Raising The Barrier Bar
Thermal barrier coatings bulk up heat and corrosion resistance
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Bowing sand in the Middle East and high levels of airborne particulate matter from industrial pollution in Asia are parts of the impetus behind a new generation of thermal barrier coatings (TBC) designed to better protect engine components and withstand corrosive elements.

TBC corrosion is becoming a growing issue, specifically attributable to the build-up of calcium magnesium aluminosilicates (CMAS).

"CMAS resistance is now the focus of TBC research and development, and is the next step in the advancement of the technology. However, CMAS protection will be an evolutionary process, in that as each coating is developed, each will have a different level of CMAS resistance," says Ravi Shankar, director of coating and process technologies for Chromalloy.

CMAS is essentially a "glass-former," explains John Nerz, special process technology leader for coatings for GE Aviation. "When the particles are ingested into the engine, they attach themselves to the thermal barrier coatings. Over time, they infiltrate and destabilize the structure of the coatings, ultimately reaching the components themselves, and making them less strain-resistant," he says. That causes them to fail before they should.

Airline fleet growth in the Middle East and Asia is driving the industry "to recognize CMAS as a critical problem," Nerz says.

No specific engine families are more vulnerable to CMAS than others, Nerz stresses. "It's definitely related more to the aircraft's operating environment."

To address this issue, GE is developing different coating structures and compositions, and deposition technologies, for components such as hot-section blades and vanes that are failing early, says Nerz. "We want to maintain the efficiency of the engines longer within their life cycles. Focusing on CMAS will help us do that."

The TBC coating application method, electronic-beam physical vapor deposition (EBPVD) itself continues to evolve as engine temperatures increase, says Tom Lewis, vice president for applications development at Praxair Surface Technologies.

"During this process, an electron beam vaporizes the ceramic, and creates a structure that enables the coating to better tolerate the wide temperature variations that take place during an aircraft engine's operating cycles," says Lewis. He predicts the EBPVD process will be used for the next 10-20 years, "but more rare-earth elements, such as yttria-stabilized zirconium (YSZ) will be added to the coating material."

Yttria is a rare-earth material that raises the melting temperature of the ceramic, while lowering the heat transfer rate. "That means that the ceramics will tolerate higher temperatures, but cool the turbine blades further," Lewis says. While yttria is now just starting to be used, it will be more commonly incorporated into TBCs during the next five years, as new-technology turbine engines are introduced, he predicts. "In most cases, this is where you will see the application of this technology."

Chromalloy's electron-beam physical vapor deposition facility is located in Orangeburg, N.Y.

Lewis adds that some new TBC compositions will include other rare-earth elements, specifically gadolinium and lanthanum. Platinum aluminide is being added to TBCs in the low-pressure turbine stages.

If there is a downside to EBPVD, it is the high capital costs of the equipment used in the application process. For that reason, the industry is looking at an alternative, known as suspension plasma spray (SPS), which costs half the average $25 million for EBPVD machinery, says Lewis. The cost differential, he explains, is because EBPVD employs a vacuum application process while SPS uses an atmospheric application method.

Along with using less capital-intensive equipment, SPS allows the use of "nano-size powders," enabling the creation of "unique structures" within the TBCs, Lewis reports. "Those structures will optimize the life of the coatings, as well as provide much better wear-resistance and corrosion protection."

Since many new engines rely on
advanced TBCs and metallurgy to meet the temperature-life cycle requirements of their design, MRO facilities will need to inspect, strip and re-coat the components to ensure longer life and reduced component part costs for the overhaul cycle.

"Advanced TBCs typically have longer lives and are less prone to spalling (separation), as compared to previous coating application technologies," says Kerry Boucher, vice president for engineering at StandardAero. "With the coating remaining on longer, the parts are better protected from the high-temperature environment created by the combustion gases."

In that regard, Boucher says turbine blades using the most advanced TBCs will generally go through the overhaul cycle showing no noticeable damage to the coating. "Very often, when a component of that kind goes into an MRO facility for overhaul, unless it's a life-cycle-limited part, it can go back into service, or the TBC can be stripped, the part overhauled and the coating reapplied. This extends the life of the part that much more."

The use of advanced TBCs, Boucher observes, is becoming more common in MRO because the capital costs of the application equipment is trending down. In fact, more StandardAero customers are specifying advanced thermal barrier coatings, using the electron-beam physical vapor deposition process.

"As a result, we are not scrapping out as many turbine blades, which typically account for a very large percentage of engine overhaul costs," Boucher notes. "The use of thermal-barrier coatings will lead to more opportunities to reduce maintenance costs."

He argues that EBPVD TBC coatings will continue to see increased usage to protect hot-section parts of all new gas turbines. "With the drive for increased efficiency and output, gas turbines will continue to be designed for higher firing temperatures, which in turn drives the need for improvements in part cooling and oxidation protection," Boucher explains.

StandardAero is investigating new uses for coatings through advancements in the equipment and process-application techniques. Boucher reports the company has developed...
patented multi-layer TBCs that also provide many of the benefits of EBPVD coatings.

"As the technology matures, MRO application of the coatings will be more prevalent and required in order to keep customer engine material costs in control," Boucher says. He predicts a pervasive use of TBCs will be consistent across all turbine engine types.

While he agrees that advanced TBCs are costly, Boucher stresses that the overall life-cycle costs of the components to which they are applied are reduced when "taking into account the increased repairability of parts and the reduction of fallout as a result of using protective coatings."

Nonetheless, GE's Nerz says that as TBC technology develops, it is more than likely that it will be an option—specified on a selective basis—for both forward-fit engines, and at the MRO level. Aircraft operators would select the new coatings taking into account where their airliners will operate, and their mission profiles.

Along this line, Chromalloy's Shankar says the benefits of the new TBC technologies "will be available to everyone," including operators with fleets of legacy engines. "As new developments with TBCs take place, they will be applicable not only to new production models, but to older turbine engines on a retrofit basis. As these new coatings are developed, the engines will benefit." 

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**THERMAL BARRIER COATING PRIMER**

New-generation turbine engines are being designed to run hotter for better fuel efficiency and lower emissions. This requires a second generation of thermal barrier coating (TBC) technologies that offer greater protection for costly engine components such as the high-pressure turbine blades and vanes.

"The new generation of ceramic TBCs, which are referred to as 'Low K TBC,' will provide lower conductivity, resulting in greater insulative conductivity," says Ravi Shankar, director of coating and process technologies for Chromalloy.

TBCs are typically a combination of metallic and ceramic materials, in which the ceramic material is bonded to the part by a metallic undercoating. In addition to its bonding properties, the metallic coating provides oxidation and corrosion protection. The ceramic coating furnishes the thermal barrier insulation, allowing the components to withstand the higher gas temperatures.

"The ceramic coatings essentially fool the components into thinking that the gas being generated is cooler than it really is," explains Shankar. "The result is less oxidation and corrosion, and longer-lasting, more durable components, which have less frequent removals."