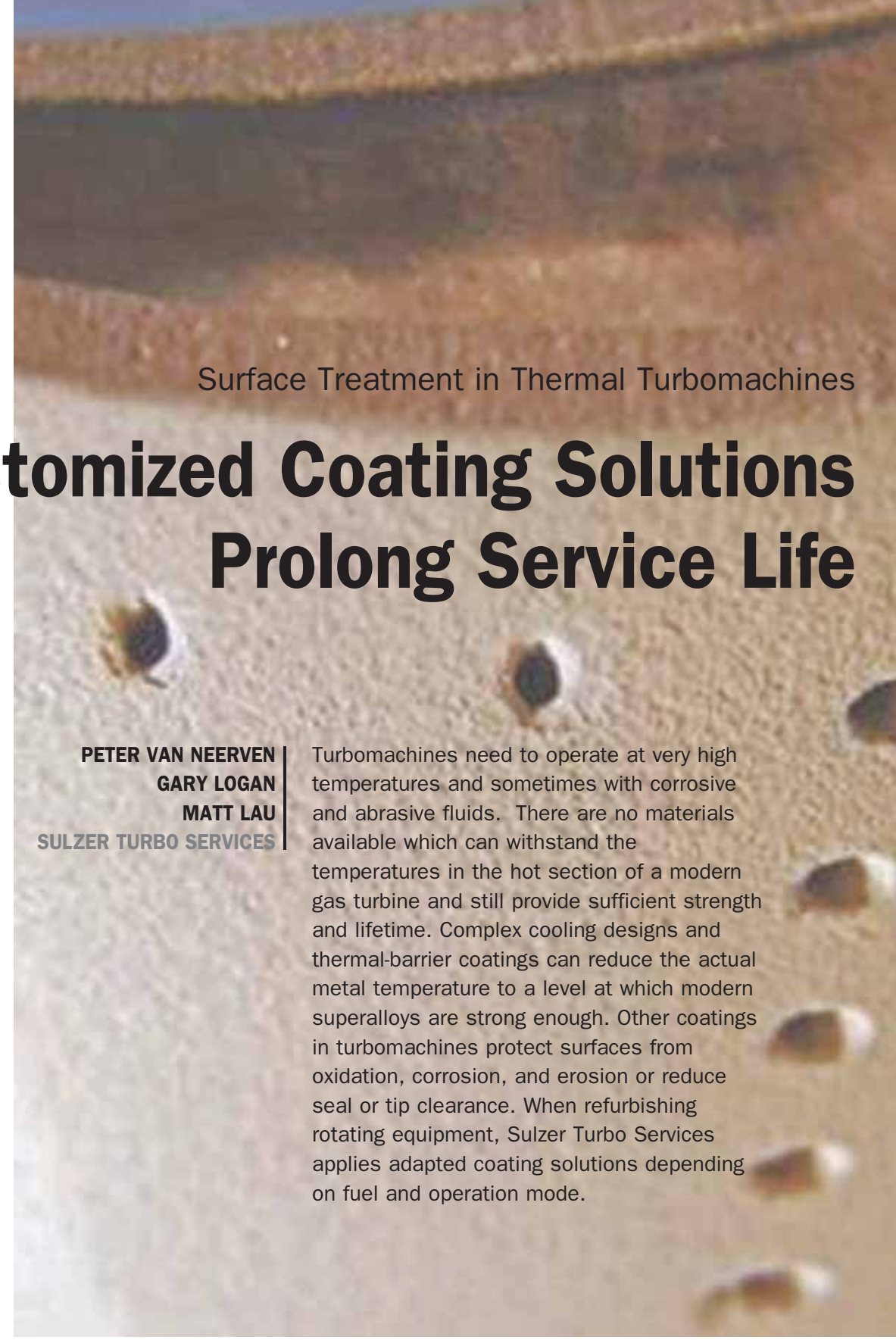

Surface Treatment in Thermal Turbomachines

Customized Coating Solutions Prolong Service Life

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Turbomachines need to operate at very high temperatures and sometimes with corrosive and abrasive fluids. There are no materials available which can withstand the temperatures in the hot section of a modern gas turbine and still provide sufficient strength and lifetime. Complex cooling designs and thermal-barrier coatings can reduce the actual metal temperature to a level at which modern superalloys are strong enough. Other coatings in turbomachines protect surfaces from oxidation, corrosion, and erosion or reduce seal or tip clearance. When refurbishing rotating equipment, Sulzer Turbo Services applies adapted coating solutions depending on fuel and operation mode.

In a turbomachine, temperature and velocity as well as the moisture content of the fluid vary both along the flow path through the machine and depending on the operating conditions. Consequently, the material is subject to a range of wear mechanisms, including corrosion, oxidation, and erosion. Heat can alter the structure of the blade material (thermal fatigue) and deteriorate its mechanical properties, e.g., strength. Different types of coating protect the equipment from the various types of attack (Fig. 1).

Oxidation, Corrosion, and Erosion Resistance

During oxidation, metal forms a metal-oxide layer on the surface. In general, this oxide layer protects the underlying material. Therefore the oxidation process will slow down as the thickness of the oxide layer increases. The intentional formation of oxides can provide a protective layer preventing further atmospheric attack.

Corrosion is a combined surface attack of oxygen and sulfur leading to a deterioration of material properties. Two different modes of corrosion can be distinguished.

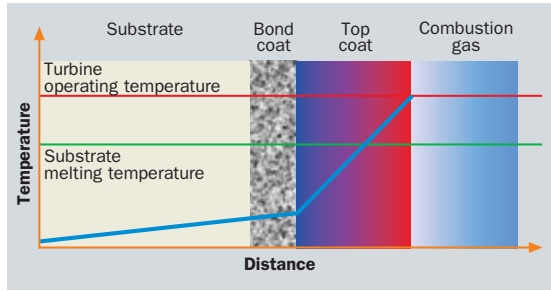
- Hot corrosion (type 1 corrosion) takes place at temperatures between 800 and 900 °C. It attacks the entire surface and develops along the grain boundaries.
- Type 2 corrosion mostly forms local spots with heavy attack and builds distinct layers of oxide and metal

Erosion as defined in materials science is the damaging of surfaces by repetitive, localized mechanical attack, e.g., by abrasive particles.

Protection from High Temperatures

In modern turbines, mostly a combination of techniques is used to create the optimal protection from different types of attack.

Oxidation and corrosion resistant coatings are usually aluminides, produced by chemical vapor deposition (CVD) processes as well as coatings produced by thermal-spray processes or combined techniques, e.g, MCrAlY applied by high-velocity oxygen-fuel (HVOF) or low-pressure plasma spraying (LPPS).

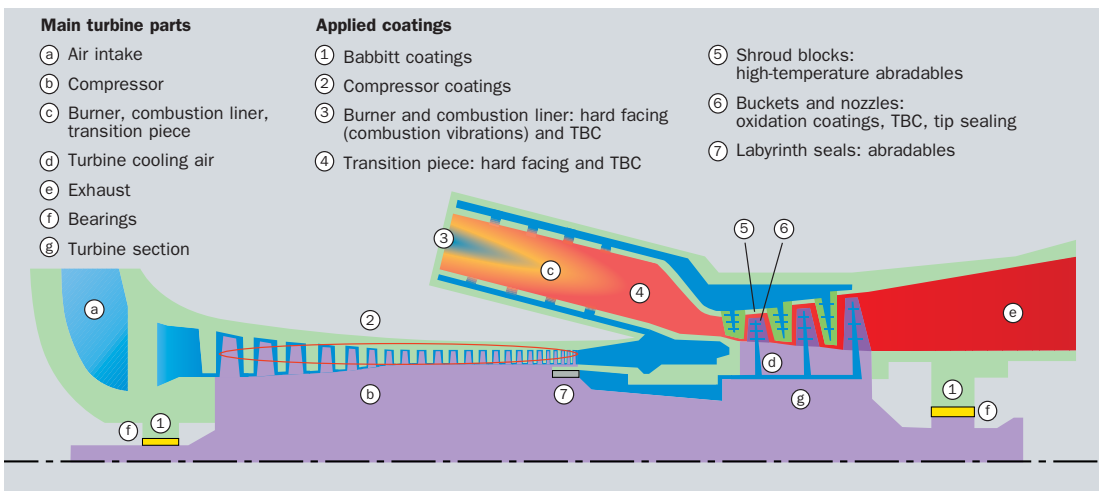


2 Schematic coating structure and temperature gradient (blue line) of a thermal-barrier coating as a function of distance.

The purpose of a thermal-barrier coating (TBC) is to enhance the longevity of coated parts by reducing metal temperatures. In addition, these ceramic coatings are used for clearance-control applications in the high-temperature regime.

TBC based on zirconia are produced normally by thermal-spray techniques or electron-beam physical vapor deposition. The thermal conductivity of zirconia used in a TBC is low, about 1 W/m·K; that of, e.g., copper is 3000 times

1 Coatings increase efficiency and extend the service life of modern gas turbines. When repairing a gas turbine, Sulzer Turbo Services engineers chose tailor-made coating solutions. The right selection can help improve performance.



greater. Sulzer Turbo Services applies a 2-layer coating system (Fig. 2). It consists of a bond coat and a top coat. The bond coat provides good adhesion between the metal substrate and the ceramic top coat. It acts as a heat shield, insulating the substrate alloy and therefore allowing higher operating temperatures or reductions in cooling requirements or both.

Erosion resistant coatings are made from hard carbides and are mainly produced by thermal-spray processes.

Clearance Control

Besides their thermal-barrier properties, zirconia-ceramic materials are also used for clearance-control applications in the high-temperature regime. Tighter clearance control leads to improved efficiency of the turbine. Clearance-control coatings, or abradable coatings, function by permitting a rotating part (such as a blade) to cut a path in a sealing abradable layer with minimum clearance (Fig. 3). Many advanced gas turbines utilize a thick ceramic coating to impart both thermal-barrier and abradability properties.

Modern Coating Technology

The basic production techniques for coatings are thermal spraying and physical and chemical vapor deposition (PVD and CVD).

Thermal spraying is an industrial coating process consisting of a heat source and a material. The process involves heating a material, in powder or wire form, to a molten or semi-molten state. The material is propelled using a stream of gas or compressed air towards the material to be coated, or substrate, creating a new surface structure as it impacts. The coating materials can be melted using several different processes, including fuel combustion, plasma spray, and electric-arc delivery systems. The process can take place under standard atmospheric conditions or in a special, highly controlled atmosphere.

The speed of the molten material and the atmosphere under which the process is carried out influence the properties, e.g., density or hardness, of the coating. Sulzer Turbo Services applies LPPS, atmospheric plasma spraying (APS), or HVOF spraying depending on the requirements.

Environment-Friendly Process

Applications include protection from wear, high temperatures, or chemical attack, as well as environment-friendly use for corrosion protection as a substitution for hard chromium. Coatings can be metallic, ceramic, or any combination desired to meet a broad range of physical criteria.

Diffusion coating is a process in which a base metal or alloy component is either coated with another metal or alloy and is heated to a process specific temperature within a closed environment. The coating is then diffused into the surface of the component by exposure to a gaseous medium. Diffusion coatings provide superior oxidation, corrosion and erosion resistance for applications as internal cavities and are widely used as standard oxidation protection for external surfaces.

Case Study 1: Operating Costs Reduced

The need for smooth, corrosion resistant coatings for gas turbine compressor blades was recognized some time ago. Although the base alloys have good corrosion resistance and a smooth surface finish when first installed, these properties can deteriorate quickly once in service. Sulzer Turbo Services has developed various compressor coatings. The crack-gas compressors in the ethylene unit of a global chemical company required regular shutdown and cleaning. Sulzer Turbo Services applied anti-fouling coatings to the compressor rotors and diaphragms, completely eliminating the need for off-line washing, providing an annual saving of over USD 1 million to the client. This cost reduction is due to

3 Inner shroud of a gas turbine freshly coated with an abradable coating (left). The picture after 18 000 operating hours shows the abradibility of the coating system.

improved availability and the fact that no more washing fluid is necessary. The customer chose Sulzer Turbo Services exclusively, because the company could guarantee quick response time during the tightly scheduled outage.

Case Studies 2 and 3: Service Life Extended

For the gas turbines of one customer, Sulzer Turbo Services coats the transition pieces exclusively, because the client can now reuse them without any need for repair after running an operating cycle of 8000–12 000 hours (Fig. 4). Before, other vendors had coated the parts, and after one cycle, the transition pieces had to be taken from the turbine, the coating that was left had to be completely removed and the transition pieces had to undergo weld repair before being recoated.

In 2005, Sulzer Turbo Services received one unit of a 25-MW steam turbine from an Indonesian company. The last-stage blades of the turbine had suffered from severe erosion on the leading edges. Sleeve rubbing on both journal bearings was also found. Observing the damage on the last stage blades, they were considered for replacement. However, due to budget and time constraints, the customer wanted to reuse the blades applying the quickest possible repair option. Sulzer Turbo Services restored the blades by dressing the erosion area and applying chrome-carbide coating using the HVOF method (Fig. 5). The journal bearings were also refurbished by HVOF coating. The coating process was applied to both journals first and the blades of the last 2 stages afterwards. After completing, the rotor was shipped back to the customer for installation and immediate return to operation.

Adapted Coatings

Sulzer Turbo Services offers a variety of coatings to extend the life of critical turbomachinery, adapted to the specifics of the respective machine and its operation modes. These coatings are designed to keep machinery running longer and in many cases more efficiently. In advanced gas turbines, which operate at temperatures higher than the melting points of the newest alloys, the cooling and coatings determine the lifetime.

4 Coating the inner diameter of these transition ducts increased their service life and reduced the need for weld repair.

5 Manual coating of steam-turbine blades.

The newest generation of turbine parts is challenging for repair companies, this is because of the many small cooling holes (very often more than 500 in a single part!). The repair requires new coating solutions since conventional plasma-spaying processes would close up many of small holes when spraying. Sulzer Turbo Services and Sulzer Metco put a lot of much effort into new techniques for improved coatings but also in improved coating application techniques to keep the holes open during spraying.

The combination of the broad experience of Sulzer Turbo Services in refurbishing turbomachinery and the coating expertise of Sulzer Metco makes sure that the clients' processes are back online as fast as possible after a shutdown. ◀

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