Development of a 1-T Class Force-Balanced Helical Coils Using REBCO Tapes

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I. Introduction

Applying high-temperature superconducting referred to HTS coils to superconducting magnetic energy storage (hereafter referred to SMES) is expected to improve small-sized high magnetic field coils. In developing high field coils using HTS tapes, however, large electromagnetic forces caused by large current and high field can degrade the critical current of HTS in the winding. To decrease the electromagnetic forces, the authors proposed the force-balanced helical coils referred to as FBC concept as a feasible option for SMES. The authors design and develop a 1-T class helical coil (hereafter referred to as HTS-FBC) based on the FBC concept using different REBCO tapes. The FBC concept can minimize the mechanical stresses induced by the Lorentz force in the winding process and can use complicated shapes of the helical windings. Other words, since the tensile strain, the bending strain and the torsional strain simultaneously apply to the REBCO tapes, the critical current can be degraded.

The objectives of this work is to clarify the critical current property of REBCO tapes depending on the applying complex mechanical stress due to the winding process, the winding configuration and the electromagnetic forces through the development of the HTS-FBC.

II. Design Parameter of a 1-T Class HTS-FBC

- REBCO tape: 0.2 mm thick x 13 layers
- REBCO tape thickness: 0.2 mm thick x 13 layers
- Winding Structure: 8 parallel layers x 13 layers
- Total Tape Parallels: 654 turns (13 layers x 48 coils)
- Operating Coil Current: 15 H x 77 K
- Nominal Magnetic Field: 1300 G x 13 layers
- Self Inductance: 8.3 mH
- Total Conduct Length: 155 m (13 layers x 12)

III. Critical Current Evaluation for Complex Uniaxial Strain

- Critical Current (Ic): 200 A at 77 K
- Tape Thickness (w): 0.2 mm thick x 13 layers
- Strain Limit (γ): 5% (24 days at 273 K)
- Strain Limit (γ): 15% (24 days at 273 K)
- Tensile Stress (σ): 400 MPa
- Bending Stress (σ): 20 MPa

IV. Development of a Helical Winding Machine

- Torsion Control Schemes of the HTS Tape Bobbin

What is required for helical winding machine...
- Capability of helical winding without degradation in critical current of HTS tapes
- Capability of helical winding with a certain tension in HTS tapes
- Capability of continuous layer winding

- Assembly of Helical Winding Machine for HTS Tapes

The assembly of the helical winding machine has been finished.
- From the results of the test operation, the authors visually confirmed that the support for the winding bore works without interfering with the torsion control scheme.

Further step of this work, the authors carry out the winding of the 1-T class HTS-FBC using REBCO tapes and the evaluation test of the 1-T class HTS-FBC.