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CHARACTERISTICS OF ASYMMETRIC HEADS

Chia Shen Wang and Huei Li Huang

Physics Dept., National Taiwan Univ., Taipei, Taiwan, ROC

Abstract. Calculations shows that asymmetric ring heads exhibit sharp field gradient for both the $H_x$ and $H_y$ field components at large inclination and low spacings. These characteristics can be exploited to improve bit density in longitudinal and vertical recording, respectively.

Introduction

Theoretical and experimental studies of both longitudinal and vertical modes of magnetic recording all supports the idea that magnetic recording is write field limited and not demagnetization limited [1]. Fundamental limitations to head field gradients give rise to a minimum transition width that is larger than the simple stability-versus-demagnetization limit [2]. For this reason, it is highly desirable to find a magnetic head which has large field gradient in the writing process, and has a narrow field width in the reproducing process. Asymmetric ring head is a prime candidate equipped with the characteristics whereby high bit density recording can be effectively realized.

Head field calculations

The essence of an asymmetric ring head is shown in figure 1. Assuming that the relative permeability of the head core is infinite, we may use Schwartz transformation to map the upper edge of the recording head in the $Z(x,y)$-plane onto the real axis in the complex $W(u,v)$-plane, as shown in figure 2. For a given inclination angle $\theta$, the generalized Schwartz transformation is

$$\frac{dz}{d\omega} = A (\omega + 1 - \beta)^{D-1} (\omega - 1 - \beta)^{1/D} \omega^{-1} \tag{1}$$

where $D$ is related to the inclination angle $\theta$, $\beta$ is related to the coordinate of the head corner in the $\omega$ plane in relation to that in the $Z$-plane, and $A$ is related to the magnification (Shrinkage) of the transformation itself. Through numerical integration and proper boundary conditions the following results are obtained.

$\theta = 90^\circ, \ A = 0.318, \ \beta = 0, \ D = 2$

$\theta = 60^\circ, \ A = 0.328, \ \beta = 0.333, \ D = 3$

$\theta = 45^\circ, \ A = 0.342, \ \beta = 0.5, \ D = 4$

$\theta = 30^\circ, \ A = 0.362, \ \beta = 0.666, \ D = 6$

$\theta = 10^\circ, \ A = 0.425, \ \beta = 0.889, \ D = 18$

For example, the point $d$ at $(0.5, 0)$ in the $Z$-plane is mapped into the point $d'$ in the $W$-plane at $(1, 0)$, $(1.333, 0)$, $(1.5, 0)$, $(1.667, 0)$, and $(1.889, 0)$, respectively, for $\theta = 90^\circ$, $60^\circ$, $45^\circ$, $30^\circ$, and so on. Thus, an one-to-one mapping of any point in the upper half $Z$-plane to a point in the $W$-plane, and vice versa via the inverse mapping can be carried out. If we denote $W$ by $(\gamma, \alpha)$ in the polar coordinate in the $W$-plane then the equipotential lines are $\alpha = \text{const}$. The magnetic potential $\Phi$ at $(\gamma, \alpha)$ is $V_0/\pi$ and

$$\frac{d\Phi(W)}{dW} = \frac{\partial\Phi(\gamma, \alpha)}{\partial\gamma} \frac{\partial W}{\partial\gamma} + \frac{\partial\Phi(\gamma, \alpha)}{\partial\alpha} \frac{\partial W}{\partial\alpha} = -\frac{iV_0}{\pi W}. \tag{2}$$

If the magnetic potential in the $Z$-plane is $\Psi(x,y)$, the magnetic field intensity can be written as

$$H_x = i H_y = -\frac{d\Psi(W)}{dW} \frac{dZ}{dW} = \frac{iV_0}{\pi W} \frac{dZ}{dW} = \frac{iV_0}{\pi A (W + 1 - \beta^{D})} \frac{dZ}{dW} \tag{3}$$

$^{1}$Supported in part by the National Science Council of ROC.
The equipotential lines are crowded near the acute side of the head gap. Consequently, it shows a sharpened X-component field distribution at low spacings. A typical plot of the $H_x$ field distribution at spacing $d = 0.10 \, g$ is shown in figure 3. The $H_y$ component field distribution is relatively flat and broad at moderate spacing. At lower spacing, say $d = 0.05 \, g$, it turns much sharper, as shown in figure 4.

![Fig. 3. $H_z$ field component distribution.](image)

![Fig. 4. $H_y$ field component distribution.](image)

**Longitudinal recording mode**

In longitudinal recording mode, when the medium is traveling from right to left over the asymmetric head, the shape of the left edge of the $H_z$ component field, that is, the field gradient, determines to a great extent the bit density it can achieve. From the curves in figure 3, we obtain the field gradients (in unit of $V_0/g^2$) for different $\theta$ angles:

<table>
<thead>
<tr>
<th>$\theta$ angle</th>
<th>90°</th>
<th>60°</th>
<th>45°</th>
<th>30°</th>
<th>10°</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_z$ gradient</td>
<td>3.2</td>
<td>4.9</td>
<td>5.8</td>
<td>6.5</td>
<td>10.6</td>
</tr>
</tbody>
</table>

It is apparent that the larger the inclination (smaller $\theta$), the greater the field gradient, and the higher the bit density it can achieve. By comparison, the $H_x$ component field of a thin film head [3] of the pole length $P$ equal to the gap width $g$ is not as sharply distributed. In fact, the thin film head $H_z$ field distribution is very similar to that of a conventional ring head ($\theta = 90°$) in the gap region.

**Vertical recording mode**

In vertical recording mode, the $H_y$ component field distribution determines the usefulness of the head. Figure 4 shows that the greatest field gradient occurs at the inner side of the sharp edge of the head. In order to obtain high bit density, we must let the medium travel from left to right. The value of the field gradient is $37.5 \, V_0/g^2$ at $\theta = 10°$, $23.1 \, V_0/g^2$ at $30°$ and $11.5 \, V_0/g^2$ at $45°$. In the recording process, the head triggers the magnetization reversal from one direction to another at a certain $H_y$ value around $H_z$. This $H_y$ value is determined by the magnetic property and preparation procedures of the medium, and has some distribution. Denote the extremum of the positive (negative) portion of the head field by $H_y^+$ ($H_y^-$). The triggering $H_y$ value must be substantially smaller than $H_y^+$, but larger than $H_y^-$ in order to be effective and useful. The coefficient of effectiveness of the head against the variation of the medium property and operation parameters can be represented by $R = (H_y^+ - H_y^-) / (H_y^+ + H_y^-)$. For different $\theta$ angles, the $H_y^+$, $H_y^-$ and $R$ values are as shown below:

<table>
<thead>
<tr>
<th>$\theta$</th>
<th>90°</th>
<th>60°</th>
<th>45°</th>
<th>30°</th>
<th>10°</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_y^+$</td>
<td>0.99</td>
<td>1.20</td>
<td>1.35</td>
<td>1.66</td>
<td>2.14</td>
</tr>
<tr>
<td>$H_y^-$</td>
<td>0.99</td>
<td>0.80</td>
<td>0.70</td>
<td>0.60</td>
<td>1.03</td>
</tr>
<tr>
<td>$R$</td>
<td>0</td>
<td>0.20</td>
<td>0.32</td>
<td>0.47</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Based on the above data the asymmetric head at $\theta \approx 30°$ is quite suitable for vertical recording purpose.

**Conclusions**

We have demonstrated that asymmetric heads with large inclination have better characteristics required for high bit density recording than is possible for symmetric heads.