Motion of Individual Domain Walls In a Nickel-Iron Ferrite

Erratum

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In footnote (20) to a paper[1] of the above title it was asserted that the theory of magnetic after-effect* given by L. Néel[2] leads to zero loss for large motions of a 180° domain wall. It has since become clear that this assertion is based on a misinterpretation of Section 10 of Néel's paper, and is therefore not correct. In fact, Professor Néel has pointed out in a private communication that if the general analysis in his paper is used to calculate the viscous drag on a 180° domain wall, a result substantially the same as that given by equation (38) in Reference 1 is obtained. Néel's theory therefore does not lead to a result inconsistent with the domain wall data given in Reference 1; it appears to be possible to account for this set of data with either his theory or the analysis presented in Reference 1.

The following is a derivation, which is due to Néel, of the result which is to be compared with equation (38) in Reference 1. We start from equation (26) of Reference 2, and use Néel's notation:

$$P = -W_0 \int_0^t f(U)g(t - \tau)\, d\tau \tag{1}$$

Here P is the pressure due to magnetic drag, W_0 is a constant which determines the magnitude of the energy to be gained by rearranging carbon atoms (valence electrons in the case of the ferrite) and $g(t - \tau)$ is a weighting factor which takes the form

$$\frac{1}{\theta} \exp \frac{(\tau - t)}{\theta}$$

if only one relaxation time, θ, is involved. U is the distance between the

* Traînage.
[1] J. K. Galt, B.S.T.J., **33,** p. 1023, Sept., 1954.
[2] L. Néel, J. Phys. et Radium, **13,** p. 249, 1952.

positions of the wall at time τ and at time t; $f(U)$ is defined thus:

$$f(U) = \frac{\partial F(U)}{\partial U} \tag{2}$$

where

$$F(U) = -\frac{1}{W_0} \int_{-\infty}^{\infty} E_d(\tau)\, dx \tag{3}$$

The function $F(U)$ is an integral, over a cylinder of unit cross-section normal to the wall, of the angular dependence of the energy E_d to be gained by rearranging carbon atoms (valence electrons in the case of the ferrite). Further details will be found in Reference 2.

In the case of a domain wall moving with constant velocity v,

$$U - v\tau - vt,$$

and we assume that only one relaxation time is important in the loss mechanism. In this case Equation (1) becomes

$$P = -\frac{W_0}{v\theta} \int_{-vt}^{0} f(U) e^{U/v\theta}\, dU \tag{4}$$

If we note that $f(U)$ is an odd function (Section 8 in Reference 2) and rearrange the limits of integration, this becomes:

$$P = \frac{W_0}{v\theta} \int_0^{\infty} f(U) e^{-U/v\theta}\, dU. \tag{5}$$

Now because of the factor $e^{-U/v\theta}$, we only get contributions to the integral in Equation (5) from the region where U is comparable to or less than $v\theta$. If d is the thickness of the domain wall, and if the velocity of the domain wall is slow enough so that $d \gg v\theta$, $U \ll d$ in the region of importance. We may therefore use the first term of the series for $f(U)$ discussed in Section 8 of Reference 2. From this we find

$$\begin{aligned} P &= -\frac{4W_0}{3v\theta d} \int_0^{\infty} U e^{-U/v\theta}\, dU \\ &= -\frac{4W_0 v\theta}{3d} \end{aligned} \tag{6}$$

If we set this pressure, due to viscous drag, equal to the pressure from the applied steady field on the domain wall, $2\, M_s H_0$, we find

$$v = \frac{1}{\theta} \frac{3M_s d}{2W_0} H_0 \tag{7}$$

This relation is to be compared with Equation 38 in Reference 1. They are of the same form, and in particular they both lead to the same dependence of v on applied field and temperature (note that the relaxation time θ depends exponentially on the temperature). They both can therefore be used to fit the experimental data in Reference 1, and comparisons with other data will be necessary to distinguish between the two approaches.