BY REGINALD TUCKER

Chromalloy Keeps Aircraft Engines Aloft

Advanced thermal barrier coatings ensure high-revving gas turbines 'stay cool' under pressure.

Traditional hard chrome electroplating and Type II anodizing technologies have long been employed in the surface preparation or final coating of various aircraft components—landing gears and other functional parts chief among them. But for other key sections of the aircraft—namely the critical blades comprising the workhouse gas turbine engines—repair stations and OEMs typically opt for the higher performance thermal barrier coatings. Generally applied via electron beam physical vapor deposition, or EBPVD, these thermal barrier coatings—proponents say—are better equipped to handle the extremely high temperatures of today's advanced gas turbine engines, which can exceed 2400°F.

One highly regarded specialist in this area is Chromalloy, a leading independent supplier of technologically advanced repairs, coatings, and FAA-approved re-engineered parts for turbine airfoils and critical engine components for commercial airlines, military craft, industrial turbine engines, and aero-derivative applications. A pioneer in the development of commercially viable aluminide coatings, Chromalloy has introduced a series of innovative and proprietary processes that allow engines to perform at improved efficiency levels, at higher operating temperatures and under severe environmental conditions.

Dr. Ravi Shankar, director of coating and process technologies at Chromalloy, offers his perspective on why these thermal barrier "ceramic" coatings are so effective for these demanding applications (See Figure 1). "Ceramic coatings are inherently brittle. The EBPVD process creates a microstructure consisting of ceramic columns with gaps or porosity in between the columns, and this imparts on the coatings a thermal cycling resistance to the rapid cycles that occur in gas turbine engines. Other types of processes (i.e., powder coating, liquid paint, etc.) will produce coatings that have porosity, but they are only suitable for lower temperatures or limited temperature ranges. They simply would not survive the very rapid temperature exposures that are so prevalent in a gas turbine engine."

In that sense, one might consider ceramic finishes to be "smart" coatings, so to speak. "Thermal barrier coatings are used to essentially allow the engine temperature to run a little harder—the technology essentially 'fools' the blade into thinking that it's running colder," Dr. Shankar explained. "Use of thermal barrier coatings has allowed the operating temperatures of the high pressure turbine vanes and blades to increase significantly, thereby minimizing the deleterious effects on the part base metal."

Shankar points to other benefits. Not only has the overall efficiency of the gas turbine improved due to these thermal barrier coatings, but

Chromalloy's electronic beam physical vapor deposition center in Orangeburg, N.Y.

Figure 1. Aerospace turbine engine blade with thermal barrier coating. Ceramic coatings, which are electrically non-conductive, cannot be reproduced by electroplating or anodizing.

Partners in Research and Development

Chromalloy makes it a point to scout out opportunities for joint ventures and strategic partnerships both within and outside the traditional supply chain. One such opportunity surfaced in 2011, when it signed on as an "organizing industry member" with the Commonwealth Center for Advanced Manufacturing (CCAM), a public/private collaboration of member companies and Virginia's premier research universities: the University of Virginia, Virginia Tech and Virginia State University.

CCAM is primarily tasked with development of new manufacturing technologies and transference of processes from the research lab into the production environment. The center's organizing industry members, led by titans such as Rolls-Royce—the venerable turbine engine manufacturer—comprise diverse industries. Other prominent partners include Canon Virginia, Northrop Grumman Shipbuilding, Siemens and Sandvik.

In 2012 CCAM unveiled its new facility on 20 acres adjacent to the Rolls-Royce jet engine manufacturing facilities in Virginia. Rolls-Royce donated land for the 60,000-square-foot CCAM facility, which houses computational and large-scale production labs as well as open production space for heavy equipment and surface coating processes. Dr. Ravi Shankar, director of coating and process technologies for Chromalloy, recently told *Metal Finishing* magazine that his company is conducting both proprietary research as well as some generic research with the partners of CCAM. While the advancement of surface engineering is the focal point of this research and development, innovation in precision parts manufacturing is also high on the list.

For more information on the program, please visit www.ccam-va.com.

there have also been significant increases in the time intervals between required overhaul and maintenance, he explained. This results in significant cost savings to the gas turbine operator or repair station.

While Chromalloy says it is responsible for ushering in more recent innovations in this particular field, it won't take responsibility for the initial development of thermal barrier coatings (TBCs). That honor, according to Shankar, goes to the NASA, the National Aeronautics and Space Administration, which developed TBCs back in the 1970s. Back then TBCs were originally applied via plasma spraying—a more "conventional" application method. While application of ceramic coatings via plasma spray is still very much in use today, industry observers say operators tend to relegate that process for turbines used in the power generation industry, as the blades/vanes in those applications usually rotate at much slower speeds compared to aircraft turbine engines—and slower speeds translate into less centrifugal force.

By comparison, the EBPVD process employed in the coating of the more rapidly moving engine turbines grew in popularity as operators realized the benefits of the application process. As Shankar describes it: the electron beam melts a pool of ceramic ingots, which physically evaporate and condense on the part. As the part rotates over the molten pool, it generates a microstructure (similar to a toothbrush) with ceramic columns. To that end, as the base metal expands and cools in a gas turbine engine, these ceramic columns expand and close without cracking. "Because the coatings are applied at a very high temperature, the bonding is chemical, so it's stronger than the plasma spray coating," Shankar said. "And because each ceramic column is so dense, it provides good erosion resistance that can withstand the high-speed rotation of the blade."

The plasma spray method differs markedly from EBPVD, according to Shankar. Under the conventional plasma spraying procedure, he says operators essentially melt ceramic powders (using the plasma gun), which are then sprayed onto the part. Much like an organic painting process, layers of porosity are built in between as operators apply them onto metallic bond coatings that provide mechanical bonding. Because of this, Shankar argues, they have slightly lower erosion and thermal cycling resistance—which, at least in the aerospace industry, has limited their use to stationary parts such as nozzle guide vanes.

NEXT GENERATION INNOVATIONS

Having virtually mastered the requirements of today's demanding commercial and military aerospace applications, Chromalloy has its sights set on the next big hurdle—the even higher-burning gas engines of tomorrow. Manufacturers have made no secret of their goal to increase the gas temperature to levels greater than what was previously achievable, so the engines can produce more power and thrust.

To that end, Chromalloy is putting a lot of stock in one of its newest innovations, a patented coating called Low K RT-35™, a lower thermal conductivity coating that allows for the same coating thickness for optimal insulation, but enables the turbine blades to run cooler while

Figure 2. An aerospace turbine engine blade coated with Chromalloy's Low K RT-35 coating.

Figure 3. Air plasma spray robot applies thermal barrier coating.

the engine temperatures heat up (See Figure 2).

According to Chromalloy, the new Low K RT-35™ coating was the result of a multi-year process that culminated with certification for commercial aircraft engines. The coating was engineered to address a very specific challenge: When operating temperatures escalate in advanced gas turbine engines—especially temperatures exceeding 2400°F—the conventional "7YSZ" thermal barrier coated parts showed rapid deterioration due to insufficient thermal protection. In addition, researchers found its own sintering reduced the thermal barrier coating's compliance, causing additional stresses resulting from volume changes due to phase transformation at the higher temperatures. To address this issue, Chromalloy and other developers produced new thermal barrier coatings to provide lower thermal conductivity to more effectively insulate the thermal transfer to the components.

Chromalloy's Low K RT-35™ coating, applied via EBPVD, of course, was successfully flight tested by a prominent Asian airline. The coating was demonstrated to enhance thermal insulation and provide greater protection for erosion and thermal cycling initially on coupons and pins, according to Shankar. (Additional planes incorporating the specially coated blades are continuing to fly, with no negative feedback, he reports.)

Chromalloy's Low K RT-35™ coating was ultimately certified by the FAA in 2010 for use on the PW4000 second-stage high-pressure turbine blade. Certification followed a series of tests confirming the low thermal conductivity (50% lower, to be more precise), high thermal cycle durability, high sintering resistance, high thermal–chemical stability, and good phase stability of the coating. What's more, Low K RT-35™ increases oxidation and corrosion resistance of the underlying bond coating, thereby extending the life of the engine components.

The next challenge for Chromalloy centers on the potential for the development of coatings that entail more usage of composites—materials that are being considered for commercial aircraft design. According to Shankar, some OEMs have tried to make turbine/compressor components with composites for engine tests. In those cases, Chromalloy has provided coatings for experimental purposes. But Shankar admits they haven't really gone to the stage where they have been commercialized and mass produced. "I think it will be a few years before composites get into routine production," he surmised.

So, for the time being, Chromalloy is sticking to its recipe for success by continuing to work with the OEMs and customers in commercial aviation and other market segments to address both present and emerging manufacturer and operator needs.

"As turbine manufacturers increase the internal operating temperatures of engines to provide more power and improvements to the engine operation," Shankar notes, "the need for new coatings will continue."

ABOUT CHROMALLOY

Chromalloy employs more than 4,000 people and maintains sales and production operations in 17 countries. The company supplies components, coatings, and advanced manufacturing services to original equipment manufacturers, and it also offers extensive engineering and component repair capabilities for aviation, marine, and land-based aero-derivative and heavy industrial turbine engines.

Now in its 61st year of operation, Chromalloy has built up a repertoire of coatings for aero engines and energy generation alike. Chromalloy is also focusing on the manufacture of replacement parts, offering a full array of castings, coatings and repairs, developed both independently and in conjunction with OEMs.

For more information, please visit www.chromalloy.com.