Development of Superconducting Bearings for Industrial Application

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1 Introduction

High-temperature superconducting (HTS) magnetic bearings are promising candidates for application in machines with high rotational speed. The interaction between HTS and permanent magnets can be technically exploited to realize bearings with novel properties. In recent years a number of small experimental HTS bearings were manufactured and tested worldwide. Encouraging findings on these bearings gave evidence for several advantages.

HTS bearings show self-stabilizing behaviour without any active control. Due to their contactless design they provide wearless suspension with very low friction. They are inherently safe. Because of their oil-free design these bearings can reduce environmental risks and fire hazard. The fire load is minimized.

Rapid progress in development of high quality HTS enables and accelerates application of HTS in electrical machines and levitation systems. Single-domain YBCO monoliths fabricated by a top-seeded-melt-growth process at Nexans SuperConductors exhibit self-field critical current densities up to 1.3 x 10^5 A/cm^2 at 77 K.

Typical areas of application for passive HTS bearings are rotating machines with high rotational speed like motors and generators, energy storage flywheels and oil-free turbines.

2 Heavy Load HTS Bearings

In a first step towards heavy load capability an HTS bearing for a 400 kW synchronous motor with HTS rotor windings was designed, constructed and tested. Feasibility of HTS radial bearings for large machines was demonstrated impressively in this project. However, this bearing was only a demonstrator.

Consequently in the next step of our long-term program at Siemens an improved heavy load bearing was developed. This bearing, suitable for continuous operation in industrial environment, was designed for the rotor of a 4 MVA HTS synchronous generator (weight ~ 1000 kg) and manufactured by Nexans SuperConductors [1]. Figure 1 shows the bearing mounted in a test frame.

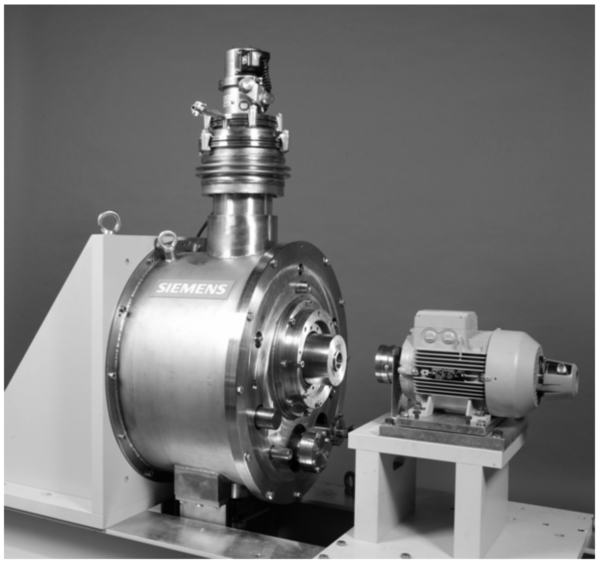

Fig. 1: HTS bearing in test frame

Static and dynamic investigations were performed in a modified tensile testing machine [2]. The bearing properties were characterized at various temperatures of the HTS stator between 25 K and 77 K. For bearing tests under rotation a 3 kW drive (on the right side in figure 1) can be connected to the shaft via an electromagnetic coupler. The drive is powered by a SIMOVERT MASTERDRIVE frequency converter allowing a maximum speed of 4500 rpm.

Cooling down of the HTS stator before operation takes about 32 h. After activation of the bearing force versus displacement curves were measured to evaluate the bearing capacity. These curves show linear behaviour in the investigated range of ± 0.3 mm around the centre position of the shaft. The radial bearing stiffness is 5.1 kN/mm. Bearing capacity and stiffness measured without rotation were in good agreement to results from tests at the nominal operational speed of 3600 rpm. Very low vibration levels were found in the entire range between resonance frequency of the test set-up (approximately 20 Hz) and 4400 rpm (corresponding to generator overspeed testing) [3]. At this speed the amplitude of shaft oscillations was about ± 5 μm.

Figure 2 shows the radial bearing capacity for various temperatures between 25 K and 77 K. In the temperature range below 60 K the bearing capacity is almost constant. At elevated temperatures above 65 K one can observe a significant reduction.

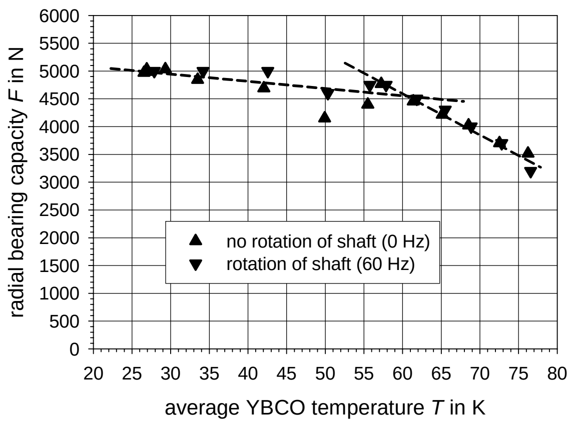

Fig. 2: Radial bearing capacity versus temperature of HTS stator

The weak dependence of bearing capacity on temperature below 60 K gives an intrinsic safety of HTS bearings. In case of problems with the cooling system there would not be an abrupt loss of levitation. The bearing, initially cooled down to 28 K, can still be operated for additional 2 hours without cooling.

The radial bearing capacity of 500 kg, radial stiffness of 5.1 kN/mm and a cryofree cooling system turn this HTS bearing into an international front-runner. Our project was partly funded by BMBF under FKZ 03SX143.

3 References

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[2] P. Kummeth, W. Nick, H.-W. Neumüller, H. Walter, J. Bock, Ch. Frohne, K. Schippl, H. May, and W.R. Canders, Proceedings of 8th International Symposium on Magnetic Suspension Technology, Dresden, Germany, Sept. 26-28, 2006, p. 120-125

[3] P. Kummeth, W. Nick, G. Nerowski, H.-W. Neumüller, to be presented at VDI-Tagung Elektrisch-mechanische Antriebssysteme, Böblingen, Germany, Sept. 27-28, 2006