Thermal Conductivity Test of YBCO Coated-Conductor Tape Stacks Interleaved with Insulated Stainless Steel Tapes

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Introduction

A 32 Tesla, all-superconducting user magnet, which consists of two HTS YBCO inner coils producing a field of 17 T in an LTS Nb_3Sn and NbTi outer magnet producing a background field of 15 T, is being developed at the National High Magnetic Field Laboratory. The YBCO coils are pancake-wound as opposed to layer-wound for a variety of reasons including available conductor piece length [1]. The degradation of epoxy-impregnated YBCO coils resulted in selection of the dry-wind approach for the 32 T YBCO coils to avoid de-lamination of the tape [2]. The inter-turn insulation uses a sol-gel alumina-insulated co-wound stainless steel tape. The YBCO inner coils are to be cooled at 4.2 K liquid helium in normal operation. The heat losses in the coils, such as Joule-heating in the joints, the heat loss from the current leads and the ramping loss (AC loss) during ramping up/down the magnet, have to be transferred away to the external surfaces of the coil and then to LHe. Such internal cooling depends on the effective heat conduction of the coils. There are hundreds of contact interfaces between the YBCO conductors and stainless steel tapes in the radial direction of the coil, and the cross section of YBCO tapes are not strictly rectangular, which makes a prediction of the thermal conductivity generally impossible because the thermal contact resistances may play an important role.

Figure 1. Assembly of the sample with two YBCO stacks installed symmetrically in the Thermal Transport Sample Puck.

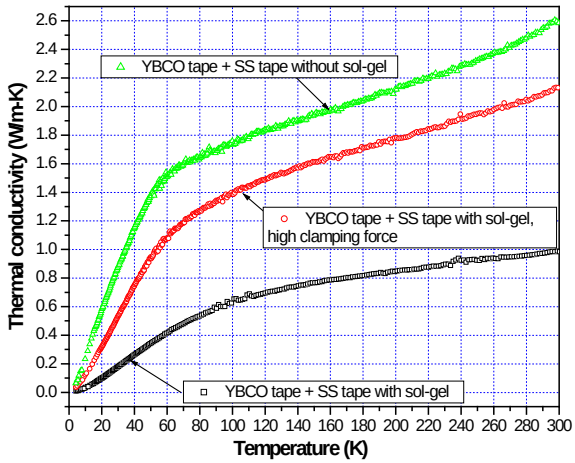

Figure 2. Thermal conductivity for three different cases: 1, YBCO tape and sol-gel coated SS tape under moderate clamping force. 2, YBCO tape and sol-gel coated SS tape under high clamping force; 3, YBCO tape and SS tape without sol-gel coating under moderate clamping force.

Experimental Results and Discussion

The thermal conductivity was measured in the Physical Property Measurement System (PPMS) of Quantum Design. The test sample consists of two stacks and each stack has 15 YBCO tape pieces and 15 stainless steel tape pieces stacked together. Two identical stacks were made for the test and they are installed and clamped in a copper frame by two bolts at both ends, shown in **Figure 1**. Tests were done in a continuous measurement mode and the measurements were taken automatically as the temperature ramped up from 4.2 K to 80 K or 300 K. **Figure 2** shows the results.

The estimated radial conductivity turns out to be about 1.2 W/m·K at 4.2 K without including the thermal contact resistance. This is almost two orders of magnitudes higher than the experimental value. It is mainly because the thermal contact resistance plays a dominant role in the heat conduction. In the YBCO tape fabrication process, the stabilizing copper is electroplated in the final step. The final conductor thickness is determined by the copper thickness and this thickness is found to vary on the conductor. The cross section of YBCO tapes are of a dog bone shape. This causes gaps between turns that result in the very poor thermal contacts between the turns. The turn insulation is made by insulated co-wound stainless steel tape between bare conductors. This insulation decreases the radial thermal conductivity further.

References

[1] W. D. Markiewicz, *et al*, *IEEE Trans. Appl. Supercond.,* 22 (3), 1051-8223(2012).
[2] T. Takematsu, *et al*., Physica C 470, 674-677(2010).