Development of Superconducting Magnetic Bearings

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Electric power is a type of energy that is absolutely indispensable to our daily lifestyles, and the effects of its consumption patterns on the global environment are significant. In recent years, hopes have become increasingly pinned on the equalization of electric power loads using electric power storage technology as a means of alleviating global warming. Even in the railway sector, there is a high likelihood that it will be possible to apply electric power storage technology for such purposes as ensuring that the regenerative power of electric trains is effectively utilized and improving the reliability of electric power supply in information systems.

It is against this backdrop that our research laboratory has been working on a research and development project for magnetic bearings that apply superconductivity technology and that will be used as the support bearings of the flywheels used for storing electric power. On the one hand, flywheels have a high energy density and are extremely useful for running systems characterized by start/stop operation and load responsiveness, but on the other hand there are problems with the service life and economic aspects of their systems. Our research project has the objective of resolving problems concerning the maintenance of mechanical parts and offsetting the reductions in operating efficiency due to such factors as the friction loss in the bearing parts, and it aims to attain these objectives by supporting the flywheels using superconducting magnetic bearings.

Superconducting magnetic bearings are characterized by the fact that they combine superconducting coils with high-temperature bulk superconductors. Configuring the magnetic bearings using superconductors has the effect of eliminating the constraints both on the limits of the magnetic fields applied in conventional magnetic bearings featuring a combination of conventional permanent magnets and bulk superconductors and on the limits of the magnetization attained using magnetic bearings that utilize the power of attraction of ferromagnetic material and the superconducting coils, enabling the load capacity of the bearings to be increased.

Figure 1 shows an illustration of the superconducting magnetic bearing that has been created as a prototype. Part of the rotating shaft configures a liquid nitrogen Dewar vessel containing a 60 mm diameter bulk superconductor that is cooled by the liquid nitrogen. This rotatable Dewar vessel is positioned at the through hole of the superconducting coil to configure a magnetic bearing.

When a bulk superconductor is used in conditions where it is cooled by liquid nitrogen, the applied magnetic field is limited to less than 2T by the critical current of the bulk superconductor at 77 K. For this reason, a superconducting coil that can create a cusped magnetic field through the heteropolar excitation of two coils was developed as the superconducting coil to be positioned on the fixed side of the bearing. By creating a cusped magnetic field, the magnetic flux in the axial direction is canceled out to zero in the axial (vertical) center of the two coils, and the magnetic field gradient in the axial direction reaches its greatest proportion in the place where it is slightly moved in the axial direction from this point. When a bulk superconductor is positioned in this place, a high levitation force that has an applied magnetic field of less than 2T and that is proportional to the magnetic field gradient is generated. In this way, it is possible to support a bearing load commensurate with the levitation force.

Figure 2 shows an example of the results obtained from a static load test on superconducting magnetic bearings. In this experiment, a levitation force of 8 kN was generated. Future plans call for tests involving flywheel rotating bodies weighing 500 kg to be supported by superconducting magnetic bearings and to be rotated at high speeds in order to ascertain the bearing characteristics.

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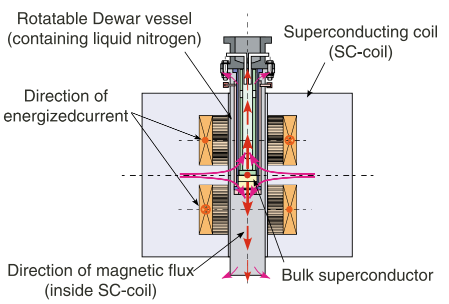

Fig. 1 Structure of a superconducting magnetic bearing

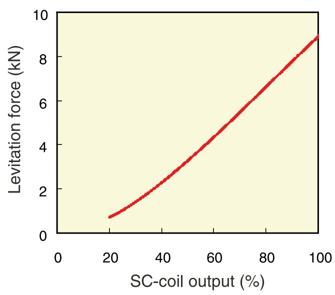

Fig. 2 Results obtained from a static load test

Apparatus for measuring the electromagnetic force generated by a bulk superconductor positioned inside a superconducting coil

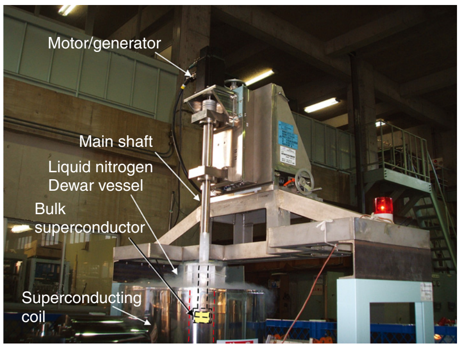

Fig. 3 Apparatus used for the experiment