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

oerlikon metco

The benefits of thermal-sprayed coatings in water turbines

Surfaces for longer life and higher energy efficiency

Hydroelectric power contributes importantly towards the expansion of renewable energy sources. Sulzer Metco coatings protect many water turbine components from erosion and corrosion damage; thus, they contribute to a safe, economical, and environmentally friendly energy supply.

According to the *World Energy Outlook 2010* report of the International Energy Agency, the worldwide primary energy demand will be 35% higher in 2035 than in 2008 as a result of increasing world population and increasing prosperity, particularly in the emerging markets. However, on the whole, the proportion of demand for different primary energy sources will change. The study predicts an overall increase in oil consumption of only about 20%—well below the average predicted rise in demand.

Gas, hydro, and other renewable energies will grow in all countries [1]. The share of renewable energies for electricity production will increase from 19% in 2008 to 32% in 2035. But, after the Fukushima nuclear disaster in March 2011 and the declaration of a


Dam of a hydroelectric storage power plant in the Alps.

nuclear phase-out by some of the leading industrial nations, it can be assumed that the growth of renewable energies will occur much faster than was predicted in 2010.

One of the most environmentally friendly forms of energy production is hydropower. Water-powered electric utility plants can be differentiated between run-of-the-river power stations, reservoir power stations (e.g., dams), and pumped-storage hydropower stations. Run-of-the-river hydroelectric power plants are built directly in the river and produce energy continuously. Pumped-storage hydropower plants can also be used for energy storage.

Energy storage is nowadays an important factor for on-demand electricity consumption. Germany currently has an installed pumped-storage capacity of about 7 GW with a daily operating capacity of 4 to 8 hours. This results in a remarkable overall storage capacity of about 40 GWh. Future projects will notably increase that capacity. Another advantage of pumped-storage power plants is that they are highly efficient, i.e., the excess electrical energy can be stored with an overall efficiency of 80%.

Hydropower plants, particularly the turbines, face efficiency losses from corrosion and wear by erosion (hydro-abrasion, fluid erosion and cavitation erosion) that depends on the type of power plant, the turbine design (Francis, Kaplan, or Pelton) 2, and the specific operating conditions (e.g., the corrosive potential and the sand, gravel, and stone debris in the water) 3.

The first hydroelectric power plant was built in 1880 in Northumberland, England. The high wear on the blades caused by corrosion and erosion required, at that time, that the turbines be manufactured from expensive high-alloy steel castings. The technology of today's power plants differs significantly from that in Northumberland. Tools such as computer modeling optimize component designs to minimize cavitation. On the other hand, the overall stress loads on turbine components have risen.

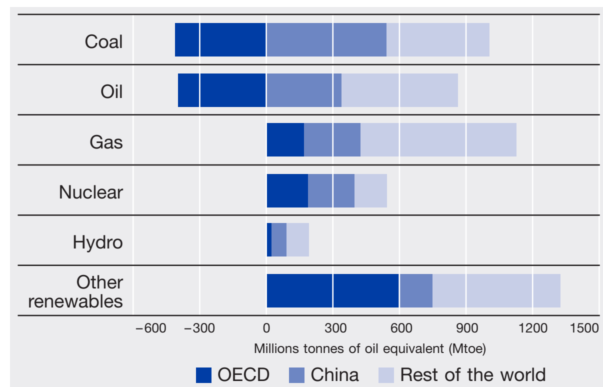
This is caused not least by ambitions to achieve greater profitability, exploit greater heads (water pressures and velocities), and expand weirs into inaccessible mountain regions, such as the Himalayas and the Andes. It is also caused by the desire to build faster-rotating, small turbines as well as large "monster" turbines and power plants in rivers that are contaminated with sand and chemicals.

As the expectations of service life, maintenance intervals, and turbine efficiency are constantly rising, wear protection for power plant components is of increasing importance.

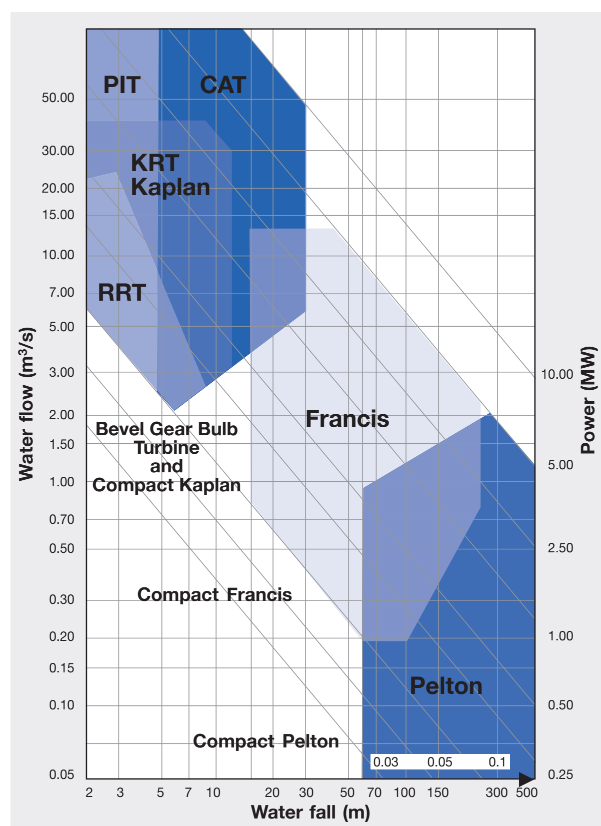
Longer lifetime of water turbines with coating solutions from Sulzer Metco

The names Sulzer and Metco have been closely associated with the field of hydropower for a long time. As early as the 1930s, Metco applied steel, chromium steel, bronze, and zinc coatings to Francis runners to investigate the performance of these coatings in cavitation tests.

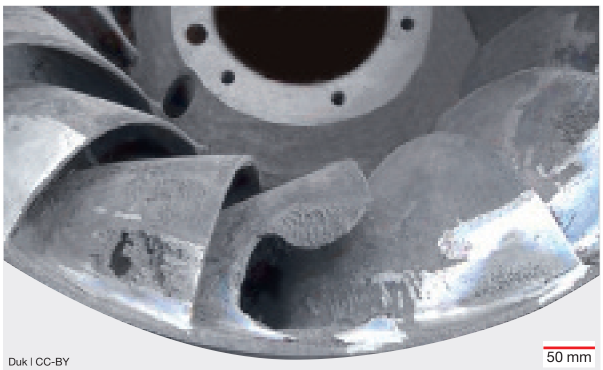
In Germany and Austria during the 1960s, abrasion tests were performed on Kaplan machines using Metcoloy 2 (13% chromium steel wire) coatings at the Inn power plants. Later, these coatings were used successfully in the field. Combustion wire spray has become a standard coating technology in the turbine business and has since been used suc-



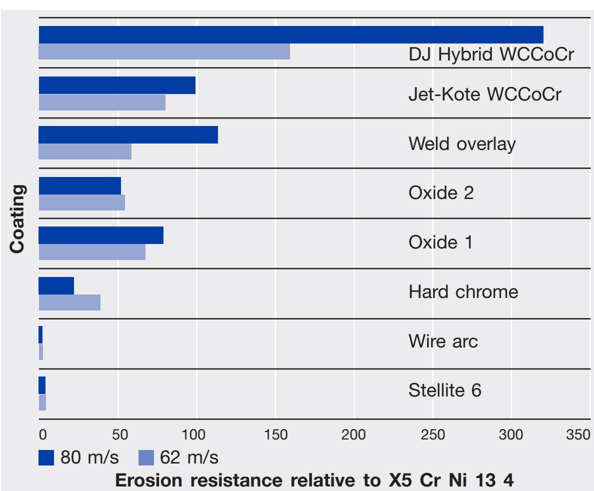
1 Projected growth in primary energy consumption by technology from 2008 to 2035. (Source: OECD / IEA World Energy Outlook 2010)



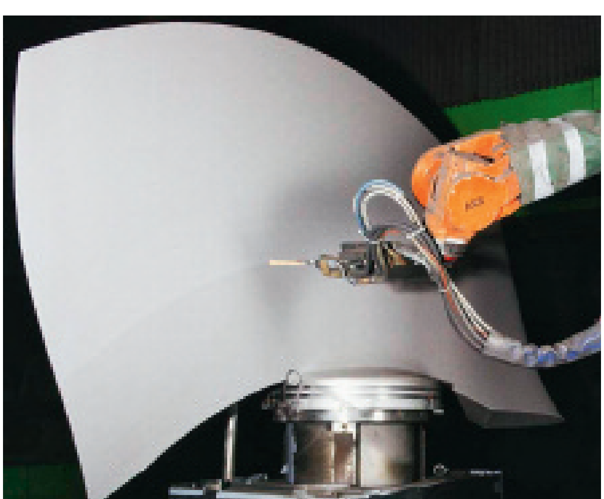
2 Conditions of use for water turbines.
(Source: Catalog Sulzer Hydro / Sulzer Escher Wyss)



3 Cavitation damage on a Francis turbine.



4 Erosion resistance of different materials and coating systems.



5 A Kaplan turbine blade, coated with Sulzer Metco SUME™*Turb*.

cessfully in almost all types of water turbines. Compared to the formerly used standard technology—weld buildup—the primary benefits were much shorter processing time and reduced detrimental thermal effects to the base material and components.

Successful launch

Toward the end of the 1980s, Metco introduced its new Diamond*Jet*™ high-velocity oxygen fuel spray process (HVOF). This new technology was suited for the workshop and was adequate for everyday use due to its simple design. The first early attempts on sleeves were very promising, and so the range of parts to which coatings such as tungsten carbide materials (of type WCCoCr) were applied expanded very quickly. The component lifetimes achieved using these new HVOF coatings exceeded the boldest expectations.

Thus, material erosion was reduced by a factor of 50 from that of turbine steel (1.4313). The transition from the very thick layers that were common at that time (e.g., 10 mm thick wire combustion-sprayed Metcoloy 2) to the thinner, but also more erosion-resistant, HVOF-sprayed carbide coatings was then initiated. Diagram 4 shows a comparison of the wear characteristics of various surface coatings. The dominant position of the HVOF process with WCCoCr as the coating material is evident.

Groundbreaking coating development

In the 1990s, Sulzer Innotec, Sulzer Metco, and Sulzer Hydro collaborated to develop groundbreaking coatings and models for hydroturbine applications. An example is the development of the SUME™*Turb* coating especially for Kaplan turbine blades 5. This WCCoCr coating is applied with the Sulzer Metco Diamond*Jet* HVOF gun. The coating thickness is 400 µm or less.

Additionally, a large percentage of Francis and Pelton turbines parts that are in contact with the water are coated. Some components, such as labyrinth seals on Francis machines, are constructed for optimal ease of coating. In the majority of cases, the coated components can be used without further treatment.

Proven materials

Figure 6 provides an overview of the commonly used coating systems for the different types of water turbines.

Typical standard Sulzer Metco WCCoCr materials that have proven their value in this area—considering load condition, the specific application, and the HVOF system used—are Diamalloy 5849, Amdry 5843, Sulzer Metco 5847, Woka 3652, Woka 3653, and SUME*Turb*. Despite practically identical chemical composition, these powder materials have different particle shapes, morphologies, particle size distributions, primary carbide sizes, and bulk densities. Therewith, they differ in production and manufacturing parameters and the starting raw materials used.

These differences are clearly visible in wear test results 7. However, these differences are not noticeable through the usual hardness test performed for quality assurance.

Thus, it becomes evident that in the water turbine industry high-velocity oxygen fuel spray (in the workshop, with Diamond*Jet*, Woka*Star*, or Woka*Jet* guns) or wire combustion spray (in the workshop or on-site with 14E, 16E or

EGD-K) are mainly used. Plasma spray, yet another thermal spray process, has largely lost importance in this area whereas it was previously used to apply wear coatings to needles, nozzles, and Francis turbine parts.

Development support

As with most mechanical parts, a general recommendation of a suitable coating solution cannot be made without detailed analysis of the application. Depending on the design of the machine, its specific operating parameters, and its specific service conditions, extensive differences in the dominant or overlapping wear mechanisms can prevail.

In the worst case, it can happen that the stresses mutually reinforce one another. In general, however, it can be assumed that wear due to hydroabrasion, corrosion, and cavitation erosion increases with the flow velocity, the quantity of entrained solids, and the corrosion potential of the fluid. The wear in operation depends on factors such as size, shape, and hardness of the solid particles. Therefore, predictable limits for individual materials cannot be specified.

Because the wear behavior of a material cannot be predicted by its simple physical and mechanical characteristics such as hardness, elastic modulus, and tensile strength, it becomes necessary to employ specialized wear tests. While phenomenological tests are used to determine the basic wear behavior of materials under well-defined loading conditions, application-specific tests are designed for specific conditions and components. The results of these tests can usually be transferred directly to an application[1].

Component	Coated area	Coating	Wear mechanism
Kaplan turbine			
Discharge ring	Partial or entire discharge ring	• Wire combustion-sprayed 15 mm thick Metcoloy 2	Erosion (hydroabrasion, fluid erosion)
Kaplan blade	Partial or entire blade	• HVOF 0.4 mm thick WCCoCr • wire combustion-sprayed 5 mm thick Metcoloy 2	
Guide vane ring	Between planar surface and draft tube liner	• Wire combustion-sprayed 5 mm thick Metcoloy 2	
Protective sleeve	2-part sealing elements	• HVOF 0.3 mm thick WCCoCr • wire combustion-sprayed Metcoloy 2	Seal area, abrasive wear
Radial bearing	Applied to new or repaired components	• Wire combustion-sprayed Sprababbitt A	Sliding wear
Crank	Slide bearing area	• Wire combustion-sprayed Sprasteel-LS	
Crank pin	Slide bearing area	• Wire combustion-sprayed Sprasteel-LS	
Francis turbine			
Cheek plate	Complete area	HVOF / WCCoCr	Erosion (hydroabrasion, fluid erosion)
Guide vane	Complete guide vane, also disc and face side seals		
Turbine cover	Clearance and labyrinth area, wear ring area		
Runner wheel	Clearance and labyrinth area, runner inlet channel		
Pelton turbine			
Pelton bucket	Inside and edge	HVOF / WCCoCr	Erosion (hydroabrasion, fluid erosion)
Pelton needle	Area subject to wear	• HVOF / WCCoCr • Plasma / Cr_2O_3	
Needle spear	Area subject to wear	• Wire combustion-sprayed Metcoloy 2 / Sprabronze	Sliding wear
Nozzle tip	Entire internal contour	HVOF / WCCoCr	Erosive and abrasive wear
Nozzle tip insert ring	Area subject to wear		
Jet deflector	Area subject to wear		
Jet deflecting cover	Area subject to wear		

6 Selection of the most important applications for thermal-sprayed coatings in water turbines.

Together with its partner Sulzer Innotec, Sulzer Metco is fully equipped with test benches both for phenomenological studies as well as for customer- and application-specific coating development. In detail, the following test facilities are currently available:

- Cavitation/erosion test per ASTM G32-03
- Abrasion test bench per ASTM G65 (dry sand rubber wheel)
- Abrasion/corrosion test (modified ASTM G65 test)
- Salt-spray test per ASTM B117, also suitable for ASTM G85, ASTM B368, ASTM G43, and ASTM D2247
- Current-potential measurement
- GE erosion test per GE50TF121
- Taber abraser per ASTM G75
- Two-body block-on-ring test (wear of friction pairs under sliding friction)
- Water-jet erosion test

Sulzer Metco offers its coating application expertise and its expertise analyzing data generated from the above-mentioned test beds to develop customized applications. It can be determined, for example, which of the available coating systems is best suited for a given stress. For example, a special cavitation test bed is used at Sulzer Metco 8 especially to assess the cavitation of HVOF-sprayed coatings.

Through close and proprietary cooperation, Sulzer Metco provides its customers the ability to select the best solution from a number of existing coatings or to further develop an existing coating to fulfill the customer's specific turbine requirements. Thus, hydroturbines can operate for longer periods at even greater efficiencies, further contributing to effectiveness of these renewable energy resources.

8 Cavitation test rig at Sulzer Metco.

Acknowledgment

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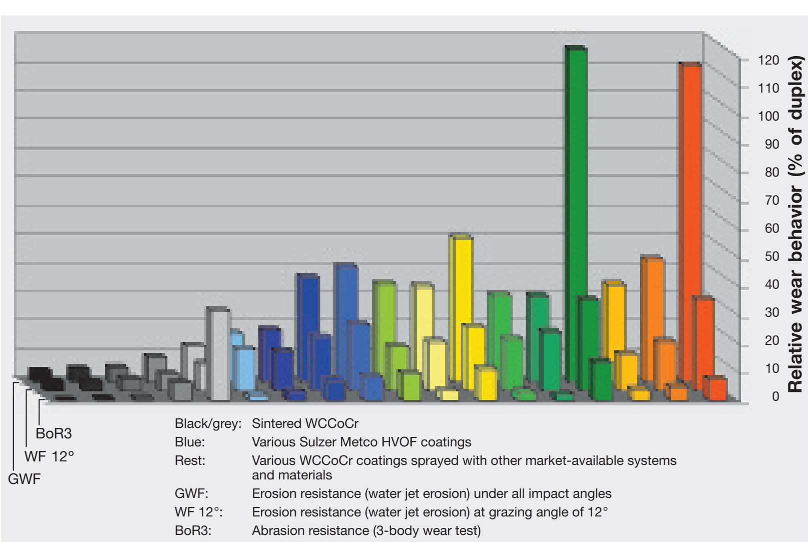

7 WCCoCr coating wear behavior.

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