Comment on ``Exact solution for flux creep with logarithmic U(j) dependence: Self-organized critical state in high-T_{c} superconductors''

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published in
Physical Review Letters
1992

document version
Publisher's PDF, also known as Version of record

Comment on "Exact Solution for Flux Creep with Logarithmic $U(j)$ Dependence: Self-Organized Critical State in High-T_c Superconductors"

Vinokur, Feigel'man, and Geshkenbein [1] solve the partial differential equation for flux creep in a one-dimensional superconductor for a potential barrier $U(j) = U_0 \ln(j_c/j)$, where $j = j(x,t)$ is the electric current density. Using a scaling form for the solution they finally arrive at two formulas for the magnetic moment as a function of time, for large times:

$$\ln M(t) = \text{const} - (d_0/\sigma d)\ln(t/\tau_0), \quad t < t^*, \tag{1}$$

$$\ln M(t) = \text{const} - (1/\sigma)\ln(t/\tau_0), \quad t > t^*. \tag{2}$$

Equation (1) applies to the partially penetrated state and Eq. (2) to the fully penetrated state. t^* is the time at which the sample is fully penetrated, d the thickness of the sample, d_0 the Bean penetration depth, and $\sigma = U_0/kT$. The authors conclude from these formulas that in a $\ln M$ vs $\ln t$ plot, a kink should be visible at $t = t^*$.

We have solved the differential equation numerically, for representative values of σ. The resulting magnetic moment is shown in Fig. 1. Equation (2), for full penetration, is found to be correct. In the partial penetration state, however, there is no evidence of a straight-line behavior, as predicted by Eq. (1). This is due to the fact that the long-time limit for which Eq. (1) is valid is never reached before full penetration. Furthermore, no kink is visible at t^*.

The second point of this Comment is that the correct results for $M(t)$ can easily be reproduced by simply approximating the field profile in the superconductor by a straight line. By integrating the partial differential equation over the cross section of the sample and expressing the magnetic moment as a function of the mean current, we arrive at an *ordinary* differential equation for $j(t)$ [2]:

$$\frac{dj}{dt} = -Re^{-U(j)/kT} \tag{3}$$

for full penetration. For $U(j) = U_0 \ln(j_c/j)$ we obtain

$$\ln M(t) = \ln M(t^*) - (1/\sigma)\ln[1 + (t - t^*)/\tau_f], \tag{4}$$

where τ_f is a characteristic time that can be calculated exactly. For large times, we can show that Eq. (4) transforms exactly into Eq. (2), with the same τ_0. For the partial penetration case ($t < t^*$), we find

$$M(t) = 2M(t^*)\left\{1 - \frac{j_c}{j_0}\frac{d_0}{d}\left[1 + \frac{t}{\tau_p}\right]^{1/(\sigma+2)}\right\}, \tag{5}$$

where τ_p is a characteristic time again and j_0 is the starting value of the current, at $t = 0$. The solutions fit smoothly to each other at $t = t^*$, as expected. Both relations have been checked: In Fig. 1 the approximate solutions Eqs. (4) and (5) fall within the line thickness on the curves of the exact numerical solutions. The approximate formulas have also been checked [3,4] for other potential forms, e.g., $U = U_0(1 - j/j_c)^n$ with $n \geq 1$. We conclude that there is *no* sharp transition and *no* kink in the relaxation behavior when the flux fronts from opposite sides of the sample merge at the center of the sample. Furthermore accurate relations for $M(t)$ can be obtained from

$$Rt = -\int_{j_0}^{j(t)} \exp[U(j)/kT]\,dj, \tag{6}$$

which is the integrated version of Eq. (3).

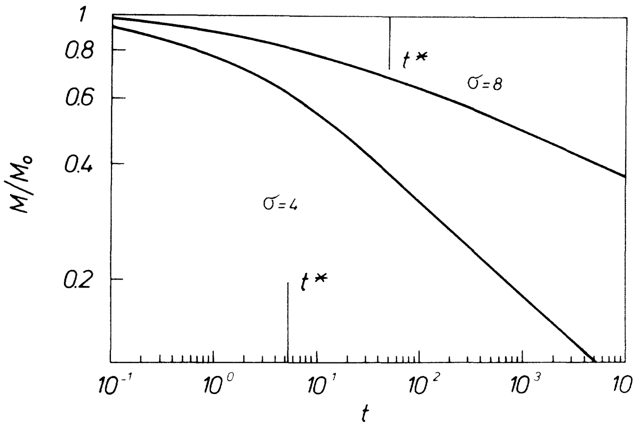

FIG. 1. Magnetic moment relaxation curves for two values of $\sigma = U_0/kT$. The normalized sample thickness is $d/d_0 = 4$. The flux front collapse time is $t^* = 5.6$ for $\sigma = 4$, and $t^* = 51$ for $\sigma = 8$. t is the dimensionless time used by Vinokur, Feigel'man, and Geshkenbein [1].

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Received 13 November 1991
PACS numbers: 74.60.Ge, 05.60.+w, 64.60.Ht, 74.60.Jg

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