§10. Structural Design of the Remountable Magnet and Development of Joint Section of a High-temperature Superconducting Conductor

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Segmented high-temperature superconducting (HTS) magnets have been proposed for helical reactor, FFHR-d1. [1)-4)] The magnet is constructed by assembling short conductors (joint-winding magnet) or segments (remountable magnet) with resistive joints. HTS materials can allow the resistive joint because they have high thermal stability and achieve low electric power to run cryoplant. Objectives of this corroborative study are development of mechanical joints of large-scale HTS conductors to be used for the magnet, and investigation of mechanical strength of the joint by means of tensile shear test of joint samples and structural analysis of helical coils.

For the development of mechanical joints of large-scale HTS conductors to be used for the magnet, we fabricated a 100-kA-class HTS conductor sample.[5)] The conductor has three rows and fourteen layers of Gadolinium Barium Copper Oxide (GdBCO) tapes, embedded in copper and stainless steel jackets. The conductor sample also has a joint section of the bridge-type mechanical lap joint with an inserted indium foils. The conductor sample was tested at the test facility which can provide bias magnetic fields up to 9 T at NIFS in 2013 and 2014. Fig. 1 shows joint resistance as a function of bias magnetic field, where 1st and 2nd Trials mean tests in 2013 and 2014. The result shows good reproducibility of evaluated joint resistance and obtained joint resistivity is small enough to properly run the cryoplant of the reactor in the FFHR-d1.

Fig. 2 shows distribution of in-plane shear strain in the cross-section of the helical coil obtained by the structural analysis. Distribution of *xy*-component of shear stress in the Rare-Earth Barium Copper Oxiside (REBCO) tape region is also shown in Fig. 2, which is locally evaluated in a region of the helical coils where the maximum shear stress occurs. The maximum shear stress is estimated to be 32 MPa. We also evaluated normal strain distribution along the winding direction (tensile strain) of the helical coils. The maximum tensile strain is estimated to be 0.145%, which is acceptable from the viewpoint of tensile strength of GdBCO tapes having an irreversible strain of 0.4%. Fig. 3 shows shear strength of mechanical lap joint samples of GdBCO tapes as a function of joint pressure obtained by the tensile shear test at 77 K. According to the results obtained by the structural analysis and the tensile shear test, a joint pressure of >50 MPa is considered to be necessary to tolerate the shear stress induced by electromagnetic forces.

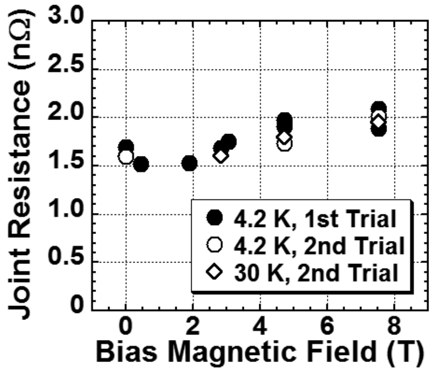

Fig. 1. Joint resistance as a function of bias magnetic field for the 100-kA-class HTS conductor.

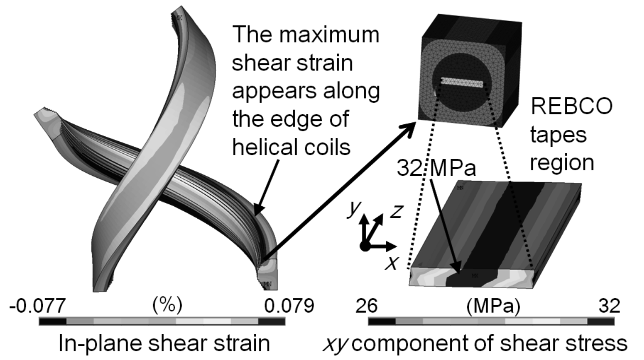

Fig. 2. Distribution of in-plane shear strain in helical coils (left figure) and distribution of *xy* component of shear strain in the REBCO tape region (right figure).

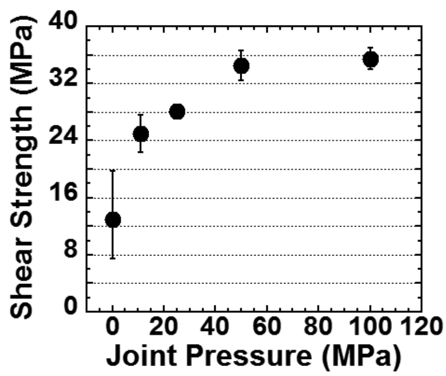

Fig. 3. Shear strength of joint as a function of joint pressure obtained in tensile shear test of a mechanical lap joint of GdBCO tapes.

1) Hashizume, H. et al.: J. Plasma Fusion Res. Ser. **5** (2002) 532.
2) Yanagi, N. et al.: Fusion Sci. Technol. **60** (2011) 648.
3) Sagara, A. et al.: Fusion Eng. Des. **89** (2014) 2114.
4) Hashizume, H and Ito, S.: Fusion Eng. Des. **89** (2014) 2241.
5) Ito, S. et al.: Plasma Fusion Res., **9** (2014) 3405086.