

THE EFFECT OF INTERACTIONS ON THE AC MAGNETISATION PROCESSES

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The interactions in particulate ferromagnetic media are usually characterised using the ΔM plot. However, the ΔM plots cannot give a separate indication on the existence of the mean field and statistical interactions used in Preisach models to describe the interactions, and other experimental methods have to be addressed. This paper presents the effect of statistical and mean field interactions on the ac magnetisation processes to investigate the possibility of using this type of processes in the characterisation of the properties of magnetic recording media.

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1. Introduction

In Preisach type models [1] the interactions are described by a statistical interaction field distribution and a mean interaction field term assumed to be proportional to the magnetic moment of the system. The interactions in particulate ferromagnetic media are usually characterised by the use of ΔM plots [2]. Thus, a positive ΔM plot is considered to be obtained for powerful mean field interactions in particulate media. However, the shape of the ΔM plot is given by the balance of statistical and mean field interactions and a negative ΔM plot does not provide any indication of the presence of mean interaction field. Consequently, for a separate identification of different types of interactions one has to address other experimental methods and we address here the possibility of using the λ plots [3] in the characterisation of interactions in magnetic recording media.

2. The λ plots

The two AC processes relating to this study were the AC demagnetisation process (ACD) and AC remagnetisation process (ACR) curves. A typical pair of curves is shown in Fig. 1 and is referred to as λ plot.

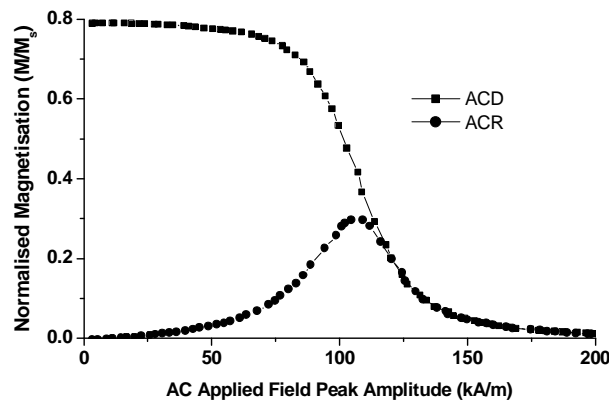


Fig. 1. The λ plot for a metal particle video tape sample.

The ACD was achieved by applying an AC field to an initially DC saturated sample. The AC field was reduced to zero and the remanence measured. A plot of magnetisation against peak AC applied field is the ACD curve. The ACR was obtained by applying an AC field to an initially DC demagnetised sample i.e. saturated, then subject to a field $-H_r$, which was then removed to give zero magnetisation. The application of an AC demagnetising field has the effect of randomising the magnetic moments with switching fields up to the peak AC applied field. The ACR curve presents a peak near the remanence coercivity H_r . This is explained by the fact that AC fields with peak amplitudes up to H_r address the same magnetic moments which were switched in the negative direction when the DC demagnetised state of the system was obtained.

The ACD magnetisation process starts from the saturated magnetic state of the system. Using the Everett integral, the normalised saturation magnetic moment may be written as:

$$m_{rs} = 1 - 2e(H_m, 0) \quad (1)$$

Following the calculus of the magnetic moment on the ACD process when applying the demagnetising field H_{ac} , one may write:

$$m_{ACD} = m_{rs} + e(H_{ac}, -H_{ac}) - 2e(H_m, -H_{ac}) + 2e(H_m, 0) \quad (2)$$

The ACR curve starts from the DC demagnetised state. When applying an AC demagnetising field of initial amplitude H_{ac} to the DC demagnetised state, a positive magnetic moment of the system will be obtained in the balance of the positive and negative zones indicated in the Preisach plane.

The magnetic moment on the ACR could be calculated as follows:

$$\begin{aligned} m_{ACR} &= 2e(H_{ac}, -H_r) - 2e(0, -H_r) - e(H_{ac}, -H_{ac}), \text{ for } H_{ac} < H_r \\ m_{ACR} &= m_{rs} + e(H_{ac}, -H_{ac}) - 2e(H_m, -H_{ac}) + 2e(H_m, 0), \text{ for } H_{ac} > H_r \end{aligned} \quad (3)$$

The equations above are valid for a system carrying statistical interactions and no mean field interactions.

3. Non-interactional systems

If one assumes a system with no interactions, then, using (2) and (3) and the fact that all particles are on the second bisector of the Preisach plane, one may write:

$$\begin{aligned} m_{ACR}(H) &= m_{IRM}(H), \quad m_{ACD}(H) = m_{IRM}(H) + m_{DCD}(H) \quad H < H_r \\ m_{ACR}(H) &= m_{rs} - m_{IRM}(H), \quad m_{ACD}(H) = m_{IRM}(H) + m_{DCD}(H) \quad H > H_r \end{aligned} \quad (4)$$

In the formulas above we have ignored time dependent effects as well and we have used equivalent processes which address the same magnetic moments considering static measurements.

Using (4) one may write the sum (S) and the difference (D) of the ACD and ACR curves:

$$\begin{aligned} S &= m_{rs}, \quad D = m_{rs} - 2m_{IRM}(H) = m_{DCD}(H) \quad H < H_r \\ S &= 2m_{rs} - 2m_{IRM}(H) = m_{rs} + m_{DCD}(H), \quad D = 0 \quad H > H_r \end{aligned} \quad (5)$$

Fig. 2 shows the ACR, ACD, DCD and IRM magnetisation processes for a non interacting particulate system simulated with the Generalised Preisach Model [4].

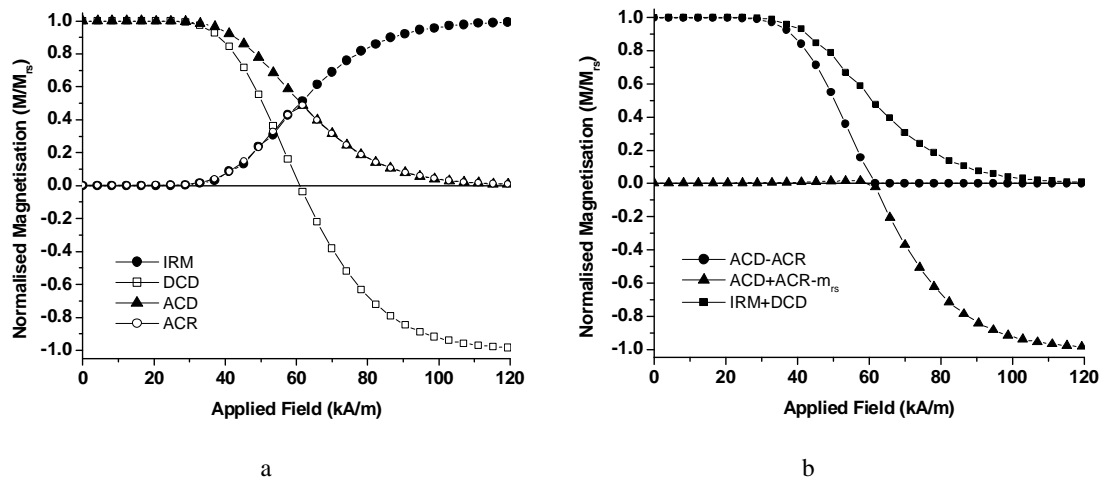


Fig. 2. Simulated AC and DC remanent magnetisation processes for a particulate non-interactive system.

One may see from (4) and (5) that, for a noninteracting system, the ACR process is equivalent to the IRM process up to the remanence coercivity where it has a peak value equal to half of the remanent saturation magnetisation. Up to H_r the sum of ACR and ACD processes is not depending on the field and is equal to the remanence saturation.

The difference between the ACD and ACR processes is equivalent to the DCD process in this case. For values of the applied field higher than H_r the magnetic moments on the two processes have the same value and their sum may be calculated using the DCD process. At H_r the ACR process has a peak and then both ACR and DCD processes take the same value for any value of the applied field. One may also notice that the ACD curve is given by the sum of the IRM and DCD processes.

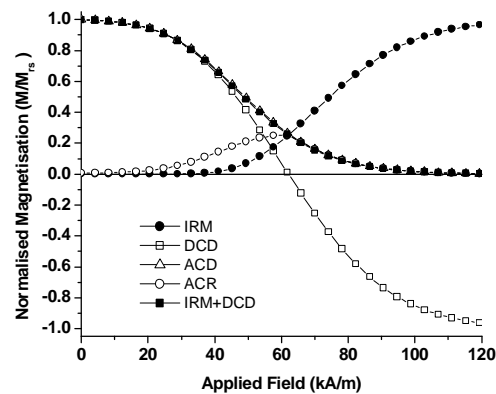


Fig. 3. Simulated AC and DC remanent magnetisation processes for a particulate system with statistical interactions.

4. Systems with statistical interactions

Let us now consider a system with statistical interactions but no mean field interactions. The ACD and the ACR processes may be described by equations (2) and (3). Fig. 3 shows the ACR, ACD, IRM and DCD magnetisation processes simulated with the Generalised Preisach model. As one may

see in Fig. 3, there are important changes in the shape of the AC and DC magnetisation processes with respect to the non-interactive case.

However, there are several features which did not vary when statistical interactions were considered in the system. One may notice that the ACD curve may still be obtained as the sum of the IRM and the DCD magnetisation processes:

$$m_{ACD}(H) = m_{IRM}(H) + m_{DCD}(H) \quad (6)$$

Moreover, the values on the ACR, ACD and IRM corresponding to the remanent coercive field of the system are the same and the ACR and ACD processes are identical for values of the applied field higher than the coercive field. Up to H_r , the values of the ACR curve are higher than the corresponding values on the IRM process.

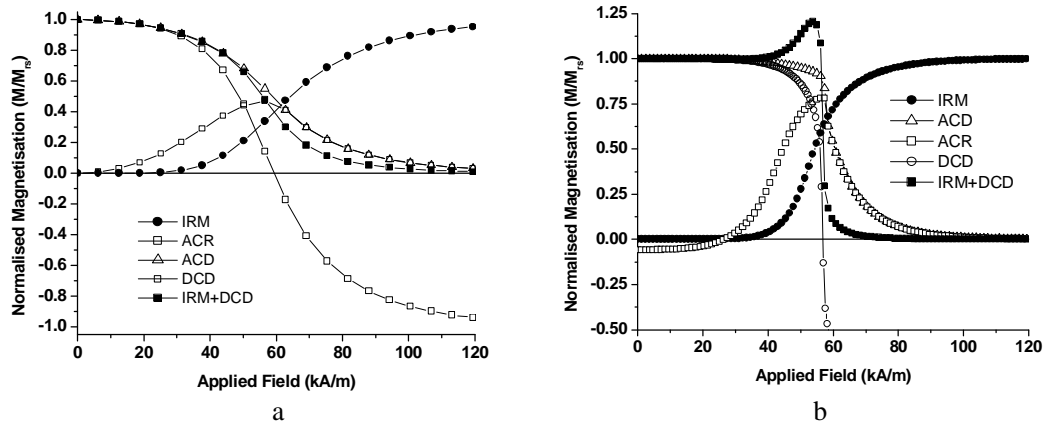


Fig. 4. Simulated AC and DC magnetisation process for a particulate system with statistical and mean field interactions (a. $\alpha = 0.2$, b. $\alpha = 0.5$).

5. Statistical and mean field interactions

If one considers a system with both statistical and mean field interactions, then one observes (Fig. 5) that the ACD curve is above the sum of the IRM and DCD processes and that the peak of the ACR magnetisation process corresponds to a higher value of magnetisation. Fig. 5 a presents the related AC and DC remanent curves for a metal particle MP magnetic recording media. Fig. 5 b presents the related AC and DC remanent curves for an oriented BaFe particulate media.

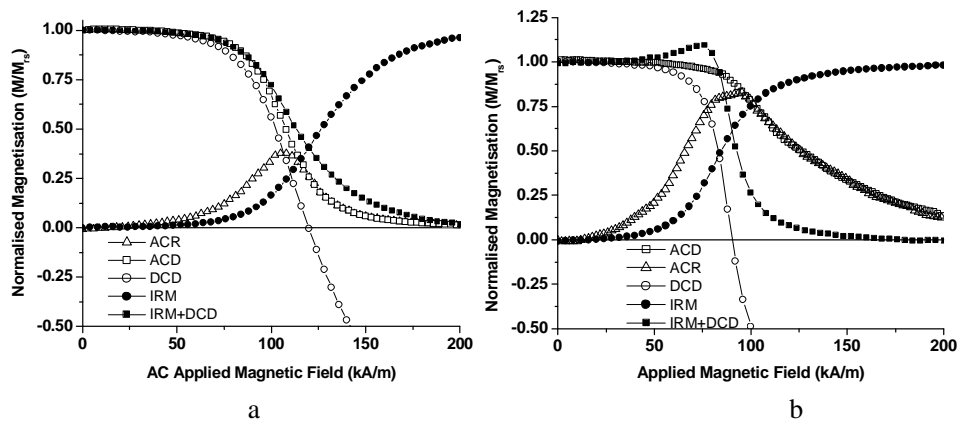


Fig. 5. (a) Magnetisation processes for an MP particulate media (b) Magnetisation processes for an oriented BaFe particulate media.

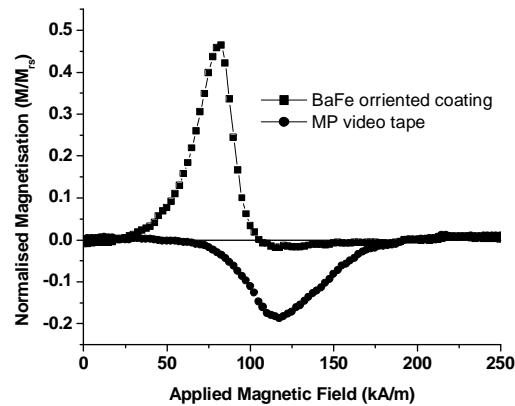


Fig. 6. The ΔM plot for the oriented BaFe and the MP samples.

One may see (Fig. 5 a) that the MP sample is a recording media with statistical interactions and low mean field interactions. The ACD curve is below the sum of the IRM and DCD processes indicating the presence of mean field interactions.

The BaFe sample (Fig. 5 b) presents powerful mean field interactions consistent with a clearly positive ΔM plot (Fig. 6).

We can summarise the results as follows:

- For the non-interactional system the ACD curve is the sum of IRM and DCD; the ACR curve is identical with IRM up to H_r and identical with ACD for fields higher than H_r .
- For a system with statistical interactions, the ACR curve is above the IRM curve up to H_r but the ACD curve is still given by the sum of the DCD and IRM;
- For a particulate system with both statistical and mean field interactions, the ACR curve is above the IRM curve and the ACD curve is above the curve describing the sum of the IRM and the DCD processes.

6. Conclusions

We found that the λ plots are sensitive to both statistical and mean field interactions and they can be used to separately identify the mean field and statistical interactions in particulate magnetic media. Thus, for low mean field interactions where the ΔM is negative and gives no indication on the mean interaction field, the λ plots have a distinct behaviour.

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