Wear-Resistant Thermal Spray Coatings

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Within most industry segments, significant financial losses may be incurred due to accelerated wear of various components. In order to minimize the effects of mechanical wear and extend product life, Sulzer Metco has implemented thermal spray coating solutions into production and is further developing them to meet even more demanding wear applications.

Wear is defined as the unwanted removal of material from a surface as a result of mechanical action. Mastering the wear process means controlling a complex set of system and process variables. This starts with a clear understanding of the component, its material history (alloy chemistry, processing, surface hardness, grain size), the type of wear the component will see, and the type of environment (temperature, gas). For each type of wear, there is a corresponding specific wear mechanism.

Thermal Spray Coatings Against Wear

Applying coatings using thermal spray is an established industrial method for resurfacing metal parts. The process is characterized by simultaneously melting and transporting sprayed materials, usually metal or ceramics, onto parts.

The spray material is propelled as fine molten droplets, which, upon striking the part, solidify and adhere by primarily mechanical and, in some cases, metallurgical interaction. Each layer bonds tena-

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ciously to the previous layer. The process continues until the desired coating thickness is achieved. Thermal spraying can be used to apply coatings to machine or structural parts to satisfy a number of requirements:

- Repair worn areas on parts damaged in service
- Restore dimension to mis-machined parts
- Increase a part's service life by optimizing the physical surface properties

The primary advantages of thermal spraying include the range of chemically different materials that can be sprayed, a high coating deposition rate, which allows thick coatings to be applied economically, and spray equipment portability.

Different Materials and Processes Available

The first step in selecting a thermal spray coating for a specific application is to define the coating function. Some of the most common wear functions for thermal spray coatings, types of materials used, and application examples are listed in the table above.

Thermal spraying consists of five basic processes:

- Wire flame spraying
- Powder flame spraying
- Arc wire spraying
- Plasma arc spraying
- High-velocity oxy-fuel (HVOF) spraying

The HVOF process gives coating microstructure densities closest to that of wrought materials.

All of these processes can also be applied in a controlled environment (using ChamPro™ in-chamber coating equipment) in order to enhance caoting properties.

Types of Wear, Materials Used, and Application Examples for Thermal Spray Coatings

Type of wear	Application	Materials
Abrasive wear	Cutting blades	Tungsten carbide-cobalt
	Glass mould plungers	Nickel chrome-chrome carbide
	Pump volute	Cobalt-based hardfacing alloy
		Nickel/cobalt self-fluxing alloy
Sliding wear	Piston rings	Cast iron-molybdenum
	Impeller shafts	Molybdenum-based self-fluxing
	Cylinder bores	Alumina-titania babbitt
		Cobalt chromium molybdenum
Impact, vibratory fretting wear	Mid-span dampers	Tungsten carbide-cobalt
	Sucker rods	Nickel-base self-fluxing
Erosion/cavitation wear	Stream turbine blades	Tungsten carbide-cobalt
	Water turbine applications	Tungsten carbide-cobalt chrome
		Nickel chrome-chrome carbide

Many Applications Possible

In the following, examples and case studies show the broad variety of applications of thermal spray coatings:

- Erosion occurs when solid particles impinge or impact on a surface, resulting in eventual material removal. The mechanism of wear is based on the angle of impact, the size of the particles and the physical characteristics of the debris. Temperature and environment can also play a role on wear. Typically, stainless-steel steam turbine blades are exposed to high temperatures of up to 540 °C (1000 °F). Since the cost to replace these blades is significant, researchers have looked to coat these blades with proprietary materials.

High-temperature erosion is also a problem in boiler tube applications in the pulp and paper indus-

1 A technician uses a Sulzer Metco SmartArc® wire spray gun to apply high nickel alloy coating on boiler tubing used in a biofuel cogeneration plant. Thermal spray more than doubled the time between repairs and extended service life by a factor of ten.

2 Sliding wear is common in automobile synchronizer rings and transmission systems. Sulzer Metco coatings are frequently used to extend product life by producing a constant friction level and protecting against overloading.

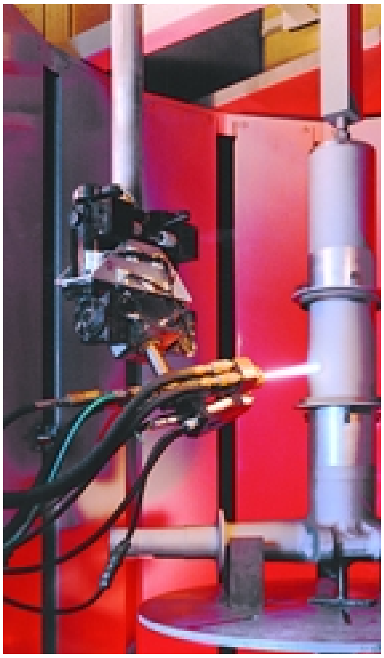
try. In these applications, boiler tubes are subjected to high-temperature corrosion (sulfidation) and erosion. In black-liquor recovery boilers, for example, the combination of char (solid particles rich in sulfur) and the hot gas environment results in metal wastage of the tubes. In order to minimize this problem, nickel-based alloys high in chromium have been developed (Fig. 1).

▶ Key contributors to sliding wear are mechanical loading, types of loads, chemical media, temperature, as well as type and amount of lubricant. Sliding wear is common in automotive and heavy-duty piston ring applications, synchronizer rings and transmission systems (Fig. 2), automotive and large-bore cylinder bores for gas transmission applications, hydraulic rods for earthmoving equipment (Fig. 3), and landing gears for mainframe aerospace applications that replace hard chrome plating. Sume®Sol, a Sulzer Metco product, is an innovative coating solution for difficult sliding-wear applications.

▶ Today, a number of applications are replacing hard-chrome plating with alternative materials and processes. HVOF technology is an excellent alternative due to environmental restrictions on chrome plating, ease of operation, quick turnaround, wide material selection, and low cost. The U.S. Navy has approved HVOF coatings to replace hard chrome for hydraulic rods, and major aircraft manufacturers have approved materials such as SM 5847 for landing gear applications (Fig. 4).

▶ Abrasive wear occurs with the removal of material by particles moving across a surface. The particles may be loose or part of another surface in contact with the surface being worn. Examples of abrasive wear applications are in

3 Countless pieces of construction machinery, such as these concrete chisels, utilize hydraulic pistons to perform work. Sulzer Metco tungsten carbide/cobalt HVOF coatings on the pistons replace chrome plating.



4 HVOF thermal spray replacement coatings applied on airline landing gear instead of hard chrome plating show better performance.

the agriculture and glass industry. Cutting blades and glass mould plungers (Fig. 5) have cobalt-tungsten carbide/self-fluxing alloys allied with either low- or high-velocity oxy-fuel gun processes. The benefit of fusing the coating is to create a metallurgical bond between the substrate and coating. This improves the impact resistance. Important considerations for abrasive wear are the coatings matrix hardness and chemistry. Hardness and toughness typically run counter to each other. Therefore, the alloy design has to be optimized for the application.

Plasma and HVOF processes are used for less severe impact applications. Tungsten carbide-cobalt (chromium) and nickel chromium-chromium carbide are the main carbides of choice. Tungsten carbide-cobalt is used for low-temperature wear applications (400–500 °C), cobalt chromium tungsten carbide coatings for corrosive low-temperature wear, and nickel chromium-chrome carbides for high-temperature wear (1000 °C). Typically, carbide coatings of cobalt chrome have over 4–6 times the abrasive-wear resistance of hard-chrome plating and are approximately 30% better than nickel chrome-chromium carbide. Material hardness is not the only factor in determining abrasive-wear resistance between material systems, however.

▶ The majority of applications are based not on one mechanism, but many. A good example is a sucker rod coupling used in oil field pumping machinery, which sees abrasive, sliding, and corrosive wear. Another example is a pump volute used in the petroleum industry, which encounters abrasion, erosion, and corrosion.

The Key to a Successful Coating

Before designing the proper coating system, several factors must be evaluated. Technical considerations are based on an understanding of the wear mechanism and environmental factors the engineering parts are exposed to. Cost considerations include the materials used, gun and process employed, and the normal life of the components before they need to be repaired. The combinations are many, but the solution options are as great, and offer impressive benefits. ◀

5 Abrasive materials wear caused by molten glass is controlled on mold plungers used in the glass industry by application of Sulzer Metco cobalt/tungsten carbide/self-fluxing alloys.

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