RECORDING HEAD FIELD MEASUREMENT WITH A MAGNETORESISTIVE TRANSDUCER

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ABSTRACT

This paper describes the measurement of recording head fields with the help of a magnetoresistive transducer. Attention is payed to the computer program to simulate the transducer behaviour in inhomogeneous fields (with emphasis on the accuracy) and to the experimental procedure to overcome the difficulties of positioning the transducer in the head gap region accurately.

Results of measurements on two audio heads with gaplength 3.3μm and 7μm are analysed and show a reasonable agreement with the theoretical predictions.

INTRODUCTION

In treatments of the magnetic recording write and read process assumptions are mostly needed about the form and magnitude of the head fields. Head field calculations are known since long and can be carried out in considerable detail (including pole-tip saturation effects, side fringing fields and so on). In the calculations assumptions are made, in turn, about the geometrical and material structure of the head in the vicinity of the gap. In spite of the plausibility of those assumptions one must admit that they are based on a "macroscopic" view and that one can not be sure of the results for heads, with gap length of the order of micrometers, until they are affirmed experimentally. And the fact is that the scarcely published direct experimental evidence is not very convincingly pointing into that direction[1].

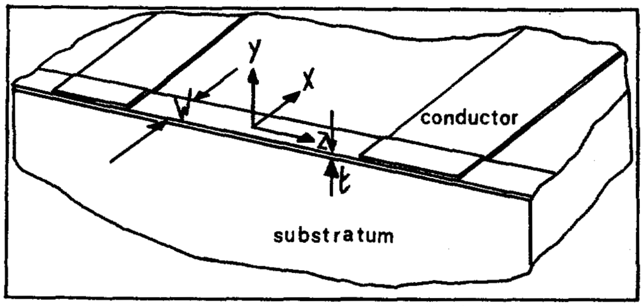

Fig. 1: Magnetoresistive transducer, situated at the edge of a glass substratum. Details concerning geometry and method of production are in ref. 3.

We have therefore tried to obtain additional information about the experimental head fields and have employed the magnetoresistive transducer, proposed by Hunt[2], for this purpose. Such transducers can be produced[3] to have a small width (w, see fig. 1), of the same order as the gaplength 2g of the heads to be measured. But then it is still a problem that the resolving power of the transducer is relatively low. This can be compensated for by gathering a large number of data by shifting the position of the transducer over distances much smaller than w. And this, in turn, attracts the attention to a second problem: the accurate positioning of the transducer with respect to the head gap region. These problems are discussed in the next sections with, in the end, a report of measurements on ferrite heads with gaplengths of 3.3μm and 7μm respectively.

COMPUTER SIMULATION

To make possible an interpretation of results obtained with a detector that may be large compared to the head field gradients, one must be able at least to deduce the detector output from a field contour that is known. The relation which must be obeyed by an applied (inhomogeneous) magnetic field $H_a(x)$ directed along the x-axis (see fig. 1) and the x-component of magnetization $M_x(x)$ resulting from that field reads:

$$H(x) = H_a(x) + \int_{-w/2}^{w/2} \frac{1}{\pi} \frac{dM_x(H(x_0))}{dx_0} \operatorname{arctg} \frac{t}{2(x_0-x)} \, dx_0 \quad (1)$$

The second term on the right hand side is the demagnetizing field in the transducer, generated by the magnetic charge density dM/dx_0 (including possible edge charges at $x = \pm w/2$). $H(x)$ is the local field pointing in the x-direction and $M_x(H(x_0))$ is the consecutive relation which is locally valid between the field and the resulting magnetization. This relation is derived from the well known single domain model applicable for the material ($Ni_{80}Fe_{20}$) and geometry. Discretization of (1) is obtained by a division of the transducer in substrips (31 in our case), so that we arrive at a vector equation $\vec{H} = \vec{H}_a + \vec{\vec{A}}.\vec{M}(\vec{H})$ or:

$$\vec{G}(\vec{H}) \equiv \vec{\vec{A}}.\vec{M}(\vec{H}) + \vec{H}_a - \vec{H} = \vec{0} \quad (2)$$

These are vectors in the 31 dimensional space defined by the number of substrips. Each component gives the magnitude of the field or the magnetization in the relevant substrip. $\vec{G}=\vec{0}$ is solved by employing the Newton-Raphson approximation leading to the iteration:

$$D\vec{\vec{G}}^{(k)} * (\vec{H}^{(k+1)} - \vec{H}^{(k)}) = - G(\vec{H}^{(k)}) \quad (3)$$

where $D\vec{\vec{G}}^{(k)}$ is the Jacobian of $\vec{\vec{G}}$ with elements $\partial G_i/\partial H_j$ and the superscript k the number of the iteration step. The details of the procedure are analogous to those of the computation of fluxreversals in a recording medium and are described elsewhere[4].

The accuracy of the computer simulation has been determined by comparing results of computations in some cases where an analytical solution is also present (homogenous and exponential fields). In figure 2 the dashed curve is the analytical solution and the crosses

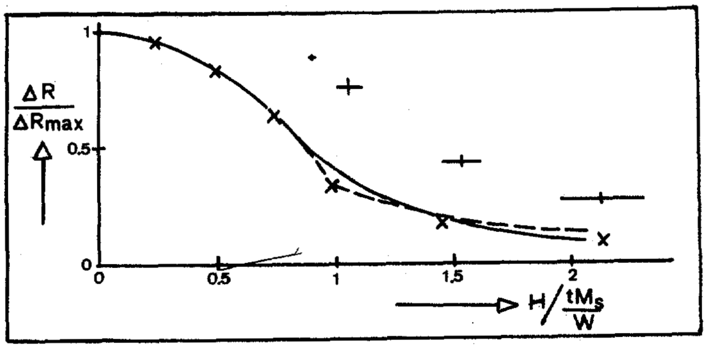

Fig. 2: Normalized transducer resistance as a function of normalized applied field (homogeneous). Experimental curve (drawn) is compared with result of computer simulation (X) and analytical results (- -). Errorbars, positioned with respect to the abscissa, indicate estimated errors.

Manuscript received March 14, 1978.

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0018-9464/78/0900-0433$00.75 ©1978 IEEE

represent computed results (homogeneous fields with $H_k << tM_s/w$, H_k is the constant of uniaxial anisotropy of the material).

Besides the error as a consequence of the approximations in solving eq. (1) there is some disagreement between theory and experiment. The drawn curve in fig. 2 is the response to homogeneous fields of the transducer used in the experiment described in the next sections. This deviation from theory is characteristic for all other transducers we have measured. The total error is given by the errorbars in fig. 2. In the measurements of the head fields we have avoided saturation of the transducer so we expect that head fields, derived from measurement, are correct within, say, 5%.

For greater security we have also carried out a test in the inhomogeneous field of a large gapped (180µm) erase head.

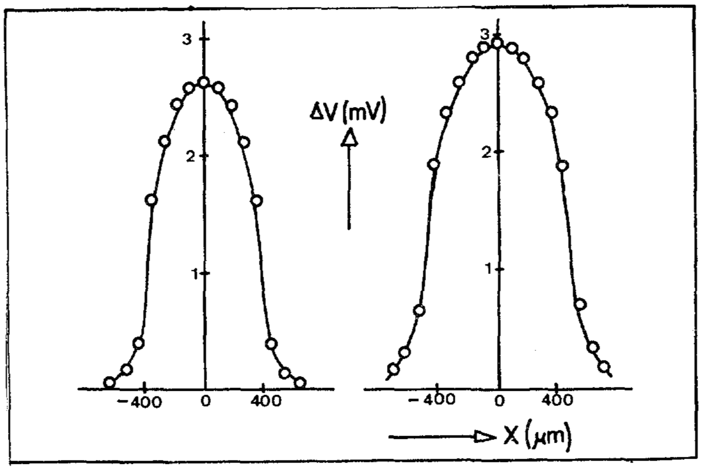

Fig. 3.: Test of computer simulation (circles) in inhomogeneous fields of 180µm gapped head (two drive currents). Drawn are outputs of 550µm wide transducer.

With a 3.1µm wide transducer the head field component parallel to the head surface was measured at a level of 50µm. Since the width of this transducer is small compared to the length of the head gap in this case, it is allowed to derive the magnitude of the magnetic field directly from the calibration curve of fig. 2. This field was used then to compute the response of a 550µm wide transducer and these results were compared with results which were actually measured with a 550µm wide transducer. Figure 3 demonstrates the close agreement between the computed and the measured transducer outputs.

EXPERIMENTAL PROCEDURE

The experimental problem is to position the transducer in the head gap region accurately. The transducer substratum is mounted on the moving part of a Talytron S90 (an air-bearing traversing table designed to carry out straightness checks), and a very well defined movement of the transducer underneath the head can be generated (see fig. 4). The recording head is sucked onto a reference plane, so that the head is fixed properly but can easily be slipped up and down. At the start of an experiment the transducer-substratum is forced into contact with the head by lifting the substratum (mechanically) until one can see the head move upwards. Then the apparatus is left in this position for some time to restore thermal equilibrium (which may be disturbed). After that, one cannot be sure that the contact between head and substratum still exists. Therefore the substratum is lifted again, but now remotely controlled by increasing the air-pressure of the table bearing. It is a happy coincidence that the level of the table can be controlled very accurately in this way over a range of several micrometers. So the contact between head and transducer is warranted and immediately after that, the table is lowered again over a precisely known distance. Then the horizontal table motion is started and a head-field-contour is measured and displayed on an X-Y recorder. Measurements are repeated then after varying the head/substratum separation y. The reproducibility with respect to y, established in this way, is very good i.e. if a head/substratum separation is repeated after some other measurements the results reproduce within experimental error.

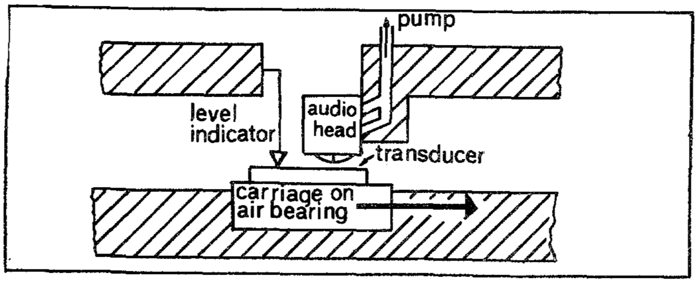

Fig. 4: Scheme of experiment.

The crucial point, however, is that one does not know the "zero-separation" i.e. the separation between head and substratum at the start when it is believed that there is contact. In the experiments described here the "zero-separation" did not reproduce but this can be overcome by repeating complete experiments, including the contact adjustment. In the next section it is described how the unknown "zero-separation" is eliminated in the interpretation of the results. It is our experience that the error in the "zero" of an isolated experiment may be several micrometers.

It is clear that the procedure described here confines the experiments to the measurement of the head field component parallel to the head surface.

RESULTS AND CONCLUSIONS

Figure 5 shows characteristic results of measurement on two audio heads (with gaplength 7µm and 3.3µm respectively) taken with the transducer of figure 2.

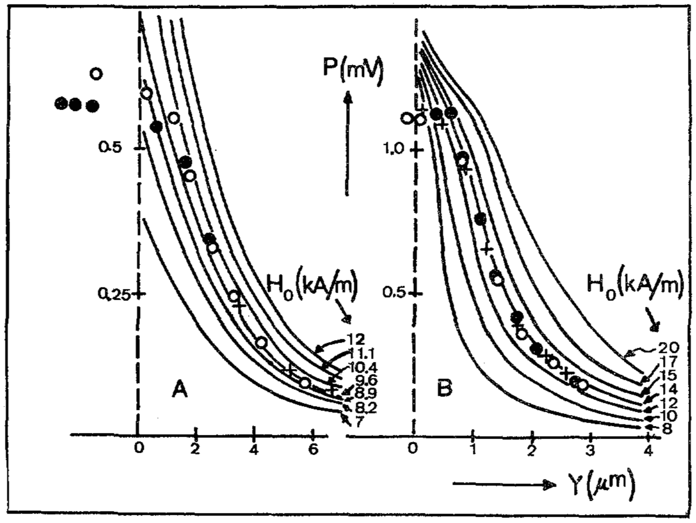

Fig. 6: Output of transducer located in front of gap taken in three separate measurements (•,o,+) Drawn curves are calculated with H_0 as a parameter.
A. Head gap 7µm B. Head gap 3.3µm

The detector output curves can be analysed by studying

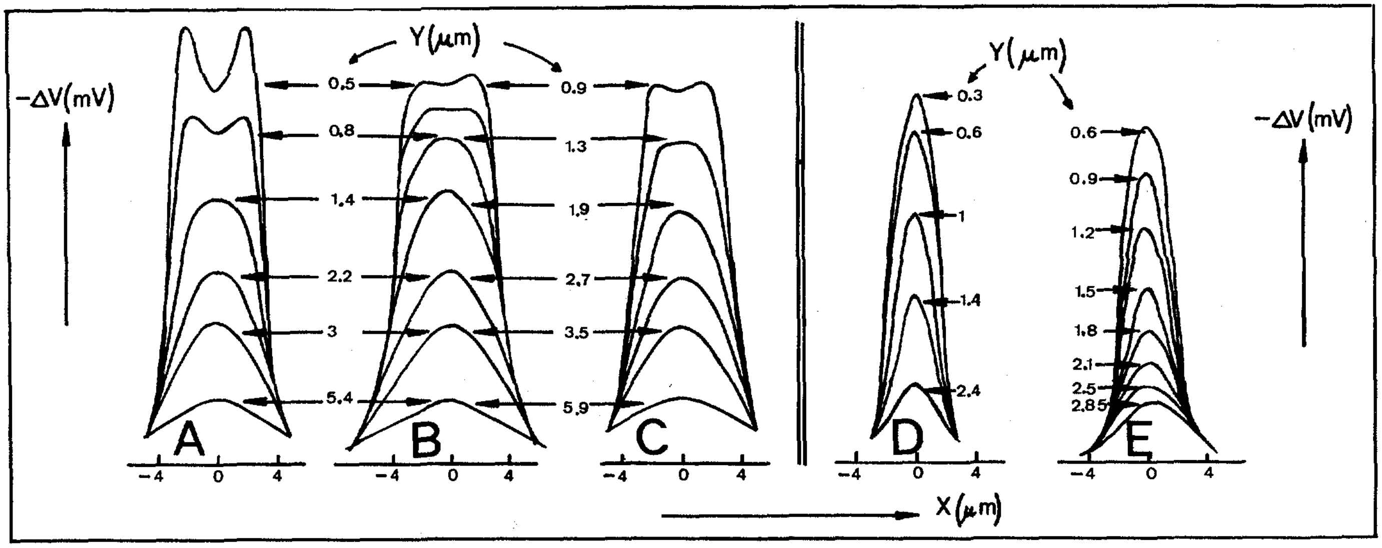

Fig. 5: Transducer output curves fitted to calculated results. B and E are experimental results for the 7μm and the 3.3μm head gap respectively. A and C are fits to B with H_0 = 9.600A/m and 10.400A/m respectively D is fit to E at H_0 = 14.000A/m

its value P at the centre of the curves, since P depends strongly on the head/transducer separation y. This is shown in figure 6 where results are given for three separate and independent measurements. The "zero separation" is unknown and probably different for each of these measurements, so the results are shifted along the y-axis until they overlap and the fact that this is possible shows that the reproducibility with respect to increments of y is good indeed. It is seen that the P values remain constant at the left hand side of the curves where the head/transducer separation obviously did not change any more on increasing the pressure of the table and lifting the transducer.

The drawn curves in figure 6 are computed with the simulation program. The deep gap field H_0 is a parameter which is unknown in the experiment so we have computed P(y) for several values of H_0. These computations are based on the theoretical head field expressions known for an ideal head, i.e. a head with very well defined magnetic mirror planes[5]. In the computations, we have taken account of the effect of the mirror charges which are generated in the head by the magnetized transducer. Omission of this effect may lead to wrong results (10% in the case we have checked). So the matrix $\bar{A}$ in formula (2) has not been derived from the simple expression (1), but has been computed including the effect of the mirror planes. It is seen from figure 6 that a good fit of experimental to computed results is possible when H_0 is chosen properly. From this fit the head/transducer separation is derived for all experimental points and then the full head field curves are computed in order to be able to compare the overall characteristics.

In the case of the 7μm gap the agreement between the experimental and the computed results proved to be rather sensitive on the exact choice of H_0. However, H_0 can only be determined within certain limits, so we have computed head field curves for two values of H_0 (which may be seen as limiting cases). The overall agreement favours the choice of H_0 = 10.400A/m. Unfortunately this analysis cannot be applied to the results of the 3.3μm gap field because the typical peakstructures at the gap edges are completely smoothed out by the width of the detector in all cases.

A close look at the width of the curves reveals some deviations between theory and experiment. Thanks to the steepness of the flanks in the head field curves, the width, defined by the coordinates where the transducer output is ½P, for example, can be determined rather accurately and seems to exceed the theoretically derived values systematically by an amount of about 0.4μm. The influence of such a deviation is of importance of course in cases where the gaplength is in the order of 1μm. However, 0.4μm is close to our experimental error so that a detailed analysis of this deviation is not justified at this moment. More accurate results are needed for this purpose and this is the next step in our research program.

The drive currents used are small not only to prevent transducer saturation but also to prevent pole tip saturation. On the basis of theoretical predictions taken from literature we do not expect such an effect and this has been confirmed by measurements of head field curves taken with other drive current values. No influence on the width has been detected.

Our conclusion is that apart from a probable deviation in the width of the head field curves the overall agreement between theory and experiment is not as large as expected from indications published in the literature[1].

AKCNOWLEDGMENTS

Many ideas in the original design of the equipment are from Ing. J. Veldkamp and Ir. A. van Herk. Tests and preliminary measurements were perfomed by students working with our group (J.C.M. Henneman, J. Marchal, B. Elzen, H. Meershoek, F.D. Oppersma). The transducers were produced by B. Hurenkamp and H.W. Krabbe. Technical assistance was given by A. Hollink but almost all coworkers of our group and many of the technical staff are involved incidentally in this project.

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