System Regulates the Water Contents of Fuel-Cell Streams

Lyndon B. Johnson Space Center, Houston, Texas

An assembly of devices provides for both humidification of the reactant gas streams of a fuel cell and removal of the product water (the water generated by operation of the fuel cell). The assembly includes externally-sensing forward-pressure regulators that supply reactant gases (fuel and oxygen) at variable pressures to ejector reactant pumps. The ejector supply pressures depend on the consumption flows. The ejectors develop differential pressures approximately proportional to the consumption flow rates at constant system pressure and with constant flow restriction between the mixer-outlet and suction ports of the ejectors. For removal of product water from the circulating oxygen stream, the assembly includes a water/gas separator that contains hydrophobic and hydrophilic membranes. The water separator imposes an approximately constant flow restriction, regardless of the quality of the two-phase flow that enters it from the fuel cell. The gas leaving the water separator is nearly 100 percent humid. This gas is returned to the inlet of the fuel cell along with a quantity of dry incoming oxygen, via the oxygen ejector, thereby providing some humidification.

This work was done by Arturo Vasquez and Scott Lazaroff of **Johnson Space Center.** *For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809.*
MSC-23079

Five-Axis, Three-Magnetic-Bearing Dynamic Spin Rig

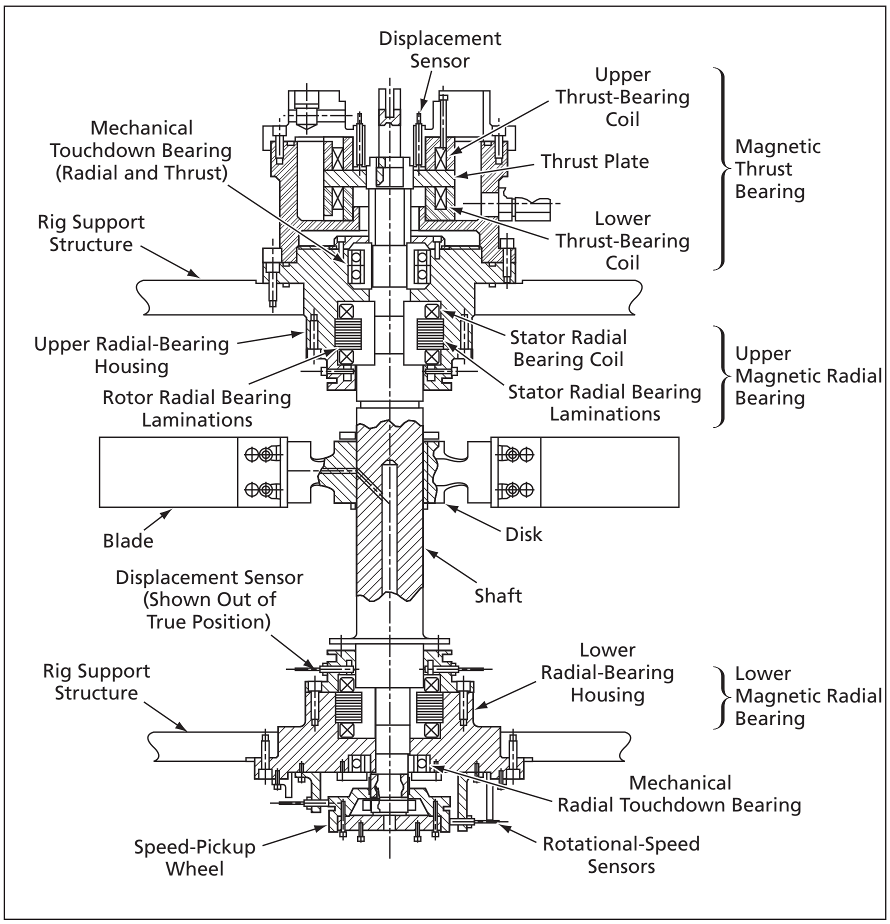
Higher-order vibrational modes can be excited and higher rotational speeds attained.

John H. Glenn Research Center, Cleveland, Ohio

The Five-Axis, Three-Magnetic-Bearing Dynamic Spin Rig is an apparatus for vibration testing of turbomachine blades in a vacuum at rotational speeds from 0 to 40,000 rpm. This rig (see figure) includes (1) a vertically oriented shaft on which is mounted an assembly comprising a rotor holding the blades to be tested, (2) two actively controlled heteropolar radial magnetic bearings at opposite ends of the shaft, and (3) an actively controlled magnetic thrust bearing at the upper end of the shaft. This rig is a more capable successor to a prior apparatus, denoted the Dynamic Spin Rig (DSR), that included a vertically oriented shaft with a mechanical thrust bearing at the upper end and a single actively controlled heteropolar radial magnetic bearing at the lower end.

The five-axis, three-magnetic-bearing configuration of the present rig enables full magnetic suspension of the rotor — eliminating mechanical contact between the rotor and the bearings during operation. Whereas frictional heating in the mechanical thrust bearing of the prior DSR made it necessary to limit rotational speed to 18,000 rpm or less, the absence of frictional heating in the present rig makes it possible to operate at higher speed, provided that a rotor of appropriate high-speed design is installed.

In the prior DSR, it was not possible to excite vibrations in higher-order modes in bladed-disk test assemblies by



The **Five-Axis, Three-Magnetic-Bearing** configuration of this dynamic spin rig makes it possible to excite high-order vibrational modes of the disk-and-blade assembly. The five axes are the vertical thrust axis of the thrust bearing and two mutually perpendicular horizontal force axes for each of the two radial bearings.

applying feed-forward control excitations to the magnetic bearings. This limitation was due partly to the lateral constraint imposed on the rotor by the mechanical bearing at the upper end of the shaft, partly to the direct effect of friction in that bearing, and partly to the aforementioned speed limit imposed to prevent excessive frictional heating. In contrast, by virtue of the fully magnetic nature of the present suspension, there is no lateral constraint against vibrations, and excitation amplitudes can be greater than in the prior DSR. By applying appropriate feed-forward bounce-mode and tilt-mode control excitation command to the active magnetic bearings in the present rig, one can excite vibrations in a variety of modes. The combination of large-amplitude feed-forward excitation and higher rotational speed makes it possible to excite higher-order vibrations in a bladed-disk test assembly.

This work was done by Carlos R. Morrison, Andrew Provenza, Anatole Kurkov, Oral Mehmed, and Dexter Johnson of **Glenn Research Center***; Gerald Montague of The Army Research Laboratory; and Kirsten Duffy and Ralph Jansen of The University of Toledo. Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17757-1.