HTS Windings - a winding machine dedicated to High Temperature Superconducting tapes

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High critical temperature superconducting (HTS) coated conductor tapes are very promising for several applications involving coil fabrication, especially high field insert because of their high critical field well above the one of classical, low temperature superconductors. But the specific architecture of these tapes (mainly, a 1-2 µm functional superconducting layer made of a well textured brittle ceramic deposited on a 50-100 µm high mechanical strength Hastelloy substrate) requires a dedicated winding machine with special features : adapted and controlled smooth tension and guides, several winding payoffs together enabling co-winding technique, enough torque and space to accommodate several coil sizes, safety and dust protective cover with a preserved and easy access for mounting operation, easy change of the settings for prototyping, and last but not least, reproducibility and reliability.

After a long search for a suitable on-the-shelves winding machine, we finally fabricated our own machine (Fig.1) with the help of an external consultant. This winding machine is at the heart of our work for developing high-field magnets in the frame of the ANR project NOUGAT, aiming at fabricating a 10 T HTS insert to be operated in a 20 T background magnetic field at LNCMI. A careful development was conducted to fix critical issues such as tension control throughout the whole winding process, careful alignment of the guideways, several procedural points using Hastelloy dummies, and then tests with the superconducting tapes to control the effect of tension on the joints and the winding quality. We recently wound two double pancakes meant to be mounted together as a first prototype of our high field insert (Fig. 2). We used a technology called "metal as insulation" (MI) consisting in co-winding bare HTS and stainless steel tapes for mechanical reinforcement as well as for electrical protection purpose.

This HTS insert prototype was then tested at 4 K at several fields up to 20 T. At 20 T the insert generated successfully 7 T leading to a total of 27 T magnetic field, with a current of 416 A (engineering current density of 658 A/mm^2), twice the foreseen operating current of the final insert. This is a very important step towards an all-superconducting 30 T+ magnet, and to our knowledge the first operation of an insert coil using the MI technology in such extreme conditions.

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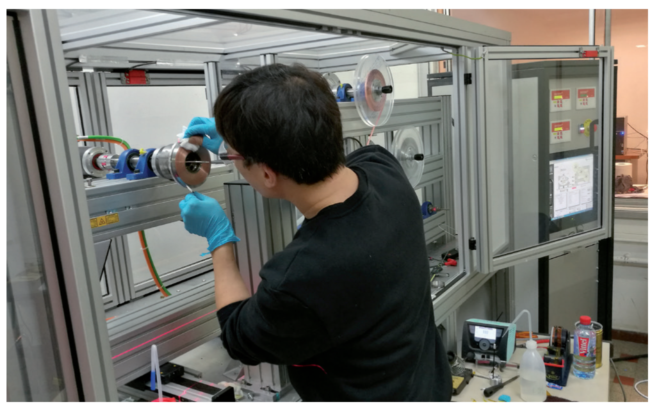

Fig 1: The HTS winding machine during operation

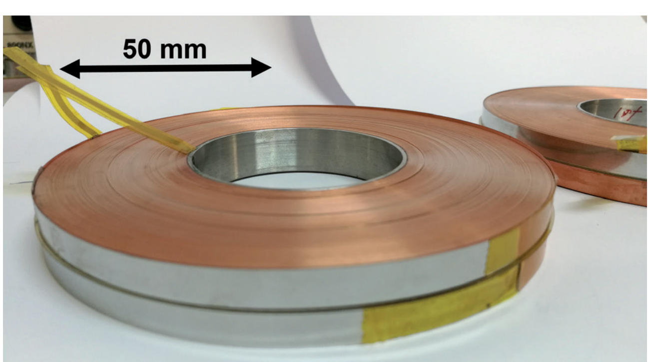

Fig. 2: Ø50 / Ø110 "metal as insulation" double pancake insert leading to a total of 27 T magnetic field.

OUTCOMES

Publications:

[1] "Metal-as-insulation variant of no-insulation HTS winding technique: pancake tests under high background magnetic field and high current at 4.2K", Supercond. Sci. Technol. 31 055008(2018).

[2] "Metal-as-Insulation sub-scale prototype tests under High Background Magnetic Field", Supercond. Sci. Technol. doi. org/10.1088/1361-6668/aad225.

Leverage: ANR project NOUGAT "NOuvelle Génération d'Aimant supraconducteur pour la production de Teslas avec une consommation électrique réduite" 2014-2018, project leader: Xavier Chaud (LNCMI), partners: LNCMI, CEA DACM, NEEL, G2ELab.

FET-Open project FuSuMaTech "Future Superconducting Magnet Technology" 2017-2019, project leader: Antoine Daël (CEA), partners: CEA, CERN, CNRS, KIT, PSI, STFC, ASG, Bilfinger, Elytt, Oxford, Sigmaphi, Tesla.

Collaboration: Thibault Lécrevisse and Philippe Fazilleau (CEA Saclay, DACM)

PhD: Tara Benkel (2014-2018) « Contribution to the design and realization of a HTS insert to obtain high magnetic field »