

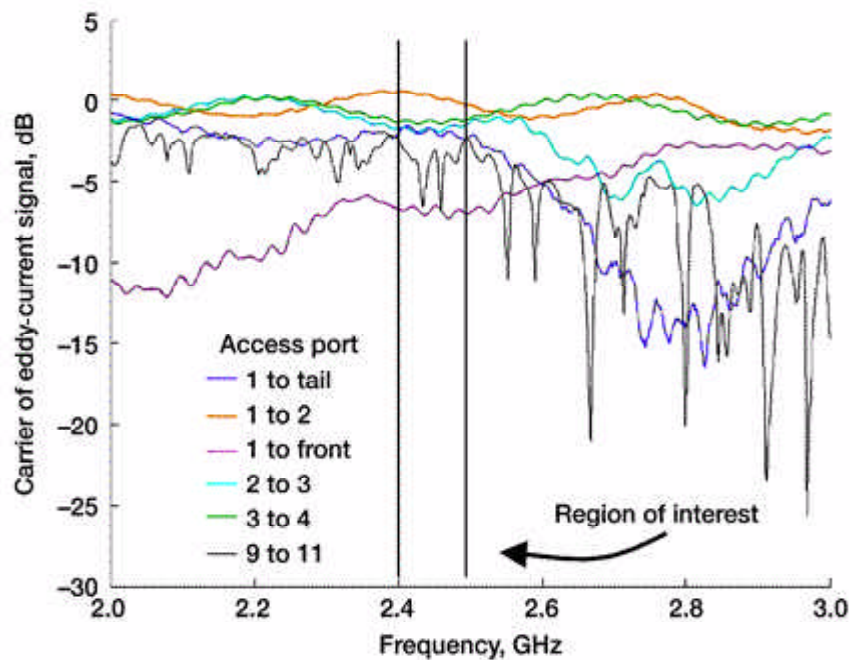
Methods Developed by the Tools for Engine Diagnostics Task to Monitor and Predict Rotor Damage in Real Time

Tools for Engine Diagnostics is a major task in the Propulsion System Health Management area of the Single Aircraft Accident Prevention project under NASA's Aviation Safety Program. The major goal of the Aviation Safety Program is to reduce fatal aircraft accidents by 80 percent within 10 years and by 90 percent within 25 years. The goal of the Propulsion System Health Management area is to eliminate propulsion system malfunctions as a primary or contributing factor to the cause of aircraft accidents. The purpose of Tools for Engine Diagnostics, a 2-yr-old task, is to establish and improve tools for engine diagnostics and prognostics that measure the deformation and damage of rotating engine components at the ground level and that perform intermittent or continuous monitoring on the engine wing.

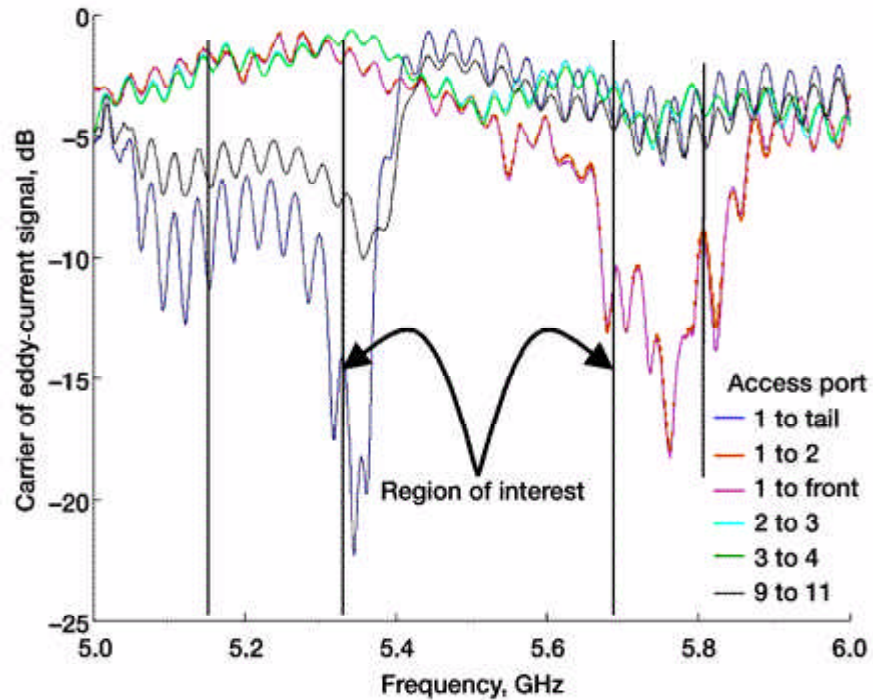
In this work, nondestructive-evaluation- (NDE-) based technology is combined with model-dependent disk spin experimental simulation systems, like finite element modeling (FEM) and modal norms, to monitor and predict rotor damage in real time. Fracture mechanics time-dependent fatigue crack growth and damage-mechanics-based life estimation are being developed, and their potential use investigated. In addition, wireless eddy current and advanced acoustics are being developed for on-wing and just-in-time NDE engine inspection to provide deeper access and higher sensitivity to extend on-wing capabilities and improve inspection readiness. In the long run, these methods could establish a base for prognostic sensing while an engine is running, without any overt actions, like inspections. This damage-detection strategy includes experimentally acquired vibration-, eddy-current- and capacitance-based displacement measurements and analytically computed FEM-, modal norms-, and conventional rotordynamics-based models of well-defined damages and critical mass imbalances in rotating disks and rotors.

Reference 1 briefly describes the approach adapted at the NASA Glenn Research Center for monitoring the health of rotating subscale engine disks and blisks. Two spin facilities were built, a single high-temperature disk spin system and a room-temperature multidisk spin system, both equipped with advanced NDE sensors and rotordynamic software analysis based on center-of-mass and revolutions-per-minute changes. In addition, preliminary modeling of cracked disks with modal norms via reduction in modulus demonstrated that the method can locate damage and qualify its effect from changes in the natural modes of the damaged structure. These rotor and disk health-monitoring facilities can now be used to improve the understanding of field damage phenomena by experimentally simulating them with a whole suite of modeling approaches, like center-of-mass changes, conventional rotordynamics, and modal norms analysis. Time-dependent fatigue crack growth routines and defect-energy damage detection schemes, once fully developed, will give a more accurate estimation of safe life for engine components.

Preliminary NDE results from nonlinear surface acoustic waves demonstrated sensitivity to fatigue damage via higher harmonics. Also, thermal acoustics demonstrated that critical-size cracks can be detected in high- and low-cycle fatigue samples as well as in compressor blades. However, more work is in progress for the final selection of a just-in-time NDE technique for ground-based in-engine and on-wing inspection. Preliminary wireless eddy current was found to be feasible for remote communication and on-wing inspection deep in the engine. It was also demonstrated that communication data between ports can be acquired in frequency bands reserved for industrial, scientific, and medical purposes, called ISM bands. More work is planned for wireless eddy-current inspection sensitivity so that it becomes comparable to current wired inspection (see the graphs). These preliminary NDE results and damage detection strategy approaches, when fully developed by the end of the program, will improve prognostic sensing while the engine is running, assuring safety and reducing maintenance costs by eliminating overt actions, like tear-down inspections.



Eddy-current magnitude plot between engine access ports from 2 to 3 GHz.



Eddy-current magnitude plot between engine access ports from 5 to 6 GHz.

References

1. Baaklini, G.Y., et al.: Tools for Engine Diagnostics Under the NASA Aviation Safety Program. Materials Evaluation, vol. 60, no. 7, July 2002, pp. 878-883.

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