**Greatly Enhanced Strain Margins in Strongly Reinforced Bi-2223 HT-NX**

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**Introduction**

 Superconducting solenoids beyond 23.5 T need to be constructed using high temperature superconducting (HTS) insert coils. Multi-filamentary Bi2Sr2Ca2Cu3Ox / Ag-alloy (Bi-2223) HTS tape conductors are a candidate material for such solenoids but the bare Bi-2223 conductor (type H) is mechanically weak due to the soft Ag-alloy matrix. The bare type H conductor is therefore often reinforced by laminating it with copper-alloy (HT-CA) or stainless-steel (HT-SS) tape. This process yields conductors with stress and strain margins up to 250 MPa and 0.35%, respectively, and a 60 mm safe bending diameter [1,2]. A new version, named Bi‑2223 HT‑NX, has recently become available [3]. This version is laminated with a high strength Ni-alloy tape. The new high strength Bi‑2223 HT‑NX has a specified 400 MPa tensile strength, 0.5% strain margin, and a 40 mm safe bending diameter [2], but these specifications were surpassed in tests by our collaborators [1,4]. Here we demonstrate that bending causes a substantial amplification of the strengthening, resulting in even larger limits.

**Experiments, results, and discussion**

 We performed a 9-month feasibility study on Bi-2223 NX‑HT, using basic conductor mechanical analyses (e.g. **Fig. 1**), hard way and easy way bend tests using small coils, double and single bend tests, high field tests of critical current (*I*c) up to 31 T (cell 7) in various field directions, and high field tests up to 17 T (cell 4) on four 4 layer, 20 turn coils (**Fig. 2**) with layer transitions, splices, etcetera, i.e. all the basic building blocks for larger coils.

 The results in **Fig. 1** show that the stress and strain limits of high strength Bi-2223 NX‑HT are 515 MPa and 0.57%, respectively, leading to an effective whole conductor Young modulus of 90 GPa. *I*c collapse occurs when the support yields. In single bend tests, however, it was found that the onset of *I*c degradation occurs between 25 and 22 mm diameter, which corresponds to an elastically calculated strain of 0.8 and 0.85% on the Bi-2223 filaments. Hoop stress tests on two single layer coils in 31 T field showed an onset of filament breakage between 0.8 and 0.85% strain, and tests of the 20 turn coils also identified a similarly high strain limit in bent tapes when bending strain and hoop strain are added (**Fig 2**: Irreversible damage occurs between the green and red circles).

**Conclusions**

 A 0.8% strain limit was found for Bi-2223 HT‑NX in coil-relevant configurations using three independent experiments. This high strain limit can simplify the construction of 30 to 40 T class superconducting magnets.

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**References**



**Fig. 2** Coil voltages and total strain as a function of coil current at 4.2 K and 17 T background field for a 114 mm ID, 4 layer, 20 turn coil wound from Bi-2223 HT‑NX.



**Fig. 1** Strain and critical current as a function of applied stress at 77 K of non-reinforced Bi-2223 type H, reinforced type HT‑NX, and the Ni-alloy reinforcement tape from type HT‑NX.

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