Importance of Tensile Strength of Bulk Superconductors – Routine 17 T Trapping in Bulk

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Introduction

The ability of large grain, $REBa_2Cu_3O_{7-\delta}$ [RE = rare earth] bulk superconductors to trap magnetic field is determined by their critical current. With high trapped fields, however, bulk samples are subject to a relatively large Lorentz force, and their performance is limited primarily by their tensile strength.

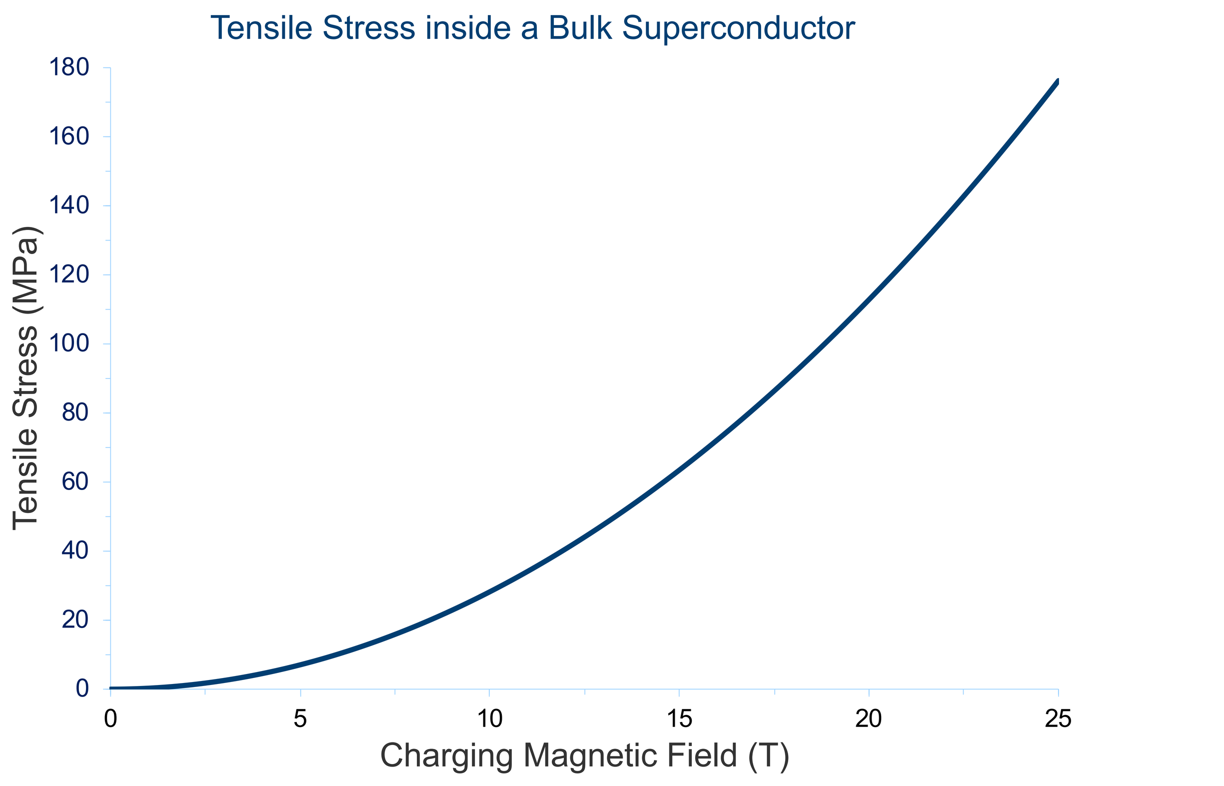

Fig. 1. Prediction of typical tensile stress inside a superconducting bulk charged at different external fields from equation given in [3]. Stress is proportional to the square of the charging field.

Previous Work

Using a technique employing pre-shrunk steel rings to reduce tensile stress in the material we have previously succeeded in trapping a magnetic field of over 17 T in a stack of two 24 mm diameter bulk superconductors. [1]

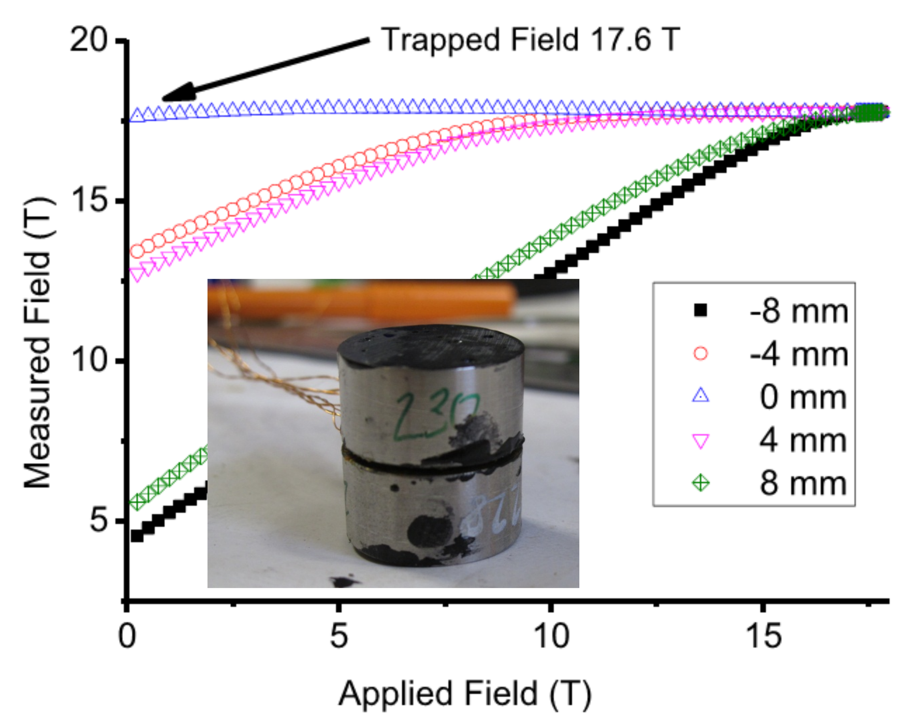

Fig. 2. Data from [1] showing a trapped field of 17.6 T from an 18 T charging field

Challenges and Potential

While we have demonstrated high fields using steel pre-stressing rings samples appeared to be damaged by each trapped field measurement, it proved impossible to repeat a "champion" measurement in any particular sample. A failure to address this issue would greatly inhibit industrial and technical exploitation.

Numerical modelling based purely on critical current shows that 24 mm bulks should be able to trap far in excess of the current world record trapped field at 20 K.

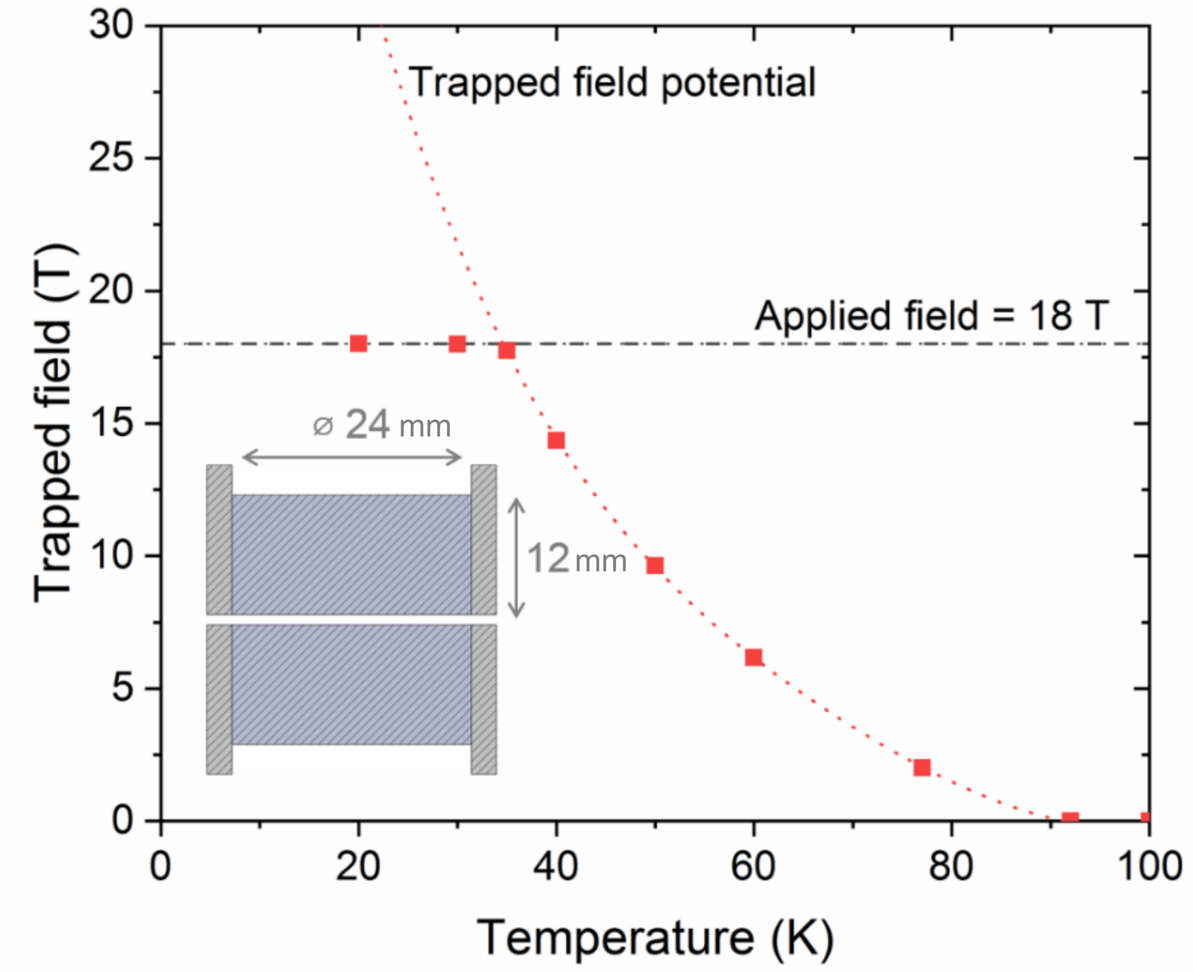

Fig. 3. Numerical simulation results for the trapped magnetic field achievable in the centre of a conventional two-sample stack at various temperatures with an applied field of 18 T. The inset shows the sample geometry used in the numerical simulations. The applied field and sample dimensions chosen are very similar to the ones used in several experimental studies [1] [2] [3].

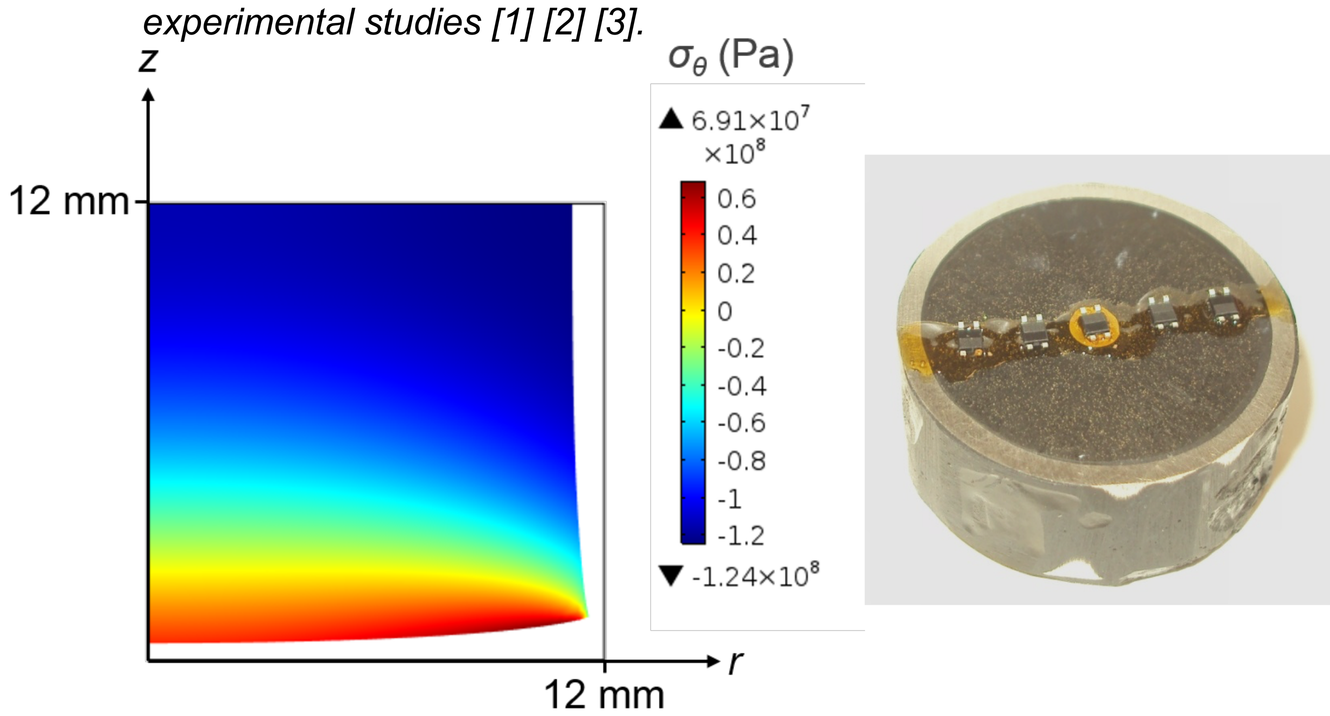

Fig. 4 Modelled stress state due both to cooling and charging of a sample with a stainless steel ring showing edge effects. Strain is exaggerated (x1000).

A New Approach – The Hybrid Stack

Recently Patel *et al.* [4] showed that stacked coated conductors were a promising approach to fabricating a bulk superconductor capable of trapping a high field. Unfortunately while the maximum trapped fields were competitive with those found in [1], they were achieved at much lower temperatures.

Nonetheless, the concept of integrating a stack of steel with pre-stress and sliced bulk superconductors is interesting and has been explored by other workers [5]. We have, therefore, explored the concept of alternating steel and superconductor layers from [4] with bulks rather than coated conductor to optimise effective J_e.

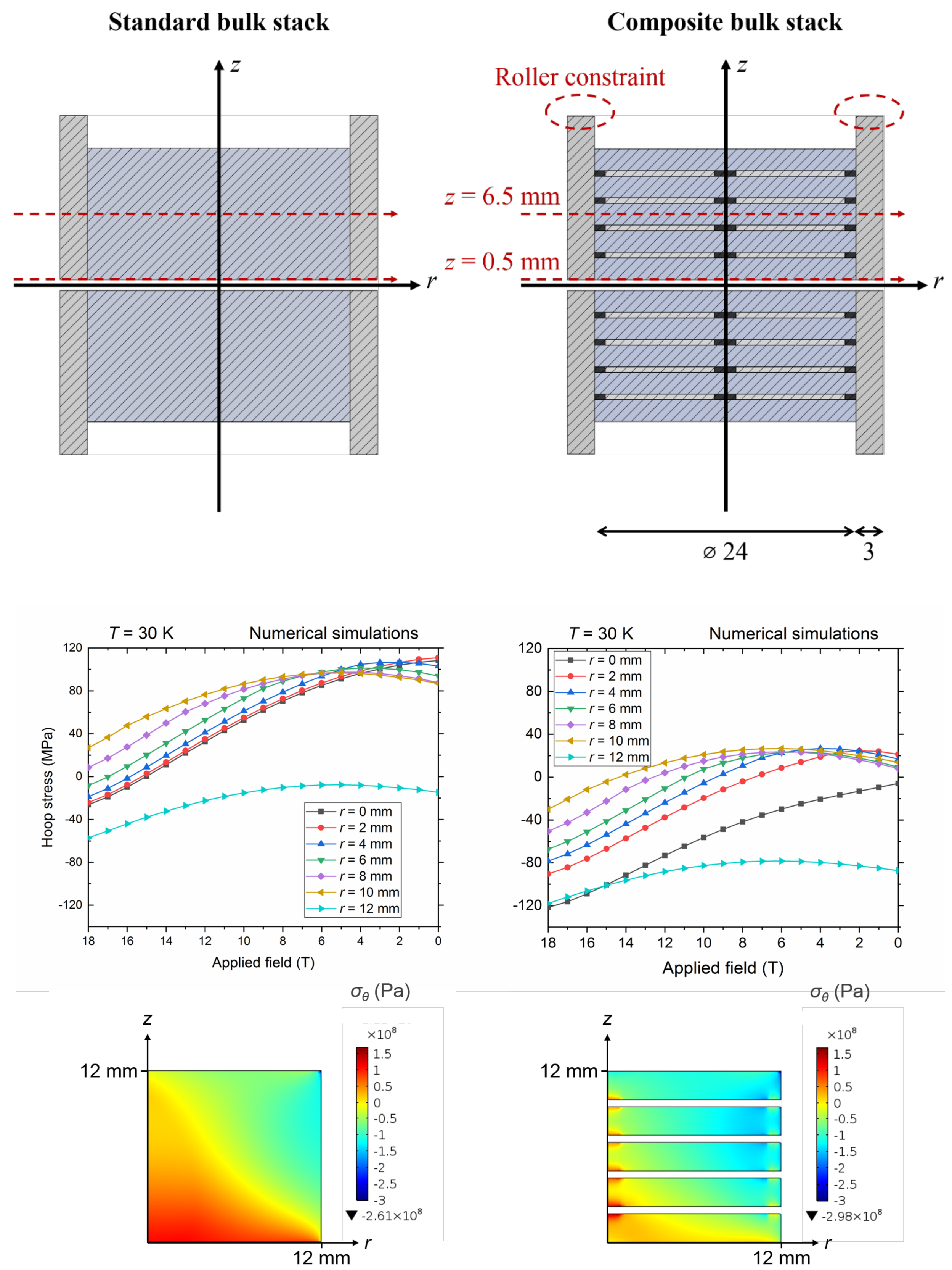

Fig. 5. Design and predicted performance of (left) conventional stack and (right) hybrid stack with reinforcement extending above surface. The hybrid stack shows much more compressive stress through volume.

Repeatable High Field Performance

In measurements in the 18 T SCM-2 magnet at NHMFL we have shown that this system can repeatedly achieve world record class performance (~17 T). More importantly the first sample we measured using this technique achieved this level of performance, as compared to reinforcement ring alone where only one of a number of samples achieved >17 T and samples only survived one measurement run.

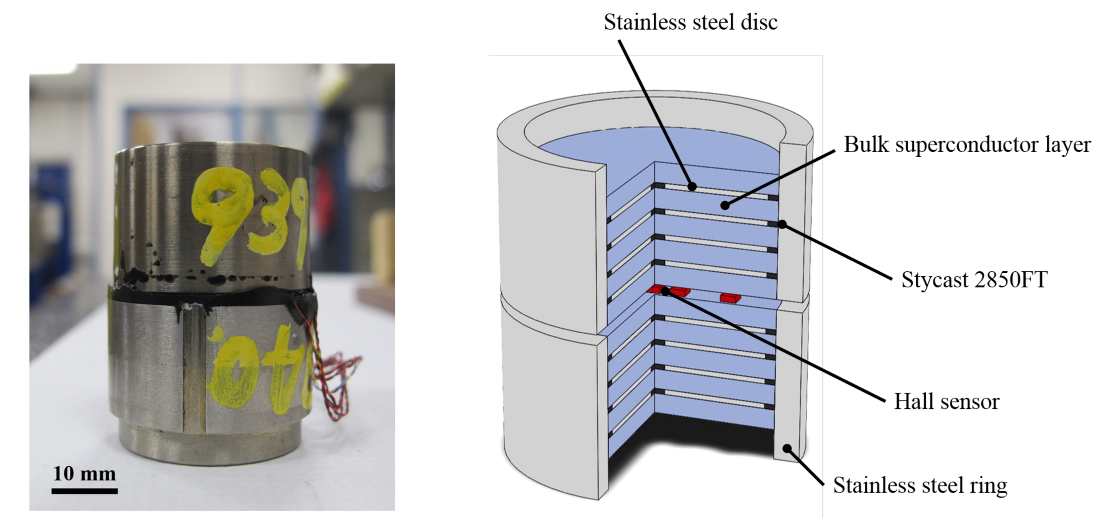

Fig. 6. Details of hybrid stack sample construction

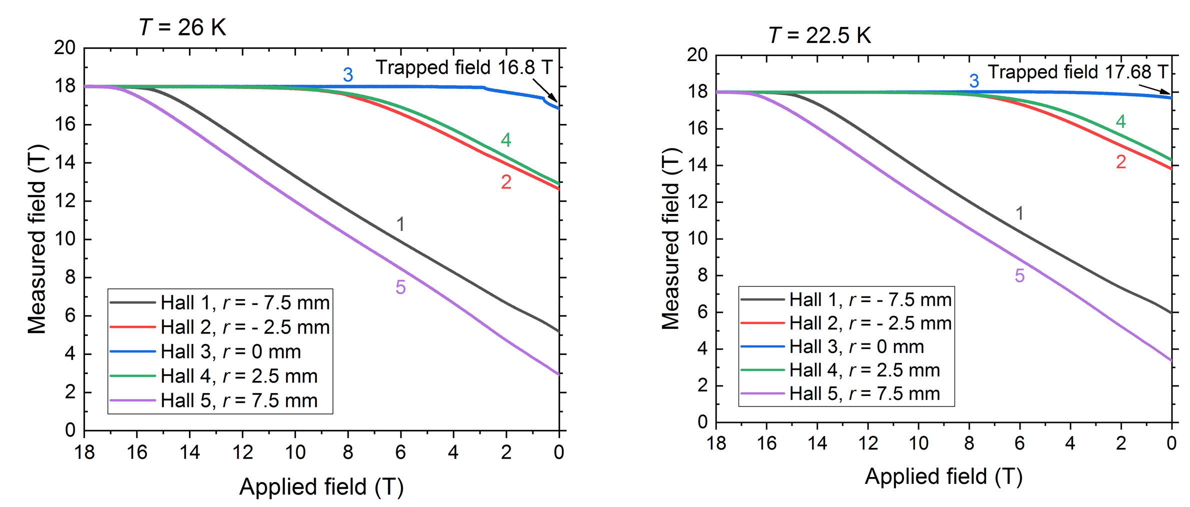

*Fig. 7. Trapped field performance in sequential magnetisation runs (fully warmed between) of the **same** hybrid stack bulk*

Conclusions

The hybrid stack approach allows high fields to be trapped in bulk superconductors. More importantly it appears it is able to do so in a more robust and repeatable way than compression rings alone. This performance is achieved at higher temperatures than comparable fields in stacked tape designs for superconductor trapped field magnets.

References

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