Abstract

This thesis delves into the crucial aspect of welding Incoloy 800HT and P91 steel, fundamental materials in advanced ultra-supercritical (AUSC) reactors aimed at enhancing power generation efficiency while minimizing CO_2 emissions. The study primarily focuses on dissimilar metal welding (DMW) to unite these materials and addresses the complex challenges associated with DMW, such as phase transformations, creep-related issues, and microstructural heterogeneity. Various welding techniques, including gas tungsten arc welding (GTAW), electron beam welding (EBW), shielded metal arc welding (SMAW), and activated tungsten inert gas (A-TIG) welding, are explored to determine their efficacy in creating robust and durable joints.

The investigation revolves around understanding the microstructural alterations, mechanical behaviors, and optimal welding parameters necessary to refine the welding process. Advanced characterization tools viz., field emission scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (FESEM/EDS), electron probe micro-analysis (EPMA), electron backscatter diffraction microscopy (EBSD), transmission electron microscopy (TEM), and X-ray diffraction (XRD) are utilized to scrutinize the welds' microstructural features in detail. Mechanical evaluations encompass room temperature tensile testing, high-temperature tensile testing (up to 650 °C), Charpy impact toughness testing, fractography, residual stress measurements (using deep hole drill method), and microhardness measurements. These tests are pivotal in correlating microstructural transformations with the mechanical integrity of the DMW.

Furthermore, the study investigates post-weld heat treatment (PWHT) as a potential solution to mitigate heterogeneous microstructures in the P91 heat-affected zone (HAZ) resulting from the DMW process. The thesis emphasizes the importance of achieving joint integrity and performance, particularly in high-temperature operating conditions typical of AUSC reactors. The findings underscore the superiority of A-TIG welding over conventional methods, exhibiting enhanced weld quality and superior mechanical properties. A-TIG welding is recommended as the preferred approach for joining Incoloy 800HT and P91 steel due to its ability to produce fine-grained textures, evenly distributed precipitates, improved mechanical strength, and reduced risk of microstructural degradation.

In summary, this research contributes significantly to the understanding of DMW challenges, weld quality enhancement, and performance optimization for critical applications in AUSC reactor technology, ensuring safe and efficient power generation processes.

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