The Acoustic Emission Energy Analysis of Subambient Pressure Tri-Pad Slider

[1]Galina Pan (Dept. of Mech. Eng., Yeungnam Univ.) galina@yumail.ac.kr
[2]Pyung Hwang (School of Mech. Eng., Yeungnam Univ.) phwang@yumail.ac.kr
[3]Wu Xuan (Dept. of Mech. Eng., Yeungnam Univ.) wuxuan0707@hotmail.com

ABSTRACT

The object of the present work is the acoustic emission energy analysis of subambient pressure tri-pad slider. Head/disk interaction during start/stop and constant speed were detected by using acoustic emission (AE) test system. The frequency spectrum analysis is performed using the AE signal obtained during the head/disk interaction. Natural frequency analysis was performed using Ansys program. Acoustic emission energy was calculated for the slider modes.

Keywords : acoustic emission energy, subambient pressure tri-pad slider, natural frequency.

1. Introduction

Acoustic emission (AE) measurements have been used extensively to monitor slider-disk contacts in hard disk drives.

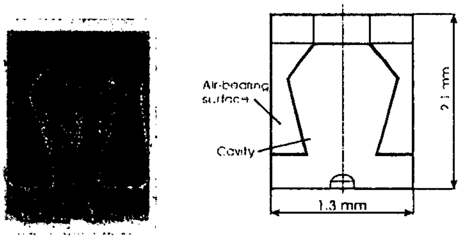
Kita et al. [1] first documented the use of acoustic emission for contact detection. They used acoustic emission to study the transition of two-rail sliders from sliding to flying. They found that the AE signal increases with velocity, reaches a well-defined maximum, and then decreases to the noise floor 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. Sharma et al. [3], who observed that tri-pad sliders showed a distinct double peak in the AE signal, also used acoustic emission analysis. Jeong and Bogy [4] studied the natural frequencies of sliders and transducers using finite element calculation. Khurshudov and Talke [5] used acoustic emission to study of subambient pressure tri-pad sliders.

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 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 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 this study, we investigated the energy in the AE signal associated with slider body resonances. We calculated the power spectra as a function of velocity for the subambient pressure tri-pad slider. Thereafter, we determined the relative amount of acoustic energy associated with the bending and torsional modes of the slider.

2. Experimental procedure

Typical subambient pressure tri-pad slider was used in this investigation (Fig. 1).



(a) (b)

Fig. 1(a) Picture of the slider
Fig. 1(b) Schematics of subambient pressure tri-pad slider

The CSS tests were conducted with the PCA Contact-Start-Stop (CSS) tester. Fig. 2

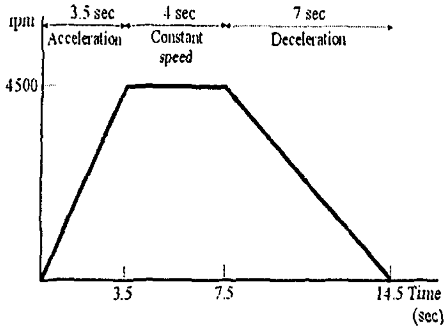


Fig. 2. Acceleration profile of CSS test

presents the acceleration profiles used in our experiments.

As we can see from Fig. 2, each CSS cycle was 14.5 seconds at the maximum spindle speed of 4500 rpm. During start-up, the disk was accelerated in 3.5 seconds to its maximum speed. The disk was then kept at constant speed for 4 seconds, and was decelerated to a complete stop in 7 seconds. In all tests, AE sensor was attached to the base of the suspension.

To determine the resonant frequencies and corresponding mode shapes, the subambient pressure tri-pad slider was modeled as free body using Ansys program.

3. Experimental results

Fig. 3 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. 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.

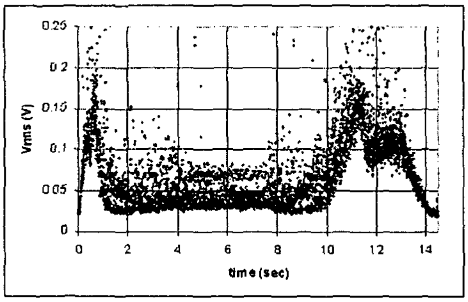
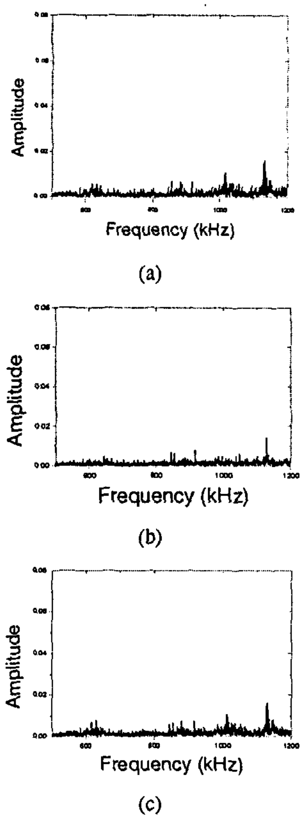


Fig. 3. The AE signal versus time

After gathering data from the AE signal, we used the Fast Fourier Transform (FFT) to determine the frequency range of the acoustic emission signal.

Fig. 4 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.



(a)

(b)

(c)

Fig. 4. The frequency spectrum of the AE signal of the subambient pressure tri-pad slider for (a) acceleration (b) constant speed and (c) deceleration

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.

In Fig. 5, the intensity of the normalized AE signal is shown as a function of velocity for the subambient pressure tri-pad slider.

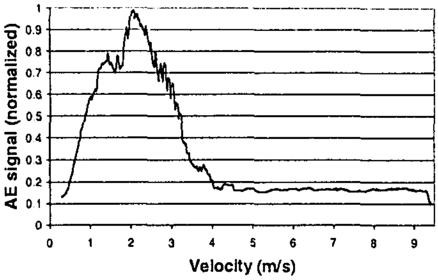


Fig. 5. Normalized AE signal for subambient pressure tri-pad slider

We observe that AE signal raises sharply from zero, reaches a well-defined peak at 2.1 m/s and then decreases.

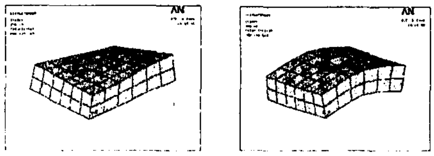
3. Finite element analysis

The geometrical and physical characteristics of the subambient pressure tri-pad slider are shown in Table 1.

Table1. Geometrical and physical characteristics of the slider

Length, *mm*	2.10
Width, *mm*	1.30
Height, *mm*	0.45
Weight, *mg*	6.20
Young's modulus, *GPa*	407
Density, *g/cm*^{3}	4.00
Poison ratio	0.20

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.



Mode 1 (927 kHz) Mode 2 (1.125 MHz)

Fig. 6. Natural frequencies and mode shapes of the subambient pressure tri-pad slider

Fig. 6 shows the vibration modes of the subambient pressure 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 927 kHz. The second mode is a bending mode about the transverse axis with a natural frequency of 1.125 MHz.

4. Calculation of the AE energy

Using the frequency spectrum of acoustic emission signal, we have determined the energy in AE signal corresponding to each mode of vibration as a function of velocity. The energy in the AE signal can be calculated using

$$Energy \equiv \frac{1}{N}\sum_{k=0}^{k=N-1}\left|X(k)\right|^2$$

where $\left|X(k)\right|^2$ is the frequency spectrum and N is the total number of data points [8]. The energy in the AE signal corresponding to the torsional and bending mode can be calculated by defining a window around the corresponding frequency such that,

$$Energy(torsional) \equiv \frac{1}{N}\sum_{k=t_1}^{k=t_2}\left|X(k)\right|^2$$

$$Energy(bending) \equiv \frac{1}{N}\sum_{k=b_1}^{k=b_2}\left|X(k)\right|^2$$

where t_1, t_2 and b_1, b_2 are the lower and upper limits of the window around the torsional and bending mode frequency, respectively [8].

5. Results and discussion

As we noted above, we can ignore the first three vibration modes. Thus, we are interested in the torsional and transverse bending modes. We can observe two peaks in the frequency spectrum of an AE signal (Fig. 4). The peak around 1 MHz corresponds to the torsional mode about the longitudinal axis of the slider. From finite element calculation, we got the first mode at 927 kHz. The peak at 1.17 MHz corresponds to the transverse bending mode of the subambient pressure tri-pad slider. From finite element calculation, we got the second mode at 1.125 MHz. Now we can say that we achieved acceptable accordance of finite element calculation results with our experimental results.

In Fig. 7, the AE energy is shown as a function of velocity for both modes.

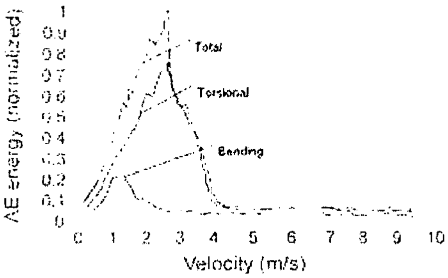


Fig. 7. AE energy for subambient pressure tri-pad slider as a function of velocity

We observe that at velocities below 4.0 m/s, the AE energy in torsional mode is much larger than the AE energy in the bending mode. It means that at low velocities most impacts occur on the side rails of the subambient pressure tri-pad slider.

6. Conclusions

Finite element analysis shows that the lowest natural frequency of the subambient pressure tri-pad slider is about 927 kHz. The approximate value has been verified by the FFT analysis and AE measurements.

The AE energy of the torsional mode was higher than that of the bending mode at low velocities.

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

References

1. Kita, T., Kogure, K., Mitsuya, Y., and Nakanishi, T., "New Methods of Detecting Contact Between Floating-head and Disk", IEEE Transaction on Magnetics, Vol. 16, No. 5, pp. 873-875, 1980.
2. Benson, R.C., Sundaram, R., and Talke, F.E., "A Study of Acoustic Emission from the Slider/Disk Interface in a 5.25 inch Hard Disk Drive", STLE, SP-25, pp. 87-93, 1988.
3. Sharma, V., Talke, F.E., and Ng, Q., "Tribological Investigation of Tri-pad Slider", IEEE Transaction on Magnetics, Vol. 32, No. 5, pp. 3651-3653, 1996.
4. Jeong, T.G., Bogy, D.B., "Natural Frequencies of Sliders and Transducers Used to Detect Slider-Disk Contact", IEEE Transaction on Magnetics, Vol. 25, No. 5, pp. 3725-3727, 1989.
5. Khurshudov, A.G., Talke F.E., "A Study of Subambient Pressure Tri-Pad Sliders Using Acoustic Emission", Transactions of the ASME, Vol. 120, pp. 54-58, 1998.
6. Cha, K.-H., Lee, S.-C., Han D.-G., Lee, S.-M., and Kim, D.-E., "Experimental Investigations of AE and Friction Signals Related to the Durability of Head/Disk Interface", Tribology International, Vol. 32, pp. 399-405, 1999.
7. Kim, J.H., Kim, T.W., and Cho, Y.J., "Detecting of Scuffing Using Acoustic Emission", Proc. 2nd Asia International Conference on Tribology, Jeju Island, Korea, pp.191-192, 2002.
8. McMillan, T. C., Talke, F.E., "Identification of Slider/Disk Contacts Using the Energy of the Acoustic Emission Signal", IEEE Transaction on Magnetics, Vol. 34, No. 4, pp. 1819-1821, 1998.