Improved power plant performance

By using modern technologies, Sulzer Turbo Services has been able to develop unique solutions to support the owner's operational needs. This approach is applicable to both steam and gas turbines and can provide sustainable competitive advantages. The article looks at three completed projects.

PROJECT 1
Uprates to a gas turbine

It is normal for a gas turbine during the lifetime of the model to increase its performance both in terms of efficiency and output. The easiest way to improve both is to simply increase the firing temperature of the gas turbine. However, without additional changes to the components, this will increase the costs. The simple rule of thumb is that for every 10 °C increase in firing temperature, the life time of the parts is reduced by 50%.

To combat what would be a loss of life and increase maintenance costs, Sulzer Turbo Services has been working on new and improved components for a 120 MW gas turbine, which will provide numerous operational benefits to the owner.

The full gas path is shown in the drawing and consists of four rows of stationary vanes and rotating blades. The original unit gave a nominal output of 120 MW, with 32.5% simple cycle efficiency and a maintenance cycle based on 25,000 Equivalent Operating Hours (EOH). Today, with the latest blading and improvements to the combustion system it is anticipated that the efficiency will increase to ~34.3% and the output to ~165 MW, generating an additional 20 million dollars per year of revenue (based on 6500 hours and price of 70 $/MWh).

CAD view of the hot gas path section.

Sulzer engineers worked on a redesign of the parts that would provide increased capacity or allow for extended maintenance intervals. To assist the owner the parts can be operated at either 1060 °C or 1075 °C with a different 'cost of maintenance' and different unit output based on the chosen firing temperature. This results in the owner being able to optimize their costs and revenues based on market conditions. The uprate required three major changes compared to the previous design.

Improved cooling

The easiest way to improve the performance of a blade or vane during operation is to increase the cooling air flow to the part. However, this can significantly reduce output or increase NO_x emissions (nitrogen oxide, an air pollutant) of the unit as the air is no longer available for combustion. The toughest issue is therefore to make best use of the air flow that exists by incorporating new airflow designs to the cooled blades.

New materials

Over time new materials have become available and generally accepted for use in industrial gas turbines. New casting technologies have also helped because it is now possible to cast large parts that previously would have had to have been forged. This allows materials with better creep and oxidization resistance to be used.

Better coating systems

At Sulzer Turbo Services it has been found that the most effective way to cool the parts is to apply a preparatory MCrAlY-TBC system. The TBC, or thermal barrier coating, is a ceramic layer that insulates the metal from the full temperature of the hot gas path. The application of a TBC coating system allows two different benefits to be provided:

- Extension of maintenance interval without increase in output (e.g., at constant firing temperature)
- Increase in capacity and efficiency by raising the firing temperature but with the original maintenance interval

In our case, a preparatory MCrAlY-TBC system was also applied to the blades to improve the external oxidation and corrosion resistance to help ensure the parts were refurbishable following the planned inspections. Additional internal coatings were applied to reduce the internal oxidation of the base material that can lead to internal cracking.

PROJECT 2

Steam turbine with higher efficiency

While operating at low load, the steam turbine of a Finnish paper mill suffered a bearing failure. Stray electrical currents caused the babbitted lining of the bearing to fail. As a consequence, clearance between the rotating and stationary elements was lost, causing blade damage and the rotor to distort or bow. The turbine is was 59% reaction turbine, designed for 50 Hz operation. The design incorporated 44 stages, and each stage had a relatively low-pressure drop. Due to the low-pressure drop per stage, the manufacturer designed many identical stages, which was common practice in the past. This had the effect of limiting the efficiency of the turbine. The opportunity to produce both an economical repair of the turbine and an increase in the internal efficiency was identified. All the rotor stages that were severely damaged were disassembled. In total, about 6000 blades were disassembled with 3000 replaced by reverse-engineered blades. Stages that had to be reverse-engineered were equipped with blades that had an optimized geometry.

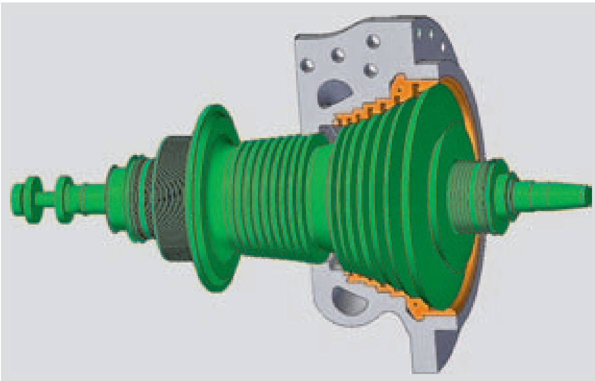
Rotor repairs

Correction of the damage to the rotor and rotating components necessitated a series of operations including specialized welding techniques and heat treatment. These processes were selected in part to improve operational durability through corrosion and erosion resistance. Where the existing design held the potential for improvement, the dimensions were analyzed and selected improvements made to reduce operating stresses.

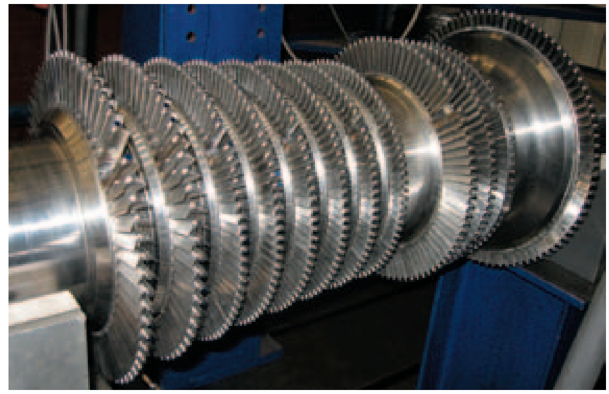
After high-speed balancing, the rotor was installed on site. The turbine was put into service and achieved full power without problems. Steam data showed that the internal efficiency of this turbine, after the straightening and repair

Sulzer Turbo Services expertise helps to extend the operational lifetime and the performance of steam and gas turbine as well as combined-cycle power stations.


Photo: BP



The rotor fitting within the casing.



The blades being installed in the new rotor.

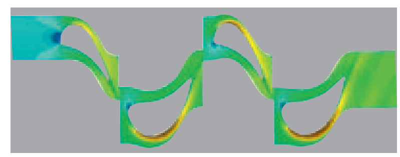
was 2% better than before the incident, providing a payback to the repair within two years.

PROJECT 3
Steam turbine with more output

Re-rating a steam turbine may sometimes require more than just the replacement of the turbine blades and the diaphragms. This was the case when an owner of a process plant approached Sulzer Turbo Services Rotterdam about the potential upgrade of a waste heat recovery steam turbine in a chemical plant in Germany. The owner had re-configured the operational process of the plant and because of this now had 25% more steam available. The current steam turbine was rated at 7 MW and was unable to accept the additional steam. One simple solution was to replace the steam turbine with a new steam turbine, however this was viewed by the owner as a very expensive option. Even worse, the lead time for a replacement unit was over 24 months. Another solution would have been to dump the steam and waste both energy and money.

Feasibility study

The requirements of the owner were very demanding. The first phase of the project was to complete a feasibility study that would lead, if successful, to a new design of the rotor/casing configuration and also ensure that the generator and other auxiliaries would be able to deal with the additional output. Using a Computational Fluid Dynamics (CFD) program, the flow path conditions were calculated at the original design parameters and then with the additional steam flow. The steam path re-design process was validated with the CFD, allowing the design phase to be completed with confidence that the customer required boundary conditions would be met. Based on the report the owner decided to go ahead with the upgrade.



Mach number plots from the CFD analysis of the steam path flow.

Steam turbine rotor installed within the casing.

Design work and repair

The steam path had been designed; however, it was still necessary to understand how the new design would interact with the casing. A computer program was again used to allow the designs to be completed, including the modifications to the casing highlighting the fit up of the old and new components. A new rotor was then forged, machined and balanced. The modifications to the casing were made and an insert ring rolled into the original casing, allowing the original but modified casing to be re-used.

Once fully bladed, the rotor was installed into the casing and all of the tolerances checked. With the casings closed, the unit was then returned to the chemical plant, re-installed and re-commissioned. The unit operated within the acceptable limits and was able to cope with the additional steam, helping the owner to operate the chemical plant more efficiently than before.

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