§16. Experiments of Bending Strain on Reduced-Scale YBCO Conductors for Fusion Energy Magnets

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The conceptual design studies on the heliotron-type fusion energy reactor FFHR are being conducted on both physics and engineering issues [1]. We propose, as an alternative design, that the helical coils of a continuous manner and a huge size (major radius: 14-18 m, stored magnetic energy: 120-150 GJ) be constructed by prefabricating half-pitch segments using high-temperature superconductors (HTS); the segments are then jointed on site. We consider "REBCO coated-conductors", such as YBCO and/or GdBCO, to be a good candidate according to the recent development of wire production technology. The present conductor design gives a nominal current of 100 kA at a maximum magnetic field of 13 T. We have successfully carried out a proof-of-principle experiment of HTS conductors with 15 kA critical current at 8 T and 20 K [2]. It was confirmed that the stability margin is about two orders of magnitude higher than that of low-temperature superconductors (LTS).

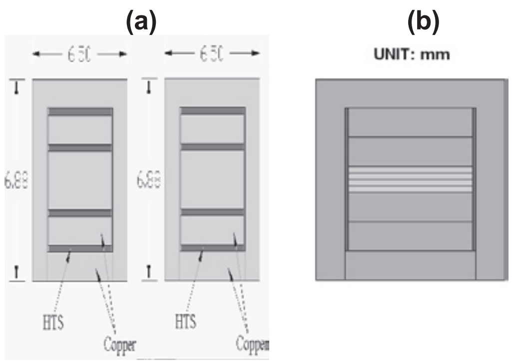

Fig. 1 Cross-sectional images of (a) a reduced-scale HTS conductor of Type-A and (b) a reduced-scale HTS conductor of Type-B.

One of the crucial requirements for conductors is to secure a sufficient margin for the bending strain applied in the winding process. In this respect, an innovative idea of having rather thin layers of HTS wires within the cross-section of a conductor is proposed [2]. With this configuration, the bending strain exerted on the HTS tapes can be minimized to be ~0.05%, which is an order of magnitude smaller than the allowable strain. In order to confirm this idea, we have carried out a proof-of-principle experiment by preparing reduced-scale samples shown in Fig. 1. Four YBCO tapes are used for both samples; in Type-A, the tapes are distributed in the whole cross-sectional area within the jacket, whereas in Type-B, the tapes are stacked together at the center. The critical currents of these conductors were measured in liquid nitrogen (temperature: 77 K) and in self-field after bending the samples using Bakelite formers as shown in Fig. 2. Voltage taps (length: 200 mm) were attached at the central part of the conductors. The experimental results are summarized in Fig. 3. The degradation of the critical current of Type-A conductor is significant above the conductor bending strain of ~0.5% (defined by the ratio between the conductor thickness and the bending diameter). On the other hand, the degradation of Type-B is much smaller, as it was expected. These experimental results clearly indicate that by having HTS tapes at the central part of a conductor (near the neutral axis), the bending strain in HTS tapes can be reduced. Thus, we consider that the conductor bending strain of 0.4% (expected value for the FFHR helical coils) should not create any degradation in the critical current of a Type-B configuration.

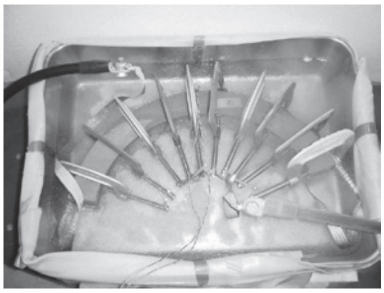

Fig. 2 Experimental setup with a conductor sample, bent with a fixture and immersed in liquid nitrogen.

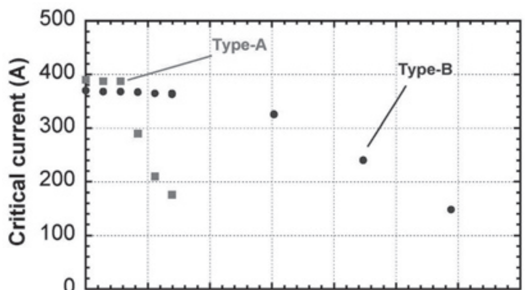

Fig. 3 Critical currents measured in liquid nitrogen for two conductor samples as a function of the bending radius defined for the whole conductor cross-section.

1) Sagara, A., et al., Fusion Eng. Des. 83 (2008) 1690.
2) Bansal, G. et al., Plasma Fusion Res. 3 (2008) S1049.