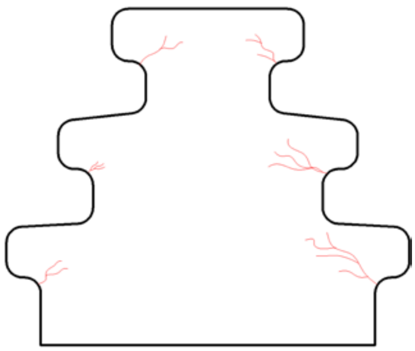
CASE STUDY

Geothermal Steam Turbine Rotor Repair After Stress Corrosion Cracking

Sulzer received a 55 MW geothermal steam turbine rotor from a customer in the Philippines for repair. The design is a double flow steam turbine type with 5 stages on each side. The rotor was received with stage 3 and stage 4 at the turbine side in un-bladed condition. The rotor was reported to have suffered blade failures during operation a few weeks after new blades on stages 3 and 4 had been installed. The customer also informed us that cracks were found in the stage 2, 3 and 4 disk steeples. The cracks were removed by machining before the blade replacement was performed. The customer requested an investigation to determine the cause of the cracking.



Using FEA software to analyze disk steeple

The Sulzer difference

- Sulzer service solutions are available wherever and whenever needed.
- With about 100 service centers worldwide, we can offer our global services on a local basis from one access point.

The challenge

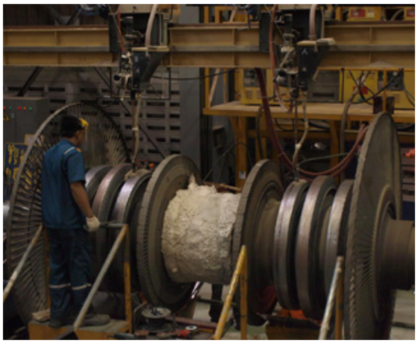
Geothermal energy is a clean and renewable source of power with very limited impact to the environment. It is cost effective, reliable, sustainable and environmentally friendly. The technology for geothermal steam turbines is continuously evolving in order to achieve higher reliability. Because geothermal steam contains various levels of sulfur oxides which are highly corrosive, corrosion is the main cause of failure. Stress corrosion cracking is a common occurrence that attacks most geothermal steam turbines. In order to prevent cracking and to extend the service life of the equipment Sulzer has developed innovative inspection and repair technologies to solve this problem.

The solution

Sulzer performed an extensive investigation and analysis to determine the stress level profile at disk steeples. FEA (Finite Element Analysis) software was used to analyze the stress profile. The result showed that the stress levels at the disk steeples caused by centrifugal forces were still in the acceptable range from a static point of view. Although the stress levels were acceptable, the stage 4 disk steeple showed stress levels close to the allowable limit. High stress level is one of the factors that can cause stress corrosion cracking (SCC). SCC happens when the following three conditions are fulfilled: The presence of a corrosive agent, a tensile stress and a susceptible material specification. The conclusion indicates that the cracks found at the disk steeple row 2, 3 and 4 were most likely caused by SCC.

Weld build-up

The existing rotor material was 1% chrome alloy that is known to be susceptible to SCC. 1% chrome alloy is commonly used for geothermal steam turbine rotor material. Based on the findings, Sulzer proposed to upgrade the material by overlay welding the disks using 12% chrome weld filler. This type of weld filler material will increase the resistance to SCC because of the higher content of chrome. Welding test specimen were tested and evaluated to find acceptable mechanical properties. The complete qualification process was established to provide complete qualification of the Welding Procedure Specification (WPS) and Procedure Qualification Record (PQR) for this welding process.



Double head welding SAW

Post-Weld Heat Treatment (PWHT)

Welding process

Welding preparations were performed prior to the welding process. A detailed Stress analysis was performed to determine the stress distributions especially in the disk area. By knowing the stress distribution, the Heat Affected Zone (HAZ) can be positioned in the low stress area. Stage 2, 3 and 4 disk steeples were then machined out. After successful Non Destructive Testing (NDT), the rotor was ready for the welding process.

The overlay welding was implemented applying Submerge Arc Welding (SAW) process. To avoid the drastic gradient of chrome, the rotor disk was buttered with 5% chrome weld filler. The sudden difference of chrome content can result in large variations in thermal expansion. After being buttered with 5% chrome weld filler the 12% chrome weld filler was applied. For production efficiency considerations, the welding process was conducted by using double head nozzles. Two rotor disks were welded together at the same time. After the welding process was completed, the rotor disks were roughly machined to provide suitable access for NDT. Ultrasonic tests were performed to ensure that there were no defects in the welded disk areas.

Post-Weld Heat Treatment (PWHT)

Any welding process involves thermal input resulting in residual stresses in the affected areas. PWHT is employed to release any residual stress that may be present. To avoid plastic deformation during stress relieving, the rotor was set up in a vertical position. Heating elements were attached to the surface areas of the welded disks. The heater controls were programed to apply gradual heat input to the rotor up to about 600°C. After PWHT was completed, surface hardness of the disks was checked and recorded. Reference to NACE MR0175, for sour environment the hardness should be less than 22 HRC to avoid SCC. After PWHT, the rotor was then set up to machine the final rotor profile.

Re-blading – shot peening – hot peening

Before the blades could be installed, a shot peening process was applied to the blade root areas and also to the shrouds. Shot peening generates compressive residual stress by impacting a blade with a steel ball having a certain amount of energy. This compressive stress will reduce or even eliminate the tensile stress. Decreasing the tensile stress will greatly improve reliability and reduce risk of failure.

Blade installation

All blades were moment weight prior to installation. The moment weighing will determine the blade distribution in order to minimize residual unbalance at each stage. The blades were then installed in the rotor disks and locked in place. Progressive balancing was performed during the installation process.

The final re-blading operation involved the shroud band installation. The shroud is secured to the blade tip by a tenon peening process. This peening process has the potential to increase the hardness of the tenon. Therefore hot peening was employed in order to limit the hardness of the tenon at low level. In hot peening, the tenon and blade airfoil were heated first prior to peening. The heating process involves the application of induction heaters for uniform heat distribution to the entire tenon and airfoil. The tenon hardness should be maintained below 22 HRC as per NACE MR0175 requirement. After completion, the shroud band was machined to specification.

Finally a complete rotor low-speed balancing was performed. Final inspection and quality checks were done to ensure the rotor meets all applicable specifications. The rotor was then preserved and packaged for shipment to the customer site for installation. Following on-site installation, the turbine with the repaired rotor passed all commission tests and is now running successfully at full load capacity.

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Customer benefit

Sulzer can with its many years of expertise and excellent knowledge not only repair equipment but provide tailored solutions to the customer which include:

- Optimized operational efficiency
- Reduction of maintenance cost and time
- Higher plant performance
- Increased availability
- Improved life cycle with a focus on long term approach

Contact
dhimas.ario@sulzer.com