§8. Current Distribution of YBCO Tapes Applied for HTS Current Leads

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High Temperature Superconductors (HTS) having critical temperatures (Tc) above 77 K, such as $Y_1Ba_2Cu_3O_{7-\delta}$ (YBCO), $Bi_2Sr_2Ca_2Cu_3O_{10}$ (Bi2223), and $Bi_2Sr_2Ca_1Cu_2O_8$ (Bi2212), are attractive conductors for current lead application. The small heat leakage into the magnets can save the consumption of liquid helium and cooling power of cryocoolers due to low thermal conductivity and no joule heating in HTS current lead. Therefore, many researches and developments [1)-3)] on HTS current leads have been studied for large scale application. In present work, transport performance and current distribution of current lead prepared by YBCO superconducting tapes at 77 K in liquid nitrogen has been reported.

Tri Fluoro Acetates - Metal Organic Deposition TFA-MOD processed YBCO tapes, with 5 mm in width and around 110 μm in overall thickness are cut from long tape. The YBCO superconducting layer with 1.5 μm is deposited on two intermediate buffer oxide layers (GZO and CeO_2) and Hastelloy substrate tape of 100 μm in thickness. An Ag layer, around 6 μm in thickness, is further deposited for improving thermal and electrical stabilization and mechanical strength. Transport current is supplied through the Ag layer.

Fig. 1 shows the HTS current lead composed of eight YBCO tapes, both end joints of Cu and a pair of stainless steel ss boards. Eight YBCO tapes are soldered to each slot (1 tape/slot) in front and back side (4 slots/side) of Cu joints. The critical current Ic of eight YBCO tapes ranges from 150 A to 180 A at 77 K and self-field. The ss boards are attached as shunt in case of quenching, and serve mechanical reinforce and relieves thermal stress in the thin YBCO tapes. Voltage taps were attached on YBCO tapes, Cu caps and joints as shown in Fig. 1. Eight Rogowski coils of 3,000 turns were set up around each YBCO tape. The current lead was cooled down to 77 K by liquid nitrogen in a tub. Transport current were measured by facilities of National Institute for Fusion Science NIFS.

The transport current of 700 A was successfully carried with no voltage (V_{YBCO}=0) on YBCO tapes. The voltages: $V_{Cu(+)}$ and $V_{Cu(-)}$ almost linearly increased with increasing transport current, and the resistances of Cu (+) and Cu (-) joints were 1.05 – 1.37 μΩ and 0.82 – 1.05 μΩ at 700 A, respectively. Fig. 2 shows the imbalance of transport current up to 700 A between eight YBCO tapes with sweep rate of 400 A/s at 77 K. The current calculated by Rogowski coils ranges from 2 A to 172 A, although mean current of eight YBCO tapes with no imbalance between eight tapes is 87.5 A. The lower current in three tapes were 2 A - 13 A, on the other hand, higher current in five tapes were 116 A – 172 A, respectively. The sum of current of eight YBCO tapes calculated by Rogowski coils is 692 A, which is the slight difference of 8 A in comparison with transport current of 700 A. The imbalance of current between eight YBCO tapes may result from the difference of contact resistance between YBCO tapes and Cu joint in soldering process.

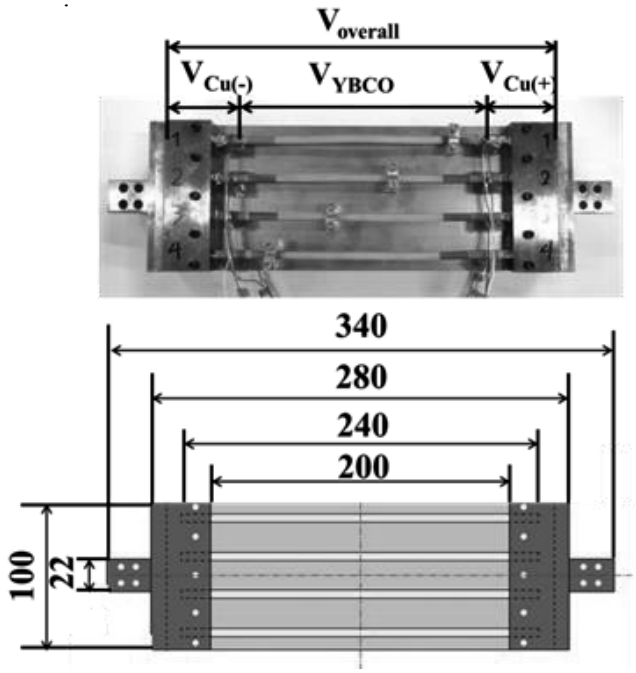

Fig. 1. HTS current lead composed of eight YBCO tapes, both Cu end joints and a pair of stainless steel boards.

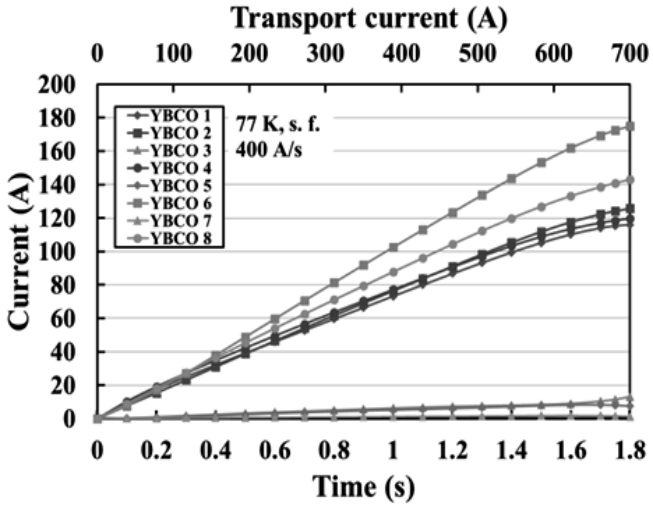

Fig. 2. Imbalance of transport current up to 700 A between eight YBCO tapes at 77 K.

1) Matsumura, R. et al.: Abstracts of CSJ Conf., **90** (2014) 156.
2) Matsumura, R. et al.: 27th ISS2014, SAP-23. Physics Procedia (2015) to be published by Elsevier B.V.
3) Yamada, Y. et al.: 23rd Magnet Technology (2013) 164.