AC loss of YBCO coated tape prepared by laser ablation

Ján Šouc 1, Michal Vojenčiak 1,4, Fedor Gömöry 1, Xavier Granados 2, Alexander Usoskin 3, Alexander Rutt 3
1 Institute of Electrical Engineering, Centre of Excellence CENG, Slovak Academy of Sciences, Bratislava, Slovak Republic
2 ICMAB, Barcelona, CSIC, Spain
3 EHTS GmbH & Co. KG, Göttingen, (EAS, Hanau), Germany
4 University of Žilina, Žilina, Slovak Republic
eleksouc@savba.sk

Abstract. AC transport loss of YBCO coated tape 4 mm wide has been investigated by standard experimental techniques. When used to evaluate the critical current of the tape in an indirect way, the results pointed toward the critical current exceeding 100 A at 77 K and zero superimposed DC field. Taking into consideration the extremely high aspect ratio of the superconducting layer, one would expect to observe the loss behaviour predicted for infinitely thin strip. However, in the case of AC transport, the loss dependence on current follows the formula derived for a strip with elliptical cross-section. The influence of the metal substrate on such behavior was experimentally excluded. To understand this result, additional experiments by field mapping over the sample carrying transport current have been performed. According these results the distribution of the transport current in the cross section of the sample fulfill the elliptical model prediction.

1. Introduction
Second generation of the long superconducting tapes constructed from HTS (YBCO coated tape) with promising superconducting as well as mechanical properties are expected to be used for power application eg power transmission cables. In this case the ac loss of YBCO coated wires can play important role to use them in practice.

Taking into consideration the extremely high aspect ratio of the superconducting layer, one would expect to observe the loss behavior predicted for infinitely thin strip. However, as was already shown in several papers [1,2] in the case of AC transport, the loss dependence on current follows the formula derived for a strip with elliptical cross-section.

In this contribution we confirm this YBCO coated behavior by standard ac transport loss measurement by contact as well as contact less method at different frequencies. More, using Hall probe, the distribution of the transport current was checked by field mapping over the sample.

2. Experimental
The sample used in this study was YBCO coated tape with $I_c = 95$ A (EHTS, Göttingen). Stainless steel NiCr tape was used as substrate. The thickness of the layer was 2 mm, the width 4 mm and measured length 10 cm. AC transport loss was measured by standard contact method as well as by
contact-less method [3] utilizing lock-in amplifier. To supply ac current in both cases the sample was connected in series to the secondary of the toroidal transformer. Because the sample was practically without stabilization metal layer (3 mm of Ag), second additive secondary winding with the same number of turns like first one was used to save sample against destroying in the over—critical current regime. The sample current was measured by Rogowski coil. Measurement set-up is schematically shown in Fig. 1. Results of the transport loss measurement were compared with theoretical prediction of the loss for strip and ellipse.

To exclude the substrate influence on the ac loss of the sample measurements with attached stainless steel NiCr tape (after elimination of the YBCO layer) as well as ferromagnetic tape were performed and compared – Fig. 2.

Using Hall probe, the distribution of the transport current in the sample was checked out by field mapping over the sample. The experiment was performed at two distances of the Hall probe from the surface of the sample – 0.3 mm and 0.6 mm. Also in this case the results were compared with theoretical estimation.

3. Results and discussion
In Fig. 3 ac loss per cycle Q dependence of the YBCO coated sample on the transport current are shown. Measurements were performed at three frequencies – 72 Hz, 144 Hz and 288 Hz. Experimental results very well follow Norris model [4] derived for elliptical cross-section in spite of high aspect ratio as was already shown in [1,2]. Practical no dependence on frequency was observed indicating no resistive behavior of the sample. Coincidence between contact and contact-less measurements excluded some possibility of the not correct contact measurements due to penetration of the current to the sample on certain length.

![Fig.1 Measurement set-up](image1)

![Fig.2 Sample with attached stainless steel or ferromagnetic tape](image2)

![Fig.3 dependence of the ac loss per cycle on the transport current at 72Hz, 144Hz and 288Hz](image3)

![Fig.4 ac losses comparison of the sample without added tape and with stainless steel or ferromagnetic tape](image4)
Excluding of the substrate influence on the ac loss measurement is illustrated in Fig. 4. Evident increasing of the ac loss was observed when the ferromagnetic tape was added to the sample. On the other hand, no change of the ac loss was registered after adding stainless steel tape (the same kind as substrate for YBCO deposition).

To understand the sample behavior illustrated in Fig. 3 the mapping of the magnetic field over the sample carrying ac transport current was performed. Hall probe moving in distance 0.3 mm and 0.6 mm over the sample was utilized for this purpose. In Fig. 5 the dependence of the By component perpendicular to the sample surface on the length from the middle of the sample is shown (full bold lines). Experimental data very well follow prediction derived for strip with elliptical cross-section (full thin lines) and evidently divert from prediction for thin strip (dashed lines). It means, in spite of extremely high aspect ratio of the sample the critical current distribution is non-homogenous. Similar conclusions were achieved in [1], where magnetic knife method was used.

4. Conclusion
Transport AC loss measurement of the thin film YBCO coated superconductor were performed by contact as well as contact-less measurement at 72 Hz, 144 Hz and 288 Hz. For all frequencies and both method the results follow Norris ellipse model in spite of high aspect ratio of the sample. Such behavior was explained by non-homogenous distribution of the critical current across the sample derived from the mapping of the magnetic field over the sample using Hall probe.

References
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