MAGNETIC FLUX DISTRIBUTION IN SUPERCONDUCTING SINGLE CRYSTALS

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Abstract
In this work, the simplest model of the critical state of a granular superconductor is studied, which makes it possible to understand the experimentally observed¬ features of the superconductor's behavior in the magnetic fields H > HC1.

Keywords: Bean model, critical state, granular superconductors.

Introduction

The distribution of the magnetic flux in superconducting single crystals and films locatedin sufficiently high external fields cannot be described by the Bean critical state model in a homogeneous sample. At present, various versions of the critical state model are used to describe the superconducting state. In particular, in the works [1, 2], a rather complex version of this mode is usedTaking into account the Pinning forces for both the granules and the intergranule medium of weak bonds has been successfully usedto describe the magnetic properties of a ceramic sample.

In this paper, within the framework of the work [1], the simplest modelof the critical state of a granular superconductor is presented, which makes it possible to understand the experimentally observed features of the superconductor's behavior in the magnetic fields H > HC1.

Results and discussions

Suppose that the plate consists of granules of a strong superconductor in a matrix of weak substanceswith low superconducting properties. Let us introduce the filling factor *of THE SAMPLE V,* which is equalto the volume of the superconducting granules to the volume of the entire sample. Let us also assume that a sufficiently large external field H > HC1, perpendicular to the surface of the sample, penetrates freely into the intergranule space. It is easy to show that the magnetic inductionin a sample, averaged over a volume containing a large number of granules, is determined by the expression

$$B = (1-\nu)^{*} H + \nu \frac{\Phi}{S} \qquad (1)$$

where F is the magnetic flux inside the granule, S *is* the cross-sectional area of the granule perpendicular to the external field. The demagnetizing factor of the granules was not taken into account here, which is realized when they have the form of plates or cylinders infinite in the direction of the field.

Approximating the model to a single crystal, we will assume that the granules are a system of plane-parallel plates with a thickness and two other sizes Lx; Ly>>d whose developed plane is parallel to the external field (Fig. 1). The plates are separated by δ-thick transition regions, i.e., the fill factor $\nu = d/(d + \delta)$. By calculating the magnetic flux inside the bean based on the Bean model [3], it is possible to use expression (1) to calculate the average magnetic induction in the sample (), which effectively acts on the indicator film, when the field is initially applied, then decreases from $+H\bar{B}_{mAh}$ to zero, and is applied in the opposite direction.

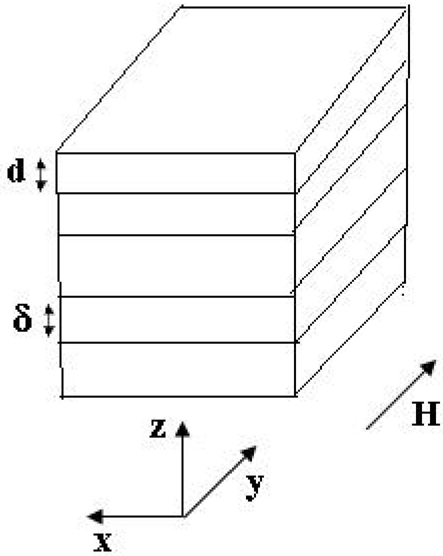

Fig.1. Model of a granular sample

Let us calculate, in particular, the average density of the magnetic flux $\bar{B}_t$ captured in the sample after removing the +Hmax field, as well as the experimentally observed value of the –H0 field, which must be applied in the opposite direction to reverse the average magnetic induction in the sample to zero. Fig. 2 (a, b, c, d) schematically shows the distributions of magnetic induction in granules and intergranular medium at H = $^{+Hmax}$ (curve 1), H = 0 (curve 2) and H = - H0 (curve 3) for the four characteristic intervals of the maximum value (+Hmax) of the applied external magnetic field. The captured stream is shaded. It is easy to show that the average density of the trapped flow in the sample

$$B_z = \begin{cases} \nu H_{max}^2 / 4H_p & H_{max} \le H_p \quad (2) \\ \nu[2H_{max} - H_p]/2 - H_{max}/4H_p & 2H_p \ge H \ge H_p \quad (3) \\ \nu/2 = H_p & H \ge 2H_p \quad (4) \end{cases}$$

where Hp is the field of total penetration at which the magnetic flux reaches the center of the bead. It followsthat the density of the trapped flux in a certain part of the sample will depend only on the filling factor and the magnitude of the field of total penetration into the beads. Since these values at the edge of the sample,generally speaking, do not differ from the rest of the sample, when the field is turned off, the magnetic flux will not escape from the edges of the sample in the first place. that on the basis of visual observations of the displacement of the

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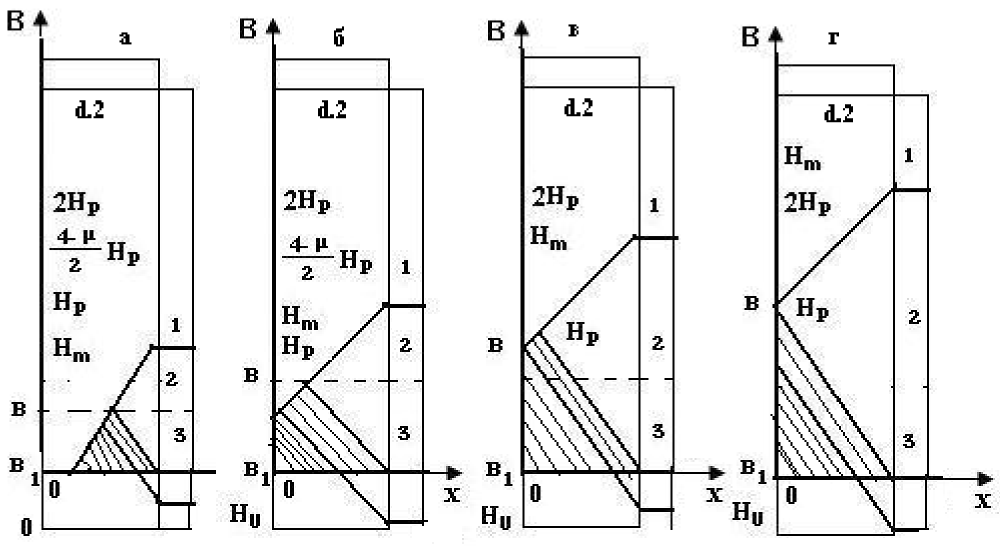
trapped flow by asteppedly changing field of the opposite direction Noi, a system of lines corresponding to the successive positions of the boundary between the same native magnetized regions of the indicator can be constructed [4]. It is obvious that for each value of the external field Noi, such a boundary will pass along the line = 0.$\overline{B}$

$H_{max} \leq H_p$; $H_p \leq H_{max} \leq H_{max} \leq H\frac{(4-\nu)}{2}p$; $H\frac{(4-\nu)}{2}p \leq H_{max} \leq 2H_p$; $H_{max} \geq 2H_p$



Rice. 2. Magnetic induction profiles in granule (X < d/2) and intergranule medium (d/2 <X<.$\frac{d+\delta}{2}$) Origin in the center of the granule. 1 - in the outer field +Hmax; 2 - after the field is turned off; 3 - in the field in the reverse direction - H0; a - Hmax ≤ Hp; b- H p ≤ Hmax ≤ $H\frac{(4-\nu)}{2}p$; c- $H\frac{(4-\nu)}{2}p \leq H_{max} \leq 2Hp$; r - $H_{max} \geq 2Hp$.

The captured magnetic flux is shaded. *Within the* framework of the proposed model of a granular superconductor on each i-th line, the magnetic flux density Bn captured after the field is turned off can be calculated from the value of H0i. For example, at $H \leq H_p$:

$$R_{tr} = \left[\frac{\nu H_{0i}^2}{4H_p}[1+\left(\frac{H_{0i}^2}{H_{0i}}\right)^{1/2}\right]^2 \qquad (5)$$

In here

$$H_{0i} = H_{0i} - \frac{2H_p(1-\nu)}{\nu}$$

Thus, the described line system with the corresponding values $\overline{B}_{Ti}$- can be considered as a topogram of the captured flow. Dependency analysis $\overline{B}_{Ti}$ (But$_i$) showed that in order to obtain a prestatements about the spatial distribution of the captured flow in the first approximation, it is possible, as it was done by the authors of the work [5], to use the ratio $B_{tr} \sim$ Noi.

Conclusion

The estimates we have given cannot claim to be a quantitative description of the phenomenon, but they allow us to understand the features of the interaction of the magnetic field with granular ones and the physical nature of some critical quantities, and can also serve as a basis for obtaining information about the spatial distribution of the captured magnetic flux from visual pictures of its displacementfield of the opposite direction. Differences in the strength of the superconducting properties of different regions of the sample can be explained by the difference in the average size of the granules d and the fill factor *v*, but the assumption that twin boundaries play the role of weak bonds cannot be proved experimentally.

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