Oerlikon Metco explains how it is improving the thermal protection of aero-engine components through innovative new material compositions, processes and coating applications. *Aerospace Manufacturing* reports.

**Oerlikon Metco** says its customers have long benefited from robust and reliable thermal barrier coating (TBC) solutions that protect their turbine engines from the ravages of high temperatures. To increase turbine engine efficiency, better solutions are needed to withstand hotter temperatures. Oerlikon Metco is meeting the challenge using a combination of new material compositions, powder manufacturing processes, and advanced coating application technology.

TBC systems consist of a heat-insulating ceramic coating applied over an oxidation-resistant metallic bond coat that results in reduced heat transfer into the base material. The benefits are improved mechanical properties and added life expectancy. These coatings are applied to transition ducts, combustors, heat shields, augmenters (afterburners), nozzle guide vanes, and blades (buckets).

One example of an application using TBCs is the F100 engine, which powers F15 and F16 military aircraft. This engine employs a TBC system on the augmenter. Here, already-hot exhaust gases are reignited to burn residual fuel, giving the aircraft additional thrust when needed. The TBC system ensures the service life and mission-readiness of the augmenter, both of which would be severely degraded without it.

**New materials solutions**

Research with universities shows alternative coating compositions are critical for future engine designs, but coating microstructure is just as important. Typical TBC ceramic microstructures are composed of large globular porosity, fine interparticle porosity and intraparticle microcracks. To minimise detrimental coating changes with time and temperature, it’s necessary to understand not only the volume of the combined porosity types, but how their size and distribution affect the coating's thermal conductivity. Changing the apparent density, porosity, and microstructure of a TBC system is not only a function of application parameters, but also powder manufacturing methodology and properties. Raw materials are selected for size, purity, chemical homogeneity and phase stability. Manufacturing details, such as heat treatment profile, particle sizing, and shape are critical for the stability and reliability of the final coating. Oerlikon Metco understands these critical factors and combines them to meet customer needs. As there is no single coating material that meets the design requirements for all turbine engines, the company offers a range of materials in standard, high-purity, and advanced low-k compositions, i.e., with better thermal insulation properties. Working with customers and academia, Oerlikon Metco is developing new material compositions, including: pyrochlore oxides (Metco 6041); zirconia structures co-doped with rare earth oxides to create oxide defect clusters (Metco 206A); Perovskite structures for advanced, low-k alternatives.

To be successful, many of these new compositions will require intermediate ceramic coating layers and improved bond coats. The Amdry 386 family of bond coats (NiCoCrAlSiHfY) is another family of Oerlikon Metco products that...
show excellent performance as a TBC bond coat. Materials can be applied by atmospheric plasma spray, controlled-atmosphere plasma spray, or high-velocity oxyfuel spray (HVOF).

TBC powders are made of the ceramic material zirconia and stabilised with yttria (YSZ). Oerlikon applies two types of manufacturing procedures for blending and fusing the components of the TBC powder: agglomeration and plasma densification. These powders are best for standard porosity, high-deposit efficiency applications. With agglomeration and sintering, these powders are best for high-porosity thick TBC coatings.

**Advances in applications**

Cascading arc technology for plasma spray guns is a proven method for reducing TBC system application costs. The Oerlikon Metco TriplexPro-210 spray gun is said to apply coatings as much as 300% more efficiently than traditional plasma spray guns, saving both time and cost. Furthermore, the inherent process stability of the TriplexPro-210 reduces both run-to-run variation and coating variability on individually coated components. This translates to more reliable TBC coatings and more predictable service life. Other plasma systems using this cascading-arc concept are those using the SimplexPro spray gun technology.

Augmenters are large parts of approximately 2m x 1.0m in diameter that require roughly 4.5 hours for TBC coating application using a conventional plasma gun. Here, the gun must be maintained after 15 hours of spray time, which causes work stoppages after every three parts. The same coating can be applied using the TriplexPro-210 in only 15 hours, and work stoppage for gun maintenance need only occur after around 150 to 200 spray hours. Moreover, TriplexPro-210 coatings are more consistent.

Oerlikon Metco has also been developing TBC applications using plasma spray in near-vacuum conditions (approximately 1mbar) to create new coating microstructures with improved compliance. This special plasma spray PVD process (called LPPS Hybrid PS-PVD) creates microstructures that resemble the thick columnar structure of traditional electron-beam PVD coatings, but at much faster deposition rates and with superior characteristics.

For the first time, this technology allows the application of thermal spray coatings to shadowed (non-line of sight) areas, making processing of compound vane and airfoil segments more practical. Metco 6700 is a high-purity, 7-8wt.% YSZ material designed for the PS-PVD process. The powder has been used to spray HP nozzle guide vanes. The PS-PVD process also allows for multilayer microstructures that may be beneficial for high-temperature erosion and calcium-magnesia-alumina-silicate infiltration.

**Coating results and economics**

New powder and equipment technologies support changes in coating microstructures that result in lower thermal conductivity and are more robust. TBC coatings with typical porosity levels of 5 vol.% are less thermally insulating and more prone to sintering and spallation than new high-purity systems with porosity levels of 10-15 vol.%. Testing has shown these high-purity systems show improved sintering characteristics, are less prone to structural changes and have better thermal-cyclic life.

Looking at coating economics, the following costs have to be considered: coating materials; coating system (spray gun), maintenance; labour; consumables (gases, electrical, etc.).

While new TBC materials with alternative rare earth oxides may be significantly more expensive than legacy materials, much of this cost will be offset by improvements in application technologies. These overall coating economics must be weighed against the expected gain in turbine engine efficiency and component service life, as well as the reduction in exhaust gas emissions. In general, these gains will be much larger than the anticipated increases in coating costs.

New ceramic materials include: high-purity zirconia-based materials for improved high-temperature sintering resistance. Low-k compositions utilising pyrochlores, perovskites, or advanced oxide defect cluster ceramic compositions for improved high-temperature heat insulation, high-temperature phase stability, and/or CMSA resistance. EBC compositions for optimal protection of CMC structures.

New methods of manufacture, such as agglomerated and sintered powders are required for high-porosity and high-coating thickness TBCs. New application techniques include: cascaded gun technology for reduced spray time, more consistent quality, and vertically segmented cracked structures; modified PVD-type processes for extremely strain-tolerant coatings; the design of multilayer TBC coating microstructures to optimise performance.

**Future developments**

For Oerlikon Metco, the development of new TBC systems and application technologies will continue into the foreseeable future and comprise two important topics. The first is Segmented TBC coatings applied with atmospheric plasma spray (APS). Besides PS-PVD and TriplexPro-210 technology, Oerlikon Metco is looking at supporting the customer base through the development of strain-tolerant, segmented coating microstructures with existing products like Metco 204F, Metco 204NS-G, Metco 233B, and new TBC chemistries.

The second topic concerns a new class of high-temperature protective coatings called environmental barrier coatings (EBCs) for ceramic matrix composites (CMCs). EBCs are expected to replace superalloy substrates, but have to be protected from water vapour attack. Oerlikon Metco’s ability to customise EBC compositions using different powder manufacturing approaches is critical to the success of this application in order to give engine manufacturers the coating properties they require.

Further advances in the performance of thermal barrier coatings will be possible by new ceramic material compositions, new powder manufacturing methods, new multilayer, functional designs in coating microstructure, and new application processes. Oerlikon Metco has invested in a strong global supply chain management and alternative powder manufacturing technologies, as well as experienced scientists, engineers, and technicians to support the commercialisation of advanced materials and future application technologies.

www.oerlikon.com/metco

**SPECIAL REPORT: SURF ACE FINISHING**

**ABOVE** The aircraft industry benefits from coatings through reduced cost of ownership, longer component life, improved engine efficiency, fuel savings, and lower emissions.

**BELOW** The commercialisation and scale-up of the LPPS-Hybrid PS-PVD process demonstrated with multiple dummy vanes mounted within the spray chamber.
Today’s aircraft power plants require new surface solutions to meet the evermore demanding needs for fuel efficiency and emission reduction. That’s why Oerlikon Metco has been hard at work developing new solutions, such as high-temperature ceramic abradable materials for better efficiency in the hot section and thermal barrier materials that allow engines to run hotter and longer. To apply these materials at lower processing time and cost, we’ve designed cascading arc plasma spray guns and easy-to-use spray control systems. These are just a few examples why power plant OEMs worldwide partner with us to develop ideal surfaces for the engines of today and tomorrow.

With Oerlikon Metco, your choice is simple!

www.oerlikon.com/metco
https://www.oerlikon.com/stories/