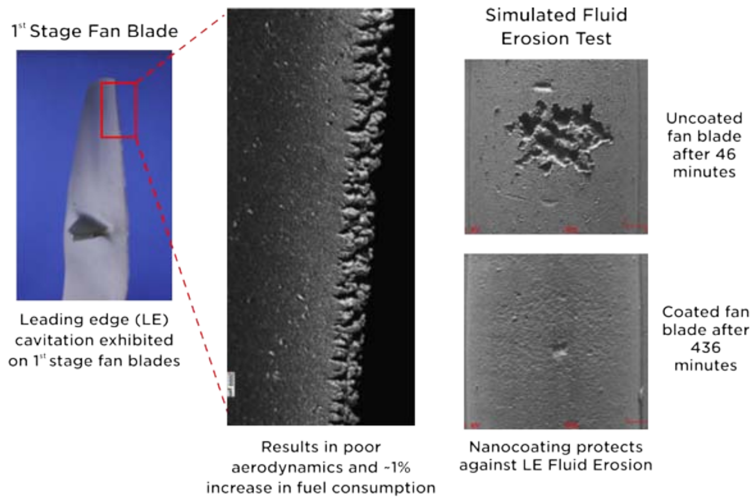
Erosion-Resistant Nanocoatings for Improved Energy Efficiency in Gas Turbine Engines

Nanocoatings Offer Low-Cost Method to Reduce Fuel Use and Increase Engine Lifetime

Optimizing the operation of gas turbine engines used in the transportation and energy sectors will result in significant annual fuel costs savings and reductions in these systems' environmental impact. Applying erosion-resistant nanocoatings to compressor airfoils that can extend component life is one means of reaching this goal.

In the transportation sector, contaminants such as road dust erode turbine air compressor blades used by the commercial aviation industry, degrading engine performance and increasing fuel consumption. In the energy sector, efficiencies in gas turbine performance can be increased under certain conditions by inlet fogging, a process that uses the evaporation of water droplets to increase inlet air density and thus increase mass flow and power. Applying engineered nanocoatings to compressor airfoils in inlet fogging systems is another way to optimize gas turbine engine performance. One key challenge in inlet fogging is that the water droplets used in fogging impact and erode compressor airfoils. Eroded compressor airfoils degrade engine performance by decreasing operational cycle time and reducing compressor efficiency. This degradation leads to increased engine operating costs, carbon emissions, and fuel consumption.

This project is addressing these challenges by optimizing and validating the performance of erosion-resistant (ER) nanocoatings designed for gas turbine engine applications. These nanocoatings will provide erosion protection to compressor airfoils, allowing engines to retain operational efficiency through a larger portion of their life cycle. Successful deployment of this technology will result in major petroleum savings for the U.S. commercial air fleet and enable the full energy efficiency benefits of inlet fogging for power generation companies.



Leading edge fluid erosion prevention.

Illustration courtesy of MDS Coating Technologies Corporation.

Benefits for Our Industry and Our Nation

By reducing fuel use and increasing engine lifetimes, erosion-resistant (ER) nanocoatings can provide numerous benefits to industry, including the following:

- Reduced carbon emissions due to higher compressor efficiencies; a 1% increase in compressor efficiency decreases carbon dioxide emissions by 1–4 pounds mass per hour
- Increased engine power due to greater use of inlet fogging, which can augment power output for an electricity-producing power plant by 7%–8% under certain conditions
- Increased productivity due to extended engine lifetimes

Applications in Our Nation's Industry

Effective ER nanocoatings will find applications in the gas turbine engines powering the U.S. commercial passenger aviation fleet and industrial power plants. Additional markets with potential applications include U.S.cargo and express package aircraft and the U.S. Department of Defense military aircraft.

Project Description

The project's goal is to test and substantiate erosion-resistant (ER) nanocoatings for application on compressor airfoils for gas turbine engines in both industrial gas turbines and commercial aviation. This project will verify this nanomaterial technology as an enabler for inlet fogging in industrial gas turbines and as an effective erosion protection strategy in commercial aviation turbines.

Barriers

- Ensuring a repeatable and nonvariable production process
- Ensuring that the quality and erosion resistance of the ER nanocoatings meet performance specifications

Pathways

The ER nanocoatings are applied using a cathodic arc physical vapor deposition process. The number of coating layers and their individual thicknesses will vary, and will be optimized depending on the erosion pattern on each compressor airfoil. If needed, a sacrificial coating layer can be applied to the ER nanocoating to provide corrosion protection.

Milestones

This project started in October 2008. Project work is pursuing two related pathways, shown below.

Industrial gas turbines:

- Performed fatigue tests on coated airfoils to confirm that the application of the ER nanocoating will not impact the material properties of the compressor blade (Completed)
- Performed ER nanocoating quality tests (hardness, surface finish, adhesion, and uniform coating thickness) (Completed)
- Perform field evaluations of coated and uncoated airfoils under inlet fogging conditions

Commercial aviation turbines:

- Performed erosion resistance tests to quantify and compare the benefits of a coated airfoil versus an uncoated airfoil (Completed)
- Performed coating quality tests (hardness, surface finish, adhesion, and uniform coating thickness) required to transition the ER nanocoating to production engines (Completed)
- Performed fatigue tests on the three different compressor stages that represent the three compressor blade material types found in the application engine (Completed)

Commercialization

For the industrial power sector, the near-term commercialization focus will be the application of the ER nanocoating to 44 engines of project partner Calpine's GE Frame 7 engine fleet. The mid-term strategy plans to transition the technology to other U.S. power plant operators and to other industrial gas turbine engine types experiencing erosion-related issues.

For the aviation sector, the near-term commercialization strategy with project partner Delta Airlines is to supply Delta with coated CFM56-7 engines (used in Boeing 737 and Airbus A320 aircraft) and coated CF6-80 engines (used in Boeing 767 and Boeing 747-400 aircraft). This strategy depends on successful certification of the coatings' flight worthiness per Federal Aviation Administration requirements. The next phase of commercialization will apply the coating to the remainder of Delta's fleet of engines. A parallel near-term strategy will pursue transition of the ER nanocoating to other large and medium-sized U.S. commercial carriers.

Project Partners

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