Advanced optical sensor for monitoring and control of multiple gas and turbine-blade properties
03-01-SR105

FACT SHEET

I. PROJECT PARTICIPANTS

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II. PROJECT DESCRIPTION

A. Objectives

Develop fiber-optic sensors for monitoring gas and turbine-blade properties.

- “research-grade” sensors for application in engine test facilities
- gain insight into strategies for “production-grade” sensing.

The optical sensors developed will be useful for improving gas turbine engine performance in a number of ways, discussed below under “background/relevancy”.

B. Background/Relevancy

Background
There are many cases in which fiber-optic sensors are well-suited to gas turbine engines. As an example, gas turbine engine designers have expressed a desire to accurately monitor and / or control the temperature distribution of gases entering the turbine. Careful optimization of this temperature distribution would enhance engine efficiency and reduce emissions. The optical sensors developed in this project have targeted such needs by enabling measurements of both gas

temperature distributions in combustion gases as well as actual turbine blade temperatures. We envision laser light distributed by fiber-optics and transmitted through the combustion gases as well as routed through turbine blade material to support these measurements. The gas and turbine blade properties are inferred from near-infrared transmission spectra. The primary goal of this project is the demonstration of such sensors in large-scale test facilities. These demonstrations will pave the way for more widespread sensor use in the gas turbine industry.

Relevancy
Ultimately, sensors such as those developed here will become a ready tool for gas turbine engine research and development. For example, they can potentially be used for "plug-and-play" attachment to prototype engines under test, thus providing critical information at the design stage and thereby reducing the cost of evaluating engine designs. Finally, the general sensing strategies that prove most successful in this project might become a foundation for future optical sensors in production engines.

C. Period of Performance

July 1, 2003 – June 30, 2006

D. Project Summary

Under the University Turbine Research (UTSR) program, the University of Wisconsin-Madison has been developing fiber-optic sensors for gas turbine applications.

Tasks carried out in this project:

1. Adapt newly-developed 'wavelength-agile' light sources for application in gas turbine environments
2. Refine strategies for routing fibers in turbine environments and embedding fiber-optic components in turbine-blade materials
3. Demonstrate gas temperature and species concentration measurements in laboratory environments containing gases at representative turbine conditions
4. Demonstrate embedded fiber-optic strategy for measuring temperature of moving metal components at representative turbine conditions
5. Attempt to measure both gas and turbine-blade properties at engine test facilities (e.g., Wright-Patterson Air Force Base - WPAFB, Dayton, OH)
6. Attempt to use sensors for online optimization or control of parameters related to gas turbine engine performance

One of the primary goals of this project is to demonstrate the potential of fiber-optic components for enabling measurements of critical parameters in harsh gas-turbine environments. Figure 1 shows four metal-sheathed fibers coupled to a mainburner sector under test at WPAFB. Laser transmission signals are collected with these fibers. Gas temperatures are derived from measured laser transmission signals in much the same way it is done in piston engine measurements (see http://www.erc.wisc.edu/advanced_diagnostics/optical_diagnostics.html, mouse-over and click on 'absorption'). Gas temperatures inferred in a gas turbine mainburner test rig at WPAFB are shown in Fig. 2 and are compared to gas temperature calculations based on sampled gas analysis. Note that the measured temperatures are laser-line-of-sight-average gas temperatures; multiple beam paths, as shown in http://www.erc.wisc.edu/erc_projects/erc_posters/Multiengine%20poster.pdf for a rocket engine test case are required to infer uniformity information.

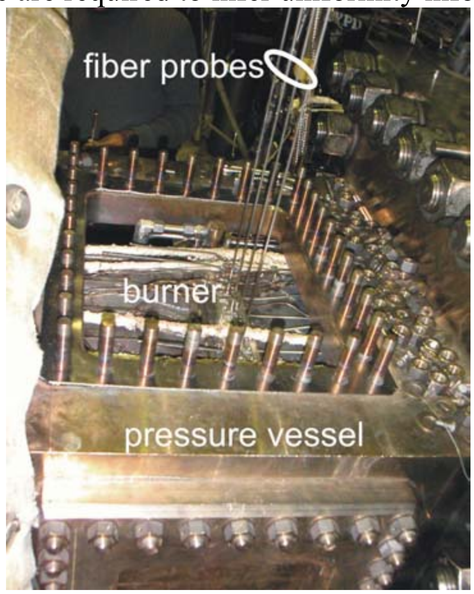

Figure 1. Photograph of WPAFB test facility with fiber-optic sensors installed; 4 metal-jacketed fiber probes are visible protruding from the top of the combustor chamber.

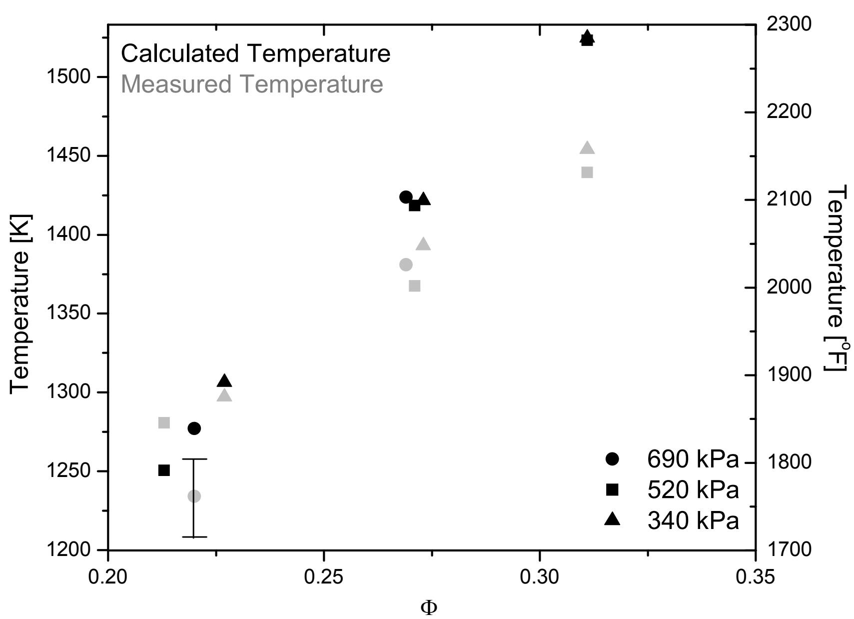

Figure 2. Gas temperatures measured by wavelength-agile absorption spectroscopy in the mainburner test facility at Wright Patterson Air Force Base.

III. PROJECT COSTS

A. Total cost to the UTSR for this project: $418,961

IV. MAJOR ACCOMPLISHMENTS SINCE BEGINNING OF PROJECT

During this project, we have made significant progress with respect to the objectives above. In particular, we have developed the wavelength-agile light source to the point that it is being considered as a commercial product in its own right. We have enlisted the help of key industrial partners such as Nufern (www.nufern.com) and Thermo Electron Corporation (www.thermo.com) to help form high-speed spectral sensing into a product that gas turbine researchers can readily use. We have demonstrated a novel, high-efficiency approach for coupling light to gas turbine environments using dual-clad fiber (DCF) (see http://www.engr.wisc.edu/me/faculty/sanders_scott/Hagen_2006_dual_clad_fiber.pdf). We have demonstrated gas-turbine combustion gas measurement capabilities as highlighted in For the purpose of embedding optical temperature sensors in turbine blades, we have identified commercial fiber Bragg gratings (FBGs) that can operate at temperatures up to ~ 1100 degrees C, and as a precursor to turbine blade measurements, we have successfully demonstrated FBG-based piston temperature measurements in a production reciprocating engine.

V. MAJOR ACTIVITIES PLANNED DURING THE NEXT 6 MONTHS

None – project ended 30 June, 2006.

VI. MAJOR ACCOMPLISHMENTS PLANNED IN OUTMONTHS (6-18 MONTHS)

None – project ended 30 June, 2006.

VII. ISSUES – None.

VIII. ATTACHMENTS – None.