FEATURES

HPC Technology Enables Advancements for Increased Gas Turbine Engine Efficiencies

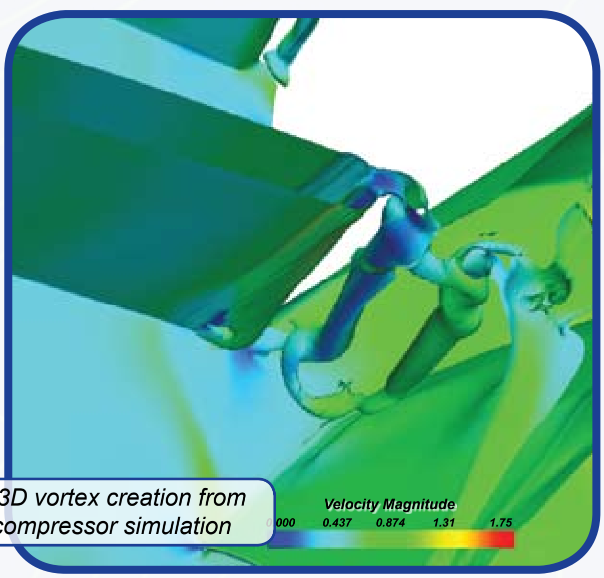
By Gary Sivak and Dinah Luneke

World demands call for increasingly cleaner, more efficient, and more reliable supplies of turbine engine power. To meet those needs, the gas turbine engine must evolve to provide improved economical performance, environmental efficiency, a streamlined design process, and longer service life. The gas turbine designs of tomorrow will quickly make the gas turbine engines of today obsolete. This exponential growth is not automatic, but it depends on the diligence, commitment, and expertise of dedicated AFRL scientists and engineers. Dr. Steve Gorrell and his team of experts are working to meet that challenge.

Built on a Rock

Dr. Gorrell has stated, "running HPC jobs at the AFRL MSRC has allowed us to be pioneers in applying computational science and engineering to gas turbine engines. We've worked to lead the way by running many first-of-their-kind simulations that were not even possible five years ago."

This work is built on the shoulders of the support staff at the AFRL MSRC, who provided the expertise and customer service needed to get the job done. They provided much needed support, such as animations of Dr. Gorrell's data for his Challenge Project. This support provided information for the Users Group Conference (UGC) and international conference presentations, presentations to AFRL's distinguished visitors, the Air Force Scientific Advisory Board, and numerous journal publications.



3D vortex creation from compressor simulation

The project has grown from around 100 million nodes, in terms of computational domain, to well over 300 million nodes. More than 2,000 processors are now used. Previously, only 400 were used, which shows the rate of growth for this work.

Codes Leading to Simulations

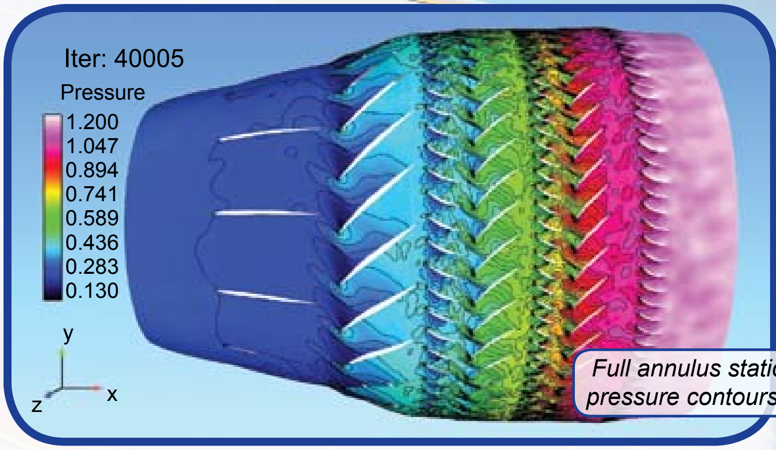
To run gas turbine engine simulations at the AFRL MSRC, the TURBO code was used, which is an unsteady Reynolds Averaged Navier-Stokes solver," Dr. Gorrell said. "This government- and industry-funded software package, developed by Professor Jen-Ping Chen at The Ohio State University, is only available to government agencies and their contractors.

Dr. Gorrell leads a team of six researchers and represents one of only a few groups doing full-annulus, multistage, and unsteady simulations of a fan or engine compressor. "This work is unique, as most researchers do not have access to computing resources to do this type of research," Dr. Gorrell commented. "We are modeling the full 360-degrees of an engine. Generally, researchers only simulate a small sector, such as a 45-degree sector."

HPCMP Computing Power

Approximately five years ago, Dr. Gorrell ran several projects at NAVO and AFRL. However, the results that were published in the Computing In Science & Engineering (CISE) magazine in 2007[1], as well as at recent UGC presentations, were based on the HPC work performed at the AFRL MSRC.

Dr. Gorrell remarked that, "Dr. Chen's code is pretty robust and can run on just about any type of machine. In addition to a good working relationship with the Center, what drives my motivation is expansion factor, or turnaround time." Members of Dr. Gorrell's team submitted some of the largest jobs to ever run at the AFRL MSRC. Their goal is to "utilize machines that can take a big job, turn it around, and get through the queue to get our simulation done. The reason why machines like the HAWK are so nice is because the AFRL MSRC machines have so many processors; therefore, we generally do not take as long to get through."



Full annulus static pressure contours

CFD Studies Speed Results

Dr. Gorrell's work is part of the Computational Fluid Dynamics (CFD) Computational Technology Area (CTA) and focuses on the unsteady simulation of flows through the gas turbine engine. The simulations model the variation of properties such as pressure and temperature in time, which are known as time-accurate studies. Steady, or time-average simulations, were used until recently, when computer power became what it is today. Steady simulations do not directly account for the unsteady flow through the engine and only calculate average performance.

Using TURBO, coupled with the HPC resources available at the AFRL MSRC with HAWK and EAGLE, unsteady flow simulations provide finer details of the complex flow that captures more of the physics. For instance, to measure inside a gas turbine engine and its moving blades, the pressure or temperature would look like a sign wave with area and time. Generally, only the average of that signal is calculated until unsteady simulations are completed. These calculations are performed through many time steps per revolution of the engine. Typical values could be on the order of 6 to 12,000 time steps per revolution.

These simulations, which directly support the AFRL Adaptive Versatile Engine Technologies (ADVENT) and Highly Efficient Embedded Engine (HEETE) programs, seek to understand complex, unsteady flow physics to improve the performance of the next-generation Air Force, Navy, and Army engines.

Through the application of time-accurate codes, better designs of the gas turbine engine can be developed with more accurate predictions of their performance at the outset, which includes thrust, efficiency, and fuel consumption.

ADVENT uses adaptive fans and cores to generate high thrust for jet engines when needed and to optimize fuel efficiency when cruising or loitering. "Generally, a fighter plane engine is designed for going fast, for going in and doing something and getting out. A transport jet engine is designed for high fuel efficiency. This new technology combines these engines, which has created, in essence, an adaptive and revolutionary engine," Dr. Gorrell said.

Tech Transfer Partnerships

This HPCMP Challenge Project, completed in 2007 at the AFRL MSRC, successfully pioneered a partnership between government and industry. With literally hundreds of millions of research dollars at stake, successful partnerships between government and industry are essential.

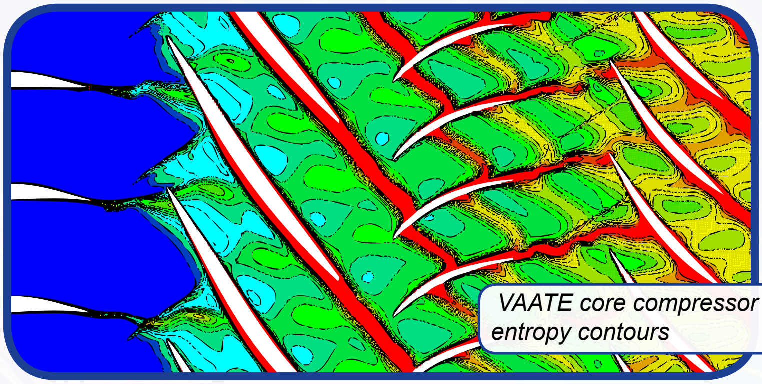
"Our team has worked with General Electric to provide resources they need to apply unsteady simulations to develop technologies for next-generation engines," Dr. Gorrell said. "We have shown the ability of government to partner with industry, and the AFRL MSRC to perform these simulations, which has been a great benefit. Now as these companies develop new engines, we are able to support them in doing simulations as they design those engines for ADVENT and HEETE programs."

Work Bridges World-Wide Impacts

During the development of a new engine, prototypes are built and tested to determine how well the engine performs. Components of an engine, like a compressor or fan, are also built and tested. Dr. Gorrell reports that his division estimates that approximately $500,000 is saved per test when taking advantage of unsteady CFD simulations. "And for the ADVENT engine, we hope to impact the actual engine itself. Since we've validated our tools with Air Force jet ▸▸

engine simulations, industry now has more confidence with using such design tools for building the ADVENT engine."

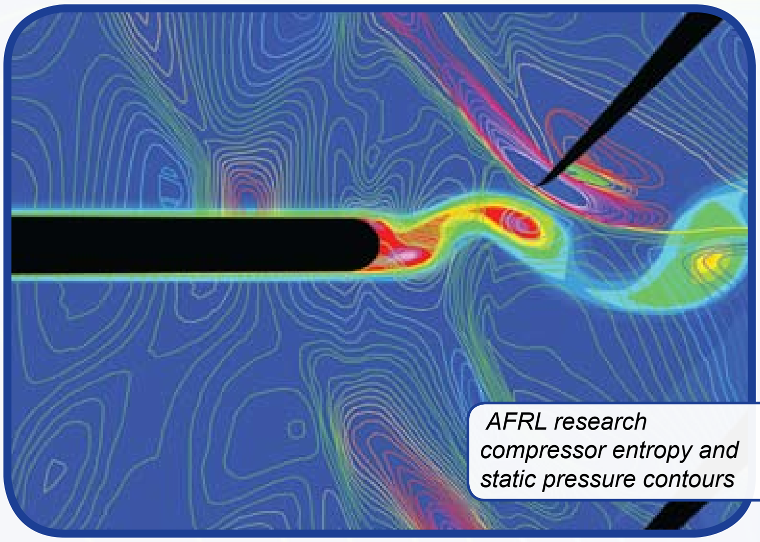
Dr. Gorrell reports, "what we are saying, proving and pioneering is that we've shown, using the AFRL MSRC resources with the right kind of simulations, that engine companies are recognizing the value of doing this type of research as they develop new engines. There is also great potential to reduce acquisition costs when using time-accurate simulations in the development process. This research work is far-reaching as military development drives the core part of commercial aircraft engines."



VAATE core compressor entropy contours

For several years, these simulations have also supported the 6.2 AFRL in-house applied research programs. Dr. Gorrell and his team have applied extremely large simulations to the engines that are being used for Air Force service, as well as using these simulations to support basic research functions in AFRL. This work helps to bridge this joint effort.

"Not only are we taking high-fidelity experimental measurements, but we're doing high-fidelity simulations," Dr. Gorrell said. "When you combine the two, that's when you really make the discoveries and advance the state-of-the-art. Without HPC resources, this research work would not be feasible." ■



AFRL research compressor entropy and static pressure contours

For more information, please contact CCAC at www.ccac.hpc.mil or 1-877-222-2039.

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1 - "Computing in Science & Engineering 2007 Annual Index, Volume 9," Computing in Science and Engineering, vol. 9, no. 6, pp. i1-i8, Nov/Dec, 2007