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Reinforcement Techniques for Bi-2212 High Field Coil Development

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Introduction - Reinforcement Techniques for Bi-2212 Coil Development

One of our interests in the Bi-2212 high field coil development is to seek better ways to reinforce Bi-2212 coils to manage magnetic hoop stress due to Lorentz force. Given that the critical stress limit of "bare" Bi-2212 wire is about 160 MPa, it is important to insert reinforcement material along with the conductor to redistribute stress through the Bi-2212 coil pack. We have selected different reinforcement methods and tested those methods with large diameter Bi-2212 stress test coils, dubbed "Riky." Riky coils that consisted different reinforcement method were tested in our 140 mm and 8.5-T cryo-cooled LTS magnet to evaluate suitable reinforcement methods.

Experimental - Stress Test Result of "Riky" Coils

Four different types of reinforcement are presented for comparison in **Table I**. Riky-1 (**Fig. 1**) had only Bi-2212 wire but no reinforcement. Riky-3 (**Fig. 2**) and Riky-6 had a fiber co-winding with different amount of fiber applied; Riky 6 had twice as much fiber as Riky-3. SRW-2, a coil with almost the same geometry as a Riky coil, was wound with aspected Bi-2212 made at Solid Materials Solutions Inc., which had a high strength alloy tape bonded to it for conductor reinforcement (**Fig. 3**). All coils were impregnated before the stress test. At a background field of 8 T, the coils were charged to produce magnetic stresses in order to observe any strain-related damage during the repetitive stress test. **Table I** summarizes the highest stress obtained from each test coil.

Results and Discussion

With different reinforcement, each coil could reach different stress level. For fair comparison, we used the conductor's current density (J_e) to calculate *BJR* stress of each coil. The BJ_eR stress can be interpreted as the source stress that is produced from the Bi-2212 conductor itself. Higher BJ_eR stress means that the stress produced from the conductor itself was successfully supported by the reinforcement in each Riky coil. Riky-1, without any reinforcement, reached the smallest stress level among the coils of 183 MPa. Riky-3, with a single fiber-bundle co-wind, was able to hold up to 264 MPa, which is ~ 100 MPa more than its own critical stress limit. Riky-6 was expected to withstand higher stresses but the coil's operating current was limited by conductor's low I_c so that we decided to make another version of Riky-6, which will be tested in early 2019. SRW-2 also reached comparable stress level to Riky-3, but the winding pack snapped at 274 MPa of BJ_eR stress due to a local stress concentration. In general we confirmed that reinforced Riky coils were able to hold more stress than the non-reinforced Riky-1 and far more than wire's critical stress limit alone.

Acknowledgements

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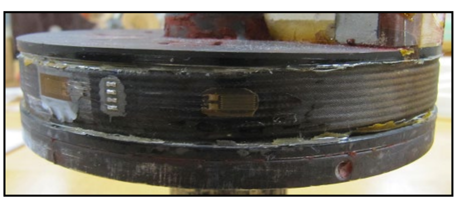

Fig.1 Riky-1 (no reinforcement)

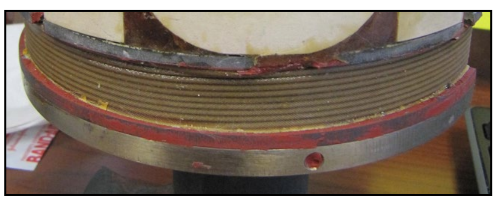

Fig.2 Riky-3 (single ceramic fiber cowind)

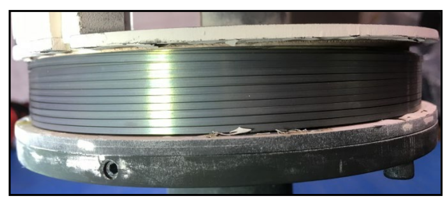

Fig.3 SRW-2 (Reinforced Bi-2212 Wire)

Table I Riky Test Coil Specifications and Stress Test Record

Reinforcement	Name	Wire [mm]	a1 ; a2 ; h [mm]	turns	B_{ext} [T]	I_{op} [A]	BJ_eR [MPa]
No reinforcement	Riky-1	Φ 1.3	62.5 ; 68.9 ; 16.3	36	7.9	454	183
Ceramic fiber x 1	Riky-3	Φ 1.0	61.4 ; 65.9 ; 12.5	38	8.0	388	264
Ceramic fiber x 2	Riky-6	Φ 1.0	58.8 ; 63.3 ; 13.5	38	8.4	320	214
Metallic alloy bonded to wire (SRW)	SRW-2	1.23 x 0.54	58.9 ; 62.4 ; 16.3	38	4.9	497	248