

Nondestructive Characterization of Critical Current Distribution Across the Width of Coated Conductor Tapes

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Abstract—For AC applications of coated conductors, tape width must be small enough to reduce the AC loss. The natural solution is the multi-filamentary structure realized by slicing or scribing wide tapes. If there is substantial inhomogeneity in the critical current value across the width of the original tape, slicing or scribing it into filaments may seriously degrade the final performance of the multi-filamentary conductor. A simple procedure based on Hall sensor array measurements to characterize the homogeneity across the width is proposed.

I. INTRODUCTION

The technology for producing long coated conductors has made a remarkable progress recently and its practical application is the next target. For the AC applications, reducing the AC loss is one of the critical issues. Good homogeneity across the width of the original tape is necessary for the multi-filamentary structure by slicing or scribing wide tapes to be effective. Although the current-carrying capacity of many coated conductors with a width of 5-10 mm is enough for many applications as a whole, the homogeneity within the tape is not always perfect in many cases. Therefore, a technique is desirable for an efficient and nondestructive characterization of the critical current distribution across the width.

In the present work, we propose a simple procedure to characterize the homogeneity across the width based on Hall sensor array measurements.

II. CHARACTERIZATION SCHEME

In our scheme, the distribution of the critical current density across the width is approximated by a quadratic function of the lateral coordinate, as is expressed in eq.(1).

$$j_c(y) = \frac{I_c}{2W} \left\{ 1 + s \frac{y}{W} + p \left(\frac{y}{W} \right)^2 - \frac{p}{3} \right\}, \quad -W \leq y \leq W \quad (1)$$

The function has three parameters, I_c , s and p , which represent the total critical current, the slope and the parabolicity, respectively. W is the half width of the tape. An additional term $-p/3$ is included so that the integration of eq.(1) from $-W$ to W gives I_c . In the present scheme, critical current distribution is expressed approximately by two dimensionless parameters, s and p , which should be of the order of unity.

The Hall sensor array measurement is performed using a commercial system (Tapestar[®], Theva) designed for the mea-

surement of the critical current distribution along the length [1]. In the measurement, the tape goes into a localized DC magnetic field and a supercurrent is induced within the tape. A typical tape speed is 50mm/s. We assume that the magnitude of the density of the induced current is the local critical current density. Magnetic fields just above the tape surface are measured by an array of seven Hall sensors covering the tape width. There must be a line at which the polarity of the induced current changes. The position e of this line depends on s and p values. The e value is determined by the condition that the net value of the induced current is zero as is illustrated in Fig.1 and is a solution of a cubic equation, eq.(2).

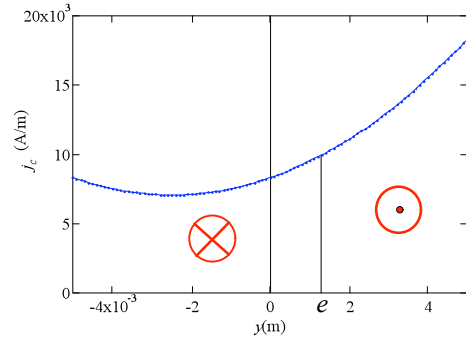


Fig. 1 A possible distribution of critical current density and the polarity of induced current.

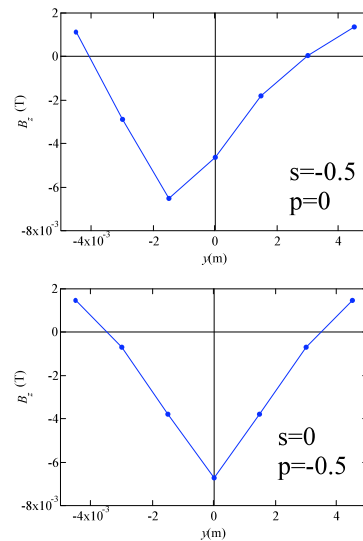


Fig.2 Magnetic field profiles expected for different sets of parameters s and p .

$$\left(\frac{e}{W}\right)^3 + \frac{3s}{2p}\left(\frac{e}{W}\right)^2 + \left(\frac{3}{p}-1\right)\left(\frac{e}{W}\right) - \frac{3s}{2p} = 0 \quad (2)$$

Magnetic field profiles which should be observed for different sets of parameters are shown in Fig. 2 in order to give a very rough idea about the sensitivity of the measurement to the inhomogeneity of the critical current density.

Three parameters are deduced in the spirit of the least square fitting from the Hall sensor array measurement data. The deduction of three parameters can be performed by a simple computer program using a personal computer. The fact that the shape of the magnetic field profile depends only on s and p , and that I_c is simply proportional to the total magnitude of the magnetic field profile makes the analysis much easier. Once the distributions of these parameters along the length are known, the current carrying capacity after a slicing or scribing treatment can be predicted within the quadratic approximation.

In the analysis, we need to assume uniformity along the length. It is estimated that the contribution to the magnetic field profile at a certain position comes from a distance of several centimeters. Therefore, if there is a defect or large non-uniformity along the length, the present analysis is not valid within the length of several centimeters.

III. ANALYSIS

An example of the application of the present technique to a real tape is shown in Fig.3. Upper panel shows the s -value distribution along the length of a 10mm tape. Where the s -value is positive, the critical current value should be larger on the right half than the left half and vice versa. The tape was cut into two 5mm tapes after the analysis and the critical current distribution was measured for each 5mm tape. It can be

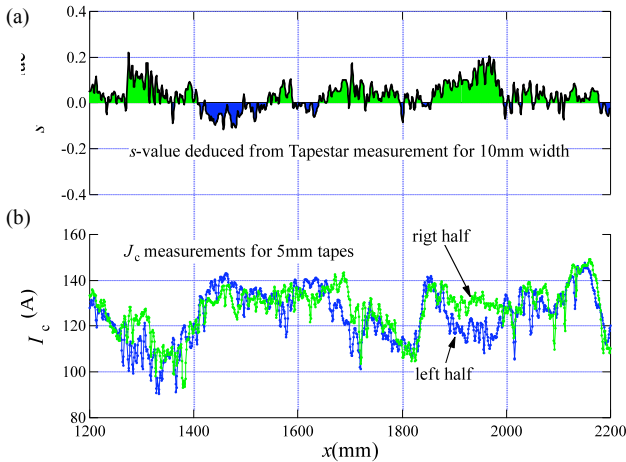


Fig. 3 An example of the analysis of a real tape. (a) s -value deduced for a 10mm tape. (b) Critical current density distribution along the length of two 5mm tapes cut from the original 10mm tape.

seen that the small imbalance of the critical current density across the width of the original 10mm tape revealed by the measurement for two 5mm tapes was predicted fairly well in the s -value distribution for the original 10mm tape.

IV. CONCLUSIONS

A simple and efficient technique for the characterization of the inhomogeneity of the critical current density across the width of coated conductors is proposed. The technique can be useful in nondestructive characterization of wide tapes before they are sliced or scribed into a multi-filamentary structure.

It should be noted that the present technique relies on the subtle difference in the shape of the magnetic field profile in the deduction of s and p values. The shape of the magnetic field profile is rather sensitive to the geometry of the measurement. Therefore, we need to know the distance between the Hall sensor array and the tape, possible shift of the tape in the lateral direction and so on with enough precision, when qualitative characterization is necessary. The development of an efficient procedure for the reliable measurement is in progress now.

It should also be noted that the Hall sensor array measurements corresponds to critical current density at a very low electric field criterion ($\sim 0.01 \mu\text{V}/\text{cm}$) [1]. Therefore, it is desirable to have information about the n -value as well, in order to compare the results with a usual criterion ($1 \mu\text{V}/\text{cm}$). We recently realized that a modified type measurement with a Hall sensor array can also be used for the estimation of the n -value, which will be described elsewhere.

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REFERENCE

- [1] K. Nakao *et al.*, *Physica C*, vol. 445-448, pp. 669-672, 2006.