THE RELATION BETWEEN THE INNER DEMAGNETIZING FACTOR OF MANGANESE MAGNESIUM FERRITES AND THEIR POROSITY AND PERMEABILITY

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It is shown that the simple relation of direct proportionality between the inner demagnetizing factor and the relative volume of the pores is not sufficient to explain the experimental data obtained on a system of manganese magnesium ferrites. An equation is derived in which the inner demagnetizing factor is directly proportional to the ratio of the relative volume of the pores to the permeability of the sample. The values calculated according to this equation agree well with the experimental results.

When studying differently sintered manganese magnesium ferrites we determined for each sample, apart from other quantities, its inner demagnetizing factor $N_i$ and relative volume of the pores $v_i$. With a ferrite having the chemical composition $\text{Mn}_{0.45}\text{Mg}_{0.76}\text{Fe}_{2.54}\text{O}_4$, of which we had a larger number of samples with different porosities at our disposal, we observed a direct proportionality between the inner demagnetizing factor and the relative volume of the pores (Fig. 1). Fundamentally, this phenomenon may be explained using the relation

$$v_i = \frac{3N_i}{N_i + 4\pi},$$

which is given by Snoek [1] for solid solutions of oxygen ferromagnets without further explanation. In our measurements the inner demagnetizing factors are negligibly small compared with $4\pi$, so that according to (1) we have

$$N_i = \frac{4\pi}{3} v_i,$$

which agrees with the observed linear dependence (Fig. 1) except that the proportionality constant $4\pi/3$ must be divided by a number approximately equal to 32. However, this number does not greatly differ from the initial permeabilities measured on samples with the above composition (Tab. 1). It thus seems that with our ferrites Eq. (2) must be replaced by the empirical relation

$$N_i = \frac{4\pi}{3} \frac{v_i}{\mu},$$
in which, for reasons stated later, the notation $\mu$ is chosen for the initial permeability. From dimensional aspects relations (2) and (3) are obviously flawless since in the absolute system of units used $N_p, v$, and $\mu$ are non-dimensional numbers. It thus remains to show that the introduction of the initial permeability $\mu$ into relation (2) is physically justified.

The following model is chosen for the actual calculation: let us assume that the magnetization process takes place in a set of spherical particles, each of which can contain one or more crystal grains of ferrite. If each particle has a magnetization $I$, then for the mean magnetization $\bar{I}$ of the sample as a whole, and a relative porosity $v$, we have

$$\bar{I} = (1 - v) I.$$  (4)

Let us further assume that each spherical particle lies in a continuous medium with permeability $\mu$, which is equal to the measured permeability of the sample. If $\mu$ denotes the permeability of each particle ($\mu > \bar{\mu}$), then between the field $H_i$ inside the particle and the field $H_o$ in its neighbourhood the following well-known relation (see e.g. [2]) holds

$$H_i = H_o - \frac{3\mu}{\mu + 2\mu}$$  (5)

together with the definition equations

$$I = \frac{\mu - 1}{4\pi} H_i, \quad \bar{I} = \frac{\bar{\mu} - 1}{4\pi} H_o.$$  (6)