Abstract

The structure and components of pipeline steel suffer a significant loss of properties due to the corrosive marine environment. It is joined with high corrosion-resistant alloys in critical zones using different welding processes. The joint of primary interest in this study is a dissimilar weld between pipeline steel API X70 and high corrosion resistant alloy super duplex stainless steel SDSS 2507. The joint find application in the marine splash zone for drilling riser and branching/sub branching sections of oil-gas distribution pipeline network.

A methodology has been proposed to develop shielded metal arc welding electrodes for fabricating the said joint. The developed coating for shielded metal welding electrodes in the laboratory utilizes CaO, CaF_2, TiO_2, and SiO_2 as major constituents. The coating composition has been characterized for physicochemical, thermophysical, wettability and structural properties to assess their suitability. Regression analysis was used to establish the influence of individual coating constituents and their interactions on properties. A mining waste red ochre from iron ore tailings after experimental characterization has been used in an as-is state as a constituent of electrode coating. The addition of mining waste has been proposed as an alternative to the commercial ferro-alloy powders, thereby making the process environmentally sustainable. The developed coating compositions were extruded on austenitic stainless steel 309L grade filler wire to fabricate shielded metal arc welding electrodes. The electrodes were then used to apply a multi-pass bead on the plate, which was examined qualitatively and quantitatively. The two most suitable coating compositions and commercial grade 309L electrodes have been used to fabricate the dissimilar weld from SMAW process. Mechanical and metallurgical characterization of the welds was done to compare the laboratory-developed electrodes' performance and assess their suitability.

A dissimilar weld between API X70/SDSS 2507 steels was also fabricated using gas tungsten arc welding (GTAW) process using two candidate fillers: (i) austenitic stainless steel (ASS) 309L and (ii) super duplex stainless steel (SDSS) 2594. The weld made with ASS 309L filler has skeletal morphology ferrite precipitated in an austenite matrix. In contrast, the super duplex filler has the precipitation of reformed austenite. The welds were examined for mechanical, microstructural, and corrosion behavior. Elemental analysis shows a significant gradient of alloying elements (Cr, Ni, Si, Mo) at the X70/weld interface. ThermoCalc has been used for Scheil's solidification calculations and equilibrium phase estimation.

An attempt has also been made to study the effect of heat treatment on wear and corrosion properties of super duplex stainless steel. The wear properties have been studied in the dry and wet medium matching the actual service conditions. Cyclic corrosion study was performed to compare the corrosion resistance of pipeline steel with super duplex stainless steel in an as-received and heat treated condition.

The work carried out and results reported in this thesis are of direct application to the offshore oil-gas exploration and transportation sectors.