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Coatings Improve Turbine Engine Performance in Naval Vessels

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In the time since the first gas turbine jet engine was developed more than 70 years ago, the industry has grown exponentially – and so has the output produced by the turbines. In addition to today's jets, gas turbines power fleets of military and commercial marine vessels, as well as industrial operations like offshore platforms, electrical power utilities, and other systems. Over the years engine output, efficiency, and reliability have increased due to advancements in turbine design, component design, materials, and of course, the coatings incorporated into critical parts – and the very design – of today's engines.

What role do coatings play in the turbines operating today? Why are they necessary when advanced superalloy materials used in turbine engine manufacturing are already resistant to high temperatures and extreme environments? Coatings offer benefits for greater performance, durability, and maintenance.

Coatings: Performance, Cost Savings

To achieve optimum performance in producing power, modern-day gas turbines need to perform trouble-free in extreme environments.

A military jet fighter pilot, for example, must have a reliable engine when in battle at Mach 2 speeds in air-to-air combat. Naval vessels powered by gas turbines require instant throttle response during surface warfare encounters in rough seas at times when the engine is ingesting salty air that would create corrosion attack on non-coated, unprotected surfaces. A cogeneration gas turbine operating on 100°F (38°C) days, day after day, to produce megawatts for an electrical utility and supply its cogeneration host with electricity or steam, requires a reliable and available gas turbine.

Similarly, offshore oil and gas platforms require engines that safely and reliably provide electrical power for gas compression, and oil extraction capabilities, as well as for support of personnel who are living and working on platforms, which can experience heavy weather and up to 80-foot (24.38m) seas.

Gas turbine manufacturers now produce high performance engines whose simple cycle thermal efficiency has increased significantly since the 1930s, when they were in the less than 20 percent range to the 40 percent range of modern gas turbines. In today's combined cycle applications, modern efficiencies reach the 60 percent range. These higher thermal efficiencies, which translate to higher power output for a land-based application, greater power in a marine vessel, and more thrust in an aircraft, are achieved through higher

Coatings provide more thrust in aircraft engines and more power in marine vessels by allowing coated turbine engine blades to operate at greater efficiencies and hotter temperatures. For every 0.001 inch (0.003cm) coating thickness of thermal barrier coating on a High Pressure Turbine vane or blade, the temperature drops about 25° F (-4°C).

operating temperatures. These higher temperatures, in turn, are achieved due to the use of the superalloys and to coatings in the gas path or critical hot section of the engine.

For every 0.001 inch (0.003cm) coating thickness of thermal barrier coating on a High Pressure Turbine vane or blade, the temperature drops about 25° F (-4°C). For a thermal barrier coating of 0.005 inches (0.013cm), this will equal a 125° F (52°C) decrease of the parent metal below the coating. The thermal barrier coating allows the parent metal to operate cooler for a constant operating temperature and extends the component life.

There are two types of coatings for the gas turbine engine – diffusion and overlay. In the diffusion process, a portion of the coating 'diffuses' into the parent metal structure. Coatings such as precious metal / diffusion aluminide coatings are sacrificial, providing protection against high temperature oxidation and low temperature corrosion.

In the High Pressure Turbine blade section of gas turbines, overlay coatings are applied using Electron Beam Physical Vapor Disposition (EBPVD) or plasma spraying. Metallic overlay coatings such as MCrAlY coatings are applied by Electron Beam Physical Vapor Disposition or by low-pressure plasma spraying. They provide oxidation- and corrosion-protection and can be used as a stand-alone coating or a bond coating for the overlay ceramic thermal barrier coatings applied by Electron Beam Physical Vapor Disposition or air plasma spraying. Use of thermal barrier coatings has allowed the operating temperatures of the High Pressure Turbine vanes and blades of the turbine to increase significantly, minimizing the harmful effects on the parent material. As a result, gas turbine efficiency has increased. Other advantages include increases in the time between required overhaul and maintenance, resulting in significant cost savings to gas turbine operators.

BELOW ▼ Chromalloy's Orangeburg, NY, Electron Beam Physical Vapor Disposition area.

Over the years, gas turbine operators – including the operators of today's naval fleets – have reaped the benefits coatings bring in today's advanced engines.

Military Gas Turbines

Chromalloy pioneered advanced coating technologies for gas turbines. The company's original core of scientists in the 1950s first developed diffusion coatings for nozzle guide vanes for the first generation of commercial aircraft jet engines. Since that time, the engineering- and technology-based company has pioneered several coatings for all sections of the gas turbine engine – from the compressor section flowing downstream to the high-pressure and low-pressure turbine sections.

As the coatings industry has grown, continued research and development of coatings, repairs, and manufacturing technologies have led to the development of electron beam physical vapor deposited ceramic coatings, low-pressure and air-plasma sprayed coatings, precious metal / diffusion aluminide coatings, and vision-guided interactive laser welding and drilling for most advanced turbine engine components, as well as many other advanced technologies. The introduction of a series of innovative and proprietary processes allows engines to perform at improved efficiency levels, at higher operating temperatures and under severe environmental conditions. Establishing joint ventures and strategic partnerships in both the commercial aircraft and industrial turbine engine arenas with engine original equipment manufacturers (OEMs) and their customers, Chromalloy provides coatings for new production, as well as a full line of turbine engine overhaul repairs, component repairs, and services.

The U.S. Department of Defense uses these turbine coatings for several military applications during repair of the turbine components. These include abrasive tip coatings on the F100 engines powering the U.S. Air Force F-16 fighter aircraft High Pressure Turbine blades, to ensure tight operating clearances. Another coatings innovation is the diffusion aluminide coatings for the TF39 engines powering the C-5 Galaxy transport planes. The diffusion aluminides have been in production for more than 20 years.

In its Surface Warfare Fleet, the U.S. Navy operates the largest marine fleet in the world powered by the LM2500 gas turbine engine and, ultimately, coatings help keep it running. LM2500 component repairs and High Pressure Turbine vane and blade coatings, as well as Low Pressure Turbine stage one and two blade coatings use Platinum Aluminide precious metal diffusion coating processes. The coatings have become critical to engine performance, reliability, and maintenance requirements covering a wide spectrum of applications — from commercial aviation, marine, and industrial aero derivatives to light and heavy industrial, and military gas turbine engines.

LEFT Turbine engine blades with Chromalloy coatings.

LM2500 turbine engine blades.

Rough Seas, Tough Coatings

The operating environment of a surface warfare vessel is a harsh one. The ship must be able to operate in heavy, high seas, while ingesting salt-laden inlet air. Saline air can cause serious corrosion to High Pressure Turbine and Low Pressure Turbine components, and can require premature overhaul of the engine – a costly requirement that, multiplied over the life of the engine, quickly adds up to hundreds of thousands of dollars or more.

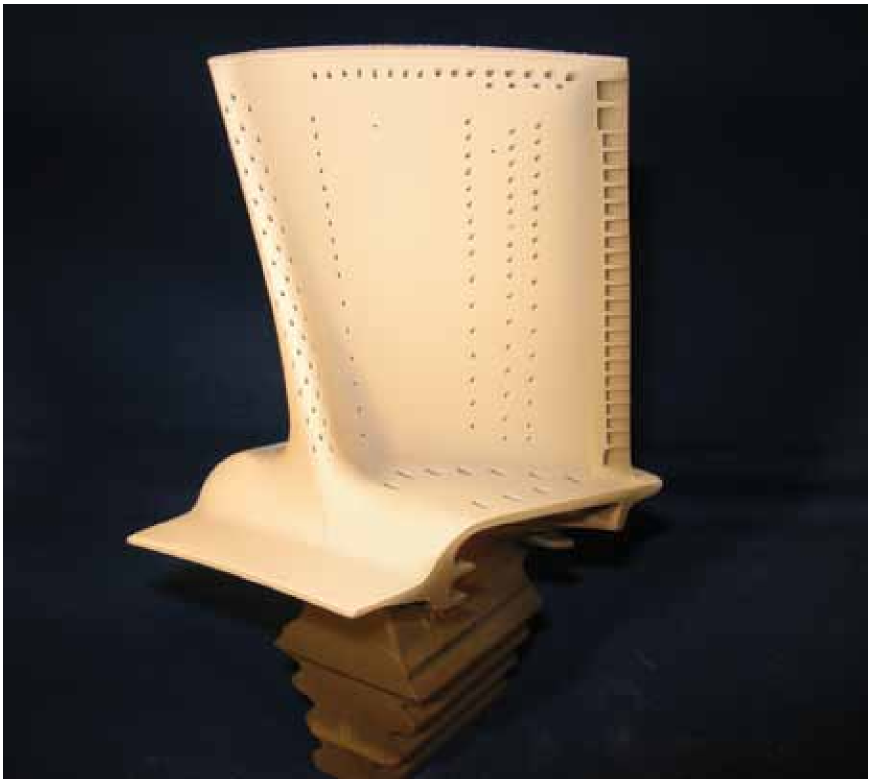
To test and further develop its coatings, in 1991 Chromalloy entered into a program with a military operator of the LM2500 engine powering its FFG-44 ships. The on-board ship test was designed to evaluate Stage 1 and 2 High Pressure Turbine blades that were repaired with Platinum Aluminide coatings. The frigate was to be borescoped during the duration of the nine-year test to inspect the blades. In 1992, based on its need to improve performance, the U.S. Navy began participating in the borescope inspections for its FFG-7 ships.

The result of the test performed over the nine-year period was that the Platinum Aluminide coated blades – and the repairs also provided by the company to the turbine engine blades – delivered quantifiable performance and maintenance improvements. Based on the test and outcome, U.S. Navy NAVSEA engineers accepted the principle of the coatings developed by Chromalloy as well as the company's component repairs.

Based on the Platinum Aluminide coatings applied to the turbines' High Pressure Turbine and Low Pressure Turbine vanes and blades during maintenance and repair, the Navy's LM2500 fleet has been shown to remain in service longer. Component performance improved with the use of Platinum Aluminide coating, which being ductile at the high temperatures, almost eliminated the cracking that affected the overlay coated parts in original service. The Platinum Aluminide coating provides significant corrosion protection in the harsh marine environment.

Chromalloy estimates the Navy has saved up to $60 million over 11 years for replacement costs of worn or scrapped turbine engine parts and lower maintenance costs on the fleet.

ABOVE ▲ Turbine engine blade coated with Chromalloy's thermal barrier coating.



Looking Ahead

Coatings are an advanced technology and a dynamic science. As the coatings industry continues to evolve, Chromalloy will continue to work with the military, as well as other commercial aviation, marine, and industrial aero derivative, light and heavy industrial turbine engine operators. As gas turbine manufacturers increase the internal operating temperatures of their engines to provide more power and improvements to the engine operation, the need for new advanced coatings also will increase. Coatings engineers and metallurgists are developing new solutions for operators to enable them to achieve better reliability and to reduce operating and maintenance costs. CP