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Experimental set-up and energy efficiency evaluation of zero-field-cooled (ZFC) YBCO magnetic bearings

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This paper presents the conception, simulation and experimental evaluation of magnetic bearings based on NdFeB magnets and zero field cooled (ZFC) YBCO superconductors.

Motivations for this research were: i) bearings using magnetic levitation are able to support highest speeds with very low friction and no wear; ii) passive magnetic bearings based only on permanent magnets do not require any power but are difficult to design as proved by the Earnshaw's theorem; iii) active magnetic bearings are used together with passive magnetic bearings to keep the load stable, but they require continuous power; iv) diamagnetic materials allow stable configurations; v) superconductor are perfect diamagnets because they expel magnetic fields due to the Meissner effect. Hence a superconductor magnetic bearing was developed in this paper to analyze their features, advantages and drawbacks. Moreover, superconducting magnetic bearings would be implemented and tested to replace the usual bearings of a standard electric motor.

Advanced research was presented in [1,2,3], among many others, for the construction of large scale flywheels or for application in industries. However all these approaches used field-cooled supercondutors, whereas the approach shown in this paper uses ZFC supercondutors. Actually, as previously shown by the authors in [4,5] Zero Field Cooling present much less power losses. The approach followed in this horizontal flywheel research is similar to a ZFC maglev implementation [4], where the linear track was closed into a looping shape with the same diameter of the superconductor magnetic bearing.

The conception and geometric placement of magnets and superconductors was projected to keep symmetry along the main axe and to minimize air gaps. Studies involved different placements of magnets or superconductors either in the rotor or in the stator. A finite element model was built for simulation and validation of the effectiveness of the solution. Estimated levitation forces were computed to check the feasibility of the magnetic bearings. Experimental validation was achieved by building holders for magnets and superconductors, one to be connected to the motor rotor and other connected to the motor stator. Holders were filled with corresponding magnets or superconductors. Channels were built for the cryogenic fluid, liquid nitrogen, to keep superconductors cooled. The mechanical bearings of an AC motor were removed and replaced by the ones projected in this work. The experimental setup is under test to validate the simulation results.

[1] Ichihara, T., et al. "Fabrication and evaluation of superconducting magnetic bearing for 10kWh-class flywheel energy storage system." Physica C: Superconductivity 426 (2005): 752-758.

[2] Matsumura, T., et al. “Prototype design and performance of superconducting magnetic bearing system for a space compatible polarization modulator operating at 4 K”, EUCAS 2015, Lyon.

[3] Sparing, M., et al. “Dynamics of rotating Superconducting Magnetic Bearings in Ring Spinning, EUCAS 2015, Lyon.

[4] Fernandes J., et al. “Superconductor joule losses in a zero-field-cooled maglev vehicle”, EUCAS 2015, accepted for publication in IEEE Transactions on Applied Superconductivity.

[5]Branco, P., Arnaud, J. “Coupled Electromagnetic-Thermal Analysis of YBCO Bulk Magnets for the Excitation System of Low-Speed Electric Generators”, EUCAS 2015, accepted for publication in IEEE Transactions on Applied Superconductivity.