the ENERGY lab

PROJECT FACTS

Hydrogen Turbines

Gas Turbine Engine Collaborative Research—NASA Glenn Research Center

Background

Advancing the efficiency and performance levels of gas turbine technology requires high levels of fundamental understanding of the actual turbine component level technology systems. The National Aeronautics and Space Administration Glenn Research Center (NASA Glenn), with support from the Ohio State University, is planning research to compile available experimental information with additional experimental observations and data to develop required design tools in several key turbine hot gas path technology areas.

Continuous operation of gas turbines at full-load conditions requires running the turbines at temperatures that are much higher than the melting temperatures of the component materials. Film-cooling is one common method of cooling these hot gas path turbine component surfaces. Designing film-cooled components requires tools such as high-fidelity computational methods and the required computer programs. NASA Glenn's focused compilation of data, numerical schemes development, and computational codes application to film-cooling flows is presently underway.

Another area of research—pressure-gain combustion—can significantly reduce engine specific fuel consumption due to its inherent thermodynamic advantages over the standard Brayton cycle. While this technology has a low readiness level, its potential impact requires system-level and component modeling tools to improve understanding, accurately assess system benefits, and, if deemed viable, enable future implementation.

This project is managed by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL). NETL is researching advanced turbine technology with the goal of producing reliable, affordable, and environmentally friendly electric power in response to the nation's increasing energy challenges. With the Hydrogen Turbine Program, NETL is leading the research, development, and demonstration of these technologies to achieve power production from high hydrogen content fuels derived from coal that is clean, efficient, and cost-effective, minimizes carbon dioxide (CO_2) emissions, and will help maintain the nation's leadership in the export of gas turbine equipment.

Project Description

NASA Glenn is studying the physics of film cooling in order to enable better modeling of film-cooling flows. The study is conducted using a comprehensive method with experimental work guiding the numerical development. Detailed velocity, turbulence, and temperature surveys have been made, and further surveys for various film cooling hole shapes and arrangements under various conditions are planned. Measurements will be made of the thermal field and the flow and turbulence in the jet flow field behind large-scale film cooling hole geometries. Surface heat transfer and film effectiveness values downstream of the holes will also be determined.

CONTACTS

Richard A. Dennis
Technology Manager, Turbines
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4515
richard.dennis@netl.doe.gov

Robin Ames
Project Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-0978
robin.ames@netl.doe.gov

James Heidmann
Principal Investigator
NASA Glenn Research Center
21000 Brookpark Rd., MS 5-11
Cleveland, OH 44135
216-433-3604
heidmann@nasa.gov

PARTNERS

The Ohio State University

PROJECT DURATION

Start Date	End Date
10/01/2010	09/30/2012

COST

Total Project Value
$270,000

DOE/Non-DOE Share
$270,000/$0

AWARD NUMBER

FE0000412

U.S. DEPARTMENT OF ENERGY

Goals and Objectives

The goal of this collaboration is to utilize the analytical modeling capabilities provided by NASA Glenn for the purpose of advancing gas turbine models and validating advanced gas turbine concepts. The fiscal year (FY) 2011 objectives of this project are as follows:

- Implementation of features into NASA code to facilitate large eddy simulation (LES)/partially resolved Navier-Stokes (PRNS) simulations.
- Collection of data from DOE and NASA experiments.
- Assessment of current Reynolds-averaged Navier-Stokes (RANS) methods for NASA and/or DOE case.
- Initial assessment of LES/PRNS feasibility for NASA and DOE cases.
- Near atmospheric two-dimensional (2-D) axis-symmetric simulation of laboratory-scale pressure-gain combustor experiment to be used for validation.
- 2-D simulation results of laboratory-style pressure-gain combustor at relevant gas turbine conditions.
- Pressure-gain combustor simulation results with oxides of nitrogen (NO_X) and other finite rate chemistry models employed.

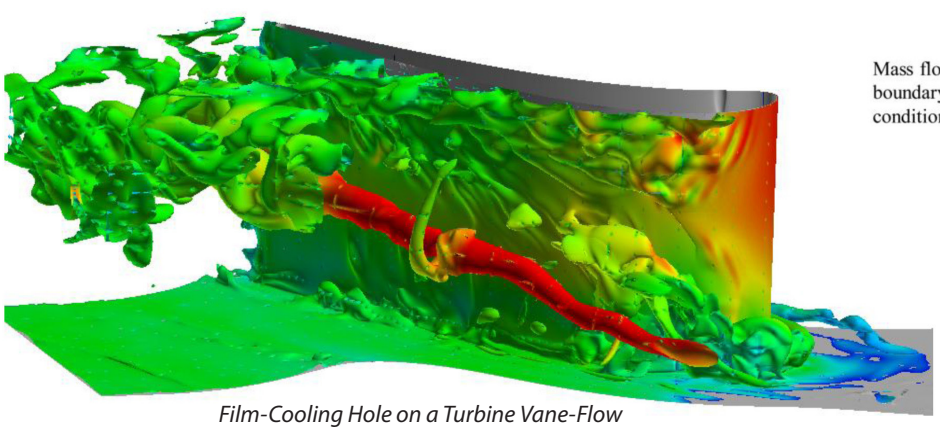
Accomplishments

The FY 2011 accomplishments are as follows:

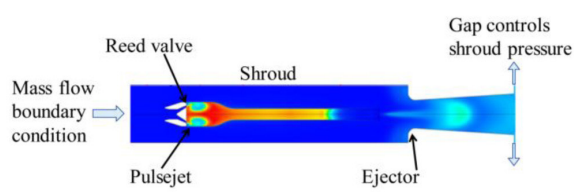
- Completed initial screening tests on novel film cooling configurations, achieving a 20% increase in film effectiveness.
- Implemented subscale models into a NASA code, Glenn-HT, to be used for flow modeling using a very large eddy simulation (VLES)/PRNS method.
- Implemented non-reflective exit boundary conditions into the code to be used for unsteady VLES/PRNS cases.
- Completed a study of alternatives to the central differencing scheme currently used in the Glenn-HT code.
- Implemented a solution probe capability, which is currently being implemented into the Glenn-HT to allow the user to specify at run-time an arbitrary number of points in the domain at which the solution is tracked and written to a file or to screen.
- A commercial computational fluid dynamics package, CFX, has been modified to simulate an existing laboratory-scale pressure-gain combustor demonstrator. The demonstrator rig is composed of a commercial pulsejet and ejector combination encased in a shroud. The simulation currently models the entirety of this rig.
- The simulation successfully resonates at relevant gas turbine conditions; however, the oscillations (and thus pressure gain) are lower than expected. This appears to be related to boundary conditions and reed valve modeling.
- The chemistry package for CFX has been examined and appears adequate for the work planned.
- Commercial software packages such as CFX (used in the present study) can successfully simulate the complex flowfields associated with mechanically valved resonant pulse combustors. This includes preliminary emissions estimates.
- CFX output, when an appropriate reed valve model is in place, closely matches experiments done at low inlet pressure (1–2 bar).
- Mechanically valved resonant pulse combustors can operate at elevated pressures and temperatures consistent with modern gas turbine compressor discharge conditions, and can provide a pressure gain. These combustors produce significantly lower NO_X levels when running resonantly than when running in a steady mode at the same average flow rate and stoichiometry.

Benefits

This collaborative project supports DOE's Hydrogen Turbine Program that is striving to show that gas turbines can operate on coal-based hydrogen fuels, increase combined cycle efficiency by three to five percentage points over baseline, and reduce emissions. NASA Glenn's Glenn-HT code has been an important tool for studying aerodynamics and heat transfer issues in gas turbines. The computer code is being fitted with more advanced computational tools such as PRNS and LES methods to allow for improved simulations, specifically, in two areas of film-cooling and flow transition.



Film-Cooling Hole on a Turbine Vane-Flow Features Colored by Velocity Magnitude.



Pressure-Gain Combustion Temperature Contours at One Instant of a Limit Cycle.