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VEQTER

Residual Stress Experts

VEQTER is an engineering company providing excellence in the measurement, analysis and management of residual stresses. We are world leaders in our field and offer expertise on any aspect related to residual stresses in engineering components and structures.

Case Study: Stainless Steel Pipe Girth Weld

Nickel base alloys are commonly used in nuclear reactor pressure vessels and piping for their corrosion resistance properties. However with aging plant worldwide and initial design lives being extended, the susceptibility to failure from mechanisms such as stress corrosion cracking is increasing. Therefore the structural integrity of nuclear components is being scrutinised ever further to prevent catastrophic failure and inhibit the current nuclear power renaissance. Accurate knowledge of the residual stresses present within a component is vital to the structural integrity analyses.

During the mid-2000's a national project was undertaken in Japan involving the regulator and manufacturers of nuclear power plants to accurately predict the residual stresses present within common nuclear reactor components using finite element analyses (FEA). Improvement and validation of the FEA models was provided by comparison with residual stress measurements carried out on full-scale mock-ups. This Case Study presents the DHD measurements carried out on a stainless steel pipe containing a nickel alloy girth weld with comparisons against modelling and measurement simulation results carried out by sub-contract.

To find out how VEQTER can help you, please contact us on +44 (0) 117 992 7970 or using experts@veqter.co.uk

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Component design:

The component investigated comprised of a stainless steel pipe (type 316) of 369mm outer diameter, 289mm inner diameter, 47mm wall thickness and 800mm length. The pipe was manufactured from two pipe sections butt-welded together in a "single-V" configuration using a nickel base alloy deposit metal (alloy 82). The weld was deposited using the TIG process with a total of 25 weld passes. A cross-sectional sketch of the weld is shown in Figure 2.

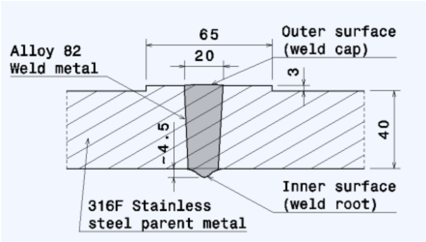

Fig. 1: Cross-section showing the weld

Measurement locations:

A total of 6 DHD measurements were carried out through the weld centreline. The measurement locations were such that the residual stresses in the pipe axial and hoop directions were measured together with the associated in-plane shear as functions of radial depth. Figure 2 shows a photograph of the pipe with a DHD machine set-up on the inner diameter surface.

Weld modelling:

The modelling of the residual stresses generated was undertaken using a 2D axi-symmetric finite element analysis containing 25 discrete weld beads. The sensitivity of the residual stresses generated with respect to the material hardening model used (i.e. kinematic, isotropic and mixed mode – kinematic/isotropic) was investigated.

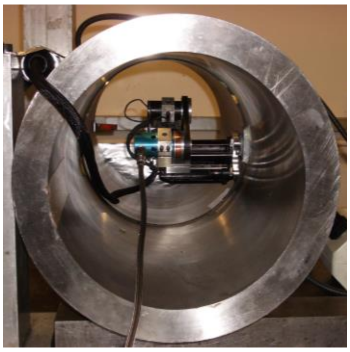

Fig. 2: DHD machine set-up on pipe inner diameter surface

Reference: Ogawa, K., et al., *"The Measurement and Modelling of Residual Stresses in a Stainless Steel Pipe Girth Weld"*, PVP 2008 – 61542

DHD simulation:

The residual stresses generated using the 2D axi-symmetric FEA model was mapped into a 3D mesh so that a virtual DHD measurement could be simulated to investigate the capabilities of the DHD technique in measuring such a residual stress field and optimise the measurement parameters.

Results and Discussion:

Figure 3 shows the hoop residual stresses measured at all 6 DHD locations. It can be seen that there is very good repeatability between all 6 measured distributions with the general trend of tensile residual stress near the outer weld surface with compression near the inner weld surface.

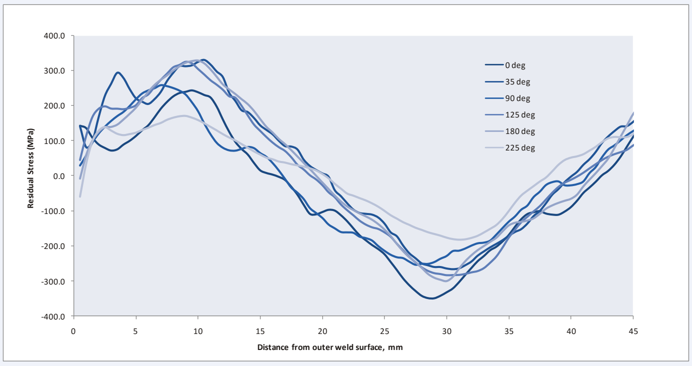

Fig. 3: Hoop residual stresses measured in the pipe using DHD

Figure 4 shows the mean of the DHD measurement results with upper and lower bounds compared with the mean of the weld modelling results and the virtual DHD simulation results.

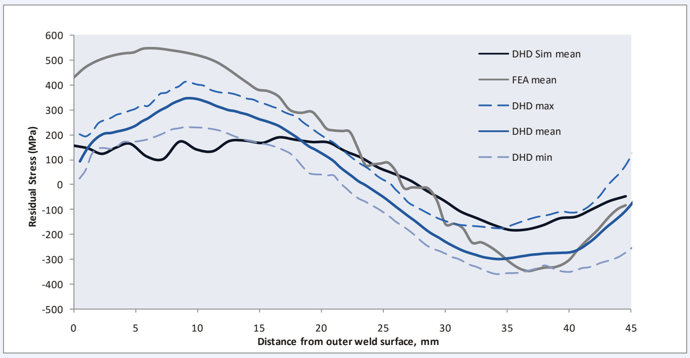

Fig. 4: Comparison of the hoop residual stresses measured and modelled

The FEA weld models showed similar trends for both hoop and axial residual stress components. Compared to the DHD measurements all of the hardening models predicted higher magnitude hoop stresses both in tension and compression. The axial stress predictions were of similar magnitude to the measured residual stresses, except at the inner weld surface. At this point the predicted stresses were once again higher in magnitude.