§26. Development of Large-current Aluminum-alloy-jacketed Nb_3Sn Conductor for FFHR

Takahata, K., Tamura, H., Mito, T., Imagawa, S., Sagara, A.

A new large-current Nb_3Sn conductor for the LHD-type fusion reactor, FFHR-d1 has been developed that has an aluminum-alloy jacket to support an electromagnetic force[1–5]. 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.

Figs. 1 and 2 show a photograph and schematic diagram of the developed conductor for FFHR-d1. The design current and its density are 100 kA at 12 T and 40 A/mm^2, respectively. The Rutherford cable consists of 216 bronze route Nb_3Sn wires with diameters of 1.6 mm. The heat-treated cable and low-melting-point metal, Sn-Bi as fillers were embedded in the aluminum-alloy jacket. The two jacket halves were welded each other by friction stir welding (FSW), which does not damage the cable[4]. The final section size is 25 mm x 100 mm. The target I_c of the conductor is 200 kA at 12 T. This target can be achieved by optimizing the cross-section structure and the heat-treatment condition of the strands. The optimization will be conducted in FY2013. However, the conductor developments in FY2012 have demonstrated that it is possible to fabricate a large-current conductor for a fusion reactor.

Fig. 3 shows the schematic diagram of a conductor for FFHR-d1. The conductor has the same configuration as the developed conductor, except that the cable is sandwiched between high-purity-aluminum strips. The aluminum strips has an important role in reducing the hot spot temperature during a quench. Simple calculation using a heat-balance equation suggests that 2 mm-thick aluminum strips can reduce the hot spot temperature down to 150 K, which does not damage the magnet.

The conductors will be cooled by means of indirect-cooling with saturated liquid helium[3]. To prevent a temperature increase by the nuclear heating, thinner insulator should be developed. This is still an issue for indirect-cooled conductors.

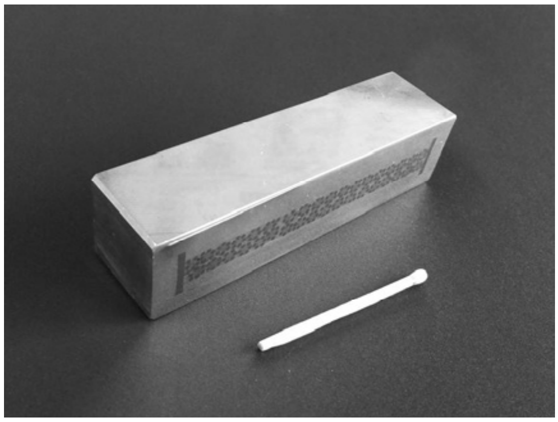

Fig. 1. Photograph of the developed conductor.

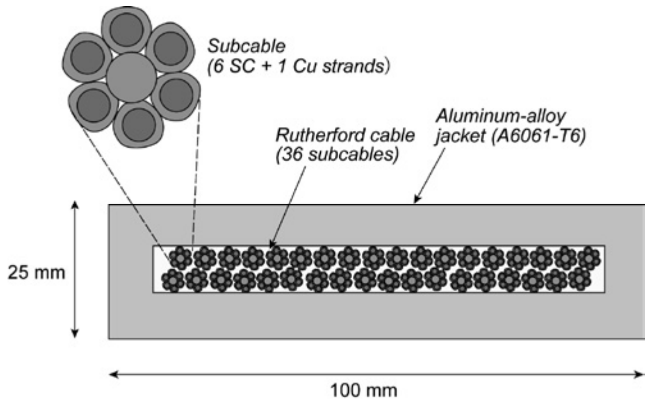

Fig. 2. Schematic diagram of the developed conductor.

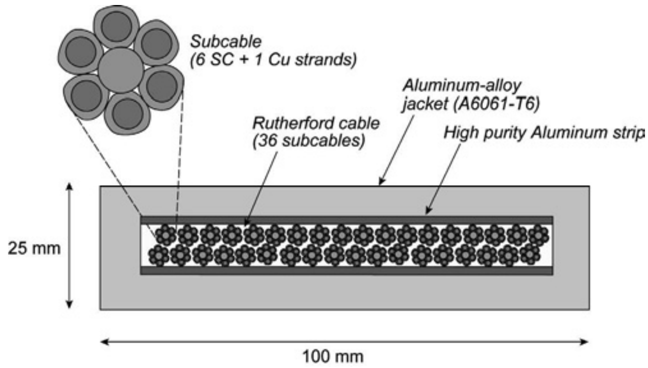

Fig. 3. Conductor for the LHD-type fusion reactor, FFHR-d1.

1) Takahata, K. et al.: Cryogenics **51** (2011) 397.
2) Tamura, H. et al.: Plasma and Fusion Res. **5** (2010) S1035.
3) Takahata, K. et al.: Fusion Eng. Des. **82** (2007) 1487.
4) Sugimoto, M. et al.: IEEE Trans. Appl. Super. (2012) 4802905.
5) Takahata, K. Et al.: Plasma and Fusion Res. **8** (2013) 2405008.