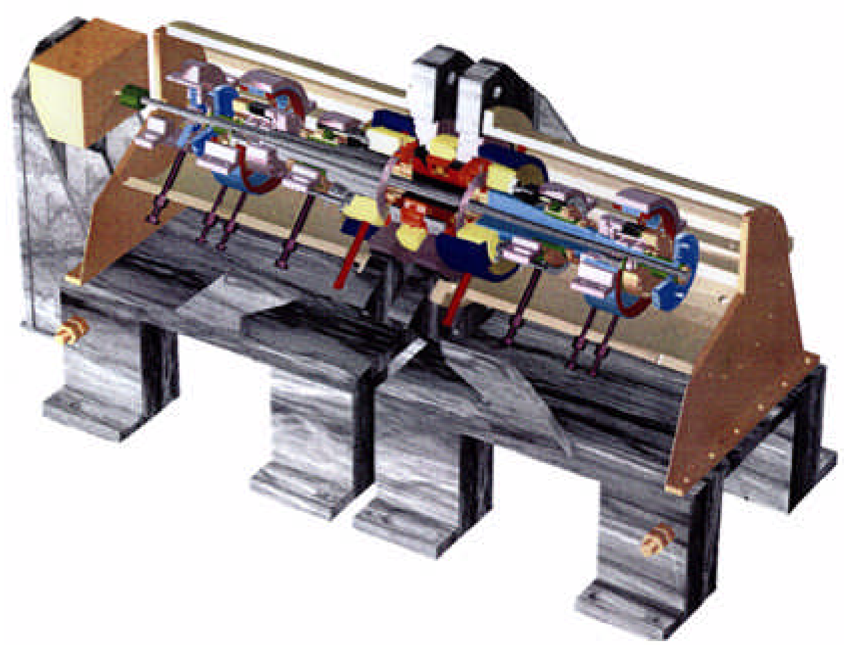
High-Temperature Magnetic Bearings Being Developed for Gas Turbine Engines



NASA Lewis' 1000 °F Magnetic Bearing Test Rig.

Magnetic bearings are the subject of a new NASA Lewis Research Center and U.S. Army thrust with significant industry participation, and cooperation with other Government agencies. The NASA/Army emphasis is on high-temperature applications for future gas turbine engines. Magnetic bearings could increase the reliability and reduce the weight of these engines by eliminating the lubrication system. They could also increase the DN (diameter of bearing times the rpm) limit on engine speed and allow active vibration cancellation systems to be used, resulting in a more efficient, "more electric" engine. Finally, the Integrated High Performance Turbine Engine Technology (IHPTET) program, a joint Department of Defense/industry program, identified a need for a high-temperature (1200 °F) magnetic bearing that could be demonstrated in their Phase III engine.

This magnetic bearing is similar to an electric motor. It has a laminated rotor and stator made of cobalt steel. Wound around the stator's circumference are a series of electrical wire coils which form a series of electric magnets that exert a force on the rotor. A probe senses the position of the rotor, and a feedback controller keeps it centered in the cavity. The engine rotor, bearings, and casing form a flexible structure with many modes. The bearing feedback controller, which could cause some of these modes to become unstable, could be adapted to varying flight conditions to minimize seal clearances and monitor the health of the system.

Cobalt steel has a curie point greater than 1700 °F, and copper wire has a melting point beyond that. However, practical limitations associated with the maximum magnetic field strength in the cobalt steel and the stress in the rotating components limit the temperature of the magnetic bearing to about 1200 °F. The objective of this effort is to determine the temperature and speed limits of a magnetic bearing operating in an engine. Our approach was to use Lewis' in-house experience in magnets, mechanical components, high-temperature materials, and surface lubrication to build and test a magnetic bearing in both a rig and an engine. Testing was to be done at Lewis or through cooperative programs in industrial facilities.

During the last year, we made significant progress. We have a cooperative program with Allison Engine Company to work on a high-temperature magnetic thrust bearing. During this program, we uncovered a problem with the conventional design of the magnetic thrust bearing. Because the thrust bearing is not laminated, it causes eddy currents that severely reduce the bandwidth. Also, we worked at Allison to bring their high-temperature magnetic bearing rig to full speed. We predicted both in-house and Allison magnetic bearing stability limits, and we tested a high-temperature displacement probe. Our flexible casing rig is being converted to a high-temperature magnetic bearing rig (see the illustration). Testing should start in the third quarter of 1997.

Our plan is to develop a high-temperature compact wire insulation, and to fiber reinforce the core lamination to operate at higher temperature and DN values. We also plan to modify our stability analysis and controller theory by including a nonlinear magnetic bearing model. We are developing an expert system that adapts to changing flight conditions and that diagnoses the health of the system. Then, we will demonstrate the bearing on our rotor dynamics rig and, finally, in a engine.

Lewis contacts: Albert F. Kascak, (216) 433-6024, Albert.F.Kascak@grc.nasa.gov, and Dr. Gerald V. Brown, (216) 433-6047, Gerald.V.Brown@grc.nasa.gov
Author: Albert F. Kascak
Headquarters program office: OASTT
Programs/Projects: Propulsion Systems R&T, P&PM, IHPTET