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DESIGN OF A DUAL STAGE ACTUATOR TAPE HEAD WITH HIGH BANDWIDTH TRACK-FOLLOWING CAPABILITY

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Introduction

In a typical tape head as shown in Fig. 1, the read/write heads are an integral part of the air bearing surface. The complete head is mounted on a bracket, which is connected to the movable coil of the voice coil motor (VCM). The read/write heads can be displaced laterally by the VCM. Alignment and stiffness is provided by a leaf spring on top of the head.

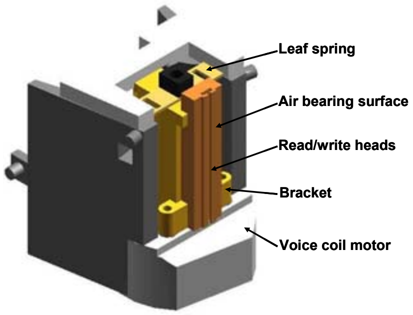

Fig. 1 Typical tape head

The lateral position of the head is controlled by a servo loop. During lateral tape displacement, an error signal is generated and the head is moved by the VCM to avoid track misregistration. However, the bandwidth of the VCM is limited, mainly due to mass and available power. LTM frequencies higher than the bandwidth of the servo actuator, generally referred to as high frequency LTM, cannot be followed by the servo actuator anymore. State-of-the-art tape head actuators have a bandwidth on the order of 750 – 1000 Hz.

Concept of a dual stage actuator head

The concept of a dual stage actuator was first introduced in hard disk drive (HDD) technology about 15 years ago. Mori et al. introduced a piezo (PZT) based rotary micro-actuator at the suspension level [1]. The VCM is used as a "coarse actuator", while the PZT is used as a "fine actuator". Different types of micro-actuator designs have been proposed in the literature. Koganezawa et al. designed a micro-actuator that operates at the suspension level of a hard disk drive using a flexural cross-shaped spring [2]. Instead of using "stacked"-PZT's, they used shear-mode PZT crystals [3]. Evans and Griesbach presented a piezoelectric micro-actuator design that takes into account manufacturability and economical considerations [4]. They modeled the dynamics of their design and presented two voltage drivers that can be used to drive the actuator. Nakamura et al. introduced a push-pull multi-layered piggyback PZT actuator that operates at the suspension level [5]. Their design features a high stroke, combined with a low voltage.

While most dual-stage designs are PZT-based, some researchers have attempted to manufacture electrostatic micro-actuators. Fan et al. implemented a milli-actuator, which is a micro-actuator that operates at the slider level instead of the suspension level [6]. A more in-depth analysis of the milli-actuator proposed by Fan et al. was presented in [7] by Hirano et al. Horsley et al. used parallel-plate capacitive electrodes to generate an electrostatic force, which was used to drive an actuator [8]. Finally, the design of an electromagnetic micro-actuator was investigated by Tang et al. [9].

This paper presents the design of a dual stage actuator tape head. Our approach attempts to increase the bandwidth of the servo loop, by introducing a second actuator stage, based on a piezo crystal (PZT). The second actuator stage serves as a fine-tuning mechanism that can follow high frequency LTM (> 750 Hz) but only offers a limited stroke. Increased servo bandwidth would allow an increase in track density, since track

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misregistration will be reduced. The main idea of this dual stage actuator tape head design is that the VCM would try to follow the low frequency LTM (< 750 Hz), while the second stage would attempt to follow the high frequency LTM (> 750 Hz).

Design of a dual stage actuator head

Fig. 2 illustrates the mechanical design of the new dual stage actuator tape head. Fig. 2 a) shows an isometric view, while Fig. 2 b) shows a side view.

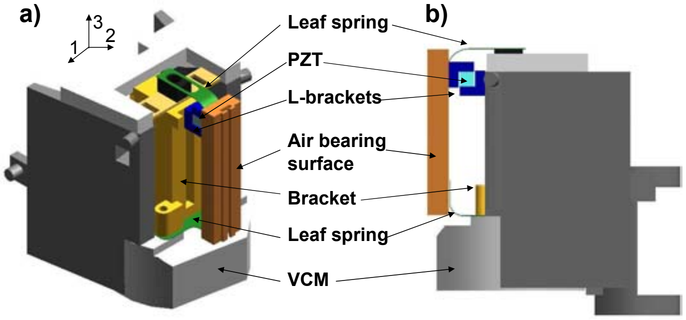

Fig. 2 Mechanical design of dual stage actuator tape head a) isometric view and b) side view

The design is based on the tape head shown in Fig. 1. Two L-brackets encapsulate a PZT transducer and form the micro-actuator which drives the second stage of the dual stage actuator tape head. The L-brackets and PZT were attached to each other and to the tape head bracket. Two leaf springs were positioned at the top and the bottom of the air bearing surface to provide alignment and stiffness. The leaf springs are very flexible to bend around axis 1 (see Fig. 2 a)), but inhibit bending around axis 2 and axis 3. Therefore, warping, torsion and other undesirable movement of the air bearing surface are excluded. The PZT is a 2 x 2 x 2 mm stacked crystal.

Dynamics

To determine the dynamic behavior of the PZT micro-actuator, the experimental set-up shown in Fig. 3 was used. A chirp signal was injected into the PZT micro-actuator, and the resulting displacement of the air bearing surface was determined with a laser Doppler vibrometer (LDV). The ratio of output and input signal, i.e., the ratio of the measured displacement and the input chirp signal, yields the frequency response function (FRF). The FRF is a transfer function, which expresses the response of a dynamic system to a given input as a function of frequency. The coherence function was determined for the FRF and found to be equal to one over almost the complete frequency spectrum. The coherence function is a measure for the quality of the FRF as a function of the frequency.

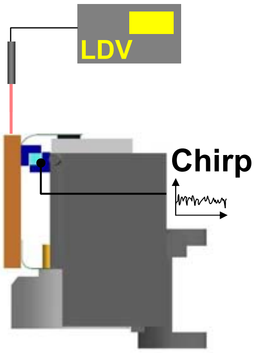

Fig. 3 Experimental set-up to determine the frequency response function

Fig. 4 shows the FRF for the case when the PZT micro-actuator was excited and the response of the PZT micro-actuator was measured. Hence, the dynamics of the PZT micro-actuator are revealed.

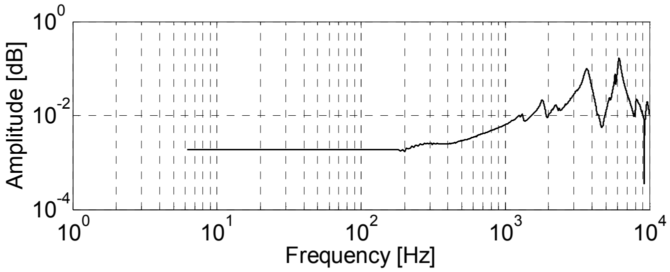

Fig. 4 Frequency response function

In Fig. 4 we observe a resonance peak followed by an anti-resonance peak around 190 Hz. This peak corresponds to the resonance frequency of the VCM. At 1.9 kHz another resonance peak, followed by an anti-resonance peak, is observed. This peak likely corresponds to the frequency where VCM and PZT micro-actuator are counter-acting each other. The resonance peaks at 3.6 and 5.1 kHz are likely eigenfrequencies related to the PZT micro-actuator.

Modeling

We have modeled the FRF using system identification techniques. We have fitted a 16th-order ARX model (Auto-Regressive with eXogeneous input) [10] to the experimentally obtained FRF, shown in Fig. 4. The results are displayed in Fig. 5. The experimental FRF is shown in solid line, while the fitted model is shown in dashed line. The details of the modeling are beyond the scope of this paper.

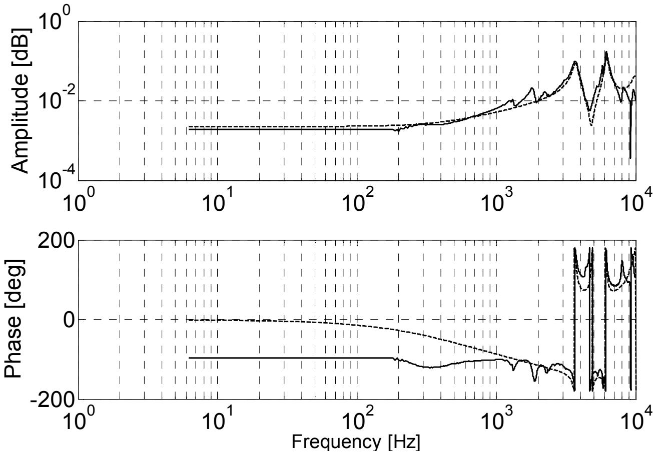

Fig. 5 Frequency response function; experimental (solid line), model (dashed line)

To evaluate the quality of our model, we have injected a position error signal (PES) from an LTO generation 2 commercial tape drive into the PZT micro-actuator, and measured the response of the air bearing surface with the LDV (using the same set-up as shown in Fig. 4). Since the PZT micro-actuator will serve as a fine tuning mechanism to track-follow LTM > 1 kHz, we have high pass filtered the PES > 1 kHz, before injecting it into the actuator. Next, we have injected the same high pass filtered PES into our model and simulated the response of the system. Fig. 6 shows both the experimentally obtained (solid line) and simulated response (dashed line) of the PZT micro-actuator as a function of time.

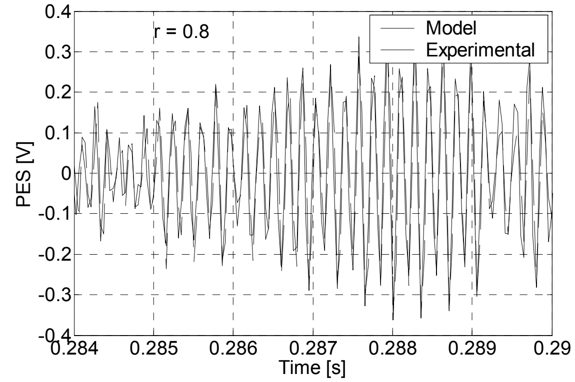

Fig. 6 PZT micro-actuator response; experimental (solid line), model (dashed line)

Comparing the experimentally obtained response with the simulated response, we observe very good agreement. We have calculated a cross-correlation coefficient between both responses of 80 %.

Conclusion

We have successfully implemented the design of a dual-stage actuator tape head for high-bandwidth track-following. The new dual-stage actuator tape head promises a significant increase in track density for future high-performance tape drives. The dynamics of the new actuator was found to be in good agreement with experimental results.

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