Study on Twist Performance of Superconducting Conductor on Round Core Cable

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Introduction

1) With high current-carrying capacity and strong mechanical properties, conductor on round core (CORC) cable is widely adopted in high-field magnet applications, for instance, in the form of solenoids, double pancakes and canted cosθ magnet.

2) However, CORC cable may be twisted in the fabrication of magnet with complex structure, as well as suffering huge Lorentz force in the operation process , which could pose unpredictable strain on helical superconducting tape , arousing secondary damage.

3) In this paper, twist performance of CORC cable is evaluated by both numerical and experimental methods. Critical twisting angle would be analyzed from the aspect of critical current degradation, which could provide important data for future optimization.

Numerical Model and Experimental Setup

A. Experimental method

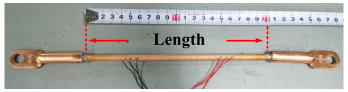

Fig. 1. CORC samples for measurement of critical twisting angle per meter

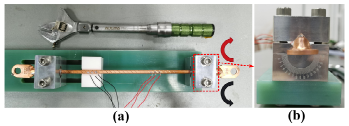

Fig. 2. photograph of (a) the device to twist the CORC samples, (b) scale of angle

- Single layer and double layer CORC cable samples were fabricated with the structure of 3 REBCO tapes wound helically around copper tube with angle of 45°. Winding directions between adjacent layers are reversed.
- Critical twisting angle is defined as the twisting angle at which the critical current degradation is larger than 5%.
- Critical twisting angle per meter is obtained after divided by the length of sample, which excludes the terminal.

- The twisting process is implemented by torque wrench with constant 10 N·m.
- Twisting angle is obtained through the scale of angle.
- There are two directions of twist in Fig.2:
  - (+) identical with the winding direction of the outer layer of helical tape,
  - (-) reverse with the helical tape.

Numerical Model and Experimental Setup

B. Geometry and boundary setting

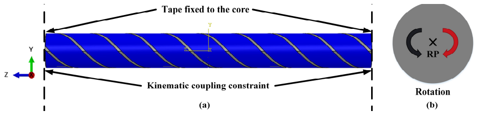

Fig. 3. (a) Boundary conditions for CORC cable twisting model, (b) reference point at the end of core

- Initial strain and stress distributions are predefined according to [1].

[1] Rui Hu, et al. "Numerical Study on Mechanical Properties of Conductors on Round Core Cables," *IEEE Tran. Appl. Supercond.*, vol. 31, no. 5, 2021, Art. No. 4801405.

- Two reference points are placed at the center of both ends of the central core separately, with kinematic coupling constraints added to the end.
- Twisting of cable is realized by the rotation applied to the reference points in opposite direction.

C. Post processing

- Ic of REBCO tape is evaluated at the area where the axial strain is the largest.
- Normalized critical current is calculated by equation (1):

$$\frac{I_c}{I_{c_0}} = \frac{1}{2\omega}\int_{-\omega}^{\omega}\frac{J_c}{J_{c_0}}(\varepsilon)\,\mathrm{d}m \qquad (1)$$

- 2ω and ε are the width and axial strain of REBCO tape, m is the width coordinate value of the tape

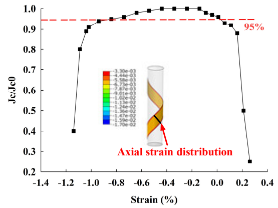

Fig. 4. Relationship between normalized critical current density and axial strain of REBCO tape

Result Analysis and Discussion

A. Single layer CORC cable with reversed twist direction

- Twist direction reverse with the helical tape would loose the REBCO tape, may leading to the stress relief.
- Both experimental data and simulation result indicate that Ic would not degrade.

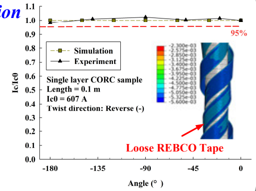

Fig. 5. Normalized Ic of single layer CORC cable with reversed twist direction

B. Single layer CORC cable with identical twist direction

- In simulation, Ic degrades after twisted above 35°, while experimental value shows no signal of degradation even after twisting angle of 50°, which may be attributed to the absence of cooling process. According to [1], the maximum strain in REBCO tape would decrease under cryogenic temperature.

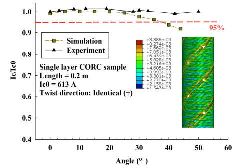

Fig. 6 Normalized Ic of single layer CORC cable with identical twist direction

C. Double layer CORC cable with twist direction identical with outer layer

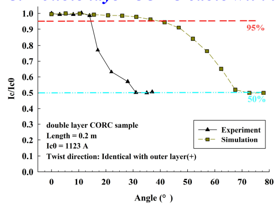

Fig. 7 Normalized Ic of twisted double layer CORC cable

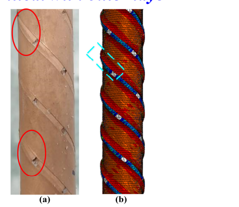

Fig. 8 Geometry: (a) crease on inner layer in experiment (b) edge distortion in simulation

- In experiment, Ic decreases sharply with twist angle above 14°, remaining 50% after twist angle reaching 30°, while Ic degrades constantly and slowly with the increase of twist angle in simulation.
- This disagreement may be attributed to difference in geometric distortion. In experiment, crease is found on inner layer, indicating current at the end is carried by outer layer completely.
- However, simulation wrongly represents the distortion in outer layer, leading to residue current in inner layer.

Conclusion

- In twist process, compared to additional strain on tape, geometric distortion due to multilayer structure of CORC cable is more harmful to current-carrying performance of cable, according to experimental result.
- Investigation on relationship between critical twist angle and the length of cable is in process.
- Numerical model needs modification to simulate the strain precisely.