§21. Development of a Helical Winding using Advanced Superconductors for High Magnetic Fields

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The objective of this work is to establish the helical winding techniques without plastic deformations of YBCO coated conductors. In this work, the research group evaluates the critical current dependence on the mechanical stresses caused by the shape of the helical windings and develops a prototype winding machine. The final target of this work is to develop a small model helical coil using the prototype winding machine. The model coil with a 0.3-m outer diameter will be excited up to 0.13 T at 77 K.

Fig. 1 shows the complex-strain-applying device in order to evaluate the critical current properties of the YBCO conductors. The novel feature of this device is that the flatwise (FW) bending, the edgewise (EW) bending and the torsional strains are simultaneously applied to the YBCO tape sample. The dimensions of the YBCO tape sample are 200 mm in length and 5 mm in width, respectively. The controllable tensile stress is from 5 MPa to 200 MPa. The FW jig and the EW jig have 30-mm and 300-mm radii, which is derived from the maximum applied bending strains of the model coil. The maximum bending strains of the model coil will be 0.33% in the FW strain and 0.4% in the EW strain.

Fig. 2 shows the complex strain distributions applied to the YBCO tape samples. The applied strain is measured by a strain gauge array with a pair of dummy gauge array. The strain gauges are set on the Hastelloy substrate of the YBCO tape sample and are specialized for one-dimensional strain measurement parallel to the longitudinal direction. When the tensile stress is more than 170 MPa, the maximum strain partly reaches to 0.8% in the outside part of the EW bending curve.

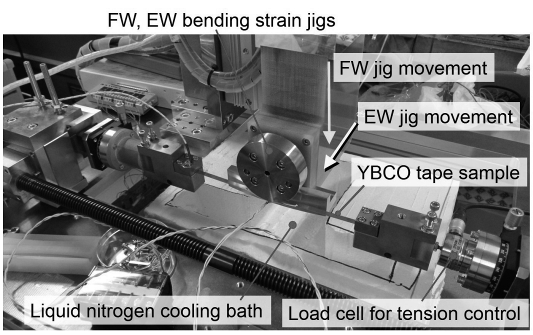

Fig. 1: Photograph of the complex-strain-applying device for the YBCO tape sample tests.

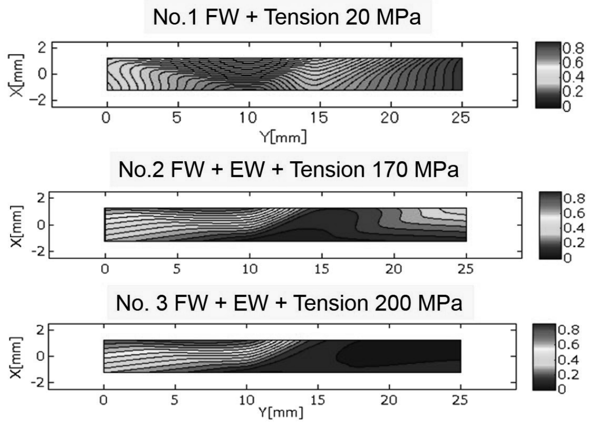

Fig. 2: Test results of the complex strain distributions applied to the YBCO tape samples. The distributions are obtained by using cubic spline interpolation from the measurement results of the strain gauges.

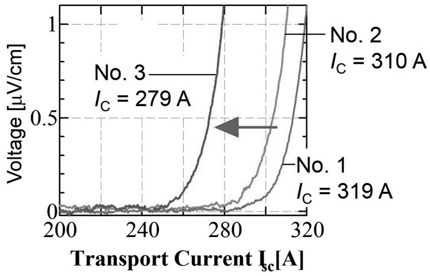

Fig. 3: Critical current dependence on the complex strain distributions. The sequence numbers correspond to the sequence numbers in Fig. 2.

Fig. 3 shows the critical current dependence on the complex strain distributions. Compared with the strain distribution in Fig. 2, the appearance of the 0.8% strain caused more than 10% of the critical current degradation, which result means that the winding tension rather than the complex bending stresses due to the shape of helical windings determines the critical current properties during the winding process of the helical coil. The obtained properties will feed back to the optimization of the helical winding techniques.

The assembly of the prototype winding machine has been finished. From the results of the test operation, the torsion control schemes for the shape of the helical windings are visually confirmed. After the further improvement of the winding machine, the research group is planning to carry out the winding of the model helical coil and the excitation tests with liquid nitrogen cooling.