thermal procedures, such as flame cutting, plate bending with induction heating, and welding.

Chapter 2 systematically summarizes the fundamental theory and method of FE computation for processing mechanics investigation, including non-linear thermal elastic-plastic FE computation with advanced computational techniques, welding inherent deformation evaluation, elastic FE computation with inherent strain/deformation as mechanical loading, interface element for fitting procedure consideration, and welding induced buckling.

Chapter 3 introduces a heating source model that is applicable to the cutting and emulation of high-strength thick plates. Then, the thermal-physical characteristic parameters of the NV E690 leg plate are calculated by JMATPRO and revised according to the theory of metallographic. The optimal values of the parameters, i.e., heating source, cutting speed, and radius of the heating source model, that ensure that the gear plates are cut through with no edge collapses during cutting are calculated. The optimized process parameters can be used to study the distribution of residual stress in the gear plates during cutting, thereby providing theoretical guideline for improving the construction technology of offshore platform legs.

Chapter 4 presents high-frequency induction heating for plate bending with double curvature. Several experiments were conducted, and out-of-plane bending deformations were measured by three-coordinate measuring devices in advance. Thermal elastic-plastic FE computations were carried out to represent the mechanical response and predict out-of-plane bending deformation. Then, the bending moment was evaluated from elastic FE computation. Good agreement was eventually observed between the computed results and the corresponding measurements.

Chapter 5 focuses on the out-of-plane welding distortion of fillet welded joints and stiffened welded structures with experimental measurements and FE computations. Fillet welded joint considered as typical welding during the construction of ship and offshore structures was practiced to measure the welding distortion, while thermal elastic-plastic FE analysis was carried out for computational accuracy validation. Moreover, stiffened welded structure deemed as the typical ship panel with fillet welding was experimentally and numerically investigated. To improve the computational efficiency, elastic FE computation was carried out with welding inherent deformation as mechanical loading. The computed results were in good agreement with measurement data, although with loss of computational accuracy.

Chapter 6 examines the out-of-plane welding distortion during the fabrication of ship structures. Hatch coaming structure fabrication of bulk-cargo ship was first examined. Then, out-of-plane welding distortion of fillet welding was measured and predicted with thermal elastic-plastic FE computation. Finally, welding inherent deformation was evaluated from elastic FE analysis. The fabrication accuracy could be enhanced by considering an improved manufacturing processing. Lightweight fabrication of ship panel was then examined with combined thermal elastic-plastic FE computation for typical welded joints and elastic FE computation for the actual ship panels. Welding induced buckling was investigated through elastic FE computation by employing the large deformation theory. Welding inherent in-plane shrinkage was the dominant cause that determined the buckling modes. Bending deformation was considered a disturbance that triggered buckling behavior when the critical buckling condition was reached. Mitigation practice with intermittent welding procedure was theoretically and numerically conducted and examined for welding-induced buckling prevention. Major welded structures of container ships such as watertight transverse bulkhead and torsional box structures were then examined for accuracy fabrication. Out-of-plane welding distortion was measured by total statin during actual fabrication. The computed results of elastic FE analysis based on a welding inherent deformation database and the measurements of welding distortion showed good agreement. For the reduction of out-of-plane welding distortion, the welding sequence influence was computationally considered for accurate fabrication of the watertight transverse bulkhead structure. Optimization of the welded joint design was also examined for accurate fabrication of the torsional box structure.

Chapter 7 investigates the fabrication accuracy of offshore structures. Fast thermal elastic-plastic FE analysis with ISM and parallel computation was carried out to examine the mechanical response and welding distortion during fabrication of a cylindrical leg structure. Bead-on-plate welding was conducted to offset the dimensional tolerance due to the fabrication welding process. Elastic FE analysis with welding inherent deformation was also applied to predict the welding distortion of a cantilever beam structure, while practical techniques with opposite deformation, welding sequence modification, and fixture constrain were numerically examined to ensure fabrication accuracy.

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Zhenjiang, China Hong ZHOU
Wuhan, China Jiangchao WANG

Contents