Abstract

Mechanistic understanding of the effect of surface working operations on the electrochemical, oxidation and stress corrosion cracking (SCC) behavior of 304L austenitic stainless steel at ambient and at high temperature (300 °C) has been developed in this study. The effect of residual stresses induced by various fabrication techniques like tube straightening, roll-expansion, machining and grinding operations on the SCC susceptibility of stainless steel has also been studied. Solution annealed stainless steel grade 304 L was subjected to three different conditions: a) machining, b) grinding and c) cold rolling. This is followed by detailed microstructural characterization using optical, scanning electron microscopy (SEM), atomic force microscopy (AFM) and confirmation of phase transformations by X-ray diffraction (XRD) and electron back scattered diffraction (EBSD) studies. SCC susceptibility was evaluated by exposing constant strain samples made from each of the three conditions in 1 M HCl solution at room temperature (26 °C). Effect of residual stresses on susceptibility to chloride induced SCC was studied as per ASTM G36. The electrochemical nature of the as worked surfaces was studied at ambient temperature by potentiodynamic polarization, electrochemical impedance spectroscopy (EIS) and scanning electrochemical microscopy (SECM). Oxidation behavior of the material subjected to different surface finishing operations was followed in-situ by contact electric resistance (CER) and EIS measurements using controlled distance electrochemistry (CDE) technique in deaerated high purity water (specific conductivity < 0.1 µScm⁻¹) at 300°C and 10 MPa in an autoclave connected to a recirculation loop system. The resultant oxide layer produced after 360 h exposure was characterized for a) elemental analyses by glow discharge optical emission spectroscopy (GDOES) and b) morphology by SEM. Results show that surface working operations drastically increased the SCC susceptibility of 304L stainless steel. This was shown to occur due to the formation of a work hardened surface layer constituted of sub micron grain size, martensite phase and high density of slip bands. The high temperature and high pressure studies on the oxidation behavior of surfaces in machined, ground and solution annealed conditions showed that surface working brings about major changes in the oxidation behavior of stainless steel surfaces and the nature of the oxide film formed. Electrochemical polarization studies of the surfaces under different conditions revealed a) early onset of transpassivity and b) higher passive current densities as a result of surface working of 304L stainless steel. The oxide formed in case of machined and ground conditions is shown to have higher specific resistivity and richer in chromium content. The thickness of the oxide film formed after similar exposure period is the highest for solution annealed condition followed by machined and ground conditions. Presence of an additional ionic transport process during oxidation has also been identified for ground condition at the metal/oxide interface.