Abstract

Dissimilar metal welds are prevalent in marine and offshore structures, posing risks of substantial financial, material losses, and potential threats to human safety in case of joint failures. Dissimilar metal welding involves scientific and technical challenges and is commonly employed in the offshore construction, oil and gas, marine, and petrochemical sectors. Erosion and corrosion in marine environments can cause significant damage to offshore and marine structures, prompting cost-effective solutions such as the replacement of critical components. Enhancing the structural integrity of marine and offshore structures requires the use of dissimilar metal welding to join steels and alloys with different mechanical and chemical properties. However, challenges such as carbon migration, unmixed zones, heterogeneity, cracking, and intermetallic phases must be carefully assessed before implementation in industrial applications. The primary focus of this study is on dissimilar welds involving high-corrosion-resistant super duplex stainless steel (sDSS 2507) paired with nitronic steel (N50), nickel-based superalloy (IN-625), and pipeline steel (X-70). The dual-phase sDSS 2507, with balanced austenite and ferrite phases, is known for excellent mechanical properties and corrosion resistance. Nitronic steel is widely used in subsea oil and gas tubes and couplers due to its superior tensile strength, corrosion, and galling resistance. Nickel-based superalloy (IN-625) finds applications in marine, aerospace, and petrochemical sectors owing to its high tensile, yield, and creep strength, as well as corrosion resistance in harsh environments. Pipeline steel (X-70) is employed in deep-water industries for tubing/tubing-coupler assemblies, subsea manifold piping systems, marine splash zones for drilling risers, and branching/sub-branching in oil-gas distribution pipelines, driven by economic considerations and its exceptional tensile and impact strength.

A multi-pass gas tungsten arc welding process will be employed to fabricate dissimilar weld joints (DWJs) using different overmatching fillers, heat input, and welding parameters, aiming to highlight the structure-property relationship and ensure structural integrity. The study investigates different facets of the welds of these dissimilar joints, including microstructure evolution, mechanical characterization, residual stress measurement, wear resistance, and corrosion behavior. Electron probe microanalysis will reveal the weld interface alloying element gradient. The investigation extends to assess the impact of heat input and filler metal composition on the residual stress, wear, and corrosion behaviors of these dissimilar joints. The deep hole drilling technique is employed to measure through-thickness residual stresses in the weld zone, mitigating the risk of catastrophic marine component failure. Sliding wear behavior is investigated under dry conditions to replicate real-world service environments for sDSS 2507/N50 DWJs, while slurry pot erosion behavior is investigated at varying slurry concentrations to simulate actual service conditions for sDSS 2507/IN-625 DWJs and sDSS 2507/X-70 DWJs. The joints are examined for corrosion resistance using immersion and electrochemical corrosion methods. This thesis aims to improve the structural integrity of marine and offshore structures in the transportation and oil and gas exploration sectors by providing insights into material selection, optimal welding parameters, heat input for weld fabrication, and design optimization.