Metco has left the Sulzer Group and is now part of the Oerlikon Group.

oerlikon metco

Improvement of compressor rotors

Lifetime extension with hardfacing

The wear and erosion of critical machine parts are problems often encountered in turbomachinery maintenance. With its combined knowledge of turbomachines and surface technology, Sulzer can increase the machines' lifetime and reduce the risk of emergency shutdowns. The following project provides insights into the benefits and challenges of applying new technology to existing machines with innovative manufacturing approaches.

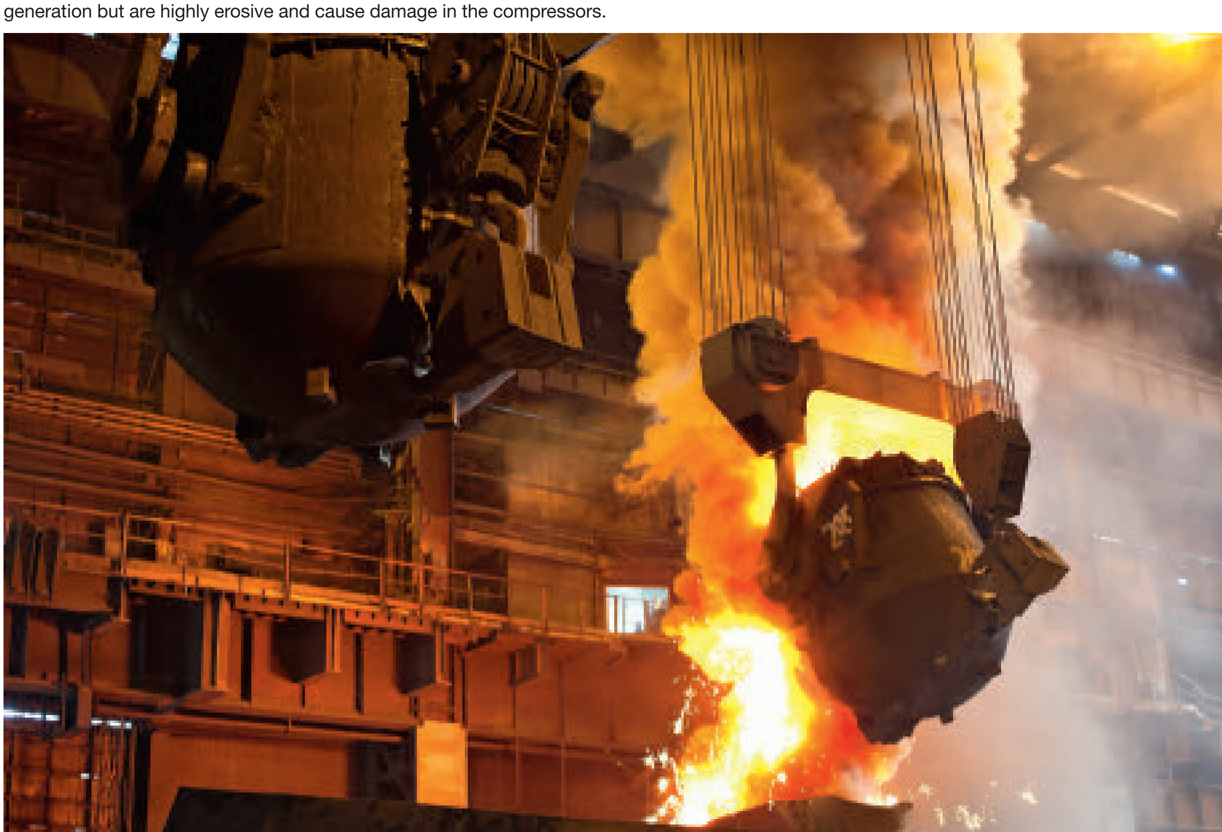
Sulzer carried out a lifetime increase of a single-stage, integral compressor rotor (KKK SL 10.00a) that was badly eroded (Fig. 1) and not meeting its expected performance. The rotor was used for compressing large amounts (70 000 m³/hr) of converter gas. This gas is a byproduct of the steel manufacturing process and is highly erosive due to its high solid-particle content. The damage to the rotor impeller was progressing rapidly because the additional turbulence created by the initial damage was increasing the rate of erosion. This factor combined with the high solids content in the gas flow and remains of the old epoxy coating were causing unbalance and vibrations.

The damaged rotor caused unbalance and vibrations.

The customer had previously tried to protect the impeller by applying different wear protection coatings on the most damaged areas of the impeller:

- Epoxy coating
- Arc-welded hardfacing of Stellite®, which is a special alloy (see infobox)
- Thermally sprayed hardfacing

Steel production processes dispose large volumes of specialty gases. Three different process stages—from coal to steel—create three different gas types: coke gas, blast furnace gas, and converter gas. These gases are used for heat and power generation but are highly erosive and cause damage in the compressors.



What is Stellite®?

Around 1907, Haynes International developed Stellite as a corrosion-resistant alloy. Stellite is now a registered trademark of Deloro Stellite Company. With its constituent components of cobalt, chromium molybdenum, tungsten, and nickel, it is highly resistant to corrosion, wear, and heat.

First implemented as a lifetime extender for cutting tools, it enabled longer operational time and higher cutting speeds. During the Second World War, the alloy proved to be suitable for investment casting of turbine blades. Nowadays, Stellite is used as a protective top layer on wear-sensitive critical steam or gas turbine blades, for example.

The high wear resistance of these alloys is created by the formation of carbides M_7C_3. The carbon percentage influences the amount of carbides being precipitated, which reflects in the hardness and brittlement of the material. Stellite 21 has a lower carbon weight percentage (0.25%) than other Stellites that have no wolfram component but a high molybdenum percentage (5.5%). For Stellite 21, this translates into less carbide precipitation, which thus provides a lower hardness but better ductility. A higher percentage of the chromium content stays dissolved in the alloy, which results in higher corrosion resistance.

1 The impeller was eroded at its most turbulent locations in the flow path: blade tip, leading edge, and shroud.

Of these solutions, only the Stellite welding gave encouraging results. However, the downside of the Stellite solution was that it was applied by hand arc welding, and therefore the resulting layer thickness and surface quality were inconsistent. Furthermore, it was difficult to apply the Stellite layer welding to larger surfaces.

Sulzer divisions join forces for customer solution

Sulzer's unique combination of turbomachinery and surface technology know-how was ideal to solve this problem. The experts from Sulzer Turbo Services, Sulzer Metco, and Sulzer Innotec worked together closely to find the best solution for the customer. Sulzer recommended the following life-extending measures to slow the wear on the impeller vanes and decrease the machine's downtime:

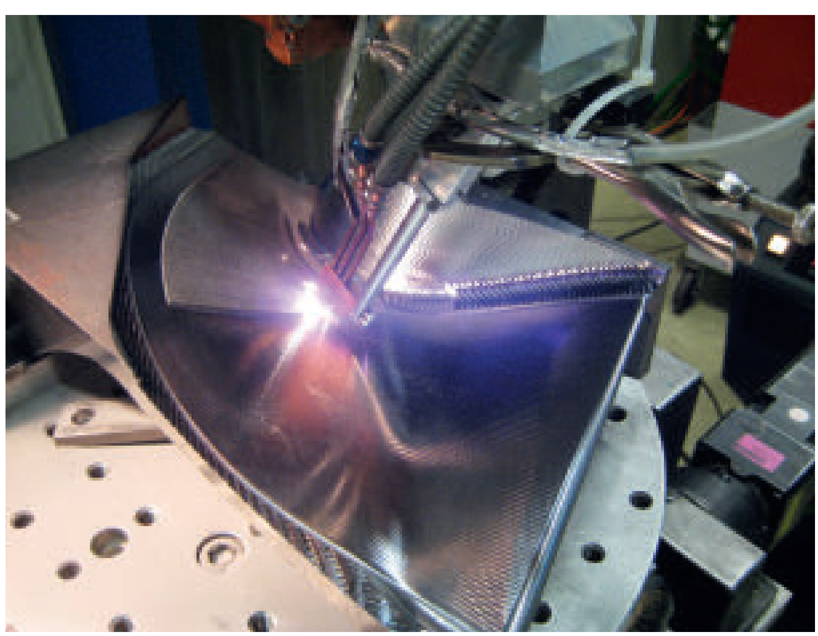
- Cladding of the impeller blades on the intake and pressure sides and of the shroud ring with Stellite 21 using a suitable welding and manufacturing process
- High-velocity oxygen fuel (HVOF) coating of the shaft with Metco Diamalloy 1008

Search for a manufacturing approach

The most challenging task was to find a suitable manufacturing process for the rotor with integrated impeller and Stellite-cladded vanes. The rotor body and impeller backplate had to be manufactured from a one-piece forging, and the vanes had to be welded onto the premachined backplate. To decide in which stage of the production process the Stellite wear shield could be applied, Sulzer engineers needed to evaluate the different production stages and to consider the specific material characteristics of the Stellite shielding material.

Sulzer's unique combination of turbomachinery and surface technology know-how was ideal to solve this problem.

Previous experience with Stellite cladding showed that the remaining internal stresses generated by the welding process and shrinkage resulted in considerable deformation of the parts.



2 Laser cladding is particularly suitable for applications that demand high dimensional accuracy. Because of the superior focusing ability of laser, components can be processed with minimal thermal loading and distortion. Sulzer has long-standing experience in laser cladding and has performed a great variety of laser applications for customers all around the world.

If the vanes were cladded with Stellite after they were assembled onto the backplate, the risk of unacceptable deformation of the vanes was high. Furthermore, the welding would have to be done manually, as some areas would be difficult to reach

Sulzer decided to apply the layer by laser cladding in order to overcome the disadvantages of manual arc welding.

with automated welding. In addition to the possibly uncontrollable deformation of the impeller vane, the manual arc welding approach had some other disadvantages:

- Additional laborious grinding procedures necessary to achieve a consistent layer thickness and surface quality
- More time-demanding balancing of the rotor due to a larger variation in individual blade weight
- Lower wear resistance of the Stellite layer due to manual application

Developing a laser-cladding solution

To keep the Stellite layer within controlled parameters (thickness and location), Sulzer engineers decided to apply the layer by laser cladding (Fig. 2) on the individual vanes before they were assembled and final welding was performed. In a cooperative effort with the welding department of Sulzer Innotec, Sulzer Turbo Services performed tests to assess the quality and continuity of the welding layer. After several test welds on a base material comparable to that of the impeller vane, samples were made to determine the achievable weld quality. Based on the best results, the welding procedure parameters for the laser cladding of the vanes were selected.

The rotor model was analyzed by means of a finite element model simulation (Fig. 3) to assess whether the additional centrifugal forces generated by the added weight of the cladded Stellite layer would result in unacceptable stress levels or in deformation of the impeller material. The values found were acceptable for the specified material characteristics so that the production could start.

The cladded Stellite layer was tested in a cooperative effort with the welding department of Sulzer Innotec.

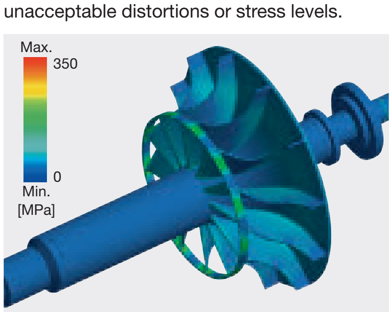
Production step 1: Machining and laser cladding

The vane's geometry was machined using 5-axis computer numerical control (CNC) out of a solid piece of forging. The machining was executed in several individual steps with intermediate dimensional inspections. This approach made it possible to measure and correct any deviations from the desired geometry after laser cladding and heat treatment. To generate the model for the 5-axis machining, Sulzer engineers extracted the blade geometry from the available 3D model of the rotor/impeller and positioned it in the most convenient setup for machining and laser cladding (Fig. 4). During production, during laser cladding, and after final machining, the engineers confirmed the correct geometry of all blades by 3D measuring the blade curve and comparing the found coordinates with the nominal model. After they had passed the final inspection in the Stellite cladding process, the blades were cut free by means of 3D laser cutting and were ready to be welded onto the premachined rotor body.

Production step 2: Assembly

Because all welds needed to be correct the first time, the process for welding the blades to the rotor disk was qualified with a testing protocol. A reference template with precut slots was used to ensure the correct placement of each individual blade before welding. At this stage, the vane support ring (which was also Stellite cladded on its axial inlet side and its inner diameter) was assembled and welded onto the rotor assembly. The temperature during final welding of the vanes and inlet ring was controlled so as not to influence the properties and quality of the Stellite layer. After welding activities had been completed, the whole rotor assembly was given a final heat

3 A finite element analysis of the rotor confirmed that the Stellite layer caused no unacceptable distortions or stress levels.



What are typical causes of damage?

Damage to turbomachines can be classified in two categories:

Predictable wear: as caused by the attack of the machines parts or by chemical, thermal, or mechanical influences. This kind of damage can be characterized by its slow and expected degradation of the base materials. Predictable degradation can be taken into account by periodic inspections and planned production stops for maintenance, thus preventing further damage and keeping a handle on expected costs.

Unpredictable wear: This kind of wear is most feared—as it can emerge at any time and disturb critical processes, causing emergency shutdowns with consequential high outage costs. Unpredictable wear can be characterized by its unsuspected and sometimes rapid progress, and, in some cases, catastrophic failure of the part. The root cause of unpredictable wear can be found in operational conditions not taken into account at the initial design stage of the part or the part being operated outside its original design parameters.

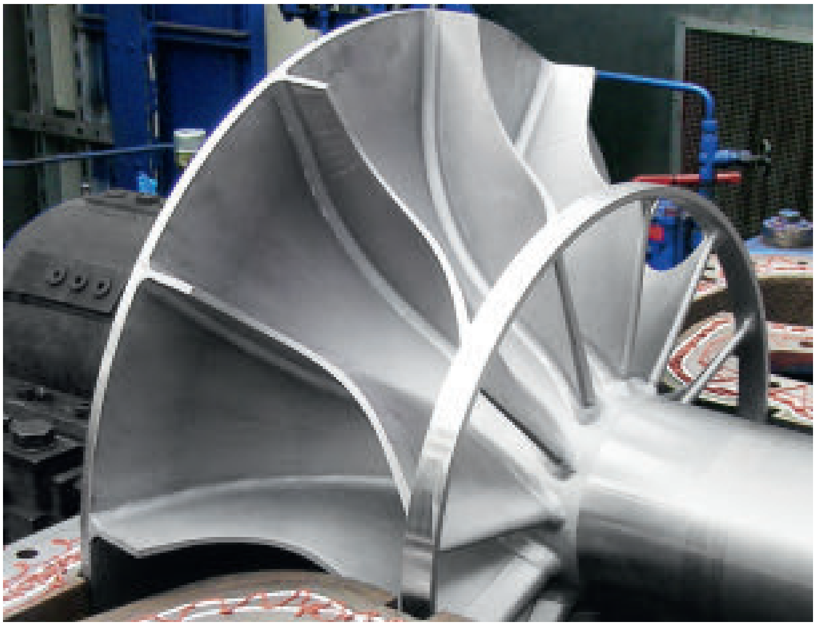
With an extensive knowledge of process conditions and the use of better-performing materials, Sulzer is able to slow down the predictable wear process and to avoid unpredictable damage.

treatment to relieve any residual material stresses in the rotor assembly.

Production step 3: Inspection and delivery

To confirm that there were no material defects as result of the heat treatment, the rotor was given a complete non-destructive inspection. Once it had successfully passed the non-destructive inspection, the rotor was machined to its final dimensions. After engineers had inspected it for defects and geometry, spin testing at 115% was performed and the rotor was balanced. When it was returned to the machine shop, the rotor was given a final inspection to ensure that there were no deformations. After it passed final inspection, the rotor was cleaned, conserved, and prepared for shipping to the customer (Fig. 5), where it was installed the following week during a planned maintenance stop.

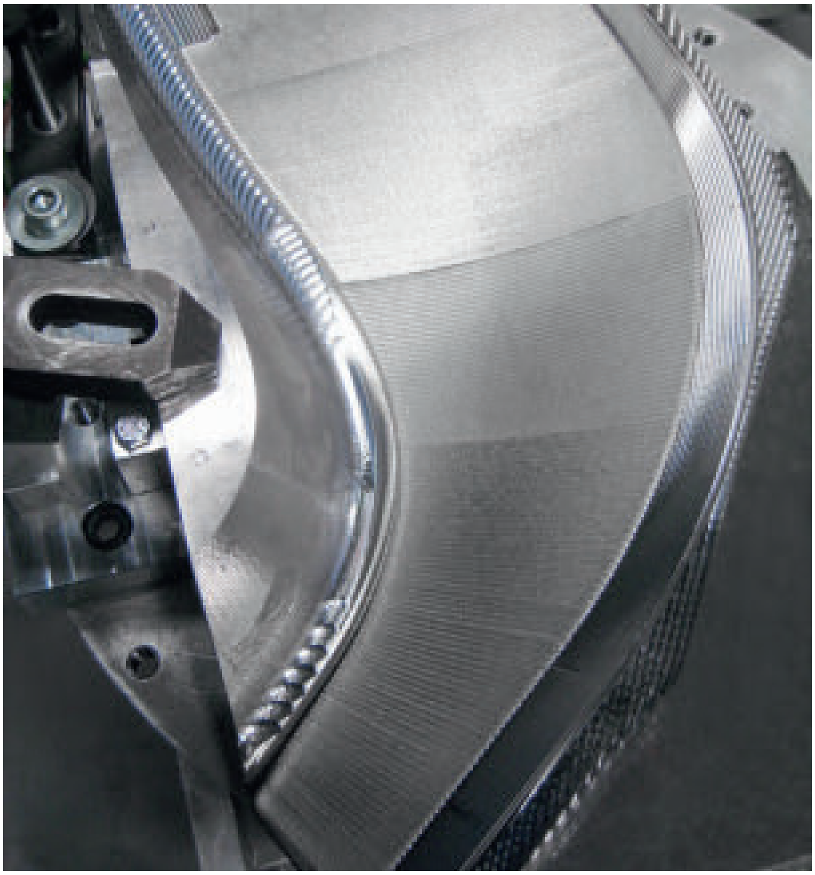
The expected lifetime of the rotor increased significantly.



5 The measures of Sulzer slowed down the wear on the impeller vanes thus increasing the lifetime and—at the same time—decreasing the machine's downtime.

The rotor has been running with satisfactory performance for over eight months now, and it is expected to have a significantly longer liftetime than the original configuration, thanks to the solution developed by the Sulzer team.

4 To keep the relative position of the blade in the base material measurable during the production process, Sulzer engineers machined reference planes and notches into the base block.



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