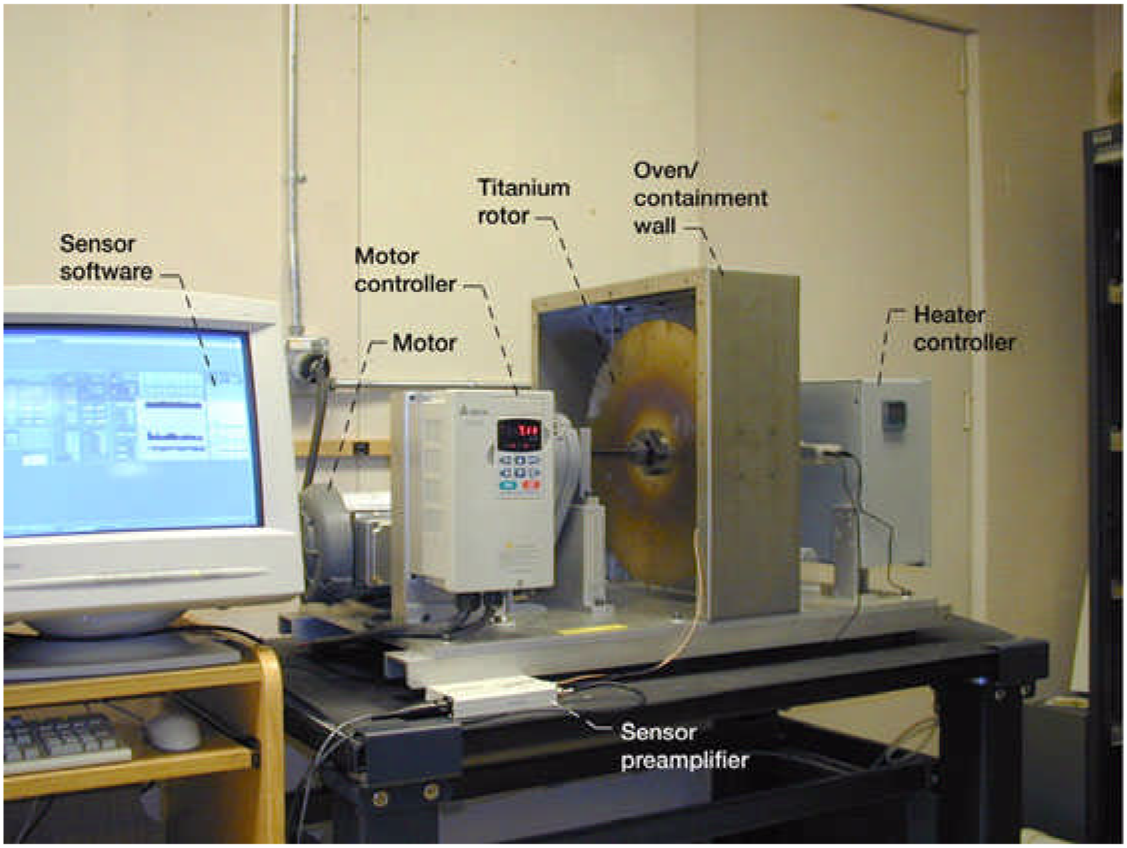
Vibration Monitoring Techniques Applied to Detect Damage in Rotating Disks

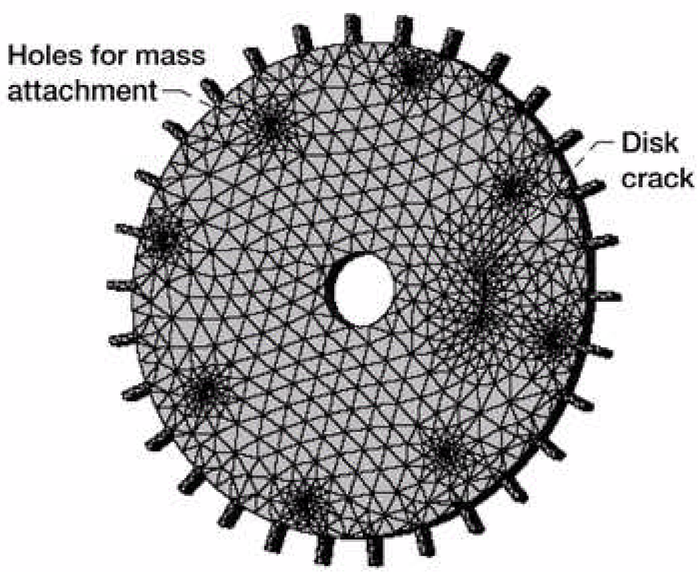
Rotor health monitoring and online damage detection are increasingly gaining the interest of the manufacturers of aircraft engines. This is primarily due to the need for improved safety during operation as well as the need for lower maintenance costs. Applied techniques for detecting damage in and monitoring the health of rotors are essential for engine safety, reliability, and life prediction. The goals of engine safety are addressed within the NASA-sponsored Aviation Safety Program (AvSP, ref.1). AvSP provides research and technology products needed to help the Federal Aviation Administration and the aerospace industry improve aviation safety. The Nondestructive Evaluation Group at the NASA Glenn Research Center is addressing propulsion health management and the development of propulsion-system-specific technologies intended to detect potential failures prior to catastrophe.



Disk spin simulation system. Note that left side containment cover is removed for viewing the rotor.

The current research is involved with experimental techniques as well as analytical results related to crack detection in rotating disks. The concept behind the crack-detection approach is based on the fact that the development of a crack is associated with the distortion in the component strain field and, consequently, with a minute unbalance. By monitoring the disk's radial vibration amplitude and phase online, one can see changes in the center of mass of the rotor system (ref. 2). To achieve the experimental setup necessary to verify and study this crack-detection technique, Glenn's Nondestructive Evaluation Group recently assembled a unique, two-bearing disk spin simulation system. The system, shown in the photograph, allows for elevated temperature, precision-controlled spin tests that can facilitate the application of various sensing technologies for the in situ detection of rotor damage. Presently, interest is focused on an innovative capacitive sensing system used to monitor blade tip clearance and the corresponding change in the center of mass of the rotor system (refs. 3 and 4). The change in the center of mass, calculated utilizing the displacement data, has been shown to be sensitive to cracks as small as 1.27 mm (0.05 in.) in jet engine rotors tested in spin pits (ref. 2). Although at this point in time, the changes seen in this parameter have been characterized in only a subjective fashion. A deeper understanding of the relationship between crack progression and the change in the center of mass can be achieved with the implementation of highly controlled crack-initiation and growth tests on subscale spinning rotors. With the current disk spin simulation system, such controlled tests can be conducted.

In a recent study, the sensor and the accompanying software were able to detect and precisely follow center-of-mass changes resulting from an attached mass on an 18-in.-diameter titanium disk (ref. 4). The disk had machined gear teeth to experimentally imitate a turbine's bladed disks. Furthermore, parametric finite element analyses are being conducted to optimize the experimental disk design as well as to gain an understanding of the change in the center-of-mass relationship with respect to crack characteristics and rotor speed (see the following finite element model). As a result of the analytical analysis, the feasibility of measuring center-of-mass changes resulting from cracked disks was mathematically defined for the given rotor systems.



Finite element model of cracked disk used for calculating change in center of mass as a *function of crack characteristics and rotational speed.*

References

1. Shin, Jaiwon: The NASA Aviation Safety Program: Overview. ASME 2000-GT-0660, 2000.

2. Haase, W.C.; and Drumm, M.J.: Detection, Discrimination, and Real-Time Tracking of Cracks in Rotating Disks. Proceedings of the 9th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery, Honolulu, Hawaii, Feb. 10-14, 2002.

3. Haase, W.C.; Roberge, J.K.; and Drumm, M.J.: High Bandwidth, Capacitive Sensing Preamplifier for Engine Health Monitoring. ExSell Inc., Concord, CA, 2000. http://www.exsell.org/rhm/, select *Products*, then select *Hi Band Preamp* (accessed Feb. 2002).

4. Gyekenyesi, Andrew L.; and Baaklini, George Y.: Rotor Health Monitoring and Damage Detection Utilizing a Disk Spin. Nondestructive Evaluation of Materials and Composites V, SPIE, Bellingham, WA, 2001, pp. 160-166.

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