

Origin of the Linear Term in the Expression for the Approach to Saturation in Ferromagnetic Materials*

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There has been confusion for many years over the origin of the a/H term in the expression for the approach to saturation, $M/M_s = 1 - a/H - b/H^2 + cH$, observed in many ferromagnetic materials. A calculation is presented which suggests that residual internal strain contributes significantly to this term. Internal strain has previously been thought to contribute only to the b/H^2 term. It is further suggested that the a/H term has been overemphasized and has validity only over a limited region of the H axis. The effect of internal strain is deduced from consideration of a problem concerning nonhydrostatic strains induced in slightly porous magnetic material subject to external hydrostatic pressure. A comparison with recent experimental work supports the calculation.

I. INTRODUCTION

There has been continued interest for many years in explaining the various terms which occur in the expression for the approach to saturation observed experimentally in many ferromagnetic materials:

$$\frac{M}{M_s} = 1 - \frac{a}{H} - \frac{b}{H^2} + cH. \quad (1)$$

The cH term has been adequately explained in terms of paraproceses. The constant in the b/H^2 term has been shown to be

$$b = \frac{8}{105} \frac{K^2}{M_s^2} + \frac{3}{5} \frac{\lambda_s^2 \langle \sigma_i^2 \rangle_{av}}{M_s^2}, \quad (2)$$

where the first part is due to crystalline anisotropy,¹ and the second part, derived by Becker and Polley,² is considered to be the influence of internal strain on the approach to saturation.

The origin of the a/H term is not well understood. Calculations by Brown³ have shown that dislocation effects can contribute to this term, while Néel⁴ has concluded that stray fields due to nonuniform magnetization may bring about forces

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The primary conclusion is that the linear term in the expansion of the energy density is due to the interaction of the magnetic field with the lattice. This is in contrast to the previous model in which the linear term was attributed to the interaction of the magnetic field with the dislocations. The present model is based on the assumption that the magnetic field is parallel to the dislocation line. This is a reasonable assumption for the case of a single crystal. The linear term is shown to be proportional to the square of the magnetic field. This is in agreement with the experimental results. The present model is a generalization of the previous model and it is shown that the linear term is due to the interaction of the magnetic field with the lattice. This is in contrast to the previous model in which the linear term was attributed to the interaction of the magnetic field with the dislocations. The present model is based on the assumption that the magnetic field is parallel to the dislocation line. This is a reasonable assumption for the case of a single crystal. The linear term is shown to be proportional to the square of the magnetic field. This is in agreement with the experimental results.

The following calculation will show that the linear term in the expansion of the energy density is due to the interaction of the magnetic field with the lattice. This is in contrast to the previous model in which the linear term was attributed to the interaction of the magnetic field with the dislocations. The present model is based on the assumption that the magnetic field is parallel to the dislocation line. This is a reasonable assumption for the case of a single crystal. The linear term is shown to be proportional to the square of the magnetic field. This is in agreement with the experimental results. The present model is a generalization of the previous model and it is shown that the linear term is due to the interaction of the magnetic field with the lattice. This is in contrast to the previous model in which the linear term was attributed to the interaction of the magnetic field with the dislocations. The present model is based on the assumption that the magnetic field is parallel to the dislocation line. This is a reasonable assumption for the case of a single crystal. The linear term is shown to be proportional to the square of the magnetic field. This is in agreement with the experimental results.

APPENDIX

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$$\frac{\partial^2 \epsilon}{\partial H^2} = \frac{1}{4} \frac{\partial^2 \epsilon}{\partial H^2}$$

This is in principle, can be solved for any value of the magnetic field. The linear term is shown to be proportional to the square of the magnetic field. This is in agreement with the experimental results. The present model is a generalization of the previous model and it is shown that the linear term is due to the interaction of the magnetic field with the lattice. This is in contrast to the previous model in which the linear term was attributed to the interaction of the magnetic field with the dislocations. The present model is based on the assumption that the magnetic field is parallel to the dislocation line. This is a reasonable assumption for the case of a single crystal. The linear term is shown to be proportional to the square of the magnetic field. This is in agreement with the experimental results.