The Application of High Energy X-Ray Diffraction to Engineering Components

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Arc welding processes involve the deposition of molten filler metal and the localised input of intense heat. The surrounding parent material and, in the case of multi-pass welds, previously deposited weld metal, undergo complex thermo-mechanical cycles involving elastic, plastic, creep and viscous deformation. These can result in the development of large residual stress gradients around the welded region, which can be particularly detrimental to the structural integrity of plant components operating at elevated temperatures. For this reason, it is important to have a proper knowledge of the residual stress distribution around the weld region to be able to predict the service life. However, due to the inherent complexity of this process the simulation of the generation of residual stresses during welding using Finite Element approaches is particularly challenging. Consequently such validation work is usually carried out on welded samples of a simplified geometry, i.e. welded plates. However, such samples are not representative of welds found in industrial plant components, where welds are carried out in more complex and highly constrained weld geometries. It is in such geometries that creep damage has been observed, leading to the initiation of reheat cracking.

Using high energy x-ray diffraction (HEXRD) facilities at ID15A (ESRF), measurements of residual stress were determined within a generic welded 35 mm thick austenitic stainless steel pipe containing a short repair weld before and after thermal soaking. Measurements were made through the thickness of the pipe wall in energy dispersive mode. Two solid-state germanium detectors were used, offset at a diffraction angle, 2θ, of 5˚, allowing high energy x-rays between 0-300 keV to be utilised. Incident slit sizes of 0.3 x 0.3 mm were used resulting in a gauge length of ~5 mm. Using this configuration full diffraction spectra were obtained for both hoop and axial components of residual strain after 300 seconds. Residual strains were determined by multi-peak fitting using software developed at Fame38 utilising Le Bail/Pawley Rietveld refinement.

The measurements within this work were essential in validating current weld simulation approaches as well developing existing creep damage models for the prediction of the initiation of reheat cracking. The reheat crack initiation test results will also provide important validation of the overall assessment approach applied to a highly constrained repair welds typically present in industrial power plant components.