DETECTION OF MODULATION AND CONTACT AT HDI WITH ELECTRICAL CURRENT

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ABSTRACT

In the present work, a novel technique for detecting head-disk contact and modulation is presented. The technique involves measuring electrical current at HDI in the ultra-low flying cases. It is found that the electrical current is very sensitive to head-disk contact and head modulation, which are confirmed with Guzik measurements. Acoustic emission (AE) is also used in the same measurements for contact detection and found to be less sensitive than the electrical current. The electrical current at HDI can be generated through either tribo-charging/discharging at HDI or externally applied bias voltage. Potential applications of this technique for both head modulation/contact testing and disk glide testing are discussed.

INTRODUCTION

With head-disk spacing getting to sub-10 nm range the head-disk contact becomes unavoidable due to either flying height (FH) fluctuation or FH variations induced by environmental changes such as temperature, humidity and altitude. The head-disk contact is the main cause for reliability issues such as head modulation, degradation, wear and even head crash for today’s high density/capacity disk drives [1,2]. For a reliable head-disk interface design, it is essential that head-disk contact kept at minimum. This requires sensitive and accurate detection of head-disk contact at either component or drive level reliability tests. Currently, acoustic emission (AE) is widely used to detect head-disk interference for component and level reliability tests [3, 4]. It is simple and has reasonably high sensitivity, but interpretation of AE is usually not straightforward. In case of wide-band AE sensor, the signal could be caused by either head-disk contact or airbearing and suspension resonance without physical contact [3, 4], therefore, AE intensity can not be directly used for detection of head disk contact. To overcome this problem, narrow band signals that are characteristics of head-disk contact, i.e. slider body resonance, were used to indicate head-disk contact [4, 5]. However, the resonance frequency for slider body modes is usually high, i.e. > 1 MHz for Pico sliders and its intensity is usually significantly lower than that for wide-band [4], and so is the detection sensitivity. This paper describes a new technique for detecting head-disk contact and related head modulation. The electrical current at head-disk interface is used as the indication for head-disk contact events. This is an extension of an early work of measuring the potential at HDI [6]. It will be shown that this technique has higher sensitivity comparing with AE, especially for contact due to presence of individual particles, while it still maintains good selectivity to contact and modulation events.

RESULTS AND DISCUSSIONS

The experiments were conducted on a modified Guzik tester (Model 1701 with a bandwidth of 180 MHz). A schematic diagram of the setup is shown in Fig. 1. The main modification is the isolation of the magnetic head from machine ground so that the electrical current due to head-disk contact can be measured. The current was measured by using an electrometer (Keithley 6517) and a current amplifier (Keithley Model 428) with a rise time of 2 µs for transient events. The head-disk contact was achieved by applying a low DC voltage (<5V) to HDI or by using disks with dispersed particles. A wide band AE sensor was also used for comparing detection sensitivity of head disk contact.

Figure 1. A schematic diagram of the experimental setup

Both magnetic heads and disks are those for 80 GB/platter disk drives. The magnetic heads were made of Pico-sized AlTiC slider with 30Å thick carbon overcoat (COC). The slider
had a sub-ambient pressure airbearing with a nominal FH of \( \sim 10 \) nm. The magnetic disks were made from aluminum alloy substrate with Co-Cr-Pt alloy magnetic layer. The disks were coated with \( \sim 25\)Å thick COC and \( \sim 12\)Å thick PFPE Z-dol lubricant.

Fig. 2 shows head modulation measurement with current and AE. In this case, a low DC voltage (4 V) from the electrometer (Keithley 6517) was applied to the HDI to induce intermittent contact and FH modulation, which was confirmed by track average amplitude (TAA) on the Guzik tester at the same time. Fig. 2a shows the TAA and current at low voltages with no head-disk contact and modulation, and Fig. 2b shows the TAA and current at 4 V, where there is a clear modulation on both TAA and current signal. As can be seen, the current signal tracks well with TAA, suggesting that current can be used to measure the head modulation.

The current due to FH modulation may be understood in the following simple analysis. A head-disk interface may be modeled as a quasi-parallel capacitor, then,

\[
I = \varepsilon A V \left( \frac{d(h_0^{-1})}{dt} \right) \tag{1}
\]

where \( I \) is the current, \( \varepsilon \) the permittivity, \( A \) the effective slider area, \( V \) the applied voltage, \( h_0 \) the spacing or FH modulation of a sinusoidal function. Equation (1) shows that a current is generated at capacitor due to FH modulation. Fig. 3 plots both the sinusoidal FH modulation and the induced current versus time with the following parameters: \( V=4.0V \), \( A=1\times10^{-5}m^2 \), \( \varepsilon=8.85\times10^{-12}C^2/Nm^2 \), \( h_0=5nm \), and modulation amplitude=2.5 nm. It shows that the current basically follows the FH in a way similar to the experimental observation (Fig. 2b).

The HDI current was also explored for detecting head-disk contact due to particles at HDI. Fig. 4 shows a measurement where a magnetic head flies over a disk with dispersed particles (<0.2 µm). In this case, the current amplifier (Keithley 428) was used to catch transient events and no DC bias was applied. A clear current pulse is seen when the head hits a particle, while there is no response from AE RMS signal for the same event. This demonstrates that current has higher sensitivity than AE technique in detecting the contact due to particles. In this case, the current is likely caused by tribo-charging/discharging at HDI.

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\begin{align*}
\text{REFERENCES} \\
1. & \text{Ono, K., and Takahashi, K., 1998, ASME 98-TRIB-58, pp1-10} \\
6. & \text{Feng, Z, Cha, E. and Zhang, X., Tribology Letters, 2005.}
\end{align*}
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![Figure 2](image-url)  
**Figure 2.** Head modulation with TAA (50 mV/div) and current (1µA/div). a) No modulation and b) With modulation.

![Figure 3](image-url)  
**Figure 3.** Sinusoidal FH modulation and current output.

![Figure 4](image-url)  
**Figure 4.** Current and AE (RMS) signal when a head flies over a particle (current: 1µA/div)

In summary, a novel technique for detecting head-disk contact, especially the light or intermittent contact and related head modulation, has been developed. This technique uses electrical current at head-disk interface as the indicator for the contact, and it has been demonstrated that the current has higher sensitivity than conventional AE technique. This technique can be used to test the susceptibility of a magnetic head to modulation at component level, where magnetic measurements are unavailable. This technique can also be used to detect particles or possibly thermal asperities (TA) on disk surfaces. Comparing with TA measurements with TAA signals, the current technique should have higher sensitivity as the whole slider surface could the probe; while for TAA method only the reader area (<1 µm) is effective. Another potential application is the glide test for disk. As the disk gets smoother, and glide height gets lower, this demands a sensor with higher sensitivity for an accurate determination of the true glide height.