KSTLE International Journal, Vol. 6, No. 1, June 2005, pp. 17-20

Femto Slider Head/Disk Interaction Detection by Acoustic Emission and Natural Frequency Analysis

Pyung Hwang[†], Galina Pan* and Xuan Wu*

School of Mechanical Engineering, Yeungnam University, Korea
**Department of Mechanical Engineering, Yeungnam University*

Abstract: The object of the present work is the natural frequency analysis of femto slider. Head/disk interaction during start/stop and constant speed were detected by using the acoustic emission (AE) test system. The frequency spectrum analysis was 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: Femto slider, head/disk interaction, FE analysis, natural frequency, acoustic emission.

Introduction

Acoustic Emission (AE) is the class of phenomena whereby an elastic wave, in the range of ultrasound usually between 20 KHz and 1 MHz, is generated by the rapid release of energy from the source within a material. The elastic wave propagates through the solid to the surface, where one or more sensors can record it. The sensor is a transducer that converts the mechanical wave into an electrical signal. In this way information about the existence and location of possible sources is obtained. The basis for quantitative methods is a localization technique to extract the source coordinates of the AE events as accurately as possible. AE analysis is a useful method for the investigation of local damage in materials. One of the advantages compared to other NDE techniques is the possibility to observe damage processes during the entire load history without any disturbance to the specimen.

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. Hwan Cha *et al.* [5] 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.

The use of femto sliders provide improvements in disk storage capacity (disk real estate utilization), power consumption, and shock resistance while maintaining comparable performance to pico in other attributes. The reduced size of the femto slider also improves manufacturing efficiency by increasing the number of devices per wafer [6].

In our work we used acoustic emission to study contact behavior of femto slider during start/stop and constant speed operation. Finite element analysis was performed using Ansys program.

Experimental procedure

The CSS tests were conducted with the PCA Contact-Start-Stop (CSS) tester (Fig. 1). For our experiments we used femto slider (Fig. 2). Fig. 3 presents the acceleration profiles used in our experiments.

As we can see from Fig. 3, each CSS cycle was 10 seconds at the maximum spindle speed of 7200 rpm. During start-up, the disk was accelerated in 3 seconds to its maximum speed. The disk was then kept at constant speed for 3 seconds, and was decelerated to a complete stop in 4 seconds. In all tests, AE sensor was attached to the base of the suspension [7].

To determine the resonant frequencies and corresponding mode shapes, femto slider was modeled as free body using Ansys program.

Fig. 4 shows the detected AE signal processing. The AE

[†]Corresponding author; Tel: 82-53-810-2448, Fax: 82-53-810-4627
E-mail: phwang@yumail.ac.kr

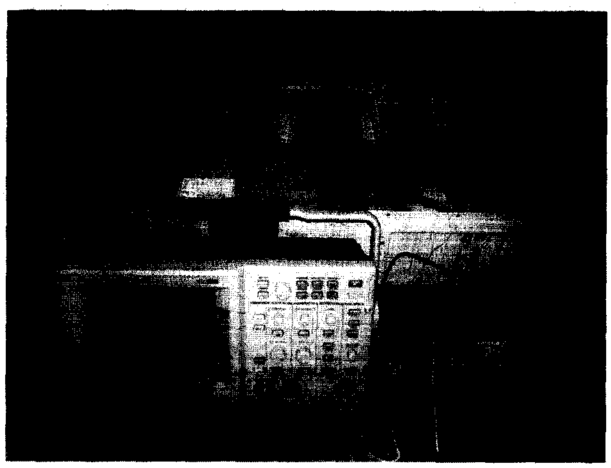


Fig. 1. CSS tester.

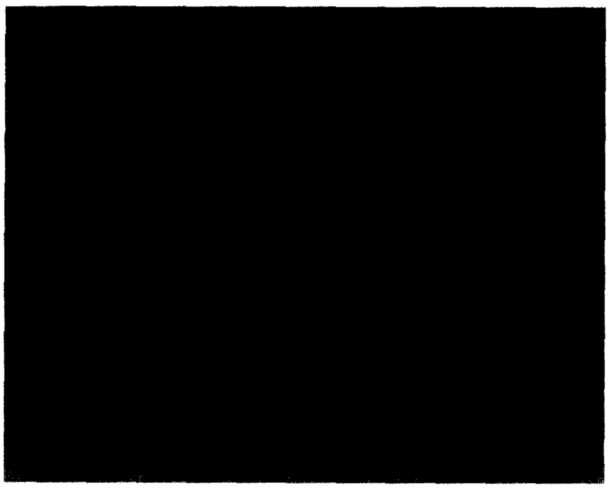


Fig. 2. Femto slider.

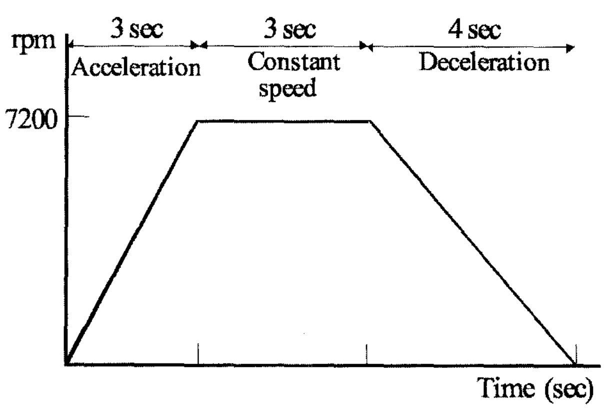


Fig. 3. Acceleration profiles of CSS tests.

signals are acquired using a digital oscilloscope.

Finite element analysis

The geometrical and physical characteristics of femto slider are shown in Table 1.

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]. Table 2 represents the vibration modes of femto slider.

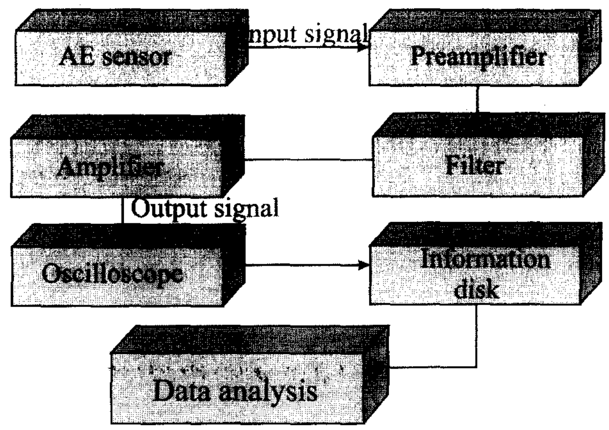


Fig. 4. AE signal processing.

Table 1. Geometrical and physical characteristics of femto slider

Length, mm	0.875
Width, mm	0.70
Height, mm	0.20
Weight, mg	0.50
Young's modulus, GPa	407
Density, g/cm^3	4.00
Poison ratio	0.20

Table 2. Vibration modes of femto slider

Twisting mode	1.83 MHz
Bending mode	2.38 MHz

Fig. 5. shows the vibration modes of femto slider.

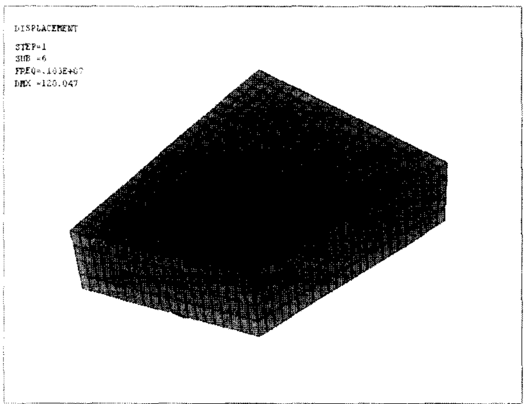
As we can see the first mode is twisting mode about the longitudinal axis of the slider with a natural frequency of 1.83 MHz. The second mode is bending mode about the transverse axis with a natural frequency of 2.38 MHz. These modes and frequencies give us a guide for identifying the observed resonances in the experiment to be discussed.

Results and discussion

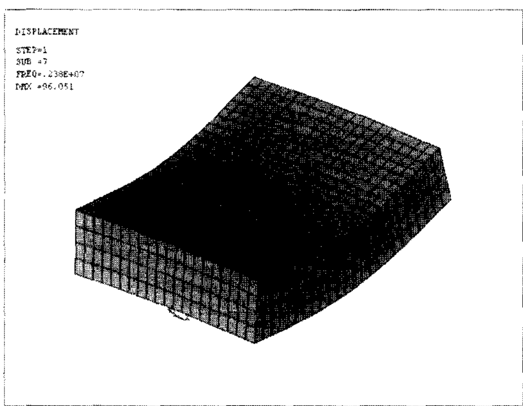
Fig. 6 shows us the AE signal versus time during a start/stop cycle. The AE signal has shown as a function of time during a complete start/stop cycle and maximum disk speed 7200 rpm.

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

After gathering the data of AE signal we used the Fast Fourier Transform (FFT) to determine the frequency range of acoustic emission signal. Fig. 7 shows the frequency spectrum of AE signal. Duration time was equal 2 ms; time interval between two points was equal 2 μs and number of points was



Mode 1 (1.83 MHz)



Mode 2 (2.38 MHz)

Fig. 5. Natural frequency and mode shapes of femto slider.

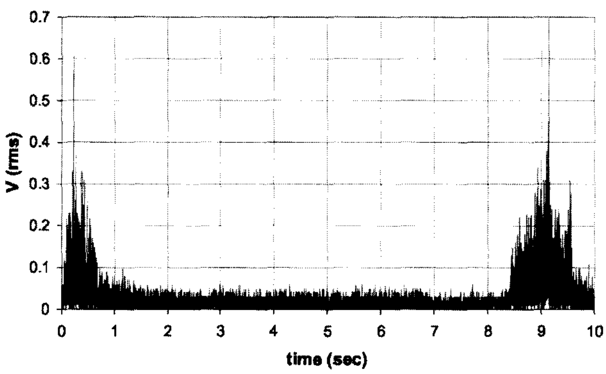


Fig. 6. The AE signal versus time of femto slider.

equal 10,000. During acceleration and deceleration we can observe few peaks on the frequency spectrum of AE signal. They are depended on vibration modes of the slider.

The frequency spectrum of AE signal during constant speed is smoother than during acceleration and deceleration because during acceleration and deceleration contact force occurs.

We are interested in twisting and transverse bending modes. We can observe two peaks in the frequency spectrum of AE signal (Fig. 7). The peak at 1.83 MHz corresponds to twisting mode about longitudinal axis of the slider. The peak at 2.38 MHz corresponds to transverse bending mode of femto slider. Now we can say that we got acceptable accordance of finite element calculation results with our experimental results.

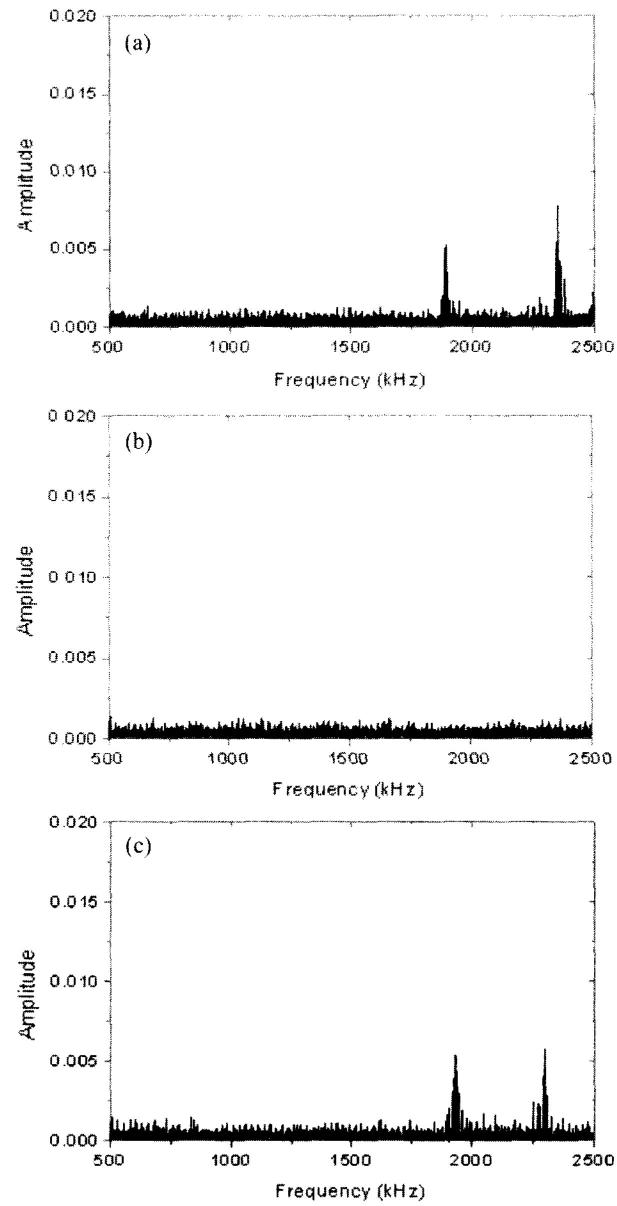


Fig. 7. The frequency spectrum of AE signal of femto slider for (a) acceleration (b) constant speed and (c) deceleration.

Conclusions

Finite element analysis shows that the lowest natural frequency of femto slider is around 1.83 MHz. Second natural frequency of femto slider is around 2.38 MHz. These values have been verified by the FFT analysis and AE measurements. We achieved acceptable accordance of finite element calculation results with the experimental results.

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

Acknowledgments

Authors would like to appreciate the financial support provided for continuing this research by the Yeungnam University Research Support Program in 2004-2005.

References

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.

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.

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.

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.

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.

Lee, D., Bolasna, S., Kolta, J., "Introduction of Femto Slider in Mobile Disk Drives", IEEE Transaction on Magnetics, Vol. 40, No. 1, pp. 349 -352, 2004.

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.

Chung, K.H., Oh, J.K., Moon, J.T., and Kim, D.E., "Frequency Spectrum Analysis of Acoustic Emission of Hard Disk Drive Head/Disk Interaction", Proc. 2nd Asia International Conference on Tribology, Jeju Island, Korea, pp.273-274, 2002.