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Jet Engine Too Hot? Schedule an Mri!

Using Magnetic Resonance Imaging to Improve Jet Engine Performance
Presentation at Fluid Dynamics Meeting Today in Long Beach, CA

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WASHINGTON, D.C., November 21, 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.

The talk, “Measurements of 3D velocity and scalar field for a film-cooled airfoil trailing edge,” is at 2:31 p.m. on Sunday, November 21, 2010, in Room 101A of the Long Beach Convention Center. ABSTRACT: http://meetings.aps.org/Meeting/DFD10/Event/132405

IMAGE: Images are available for use by reporters. Contact jbardi@aip.org

CAPTION: "Scalar Measurements Using a Medical MRI Scanner: Gas Turbine Trailing Edge Film Cooling Application"

CREDIT: Reporters may use these images so long as they credit "M. Benson, Stanford University."

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MORE MEETING INFORMATION
The 63rd Annual DFD Meeting is hosted this year by the University of Southern California, California State University Long Beach, California Institute of Technology, and the University of California, Los Angeles.

It will be held at the Long Beach Convention Center, located in downtown Long Beach, California. All meeting information, including directions to the Convention Center is at: http://www.dfd2010.caltech.edu/

USEFUL LINKS
Main meeting Web site: http://www.dfd2010.caltech.edu/
Search Abstracts: http://meetings.aps.org/Meeting/DFD10/SearchAbstract
Directions to Convention Center: http://www.longbeachcc.com/

PRESS REGISTRATION
Credentialed full-time journalist and professional freelance journalists working on assignment for major publications or media outlets are invited to attend the conference free of charge. If you are a reporter and would like to attend, please contact Jason Bardi (jbardi@aip.org, 301-209-3091).

ONSITE WORKSPACE FOR REPORTERS
A reserved workspace with wireless internet connections will be available for use by reporters in the Promenade Ballroom of the Long Beach Convention Center on Sunday, Nov. 21 and Monday, Nov. 22 from 8:00 a.m. to 5:00 p.m. and on Tuesday, Nov. 23 from 8:00 a.m. to noon. Press announcements and other news will be available in the Virtual Press Room (see below).

VIRTUAL PRESS ROOM
The APS Division of Fluid Dynamics Virtual Press Room will be launched in mid-November and will contain dozens of story tips on some of the most interesting results at the meeting as well as stunning graphics and videos. The Virtual Press Room will serve as starting points for journalists who are interested in covering the meeting but cannot attend in person. See: http://www.aps.org/units/dfd/pressroom/index.cfm

GALLERY OF FLUID MOTION

Every year, the APS Division of Fluid Dynamics hosts posters and videos that show stunning images and graphics from either computational or experimental studies of flow phenomena. The outstanding entries, selected by a panel of referees for artistic content, originality and ability to convey information, will be honored during the meeting, placed on display at the Annual APS Meeting in March of 2011, and will appear in the annual Gallery of Fluid Motion article in the September 2011 issue of the American Institute of Physics' journal, Physics of Fluids.

This year, selected entries from the 28th Annual Gallery of Fluid Motion will be hosted as part of the Fluid Dynamics Virtual Press Room. In mid-November, when the Virtual Press Room is launched, another announcement will be sent out.

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ABOUT THE APS DIVISION OF FLUID DYNAMICS

The Division of Fluid Dynamics of the American Physical Society (APS) exists for the advancement and diffusion of knowledge of the physics of fluids with special emphasis on the dynamical theories of the liquid, plastic and gaseous states of matter under all conditions of temperature and pressure. See: http://www.aps.org/units/dfd/

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