VEXTEC®

A VEXTEC CASE STUDY: # Accelerated Corrosion Testing Coated Turbine/ Compressor Blades

*Figure 1: VEXTEC small turbine engine*

## OVERVIEW

There are few operating environments harsher than the turbine engine. Couple that with their constant exposure to corrosive influences. Not all corrosion resistant blade coatings are developed and applied equally well. Conventionally used laboratory testing cannot adequately replicate the realistic engine environment well enough to identify which coatings work from those that don't from a durability perspective.

VEXTEC, using small engine testing, has launched a new practice for verifying component coating durability prior to being used in-service. Yet small engine testing can be accomplished at a fraction of the time and money required for full-scale testing.

## THE PROBLEM

Coating durability is corrosion resistance evaluated by dip testing samples in solution of caustic in the laboratory. Although the liquid is heated and stirred, it doesn't come close to the dynamic vaporous environment of an engine gas stream. Even additional "fog testing" - placing coated specimens in a cloud of caustic vapors – doesn't at all represent the true interaction of temperature, gas stream velocity, blade velocity and caustic vapor in the actual engine environment.

The USAF encountered a sulfur corrosion problem on fielded steel compressor blades. After over a year of trying, neither the USAF nor the blade manufacturer could replicate the type of corrosion using standard laboratory procedures. The USAF wanted to apply a corrosion resistant coating to the blades in order to mitigate the problem; however, that's not effectively accomplished without first being able to identify and understand the corrosion mechanism.

## THE SOLUTION

In 2009, VEXTEC launched small engine testing of turbines as a service to quickly and efficiently gather durability information on components operating in a realistic engine environment. The USAF provided VEXTEC with the seed funding to develop a better alternative to conventional laboratory (static) corrosion testing. Figure 2 shows the setup used to simulate the corrosion problem being encountered in Air Force fielded blades.

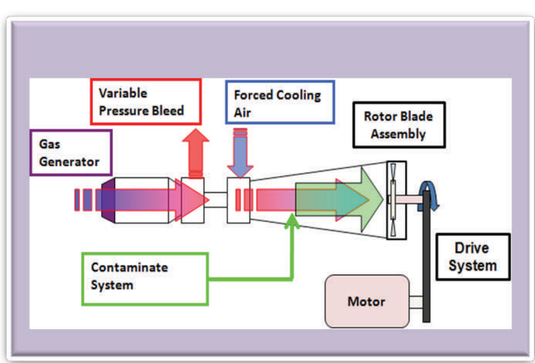


*Figure 2: Small engine corrosion set up.*

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THE SOLUTION *(cont.)*

The test configuration includes 5 basic subsystems:

- Gas generator – a small gas turbine creates the hot gas stream required to simulate full-scale environment
- Air handling – pressure bleed and force air cooling to fine tune the gas path temperature, velocity, and flow pattern
- Contaminate – controlled addition of corrosive chemicals into the gas stream
- Rotor blade assembly – coated blades mounted on a rotating disk.
- Motor drive system – rotational speed control of the test disk with coated blades

Given all prior attempts had failed to replicate the corrosion using standard laboratory procedures, a proof-of-concept test was performed to verify that small engine testing could produce field like corrosion. After 50 hours of testing it was confirmed that corrosion was being produced on the blades. A detailed metallographic inspection was performed and the results of the surface microscopic examination are shown in Figure 3. The right side of the figure shows corrosion damage into the surface of an actual fielded blade. The flight produced corrosion is a specific damage mechanism where the inter-martensitic attack the steel microstructure into the depth of the blade. The left side of the figure shows a small engine blade tested for 51 hours and that the corrosion mechanism was successfully reproduced both at the surface as well as in the depth.

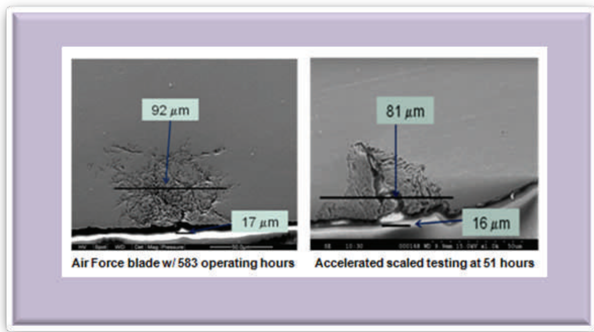


*Figure 3: Comparing flight and test produced corrosion using small engine testing.*

THE RESULTS

Given that the fielded blade corrosion was successfully reproduced, the USAF asked VEXTEC to use small engine testing to evaluate 3 different blade corrosion resistant coatings. The USAF selected the coating vendors. VEXTEC sent a set of 2 steel test blades to each, and the vendors returned the coated blades to VEXTEC. Each of the 6 coated blades, along with 4 uncoated (control) blades was mounted into the rotor assembly shown in Figure 4 and 200 hours testing were conducted as follows:

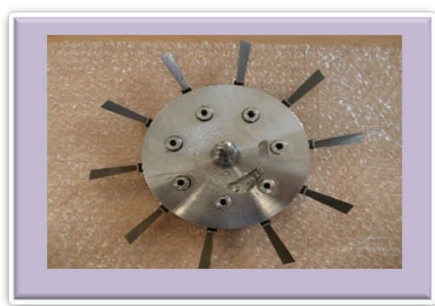

*Figure 4: Coated & uncoated blades mounted to the engine test rotor assembly*

- 5,500 RPM rotor speed
- 100% bypass air valve position
- 100% forced cooling air
- 6.8 gal/min contaminate
- 1733 PPM sulfur concentration in contaminate
- 80,000 RPM gas generator speed
- 300° F rotor gas temperature

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THE RESULTS *(cont.)*

A 300 °F rotor inlet temperature was maintained during testing since this temperature produced light condensate on the compressor blades.

Testing was stopped at 200 hours and it was readily apparent that the uncoated blades were corroded. A detailed inspection was conducted on each of the 3 vendor supplied coated blades. The results are as follows:

Vendor A (Figure 5)

- Coating failed
- Coating had crazed
- Coating had come off of leading edge and suction side
- Possible corrosion pits in exposed regions

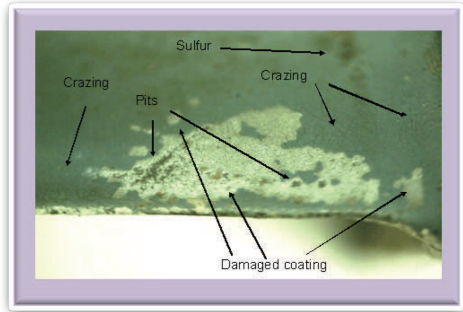


*Figure 5: Vendor A coating at 200 hrs testing*

Vendor B (Figure 6)

- Coating passed
- No apparent damage to coating
- No apparent corrosion

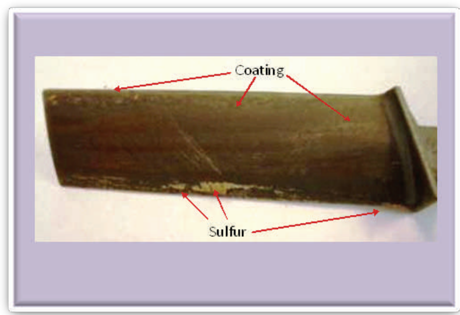


*Figure 6: Vendor B coating at 200 hrs testing*

Vendor C (Figure 7)

- Coating passed
- No apparent damage to coating
- No apparent corrosion

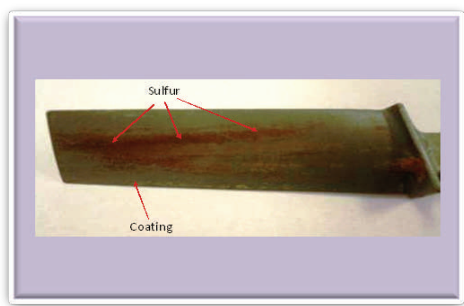


*Figure 7: Vendor C coating at 200 hrs testing*

ABOUT VEXTEC

*VEXTEC accurately, efficiently and economically predicts the performance, durability and true lifetime cost of a single component or an entire fleet—before they're ever built. Founded in 2000, VEXTEC has pioneered and patented innovations in material science and probability theory to form the foundation of its Virtual Life Management (VLM) technology. Manufacturing companies from such diverse industries as aerospace, heavy equipment, automotive, electronics, energy and medical implants can all benefit from VEXTEC's unique ability to predict product life cycles and failure, and most importantly, their financial consequences. To learn more, visit www.vextec.com.*