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Natural Frequency Analysis of Sliders and Head/Disk Interaction Detection by Acoustic Emission

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Abstract: The object of the present work is the natural frequency analysis of subambient pressure tri-pad and pico sliders. Head/disk interaction during start/stop and constant speed were detected by using the acoustic emission (AE) test system. The frequency spectrum analysis is performed using the AE signal obtained during the head/disk interaction. The FFT (Fast Fourier Transform) analysis of the AE signals is used to understand the interaction between the AE signal and the state of contact. Natural frequency analysis was performed using the Ansys program. The results indicate acceptable accordance of finite element calculation results with the experimental results.

Key words: Natural frequency, head/disk interaction, subambient pressure tri-pad slider, pico slider, acoustic emission

Introduction

Since contacts between slider and disk cause friction and wear, it is important to minimize the contact force at the head/disk interface. One of the most sensitive methods for the analysis of friction between sliding surfaces is acoustic emission (AE).

Kita *et al.* [1] first documented the use of acoustic emission for contact detection. They used acoustic emission to study the transition of two-rail sliders from sliding to flying. They found that the AE signal increases with velocity, reaches a well-defined maximum, and then decreases to the noise floor as the velocity of the disk is increased. AE were also used by Benson *et al.* [2] who studied the effect of slider design and surface roughness on the transition from sliding to flying. Acoustic emission analysis was also used by Sharma *et al.* [3], who observed that tri-pad sliders showed a distinct double peak in the AE signal. Jeong and Bogy [4] studied the natural frequencies of sliders and transducers using finite element calculations. Khurshudov and Talke [5] used acoustic emission to study of subambient pressure tri-pad sliders. Hwan Cha *et al.* [6] investigated the AE and friction signals related to the durability of head/disk interface. As we can see, acoustic emission studies have been widely used in the investigation of the tribology of sliding interface.

Proximity recording sliders are designed to keep light contact with the disk during steady-state "flying". A typical example of a proximity recording slider is the so-called "tri-pad slider" which consists of two shortened air-bearing rails and a small air bearing center pad carrying the read-write element. Another slider design used for proximity recording application is the so-called sub-ambient (negative pressure) tri-pad slider, consisting of a negative contour with an additional small center pad at the trailing edge [5]. In our work we used acoustic emission to study contact behavior of the slider during start/stop and constant speed operation. Finite element analysis was performed using the Ansys program.

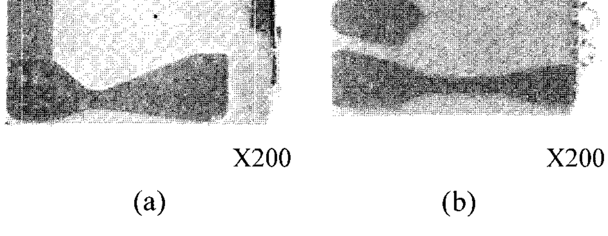
Finite Element Analysis

We used two different sliders for finite element analysis. As we can see on Fig. 1, a subambient pressure tri-pad slider (a), and a pico slider (b) are shown. The geometrical and physical characteristics of these sliders are shown in Table 1 and Table 2 respectively.

A disturbance such as a head/disk contact would excite the rigid body motions as well as the ringing frequencies. The ringing motions are more indicative of a head/disk contact than the rigid body motions, which can occur as the slider responds to disturbances through its air-bearing without contacts [4]. We can ignore the first three modes in this analysis.

Table 3 represents the vibration modes of the sliders.

Fig. 2 shows the vibration modes of the subambient pressure



(a) (b)

Fig. 1. (a) Subambient pressure tri-pad slider (b) Pico slider.

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Table 1. Geometrical characteristics of the sliders

Slider type	Subambient pressure tri-pad slider	Pico slider
Length, mm	2.10	1.25
Width, mm	1.30	1.00
Height, mm	0.45	0.30

Table 2. Physical characteristics of the sliders

Slider type	Subambient pressure tri-pad slider	Pico slider
Weight, mg	6.20	1.50
Youngs modulus, GPa	407	407
Density, g/cm^3	4.00	4.00
Poison ratio	0.20	0.20

Table 3. Vibration modes of the sliders

Slider type	Subambient pressure tri-pad slider	Pico slider
Twisting mode	1.00 MHz	2.09 MHz
Bending mode	1.17 MHz	2.76 MHz

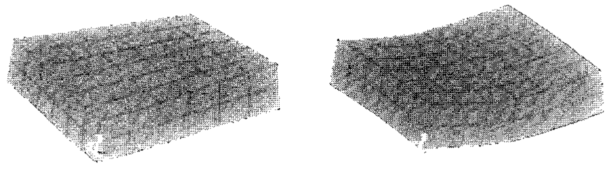
Mode 1 (1.00 MHz) Mode 2 (1.17 MHz)

Fig. 2. Natural frequencies and mode shapes of the subambient pressure tri-pad slider.

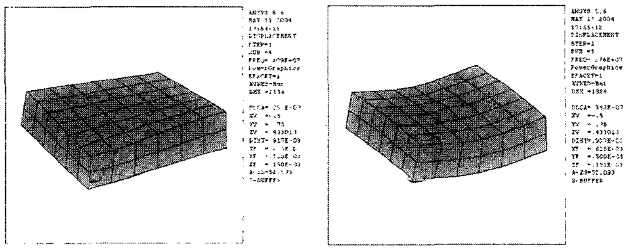
Mode 1 (2.09 MHz) Mode 2 (2.76 MHz)

Fig. 3. Natural frequencies and mode shapes of the pico slider.

tri-pad slider.

As we can see the first mode is a twisting mode about the longitudinal axis of the slider with a natural frequency of 1.0 MHz. The second mode is a bending mode about the transverse axis with a natural frequency of 1.17 MHz. These modes and frequencies give us a guide for identifying the observed resonances in the experiment to be discussed.

Fig. 3 shows the vibration modes for the pico slider. The first mode that we observed is a twisting mode about the longitudinal axis of the slider with a natural frequency of 2.09 MHz. The second mode is a transverse bending mode of the slider with a natural frequency of 2.76 MHz.

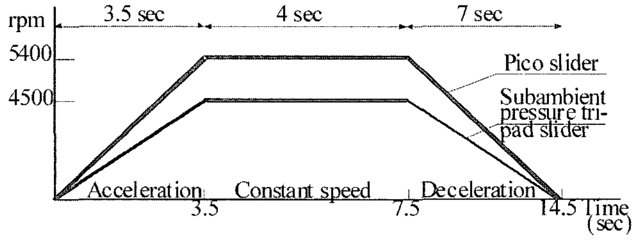

Fig. 4. Acceleration profiles of CSS tests.

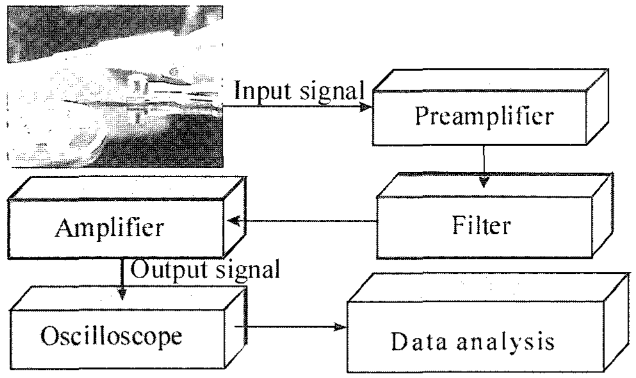

Fig. 5. AE signal processing.

As we can see, the natural frequency of the pico slider is much higher than the natural frequency of the subambient pressure tri-pad slider.

Experimental Procedure

The CSS tests were conducted with the PCA Contact-Start-Stop (CSS) tester. Fig. 4 presents the acceleration profiles used in our experiments.

As we can see from Fig. 4 each CSS cycle was 14.5 seconds at the maximum spindle speed of 4500 rpm for the subambient pressure tri-pad slider and 5400 rpm for the pico slider. During start-up, our experimental disks were accelerated to reach its maximum speed in 3.5 seconds. The disks were then kept at constant speed for 4 seconds, and were decelerated to a complete stop in 7 seconds. In all tests, an AE sensor was attached to the base of the suspension.

Fig. 5 shows the detected AE signal processing. The AE signals are acquired using a digital oscilloscope [7].

Results and Discussion

Fig. 6 shows us the AE signal versus time during a start/stop cycle. The AE signal is shown as a function of time during a complete start/stop cycle and maximum disk speed of 4500 rpm for the subambient pressure tri-pad slider, and 5400 rpm for the pico slider.

As we can see there are two well-defined peaks on this AE signal. These peaks are dependent on the contact force between slider and disk surface.

After gathering data from the AE signal we used the Fast

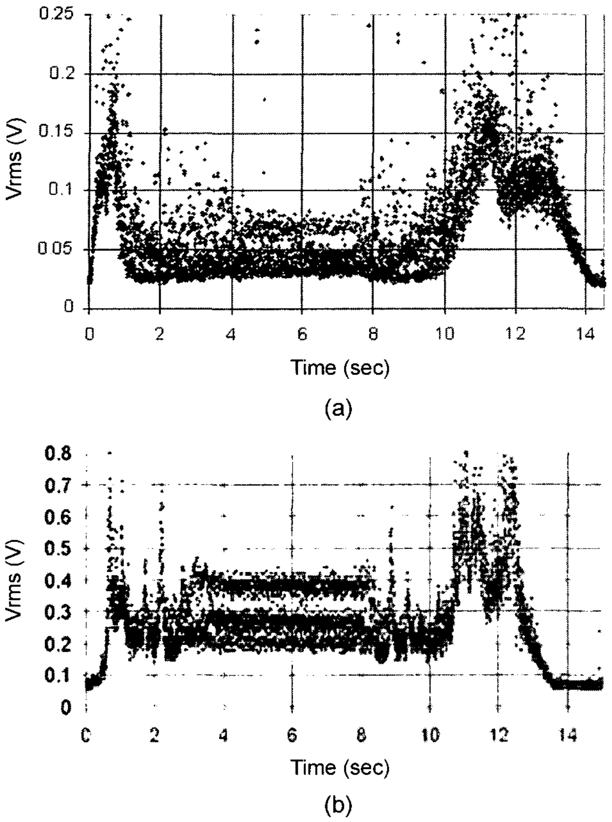

Fig. 6. The AE signal versus time of (a) the subambient pressure tri-pad and (b) the pico sliders.

Fourier Transform (FFT) to determine the frequency range of the acoustic emission signal. Fig. 6 shows the frequency spectrum of the AE signal. Duration time equaled 4 ms; time interval between two points equaled 4 μs and number of points equaled 10 000.

Fig. 7 presents the frequency spectrum of the AE signal for the subambient pressure tri-pad slider. During acceleration and deceleration we can observe few peaks on the frequency spectrum of the AE signal. They are dependent on the vibration modes of the slider. The frequency spectrum of the AE signal during constant speed is smoother than during acceleration and deceleration because during acceleration and deceleration contact force occurs.

As we noted above, we can ignore the first three vibration modes. Thus, we are interested in the twisting and transverse bending modes. We can observe two peaks in the frequency spectrum of an AE signal (Fig. 7). The peak at 1.0 MHz corresponds to the twisting mode about the longitudinal axis of the slider. The peak at 1.17 MHz corresponds to the transverse bending mode of the subambient pressure tri-pad slider. Now we can say that we achieved full accordance of finite element calculation results with our experimental results. So, we can allow that the results for the pico slider will also be in agreement.

Conclusions

Finite element analysis shows that the lowest natural frequency

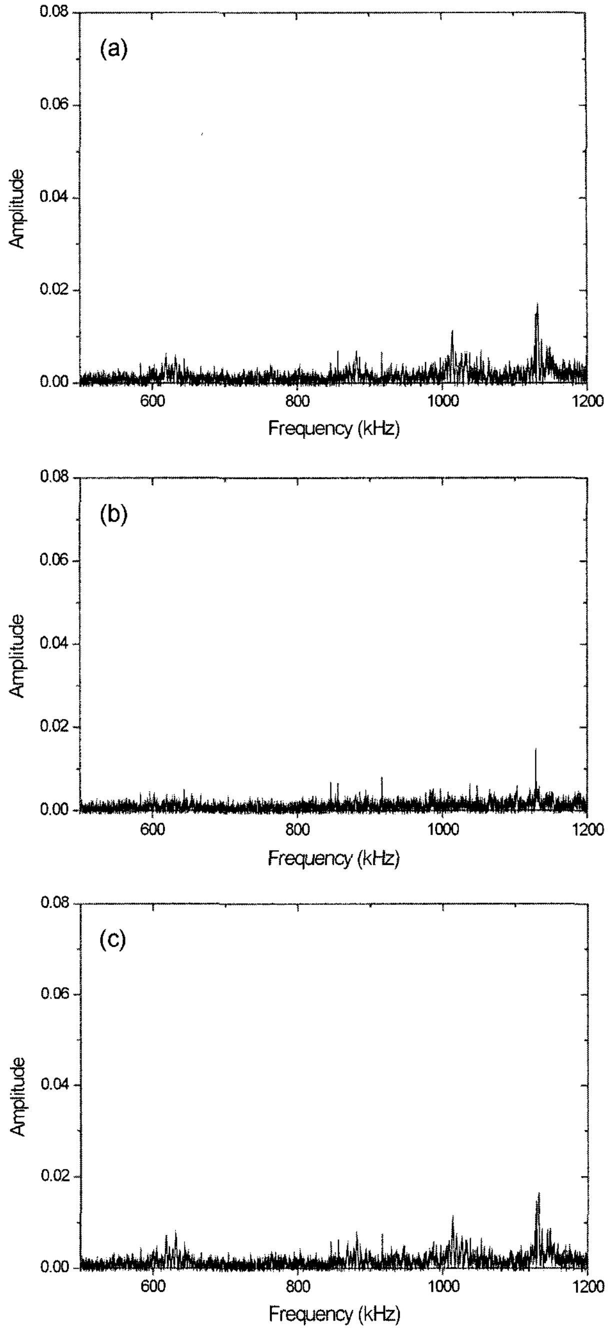

Fig. 7. The frequency spectrum of the AE signal of a subambient pressure tri-pad slider for (a) acceleration (b) constant speed and (c) deceleration.

of the subambient pressure tri-pad slider is about 1.0 MHz. This value has been verified by the FFT analysis and AE measurements.

The frequency spectrum of an AE signal for constant speed is smoother than for acceleration and deceleration because of the contact force.

The results of finite element calculations show us that the natural frequency of the subambient pressure tri-pad slider is much higher than that of the pico slider because the pico slider is much smaller in size. We achieved acceptable accordance of finite element calculation results with the experimental results.

The AE system is highly sensitive method to test the tribological characteristics of a head/disk interaction.

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