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A NEW METHOD FOR NON DESTRUCTIVE ESTIMATION OF Jc IN YBaCuO CERAMIC SAMPLES

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ABSTRACT:

This work presents a new method for estimation of Jc as a bulk characteristic of YBCO blocks. The experimental magnetic interaction force between a SmCo permanent magnet and a YBCO block was compared to finite element method (FEM) simulations results, allowing us to search a best fitting value to the critical current of the superconducting sample. As FEM simulations were based on Bean model , the critical current density was taken as an unknown parameter. This is a non destructive estimation method. since there is no need of breaking even a little piece of the sample for analysis.

Keywords: YBCO, Simulations, FEM.

ABSTRACT:

Este trabalho apresenta um novo método para a estimativa de Jc como uma característica cerne de blocos YBCO. A força de interação experimental magnética entre um imã permanente SmCo e um bloco YBCO foi comparada a simulações pelo método de elemento finito (FEM), permitindo que buscássemos o melhor ajuste para a corrente crítica da amostra de supercondutor. Como as simulações FEM foram baseadas no modelo de Bean, a densidade de corrente crítica foi assumida como um parâmetro desconhecido. Este é um método não-destrutivo, uma vez que não existe necessidade de retirada de qualquer pedaço para a análise.

Palavras-chave: YBCO, simulações, FEM.

INTRODUCTION

Melt textured YbaCuO blocks are extremelly important for the development of mechanically stable levitating devices, such as magnetic bearings. The design of maglev systems requires large superconducting samples with highly aligned and conected grains which are obtained by melt textured process (MOON 1994). The finite element method (FEM) is a powerfull tool for designing maglev machines provided the knowledge of Jc, the critical current density. Jc is required in order to build the BxH curve of the YbaCuO block, through Bean´s Critical state Model (BEAN 1994), and apply it in FEM numerical simulations of the YbaCuO sample magnetic behavior (PEREIRA ET AL. 2000).

The usual measurements of Jc are obtained by vibrating sample magnetometry of a small piece of the YbaCuO block, which is obtined by breaking the sample. As Jc is closely related to the microstructute of the sample, such a procedure has the disadvantage of obtaining a Jc value that strongly depends on the local properties of the region from where it was taken. So we loose the global representativity of Jc and cracks a sample that will be part of a real machine.

We propose a new method for the non destructive estimation of the global Jc which stands for the average microstructural magnetic behavior of the entire sample a avoids the sample craking, by using the Bean Model and the finite element method (FEM), adjusting the Jc value to an experimental levitation force curve.

As the interaction force between the YbaCuO block and a permanent magnet is the net result of the interaction of the magnet with all parts of the sample, the adjusted Jc value is in fact an average, global value that accounts for the structural details of the sample.

METHODOLOGY

In order to apply FEM and the Bean Model to the estimate of Jc, we have tried several magnetization curves (B×H curves), until we can choose the one that stands for the best agreement between the numerical force calculation and the measured force values.

The flux density due to the magnetization of the sample by an applied magnetic field is given by the relation , where depends on the sample geometry of the sample. Applying the Bean model for a cylindrical simetry of radius R, we obtain the following expression for the zero field cooled (ZFC) approach between sample and the magnet:

$$B(H) = \mu_0\left(\frac{H^2}{H_p} - \frac{H^3}{3H_p{}^2}\right)$$

where Hp = JcR, that shows the dependence of magnetization to Jc ; as the sample radius is known, the only free parameter is the critical current density, Jc. So, the value of Jc can be adjusted in order to find the B×H curve that allows the FEM computational program to find the best numerical interaction force curve that fits to the experimental one. The fluxogram bellow shows the operational sequence that was followed.

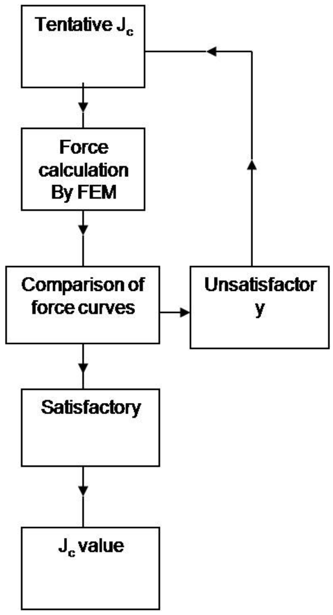

Figure 1: Fluxogram for numerical determination of Jc

The used FEM program was Ansys Multiphysics and the interaction force was calculated by the Maxwell tensor method (ANSYS 2000).

The interaction forces were measured by a software controlled data aquisition system, where a cylindrical SmCo permanent magnet with dimesions Φ = 19,00 mm, h = 6,4 mm and induction at top center B = -0,169 T, is attached to a commercial load cell (UTILCELL mod 120). Quasi-static measurements were performed (0,2 mm each step, 2,5 mm/min scan) while the SmCo permanent magnet vertically approached the YbaCuO at 77,4 K (ZFC). A set of 8 cylindrical samples made by the same method Salama was analyzed, and once all of them were made in the same conditions and have the same geometrical features (Φ = 26mm and h = 17 mm), the Jc value, the B×H curve and the reaction force to the SmCo permanent magnet approach, should be essentially the same for all of them.

The SmCo B×H curve is already available in the Ansys data bank and the B×H curve for YBaCuO samples were built by changing the Jc value until the best fitting of the levitation force curves was found.

The YBaCuO samples were also characterized by 2D mapping of the trapped magnetic flux, when exposed to an applied external induction B = 0,5 T. A BRUCKER electromagnet was used as homogeneous field source, the applied field was 0,5T, and the mapping was done by means of a Hall sensor (TOSHIBA mod THS 118) attached to a software controlled x-y positioning table no LASUP (0,4 mm each step, 1mm/s scan and total area scan time ≈ 30 min).

RESULTS AND DISCUSSION

The best adjusted value found for Jc was 7 X 10^7 A/m2, that is in the same order of magnitude of the measured values to melt textured YBaCuO samples found by the vibrating Sample Method (VSM). The best B×H curve is shown in figure 2.

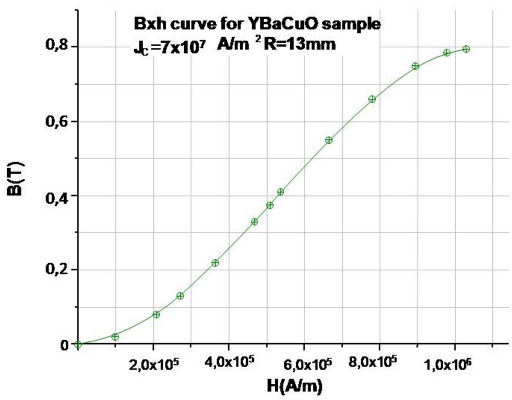

Figure 2: The best input data for YBacuO blocks with same dimensions.

Figure 3 shows the excellent agreement among the calculated and measured interaction force curves for 8 identically made YBaCuO samples Salama.

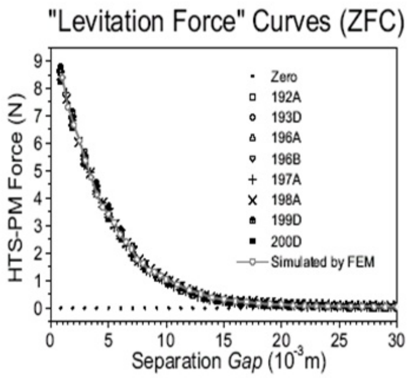

Figure 3: Measured and simulated PM-HTS interactio ("levitation") force curves as function of PM-HTS separation gap, linear scales

Figure 4 show the flux trapped mapping in the sample. As can be seen the maximum trapped field is almost the same for all samples, about 2,5 T, but some difference rises far from the center of the sample.

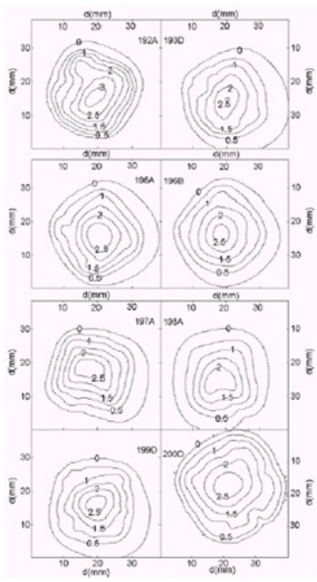

Figure 4: Trapped field pattern in all YBaCuO samples.

CONCLUSIONS

We proposed and employed a non-destructive methodology to estimate the value of her critic current density of YBaCuO. In our approach the J is a free parameter used to build the B×H curve of the YBaCuO sample, as required by the FEM software to simulate its levitation force curve. The evaluated Jc is validated to levitation requirements of device projects by the good agreement between directly measured and simulated levitation force curves, specially at small distances. Once our methodology does not requires a sample with small dimensions and uses the overall behavior of the YBaCuO block, we also propose it as an alternative to the local response and destructive ones usually employed.

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