§2. Study on Remountable Joint of YBCO Conductor for Remountable High-temperature Superconducting Magnet

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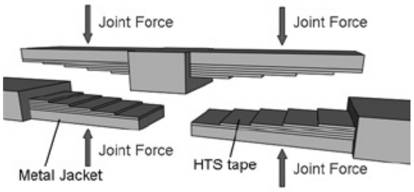
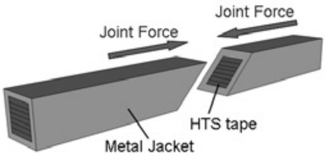
Our research group have been proposed remountable (demountable) high-temperature superconducting (HTS) magnet, segment of which can be mounted and demounted iteratively. [1] This design concept can provide engineering solution for a helical reactor having huge and complex superconducting magnets. In this corroborative study, we are aiming to develop remountable (demountable) joints of a stacked REBCO (YBCO, GdBCO and so on) conductor and design the remountable magnet based on thermal and structural analyses. This year, we investigated mechanical bridge and butt joints shown in Fig. 1. Experimental and numerical results for two joint methods are summarized in this report.

In terms of the bridge joint, we fabricated two 30 kA class HTS conductor samples (samples A and B) consisting of two rows and ten layers of GdBCO tape (Fujikura Ltd., FYSC-SC10), which has joint region using the bridge joint. The samples have joint length of 28 mm and 34 mm per one layer, respectively. Both samples have indium films of 50 μm thick inserted between joint surfaces to achieve uniform contact pressure distribution. Joint force was applied by tightening bolts and the joint stresses were controlled to 34.8 MPa and 64.0 MPa for the samples A and B, respectively. The samples are race-track shaped and have no current lead; current is applied by electromagnetic induction with external magnetic field. Current was evaluated by Rogowski coils and Hall elements and the joint resistance was calculated by time constant of current and self-inductance of the samples. Fig. 2 shows relationship between external magnetic field and joint resistance in each joint region (The mechanical bridge joint has two joint regions). The sample A showed high joint resistance in joint region #2, which is 10 times larger than predicted one based on a fundamental experiment.[2] That is caused by overlap of one layer of GdBCO tape to another layer. The sample B didn't have above problem and showed low joint resistance, which is comparable to predicted one. The obtained joint resistance was 5.5–6.9 nΩ for one bridge joint in the sample B and we achieved to apply 69.7 kA at 4.2 K without quench at the joint.

In terms of the butt joint, we carried out numerical analysis (current distribution analysis) and joint test to evaluate joint resistance depending on joint and conductor structures. The joint resistance consists of contact resistance and resistance of materials constituting the conductor. The experiment and numerical analysis showed that contact resistivity is 2.5–4.5×10^{-12} Ωm^2 in the butt joint at 77 K, self field and joint stress of 100 MPa. Based on the above estimated resistivity, we evaluate joint resistance of a demountable HTS magnet designed for FFHR and discuss the electric power required for cooling an entire helical coil. Fig. 3 shows the female component of the joint for the evaluation. The evaluated joint resistance per one conductor is 4.4–5.4 nΩ and the estimated electric power for cooling an entire helical coil is 23–27 MW. The electric power is comparable to that in LTS coil option of FFHR.



(a) Mechanical lap joint (bridge-type)



(b) Mechanical butt joint

Fig. 1. Remountable joints of a stacked HTS conductor with metal jacket.

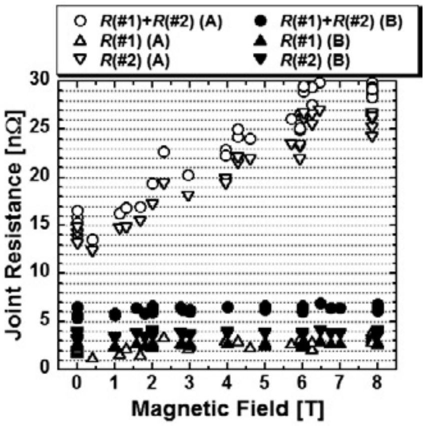


Fig. 2. Experimental results obtained in the mechanical bridge joint.

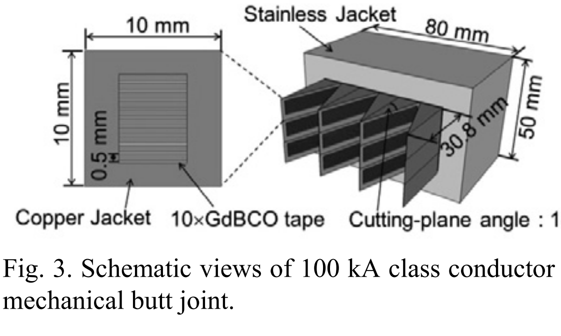


Fig. 3. Schematic views of 100 kA class conductor for mechanical butt joint.

1) Ito, S. et al.: Fus. Eng. Des., **81** (2006) 2527.
2) Kawai, K. et al.: IEEE Trans. Appl. Supercond., **23** (2013) 4801704.