Effects of Slider-driven Piezo-microactuator Placements and Profiles on HGA Sway Mode

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ABSTRACT

With areal recording density of hard disk drives (HDD) historically growing at an average of 60% per year, it is becoming increasingly more difficult to maintain the precise positioning required of the ever-smaller GMR heads to read and write data. It is predicted that 100 Gb/in^2 HDD areal density would be probably delivered by 2003. To reach such high track densities, the lower mechanical disturbances and higher servo-control bandwidth is required. The dual-stage servo system has been considered as the most promising solution. The motivation of this work is to analyze the effects of the slider-driven micro-actuator placements and profiles on head gimbal assembly (HGA) microactuator sway mode. Results showed that the sway mode frequency was obviously increased by selecting micro-actuator placements and its profiles, optimally.

Keywords: Piezo-microactuator, Head gimbal assembly, Hard disk drive, FEM, Vibration

1. INTRODUCTION

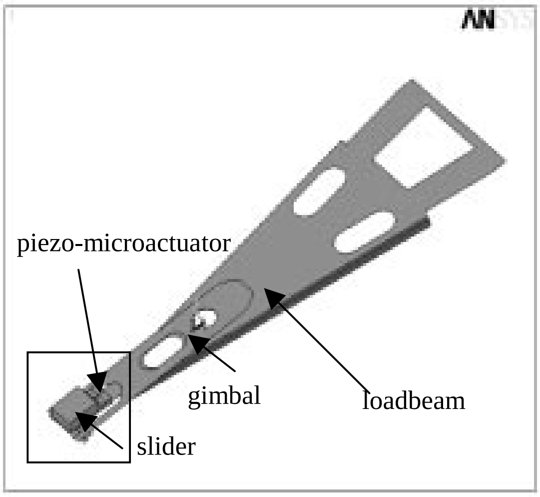
With areal recording density of hard disk drives historically growing at an average of 60% per year, it is becoming increasingly more difficult to maintain the precise positioning required of the ever-smaller GMR heads to read/write data. Following the same trend, it is predicted that the hard disk drives (HDD) with 100 Gb/in^2 areal density would be probably delivered by 2003 [1-2]. At this rate, the track density is expected to have 60,000 track per inch (TPI) and above. To reach such high track densities, the lower mechanical disturbances and higher servo-control bandwidth is required.

Currently, HDD use rotating disks to store digital data and recording heads are flying on the disk to read/write data. The recording heads are mounted on a slider-suspension-actuator assembly, which makes heads move from one track to another on the disk. The heads movement is controlled by close-loop feedback servo system. So far, the dual-stage servo system, that is, a conventional VCM as the primary stage and a microactuator as the secondary stage, has been considered as the most promising solution. To date, there are three possible microactuator designs for dual-stage servo systems: 1) suspension-driven, 2) head-driven and 3) slider-driven.

The motivation of this work is to analyze the effects of the slider-driven micro-actuator placements and profiles on head gimbal assembly (HGA) sway mode. This kind of microactuator is attached to a conventional slider, so we can continue to conveniently use the current thin-film magnetic head processing as usual. In this paper, a high performance piezo-microactuator for HDD is developed and optimized. Finite element modeling of the microactuator is based on the initial design by TDK [3]. The coupled finite element analyses using ANSYS package [4] were performed on the HGA model. The numerical results showed that the HGA micractuator sway mode frequency was obviously increased by selecting micro-actuator placements and its profiles, optimally. Vibration characteristics of HGA with the optimized piezo-micractuator can meet the design requirements for high performance HDD in future.

2. PIEZO-MICROACTUATOR STRUCTURE

The slider-driven microactuator in HGA is a piezo-microactuator. It is composed of 10 layers. The piezo-microactuator is sandwiched in between a slider and a gimbal, and drives the slider on which a read/write head is attached. Fig.1 show the schematic drawing of the HGA model with the microactuator. The micro-actuator consists of a fixed part bonded to the gimbal, a movable part bonded to a pico-slider and two piezoelectric stacked-layer beam parts which are used to induce a bending motion by one beam part contraction and other expansion. Thus, the movable part displacement and the head-slider track following motions are actuated by an applied electric field.



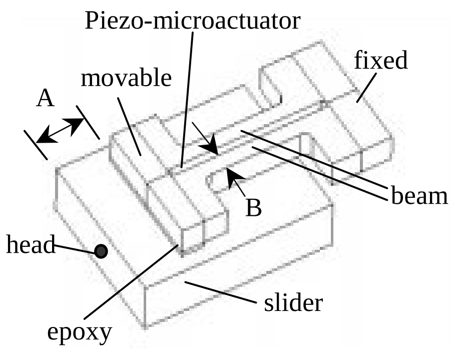


Figure 1: Schematic Diagram of the HGA with Piezo-microactuator

In this study, design targets are to get enough stroke (~1μm) and to keep the higher sway mode frequency. In a viewpoint of mechanics of system, the piezo-microactuator placements and its profiles are two important factors affecting such target performances. Due to the larger mass slider on the microactuator, it is expected that resonance frequencies of HGA drop down. Therefore, much higher resonance frequency of the head-slide piezo-microactuator is demanded . Based on the theoretical analysis of the micro-actuator, the two factors (A and B), as shown in Fig. 1, are investigated.

3. MODELING AND SIMULATION OF THE MICROACTUATOR

In the present study, the piezo-microactuator was modeled by four layer 8-node hexahedron coupled elements. The slider models were constructed using 8-node hexahedron solid elements. The model consists of 4264 elements and 5737 nodes. The FEM model of the actuator integrated with slider is shown in Fig. 2.

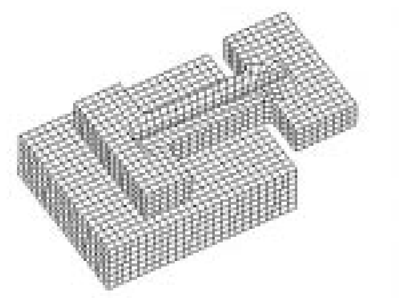


Figure 2: FEA model of slider-driven piezo-microactuator

The electromechanical coupling analysis for the microactuator was performed using ANSYS. A voltage of 5V is applied to each layer in the two pairs parallel beams. In modal analysis, ANSYS Block-Lanczos solver is used to compute its natural frequencies and mode shapes. Different design factor settings for the microactuator placements and beam width are concerned. The numerical results are listed in Table 2. It is found that the higher resonance frequency of sway mode and the enough stroke displacement of the head-slider piezo-microactuator were achieved when A and B were set at 0.6mm and 0.125mm. The overall displacement of the magnetic head attached the slider in track direction is equal to 2.0 times 0.541μm, that is 1.082 μm stroke displacement, which meets the design requirement for tracking accuracy in servo control. The corresponding sway mode frequency is 17.18 kHz. Thus, larger A is needed to keep enough stroke displacement. In meanwhile, a mean B is expected to achieve higher sway mode frequency. The stroke displacement of the microactuator for the optimal design is shown in Figure 3. The corresponding sway mode frequency and mode shape is given in Figure 4.

A (mm) \ B (mm)		0.1	0.125	0.15
0.6	Stroke	1.3 µm	**1.082** µm	0.928 µm
	Sway mode	13.46 kHz	**17.18** kHz	20.75 kHz
0.35	Stroke	1.076 µm	0.898 µm	0.77 µm
	Sway mode	14.57 kHz	18.40 kHz	21.97 kHz

Table 1: Results for different factor settings

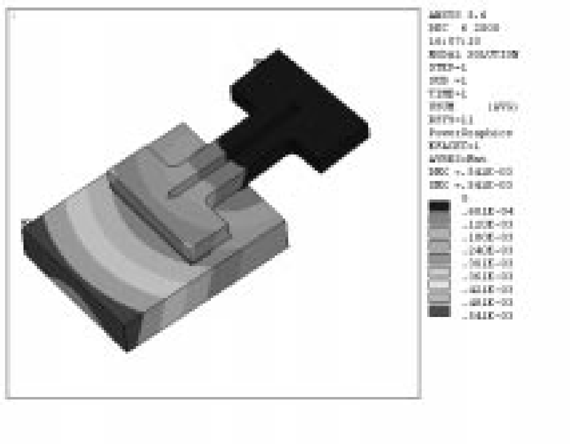


Figure 3: Tracking dispalcement of piezo-microactuator driven by applying 5 voltage

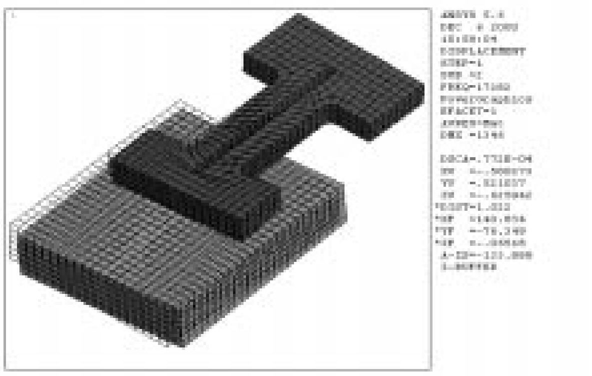


Figure 4: Piezo-micractuator sway mode frequency at 17.18k Hz

4. HGA SIMULATION

In order to investigate the effects of the microactuator placements and its beam width on the overall HGA vibration modes, we perform modal analysis of HGA with the piezo-microactuator using ANSYS. The current HGA consists of pico-slider, piezo-microactuator, gimbal and loadbeam. The gimbal is attached on the loadbeam by two or three weld points, the fixed part of the micractuator is glued on the gimbal tab by sharing four pairs of common nodes, whereas the dimple on the loadbeam is in contact with the gimbal tab. The slider is attached on the movable part of the microactuator. The loadbeam and gimbal materials are the stainless steel. The microactuator and pico-slider are made of piezoelectric and ceramic material Al_2O_3-TiC, respectively. Based on the geometric dimension, the loadbeam and gimbal were modeled by using shell element. The slider and microactuator were modeled by using the aforementioned element. The weld points were dealt with by coupling one or several nodes corresponding to the weld point with all of the degrees. The contact points were implemented by coupling corresponding nodes in vertical direction. In addition, the air bearing with spring stiffness is constructed at the trailing edge and the leading edge of the slider to emulate the head of HGA flying over rotating disk [5]. The whole HGA finite element model is shown in Figure 5.

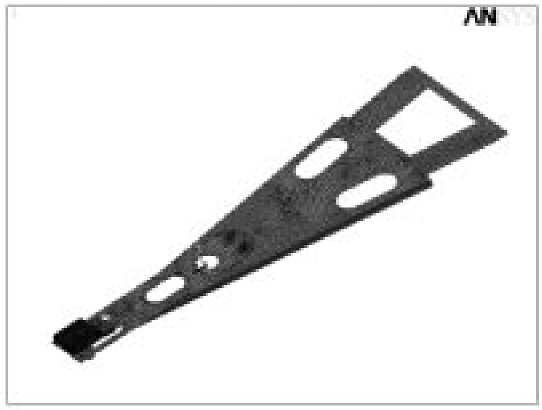


Figure 5: FEA model of HGA with piezo-microactuator

Some natural frequencies and modes of HGA obtained using ANSYS are list in Table 2. It is noted that only torsion and sway modes, which make a significant impact on the HGA tracking accuracy in servo control, are concerned. From the table, it is found that the microactuator sway mode frequency can increase 21% by selecting micro-actuator placements and its profiles, optimally. In meanwhile, other less than 12k Hz torsion and sway mode frequencies change a bit. It means that there is no significant influence on tracking accuracy of HGA except microactuator sway mode. The optimized sway mode shape at 14.09k Hz is shown in Fig.6.

No.	Description	Original	Optimized	Difference
1	Bending 1	1.3k Hz	1.29 k Hz	-0.7 %
2	Bending 2	2.95k Hz	2.93 k Hz	-0.7 %
3	**Torsion 1**	3.23k Hz	3.22 k Hz	**- 0.3 %**
4	**Sway 1**	4.30k Hz	4.15k Hz	**-3 %**
5	Bending 3	5.13k Hz	5.07k Hz	-1.2 %
6	Bending 4	6.38k Hz	6.37k Hz	-0.1 %
7	**Torsion 2**	8.11 k Hz	8.10 k Hz	**- 0.1%**
8	Bending 5	8.22k Hz	10.8k Hz	+30 %
9	Bending 6	9.17k Hz	9.17k Hz	0
10	**Sway 2**	11.76k Hz	14.09 k Hz	**+ 21 %**
11	**Torsion 3**	13.0k Hz	14.3 k Hz	**+ 10 %**
12	Bending 7	14.8k Hz	14.9k Hz	+ 7 %

Note: Original case is set at A=0.35mm and B=0.1mm

Table 2. Some comparisons of modes and frequencies between two cases

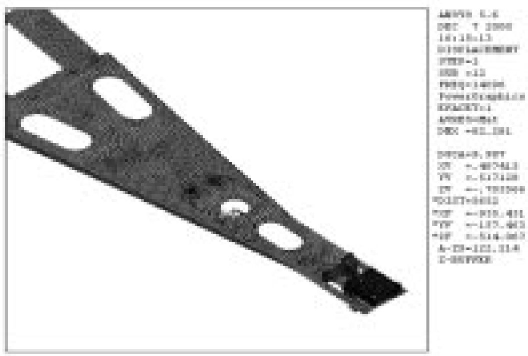


Figure 6: Sway mode shape at 14.09k Hz

5. CONCLUSIONS

This paper presents modeling, simulation and optimization of a high performance piezo-microactuator for HDD. Effects of the slider-driven micr-actuator placements and profiles on HGA sway mode are investigated. The displacement of the slider-driven piezo-microactuator under an applied electric field was computed using the coupled finite element analyses. The vibration frequencies and mode shapes of the HGA model are also obtained by ANSYS package. The simulation results demonstrate that HGA micractuator sway mode frequency is obviously increased by selecting microactuator placements and its profiles, optimally. At the same time, vibration characteristics of HGA with the optimized microactuator still meet the tracking accuracy requirements for high performance HDD.

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