Superconducting armature for induction motor of axial flux based on YBCO bulks

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Abstract

Several small scale SC rotating machines have been developed based on HTS bulk materials. Up to now, the role of the SC has been restricted to the rotor where no coil has been required. Despite the difficulty of building classical coils with ceramic materials, we have developed suitable geometries which can be built by machining melt textured YBCO pellets.

In this work, we describe a multiphase armature designed to be made from HTS ceramic pellets. The field created is designed to interact with a disk-shaped rotor producing both the torque and the forces to maintain it in working conditions. Calculations of the field in the rotor cavity generated by the armature in the working conditions are also reported.

Keywords: Superconducting Motor, Induction Motor, Axial Flux

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1. Introduction

The development of HTSC materials, both tape and bulk, has allowed the design of systems in several areas of electro-mechanical engineering. In particular, YBCO bulks have been used directly to implement hysteresis motors [1] and radial and axial flux motors [2] in which only the rotor is superconducting but the stator is made with conventional coils.

Also YBCO bulks have been used to make fault current limiters [3,4] due to the fact that they show a very effective limitation with relative low volume, but in these cases machining of the material is required.

In this work we present a superconducting single-winding coil made from YBCO bulks for a biphase axial flux motor. As the stator circuits are ceramic superconductors, the material has to be machined as in the case of fault current limiters [4,5].

Since HTSC materials can produce a very high magnetic field, we can remove the ferromagnetic core and design an induction motor with an air core. We therefore suggest a design for an axial flux air core motor made of ceramic coils as stator windings and a superconducting disk as the rotor and we show its magnetic field distribution.

This kind of motor can be applied for instance to the design of dynamic filters or liquid hydrogen pumps.

2. Details of circuit construction

Melt-textured YBCO was used to build the ceramic coils. Pellets of 30mm diameter were obtained by melting in a cylindrical furnace just above the peritectic temperature. An NdBCO seed was placed on the center of the top face of the pellet in order to grow a single domain pellet with the c-axis oriented in coincidence with the symmetry axis of the pellet. The small thermal gradient in the radial direction of the furnace helps control the expansion of the fronts growing across the surface of the pellet.

An optical recording of the process is shown in Fig. 1. The growing fronts move in the radial direction of the pellet.

The pellets were cut into disks of 2mm in thickness by a diamond saw. After an optical selection to reject unsuitable pellets with cracks, the disks were shaped by milling to the geometry of the coil. Figure 2 shows the coil after milling, except for the ends.

Silver pads, painted onto the current injection points of the circuit, form the contacts. The contact resistivity of the silver pads is reported in [6]. The coils so constructed are oxygenated conventionally, in an oxygen flow at 450ºC.

3. Suggestion of motor prototype

With these ceramic coils we are designing a biphase induction motor with both stator and rotor superconductors. For reasons of mechanical stability, the prototype consists of two parallel semistators with the rotor between them. Each semistator has two ceramic circuits $\pi/2$ rad out of phase and is arranged as in Fig. 3. The rotor is a superconductor disk.
4. Magnetic field distribution

The magnetic field in the working plane of the rotor of the proposed motor was calculated from the Biot-Savart law and the superposition principle (since the system is linear). Since it is impossible to integrate the Biot-Savart law analytically [7], we used a numerical integration procedure of the Mathematica program package, assuming that the field lines are parallel to the axis in the plane of the rotor, and neglecting losses in the superconductor.

The spatial map of the axial magnetic field was calculated for each instant of time. Figures 4(a) and 4(b) show the results at $z = 0$ for $t = 0$ and $t = 2.5$ ms, respectively with a 50 Hz AC current.

5. Conclusions

We have managed to obtain ceramic superconducting circuits with a shape that is suitable for the construction of a biphasic superconducting stator.

Neglecting losses, we evaluated the distribution of the magnetic field created by this configuration. The result is a rotatory bipolar field that has good perspectives for driving a rotating superconducting disk in its interior.

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References