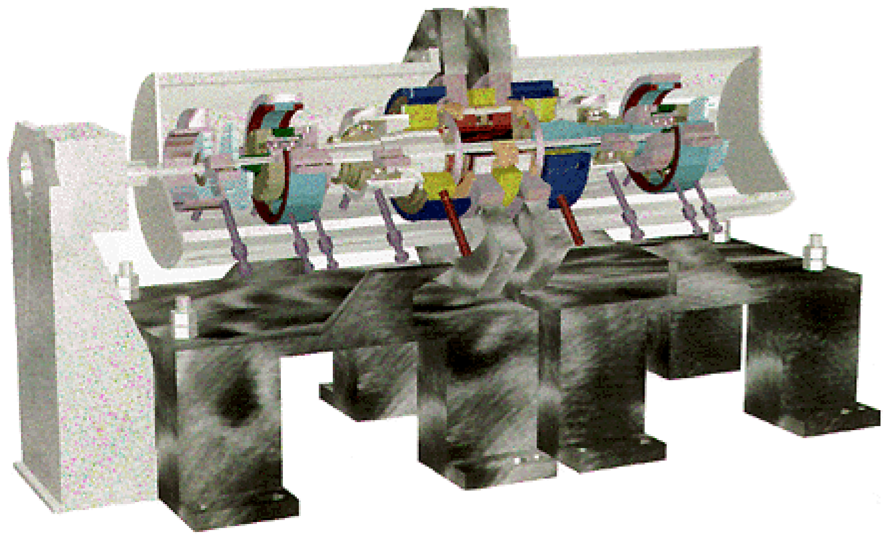
High-Temperature Magnetic Bearings for Gas Turbine Engines



NASA 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 coordination 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 the bearing times 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 (as high as 1200 °F) magnetic bearing that could be demonstrated in a 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 are a series of electrical wire coils that form a series of electric magnets around the circumference. The magnets exert a force on the rotor. A probe senses the position of the rotor, and a feedback controller keeps it in the center of the cavity. The engine rotor, bearings, and case form a flexible structure that contains a large number of 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. Therefore, practical limitations associated with the maximum magnetic field strength in the cobalt steel and the stress in the rotating components limit the temperature to about 1200 °F. The objective of this effort is to determine the limits in temperature and speed of a magnetic bearing operating in an engine. Our approach is to use our 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 will 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 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. The thrust bearing is not laminated, causing 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 rig 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 figure). Testing should start next year. Our plan is to develop a high-temperature, compact wire insulation and to fiber reinforce the core lamination to operate at higher temperatures and DN values. We plan to modify our stability analysis and controller theory by including a nonlinear magnetic bearing model. We are developing an expert system that adapts the controller 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 an engine.

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