Nature of Temperature Independent Dissipation and Relaxation in Layered Superconductors

In a recent Letter [1] Nicodemi and Jensen have demonstrated on a classical model that a nonequilibrium state can decay without thermal activation in the limit of low temperatures (T). Apparently, strongly off-equilibrium configurations have a relatively small, but statistically significant, number of ways to rearrange themselves without the need to overcome an energy barrier. This conclusion seems plausible and I do not question its validity for the presented model. I do, however, question the applicability of the mechanical model itself for the description of the relaxation and dissipation in the mixed state of layered superconductors. For several reasons it appears quite unlikely that this model can account for a phenomenon of finite creep rate in high-T_c cuprates in the limit of low T.

First, in the simulations [1] time is measured in certain units which should be of the order of the attempt time for a single vortex (there is no other *microscopic* time scale in this problem). In literature, the attempt time is estimated as 10^{-9}–10^{-11} s. Then, the results of the simulations over the range 10^5–10^6 time units [1] describe the very early stage of relaxation in the range 10^{-4}–10^{-3} s.

Another way to estimate the time of relaxation of the channels that do not require activation is by noting that such channels are far more abundant in the *supercritical state* [2]. This is the state obtained in the following way: A conventional critical state is prepared at a certain lower temperature $T - \Delta T$ and then the temperature is raised to T. As a result, a great number of relaxation channels with zero or "negative" (using terminology of Ref. [1]) activation energy appear. The decay time of such a state is very short (in fact, too short to be measured directly by conventional methods). I suggest it is of the order of the *escape time* defined in [3] as the time of relaxation uninhibited by lack of thermal energy. For a particular crystal used in Ref. [3], $\tau_{\text{esc}} \sim 1$ s. Thus, the channels of relaxations that do not require activation are long exhausted by the time the actual experiments start to measure the relaxation of the magnetic moment in the interval 10^3–10^4 s.

More generally this point can be stated as follows: any off-equilibrium configuration decays in two stages: the initial rapid supercritical "crumbling" towards the critical state subsequently crosses over into slow subcritical relaxation. In order to proceed, the supercritical phase does not require thermal activation, but the subcritical phase does. In real experiments these two stages of relaxation are easy to distinguish because they are characterized by the vastly different time scales. Apparently, it is not as easy to do in simulations. The results of Ref. [1], in my view, describe the properties of the supercritical phase but are interpreted, erroneously, as the properties of the subcritical relaxation relevant to the conditions of the experiments cited therein.

Second, the saturation of the dissipation at low T is not restricted to the relaxation of the induced magnetic moment. The crossover to T-independent dissipation takes place in transport as well as relaxation *at the same temperatures* [3]. Since the transport measurements involve field-cooled and, therefore, nearly equilibrium configurations of vortices, the main argument of Ref. [1] that T-independent residual relaxation is a property of the off-equilibrium states is not applicable. To my knowledge, no mechanical model has been able to demonstrate finite dissipation at zero temperature in a *nearly equilibrium state*.

Third, at $T \to 0$ the mobility of vortices is finite near one surface of the crystal, while it is much smaller and thermally activated near the opposite surface [3]. Thus, there must be a phase slippage boundary inside the crystal separating it into two uncoupled regions. Therefore, the vortices cannot be described as rigid rods. Add to this picture an anomalous behavior of the relaxation rate found in [2]. When a Bean profile was gradually "melted away" by short-time increases in temperature, the relaxation rate decreased initially but then saturated and stopped decreasing with decreasing total magnetic moment. This also contradicts the model [1]. Taken together, these observations lead us to the conclusion that the mechanical models similar to that of Ref. [1] are not an adequate tool for understanding these phenomena.

This, however, does not mean that quantum creep (the coherent transitions between different configurations of vortices) is necessarily the sole reason for these effects. Rather high temperatures at which the transition to T-independent creep sometimes takes place, as well as the other facts mentioned in [1], indeed raise doubts that quantum creep is the only mechanism involved.

We have speculated [3,4] that in layered superconductors the current distribution may be unstable with respect to the formation of the current-carrying layers in which the density of current is close to critical even though the average density of current is well below critical. This alone may account for most of the effects described above, or, at least, such "self-channeling" may facilitate the transition to quantum creep.

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