Modelling of High Temperature Superconducting Bearings

P.L. Ribani , A. Cristofolini, M. Fabbri, P. La Cascia, F. Negrini
Dipartimento di Ingegneria Elettrica - Università di Bologna

The paper presents a model to describe the levitation of a permanent magnet on a High Temperature bulk superconductor, during transients. The research activity is performed in the framework of a research project of the Department of Electrical Engineering of the University of Bologna, whose main goal is the development of procedures for the optimal design of flywheel superconducting systems for energy storage [1].

In order to simplify the analysis a simple geometry has been chosen (fig. 1): a cylindrical permanent magnet levitates on a cylindrical coaxial bulk superconductor (YBCO) with the c-axis parallel to the vertical axis. The permanent magnet moves in the vertical direction under the action of the gravitational force and of the magnetic levitation force due to the currents flowing in the bulk superconductor. Movements of the permanent magnet in the lateral directions are not allowed. It is thus possible to calculate the levitation force when the steady state is reached and, also, to study the stability of the system in the vertical direction.

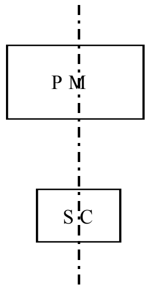

Fig. 1

The T method is utilized to calculate the current density into the bulk superconductor; due to the axial symmetry only the vertical component of the current potential needs to be considered (eq.1). When describing the relation between the electric field and the current density the flow and the creep of the magnetic flux density are considered (eq. 2) [2]. The solution of the system is obtained by means of the finite element method. The obtained results are discussed.

$$\mu_0 \frac{\partial T}{\partial t} + \frac{\mu_0}{4\pi}\, \mathbf{k}\cdot \iint \frac{\partial T}{\partial t}\, \mathbf{k}\cdot\mathbf{n}\, \nabla'\left(\frac{1}{\left|\mathbf{x}-\mathbf{x}'\right|}\right) dS = -\frac{\partial B_0}{\partial t} - \mathbf{k}\cdot\nabla\times\mathbf{E} \qquad (1)$$

$$\mathbf{J} = \nabla T \times \mathbf{k} \qquad ; \qquad \mathbf{E} = f(|\mathbf{J}|)\,\frac{\mathbf{J}}{|\mathbf{J}|}$$

$$f(|\mathbf{J}|) = \begin{cases} 2\,\rho_c\, J_c \sinh\left(\dfrac{U_0}{k\theta}\dfrac{|\mathbf{J}|}{J_c}\right)\exp\left(-\dfrac{U_0}{k\theta}\right) & \text{se} \quad 0 \le |\mathbf{J}| \le J_c \\ E_c + \rho_f\, J_c \left(\dfrac{|\mathbf{J}|}{J_c} - 1\right) & \text{se} \quad J_c < |\mathbf{J}| \end{cases} \qquad (2)$$

References

1. D. Di Leo, P.L. Ribani, F. Negrini, “Studio di sistemi innovativi per il livellamento del carico sulla rete elettrica di Tokyo” , (in italian), to be printed.
2. Y. Yoshida, M. Uesaka, K. Miya, “Magnetic field and force analysis of high Tc superconductor with flux flow and creep”, IEEE Trans. on magnetics, vol. 30,. N. 5, settembre 1994.