Experimental Report

26/03/2013

Proposal: **1-02-128** **Council:** 4/2012

Title: RESIDUAL STRESS FIELD INTRODUCED BY LOCALISED INDUCTION HEAT TREATMENT OF THICK WALLED COMPONENTS

This proposal is a new proposal

Researh Area: Engineering

Main proposer: **JAMES Malcolm Neil**

Experimental Team: JAMES Malcolm Neil
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Local Contact: PIRLING Thilo

Samples: 0.149C 0.30Si 0.57Mn 0.013P 0.015S 0.59Cr 0.475Mo 0.28V

Instrument	Req. Days	All. Days	From	To
SALSA	5	5	28/11/2012	03/12/2012

Abstract:

This proposal deals with an extension of the scientific understanding of residual stress fields surrounding heat treatment of the friction taper hydro-pillar process welds (FTHP). This technologically important development of friction stir welding potentially has application in areas such as life extension of steam power plant components. SALSA experiment 1-01-58 explored the residual stress re-distribution following FTHP welding in parent plate material, simulating, for example, repair of creep damaged plate. Post weld heat treatment (PWHT), by putting the whole sample in an oven, was shown to be very effective in reducing the residual stresses, but heat treating a whole component in service can be very time consuming. To speed up the PWHT step, a purpose made induction heating coil was identified as a possible process to temper the weldment microstructure to acceptable hardness levels. The potential for localised PWHT was confirmed by an in-depth study of heating parameters, conducted to establish the optimum heat penetration that can be achieved by variation of the measured surface temperature for certain heating times.

Experiment title:	**RESIDUAL STRESS FIELD INTRODUCED BY LOCALISED INDUCTION HEAT TREATMENT OF THICK-WALLED COMPONENTS**
Experiment No:	1-02-128
Proposers:	MN James
Team members:	DG Hattingh, P Doubell, M Newby
Local contact:	T Pirling
Experiment Date:	08:00 on 28/11/2012 to 08:00 on 03/12/2012
Beam line Details:	Wave length (λ) 1.644Å and 56 MW
Slit Size:	2.0 x 2.0 mm (Collimator setup were used)
Initial Sample Radiation:	0.88uSv/h

Aim of the Experiment

This experimental aim was to to assess the effectiveness of the application of in-situ induction heating for the PWHT of friction hydro pillar process (FHPP) welds applied on-site to thick walled steel steam pipes as used by power generation facilities.

Scientific Background:

Eskom and NMMU studied a selected number of potential applications for Friction Welding on stainless steel and creep resistant material with the principal aim of applying the techniques in-situ. These studies effectively resulted in a technique called Weldcore® that enables the removal of a cored sample from thick-walled components for evaluation of material condition. The resultant hole is then plugged using a taper stud by friction hydro pillar processing (FHPP). Figure 1 shows schematically the sequence proposed to remove a core sample, plug the hole and perform localised induction post weld heat treatment (PWHT) on the weld.

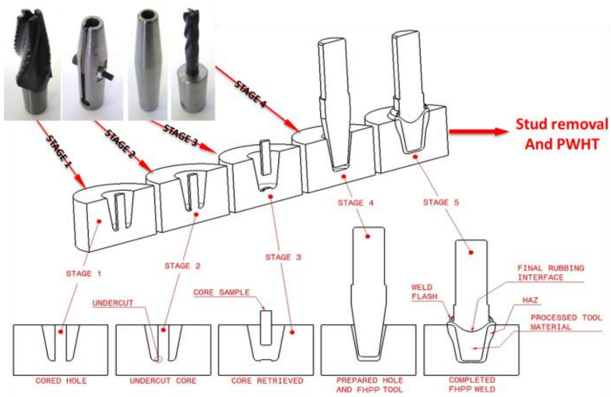

Figure 1: Weldcore Process

Experimental method and Results

Welds were performed on test pipe sections, where after they were be sectioned from the pipe for residual stress measurement. For comparison purposes a series of 3 welds were performed, namely: weld with no PWHT; a weld with in-situ induction heating PWHT process; and a weld which will have a PWHT process applied post sectioning in a furnace. All the welds were performed with a preheat temperature of approximately 200°C. For this experiment pipe manufactured from 14MoV6-3 steel was used, with the consumable friction welding tools being manufactured from 10CrMo9-10 steel.

Pipe Dimensions: $Ø_{OD}$ 366mm; wall thickness 42mm; length 750mm (2 off)

FHPP Tool: 15° Taper; 90mm Long; Ø20mm Tool Shank; Ø9mm Tool Face; 2mm base radius.

Welding Parameters: Tool Down force: 27kN; Tool Speed: 5000rpm; Tool Offset: 8mm; Forge Force: 27kN; Forging Time: 20sec

Samples:

The picture on the right show the degree of heat penetration thermocouple positions5 and 6 during induction heat treatment (inner pipe surface) while the schematic show the steps from welding the pipe to the removal of weld coupons and d_0 samples.

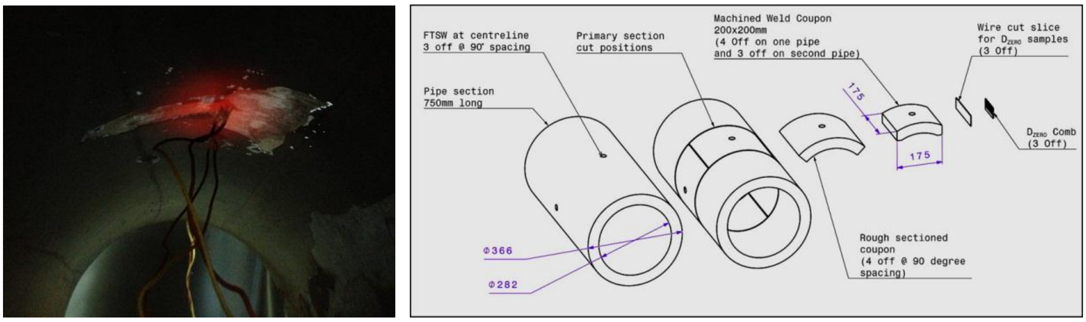

Figure 2: Degree of heat penetration during induction heat treatment (inner pipe surface) and schematic showing steps from welding to removal of weld coupons and d_0 samples.

Welded samples and their intended experimental application were:

Weld 1A: Tapered FHPP weld, no PWHT.
Weld 2A: Tapered FHPP weld, no PWHT (will be used for D_{ZERO} sample).
Weld 3A: Tapered FHPP weld, after sectioning weld coupon from pipe apply stress relieving PWHT by conventional furnace method.
Weld 4A: No weld, only apply stress relieving by in-situ induction heating procedure.
Weld 1B: Tapered FHPP weld, stress relieving by in-situ induction heating procedure (will be used for D_{ZERO} sample).
Weld 2B: Tapered FHPP weld, stress relieving by in-situ induction heating procedure.
Weld 3B: Tapered FHPP weld, after sectioning weld coupon from pipe apply stress relieving PWHT by conventional furnace method (will be used for d_0 sample).
Weld 4B: No process.

Results:
Due to time constrains it was decided to focus all attention on completing sample 2B with the PWHT done by induction heating. No measurements were done on sample 3A. d_0 measurements were done on: Samples 2A,1B and 1A.
The figures below show some of the data acquired along a traverse through the pipe sections. Peak stresses in the as-welded specimen occur at the edge of the HAZ and these are substantially relieved by localised PWHT. This data needs to be cross-correlated with microstructural and heat flow information to build up a complete picture of sources of the stress changes.

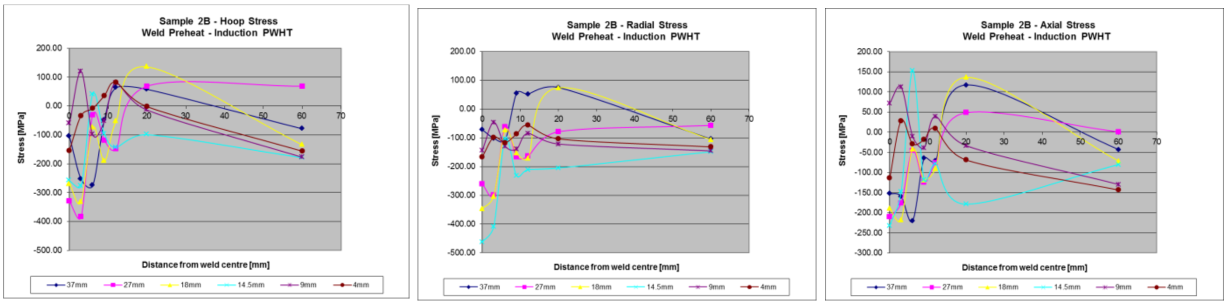

Figure 3: Calculated residual stresses for sample 2B.

Conclusions:
This work has high scientific and technological impact arising from the collaboration between researchers at Plymouth and Nelson Mandela Metropolitan universities and from the interface with ESKOM, a major operator of thermal power plant. The results further added to the understanding of how the prescribed weld repair and induction heat treatment processes influence the residual stress field of the FTSW repaired region. This knowledge will allow for the selecting of process parameters that optimise the residual stress field and mechanical properties. The data also offers valuable insights that advance understanding of residual stresses induced by FTSW as a repair technique and how these might be influenced by localised induction post-weld heat treatment. Finally this data places the modelling of residual stress distributions arising from repair processes for these high value components on a firmer footing.

Acknowledgements:
The experimental team thank Dr Thilo Pirling for assistance and support during the experiment.

References

[1] NICHOLAS, E.D., *Leading Edge - Friction Hydro Pillar Processing,* TWI, Connect, June 1992.
[2] THOMAS, W.M. & NICHOLAS, E.D., *Friction Takes the Plunge,* TWI, Connect, September 1993.
[3] BLAKESTONE, G.R., *Friction Welding on Live Pipelines,* Pipeline Technology, Volume 1, 1995.
[4] NICHOLAS, E. D., *Friction Hydro Pillar Processing, Advances in Welding Technology*, 11th Annual North American Welding Research Conference, 7-9 November 1995.