§18. Effect of Bending on Critical Current of React-and-Jacket Processed Nb_3Sn Conductor

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A new large-scale Nb_3Sn conductor has been developed that has an aluminum-alloy jacket to support an electromagnetic force[1–4]. The manufacturing process of the conductor is unique in that a jacketing process is performed after reaction heat treatment of the Nb_3Sn cable. This process, which we term the "react-and-jacket" process, imparts the conductor with a high critical current (I_c) because the compressive strain induced in the Nb3Sn filaments due to the thermal contraction of the jacket material is reduced. This conductor will be wound after the reaction heat treatment to form a magnet. This manufacturing process, the so-called "react-and-wind" process, is more attractive than the conventional wind-and-react process used to fabricate large magnets (e.g., fusion magnets) with Nb_3Sn superconductors because it does not require a large furnace for the reaction heat treatment. However, the bending strain due to winding should be carefully controlled to prevent degrading I_c. This paper reports I_c measurements of a wound sample and discusses I_c degradation by the bending strain.

Fig. 1 shows a photograph of a cross-section of the developed conductor. 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 fillers were embedded in the grooved aluminum-alloy jacket. The jacket cover was then welded by friction stir welding[4], which does not damage the cable. The I_c of the conductor was estimated to be approximately 4.7 kA at 12 T.

A 3-m-long conductor sample was fabricated and wound flatwise in a three-turn coil (see Fig. 2). The coil has an inner radius of 150 mm. It was inserted into a split magnet and I_c was measured under external magnetic fields of up to 7.1 T. Fig. 3 shows the measured I_c. The filled circles indicate I_c for the conductor sample and the open circles indicate the product of I_c for a single strand and the number of strands (=18). The I_c of the conductor was 8.3 kA at 7 T. The product for 18 strands was 11.1 kA. Therefore, the degradation of I_c was found to be 25%.

Assuming that a current can flow between filaments with a relatively low resistance, I_c for single strand will equal the integral of the critical current density over the filament bundle region[5]. For the strain dependence of the critical current density, we used the empirical formula proposed by Godeke[5-6]. The triangles in Fig. 3 indicate the predicted I_c of the conductor. The measured I_c is slightly higher than the predicted one. This result demonstrates that the conductor can be wound in a coil configuration without excessive damage.

The calculation also predicts that a small outward shift of the neutral axis will degrade I_c. Therefore, the bending neutral axis should be precisely controlled during coil manufacture. The tested conductor was bent by a bending machine with seven rollers so that its neutral axis was approximately coincident with the midline.

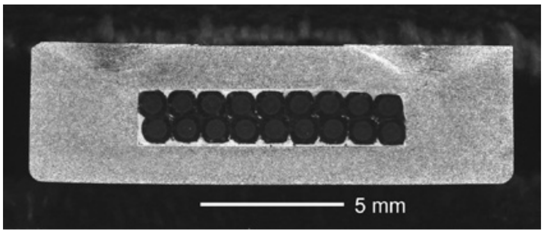

Fig. 1. Photograph of conductor cross-section.

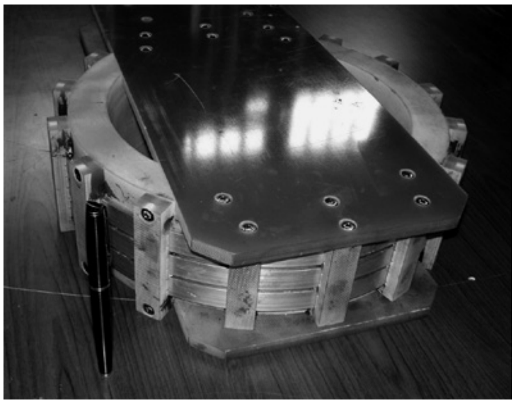

Fig. 2. Photograph of three-turn winding sample for I_c measurements.

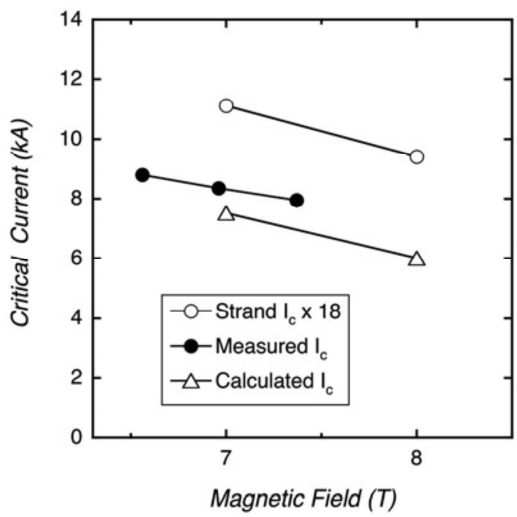

Fig. 3. Measured and predicted critical currents.

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4) Sugimoto, M. et al.: IEEE Trans. Appl. Super. (2011) DOI:10.1109/TASC.2011.2174813.
5) Takayasu, M. et al.: Supercond. Sci. Technol. **24** (2011) 045012.
6) Godeke, A. et al.: Supercond. Sci. Technol. **19** (2006) R100.