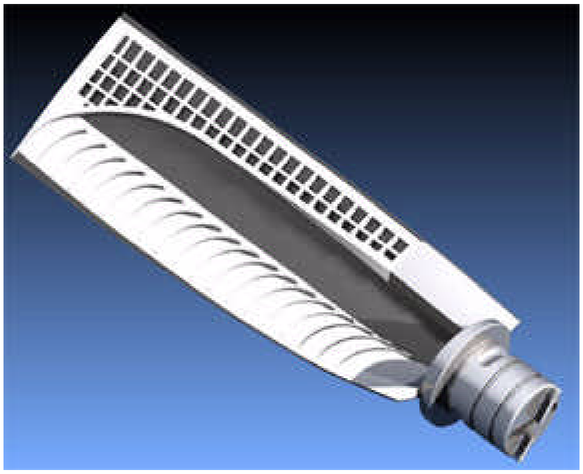
Novel Engineering and Fabrication Techniques Tested in Low-Noise-Research Fan Blades



Trailing Edge Blowing blade with top skin removed. Air enters at the retainer (bottom right) and exits through turning vanes at the trailing edge (left).

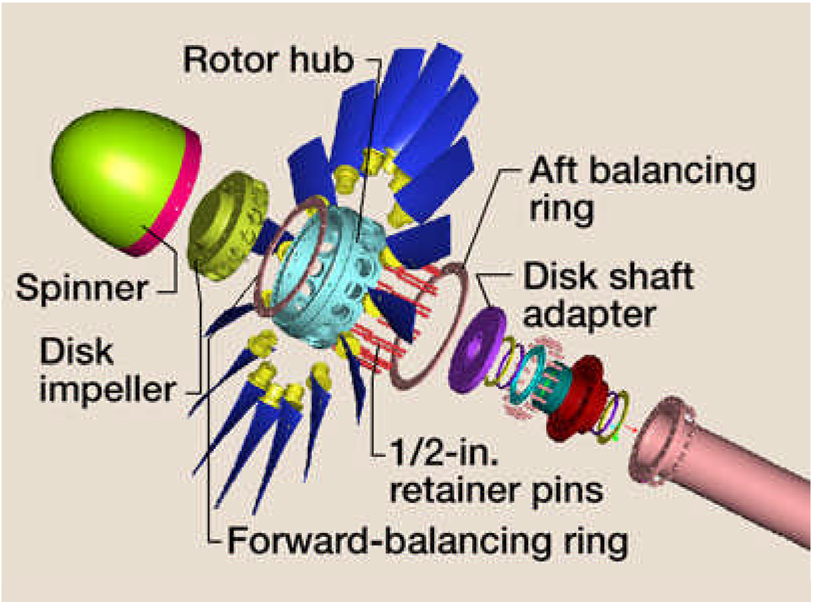
A major source of fan noise in commercial turbofan engines is the interaction of the wake from the fan blades with the stationary vanes (stators) directly behind them. The Trailing Edge Blowing (TEB) project team at the NASA Glenn Research Center designed and fabricated new fan blades to study the effects of fan trailing edge blowing as a potential noise-reduction concept. The intent is to fill the rotor wake by supplying air to the rotor blade trailing edge at the proper conditions to minimize the wake deficit, and thus generate less noise. The TEB hardware is designed for the Active Noise Control Fan (ANCF) test rig in Glenn's Aeroacoustic Propulsion Laboratory.

For this test, the air is fed from an external supply through the shaft of the rig. It is distributed to the base of each blade through an impeller, where it is forced into a plenum at the core of each blade. In actual engine configuration, air would most likely be bled from the compressor, but only at times when noise is an issue, such as takeoffs and landings.

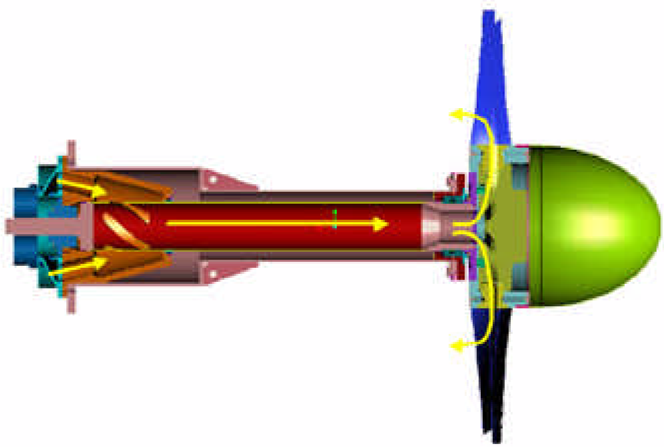
Glenn researchers designed and manufactured the blades in-house, using new techniques and concepts. The skins, which were designed for maximum strength in the directions of highest stress, were molded from multiple layers of carbon fiber. Considerable use was made of rapid prototyping techniques, such as laser sintering. The core was sintered from a lightweight polymer, and the retainer was CNC-machined (computer numerical control machined) from aluminum. All the components were joined with a cold-cure aerospace adhesive. These techniques and processes reduced the overall cost and allowed the new concept to be studied much sooner than would be possible using traditional fabrication methods.

Since this test rig did not support the use of blade-monitoring techniques such as strain gauges, extensive bench testing was required to qualify the design. The blades were examined using a variety of methods including holography, pull tests (cyclic and failure), shake tests, rap tests, and nondestructive inspection.

Acoustic testing of the ANCF fan using TEB has been ongoing since January of 2001. The fan has completed about 100 hr of testing with no structural, vibrational, or fatigue problems. Far-field acoustic measurements, in-duct mode measurements, precise hot wire surveys, and detailed performance measurements are providing data for evaluating the concept. The far-field noise data show that tone noise was reduced significantly with the initial ANCF TEB fan design. In addition, a significant reduction in unsteady stator loading has been measured, indicating the potential for stator broadband noise reduction. The acoustic benefits will be assessed and important design parameters identified to improve the ability to fully exploit any benefit provided by this technique.



ANCF Trailing Edge Blowing test rig showing the flowpath of the air supply through the shaft into the blades.



Exploded view of ANCF Trailing Edge Blowing test rig hardware. Mass flow, 2.6 lb/sec (2-percent total mass flow); pressure, 2.5 psig; rotational velocity, 2000 rpm.

On the basis of the success of trailing edge blowing, Glenn plans to continue this research with a higher speed, higher pressure ratio fan operating in an acoustic wind tunnel to simulate flight conditions.

Find out more about this research: http://www.grc.nasa.gov/WWW/7725/.

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