§22. Critical Current of React-and-Jacket Processed Nb_3Sn Conductor

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A cable-in-conduit conductor is a promising candidate for use in a fusion magnet. However, when using Nb_3Sn as a superconductor, an intrinsic problem arises from the strain effect of Nb_3Sn. Nb_3Sn is formed in strands by reaction heat treatment at approximately 1000 K together with a steel conduit. Because the Nb_3Sn has a lower coefficient of thermal expansion than conventionally used metals, such as copper, bronze and stainless steel, the shrinkage of the steel conduit applies an additional compression to the Nb_3Sn during cool-down from 1000 K to the operation temperature (for example, 5 K). This compression results in degradation of the critical current (I_c), due to the strain effect. To solve this problem, we propose a react-and-jacket processed Nb_3Sn conductor, where heat treatment of the superconducting cable is performed prior to jacketing, as opposed to fabrication of the cable-in-conduit conductor. Thermal contraction of the jacket only from 300 to 5 K affects the compression of Nb_3Sn; therefore, degradation of I_c can be inhibited. Therefore, a react-and-jacket processed Nb_3Sn conductor with an aluminum-alloy jacket was developed.

Fig. 1 shows a cross-sectional image of the developed conductor and Table 1 lists the specifications. The Rutherford cable consists of 18 bronze route Nb_3Sn wires with diameters of 1.0 mm. The heat-treated cable and indium sheets as a filler material were embedded into the grooved aluminum-alloy jacket. The cover of the jacket was then welded using a friction stir welding (FSW) technique, which avoids damage to the strands, unlike conventional welding processes.

1 m long conductor samples were fabricated and I_c was measured using an 8 T split magnet. The results of I_c measured at 4.26 K are shown in Fig. 2. Filled and open circles indicate I_c for the conductor sample and the I_c for a strand multiplied by the strand number (18), respectively. The strands of which I_c were measured were heat-treated together with the Rutherford cable of the conductor. The criterion for the definition of I_c was 100 µV/m for both the strand and the conductor. The I_c of the conductor was 9.2 kA at 8 T. The product for 18 strands yielded a I_c of 10.1 kA; therefore, the I_c degradation by jacketing was found to be only 9%. By comparison, I_c degradation of conventional cable-in-conduit conductors probably exceeds 20% at 8 T[1]. Next, I_c degradation by jacketing was estimated using an empirical scaling law[2] and was compared with the measurements. The result indicates that the I_c degradation can be explained only by thermal strain and the manufacturing process did not damage the Nb_3Sn strands[3].

The react-and-jacket processed conductor is a promising alternative for large-scale Nb_3Sn conductors over conventional cable-in-conduit conductors.

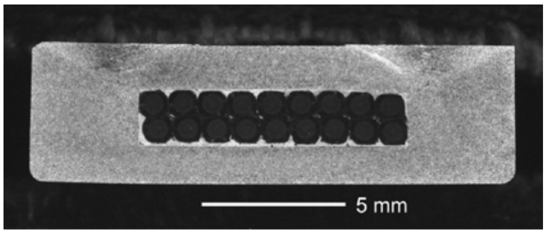

Fig. 1. Cross-sectional image of the Nb_3Sn conductor with the aluminum-alloy jacket.

Table 1. Specifications of the conductor

Strand	
Superconductor	Nb_3Sn
Diameter	1.0 mm
Copper ratio	1.0
Filament diameter	3.7 µm
Twist pitch	25 mm
Heat treatment	943 K for 96 h
Cable	
Number of strands	18
Dimension	9.2×1.8 mm^2
Cabling pitch	94 mm
Conductor	
Dimension	17.0×4.9 mm^2
Jacket material	6061-T6
Filler material in the cable space	Indium

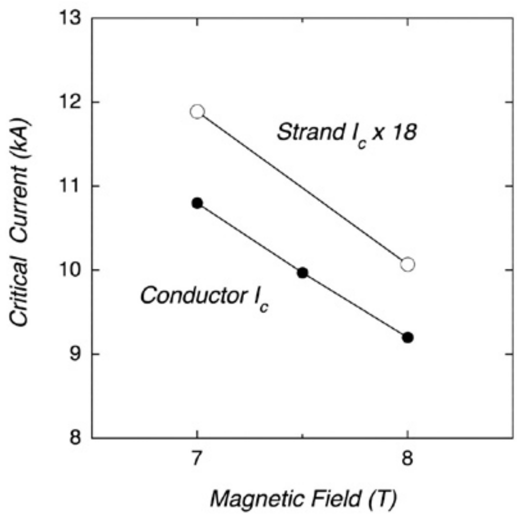

Fig. 2. Measured critical currents (I_c) of the react-and-jacket processed Nb_3Sn conductor. Filled and open circles indicate I_c for the conductor and the product of the strand number and I_c of the strand, respectively.

1) Ciazynski D.: Fusion Eng. Des. 82 (2007) 488.
2) Ekin, J.W. : Cryogenics 20 (1980) 611.
3) Takahata, K. et al. : Cryogenics 51 (2011) 397.