Mechanics/Machinery

Conical Bearingless Motor/Generators

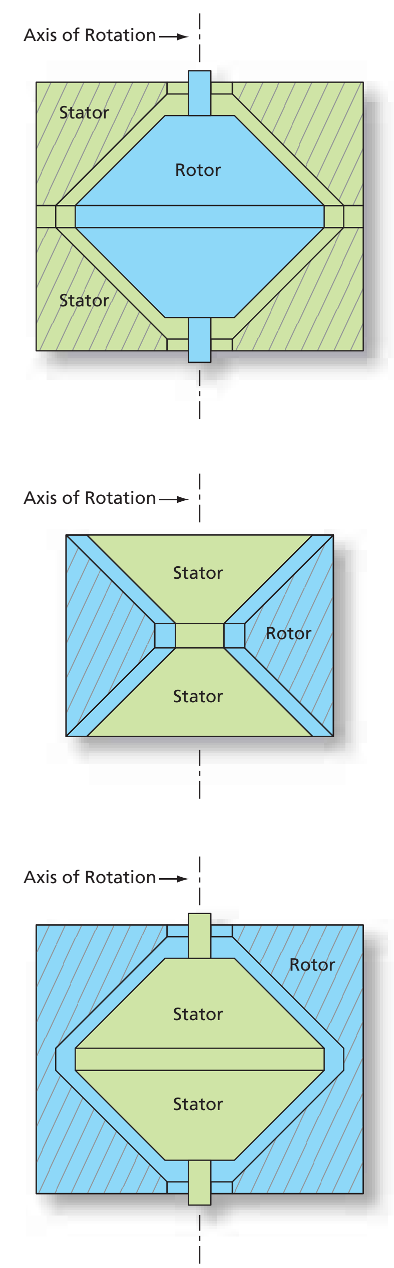
Advantages include high-speed, long-life operation in a compact form factor.

John H. Glenn Research Center, Cleveland, Ohio

Motor/generators based on conical magnetic bearings have been invented as an improved alternative to prior such machines based, variously, on radial and/or axial magnetic bearings. Both the present and prior machines are members of the class of so-called "bearingless" or "self bearing" (in the sense of not containing mechanical bearings) rotary machines. Each motor/generator provides both a torque and force allowing it to either function as a motor and magnetic bearing or a generator and magnetic bearing concurrently. Because they are not subject to mechanical bearing wear, these machines have potentially long operational lives and can function without lubrication and over wide ranges of speed and temperature that include conditions under which lubricants would become depleted, degraded, or ineffective and mechanical bearings would fail.

The figure shows three typical configurations of conical bearingless motor/generators. The main elements of each motor/generator are concentric rotor and stator portions having conically tapered surfaces facing each other across a gap. Because a conical motor/generator imposes both radial and axial magnetic forces, it acts, in effect, as a combination of an axial and a radial magnetic bearing. Therefore, only two conical motor/generators — one at each end of a rotor — are needed to effect complete magnetic leviation of the rotor, whereas previously, it was necessary to use a combination of an axial and a radial magnetic bearing at each end of the rotor to achieve complete magnetic levitation and a separate motor to provide torque.

The stator portion of each motor/generator consists of a magnetic core and back iron with a number of teeth and slots at the gap and wires (electromagnet coils) wound in the slots. The rotor consists largely of a magnetic core and, depending on the specific design, could also include permanent magnets. Except for the conical configuration, the rotor and stator resemble those of prior radial magnetic bearings and bearingless motors.



Conical Bearingless Motor/Generators both levitate and rotate the rotor with respect to the stators. These are simplified cross-sectional views of representative configurations of machines described in the text. Although stators traditionally enclose rotors, conical bearingless motor/generators lend themselves equally well to designs in which rotors enclose stators.

As in prior magnetic bearings and bearingless motors, electric currents are driven through the coils, producing magnetic fluxes in the core and rotor that result in torques and forces on the rotor; a feedback control system adjusts the current waveforms, in response to the positions of the ends of the rotor as measured by sensors, to produce the radial and axial forces needed to maintain rotor levitation at the desired radial and axial position. For motor or generator operation, times for electronic switching of coil connections for input or output currents are determined in response to the rotation angle as measured by another sensor.

Unlike in prior bearingless motors, it is not necessary to use one set of coils for levitation interspersed with another sets of coils for motor/generator operation. Instead, an improved control scheme provides for the use of a single set of coils for both levitation and motor/generator operation. The scheme requires at least six coils (for three or more pole pairs) in each bearing. In its motor aspect, the scheme provides for simultaneous operation of the equivalent of three overlapping three-phase motors. In addition, this motor configuration provides a certain amount of fault tolerance; if any of the pole-pair coils or the drive circuitry of a pole pair fails, the remaining two three-phase subsystems can continue to provide magnetic levitation and motor/generator operation.

This work was done by P. Kascak and R. Jansen of the University of Toledo and T. Dever of QSS Group, Inc. for Glenn Research Center. 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-17638-1/39-1/40-1.