MultiPhysics Analysis of Trapped Field in Multi-Layer YBCO Plates

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Introduction *(Mandatory)*
Trapped Flux Magnets (TFM) are very attractive for application to power devices. The major limitation of flux trapping capabilities of bulk YBCO stems from mechanical problems. Indeed, Lorenz forces can become very important when magnetic energy stored increases. As most of the stress is applied on the vortex network, a failure usually results in a destruction of the material structure. In order to improve flux trapping capability in TFMs, mechanical reinforcement can be done using epoxy impregnated fiber glass cloth leading to the record of 17 T trapped at 29 K. However, due to the ceramic nature of YBCO, it remains structurally weak and can very likely fail if electro-thermal instabilities occur. We have studied the feasibility of TFMs based on stacked multi-layer configurations that could be achieved by stacking disks made of coated conductors. The multi-layer configuration would bring a much better stress distribution and should lead to more stable flux trapping. Even though packing factor remains an issue for stacked coated conductors, it is expected that YBCO can be deposited advantageously in multiple layer configuration especially for this specific application. The paper presents a FEA electro-thermal-structural analysis comparing flux trapping in YBCO bulk plates and multi-layers plates in a multi-layer configuration.

Use of COMSOL Multiphysics *(Mandatory)*

COMSOL MultiPhysics is used to simulate and understand magnetic flux trapping in high temperature superconductors. Transient current distribution is computed and stability of trapped flux is analyzed through coupling of electromagnetic and thermal physics. This type of simulation is very challenging because of the very high non-linearity of the electrical conductivity of superconductors and it dependence upon electric field as shown in the following equation where J_{c0} is the critical current density at 77K and self field, E_c is the electrical field defining J_c (1e-4 V/m), T_c is the critical temperature, B_0 is a reference flux density, n is the index of the superconductor, T is the temperature and B the applied flux density.

$$\sigma[S/m] = \frac{J_{c0}}{E_c}\left(1-\left(\frac{T}{T_c}\right)^2\right)^{\frac{3}{2}}\left(\frac{1}{1+\frac{B}{B_0}}\right)\left(\frac{E}{E_c}\right)^{\frac{1}{n}-1}$$

Expected Results *(Optional)*

Simulations show that the layers forming the studied trapped flux magnet are magnetically coupled and develop a current density in agreement with the critical state model. The multi-layer configuration tend to be more stable against thermal disturbances than bulk plates after field cooling.

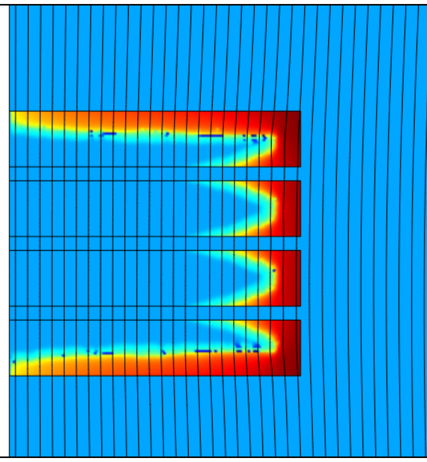

Figure 2. Current density distribution during flux trapping for 4 layers

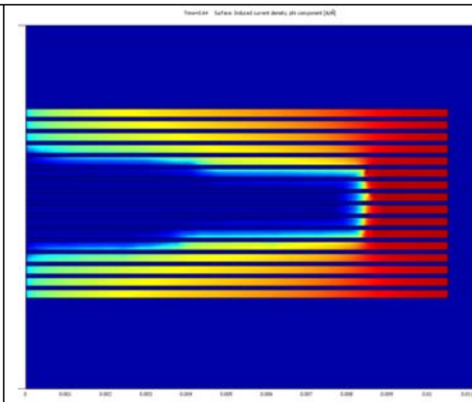

Figure 3. Current distribution in trapped flux magnet for 16 layers