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BSG

The Campbell penetration depth in type-II superconductors

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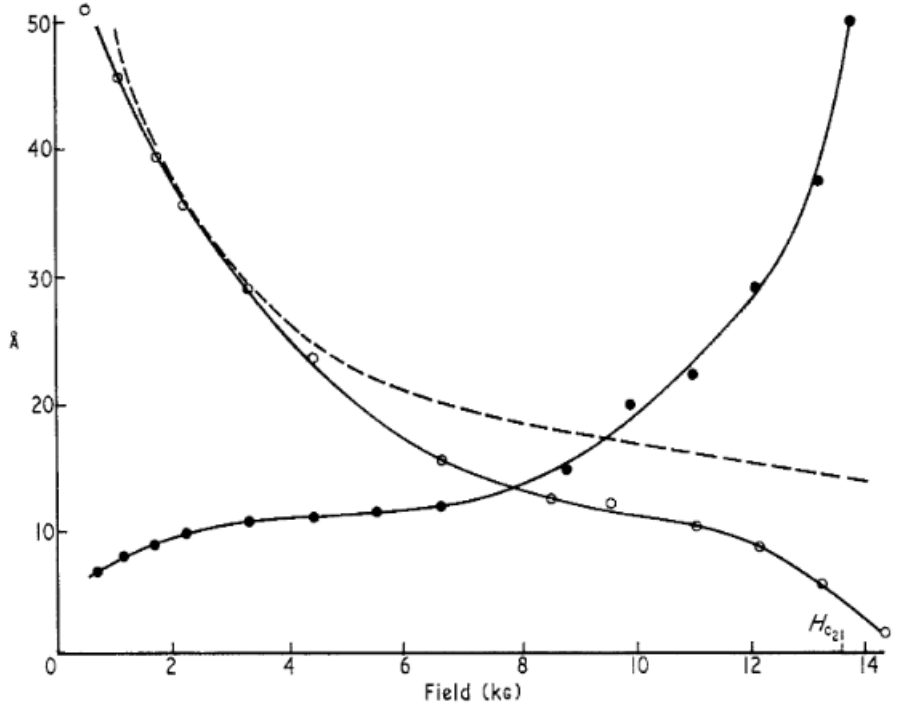
The same measuring technique, 50 years apart

J. PHYS. C (SOLID ST. PHYS.), 1969, SER. 2, VOL. 2. PRINTED IN GREAT BRITAIN

The response of pinned flux vortices to low-frequency fields

A. M. CAMPBELL
Department of Metallurgy, University of Cambridge
MS. received 21*st April* 1969



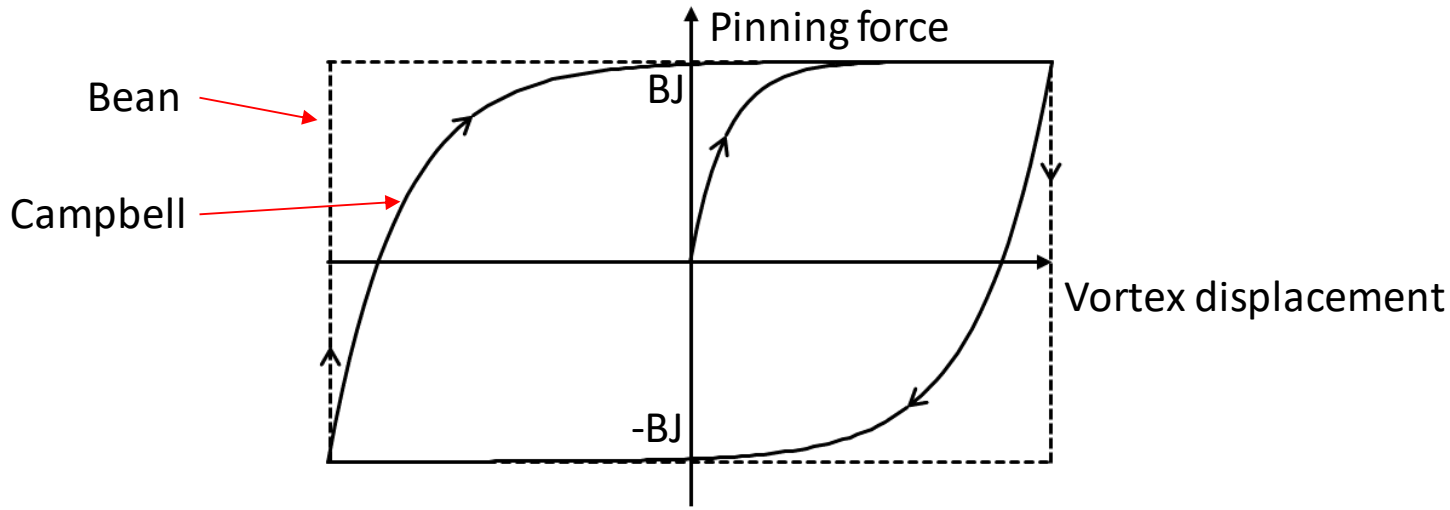
What is the limit of the Bean model?

The Bean model:

- Ignores the finite size of pinning potential (*any* J is J_C),
- Overestimates the hysteretic losses.

The Campbell model [1]:

- Assumes finite reversible movement of flux vortices (hence, lower losses),
- Provides an easy technique of measuring the size of the pinning potential.

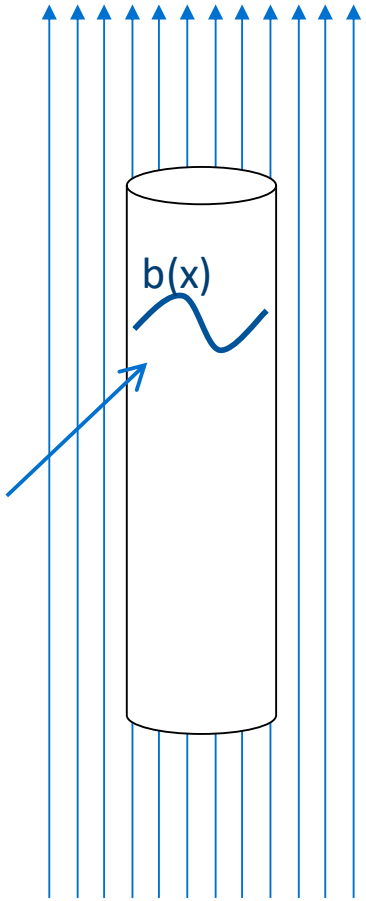


[1] A. M. Campbell, The response of pinned flux vortices to low-frequency field, J. Phys. C., 1969.

Campbell model: field profile b(x)=?

1. Long superconductor in DC field B_0.
2. We superpose a small ripple field $B_{AC} << B_0$.

3. Field profile b(x) inside = ???



Pinning force = Lorentz force

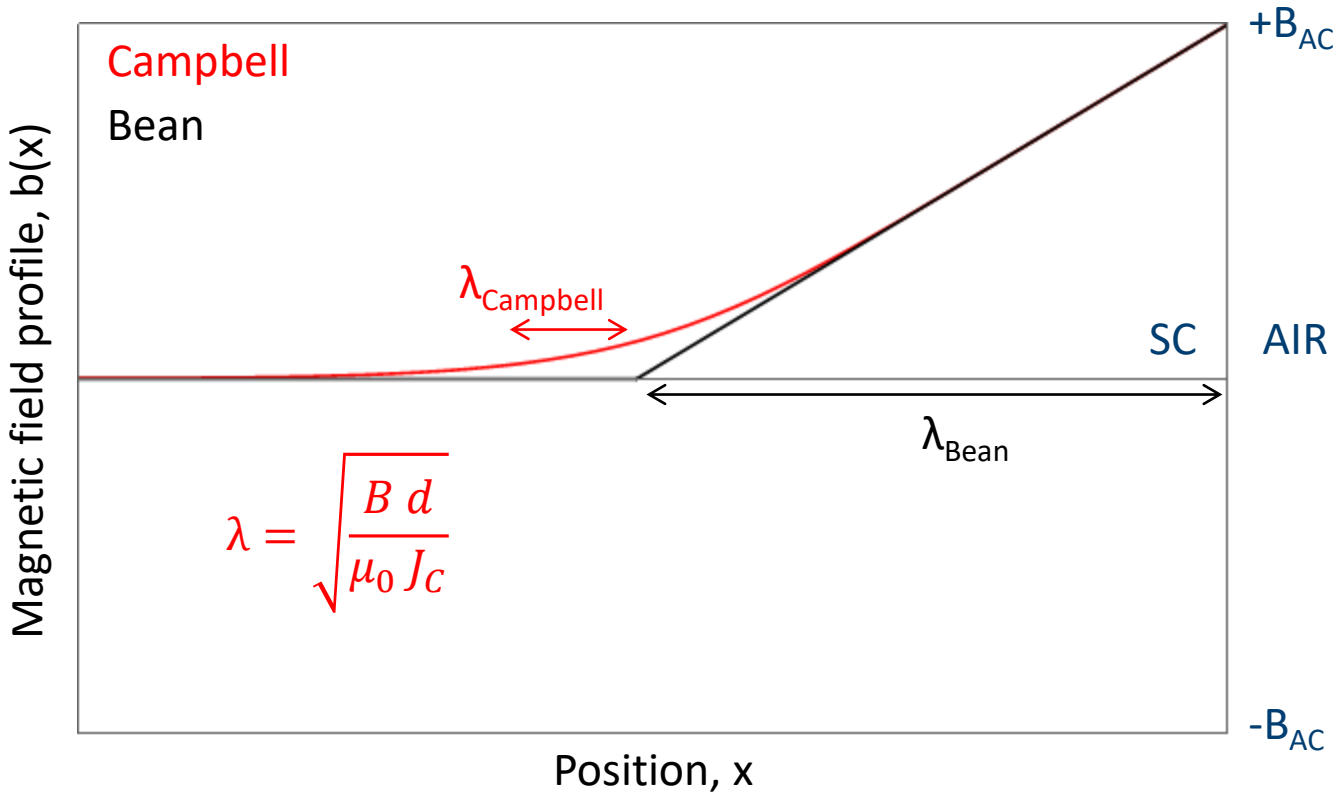
$$B_0 J_C \left(1 - \exp\left(-\frac{y}{d}\right)\right) = B_0 J$$

Ampere: $J = -\frac{1}{\mu_0}\frac{db(x)}{dx}$

Flux conservation: $\frac{b(x)}{B_0} = -\frac{dy}{dx}$

Calculated field profiles

Bean model: $\frac{\partial b(x)}{\partial x} = \pm \mu_0 J_C$ **Campbell model**: $\frac{\partial b(x)}{\partial x} = \mu_0 J_C \left(1 - \exp\left(-\frac{y}{d}\right)\right)$



Campbell penetration depth

Constant vortex spacing:

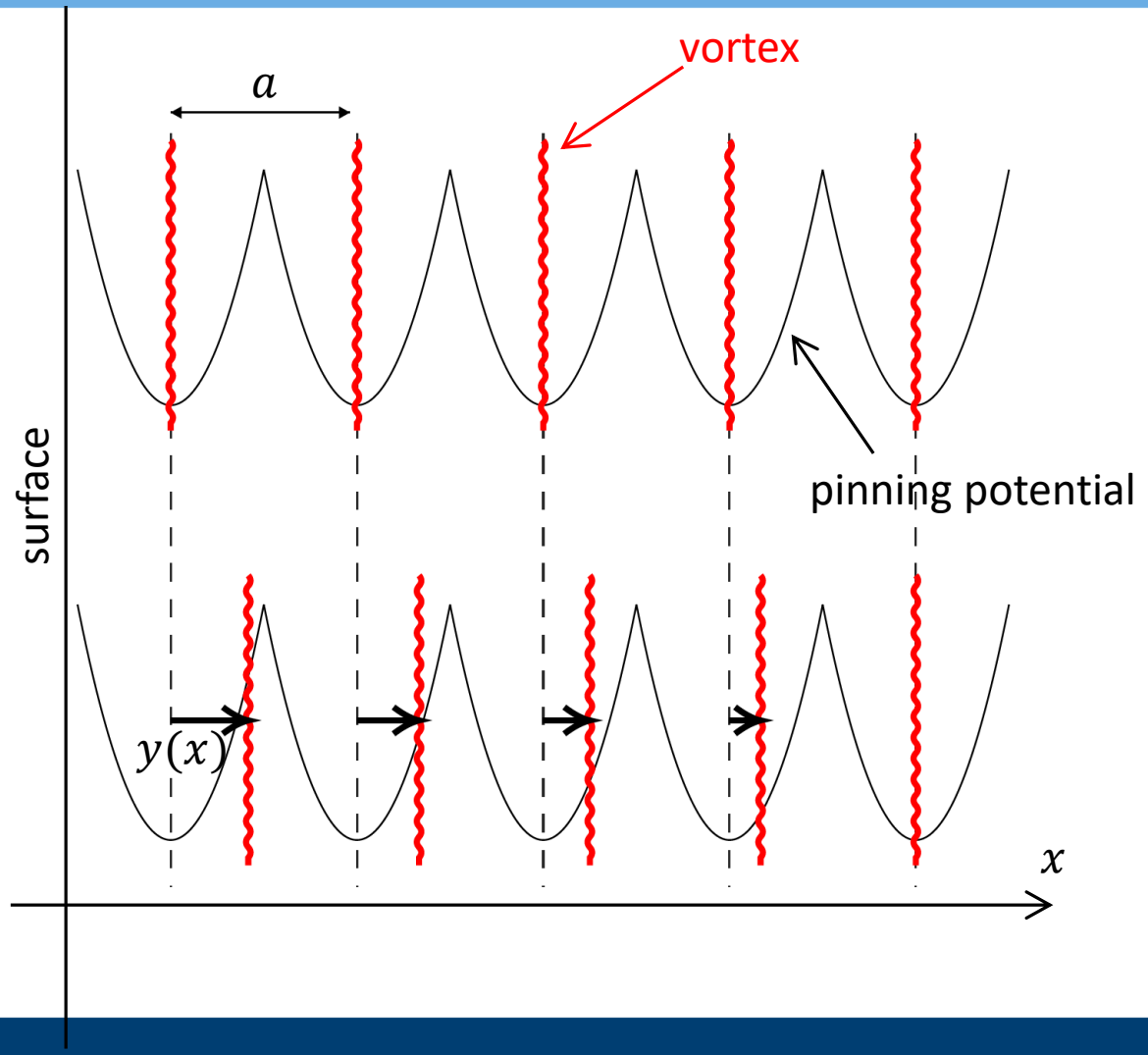
- Constant magnetic field, $B_0 \propto a^{-2}$.

Varying vortex displacement y(x):

- Varying magnetic field $b(x)$.

For a linear pinning force:

$$b(x) \propto y(x) \propto \exp\left(-\frac{x}{\lambda}\right)$$



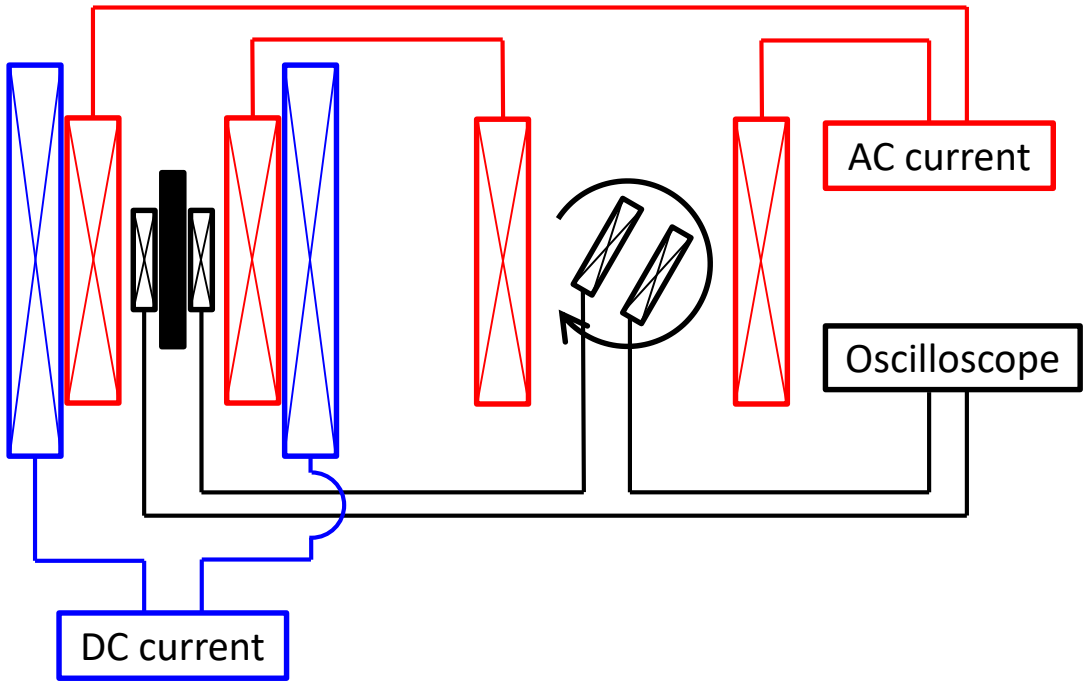
Measurement setup

Sample: 10 mm by 5 mm
$GdBa_2Cu_3O_{7-\delta}$ bulk

AC field: 1 mT (peak), 300 Hz

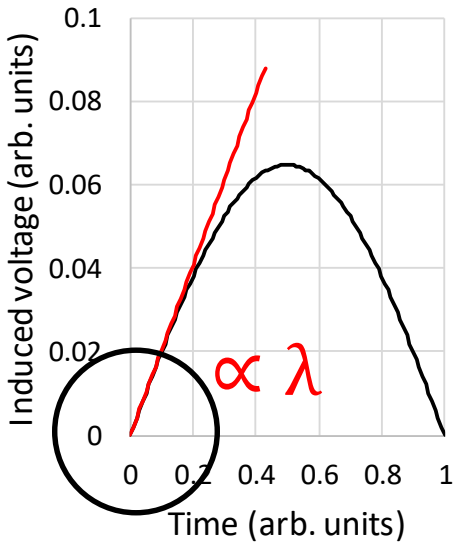
DC field: 0.5 T – 6 T

Temperature: 70 K

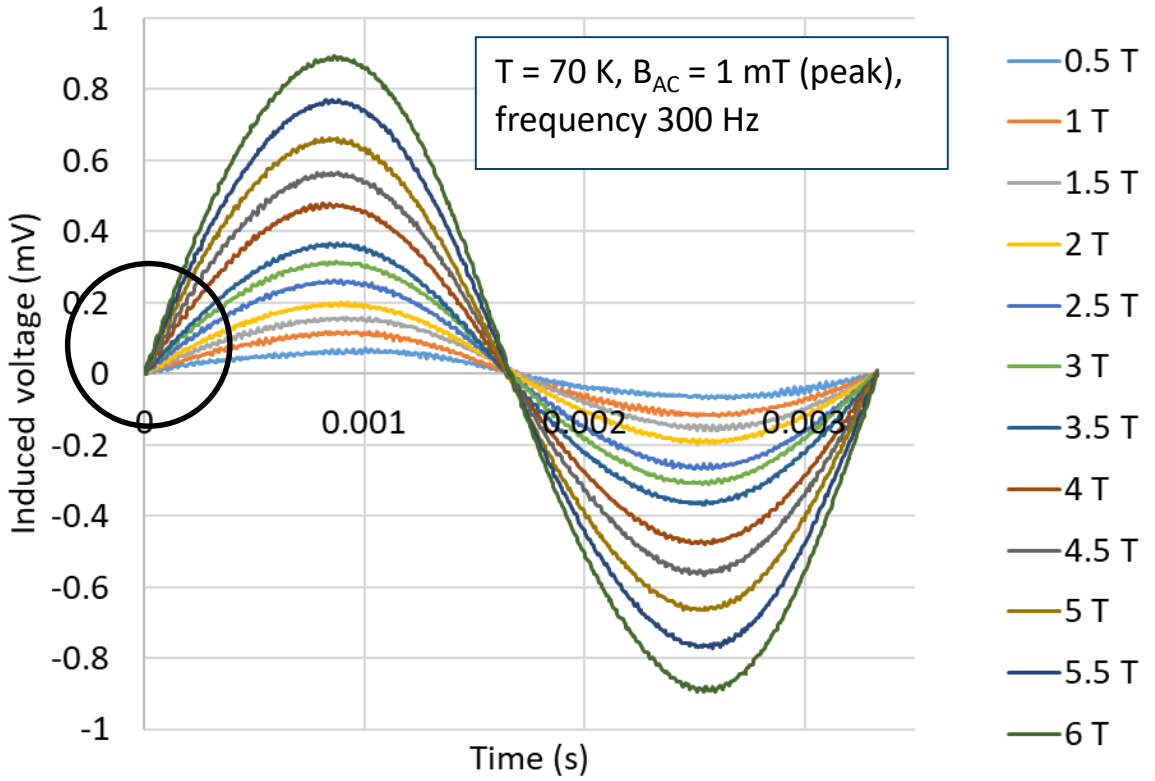


Results

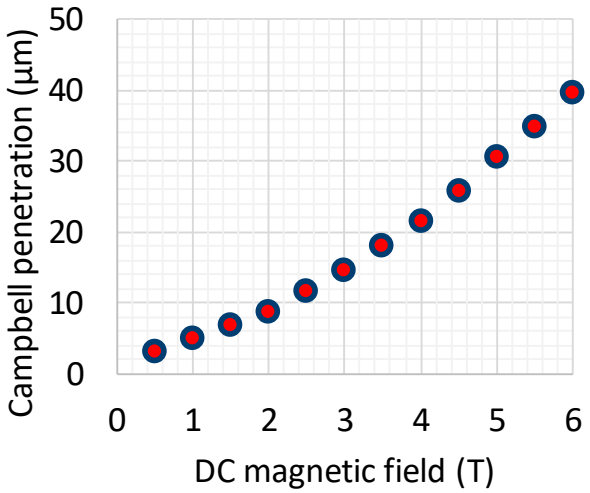
Calculation

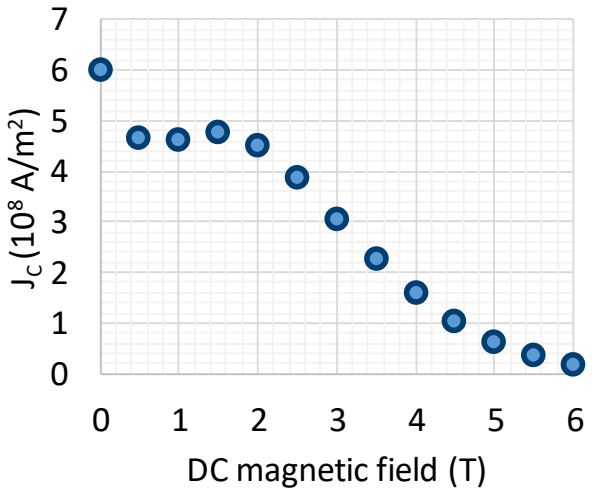


Measurement

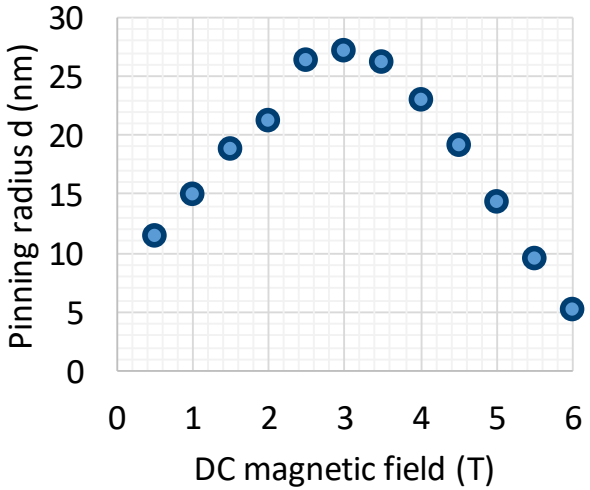


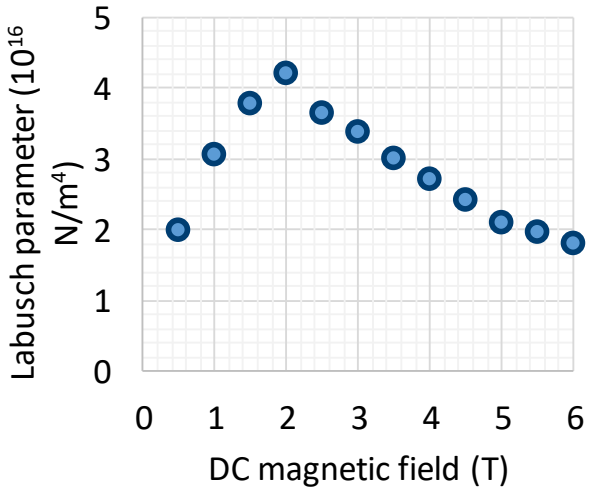
Results





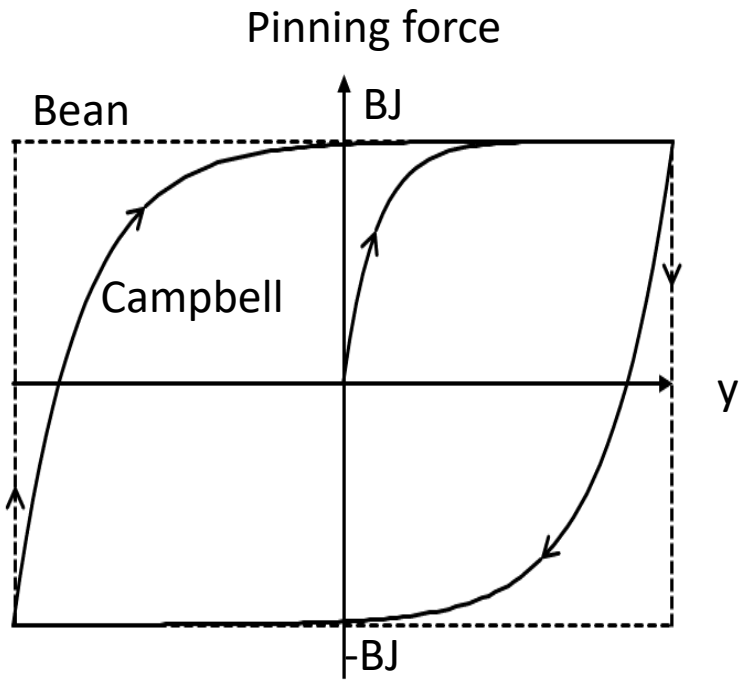
$$d = \frac{\mu_0 J_C \lambda^2}{B}$$

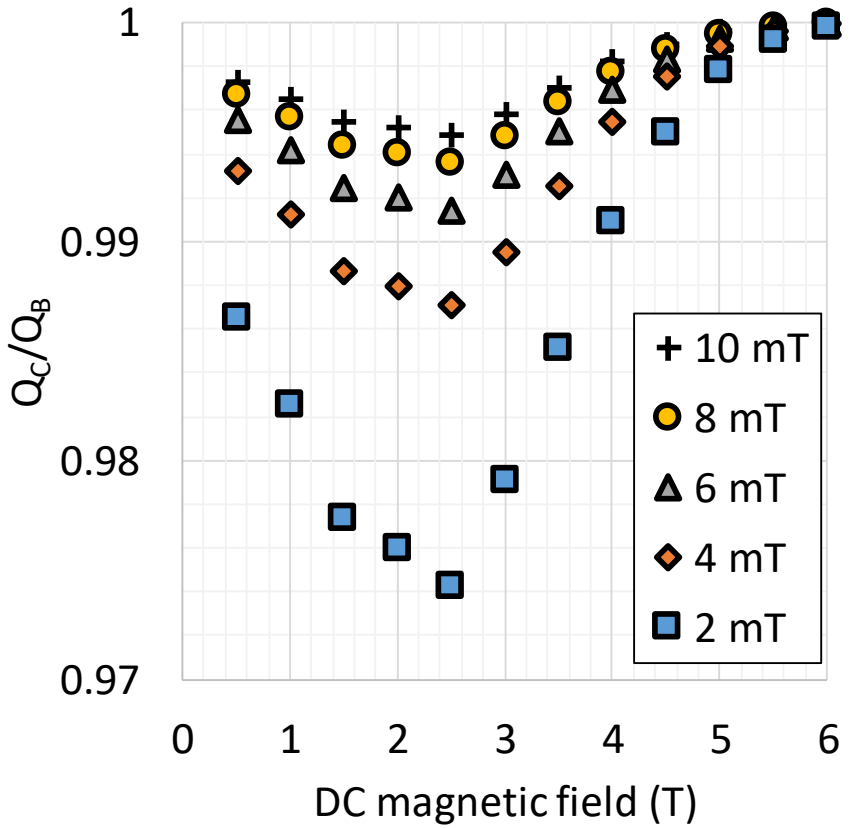




$$\alpha = \frac{B J_C}{d}$$

Hysteretic losses: Campbell and Bean comparison





Thank you for your attention.