Residual stresses in as-welded P91 steel pipe

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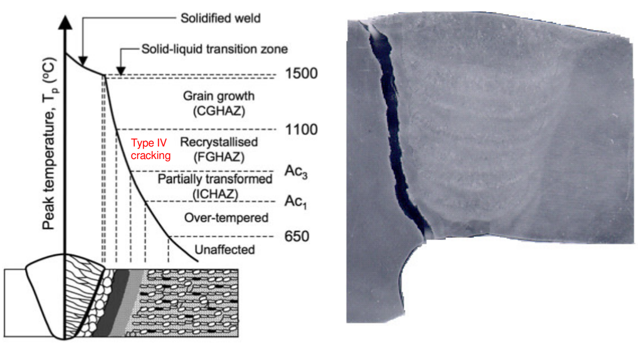
Introduction

UK power generation plants are following a worldwide trend in the electricity generating industry towards operating at higher temperatures, which leads to increases in efficiency in energy production and reductions in emissions of greenhouse gases. As part of this trend, the development and assessment of new steel-based materials, and suitable welding processes, is vital.

When compared to widely available steels such as P22(2.25Cr-1Mo), P91 steel offers superior creep (high temperature) strength. However, experience has shown that the weldments in this steel are particularly prone to premature creep failure, due to a localised form of cracking in the heat-affected zone (HAZ), which is referred to as Type IV cracking.

Type IV cracking

During welding, the base metal adjacent to the fusion zone experiences complex changes in temperature and stress, which result in a gradient in microstructure across the HAZ, whereby different zones are generated with each being defined by the peak temperature experienced. Type IV cracking occurs in the fine-grained and/or intercritical HAZ.



Temperature and microstructure distribution across the weld and example of Type IV cracking in P91 weldment

Project aim

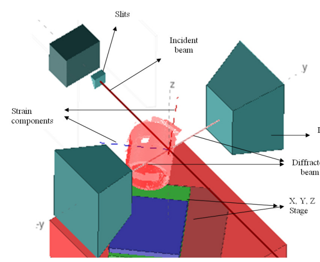
In this project, we aim to assess the significance of residual stresses and material constraint in determining type-IV-limited creep performance in welds.

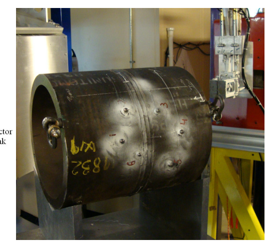
Welded test sample

The P91 pipe having an outer diameter of 324 mm and a 25.4 mm wall thickness was welded using TIG for the root runs and SAW for filling passes. A slot (60 mm x 60 mm) was machined into the component to facilitate neutron diffraction stress measurements.

Neutron diffraction

Neutron diffraction measurements were made using the ENGIN-X instrument at the ISIS facility (Rutherford Appleton Laboratory, UK). The instrument can be controlled by a unique virtual laboratory strain scanning software (SScanSS), which employs serial robotic kinematics to bring a specified sample point to the instrument focus, and aligns the specified sample direction(s) along the instrument scattering vector(s) [Nuc Inst Meth A571 (2007) 709].

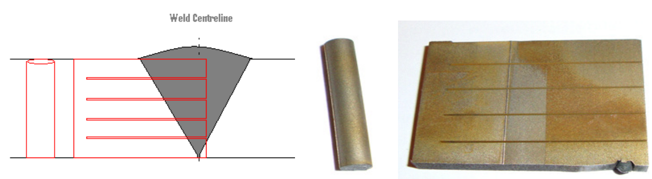




SSCANSS Simulation in progress **Experimental set-up of pipe at ENGIN-X**

Stress-free lattice parameter

Precipitation and dissolution of second phases during welding can bring about large changes in lattice spacing. Consequently, a comb specimen for the weld, and a pin for the parent metal, were extracted from the weldment and a series of strain-free lattice spacing (d_0) measurements were made in the weld metal, HAZ & parent metal.



Reference samples: pin and comb specimen to measure position dependent d_o

Results

High tensile residual stresses were found in the hoop direction with peak stresses of about 600 MPa located in the HAZ. There was also evidence of high hydrostatic tension in the same region which is known to facilitate growth and coalescence of creep cavities.