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NASA TECH BRIEF

Lewis Research Center

In-Service Turbine Wheel Crack Monitor

A turbine wheel crack monitor has been developed which can be utilized in flight or at the flight line. It monitors the disk rim for surface cracks emanating from the blade root interface.

Rotating parts present the most critical design and maintenance problems in an aircraft jet engine. Modes of failure depend not only on the material, but also on the operating stresses, vibration, temperature, and environment. Compressor, fan, and turbine disks are subject to fatigue-type failures because of the cyclic nature of stresses caused by temperature and centrifugal forces. Maintenance reports indicate that radial crack propagation from the blade root area of the disk rim has been frequently encountered in service. Further, some disks are designed with abrupt changes in web thickness that result in circumferential fatigue cracks. If not detected, these cracks can ultimately lead to engine failures.

The usual nondestructive tests for turbine disk surface cracks are the liquid penetrant, ultrasonic, and eddy current methods. These procedures usually require engine disassembly. Therefore, the inspections can be performed only when the engine is being overhauled.

This crack monitoring system consists of an eddy-current sensor, mounted approximately 1½ mm (1/16 in) away from the face of the disk, and a remotely located electrical capacitance-conductance bridge and signal analyzer. The sensor is a coil of wire wound on a bobbin of glass ceramic insulator material. The sensor can withstand operating temperatures of 811 K (1000°F), permitting its use in the high-temperature environment of the turbine section.

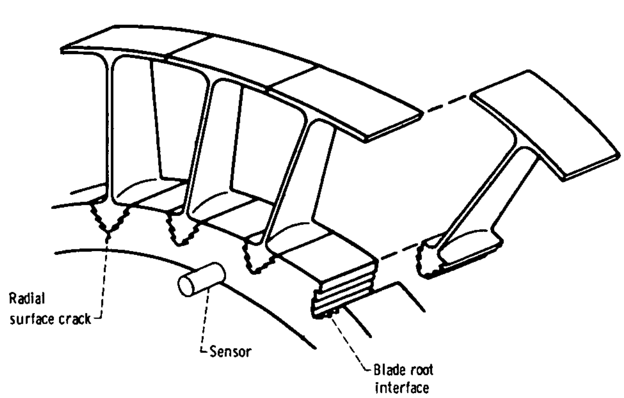

Figure 1. - Typical turbine wheel segment showing location of a radial surface crack and position of sensor.

As the rotor spins, the disk is monitored by the sensor for surface or near-surface cracks emanating from the blade root interface. Figure 1 illustrates a typical turbine wheel segment, showing the location of a radial surface crack and the position of the sensor. The sensor can be made an integral part of the stator or other appropriately located supporting strut.

Figure 2 is a simplified block diagram of the crack monitor. The sensor coil and cables are located inside the engine, while the automatic capacitance-conductance bridge and the crack signal analyzer are located remotely. The sensor and the bridge are connected by series capacitances and connecting cables.

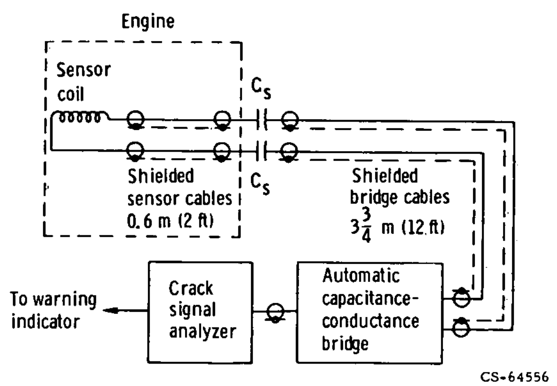

Figure 2. - Simplified block diagram of crack monitor.

The sensor cables, 3.18 mm (0.125 in) in diameter, pass through hollow stator blades or structural support members. The cables are made of thermocouple-type materials that can withstand inside-the-blade temperatures of 1200 K (1700°F).

The bridge used in the monitoring system is designed to measure capacitance and conductance. By adding capacitances in series with the sensor coil, the combined reactance can be made capacitive.

(continued overleaf)

Eddy current devices are sensitive to temperature and displacements between the coil and the surface, as well as to all surface discontinuities. The impedance of the coil varies with temperature because of changes in the resistance of the coil and of the disk. The capacitance-conductance bridge is self-balancing, automatically adjusting to changes in average coil inductance and resistance caused by temperature effects and variations in disk-to-sensor spacing. The bridge has two phase detectors, one whose output voltage is proportional to the unbalanced conductance.

The bridge takes about ½ second to balance, after which time the output of the conductance phase detector is monitored for out-of-balance voltages. The output of the conductance phase detector is used in the system since it is less sensitive to variations in disk-to-sensor spacing, during the monitoring time, than the capacitance phase detector. The sequence, balance then monitor, is repeated every 10 seconds. As the blade root region passes the sensor during the monitoring time, the conductance phase detector senses the change in effective conductance of the sensor coil.

The crack signal analyzer compares the crack voltage and the noise voltage to determine whether a crack exists. The noise voltage can be determined by measuring the negative peak amplitude of the circuit noise and blade root signal. The crack voltage is determined by measuring the positive peak voltage of the sum of the crack signal, the circuit noise, and the blade root signal. The two voltages are compared, and a crack is indicated if the crack voltage is greater than 1.3 times the noise voltage. The quantity 1.3, which was derived experimentally, prevents random pulses from exceeding the noise voltage and causing false crack indications.

Notes:

1. Tests indicate that the system is useful at disk rim velocities to 460 m/sec (1500 ft/sec).
2. The disk-crack detector should be of interest to manufacturers or users of electric ground based power systems.
3. Further information is available in the following report:

   NASA TN-D-7483 (N74-12187), Flight Monitor for Jet Engine Disk Cracks and the Use of Critical Length Criterion of Fracture Mechanics

   Copies may be obtained at cost from:

   Aerospace Research Applications Center
   Indiana University
   400 East Seventh Street
   Bloomington, Indiana 47401
   Telephone: 812-337-7833
   Reference: B75-10012
4. Specific technical questions may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B75-10012

Patent Status:

NASA has decided not to apply for a patent.

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