# Jet engine too hot? Schedule an MRI

November 22 2010

Magnetic resonance imaging (MRI), a medical imaging technology used to image organs and soft tissues, may hold the key to improving the efficiency of jet engines, according to Lt. Colonel Michael Benson, a Ph.D. student in Mechanical Engineering at Stanford University.

In only a few hours, an MRI collects as much three-dimensional data on flow and mixing as conventional methods that take two or more years of intensive measurement. This promises to slash the time needed to develop and test new designs that improve efficiency and performance, promising energy savings.

Benson is using MRI's to improve jet engine efficiency -- work he describes today at the American Physical Society Division of Fluid Dynamics (DFD) meeting in Long Beach, CA. The technique could also provide insights into other fluid mixing problems, ranging from combustion to the flow of oil through porous rock in a well.

Benson's study is one of the first to use an MRI to gather flow data. The technique was pioneered by Stanford researchers Christopher Elkins and John Eaton who used it to study coral colonies and turbine blades. Eaton suggested that Benson, currently in the Army, use the technique to analyze the mixing of hot combustion and cooling gases in jet turbines.

Jet engines are more efficient when they run hotter. In fact, the blades just downstream of the engine's combustor run very close to their melting point. To maximize efficiency, the trailing edges of these blades are razor thin.

"If you don't actively cool them, they melt," Benson said.

Turbine engines cool blades by diverting some incoming air into a series of snake-like passages that run through each blade.

"At some point, the blades become too thin to do that, so they peel off some skin at the end of the blade and let the air run over the trailing edge," Benson said.

When that cooler air exits the blade, it mixes with the hot air from the combustor, increasing the temperature of the blade surface above the coolant temperature. By analyzing how the hot and bypass air mix, Benson hopes to optimize bypass design and reduce the required amount of coolant. This would boost engine performance and fuel efficiency.

This type of analysis starts by measuring the temperature and velocity of the hot and bypass air streams as they mix. Researchers do this by releasing small particles, such as fluorescent dyes or oil droplets and hitting them with a laser. This illuminates the particles, whose positions are caught on a high-speed camera. A computer then analyzes the pictures and calculates the location and speed of the particles.

Unfortunately, the cameras capture only a small area, or tile, at a time. They also have a very narrow depth of field, the range of distance where the photos are sharp enough for analysis. As a result, all the tiles must be stitched together into a picture of a single plane. To visualize a three-dimensional experiment, many planes need to be generated and stitched together.

This takes time. "I know one Ph.D. student who spent three years collecting this type of data," Benson said.

The MRI captures the same amount of data in four to eight hours, he continued. This is because MRI's are designed to image three-dimensional objects. They do this by systematically disturbing the protons within hydrogen molecules with an electromagnetic pulse, and measuring their locations as they quickly realign with the magnetic field.

Benson uses a research grade MRI imager to run his experiments. The MRI images water mixed with copper sulfate, a low cost chemical often used to kill algae in ponds, which provides a rapid response to the pulses.

"Medical MRIs often use gadolinium as a contrast agent, but that's really expensive, especially if you're feeding fluid for a scan that runs for hours," Benson said.

Although Benson is still analyzing blade trailing edge designs, he has already made progress. "I'm already able to increase the surface cooling by 10 percent, which is equivalent to a blade temperature reduction of 100 to 150 degrees F," he said.

**More information:** The talk, "Measurements of 3D velocity and scalar field for a film-cooled airfoil trailing edge," is on Sunday, November 21, 2010. Abstract: meetings.aps.org/Meeting/DFD10/Event/132405

Provided by American Institute of Physics