3-10 Pioneering Material for ITER Superconducting Wire
－Success in Mass Production of High Performance Nb_3Sn Strands－

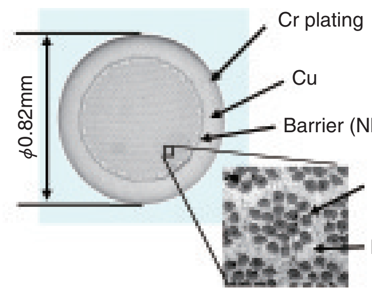

Fig.3-21 Cross section of bronze processed strand
Tin is contained in bronze and an increase of tin content in bronze has enhanced critical current density.

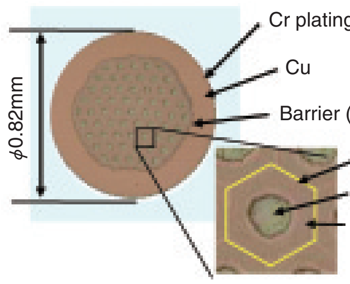

Fig.3-22 Cross section of internal tin processed strand
Tin rod is embedded in a module. The targets are reached by downsizing of the module and optimizing the ratio of niobium to tin.

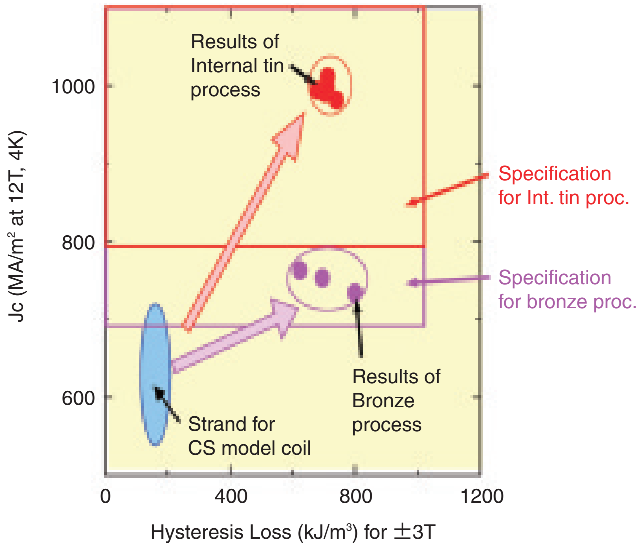

Fig.3-23 Performance of the developed strand
The important parameters are critical current density (Jc) and hysteresis loss. Strands satisfying these requirements were fabricated by both bronze and internal tin processes.

Magnetic fields of 12 to 13 T are required to generate and confine plasma for International Thermonuclear Experimental Reactor ("ITER"). To generate such high magnetic fields, huge amounts of high performance Nb_3Sn strand must be produced. The strand is required to have not only high critical current density (Jc), but also low hysteresis loss in a varying field. These are contradictory characteristics for a strand and therefore, it is necessary to develop a new technology to achieve both requirements.

Typical methods to fabricate Nb_3Sn strand are the bronze process and the internal tin process. In the bronze process, Niobium (Nb) filaments are embedded in bronze (Fig.3-21), and Nb_3Sn is produced by a heat treatment at 650℃ for 200 hours. A major barrier to improving Jc is the low tin content in a strand. Recently good quality of high tin content bronze has become available and adopting this bronze has realized the enhancement of Jc.

In the internal tin process, Nb filaments and tin (Sn) rods are embedded in copper (Fig.3-22). It is relatively easy to increase tin content in this strand and to enhance Jc, but hysteresis loss drastically increases due to the formation of superconducting rings by the joining of filaments near Sn rods upon heat treatment. A hexagon, in which a large number of filaments and a single Sn rod are embedded, is called a "module." Downsizing the module and optimizing the ratio of Nb to Sn have restrained this increase in the hysteresis loss because diameter and thickness of the ring are reduced. Consequently, both high Jc and low hysteresis loss have been satisfied.

0.1-tons strands fabricated through both processes have been demonstrated to satisfy the specifications, as shown in Fig.3-23. While Jc specifications at 4K are different between the two processes, they are the same value at the operating condition of the "ITER" (12 T, 5.7 K and strain of -0.76%). JAEA has achieved these Nb_3Sn fabrication results ahead of the other "ITER" participants, and thus JAEA will be make the largest contribution in strand supply among the "ITER" parties.

Reference

Okuno, K. et al., From CS and TF Model Coils to ITER: Lessons Learnt and Further Progress, IEEE Transaction Superconductivity, vol.16, 2006, p.880-885.