

Erosion Coatings for High-Temperature Polymer Composites: A Collaborative Project With Allison Advanced Development Company

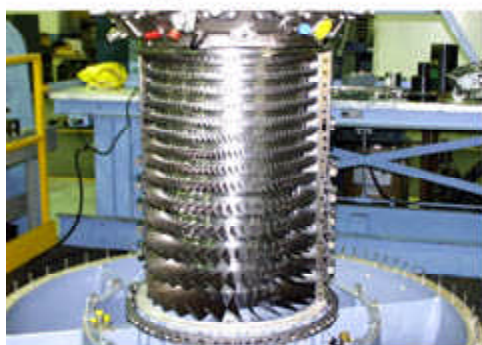
The advantages of replacing metals in aircraft turbine engines with high-temperature polymer matrix composites (PMC's) include weight savings accompanied by strength improvements, reduced part count, and lower manufacturing costs. Successfully integrating high-temperature PMC's into turbine engines requires several long-term characteristics. Resistance to surface erosion is one rarely reported property of PMC's in engine applications because PMC's are generally softer than metals and their erosion resistance suffers. Airflow rates in stationary turbine engine components typically exceed 2.3 kg/sec at elevated temperatures and pressures. In engine applications, as shown in the following photos, the survivability of PMC components is clearly a concern, especially when engine and component life-cycle requirements become longer.



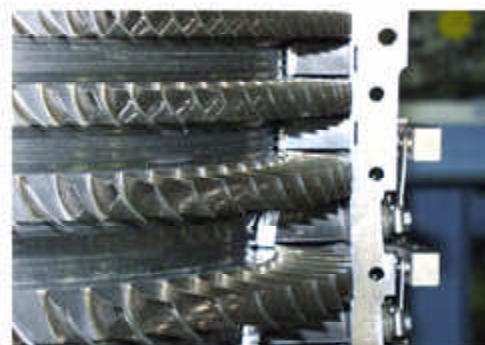
AE 2100 Inlet
Housing/Shroud/Guide Vane



AE 3007 Fan



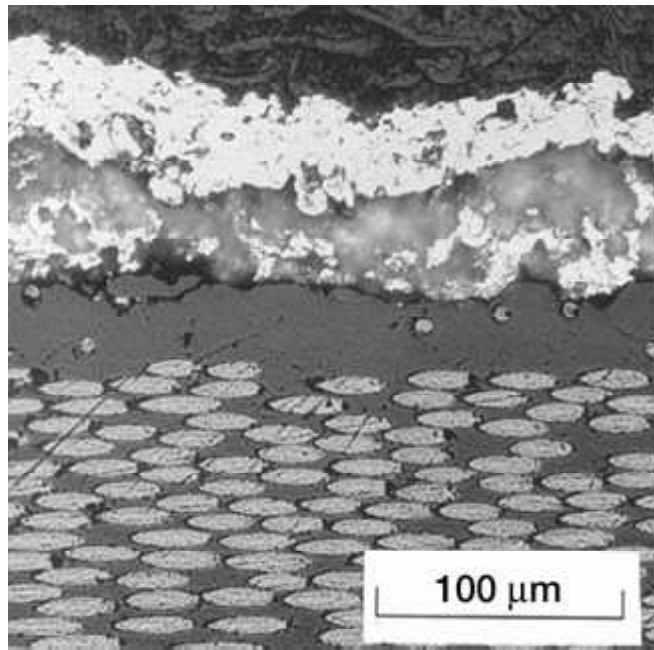
AE 3007 Rotor Assembly
Compressor Case Removed



AE 3007 Rotor Assembly/Stator Vane

Erosion coating applications in gas turbines.

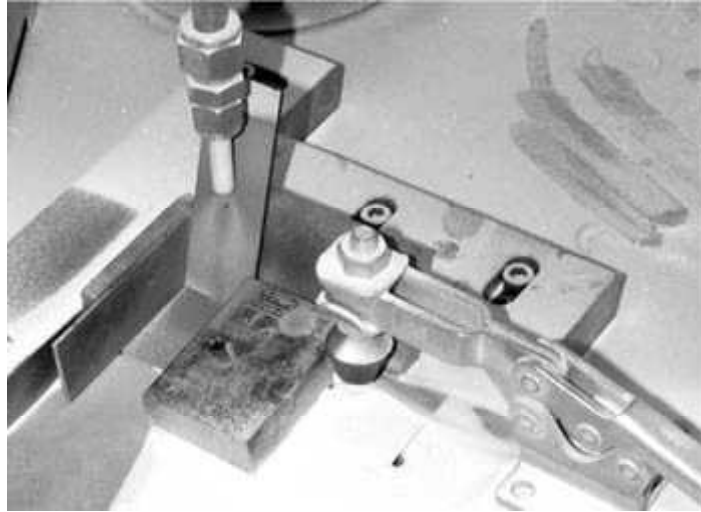
Although very few publications regarding the performance of erosion coatings on PMC's are available—particularly in high-temperature applications—the use of erosion-resistant coatings to significantly reduce wear on metallic substrates is well documented. In this study initiated by the NASA Glenn Research Center at Lewis Field, a low-cost (less than \$140/kg) graphite-fiber-reinforced T650–35/PMR–15 sheet-molding compound was investigated with various coatings. This sheet-molding compound has been compression molded into many structurally complicated components, such as shrouds for gas turbine inlet housings and gearboxes. Erosion coatings developed for PMC's in this study consisted of a two-layered system: a bondcoat sprayed onto a cleaned PMC surface, followed by an erosion-resistant, hard topcoat sprayed onto the bondcoat as shown in following photomicrograph. Six erosion coating systems were evaluated for their ability to withstand harsh thermal cycles, erosion resistance (ASTM G76–83 "Standard Practice for Conducting Erosion Tests by Solid Particle Impingement Using Gas Jets") using Al_2O_3 , and adhesion to the graphite fiber polyimide composite (ASTM D 4541–95 "Pull Off Strength of Coatings").



Erosion coating/T650–35/PMR–15.

Glenn and Allison Advanced Development Company collaborated to optimize erosion coatings for gas turbine fan and compressor applications. All the coating systems survived aggressive thermal cycling without spalling. During erosion tests (see the final photo), the most promising coating systems tested had Cr_3C_2 -NiCr and WC-Co as the hard topcoats. In all cases, these coating systems performed significantly better than that with a TiN hard topcoat. When material depth (thickness) loss is considered, the Cr_3C_2 -NiCr and WC-Co coating systems provided, on average, an erosion resistance 8.5 times greater than that for the uncoated PMR–15/T650–35 composite. Similarly, Cr_3C_2 -NiCr and WC-Co coating systems adhered to the PMC substrate during tensile tests significantly better than systems containing a TiN topcoat. Differences in topcoats of Cr_3C_2 -NiCr and WC-Co were

determined by considering issues such as cost and environmental impact. The preferred erosion-resistant coating system for PMR-15/T650-35 has WC-Co as the hard topcoat. This system provides the following benefits in comparison to the coating system with $\text{Cr}_3\text{C}_2\text{-NiCr}$ topcoat: lower powder material cost (15 to 20 percent), environmentally friendly materials ($\text{Cr}_3\text{C}_2\text{-NiCr}$ is hazardous), and higher deposition yield (10 to 15 percent), which results in less waste.



Erosion rig.

Bibliography

Naik, S.K., et al.: Erosion Coatings for High Temperature Polymer Composites. Proceedings of the 44th International SAMPE Symposium, vol. 44, book 1, 1999, pp. 68-81.

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