LARGE-SCALE MODEL STUDY ON THE HEAD MEDIUM INTERFACE OF PERPENDICULAR MAGNETIC RECORDING

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[Abstract] A large-scale experimental model of the pole-head and double layer medium combination of perpendicular magnetic recording is developed. The characteristics of the recording field with different head medium interface parameters are studied. A comparison of the field characteristics between one sided and two sided pole head design is also presented.

INTRODUCTION

Theoretical and experimental studies [1] [2] [3] show that the perpendicular magnetic recording technology has an extra high density potential for information storage. Studies [4] also prove that the combination of pole head and double layer medium is the best way at present to realize this potential.

Compared with other head-medium combinations, such as those in longitudinal recording and some quasi-perpendicular magnetic recording system with a single layer medium, the head-medium interaction with a double layer medium is much stronger and of greater importance to the read/write performance. Furthermore the recording field (both amplitude and distribution) is also strongly affected by the head structure design and head medium parameter selection in the combination. To get a better head medium interface design, a further understanding of the special features of this combination are important.

In this paper an effort has been made to conduct an experimental study of the recording field characteristics of such a head-medium combination. As normally the pole length of a pole head is very small (0.15 ~ 1.0 µm), a direct measurement of the head field is difficult. So an large-scale model experimental system is developed and used. With this large-scale model, the effect on the recording field of recording layer thickness and head structure design (both one sided and two sided pole head structures) are studied. To get a better understanding of the demagnetization effect of the auxiliary pole of the single sided pole head, the field characteristics under the auxiliary pole are also studied. Some interesting results, such as the field variation with the increase of recording layer thickness and the comparison of the characteristics of half width of the field distribution between one sided and two sided head design are presented.

LARGE-SCALE MODEL AND EXPERIMENTAL SYSTEM

Depending on the relative location of the main pole and auxiliary pole to the recording medium, the pole head structure of perpendicular magnetic recording can be divided into two classes: the one sided structure and the two sided structure. For the former, the main and auxiliary poles are located at the same side of the medium [5][6], whilst for the latter, the main pole and auxiliary pole are at opposite sides of the medium [7]. Compared with the longitudinal recording head, one of the most noticeable features of the pole head
is the non-closure of its magnetic circuit. For that reason its magnetic efficiency (both reading and writing) would be greatly reduced if no other method were introduced to improve matters. At present, the most common and successful method is to use the double layer medium \[8\], of which the top layer is the normal recording layer and the bottom layer is a soft magnetic layer providing an easy path for the head magnetic flux.

The large-scale model experimental system developed consists of 3 main parts: the head-medium system including the main pole, the auxiliary pole and the soft magnetic underlayer; the magnetic sensor and field measuring system measuring the vertical component of recording field; the sensor positioning and pole-underlayer distance controlling system. Fig.1 is a schematic illustration of the large-scale model system for a two-sided pole head. The magnetic medium and the auxiliary pole are kept still during all of the experiments while the position of the main pole and the vertical magnetic field sensor are adjustable. By controlling the position of the main pole along the Y direction (that is, upward or downward), the distance between the main pole and the underlayer is adjusted. For a given distance of main pole to the underlayer, the field variation is measured by scanning the vertical field sensor (a Hall-effect probe) from one end to the other.

The material used to represent the underlayer, main pole and auxiliary pole are the same: electrical pure iron after heat treatment. As the permeability of the recording layer is much smaller than that of the main pole, underlayer and the auxiliary pole, the permeability of the recording layer is not taken into account. The ratio of the size of a real recording system and the large-scale model is about 1:7000. The error of the position system is less than 0.04 mm and is enough for the accuracy requirements of the study.

**EXPERIMENTS AND RESULT ANALYSIS**

1. **RECORDING LAYER THICKNESS AND RECORDING FIELD VARIATION**

Experiments have shown that the read/write performance of perpendicular magnetic recording is very sensitive to the head-medium distance \[8\]. As the head-medium distance is increased, the S/N ratio will decrease rapidly. So at present the most successful application of perpendicular magnetic recording is in the case of "contact recording", such as is the case for magnetic tape and floppy disk.

Though the following experiments described are mainly for the contact recording, the conclusions obtained are still applicable to the non-contact recording situations. For the contact recording, the head-medium distance is much smaller than the medium thickness. So the distance between the main pole and underlayer is considered as equal to the recording layer thickness in our analysis.

Experimental results of the relationship between medium thickness and recording head field distribution are presented in Fig.2 together with the head structure to be discussed. To make results obtained comparable, the distance of the field sensor to the main pole are kept the same during the variation of medium thickness. To get a further comparison of the field characteristics at different medium thicknesses, the field amplitude variation as the medium thickness varies and the characteristics of the amplitude normalized field are studied. The measured field variations are presented in Fig.3.
and Fig. 4.

The results show that:
1) As the medium thickness is increased, the amplitude of the recording field increases more and more rapidly.
2) Though there is some difference in the pattern of field variation at different medium thicknesses, the main difference happens in the area under the main pole. The main characteristic is whether it has a "two peak" field variation and how obvious the "two peak" phenomenon becomes.
3) For a smaller medium thickness, the field is more likely to be of the form of "one peak". As the medium thickness increases, it changes into a "two peak" pattern.
4) Though the field amplitude might be greatly different at different medium thicknesses, the difference among the normalized fields is small, except in the area out of the main pole surface. Such a result suggests that the effect of medium thickness increase is mainly in the reduction of field amplitude. Previously, it was believed that the pole-underlayer distance is of a similar function to that of the gap length of longitudinal recording systems [9], but our results do not completely support that view.

2. FIELD CHARACTERISTICS IN THE CASE OF ONE SIDED POLE

The field variation characteristics have been studied for the same medium thickness and for the one sided pole head structure illustrated in Fig. 2.

1) Recording field
The recording field variation at different distances to the main pole of the recording head have been measured. The results for the one sided head structures are illustrated in Fig. 5. Results show that:
(a) As expected, the closer the sensor to the main pole, the stronger the recording field will be.
(b) The field gradient increases with increase of the distance of the sensor to the main pole, but that increase is not so obvious as had been expected.
(c) The field asymmetry increases with the reduction of distance to the main pole. Though in the other area the field also shows some asymmetry, the main asymmetry happens in the area just under the main pole.

(d) Though the field increases with reduction of the distance to the main pole, the greatest increase happens at the front edge of the recording head. For the trailing edge, that is, the recording edge, the field increment is small.

2) Field under the Auxiliary Pole

Normally the gap between the data sectors is much smaller than the distance between the main pole and the auxiliary pole of the one sided head. So, the field under the auxiliary pole might cause some interference to the recorded data at the end of the next data sector. To get a qualitative understanding of its field amplitude and distribution, a study of the field variation under the auxiliary pole has been made and the results are presented in Fig. 6. For the convenience of comparison, the field is normalized according to the maximum field at a distance to the pole surface of 0.5 mm in the large-scale experimental model.

It can be seen from Fig. 6 that the field has a plain part (that is, with nearly a constant value) under the central part of the auxiliary pole. There is also a peak field in most cases and this peak field always occurs at the outer edge of the pole. The shorter the distance to the auxiliary pole, the stronger the peak field becomes.

It can be seen from the figure that as the distance is decreased, the plain area length increases.

3. FIELD COMPARISON BETWEEN THE ONE SIDED AND TWO SIDED POLE HEAD STRUCTURE

A two sided pole head based on the previous one sided head has been established and studied. Its structure is illustrated at the top right corner of Fig. 7.
Fig. 7. The auxiliary pole of that head is much greater than that of the main pole. The measured field variation of that head is presented in Fig. 7 also. It can be seen from the field variation presented that:

1) The asymmetry of the recording field happens as the distance to the main pole is increased. The stronger peak field occurs at the trailing edge of the pole head. Both of those phenomena are just the reverse of the phenomena of the one sided head discussed previously.

2) The half width of the recording field increases more quickly than that for the one sided case (the half width of field is the distance between two points at which the field is reduced to half of its maximum field). This means that for the two sided case the field would spread more widely with the increasing of the distance to the main pole.

CONCLUSIONS

By the large-scale model study of the recording field of pole head and double layer medium, some useful information for the head-medium system design is obtained:

1) For the head-medium system consisting of a double layer medium and pole head, the recording field will rely on more parameters of the head-medium system than that for longitudinal magnetic recording or perpendicular magnetic recording with just one layer medium. So a comprehensive consideration of the effect of every parameter of the head-medium system is important for a good head-medium interface design.

2) There are some differences in the characteristics of the half width of the recording field between the one sided and two sided recording heads. The half width of two sided head is more sensitive to the distance to the main pole.

3) For the same head medium distance of the one sided head design, though the recording field amplitude decreases as the medium thickness increases, the variation of normalized field is small, especially on its trailing edge.

ACKNOWLEDGMENT

The authors would like to express appreciation to Mr. X.G. Fong, Ms. T.Y. Chen for their help with the experiments.

REFERENCES


