A HEAT TRANSFER STUDY IN THE HEAD DISK INTERFACE WITH APPLICATION TO HAMR ABS DESIGN

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I. INTRODUCTION

In the hard disk drive (HDD) industry, heat-assisted magnetic recording (HAMR) is being pursued and is expected to help increase the areal density to $\sim 10\mathrm{Tb/in^2}$ in HDDs to fulfill future worldwide data storage demands. In HAMR, the magnetic media is heated locally ($\sim 50 \times 50\mathrm{nm^2}$) and momentarily ($\sim 1\mathrm{ns}$) close to its Curie temperature ($\sim 450°\mathrm{C}$) by a laser energy source that is focused by a near field transducer (NFT). Since the required temperature of the NFT is much lower than the media's Curie temperature, the heat can flow back from the media to the NFT, thereby heating the NFT. Therefore, understanding the heat transfer in the head disk interface (HDI) in the area of the NFT is important.

The embedded contact sensor (ECS) and the thermal fly-height control (TFC) technologies have been developed by the industry over the last several years. The ECS is a temperature sensitive resistor embedded on the slider surface of the head near the read/write transducers, so it can detect head-disk contact. The TFC heater is a metallic resistor embedded in the slider's body somewhat above the read/write transducer. When power is supplied to the heater, it generates heat, which increases the local temperature and causes a local protrusion, thereby adjusting the fly-height. Both the ECS and the TFC heater can be used for the study of the heat transfer in the HDI.

In this paper, we report on a series of experiments and simulations for the heat transfer in the HDI. We show that the design of the air bearing surface (ABS) can significantly affect the pressure distribution in the read/write transducer area, and thereby affect the convective heat transfer coefficient. This can provide insights into the ABS design that can reduce the back heating from the disk to the NFT.

II. EXPERIMENTS

In the experiments, perpendicular magnetic recording (PMR) heads and disks were used. There are two setups. In the first setup, the head flies on the disk rotating at 5400 RPM, which is called the “fly” setup. In the second setup, there is no disk near the head, which is called the “non-fly” setup. In both setups, we increase the power of the TFC heater and monitor the resistance change of both the ECS and the TFC heater. The TFC power is increased until touch-down is reached in the fly setup or to 30mW in the non-fly setup.

Since both the ECS and the TFC heaters are metallic resistors, their resistances increase as their temperatures increase. The relationship is approximately linear in the range of interest, expressed as

$$\Delta T = \frac{1}{\alpha R_0}\Delta R, \qquad (1)$$

where ΔR is resistance change, α is the temperature coefficient of resistivity, ΔT is the temperature increase and R_0 is the resistance at the room temperature. We can then compare the temperature change of the same element in the different scenarios by comparing the resistance change.

The results of the experiments are shown in Fig. 1. Fig. 1(a) shows the resistance increase of the ECS and the TFC heater in both the fly and non-fly setups. While all four curves appear to be almost linear, it is not the case for the ECS in the fly setup. The temperature increase is greater in the non-fly setup than in the fly setup for both elements.

The reason for the different temperature increase rates is the different heat transfer coefficients at the slider's air bearing surface (ABS) in the fly and non-fly setups. In the non-fly setup, the convection on the ABS is free air convection; in the fly setup, it is usually modeled in terms of the air bearing cooling, and the convection coefficient is much larger than that of the free air convection. Therefore, the cooling on the ABS is much larger in the fly setup, thereby mitigating the temperature increases of both the ECS and the TFC heaters.

It is also noted that the only non-linear curve in Fig. 1(a) is the ECS resistance increase in the fly setup.

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All other curves are linear. This is because in the non-fly setup, the boundary condition does not change with the TFC power. Therefore, the temperature field is linear with the sole heating source, the TFC power. However, in the fly setup, the convection coefficient increases as the TFC power increases and the head-disk gap decreases, providing more cooling to the ECS, causing the reduction of its rate of temperature increase. But the TFC heater is barely affected since it is buried inside the slider's body.

Since the resistance increase rate in the fly condition is directly affected by the cooling on the ABS, we can quantitatively compare the resistance increase rates for the different setups. Here we define a temperature change ratio (ξ) as the ratio of the resistance increase in the non-fly setup to that in fly setup at a certain TFC power,

$$\xi = \frac{\Delta R_{non-f}}{\Delta R_{fly}}\bigg|_{P_{TFC}}. \qquad (2)$$

The ratios ξ for the ECS and the TFC heater are shown in Fig. 1(b) as a function of TFC power. It is seen that ξ_{TFC} remains constant at ~ 4, for the complete power range, but ξ_{ECS} increases from ~ 2 to ~ 5 and it crosses ξ_{TFC} at $P_{TFC} \sim 18$mW.

The ECS is located at the surface of the slider, which is more sensitive to the change of the heat transfer coefficient across the HDI (h_{HDI}), while the TFC heater is buried in the slider's body, which is less sensitive. Therefore, intuitively, we expect when the slider switches from the non-fly status to the fly status, there should be more cooling on the ECS than the TFC heater, i.e., $\xi_{ECS} > \xi_{TFC}$. However, from Fig. 1(b), we see that $\xi_{ECS} < \xi_{TFC}$ at low P_{TFC}, which is opposite to our intuition.

III. SIMULATIONS

To understand better the experimental results, we carried out a series of simulations using the CMLAir software. The slider surface used in the simulations was similar to that in the experiments. Two cases were simulated with P_{TFC} at 0 and 65mW, called Case 1 and 2. The convective heat transfer coefficient (h_{HDI}) based on the air bearing cooling model in CMLAir for the two cases are shown in Fig. 2. Fig. 2(a) shows the results for Case 1 and Fig. 2(b) shows the results for Case 2. It is noted that plots of pressure would look similar to those in Fig. 2. The red arrows in Figs. 2 indicate the location of the ECS. It is noted that the dimension of the ECS is $\sim 1\mu$m, which is much smaller than the TFC heater, which has the dimension of $\sim 20\mu$m. As a direct result, the air convection that is far ($\sim 10\mu$m) away from the ECS has little effect on the heat transfer of the ECS, while such a distance is still within the range of the TFC. From Fig 2(a), we can see that the ECS is located in a "valley" of the h_{HDI} distribution. Therefore, the cooling around the ECS is actually relatively low, causing $\xi_{ECS} < \xi_{TFC}$ at low P_{TFC}. However, as P_{TFC} increases, the protrusion causes the h_{HDI} to increase at the ECS location, and the "valley" disappears finally, as shown in Fig 2(b), causing $\xi_{ECS} > \xi_{TFC}$ at high P_{TFC}.

This observation may provide insights into designing a HAMR ABS to control the back heating from the disk to the NFT. We see that the ABS design directly influences the pressure distribution and the heat transfer coefficient distribution. Therefore, it may be possible to design the ABS such that the air bearing pressure at the location of the NFT is lower, which will potentially lower the back heating from the media.

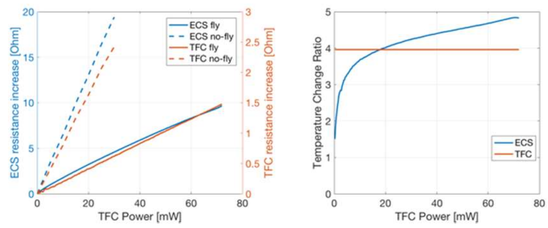

Figure 1 The experimental results.

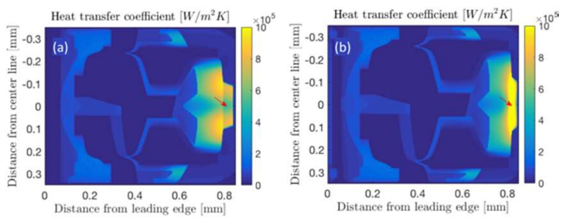

Figure 2 The simulation results.