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

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High Temperature Superconductors (HTS) such as $Y_1Ba_2Cu_3O_{7-\delta}$ (YBCO) and $Bi_2Sr_2Ca_2Cu_3O_{10}$ (Bi2223) having critical temperature T_c above 77 K, are attractive conductors for application of current lead and power cable. The YBCO tape has higher critical current density Jc and better magnetic property than the Bi2223 tape. Furthermore, thermal conductivity of YBCO tape with thin Ag layer is much lower than that of Ag-sheathed Bi2223 tape. Therefore, many researches and developments [1)-2)] 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 has been reported.

The YBCO tape with 5 mm in width is fabricated by TFA-MOD process. The YBCO superconducting layer with 1.5 μm in thickness is formed by dip-coated on intermediate oxide buffered layers which are deposited on Hastelloy (C-276) 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 protecting from moisture in open air.

Eight YBCO tapes are arrayed on the both sides and soldered into Cu caps at the both ends a commercial Pb-Sn-Ag solder as shown in Fig. 1. Voltage taps, V_{YBCO}, are attached to every YBCO tape with the tap distance of 170 mm. A pair of voltage taps $V_{Cu}(+)$ and $V_{Cu}(-)$ is similarly to the both Cu end caps. Eight Rogowski coils of 3,000 turns were looped around each YBCO tape. The current lead was cooled down to 77 K by liquid nitrogen in a tub. Transport current performance was measured by facilities of National Institute for Fusion Science NIFS.

Transport performance of the current lead is shown in Fig. 2. The transport current of 1000 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. The resistances of Cu (+) and Cu (-) joints vary from 0.206 – 0.234 μΩ and 0.210 – 0.230 μΩ at 1000 A, respectively. Fig. 3 shows current distribution of the current lead up to 1000 A at sweep rate of 200 A/s. The current calculated by Rogowski coils ranges from 4 A to 179 A, although mean current of eight YBCO tapes with no imbalance between eight tapes is 125 A. The lower current in one YBCO tape of No. 8 was 4 A, on the other hand, higher current in seven YBCO tapes of No. 5, 6, 1, 7, 3, 4 and 2 were 128 A, 129 A, 130 A, 141 A, 144 A, 148 A and 179 A, respectively. The sum of current of eight YBCO tapes calculated by Rogowski coils is 1001 A, which is the slight difference of 1 A in comparison with transport current of 1000 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.

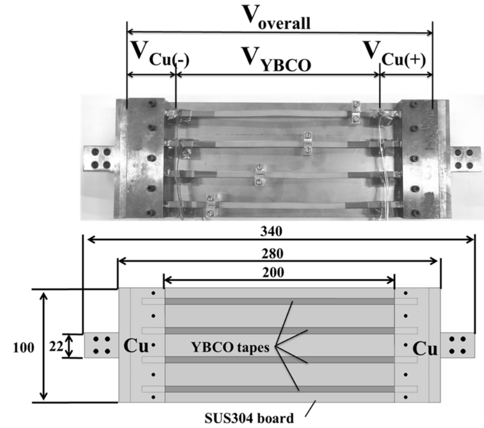

Fig. 1. HTS current lead composed of eight YBCO tapes, both Cu end joints and a pair of stainless steel boards.

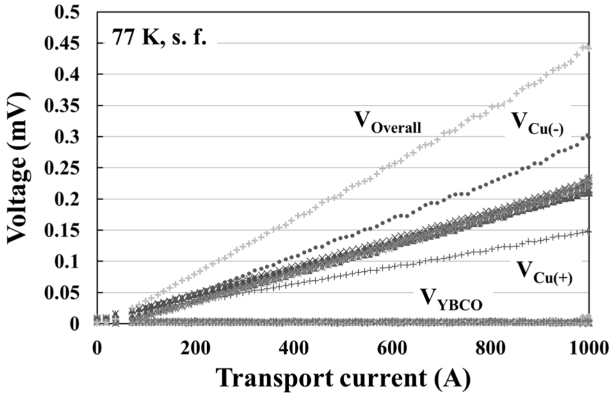

Fig. 2. Transport current performance of the current lead.

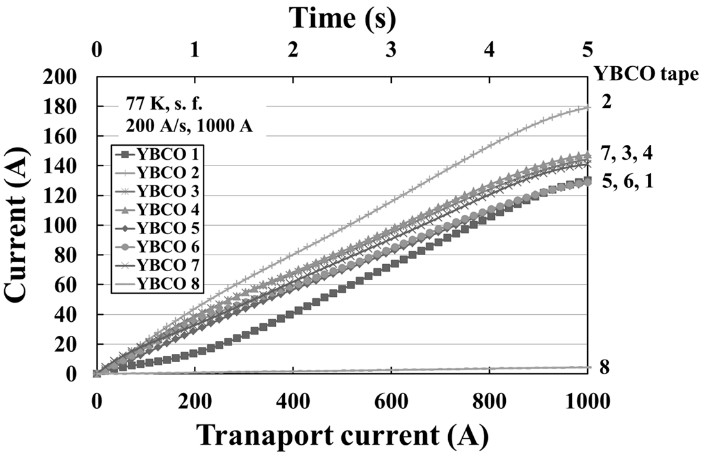

Fig. 3. Current distribution of the current lead up to 1000 A at sweep rate of 200 A/s.

1) Matsumura, R. et al.: Abst. of CSJ Conf., **92** (2015) 79.
2) Matsumura, R. et al.: IEEE Trans. Appl. Supercond., vol 26, no. 4 (2016) 4800104.