

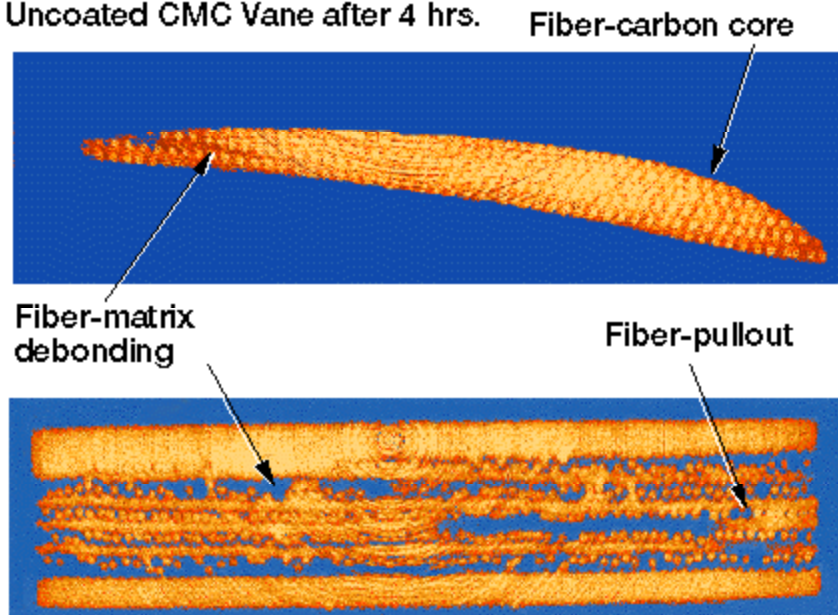
# X-Ray Computed Tomography Monitors Damage in Composites

A recent Presidential initiative in aeronautics and manufacturing technology identified critical technologies for solving key issues in materials and manufacturing. These technologies include high-quality processing of composites, rapid prototyping and reengineering, online sensors, and feedback controllers. The imperative is to reduce new-product development-cycle times and to integrate new technologies such as computed tomography (CT), smart materials with in situ sensors, and process controls. In this context, CT can provide rapid reengineering and cost-effective prototyping.

The NASA Lewis Research Center recently codeveloped a state-of-the-art x-ray CT facility (designated SMS SMARTSCAN model 100-112 CITA by Scientific Measurement Systems, Inc., Austin, Texas). This multipurpose, modularized, digital x-ray facility includes an imaging system for digital radiography, CT, and computed laminography. The system consists of a 160-kV microfocus x-ray source, a solid-state charge-coupled device (CCD) area detector, a five-axis object-positioning subassembly, and a Sun SPARCstation-based computer system that controls data acquisition and image processing. The x-ray source provides a beam spot size down to 3  $\mu\text{m}$ . The area detector system consists of a 50-by 50-by 3-mm-thick terbium-doped glass fiber-optic scintillation screen, a right-angle mirror, and a scientific-grade, digital CCD camera with a resolution of 1000 by 1018 pixels and 10-bit digitization at ambient cooling. The digital output is recorded with a high-speed, 16-bit frame grabber that allows data to be binned. The detector can be configured to provide a small field-of-view, approximately 45 by 45 mm in cross section, or a larger field-of-view, approximately 60 by 60 mm in cross section. Whenever the highest spatial resolution is desired, the small field-of-view is used, and for larger samples with some reduction in spatial resolution, the larger field-of-view is used.

This CT system demonstrated excellent resolution<sup>1</sup> at 20 lp/mm (25  $\mu\text{m}$ ) with 20 to 40 percent modulation in the small field-of-view mode, and at 10 lp/mm (50  $\mu\text{m}$ ) with 50 to 70 percent modulation in the larger field-of-view mode. It detected fibers, fiber-matrix debonding, and fiber pullout in  $[\text{O}]_5$  SiC/RBSN (reaction-bonded silicon nitride), and it detected fiber-matrix debonding and the carbon core of oxidized SiC fibers in an engine vane tested at 1040 °C for 4 hr. Images are shown in the accompanying figure. CT evaluation of thermally cycled C/SiC revealed preexisting porosity, internal architecture, cracking, degradation in coatings, and loss of SiC materials.

Engine Tested @ 1040°C (1900°F)  
Uncoated CMC Vane after 4 hrs.



Tensile Tested @ 21°C (70°F) 5-Ply CMC After Failure  
12.7mm (0.5 inch) wide

**CT cross-sections reveal fibers, fiber architecture, fiber-matrix debonding, and fiber pullout**

*X-ray computed tomography (CT) at NASA Lewis monitors damage in CMC's.*

NASA Lewis' CT facility can characterize critical manufacturing problems and compare as-designed with as-built metal matrix composite engine subcomponents (rotors and rings). The facility was developed to provide rapid reengineering and to reduce new-product development-cycle times. Lewis is cooperating with industry to transform the CT technology from a nondestructive evaluation tool to a manufacturing and structural quality improvement tool for in-process modeling, structural modeling, and product safety assurance.

<sup>1</sup>Resolution is given in lines per millimeter (lp/mm) and micrometers (mm).

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