HIGH-TEMPERATURE SENSOR APPLICATIONS FOR GROUND-TESTING OF C-17 ENGINE

Summary

The Flight Loads Laboratory (FLL) at the NASA Dryden Flight Research Center (DFRC) is attempting to acquire high-temperature dynamic strain measurements by using optical-strain sensors as a secondary experiment on the C-17 (The Boeing Company, Chicago, Illinois) engine "17th Stage Bleed-Air Duct Redesign Verification" tests. The Extrinsic Fabry-Perot Interferometer (EFPI) optical sensors have been used successfully during ground tests to measure static strains to temperatures as high as 1850° F, but no measurement attempt has been made in a combined high-temperature/vibration environment. In addition to optical strain measurements, valuable application experience and data will be generated from thermal-sprayed, free-filament, wire resistive strain gages in this hostile environment.

Objective

This task, performed under a NASA and Air Force Flight Test Center alliance agreement, allows DFRC to acquire valuable experience in applying wire resistive strain gages and also investigates the feasibility of using fiber optic strain measurements under very harsh conditions. In 1997 under the X-33 (Lockheed Martin Corporation, Bethesda, Maryland) program, the FLL installed dynamic high-temperature wire resistive strain gages for measuring combined thermal-acoustic loads on Inconel honeycomb thermal protection system (TPS) panels at the NASA Glenn Research Center in Cleveland, Ohio. The sensors provided good data with minimal failures to temperatures of 1550 °F at acoustic levels to 159 db. Unfortunately, this unique FLL measurement capability has not been further characterized since these initial tests.

Polyimide-coated optical Fiber-Bragg gratings have been used under combined acoustic loads and temperatures to 500 °F, but it is unclear whether the construction of the optical EFPI sensor will endure under similar conditions to even higher temperatures. The focus of the fiber optic research experiment on the C-17 engine during ground testing is to primarily look at sensor survivability issues such as fracturing of the gold-coated fiber, sensor head construction, and the attachment to the substrate. If successful, these tests could lead to an increased effort to develop flight-hardened fiber-optic systems, a technology area currently lacking in research. The commercial EFPI ground system used for these tests can sample at 1 KHz, but the manufacturer is currently working to increase the sample rate to 100 KHz. If the sensor survives and the sampling rate is eventually increased, valid high-temperature measurements can be achieved using a single optical sensor to obtain both dynamic and static strains.

Approach

Thermal-sprayed wire resistive strain gages, seen in figure 1, were attached to the 17th stage case wall near the right and left boss flanges and also on the 10th stage manifold per test requirements dictated by The Boeing Company and Pratt & Whitney (East Hartford, Connecticut). The U.S. Air Force-required tests will be conducted by Boeing in an attempt to isolate a possible unbalance of blades during bird strikes and the resulting vibration fatigue effects on 17th stage bleed-air duct. The instrumented areas are expected to exceed 1000° F during several engine runs.

Axial and circumferential gages were attached using thermal spray procedures described in NASA document DEI-R-011 (unpublished, internal report). Both plasma spray and Rokide flame-spray processes were used to roughen the surface, electrically insulate, and encapsulate the strain gages. Similar methods were used to attach the optical EFPI strain sensors. The optical sensors, seen in figure 2, are not required for the C-17 engine tests, but were integrated to provide research data on the sensor survivability.

Since two different types of high-temperature wire resistive gages are currently preferred for both a dynamic and static (temperature-compensated) measurement, the use of a single EFPI to accomplish the same measurement would be of great benefit. These tests will give NASA insight into the survivability of optical-strain sensors in harsh environments and the installation procedural changes required to improve this technology.

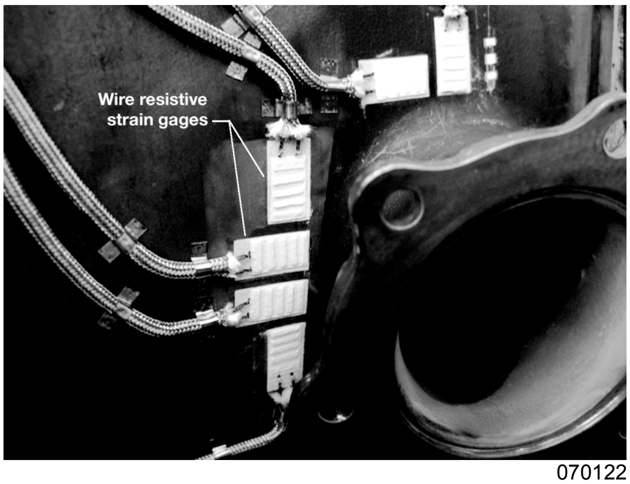

Figure 1. Left hand 17th stage bleed air boss instrumented with six strain gages and one optical EFPI.

Figure 2. Example of 10th stage duct instrumentation illustrating the optical EFPI strain sensor.

Status

Currently, developed attachment techniques for the EFPI sensor have been investigated only in high-temperature environments. Laboratory evaluations of the attachment integrity and sensor performance were done in static environments to 1850 °F on both Inconel and ceramic composite substrates. The attempt to measure under high-temperature dynamic conditions using the EFPI sensor is high-risk at this time since no coupon level work in this area has been initiated. Unfortunately, test opportunities that provide the needed test conditions, such as the upcoming C-17 engine ground tests, are rare.

Plans have been initiated to examine this sensor in similar thermal/dynamic laboratory conditions, but have not been implemented as of this time. Failure of the EFPI sensor during the C-17 engine ground tests does not exclude its eventual use for this type of application. It will, however, provide data that will guide future laboratory testing required to improve its ruggedness.

Contact:

Anthony Piazza, DFRC, RS (661) 276-2714