

§25. Microstructural Observations on Butt Joint of JT-60SA CS

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The JT-60SA CS coil is composed of four modules. One module is composed of six octa-pancake coils and four quad-pancake coils. To join these coils wound with Nb₃Sn cable-in-conduit conductors as listed in Table 1, a butt joint technology was adopted in the CS coil. The butt joint is very attractive for the CS coil of a tokamak machine because it allows embedding of the joint into a winding pack that provides maximum flux at a given peak field in the winding[1]. To evaluate the fabrication technology of the butt joint as shown in Fig.1, a joint resistance was measured using a butt joint sample. As a result, the sample fulfilled the design requirement that the joint resistance was less than 5 nΩ at 2 T[2].

Compared to a lap joint technology, the butt joint technology is inexperienced and challenging for the present. Hence, not only joint resistance but also microstructural observation should be necessary to fully evaluate the butt joint. In this study, joint interface and Nb₃Sn strands of the sample were observed using a field emission scanning electron microscope (FE-SEM) after the joint resistance measurements.

To make a sample for the microstructural observations, vacuum impregnation of the butt joint sample was conducted after the joint measurement, and the butt joint sample was sundered around the butt joint interface. Then, a piece sundered from the butt joint sample was split. Finally, surfaces split from the piece were polished for the observation.

Microstructural observations of a butt joint interface were conducted using the FE-SEM (Model number: JSM-7100F, JEOL Ltd.). Fig 2 shows the micrograph of the butt joint interface at a strand scale. The configurations of Nb₃Sn strands, copper wires and a copper sheet were clearly observed. The micrograph indicates that Nb₃Sn strands and a copper sheet were butted properly. To investigate the condition of Nb₃Sn filaments, the butt joint interface was observed at a filament scale. Fig.3 shows the Nb₃Sn filaments close to the butt joint interface. In some of Nb₃Sn filaments, there were hairline cracks perpendicular to the copper sheet.

Table 1 Main parameters of CS conductor.

Nb ₃ Sn filament diameter [μmm]	3.5 (Nominal value)
Number of Nb ₃ Sn filament	8130
Strand diameter [mm]	0.82
Number of Nb ₃ Sn strands	216
Number of Cu wires	108
Cabling pattern	(2 +1Cu) ×3×6×6
Jacket outer size [mm×mm]	27.9×27.9
Cabling diameter [mm]	21.0
Central spiral (id/od) [mm]	7/9

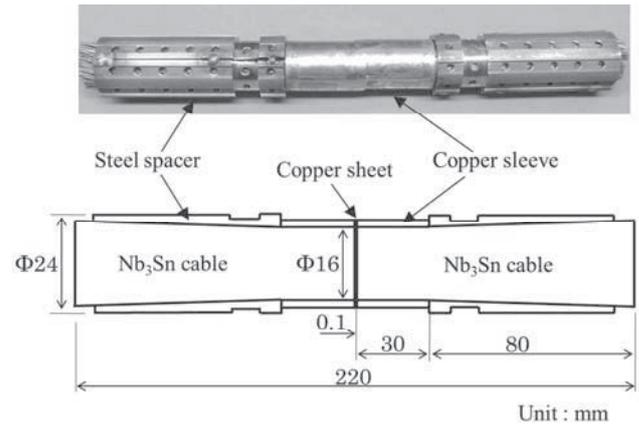


Fig. 1. Configuration and photograph of the butt joint.

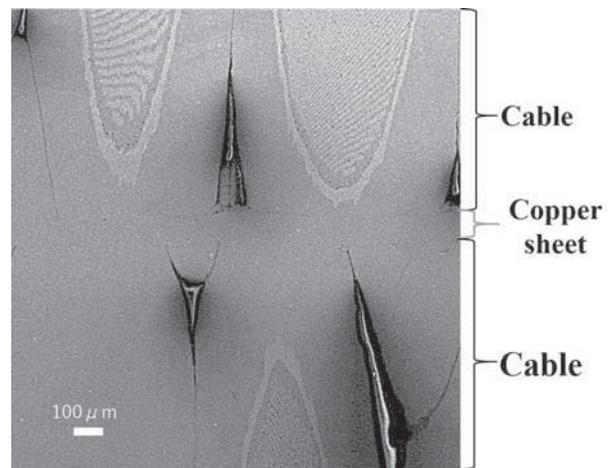


Fig. 2. Micrograph of the butt joint interface at a strand scale.

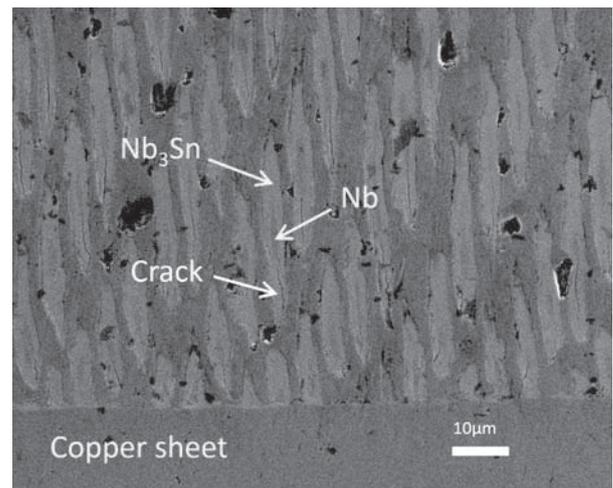


Fig. 3. Micrograph of the Nb₃Sn filaments close to the butt joint interface.

- 1) Yoshida, K., : Physica C **470** (2010) 1727.
- 2) Obana, T.,: Cryogenics **73** (2016) 25.