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published in

Physical Review Letters
1992

document version

Publisher's PDF, also known as Version of record

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citation for published version (APA)

Griessen, R., & Schnack, H. G. (1992). Comment on ``Exact solution for flux creep with logarithmic $U(j)$ dependence: Self-organized critical state in high- T_c superconductors". *Physical Review Letters*, 68(17), 2706-2706.

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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:

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

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

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]:

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

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

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

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

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

where τ_p is a characteristic time again and j_0 is the starting value of the current, at $t=0$. The solutions fit

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].

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

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

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

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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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