Robust Experimental Characterization Of Recording Media

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Abstract-In order to accurately measure the hysteresis parameters of recording media, it is necessary to control the operative field, \( h = H + \alpha M \), rather than the customary method of controlling the applied field, \( H \). An automated iterative algorithm was implemented and tested that sets any prescribed value of \( h \) while ensuring that this target field is approached monotonically. The method was implemented on a DMS Vibrating Sample Magnetometer and experimentally tested on a commercial \( \gamma \)-Fe\(_2\)O\(_3\) recording sample. The experimental results show that the new method gives substantially different minor loops than could be used to automatically measure a recently proposed set of hysteresis parameters for recording media.

I. INTRODUCTION

Using statistical analysis, recently developed models based on the moving Preisach model can give physical insight into the magnetizing processes of a large number of interacting “particles” [1]. An analysis of the statistics of the interaction field [2] for thick film recording media has shown that the distribution of the interaction field is Gaussian. Furthermore, its standard deviation is constant but its average value is directly proportional to the magnetization. Thus, an operative (mean) field, \( h \) can be defined, which is equal to the applied field, \( H \), plus \( \alpha M \), where \( \alpha \) is the material dependent moving constant and \( M \) is the total magnetization. It was also shown that the interaction field distribution in longitudinal media is Gaussian with a mean proportional to the magnetization [2]. In case of perpendicular media, both the mean and the standard deviation of the interaction field are dependent on the magnetization. Using hysteresis models based on the moving Preisach model, an alternate set of hysteresis parameters has been proposed for recording media [3]. Using this set of standard measurements, recording media can be accurately characterized and interaction-related parameters, such as Henkel plots and anhysteretic magnetization curves can be correctly explained.

In traditional measurement techniques, performed using a Vibrating Sample Magnetometer (VSM), the external magnetic field, \( H \), is applied and the resulting magnetization, \( M \), is measured. However, since the media is exposed to the operative field, \( h = H + \alpha M \), rather than \( H \), one needs to control \( h \) to accurately measure hysteresis parameters other than \( M_S \) and \( H_C \).

A modified, automated, experimental technique for analyzing recording media has been developed and validated on a \( \gamma \)-Fe\(_2\)O\(_3\) recording sample using a DMS VSM. The expected value of the interaction field is proportional to the magnetization; therefore, the operative field, \( h = H + \alpha M \) has to be controlled during any measurement, rather than the applied field \( H \), as is customary. The moving parameter, \( \alpha \), is automatically determined from the major hysteresis and remanence loops [5]. Using \( \alpha \) the required value of \( h \) can be ‘applied’ using our asymptotic iterative measurement process.

The proposed measurement framework provides a new method of analyzing media. The correlation between the parameters provided by this framework and recording performance is much more reliable than that provided by “traditional” recording industry parameters, such as \( M_S \), \( S \), \( S^* \), SFD and \( H_C \) [3]. The interaction field calculations also provide the basis for variable variance models for perpendicular media.

II. EXPERIMENTAL ANALYSIS

A. The Identification of the Moving Parameter, \( \alpha \)

In order to apply the operative field, \( h \), the major loop and the major remanence loop are first measured at identical field points using a DMS VSM. This ensures, that, when identifying the moving parameter, \( \alpha \), no data interpolation is necessary. The identification of \( \alpha \) is based on symmetrizing the measured major remanence curve. A major remanence curve was measured for a \( \gamma \)-Fe\(_2\)O\(_3\) sample, as shown in Fig. 1. The lower half of the curve is reflected about \( H_r \), which is indicated by the dashed line. The reflected curve lies above the upper half of the curve, indicated by the solid line. The area enclosed between the two curves is \( 4 \times 10^{-2} \) Oe emu.

Using the corresponding magnetization values of the major loop, the applied field axis of the remanence curve was translated into the operative field axis, \( h = H + \alpha M \), by iteratively searching for the value of \( \alpha \) that minimizes the area between the lower curve and the upper curve, as shown in Fig. 1. The details of this identification technique can be found in ref [5]. Using this automated search technique, the moving parameter for this recording sample was found to be 79350 Oe/emu. To indicate the accuracy of the technique, the operative remanence curve is shown in Fig. 2. It is seen that the operative remanence curve is symmetrical, as predicted by the identification technique. Using the optimum value of \( \alpha \) the area between the two curves is \( 1.6 \times 10^{-6} \) Oe emu, which is four
orders of magnitude less than that of the customary remanence curve.

B. Operative Minor Loop Measurements

Using a computer controlled DMS Vibrating Sample Magnetometer an automated data acquisition technique was implemented that uses operative field measurements. This magnetometer uses an applied field setting method that always approaches the target field asymptotically with an accuracy better than 1 Oe and measures the magnetization when the target field has become stationary.

The operative field setting algorithm is software controlled and relies on the accurate field setting method of the VSM. The algorithm first measures the moving parameter as described above. Using this value of $\alpha$, any desired value of $h = H + \alpha M$ can be set without overshoot. Using the measured values of $H$ and $M$, respectively, the algorithm determines the next value of $H$ at which $M$ is measured. Taking this data, the interim value of $h$ is computed to determine the next value of $H$ to apply. The algorithm ensures that the target value of $h$ is never overshot. In order to accomplish this, 5 to 30 interim points, depending on the field step size, are measured for every value of $h$ that is recorded. In order to validate the algorithm, various operative field minor loops were automatically measured. All measurements started at negative saturation. First, a symmetrical operative field minor loop measurement was performed. The field extrema were chosen to be $\pm 1320$ Oe, which is exactly the operative remanent coercivity, $h_r = H_r + \alpha M_H$, of this sample. As shown in Fig. 3, it is seen that the operative field minor loops are monotonic between the field extrema, indicating that the algorithm does indeed work as prescribed. It is also seen that, while the minor loops are symmetrical in the operative field, $h$, the customary minor loops, indicated by the dashed lines, are asymmetrical with respect to the $H = 0$ axis. It is also seen that both minor loops accommodate towards a stable minor loop. This type of
symmetrical operative field measurement can be used to identify the accommodation parameter of a physically derived accommodation model [7] and warrants further study in the future.

In another measurement, shown in Fig. 4, the lower and upper operative field reversals were -1600 Oe and +700 Oe, respectively. Since the coercivity of the sample is approximately 650 Oe, it is seen that the operative and the customary set of minor loops coincide at this point since the magnetization is zero. The lower reversal points are different since at these points the magnetization is nonzero.

![Operative Field Minor Loop](image)

Fig. 4. Asymmetrical operative field minor loop measurement. The upper reversal point is \( H_+ = h_+ = 700 \) Oe and the lower on is \( h_- = -1300 \) Oe.

### III. Conclusions

In order to accurately measure the hysteresis parameters of recording media, it is necessary to control the operative field, \( h \), rather than the customary method of controlling the applied field, \( H \). An automated algorithm was implemented so that any prescribed value of \( h \) can be applied while ensuring that the target field is approached monotonically. The method was implemented on a DMS Vibrating Sample Magnetometer and experimentally tested on a commercial \( \gamma \)-Fe\(_2\)O\(_3\) recording sample. Two types of minor loop cycling measurements were performed. The experimental results show that the new method gives substantially different minor loops from the corresponding customary measurement technique. In our future research the proposed technique will be used to automatically measure the moving Preisach parameters of recording media on a VSM. This would make it possible to characterize the recording performance of the media using only VSM-based measurements which could greatly improve the design cycle of future recording materials.

### References


