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EVALUATION OF INTERACTIONS IN PARTICULATE MEDIA THROUGH DC MEASUREMENTS

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The paper presents a mixed (parametric-non parametric) method to identify the Preisach distribution and the mean field parameter of particulate recording media. The algorithm is tested on computer generated data. The identification is realized using remagnetisation curves and taking into account a linear mean field term and a reversible part of magnetisation on the first bisector of the Preisach plane.

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1. Introduction

The Preisach type models describe the interactions between particles in particulate media using a distribution of random interaction fields and a mean field term proportional to the magnetic moment of the sample (moving term). The coercive fields of the particles are taken into account by a distribution of coercive fields. To use a Preisach model in order to predict the magnetisation processes of a particulate medium one needs to identify the specific parameters of the model.

The generalised ΔM plots (GDM) [1,2,3] use the remagnetisation curves starting from different initial reproducible remanent states to build a DCD like curve which has been denoted by DCD' and which replaces the DCD curve in the equation describing the classical ΔM plot (Fig. 1). The initial remanent state used to obtain a GDM plot is obtained by positively saturating the sample, applying a negative field $-H_n$ and removing the applied field. For different values of $-H_n$, one obtains the generalised ΔM plot corresponding to each initial remanent state. The generalised ΔM plots contain all the information needed to extract the Preisach distribution.

2. The identification algorithm

The m_+ and m_- curves (Fig. 1) are the positive and negative remanent magnetisation curves starting from the same remanent state on the DCD process.

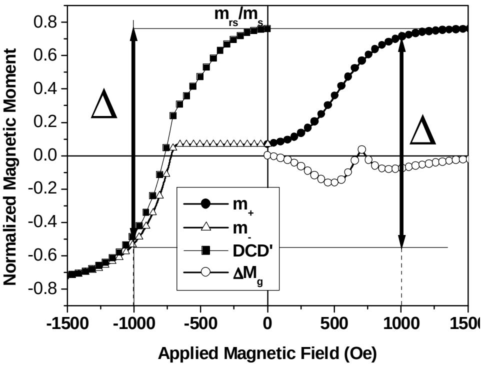

Fig. 1. A Generalised ΔM plot and the magnetisation processes used to obtain it, for H_n = 650 Oe. $\Delta = m_+(H) - m_-(-H) = m_{rs} - m_{DCD'}(-H)$.

Considering no mean interaction field, the remanent positive curve m_+ switches the magnetic moments corresponding to square zones defined by the applied field in the Preisach plane as described in [4] and one may obtain the Preisach distribution by representing the magnetic moments corresponding to each zone against the fields which defines it as the limits of critical fields of the particles in that zone. When the mean interaction field can not be neglected, this method gives significant differences from the experimental curves. In order to determine the Preisach distribution by magnetic measurements one has to take into account both the mean interaction field and the reversible part of magnetisation which is coupled with the irreversible part of magnetisation.
The effective field in the sample may be considered as given by the sum of the applied field and the mean field described by the moving term.

$$H_{ef} = H_0 + \alpha m \tag{1}$$

The reversible part of magnetisation may be approximated by using a distribution of step operators placed along the first bisector of the Preisach plane [5]. Thus, the reversible magnetic moment may be calculated as:

$$m_{rev}(H) = \frac{1-S}{h_{r\sigma}} \int_0^H \exp\left(-\frac{|H|}{h_{r\sigma}}\right) dH \tag{2}$$

In the equation above, S is the saturation irreversible magnetic moment of the sample, and $h_{r\sigma}$ is a parameter. The parameters S and $h_{r\sigma}$ describing the reversible part of magnetisation may be identified on the descending branch of the hysteresis loop in an iterative process making a "first guess" on the moving parameter.

The effective field in the major hysteresis loop (MHL) may be written as:

$$H_{ef} = -H_n + \alpha\, m_{MHL}(H_{ef}) \tag{3}$$

For a given value of the moving parameter, measuring the applied field $-H_n$ and the magnetic moment on the MHL one may find the effective applied field.
Assuming that the total magnetic moment is given by the sum of the reversible part of magnetisation described by equation (2) and the irreversible magnetisation, one may write the irreversible variation of magnetisation on the major hysteresis loop (MHL) as

$$m_{ri}(H_{ef}) = m_{MHL}(H_{ef}) - m_{rev}(H_{ef}) \tag{4}$$

Thus one may approximate both the effective field corresponding to each value of H_n and the magnetic moment irreversibly switched to define the initial remanent state for the remagnetisation curves.

By removing the field H_n, the field H_0 becomes zero but the effective field in the sample will be given by the mean interaction field produced by the sample itself

$$H_{ef}(-H_n, 0) = \alpha\, m_r(-H_n, 0) \tag{5}$$

m_r is the magnetic moment that one actually measures after the removal of the field $-H_n$.

When applying and removing a field in the positive direction, the effective field created, $H_{ef}(-H_n, H)$, produces an irreversible magnetic moment

$$m_{ri}(-H_n, H) = m_r(-H_n, H) - m_{rev}(-H_n, H) \tag{6}$$

One measures the remanent magnetic moment $m_r(-H_n, H)$ but to define the irreversible variation of magnetic moment one has to obtain the effective applied field in the positive direction in an iterative process considering that the magnetic moment of the sample in the presence of the field is given by

$$m(-H_n, H) = m_{ri}(-H_n, H) + m_{rev}(-H_n, H)$$
$$H_{ef}(-H_n, H) = H + \alpha m(-H_n, H) \tag{7}$$

Thus one obtains the irreversible magnetic moment and the effective field used to create it for all values of the applied field. Considering that the interaction field distribution is symmetric with respect to the second bisector of the Preisach plane one needs to obtain the magnetic moments corresponding to the area in the forth quadrant, above the second bisector.

The magnetic moment corresponding to the shaded area in fig. 2 may be written as

$$\begin{aligned} m_{j,i} &= m_{ri}(-H_{n,j}, H_i) - m_{ri}(-H_{n,j}, H_{i-1}) \\ &- m_{ri}(-H_{n,j-1}, H_i) + m_{ri}(-H_{n,j-1}, H_{i-1}) \end{aligned} \tag{8}$$

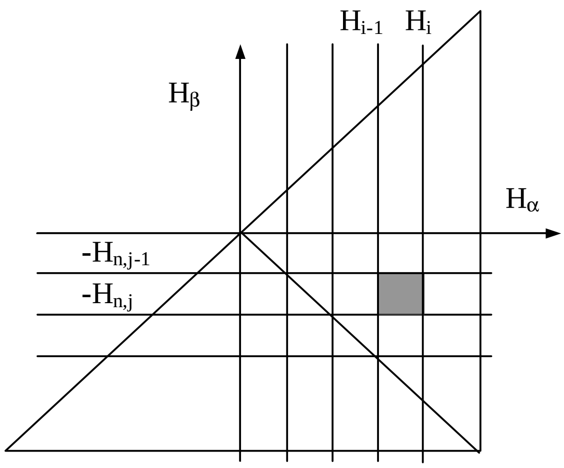

Fig. 2. To the calculus of the magnetic moment corresponding to the hashed zone.

The algorithm described above uses the generalised moving Preisach model (GMPM) [5] hypotheses and, in order to test the algorithm, we have generated the remagnetisation curves using the GMPM and reobtained the Preisach distribution to study the accuracy of the algorithm for "perfect data". Thus, we have used a reversible part of magnetisation defined by (2), Gaussian distribution of interactions, lognormal distribution of coercivities and a mean field term to generate a set of remagnetisation curves starting from remanent states obtained for different applied fields in the MHL process. Fig. 3 and 4 represent the interaction field distribution and the coercive field distribution obtained with the algorithm described using the values of α, S and $h_{r\sigma}$ that were used to generate the original curves. Fig. 5 represents the Preisach distribution obtained with the algorithm.

The Preisach distribution and the moving parameter are then used as input for the GMPM model to simulate the MHL, DC demagnetisation and isothermal remanent magnetisation. Fig. 6 presents the MHL loops simulated with the GMPM for several different values of the moving parameter. The convergence of the method is based on iterating the moving parameter to minimise the areas between the experimental and simulated MHL, IRM and DCD. Starting from a minimum value of α and increasing it step by step, the parameters are changing continuously to adapt to the new mean field term until the minimum area is reached.

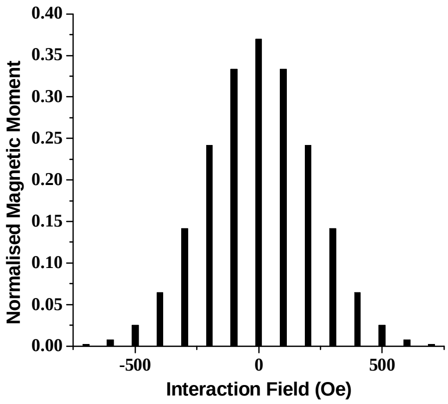

Fig. 3. The interaction field distribution obtained using $\alpha = 300$.

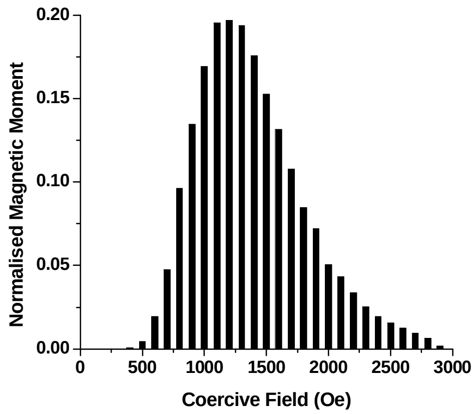

Fig. 4. The coercive field distribution obtained using $\alpha = 300$.

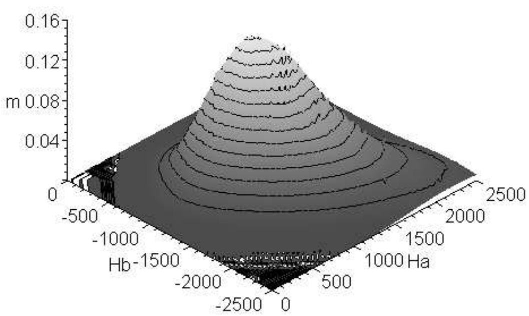

Fig. 5. The Preisach distribution obtained using the algorithm.

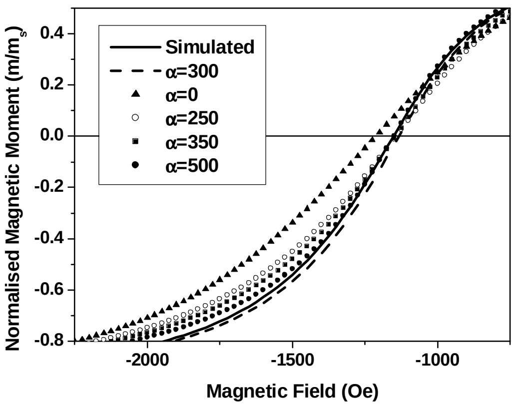

Fig. 6. Hysteresis loops obtained for different values of the mean field parameter.

In Fig. 6 one observes that, for values of the mean field parameter above or below the exact value, the parameters obtained using the algorithm produce simulations that do not satisfy the minimum area condition.

3. Conclusions

The identification method presented allows the obtaining of the Preisach distribution characterising the sample and the mean field parameter under the hypotheses used in the GMP model. An important advantage of the algorithm is that allows the obtaining of the Preisach distribution without making any assumption on the shape of the distribution, which is important when the Preisach distribution is not close to the analytical distributions that are normally used to describe it.

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