

Experimental and Numerical Investigation of Distortion in Thick-Section GTAW Welds

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Abstract

Gas Tungsten Arc Welding (GTAW) has long been recognized for producing superior weld quality in applications where precision and reliability are paramount like nuclear, defense and aerospace sector. In the present work, welding was carried out on a 65 mm thick plate using a full penetration double-U groove configuration by GTAW. Parameter optimization, welding sequence, number of weld pass and clamping methodology was developed and validated to ensure the penetration and fusion across the joint thickness. A comprehensive series of destructive and non-destructive examinations, including radiographic testing, tensile tests, and bend tests were performed to confirm the structural integrity and compliance with relevant codes and standards.

In parallel, welding simulation was employed to model the distortion behaviour of the thick-section weldment. The predicted distortion patterns from the simulation exhibited close agreement with the experimentally measured values, thereby validating the robustness of the numerical approach. The integration of experimental qualification and computational modelling will enhance the understanding of weld behaviour and also provided a predictive tool to optimize process parameters and minimize trial-and-error iterations.

This study is applicable to the manufacturing of the Diagnostic Neutral Beam (DNB) Vessel, which is a 9 m long, 5 m high, and 5 m wide rectangular vacuum enclosure that houses the beam-line components of the ITER neutral beam system. The DNB vessel consists of (1) a large main shell with appropriately sized stiffeners and a 200-mm-thick end flange welded along its periphery, and (2) a detachable top lid, 9 m × 5 m in size and 115 mm thick, designed to allow movement of internal components during installation and maintenance. Fabrication of the DNB vessel requires extensive thick-section welding, strict control of distortion, and assurance of dimensional stability to maintain vacuum integrity and alignment of internal components. The ability to predict and control weld-induced distortion will directly support the assembly tolerances, flange alignment, port positioning, vacuum integrity of DNB vessel and provides a significant support for the successful fabrication of the DNB vessel.

The findings of this study demonstrate that the combination of weld qualification and validated simulation offers a reliable methodology for producing high-quality welds in thick-section components. These results are also having significant relevance to industries such as nuclear, and heavy fabrication, where structural integrity and dimensional accuracy are of critical importance.

Keywords: GTAW, thick-section welding, double-U groove, weld qualification, welding simulation, distortion analysis, residual stresses