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Experimental Study of Current Sharing and Transfer in Superconductor Joint

S. Mizumaki* and A. Yamamoto*, **

*The Graduate University for Advanced Studies, 1-1 Oho, Tsukuba, Ibaraki, 305, Japan

**National Lab. for High Energy Physics (KEK), Tsukuba, Ibaraki, 305, Japan

Abstract---A fundamental study of current sharing and transfer in superconducting joint has been carried out. The variation of the current sharing in the joint, with increasing the joint current, has been observed by using Hall probes attached to the joint block. The measured result is consistent with a proposed current transfer model in the joint. The experimental method and the test results are reported in this paper.

I. INTRODUCTION

In application of superconducting magnets such as medical imaging spectrometers, unexpected spontaneous quenches during the long term operation in persistent mode have been a major subject to be understood and to be solved. As a possible candidate, a superconducting joint installed in the magnet has been considered to be an origin of the quench because of the imperfectness in superconductivity. A time dependent variation of the current sharing path in the joint could be an origin of the quench trigger. Especially in the superconductor joint to the persistent current switch, much different conductor condition from the coil conductor causes more imperfect joint condition. It may result in inhomogeneous current sharing and transfer, and further time dependent unbalance may be induced.

In this work, the current transfer and its movement in the joint has been observed through magnetic field measurement by using Hall probes. The preliminary results has shown enough sensitivity to measure the current distribution. Fig. 1 shows a schematic view of the superconducting joint which was examined in this experiment. A simple face-to-face lap joint was prepared to observe the current transfer across the joint and its possible transverse movement with increasing the current. In order to simulate a practical situation, the joint was prepared by using a wire for the persistent current switch (PCS) and a wire for the coil winding. Table I gives main parameters of those superconducting wires.

TABLE I
SUPERCONDUCTOR SPECIFICATIONS

Superconductor	unit	A	B
Matrix material		Cu	CuNi
Cu (CuNi)/SC ratio		1.00	1.05
Dimension :			
Height	mm	0.80	0.68
(incl. insulation)			
Width	mm	1.75	1.02
Filament:			
diameter	μm	35	20
number		677	931
area	mm^2	0.651	0.304

Fig. 1. A schematic view of the superconductor face-to-face joint made with direct metallurgical diffusion bonding.

Fig. 2. A schematic diagram of the current loop in the joint and transverse magnetic field to be detected by using Hall probes

Fig. 3. Magnetic field as function of the Hall probe position.

II. CURRENT TRANSFER MODEL IN THE JOINT

Fig. 2 shows a schematic diagram of the rectangular current loop in the face-to-face lap joint. The magnetic field (B_z) transverse to the central axis (x axis) is induced by there current loop. It basically consists of two components induced by line current (going/returning and traversing) components. The magnetic field may be expressed by the following equations:

(a) the component of the going and returning line current

$$B_1 = \frac{\mu_0 a I}{2 \pi (a^2 + z^2)} \left\{ \frac{x}{\sqrt{x^2 + a^2 + z^2}} + \frac{L - x}{\sqrt{(L - x)^2 + a^2 + z^2}} \right\}$$

(b) the component of the traversing line current

$$B_2 = \frac{\mu_0 x I}{2 \pi (x^2 + z^2)} \frac{a}{\sqrt{x^2 + a^2 + z^2}}$$

where x and z are the coordinates of the calculated position, L is the length of the going/returning line current, and a is the half gap (width) of the traversing line current. Fig. 3 shows calculated magnetic field as a function of the Hall sensor location. If the location of the traverse current moved far in the joint, the transition of the magnetic field should be observed by the Hall probe. Fig. 4 shows a proposed simplified model for the current paths depending on the overall transfer current changed in the joint. If the traverse

Fig. 4. Possible current path models in the face-to-face superconductor joint.

Fig. 5. Cross sections of the joint sample with Hall probes.

current path moved, the Hall probe should detect the movement according to the transition.

III. JOINT SAMPLE PREPARATION

The superconducting joint sample was made by using diffusion bonding technique with the following process [1-2]:

- (i) Removing stabilizer by using nitric acid solution,
- (ii) Rinsing by using fluoric acid and pure water,
- (iii) Cleaning by using water and Acetone with ultra-sonic oscillation,
- (iv) Drying in pure nitrogen,
- (v) Installing both filaments face-to-face in Cu case,
- (vi) Diffusion bonding at 450 deg. C with mechanical pressure in vacuum.

Fig. 5 shows cross sections of the joints with major dimensions. The Hall probes were placed both sides of the Cu joint-case. Fig. 6 shows cross section of the sample holder and experimental set up surrounded by a solenoid magnet (for possible future tests in magnetic field).

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

Fig. 7 shows a result of the measurement (@ $B=0$) as a function of the overall joint current. The lower figure is expanded in the vertical scale to enhance the transition. The magnetic field transition was observed with each Hall probe according to the current increasing.

Fig. 6. Cross sectional view of the experimental set up. The joint sample holder is at center.

Fig. 7. Magnetic field, measured with Hall probes, as a function of the overall joint current.

Fig. 8. Calculated magnetic field at the Hall probe position, with assuming the current loop model-2.

Fig. 9. The measured magnetic field compared with the calculation with the model-2.

It has been understood that the current distribution expanded to the far-end direction in the joint with increasing the overall current. Fig. 8 shows calculated results with the model-2 discussed above. Fig. 9 shows a comparison of the measured result with the simulation. We consider that those are reasonably consistent with each others. The current path movement with increasing the overall current may be explained by using the proposed model.

V. SUMMARY

The current sharing and transfer in the superconducting joint has been investigated. As an experimental result, redistribution of the transverse current in the joint has been verified with increasing the overall current. This behavior is consistent with a calculated result by using a rectangular current loop model. The experimental technique to observe the change of the current distribution in the joint has been established. Further precise experiment is to be carried out to understand the external magnetic field effect and long term stability of the superconducting joint.

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REFERENCES

- [1] M. J. Leupold and Y. Iwasa, "Superconducting joint between multifilamentary wires 1. Joint-making and joint results", *Cryogenics*, April (1976), pp. 215-216
- [2] Th. Schneider and P. Turowski, "Critical Current Degradation of a NbTi-Multifilament Conductor due to Heat Treatment", *IEEE Trans. Magn.*, vol. 30 (1994) pp.2391-2394