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Dipartimento di Matematica e Informatica

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The relaxation field r is usually proportional to $\dot{\mathrm{m}}$ through a positive constant α. This kind of viscous-like friction effectively accounts for dissipation mechanisms that dominate at resonance or during relaxation; it is not clear, however, whether it is appropriate to capture the rate-independent response observed during quasistatic evolution, when the system, driven by a slowly-varying applied field, evolves through a series of states of equilibrium, alternated with a series of irregular random bursts, the so-called *Barkhausen jumps*, resulting from the pinning of domain walls by impurities and lattice imperfections.

Baltensperger and Helman suggested in [2] that rate-independent dissipation mechanisms may be phenomenologically accounted for by adding a dry-friction term to the standard Gilbert damping. Using the notion of subdifferential of a convex function, the prescription for the relaxation field proposed in [2] can be written as:

$$\mathrm{r} \in \partial R_{\alpha,\beta}(\dot{\mathrm{m}}) \text{ where } R_{\alpha,\beta}(\mathrm{v}) := \frac{1}{2}\alpha|\mathrm{v}|^2 + \beta|\mathrm{v}|. \qquad (1.3)$$ gilbmod0

Dry-friction dissipation was also proposed by Visintin in [33] as a device to better model *hysteresis* in ferromagnets. Visintin modified the Landau-Lifschitz equation [23] by augmenting the effective field with a rate-independent term. The resulting equation is, however, not equivalent to the modified Gilbert equation proposed in [2]. This has been pointed out by Podio-Guidugli in [28], where the conceptual differences between the Gilbert and the Landau-Lifschitz formats have been elucidated, and where several constitutive prescriptions, including (1.3), have been given a precise significance from the standpoint of Continuum Thermodynamics. From this standpoint, the nonnegativity of α and β is a requisite of consistency, in the sense of Coleman and Noll [10], with the Second Law of Thermodynamics.

The standard Gilbert equation with viscous dissipation (that is, with $\alpha > 0$ and $\beta = 0$) has been the object of an impressive amount of mathematical work. Here, we limit ourselves to mentioning a handful of references concerning existence [1, 5, 17, 32], regularity [8, 9, 17, 25] and qualitative behavior of solutions [18, 19, 34], and we refer to the survey [22] for a more detailed bibliographical account. The mathematical literature concerning micromagnetics with dry-friction dissipation seems, on the other hand, much less developed [21, 29].

In this paper we study existence of weak solutions to (1.1) with r given by (1.3), and we identify E with the following *Gibbs free energy*:

$$E(t, \mathrm{m}) := \int_\Omega \frac{1}{2}\mu|\nabla \mathrm{m}(x)|^2 + \psi(\mathrm{m}(x)) - \mathrm{h}(t, x) \cdot \mathrm{m}(x)\, \mathrm{d}x, \qquad (1.4)$$ effect1

where $\Omega \subset \mathbb{R}^3$ is a bounded open set, $\mu > 0$ is the exchange constant, $\psi : \mathbb{R}^3 \to \mathbb{R}$ is any smooth extension to $\mathbb{R}^3$ of the anisotropy energy (defined on the unit sphere), and h is a time dependent applied field. For simplicity, we neglect the demagnetizing field, whose energetic contribution would not affect the main technical points of our proofs. We point out that the demagnetizing energy is mostly relevant when studying development of magnetic microstructures [12, 14].

In the integral on the right-hand side of (1.4) the first term accounts for exchange effect and it penalizes spatial variations of the magnetization; the second term accounts for anisotropy effects which tend to align the magnetization with some favourite directions; the last term accounts for the interaction of the magnetization with the external

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