§13. HTS Current Leads Prepared by Y-based Superconducting Tapes

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HTS High Temperature Superconductors are attractive for current lead application in superconducting magnet system. 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 on HTS current leads have been studied for large scale application[1)-3)]. In present work, transport performance of current lead prepared by Y-based YBCO ($Y_1Ba_2Cu_3O_7$) superconducting tapes at 77 K in liquid nitrogen has been reported.

The YBCO tapes with 5 mm in width are fabricated by Tri Fluoro Acetates - Metal Organic Deposition (TFA-MOD) process. The YBCO superconducting layer of 1.5 μm in thickness is formed on the intermediate oxide buffered layers deposited on Hastelloy substrate. An Ag layer of around 24 μm in thickness is deposited on the YBCO layer for improving thermal and electrical stability and protecting from moisture in open air.

Fig. 1 shows the assembled HTS current lead composed of four current lead units prepared by YBCO tapes. The unit is composed of twenty-four YBCO tapes, both end caps of Cu and a pair of stainless steel ss boards. Six bundles stacked by four YBCO tapes are soldered to each slot (4 tapes/slot) in front and back side (3 slots/side) of Cu caps. The critical current of 24 YBCO tapes ranges from 147 A to 155 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. The current lead was assembled from four units which were bolted onto the square-shaped Cu joint. Voltage taps were attached on YBCO tapes, Cu caps and joints as shown in Fig. 1. Rogowski coils of 3,000 turns were set up around each unit. 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 10 kA 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 reached around 1.37 mV and 1.32 mV at 10 kA, respectively. The low voltage results from the low contact resistance of 0.5 μΩ between Cu cap and YBCO tapes, and cause a small Joule heating at the joints. Using Rogowski coils, imbalance of transport current between four current lead units (1-4) at sweep rate of 1,000 A/s up to 10 kA was evaluated as shown in Fig. 2. Since transport current of four units is evaluated to be 2,120 A, 3,170 A, 2,670 A and 2,810 A respectively, the imbalance of 1,000 A may occur between four units at 10 kA.

The heat leakage of the current lead unit 200 mm in length is calculated to be 367.5 mW between 77 K and 4.2 K. Therefore, the heat leakage of the assembled HTS current lead at transport current of 10 kA corresponds to 147 mW/kA, which is one order of magnitude smaller than that (1.2 W/kA) of conventional Cu current lead. The small heat leakage results from high current performance and low thermal conductivity in the TFA-MOD processed YBCO tapes.

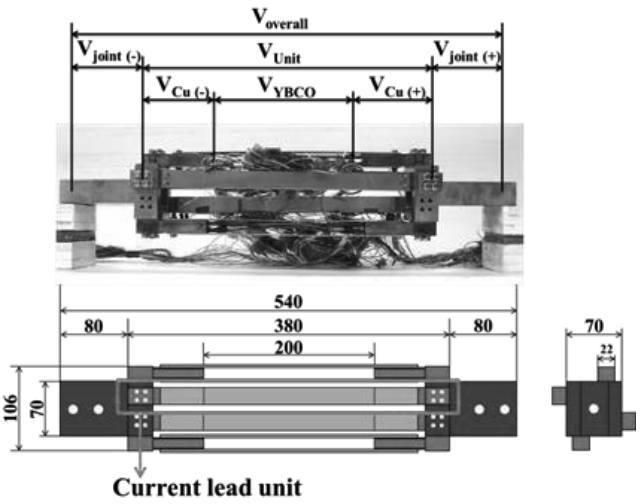

Fig. 1. Assembled HTS current lead composed of four YBCO current lead units.

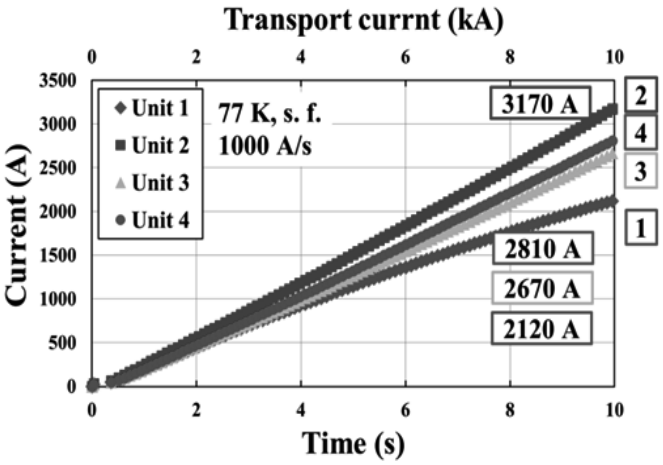

Fig. 2. Imbalance of transport current up to 10 kA between four current lead units at 77 K.

1)Yamada, Y. et al.: 23rd Magnet Technology (2013) 164.
2)Hosono, Y. et al.: Abstracts of CSJ Conf., **88** (2013) 146
3)Yamada, Y. et al.: IEEE Trans. Appl. Supercond. **21** (2011) 1054.