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Characterisation of Austenitic Stainless Steel Pipe Weld Joints Using XRD and in situ Metallography Techniques

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Abstract

Austenitic stainless steel pipes find extensive applications in many engineering industries and power plants due to their excellent mechanical properties and corrosion resistance. Intergranular corrosion and intergranular stress corrosion cracking are the common mode of failures of stainless steel welds in service. Characterisation of TIG welded austenitic stainless steel pipe joint is essential and important to avoid failures by IGC and IGSCC. Hence a study was undertaken to determine the microstructural condition at the heat-affected zones (HAZ) of stainless steel pipe weld joints using nondestructive insitu metallography technique. The residual stresses present in the pipe weld joints were determined by X- ray diffraction technique (XRD). This paper highlights the details and results of the study made on TIG welded austenitic stainless steel pipe joints. Seamless pipes of AISI type 304 stainless steel of different diameters (26.5, 48.0 and 60.0 mm outer diameter) and same wall thickness of 3.0 mm were used for making the pipe welded joints. Single 'V' weld groove configuration was employed and TIG welding process with stainless steel filler wires of 308 grade were used. X- ray diffraction studies were carried out using a portable X-ray stress analyser. Multiple $Sin^2 \psi$ method was employed. Cr K_β radiation was used in the XRD analysis for the stainless steel tubes. The axial residual stresses profiles of the welded joints of stainless steel pipes having different diameters indicated that maximum tensile residual stress is present at the weld centre and the values for the three pipes are around 215, 185 and 167 MPa respectively. The maximum compressive residual stresses were noticed at the heat affected zones (HAZ) of welded joints and the values are around 200, 187 and 148 MPa respectively. The residual stress profiles for all the pipes having different outer diameters are similar in nature. All the residual stress profiles showed the same characteristic bell shaped stress distribution as a result of weld metal shrinkage. The stresses are usually tensile at the weld metal and in the HAZ up to around 10 mm from the weld centre line, and beyond which the stress are compressive. The smallest diameter pipe welded joint has the highest axial tensile residual stress and the largest diameter pipe welded joint has lowest axial tensile stress. For stainless steel pipes having same wall thickness, the residual stress pattern becomes broader as the outer diameter of the pipes is increased. The small diameter pipe might have received comparatively more localized heating during welding than higher diameter pipe and this might have led to higher axial tensile stress formation in the weld of small diameter pipes than the large diameter pipes. Insitu metallography is a NDT method, widely used to find out the microstructural condition of materials during pre-service as well as in-service inspection and hence it was used in this study. Insitu metallography was conducted at a few locations having weld metal, HAZ and the base metal regions. After grinding and polishing the selected locations, electrolytic etching was carried out with 10% Oxalic acid as electrolyte. Replication technique was used for recording the microstructural features in a thin film for further analysis at about 250X magnification. The microstructures were evaluated as per the ASTM A262 standard practice 'A'. The microstructures at different locations are 'Step structure' in nature (steps only between grains, no ditches at grain boundaries) indicating that the microstructure at the HAZs are not sensitised.