§30. Joint Resistance Measurements of the Shake-hands Lap Joints for JT-60SA EF Coils

Obana, T., Takahata, K., Hamaguchi, S., Mito, T., Imagawa, S.,
Kizu, K., Murakami, H., Yoshida, K. (JAEA)

The magnet system in the JT-60 Super Advanced (JT-60SA) fusion experiment is composed of 18 toroidal field coils, 4 stacks of central solenoid (CS) coils, and 6 plasma equilibrium field (EF) coils [1]. In the EF coils, two types of cable-in-conduit (CIC) conductors are utilized because of the difference of the maximum magnetic field in the coils. The EF coil for high field (EF-H) conductor is composed of NbTi strands, and the EF coil for low field (EF-L) conductor is composed of NbTi strands and copper wires. The joint between the EF conductors is a one box-type joint that is suitable for a NbTi joint without using a bonding plate of copper and stainless joint. A joint can be assembled using a 60Sn-40Pb solder and covered by a simple case with closure welding. The EF coil has a "pancake joint" which is the joint between pancake coils, and a "terminal joint" which is the joint between the pancake coil and the current feeder.

The sample, including the pancake and terminal joints, was developed to evaluate the fabrication technology of the joints. Using the sample, joint resistance tests were conducted at NIFS test facility.

Fig. 1 shows the configuration of the joint sample. It has a racket shape and is 300 mm in diameter at the circular section. The pancake joint is composed of the shake-hands lap joint between the EF-H coil conductors, and the terminal joint is composed of the shake-hands lap joint between the EF-H and EF-L coil conductors. The EF-H and EF-L coil conductors are CIC conductors equipped with a central spiral. The EF-H conductor's cable is composed of only 450 NbTi strands, and the EF-L conductor's cable is composed of 216 NbTi strands and 108 copper wires. The NbTi strands are plated with Ni. Specifications for the conductors are described in Ref. [1]. As shown in Fig.2, a saddle-shaped spacer of pure copper (C1100) is located between the conductors in the joints of the sample, removing a conduit and the Ni plating of the conductor surface. The spacer and conductors are electrically connected with a 60Sn-40Pb solder and clamped with SUS304. Additionally, the central spiral is replaced with a stainless tube. The connected length is 160 mm in the longitudinal direction. This length is the same as the final pitch of the conductors. The conductors are compacted in the joint, and the void fraction of the conductors is 25 %. There is a liquid helium (LHe) inlet located at the circular section of the joint sample.

The test facility can accommodate the testing of superconductors cooled by LHe, under an external field generated by a superconducting split coil. The joint sample was installed into the gap of the split coil so as to fit the center of the joint sample with that of the split coil. The joint sample was subsequently immersed in LHe. As illustrated in Fig. 1, the joint sample was equipped with voltage taps attached to the conduit. To measure the joint resistance properly, two pairs of the voltage taps were used for each joint such as the pairs (V2-V5, V3-V4) for the pancake joint and those (V6-V9, V7-V8) for the terminal joint.

Electrical resistances were measured at the joints of the sample. For these measurements, the sample was energized to 20 kA at a ramp rate of 100 A/s, and was maintained for 500 s. The sample was then degaussed. Fig. 3 shows the resistances for the pancake and terminal joints. The resistances of both joints are proportional to the external field strength, and the resistance of the pancake joint is slightly higher than that of the terminal joint. The resistances of the pancake and terminal joints are 1.85 nΩ and 2.1 nΩ respectively, at the external field of 3T. This fulfilled the 5 nΩ at 3 T design requirement.

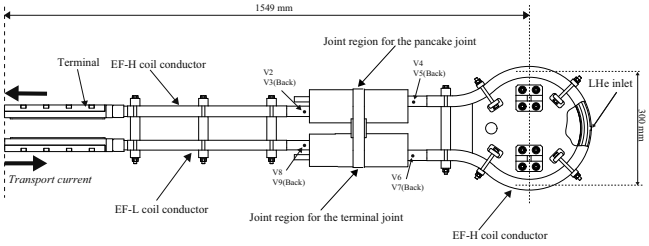

Fig. 1. Schematic view of the joint sample.

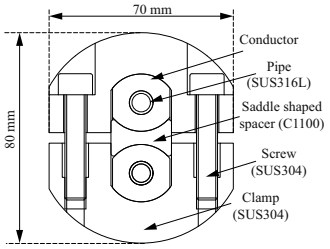

Fig. 2. Cross-section of the shake-hands lap joint.

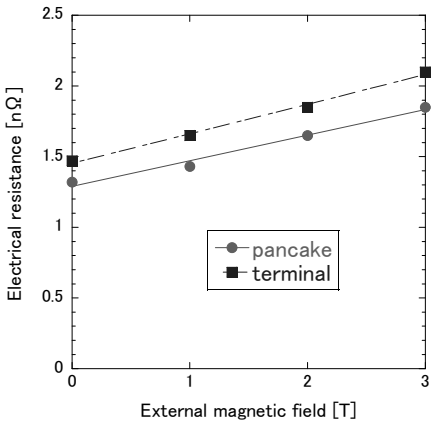

Fig. 3. Measurement results of the joint resistance.

1) Yoshida, K.,: Physica C **470** (2010) 1727.