Progress in No-Insulation REBCO Magnet Technology: Lessons from >40 T Operations

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Introduction

Substantial progress has been made for the last couple of years in no-insulation (NI) REBCO magnet technology. In 2017, we made a series of NI-REBCO inserts, named "Little Big Coils", of which the last one (LBC3) reached 45.5 T at an overall coil current density of ~1200 A/mm^2 in a background field of 31.1 T by the resistive magnet at Cell 7. In addition to the achievement of a record high DC magnetic field, the results provided us valuable information on design and operation of ultra-high field (>40 T) NI-REBCO magnets. One of the key discoveries is the "one-side-edge" plastic deformation of REBCO tapes used for winding the single pancake coils of LBCs. The REBCO tapes, newly made by SuperPower Inc., had a 30-μm substrate made of Hastelloy C276 having an yield stress of >1 GPa at 4.2 K; yet, after the >40 T field tests, the wavy deformation on the "axially outer-edge" of the REBCO tapes was identified. Further investigation using YateStar revealed the correlation between the deformation and the REBCO tape damage. Also, we learned that some REBCO tapes experienced neither damage nor deformation with the slit edge of the tape oriented axially outer-ward. An in-depth simulation work also revealed the "screening-current-induced-stress" as the potential source of the damage, which is the first quantitative explanation on the plastic deformation. As a continuous work, we performed experiment on single pancake NI coils (**Fig. 1**) and investigate the related issues more in details.

Experimental

Four different types of test coils were prepared as shown in **Table I**. The location of Coils A and B was at 100 mm above from the magnet center to imitate the top-most pancake of LBC which experienced a high radial field. Coils C and D, on the other hand, were tested at the magnet center. All tests were conducted in a bath of liquid Helium at 4.2 K.

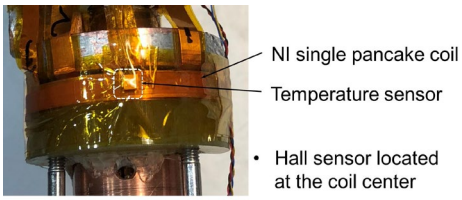

Fig. 1 Photo of an NI test coil.

Table I Parameters of the LBC type test coils.

	Coil A	Coil B	Coil C	Coil D
Test condition	Off-centered test		Centered test	
Tape slitting information	One-slit edge			Never slit
Slit edge orientation against the magnet center	Inward	Outward	Outward	-
Substrate material	Hastelloy			SS310

Results and Discussion

After the multiple charging-discharging tests, we un-wound the coils and performed the post-mortem through YateStar. Coil A, which had a REBCO tape in a way to have the slit edge located axially "inward" to the magnet center, did not show any substantial degradation except the region corresponds to outer-most of the pancake; the damage occurred likely during the solder joint process as seen in **Fig. 2 (a)**. **Fig. 2 (b)** confirmed the periodic damages at slit edge of Coil B, and the plastic deformation was found via the visual inspection. Coil C showed no degradation except from the groove of the copper mandrel and solder joint (**Fig. 2 (c)**). Coil D showed relatively good critical current (I_c) retention without showing any delamination though it plastically deformed after the test (**Fig. 2(d)**).

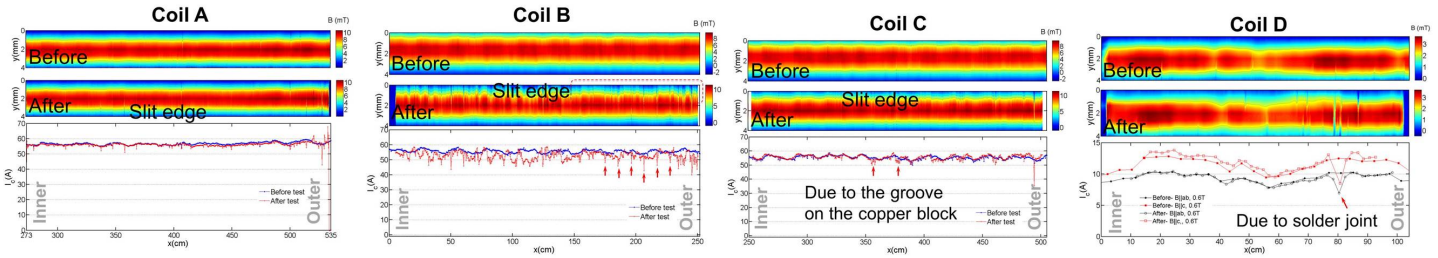

Fig. 2 YateStar measurement results of each NI single pancake test coil.

Conclusions

When NI coils located at the off-centered with the slit edge facing outward from the magnet center, the obvious degradation was found at the edge. With the un-slit edge, the tape experienced neither degradation nor deformation. This verifies our assumption on the strong correlation between edge orientation and plastic deformation of REBCO tapes

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