Turbine & Generator Rotor Welding to Solve Reliability and Performance Issues

Tom Smith
President
T and A Consultants
April 16-17, 2013
Rotor Welding History

- Rotor welding was developed in the U.S. in the late 1970’s
- Turbomachinery OEM’s will try and sell new rotors to customers versus repair by welding
- Thousands of rotors have been salvaged by welding damaged shaft areas and turbine wheels
- Many millions of dollars have been saved by customers & insurance companies using weld repair over the cost of new equipment and the long lead times they require
Typical Shaft Damage

- Scored Bearing Journal
- Bond Failure of Coating
- Erosion, Rubbing
- Interstage Packing Rubs
Submerged Arc Shaft Welding (SAW)
Welded GT Rotor Bearing Journal & Seal Areas
Generator Shaft Weld Repair

Welding With Dual Heads for Greater Deposition
Generator Shaft Weld Repair
Cracked or Broken Shafts
Attachment of Stub Shaft Forging

The stub shaft & rotor are first joined by TIG welding and then the "V" area is filled with SAW.
Yes, this one was repair welded with a new stub shaft!!
Partial Rotor Replacement

Rotor Prep
Stub Shaft Prep

Stub Shaft Includes the L-0 Stage Wheel
Stub Shaft Fit Up
Narrow Groove Welding - TIG Process
This rotor was not repaired, but could have been
Turbine Wheel Problems

Thrust Bearing Failure - Wheel Contacts Diaphragm
Stress Corrosion Cracking (SCC)

Figure 2. Stress corrosion cracking (SCC) requires the combined effects of material, stress, and environment (chemistry).

Intergranular Cracking
Boiler Compound Buildup - SCC Coming!

Circumferentially Loaded Blades

Axial Entry Blades
SCC Starts Inside of Blade Slots
SCC In Steam Balance Holes & Shaft

This rotor was less than 5 years old!
SCC Wheel Failure

Wheel failure in the sister rotor to the one in the previous slide
Phased Array UT Wheel Inspection

Scan showing multiple cracks in the wheel

Calibration Blocks
Removal of Damaged Wheels

5 Complete wheels & 1 rim
Wheel Rim & Full Wheel Welding

More than 2,000 lbs of Weld Wire on 14th wheel
Full Wheel Weld Initial Weld Buildup
Intermediate & Final Weld Buildup
Stress Relieving Using Resistance Heaters

Rotors hung vertically to prevent distortion
Stress Relieving with Induction Heating
Increased wheel thickness & radii

Finish Machined & Upgraded Wheels
Upgrade Options by Welding

- Use 12Cr wire to eliminate future SCC
- Modify blade root design to lower operating stresses
- Manufacture new blades from lighter material (titanium = 30% lighter)
- Shot peen the blade roots and the blade slots in the wheel to induce compressive stresses to offset operating tensile stresses
- Any combination of the above
Finish Welded L-0 Wheel
Upgraded Blade Root Form

Upgraded root design lowered peak operating stresses by 45%
Case Study - Geothermal Unit

- Original rating of 54 MW
- Steam field depleted
- Unit operating at 29 MW
- Removed 1st stage wheels
- Welded six wheels to modify root design
- Supplied new design blades and diaphragms
- Unit tested at 55 MW
Both 1st stage wheels removed, welded 2nd, 3rd, 4th wheels in order to modify the blade roots
Converted from 6-Stage to 5-Stage
Wheel Welding Video
Reliability Upgrade L-0 to Integral Snubbers

Twisted Airfoil
Case Study, L-0 & L-1 Blade Failures

- Repeated blade failures
- OEM changed blades from stainless to titanium with additional failures
- Removed L-0 & L-1 wheels
- Welded wheels considerably wider
- Supplied new design titanium Z-Shrouded blades
- Harmonic tuning of diaphragms to reduce blade stimulus
- Also gained 8% in unit output & improved LP end efficiency by 37%
L-0 Blade Failures
Welded & Machined Wheels
Bladed Rotor
Bent Rotor in Straightening Stand
Stress Relief in Process Using Induction Coils
Yoke Over Rotor During Straightening
Weld wire? Probably not.....

Thank You !!