Experimental Report

16/06/2015

Proposal: 1-02-152 **Council:** 4/2014

Title: RESIDUAL STRESSES IN TURBINE BLADESHROUD TENONS AFTER LASER OR TIG WELD BUILD-UP

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: 0.12C 0.20Si 0.80Mn 11.70Cr 1.70Mo 2.70Ni 0.30v 0.04N

Instrument	Req. Days	All. Days	From	To
SALSA	5	5	24/11/2014	29/11/2014

Abstract:

The proposed work is technologically important to reducing operating costs and minimising outage time for turbines operating in the thermal energy generation industry which accounts for 74% of European electricity and 79% of world electricity. It also forms an integral part of a postgraduate University research project.

This experiment is relevant to the situation where a localised weld repair is performed on turbine blades, in particular after mechanical damage occurs on blade tips with shroud attachments, during maintenance activities. It will compare the magnitude and orientation of residual strain introduced into steam turbine blades when weld build-up is performed on the blade tip using different procedures. The residual stress distribution obtained with two different weld processes, laser beam welding (LBW) and tungsten inert gas (TIG) welding, and the effect of post-weld heat treatment (PWHT) will be evaluated.

EXPERIMENTAL REPORT ILL – November 2014

Experiment title: **RESIDUAL STRESSES IN TURBINE BLADE SHROUD TENONS AFTER LASER OR TIG WELD BUILD-UP**
Experiment No: 1-02-152
Proposers: MN James
Team members: D Asquith, DG Hattingh, P Doubell, M Newby
Local contact: T Pirling
Experiment Date: 08:00 on 24/11/2014 to 08:00 on 30/11/2014
Beam line Details: Wave length(λ) 1.644Å and 56. MWatt
Slit Size: 2.0 x 2.0 mm (Collimator setup was used)

Aim of the Experiment

The proposed work is technologically important to reducing operating costs and minimising outage time for turbines operating in the thermal energy generation industry which accounts for 74% of European electricity and 79% of world electricity. It also forms an integral part of a postgraduate University research project. This experiment was relevant to the situation where a localised weld repair is performed on turbine blades, in particular after mechanical damage occurs on blade tips with shroud attachments, during maintenance activities. It compared the magnitude and orientation of residual strain introduced into steam turbine blades when weld build-up is performed on the blade tip using different procedures. The residual stress distribution obtained with two different weld processes, laser beam welding (LBW) and tungsten inert gas (TIG) welding, and the effect of post-weld heat treatment (PWHT) was evaluated.

Scientific Background:

A tenon on a turbine blade is used to position and fix the tips of adjacent blades by shrouds. The function of the shrouds is to control in-service vibration response of the blades. A large number of turbine blades are scrapped during turbine maintenance as the tenons of blades need to be ground down to remove the blades for inspection or other maintenance activities. Typically a row of blades is replaced with an estimated cost for the blades of €60000. In some cases only singular blades have to be replaced but this still requires at least 5 to 10 blades to be scrapped. Removed blades cannot be used again as the remaining tenon stub is too short to be riveted a second time. Rebuilding tenons by welding is a viable option to repair the blades for further use. Figure 1 shows the blade tenon configuration and their function. The tenons are subjected to high centrifugal loading during normal operation. One limitation of a weld repair to be cognisant of is the possibility of introducing a blade material failure mechanism related to weld residual stresses. This is especially relevant to the material from which the vast majority of turbine blades in the power generation industry are manufactured from, typically12% chromium martensitic stainless steel. This material is known to be prone to failure mechanisms such as stress corrosion and hydrogen induced cracking when subjected to high localised stresses in a susceptible environment. It is therefore of great importance to know the level of weld residual stresses introduced by candidate weld repair processes as part of the risk assessment of the refurbishment technique.

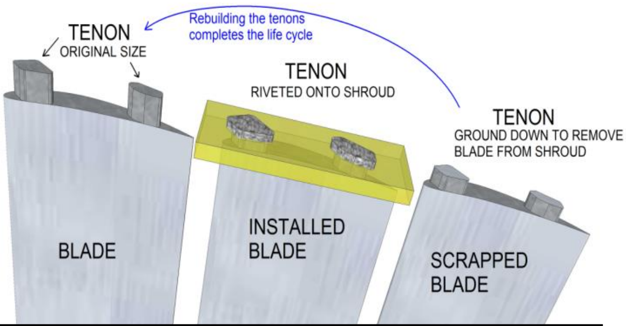


Figure 1 Steam Turbine blade tenon configuration

Experimental method and Results

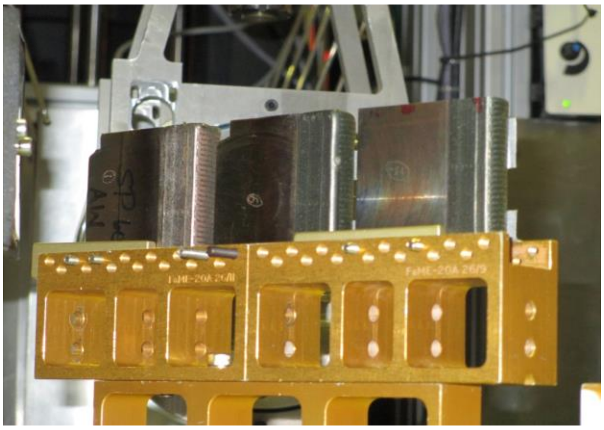
Welds were performed on test coupons were prepared by different weld procedures and heat treatment conditions as shown in Table.

NUMBER	WELD TYPE	CONDITION	
1	Laser weld. Martensitic consumable	As welded	
2	Laser weld. Martensitic consumable	PWHT	
3	Laser weld. Martensitic consumable	PWHT and machined	
4	TIG weld. Martensitic consumable	PWHT	
5	TIG weld. Martensitic consumable	As welded	
6	Laser weld. Inconel (austenitic) consumable	As welded	
7	Laser weld. Inconel (austenitic) consumable	PWHT	
8	Laser weld. Inconel (austenitic) consumable	PWHT and machined	Not tested

For comparison purposes a series of 8 welds were performed, however due to time constraints sample no:8 was not measured. All the welds were performed with a preheat temperature of approximately 200°C.

Sample Dimensions: wall thickness 15mm; length and width: 50mm x 50mm.

The picture on the left show the set-up pisition for three samples during scaning while the schematic on the left clarifies scan directions. Dzero samples in the form of EDM combs were also evaluated.



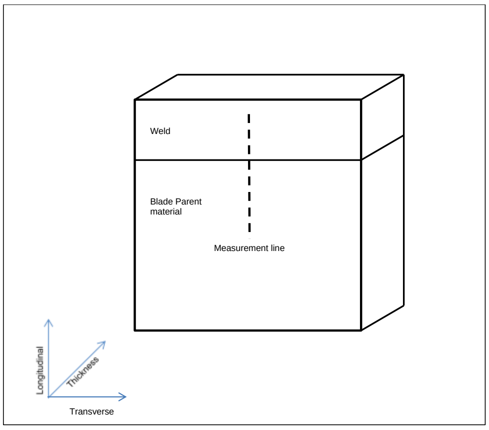


Figure 2: Sample sset-up on beam line with measuring direections for different scans.

Results:
Figures 3 show the calculated residual stresses for some of the process data acquired from a laser welded sample with no PWHT along the longitudinal, thickness and traverse directions. Peak stresses in the as-welded laser sample occur at the edge of the HAZ for both the longitudinal and traverse scans. These were substantially relieved by PWHT. This data needs to be cross-correlated with microstructural and weld interface properties to build up a complete picture of the stress changes and impact on the long-term performance of these components to identify the most suitable repair procedure.

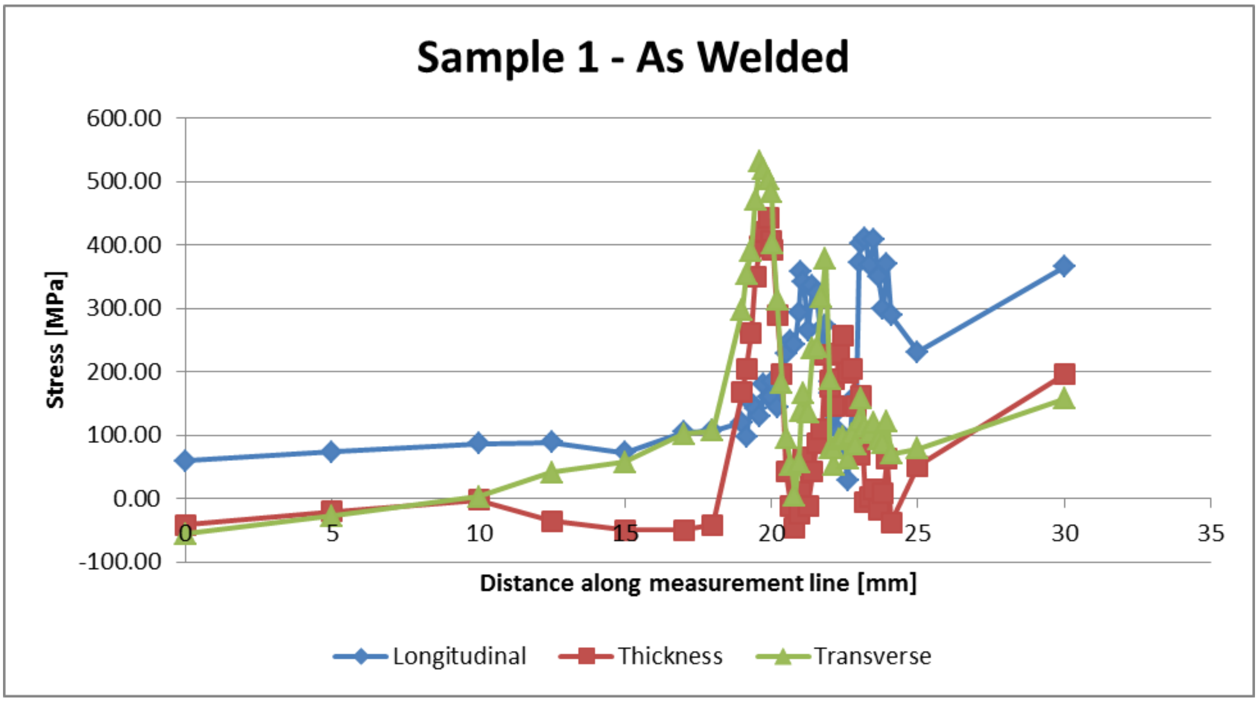


Figure 3: Calculated residual stresses for a Laser welded sample with no PWHT.

Conclusions:
This work has high scientific and technological impact arising from the collaboration between researchers at Plymouth, Sheffield Hallam, Nelson Mandela Metropolitan universities and from the interface with ESKOM, a major operator of thermal power plant industry who prepared the samples. This work enhances the

understanding of how typical weld repair processes affect the residual stress field of turbine blades at the weld repaired areas. This understanding allowed for identifying the most suitable repair procedure.

The data also offers valuable insights that advance understanding of residual stresses induced by laser compared to TIG repair technique and how these might be influenced by 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.

This knowledge will be of great importance from a blade reliability and structural integrity point of view as the residual stress data will help to validate FE model predictions of this process, and ultimately the work will lead to a better understanding of the risk involved with weld repairs on rotating components.

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

References

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