Experimental Investigation of Trapped Flux Stability in Bulk YBCO

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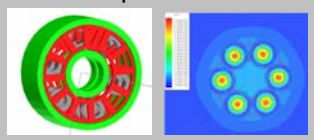
Development of bulk YBCO plates has lead to the availability of high performance trapped flux magnets (TFM) enabling power applications such as magnetic bearings, rotating machinery, and fault current limiters. Today, more than 2 T can be trapped at 77 K. Electro-thermal stability of TFM is paramount to achieve reasonable reliability of power devices. We propose to investigate experimentally the stability of trapped flux in single crystal bulk YBCO plates at different operating temperatures. Modifications of the trapped flux magnitude after energy was transferred through a thermal disturbance are monitored. Magnetic and thermal measurements via Hall Probes and an RTD, respectively, were used to study the thermal-magnetic effects of forced instability at various operating temperatures. Instabilities were observed in the form of partial quench of the superconductor, flux jumps and decrease of the trapped flux. The experiments showed a temperature range of high stability for YBCO bulk elements when no relaxation is performed.

Experimental setup

Motivation

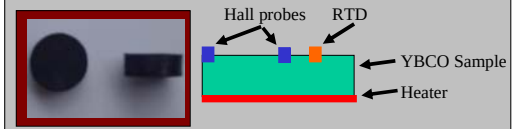
High performance trapped flux magnets (TFM) enable the development of compact power devices such as motors, FCLs, bearings in which stability of the trapped flux is paramount.



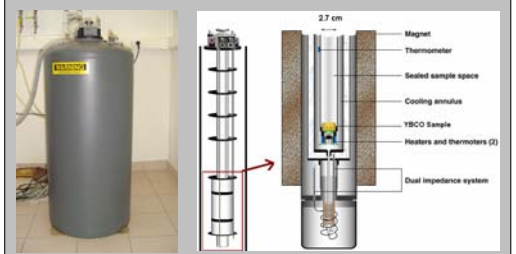
Axial flux motor using TFM as excitation

Large YBCO disk and HTS bearings (Nexans)

Experimental Equipment



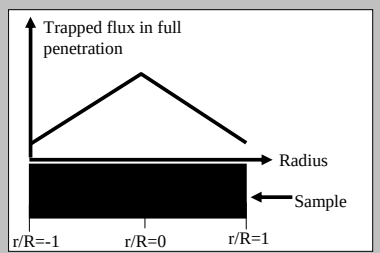
The bulk YBCO sample tested (pictured left) measured 21mm in diameter and 8 mm in thickness. The instrumentation (picture right) included a heater at the bottom of the plate and 2 Hall probes and an RTD sensor at the top of the sample.

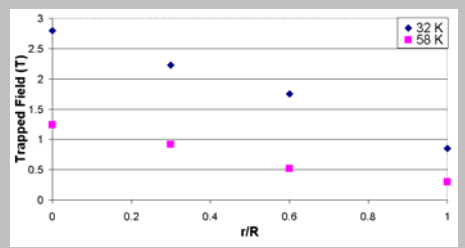


The sample was tested using a Quantum Design PPMS generating a variable uniform flux density up to 7 T and variable temperature down to 4 K.

Sample characterization

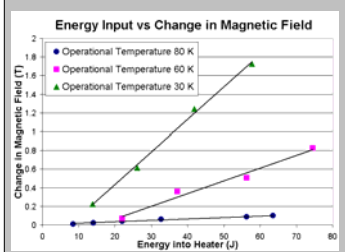
Trapped Field versus Sample Radius





The trapped magnetic field is a function of the radius, its variation along the radius is close to linear when the material is fully saturated in current.

Change in Magnetic Field versus Energy Input to Heaters

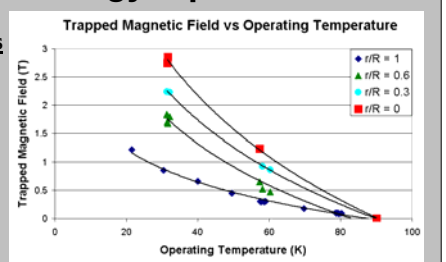


Linear Relationships

80 K:
$\Delta B_T = 0.0015 * E - 0.0031$

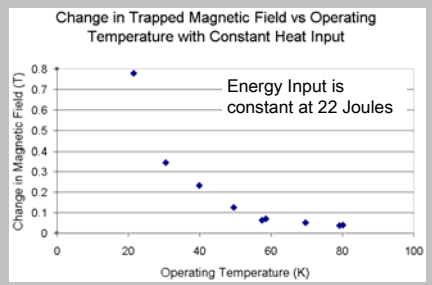
60 K:
$\Delta B_T = 0.0136 * E - 0.208$

30 K:
$\Delta B_T = 0.0349 * E - 0.264$

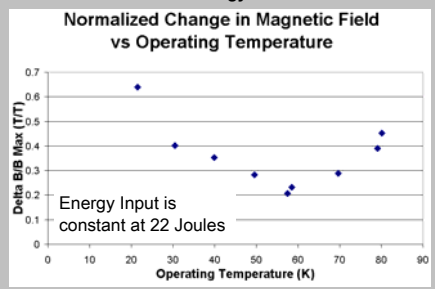


The stored magnetic field is decreased when energy is inputted into the superconductor. The decrease of trapped flux is directly proportional to the energy input all the way to the full loss of the trapped flux. No full quench leading from electro-thermal instability has been observed.

Experimental results



The change of trapped flux due to a heat input of 22 J decreases as the temperature increases and therefore as the stored energy decreases..



The relative loss in trapped flux shows a minimum at around 57 K, the result of lower ΔT (higher heat capacity) at higher temperature and the relative decrease of Jc corresponding ΔT.

Conclusion

1. **Trapped flux decreases linearly with energy input**
2. **No sudden quench of the YBCO TFM was observed**
3. **There is a minimum in the relative decrease of trapped flux due to a constant energy input at about 57 K.**