Case Studies

eNtsa Eskom projects

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Contents

Case Study I:
Novel Sampling Technique for Through Wall and Complex Geometry Creep Damage Assessment

Background

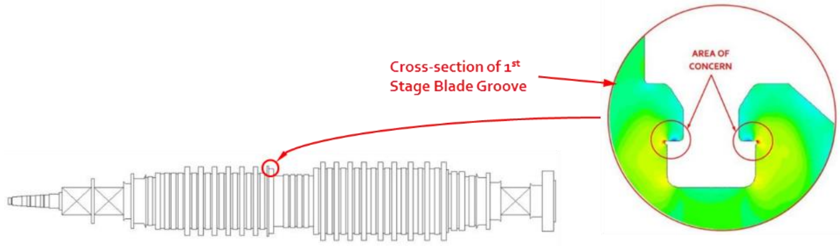
- The nominal design life of power generation plant is South Africa has been exceeded at a number of stations
- Decisions to safely operate the plant beyond the design life require careful assessment to allow accurate estimation of the remaining life of plant components
- In South Africa creep damage characterisation of HTP plant components is predominantly performed by the Replica technique where more than a 100 000 replicas are taken annually
- However, there are numerous areas of plant components which are not accessible for Replica inspection; due to complex geometry or limited access
- An example of a complex geometry issue occurred where the creep condition at the 1st stage blade attachment area of a HP turbine rotor required assessment

Turbine Rotor Creep Damage Problem

- An HP turbine rotor is approaching 300kh of base load operation where the original design life was 100kh
- The OEM of the turbine rotor advised that there may be a risk of failure of the HP 1st stage blade attachment area due to creep
- A high level creep assessment was conducted that advised that creep strain accumulation at the pullface areas of the blade attachment groove was high and that creep crack initiation could not be excluded
- The crack growth rate calculation showed high growth rates for 2mm deep cracks. As UT detection limits are in this order propagation life cannot be considered a viable management option
- A recommendation was given for an inspection to quantify the actual creep damage present
- As replicas cannot feasibly be taken inside the blade attachment groove, at the pullface, an alternative inspection technique was required

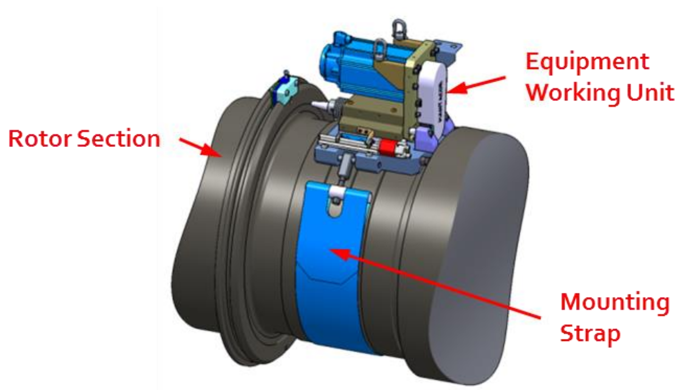
Area of Concern

- The area of concern was identified, as indicated below, at the corner radii of the blade attachment groove pull face
- The accumulated creep strain (300kh) at the blade groove ring was estimated by FEA in an attempt to determine whether the actual observed damage by Replicas at the outer surface can be used to estimate the damage at the inner surfaces
- However, the initial model used the minimum creep properties but to accurately calibrate the model the actual observed material damage at the corner radii is required
- As seen a Replica cannot feasibly be taken at the pull face, position, necessitating an alternative technique for inspection
- The extracted sample would therefore need to incorporate the corner radius area for analysis



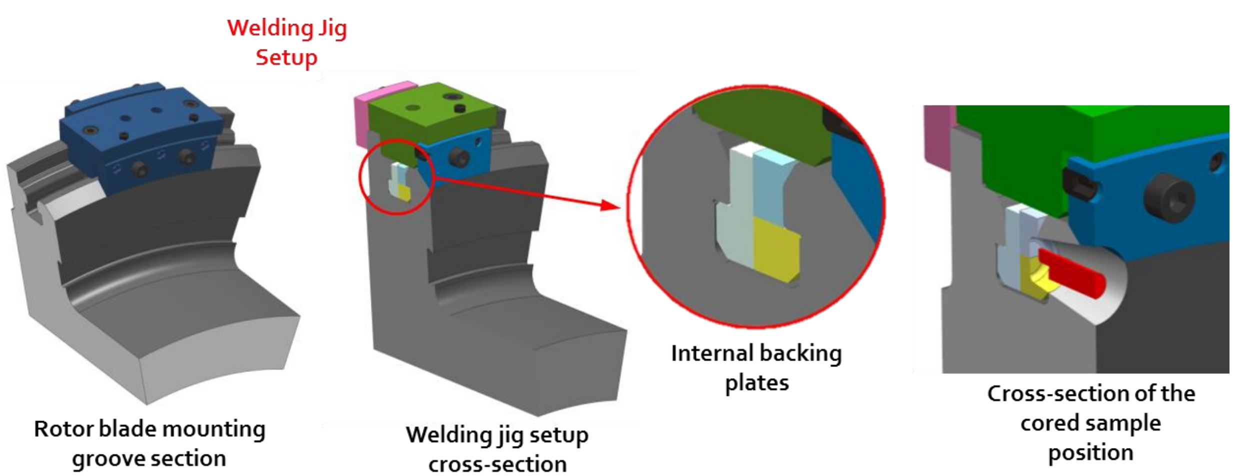
WeldCore® Sampling Procedure

- It is a solid state friction welding technique with inherent advantages over conventional arc welding; i.e. reduced heat input, small HAZ, reduced distortion, highly repeatable process
- The technique involves axially rotating a consumable tool, under an applied load, co-axially in a circular cavity, continuously generating and depositing plasticized layers of material
- A parallel sided hole-tool or a tapered hole-tool arrangement can be employed

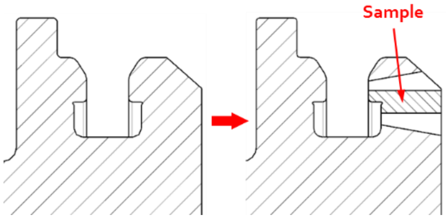


Turbine Rotor Application Development

- Customised equipment was designed to perform the core sample extraction as well as the repair FHPP weld and is a combination of servo electric and hydraulic drives
- The coring and welding processes are fully automated resulting in repeatable operations
- A system to provide backing support for the welding process was developed
- Backing jig is setup on the blade groove prior to core extraction and remains in position for the duration of WeldCore® procedure



Stage 1: Sample Extraction



Stage 2: Sample Extraction Site Repair (FHPP Weld)

- Preheating is required for the FHPP repair weld
- Equipment remains in position during the preheating of the weld site

Weld Setup

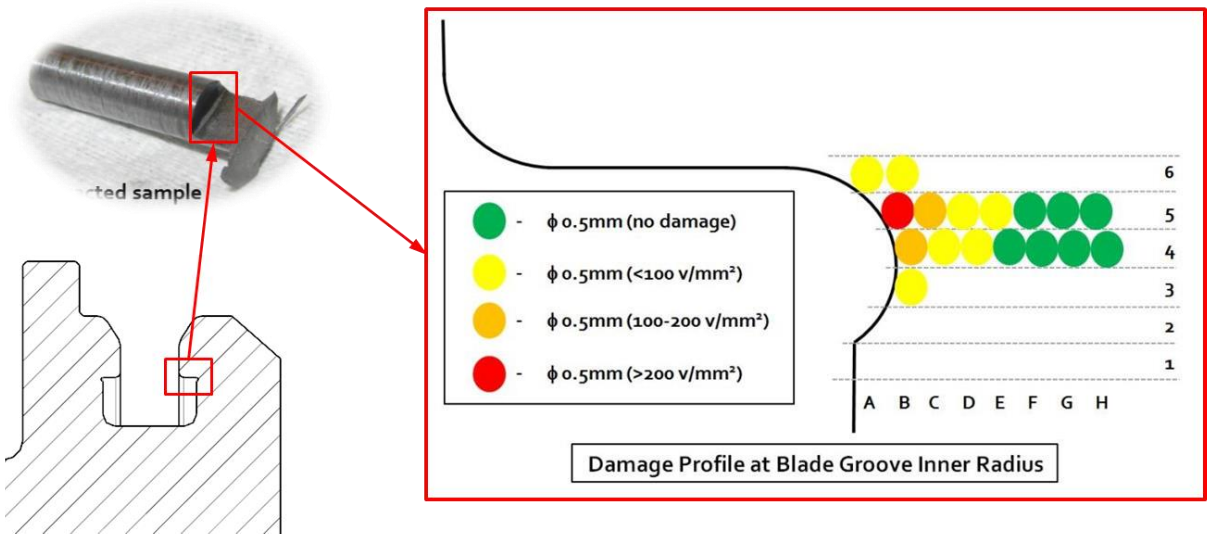
Welding

Completed Weld

Direct Creep Damage Valuation

Sample analysis

- Creep damage assessment was conducted on the extracted samples where typical void counts (voids per mm2) were seen, as depicted below



Conclusion

- The samples extracted provided crucial creep condition information to assist with rotor management decisions
- Direct measurement of creep damage can assist with calibration of FEA models and become an important methodology in the management of remnant life of high value engineering components - beyond specified design life
- The WeldCore® Sampling Procedure has to date been applied to four identical turbine rotors - three out of four rotors could be returned to service for a further 10 years after damage was machined away

This intervention conservatively deferred capital expenditure estimated at R500M + for Eskom

Case Study II:

Turbine Rotor Serration Grinding as Removal and Preventative Technique to Stress Corrosion Cracking (SCC)

Background

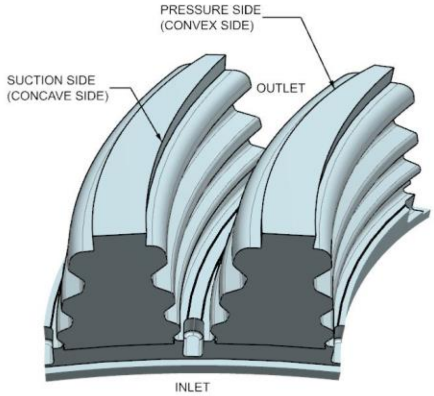
- Stress corrosion cracking was identified in Kendal LP rotors 1 through 4
- SCC propagation rates suggest that if not addressed it may require major repairs or rotor replacement in the long term.
- eNtsa has developed a technique to perform either preventative or crack removal serration grinding on all identified stages of the rotors
- Preventative grinding can be used to reset the SCC lifetime back to day zero

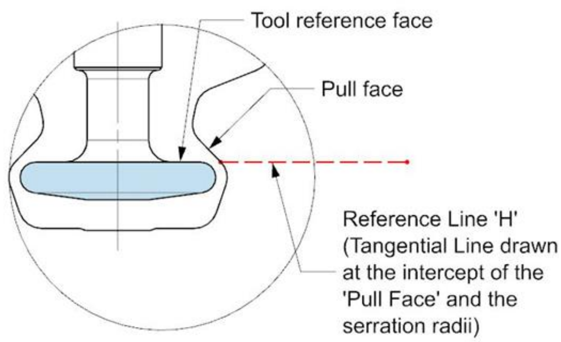
Turbine Rotor Stress Corrosion Cracking Problem

- It is assumed that SCC incubation period has expired on serrations not showing evidence of cracking during inspection and that cracking will commence once the rotor is re-commissioned.

Area of Concern

- Stage 5 displayed the most severe SCC on both suction and pressure side.
- Stress analysis indicated that offloading occurs to the middle and lower serrations, as cracks propagate through the top convex-side serration. Stress in the lower serrations increases due to offloading, but peak values remain lower than design top serration peak values for cracks or excavations.
- Complete loss of the top serration results in significant offloading to the bottom serrations. Nonetheless, only limited local areas of yielding are expected with the reference stress well below the yield strength.





Rotor Serration Grinding System

- eNtsa developed a system capable of grinding all the serrations on the steeples of stage 4, 5 and 6 up to a depth of 5mm on Kendal LP rotors.
- The system is also capable of removing individual cracks within the serrations or pockets along the length of the serration.

- During the application this was performed on all individual cracks, mainly evident in stage 5, all additional serrations where ground to depth of 0.5mm as preventative measure.

Top two images indicate the rotor and a team on site performing rotor serration grinding, the lower images are of the tools utilised and the completed grind

Images above: Before and after images of crack and serration post grinding

Conclusion

- Preventative machining was performed on LP1 and LP2 for Kendal ex unit 1.
- Preventative machining on LP1 and LP2 was complete within 27 site days, running two shifts a day, weekends included.
- This negated the requirement to possibly ship the rotors out of the country for machining purposes, shortening time out of service and significantly reducing cost.

All the serrations on both rotors were successfully machined over a period of twenty seven site days

Estimated deferred Capital Expenditure

R160M + for Eskom