

A reliable custom-engineered repair cuts cost and turnaround time to one-third

Secure rotor reconstruction

After a few years of service, a steam turbine used in the petrochemical industry was inspected. Severe operating conditions had led to heavy erosion in various disks. The rotor was no longer useable in its existing condition, and the only option offered by the original equipment manufacturer (OEM) was a replacement rotor. The rotor was shipped to Sulzer Turbo Services and, upon arrival and inspection, it was determined that the rotor could be salvaged by converting the low pressure disks of the rotor from an integral to a stacked design. The time frame of the complete repair was twenty weeks, compared with a twelve-month delivery for a new rotor from the OEM. Additionally, the cost of the repair was approximately a third of the cost of a new rotor.

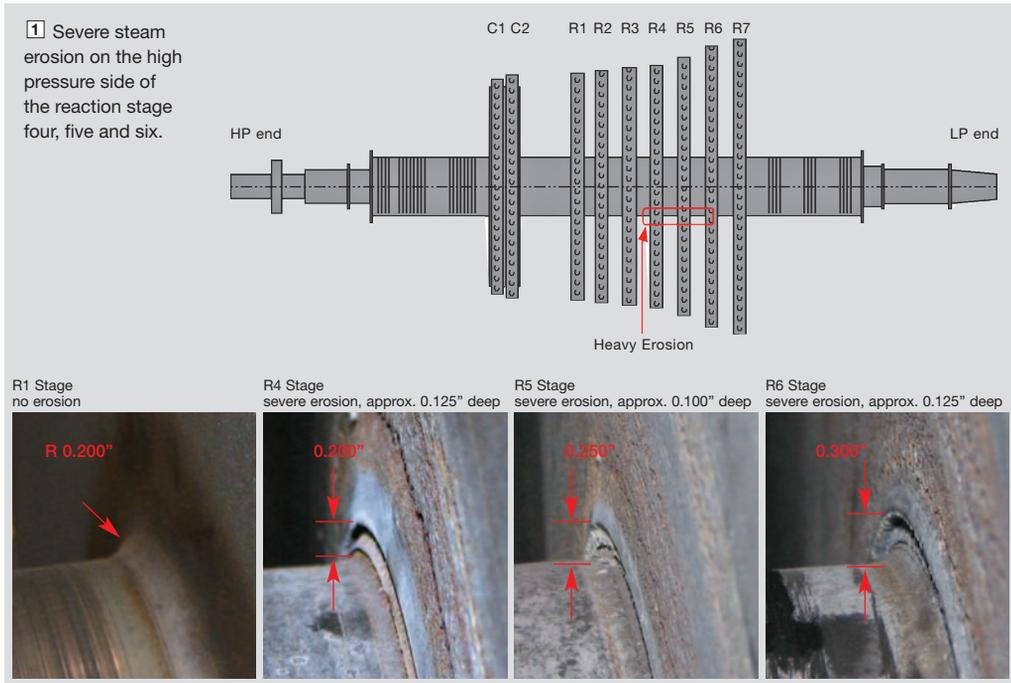
The subject rotor was an eight-stage integral steam turbine rotor with one Curtis stage and seven reaction stages. The turbine is rated for 5340 kW at 5525 RPM. After a few years of service in a petrochemical plant, the rotor was inspected. Improper steam conditions led to heavy erosion in various disks particu-

larly in the latter stages where excessive steam condensation occurred. The rotor was no longer useable in its existing condition, and the only option offered by the original equipment manufacturer was a replacement rotor. The rotor was shipped to Sulzer Turbo Services in Houston, Texas. Heavy erosion was noted on the

high-pressure side of the fourth, fifth, and sixth reaction stage disks [1]. The erosion was focused at the base of each disk, and had generated approximately three millimeter deep grooves. The damage did not extend to the interstage seal areas, which had been previously coated with a hard surface coating.



Checking the dimensions of a steam turbine rotor.



Finite element analysis – basis for decisions

Sulzer Turbo Services first investigated the possibility of removing the erosion grooves by machining a seven millimeter fillet at the base of the high pressure side of each disk. A finite element analysis (FEA)—a method to analyze stresses on structural components—was performed to predict the change in stresses associated with the repairs. The analysis was conducted for the sixth stage—the largest of the affected stages. A baseline stress level was first established by analyzing the stresses on the intact geometry of the sixth stage. Next, a 7.6 mm radius fillet was introduced at the base in the computer model, and the stresses reevaluated 2. The finite element analysis

showed that this type of repair would increase the stresses between 15 and 24 percent—depending on the location. Sulzer Turbo Services advised against this repair because the simulated stress magnitudes approached the yield strength of the material. The repair would additionally reduce the thickness of each disk, which could compromise the rigidity of each disk in the axial direction.

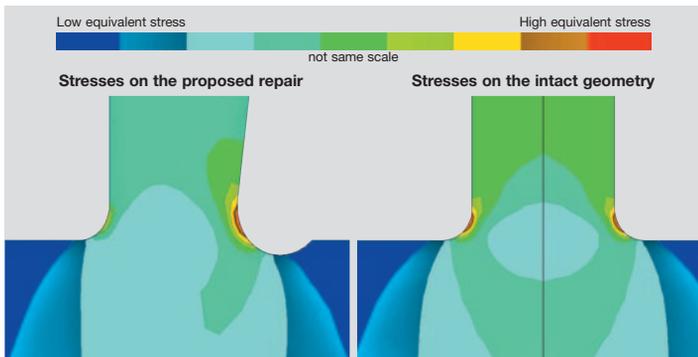
Multiple repair techniques elaborated

Additionally, a local weld reconstruction was considered which involved the removal and weld build-up of each disk. This repair strategy was deemed unfeasible because of the potential for distortion problems in the relatively small diameter

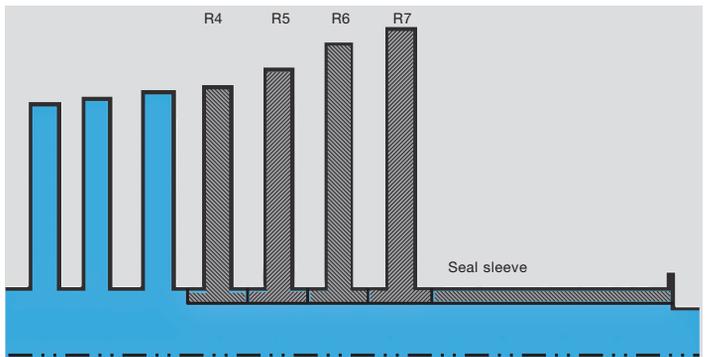
shaft. In the end, Sulzer Turbo Services recommended removing the last four disks and replacing each disk with a stackable, shrunk-on disk 3. This was a feasible option because this is a relatively low tip-speed turbine and an integral design is not necessary. Many turbines of similar size running at this speed feature a stacked rotor design. Since the outer diameter of the interstage seal areas would remain at its original size, the shaft diameter would need to be reduced by the appropriate amount for this to occur. A rotor dynamic analysis (RDA)—a method to predict critical speeds and the vibratory response of a rotor—was performed to determine the effect the repair would have on the rotor dynamic behavior of the rotor.

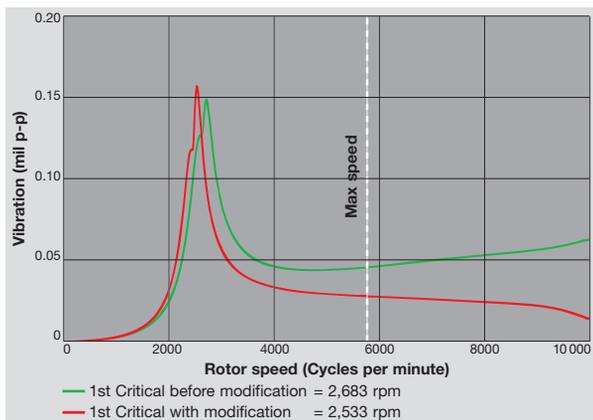
The model results showed a marginal decrease of the first critical speed after repair from 2683 rpm to 2533 rpm 4, which was expected due to the slightly softer characteristic of a shrunk-on disk versus an integral one. Later, the at-speed balancing showed the first critical speed

2 Finite element analysis of reaction stage six.



3 Schematic of proposed repair.





to be approximately at 2300rpm, confirming the rotor dynamic analysis. This speed is well away from the machine operational speed of 5525 rpm. The second critical speed was not recorded as the rotor was spun to a maximum speed of 5800rpm. The results from rotor dynamic analysis also showed that the vibration response levels and deflected mode shapes were nearly identical between the original and the repaired rotor. Sulzer Turbo Services additionally recommended using steel with a higher percentage of chrome and nickel for the disks to provide a higher corrosion resistance which was desirable in this application. Furthermore Sulzer Turbo Services recommended coating them with a hard surface coating to help reduce steam erosion and prolong lifetime. Other repairs in the rotor included weld build up of the shaft end to correct excessive run-outs in the shaft.

Satisfied customers

Due to the experience of Sulzer Turbo Services, it was determined that it was not necessary to construct the rotor from a single forging. The rotor could be salvaged by machining off the disks damaged by erosion and stacking new disks [5]. Sulzer Turbo Services has shown the capacity to produce the engineering analyses to evaluate and justify unique repair options. Most of the equipment repaired by Sulzer Turbo Services is critical, which means that if it fails, it will generate massive production losses. Therefore, customers in the petrochemical plants and the refineries demand that

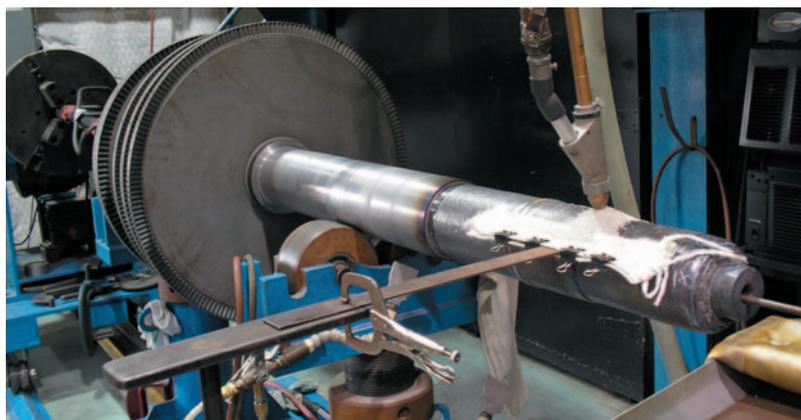
specialized repair proposals are accompanied with in-depth engineering analysis, such as finite elements, rotor dynamic analysis, and metallurgic evaluations— all of which are carried out by the engineering staff of Sulzer Turbo Services.

The repairs completed in the past have proven the effectiveness of Sulzer Turbo Services' technology for rotor rejuvenation. Rotors that would have been considered scrap a few years back can now be successfully rejuvenated using sound engineered repair solutions [6]. An extensive repair of this nature can normally be

completed significantly quicker than a new rotor can be manufactured. Additionally, the cost of a repair of this nature is approximately a third of the cost of a new rotor. This cost and time effectiveness of the process, along with the proven results, have resulted in the increase in acceptance of repairs on rotating turbomachinery components.

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6 Fully repaired stages.



5 Rotor during weld repair of shaft. Fourth to seventh reaction stage have been removed.