A High Bandwidth Piezoelectric Suspension For High Track Density Magnetic Data Storage Devices

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***Abstract*—Maintaining the trend towards higher track densities and data rates in magnetic recording devices requires track following servo systems of increasing bandwidth for reliable storage and retrieval of data. The increase in bandwidth is limited by the presence of mechanical resonance modes and other nonlinearities in the voice coil motor (VCM) actuators. One approach to overcoming the problem is by using a dual-stage servo mechanism. In such a mechanism, a VCM is used as a primary stage while a microactuator is used as a secondary stage. The paper proposes a planar piezoelectric actuator design and a piezoelectric suspension made of the planar piezoelectric actuator. The design has a high bandwidth, simple structure and low cost. A prototype of the piezoelectric suspension is designed, fabricated and tested. The experimental results demonstrate that the piezoelectric suspension can satisfy the requirements for the dual-stage servo system.**

***Index Terms*—Dual-stage servo system, microactuator, piezoelectric suspension, planar piezoelectric actuator.**

I. INTRODCUTION

A well-known trend in magnetic data storage is the 60% areal density growth per annum. At this rate, an advanced magnetic storage device is expected to have above 30,000 tracks per inch (TPI) by year 2000. The maximum tolerable offset between the R/W head and the track center is less than 10% of the track pitch for accurate read/write of data. It is estimated that a drive spinning at 7,200 rpm supporting the above track density would require a close-loop servo bandwidth of about 4 kHz[1].

To achieve so high track density, one solution that can eliminate the small signal friction and provide higher bandwidth tracking ability is by using a dual-stage servo system, that is, a voice coil motor (VCM) as the primary stage and a microactuator as the secondary stage. The high bandwidth secondary stage combining with the primary stage will increase the whole system's servo bandwidth, thus achieve high track density in magnetic storage devices. Besides the high bandwidth requirement, the microactuator has to be small in size and simple in structure but yet be able to provide sufficient displacement with reasonably low control input. Many alternative designs of secondary actuators for disk drives have been reported in the literature [1]–[6]. The paper proposes a new planar piezoelectric secondary actuator and a piezoelectric suspension made of the planar piezoelectric actuator. A prototype of the piezoelectric suspension was fabricated and tested.

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II. HIGH BANDWIDTH PLANAR PIEZOELECTRIC ACTUATOR

Fig.1 illustrates the basic structure of a planar piezoelectric actuator. It is a single piece of piezoelectric rectangular plate polarised in the direction of its thickness and "d_{31}" operation mode is used. The upper and lower electrodes are split into two separate symmetric parts, between which there is one electrode crevice where no electrode is applied on the piezoelectric plate. The two half parts A and B can be poled either in the same direction or opposite to form the so-called parallel split-morph or anti-parallel split-morph. Shown in Fig. 1 is an anti-parallel split-morph.

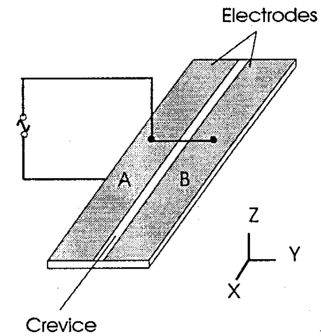

Fig.1. High bandwidth planar piezoelectric actuator.

As shown in Fig. 1, we designate the length direction of the planar piezoelectric actuator as x-axis, the width direction as y-axis and the height direction as z-axis. Under a driving voltage, one half part, for example, A, of the actuator will expand while the other half part, B, will contract. Thus, if one end of the actuator is clamped on a base, the deflection of the other end will be along the y-axis. Because the stiffness of the piezoelectric actuator in the y-axis is very high, we can expect a high first resonance frequency in this direction. This can be proved by the measured frequency response later. The displacement/voltage sensitivity and the resonance frequency of the actuator can be controlled by varying the dimensions of its length, width, and thickness.

III. Piezoelectric Suspension

In order to meet the head/media interface requirements and obtain high servo bandwidth, the design of the suspension and the gimbal assembly should be such that it is relatively soft in the vertical, pitch and roll directions and stiff in the in-plane directions. Therefore, one of the suspension design objectives is to increase the in-plane stiffness. In a hard disk servo mechanism, the driving direction of the secondary actuator should be in the track seeking or following direction, that is, perpendicular to the long axis of the suspension. As described above, the planar piezoelectric actuator just possesses this property so that it can be used to form a piezoelectric suspension, which can serve as both a part of the suspension to support the slider/head and a secondary actuator to provide rapid and accurate positioning to the recording head in the y-axis. Shown in Fig. 2 is a piezoelectric suspension. A 9mm×5mm×0.2mm planar piezoelectric actuator with d_{31}=171pC/N is mounted on the load beam of the conventional suspension (Hutchinson TSA850), and the slider is directly attached to the tip of the actuator through a gimbal. It should be noted that the actuator must be electrically isolated from both the load beam and the gimbal.

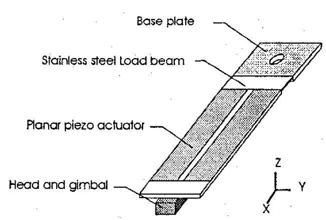

Fig. 2. Suspension made of a planar piezoelectric actuator.

IV. Experimental Results

Experiments were designed to measure the static displacement output and the dynamic response of the piezoelectric suspension. The experimental setup is shown in Fig. 3. Since LDV directly measures the velocity of the moving target, in this article we use the results of the velocity frequency response to analyze the actuator's dynamic performance.

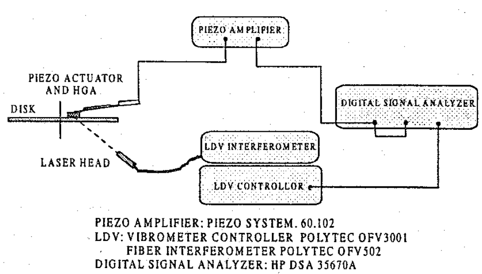

Fig. 3. Experiment setup for the dual-stage servo system.

Fig. 4 shows the displacement output of the piezoelectric suspension. With a ±20volts sine wave voltage at 1KHz, the displacement output on the slider is about ±1.0μm. Fig. 5 shows the velocity frequency response of the planar piezoelectric actuator with its one end fixed on a heavy base. The measurement is taken at the free end of the actuator. Its first resonance frequency is at about 9.5 kHz. Fig. 6 illustrates the velocity frequency response of the piezoelectric suspension with its base plate clamped on a heavy base. The slider flies over a rotating disk surface with a proper air-bearing created between the slider and the disk surface. At 2.1KHz, there is one small resonance peak, which is caused by the resonance of the slider and gimbal. A pair of resonance peak and valley occur at 6.3KHz and 10.6KHz, respectively, which result in about 180 degree phase shift. Comparing Fig. 6 with Fig. 5, the dominant resonance frequency of the piezoelectric suspension is reduced by about 3KHz. One reason for this reduction is caused by the existence of the relatively soft load beam. For a 30KTPI dual-stage servo system, the close-loop servo bandwidth is expected to be about 4KHz, thus for the resonance peak at above 6KHz, we can either use a notch filter to compensate it or design a controller to attenuate its effects.

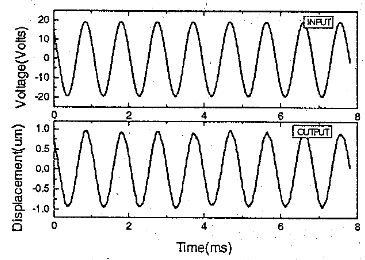

Fig. 4. Displacement output of the piezoelectric suspension.

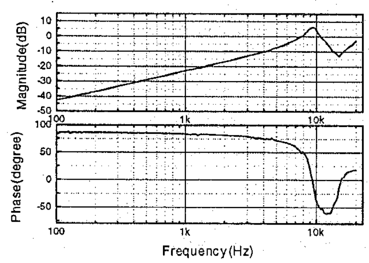

Fig. 5. Frequency response of the planar piezoelectric actuator.

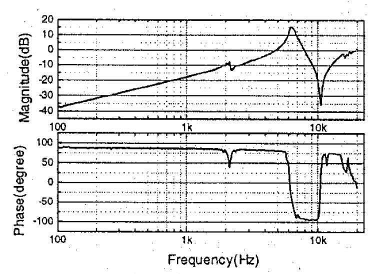

Fig. 6. Frequency response of the piezoelectric suspension.

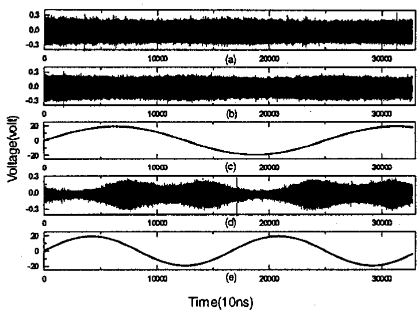

Fig. 7. Readback signal with the piezoelectric suspension: (a) No motion in the y-axis; (b) Motion in the y-axis with ± 20volts driving voltage at 4KHz; (c) 4KHz driving voltage; (d) Motion in the y-axis with ± 20volts driving voltage at 6KHz; (e) 6KHz driving voltage.

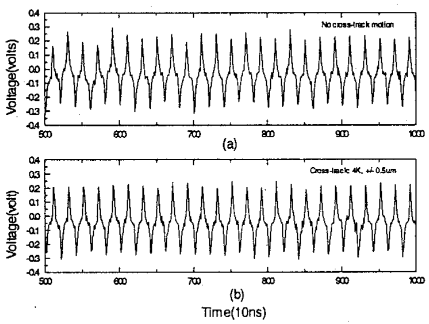

Fig. 8. Zoom-in view of the readback signals with the piezoelectric suspension: (a) No motion in the y-axis; (b) Motion in the y-axis with ± 20volts driving voltag at 4KHz.

Another experiment is designed to study the effect of the motion in the y-axis on the flyheight, that is, the read/write process. The piezoelectric suspension is clamped to the adapter of a GUZIK spinstand S-1701 and loaded on the surface of a disk rotating at 5400rpm. The head used in this experiment is a thin film head with 35Ω resistance. The write current is 20mA with a flux reversal frequency 20MFlux/Sec. The readback signals and the driving voltages of the piezoelectric actuator are recorded and illustrated in Fig. 7. Fig. 7(a) shows the readback signal with the piezoelectric suspension standing still. The small change in the amplitude may be caused by the fluctuation of the rotating disk. Fig. 7(b) is the readback signal with the piezoelectric suspension excited by a ± 20volts sinusoidal voltage at 4KHz, as shown in Fig. 7(c). And Fig. 7(d) is the readback signal with the piezoelectric suspension excited by a ± 20volts sinusoidal voltage at 6KHz, as shown in Fig. 7(e). In this experiment, the ±20volts voltage at 4KHz can generate ±0.5μm motion on the slider. Compared with Fig. 7(a), Fig. 7(b) has no obvious change in the amplitude of the readback signal. This proves that at this frequency the motion in y-axis has no obvious effect on the recording process. The zoom-in views of Fig. 7(a) and (b) are shown in Fig. 8(a) and (b), respectively. However, as shown in Fig. 7(d), the amplitude of the readback signal changes greatly with a driving voltage at 6KHz. From Fig. 6, there is one resonance peak at 6.3KHz. Since the driving voltage at 6KHz is near the resonance peak, it can excite a much larger motion in the y-axis than that at a frequency far away from the resonance frequency with the same amplitude. Therefore, it can make the recording head offtrack its track centre far engouh to greatly reduce the amplitude of the readback signal. Another possible reason for the fluctuation of the readback signal is the coupling of the motion in the y-axis to the z-axis, that is, the flyheight. To further study the coupling between the y-axis and the z-axis, we also measured the flyheight change with the piezoelectric suspension excited by a driving voltage at 6KHz. The measurement result shows that no obvious flyheight change is observed. It is concluded that the fluctuation of the readback signal with a driving voltage at 6KHz is mainly caused by the high offtrack motion in the y-axis and the coupling between the y-axis and the z-axis is negligible.

V. Conclusions

A high bandwidth planar piezoelectric actuator and a piezoelectric suspension, which can serve as both a conventional suspension to support the slider/head and a secondary microactuator to provide accurate and rapid positioning to the recording head, are designed, fabricated and tested. The first dominant resonance frequency of the piezoelectric suspension is at 6.3KHz. With a ±20volts driving voltage, the motion in the y-axis on slider is about ±1.0μm. Spinstand and flyheight tests prove that the effect of the motion in the y-axis on the read/write process can be negligible. The piezoelectric suspension can satisfy the basic requirements for the dual-stage servo system.

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