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THE PROCESS OF MAGNETIC FLUX PENETRATION INTO SUPERCONDUCTORS

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Abstract

In the present paper the magnetic flux penetration dynamics of type-II superconductors in the flux creep regime is studied by analytically solving the nonlinear diffusion equation for the magnetic flux induction, assuming that an applied field parallel to the surface of the sample and using a power-law dependence of the differential resistivity on the magnetic field induction. An exact solution of nonlinear diffusion equation for the magnetic induction B(r, t) is obtained by using a well known self-similar technique. We study the problem in the framework of a macroscopic approach, in which all lengths scales are larger than the flux-line spacing; thus, the superconductor is considered as an uniform medium.

Key words: *magnetic flux penetration, critical state, nonlinear diffusion*

1. Introduction

Theoretical investigations of the magnetic flux penetration dynamics into superconductors in a various regimes with a various current-voltage characteristics is one of key problems of electrodynamics of superconductors. Mathematical problem of theoretical study the dynamics of evolution and penetration of magnetic flux into the sample in the viscous flux flow regime can be formulated on the basis of a nonlinear diffusion-like equation [1, 2] for the magnetic field induction in a superconductor [3-5]. The dynamics of space-time evolution of the magnetic flux penetration into type-II superconductors, where the flux lines are parallel to the surface of the sample for the viscous flux flow regime with a nonlinear relationship between the field and current density in type II superconductors has been studied by many authors [4-14]. The magnetic flux penetration problem was theoretically studied for the particular case, where the flux flow resistivity independent of the magnetic field by authors [5]. Similar problem has been considered in [6] for the semi-infinite sample in parallel geometry. The situation, where flux flow resistivity depends linearly on the magnetic field induction was considered analytically in [4]. Analogical problem for the creep regime with a nonlinear relationship between the current and field has been considered in [8-14]. The magnetic flux penetration into the superconductor sample, where the flux lines are perpendicular to the surface of the sample is described by a non-local nonlinear diffusion equation [7]. This problem has been exactly solved by Briksin and Dorogovstev [7] for the case thin film geometry in the flux flow regime of a type-II superconductors. In the present paper the magnetic flux penetration dynamics of type-II superconductors in the flux flow regime is studied by analytically solving the nonlinear diffusion equation for the magnetic flux induction, assuming that an applied field parallel to the surface of the sample and using a power-law dependence of the differential resistivity on the magnetic field induction. An exact solution of nonlinear diffusion equation for the magnetic induction $\vec{B}(r,t)$ is obtained by using a well known self-similar technique. We study the problem in the framework of a macroscopic approach, in which all lengths scales are larger than the flux-line spacing; thus, the superconductor is considered as an uniform medium.

2. Formulation of the problem

Bean [15] has proposed the critical state model which is successfully used to describe magnetic properties of type II superconductors. According to this model, the distribution of the magnetic flux density $\vec{j}$ and the transport current density inside a superconductor is given by a solution of the equation

$$rot\vec{B} = \frac{4\pi}{c}\vec{j} \tag{1}$$

When the penetrated magnetic flux changes with time, an electric field $\vec{E}(r,t)$ is generated inside the sample according to Faraday's law

$$rot\vec{E} = -\frac{1}{c}\frac{d\vec{B}}{dt} \tag{2}$$

The motion of vortex filaments with a velocity v leads to the appearance of an electric field