## §11. Thermal Stability of Joint between Conductors for Large-scale Superconducting Magnet

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i) Introduction

The JT-60 Super Advanced (JT-60SA) in Japan Atomic Energy Agency aims to contribute to the early realization of fusion energy by providing support to the operation of ITER. The magnet system for JT-60SA consists of 18 toroidal field (TF) coils, a central solenoid (CS) with 4 modules, and 6 equilibrium field (EF) coils. The coils are separately fabricated in Japan and Europe. The PF coils (CS and EF coils) are fabricated in Japan. There are two types of joints in the PF, the lap and butt joint. Fig. 1 shows a schematic of the lap and butt joint. In case of the lap joint, two conductors are pressed by overlapping them with copper blocks and connected by soldering. As for the butt joint, two conductors are pressed onto each side of a copper sheet and diffusion bonded by heating. The former is used between the EF pancake coils, and between the PF coil and the current feeder, and the latter is used between pancake coils in the CS. When a time-varying magnetic field is applied to the joints, an AC losses occurs, and temperature margin of the joint decreases due to the AC losses. For example, PF coil are strongly coupled with the plasma current, so the evaluation of AC loss at the plasma disruption is important. The loss is the main origin of instability in the joint, and hence, to protect this coil system from quench, it is necessary to understand the temperature margin of the joints.

In this study, we fabricated lap and butt joints and measured their AC losses under the time varying field. Based on these experimental results, we analyzed the temperature rise caused by AC loss of the joints by using FEM under the plasma disruption scenario.

ii) Experimental and Analytical results

Fig. 2 shows typically obtained data of the measured AC losses of the lap and butt joints. In this figure, as the lap joint, the magnetic field is constant (0.4 T), and the magnetic field angle is from 0 to 90 degrees. As for the butt joint, the maximum field is 1.2, 1.0, 0.8 T, and the magnetic field angle is constant (0 degree). The horizontal axis is the ramp rate of the magnetic field, and the vertical axis is AC loss. When the magnetic field and dB/dt increased, the AC losses of both joints also increased. The AC loss of the butt joint is smaller than the AC loss of the lap joint, because copper volume in the butt joint is smaller than the volume in the lap joint. The AC loss of the lap joint becomes large when the angle of the magnetic field applied to the sample joint is large. The reason is that the area exposed by the magnetic field on the copper block becomes large.

In this analytical models, based on the AC losses, we calculated the temperature rise at the joints to evaluate the stability at the coils. The results of the butt joints at the plasma disruption is shown in Figs. 3. When the mass flow of the SHe increased, the maximum temperature of the butt joint decreased. In this analytical results, if the mass flow of the SHe is 4 g/s and more in the all initial temperatures (4.2-7.0 K), the thermal stability of the butt joint is ensured sufficiently.

iii) Conclusion

We measured and analyzed the AC losses of the lap and butt joints of the CS and EF conductors for JT-60SA under a time-varying magnetic field. Based on the analytical AC losses, the temperature rise of the joints at the plasma disruption is estimated.[1] The results of the work are as follows:

(1)When the magnetic field and dB/dt increased, the AC losses of the lap and butt joints also increased, and the AC loss of the butt joint is smaller than that of the lap joint because of the difference of the copper volume in the joint.

(2)When the mass flow of the SHe is 4 g/s and more in the all initial temperatures (4.2-7.0 K), the butt joint have a sufficient temperature margin at the plasma disruption.

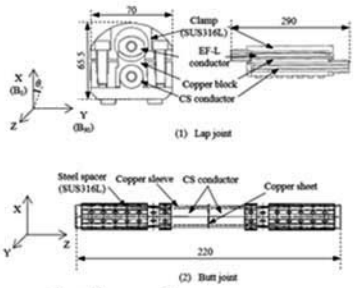

Fig. 1. Schematic of samples

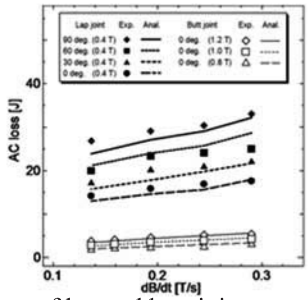

Fig. 2. AC loss of lap and butt joint

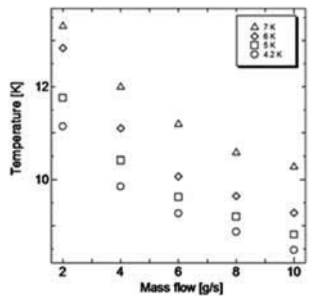

Fig. 3. Maximum temperature at butt joint

1) Nakamura, K. et al. : IEEE Trans. Appl. Supercond. Vol. 25 (2015).