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Evaluation of Stress Corrosion Cracks in Inaccessible Lattice Tube Weld Using Ultrasonic Signal Analysis - A Case Study

A. S. Ramesh, C. Rajagopalan, R. Chellapandian, Hassan Sheik, P. Kalyanasundaram, Baldev Raj

Metallurgy and Materials Group
Indira Gandhi Centre for Atomic Research, Kalpakkam – 603 102

Abstract

Welding of austenitic stainless steels (grades ANSI 304 and 316) results in sensitized microstructure and residual tensile stress in the heat affected zone (HAZ) making this zone susceptible to Intergranular Stress Corrosion Cracking (IGSCC) in presence of a specific environment in the heat affected zone (HAZ). Cold deformation and forming, welding, heat treatment, machining and grinding introduce residual stresses in the material which is also significant in aiding the development of stress corrosion cracking in the specific environment. The bi junction weld between the lattice tube and the end shield of Calendria Side Tube Sheet (CSTS) of a pressurized heavy water reactor (PHWR) is a crucial and important joint. The lattice tube is around 1133 mm long with a maximum wall thickness of 27 mm. The CSTS is around 75 mm thick. This joint is a thickness reduction joint from a wall thickness of 27mm to 13 mm and it is welded at the inner side of the tube sheet by internal bore welding adjacent to the tube sheet (4 mm). The thickness reduction to facilitate the joint configuration resulted in complex geometry at the lattice tube side and as well as at the CSTS near the weld. As a large number of joints are made for the calendria vessel, accessibility to this weld for ultrasonic inspection is not feasible through the outside of the lattice tube, thus necessitating the inspection through the space available through the bore. The bore is made for the insertion of calendria tube and coolant tube. The complex configuration at the weld junction eliminates the use of contact angle beam examination from the ID side of the lattice tube as well as from the CSTS side. Since the weld joint is a crucial joint, the inspection and evaluation by ultrasonic testing is important from the structural integrity point of view. After the erection of the end shield at site, this joint would not be accessible for in service inspection (even for visual examination) as both the ends of the joint are closed by the end plug as well as by the rolled calendria tube and coolant tubes. Since a 129 m diameter bore is only available to inspect the circumferential butt joint which is around 186 mm in inner diameter and a wall thickness of around 13 mm. After the internal bore welding, inspection has to be performed through this bore access only. This situation warrants specialized ultrasonic test procedures for inspection and evaluation of these welds using remote handling gadgets. In order to develop the ultrasonic inspection procedure and to evaluate the stress corrosion cracking, two such mock up lattice tube joints were used for the study. Out of these two mock up blocks received, one was subjected to corrosion attack for generation of stress corrosion cracks in the weld and HAZ regions. For this, the mock up lattice tube was exposed to a boiling solution of 45% magnesium chloride solution at 423 K for 110 hours to develop stress corrosion cracks. The residual stresses present in the weld aided in generation of stress corrosion cracks. This paper highlights the in-house development of ultrasonic immersion test technique to inspect this bi-junction weld from the ID side. The developed procedure was used on mock up lattice tube having artificial notches (axial notches) of 3 mm in length, 150 in width and having 200 µm, 300 µm, 500 µm and 1 mm in depth placed on the outer surface on the HAZ for standardizing the ultrasonic test procedure. The stress corrosion cracks were evaluated using signal analysis methods thus validating the developed procedure for inspection of this weld joint. The results of advanced signal analysis revealed the detectability of the stress corrosion crack of around 200 µm in depth and having a length of around 3 mm.