Dynamic Modeling of the Resistance Heater Element in Thermal Flying Height Control Sliders

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***Abstract*—The dynamic model of a resistance heater element in a thermal flying height control slider is estimated based on step response measurements. The head-disk clearance is measured in two different ways: by only using the servo sectors and by only using the data sectors. A realization algorithm is used for obtaining a 2nd order discrete-time model of the heater element. Based on the model, the feasibility of high-bandwidth dynamic flying height control is discussed.**

Index Terms—**Dynamic Modeling, Realization Algorithm, Thermal Flying height control.**

I. INTRODUCTION

To increase the storage density in hard disk drives (HDD) beyond 1 Tbits/in^2, the flying height of the read/write head over the recording disk must be decreased to the order of a few nanometers. To maintain a low bit error rate during reading, flying height modulations of the head-medium interface have to be kept as small as possible while maintaining a minimum head-medium spacing. In recent years, "thermal flying height control sliders" have been introduced in commercial disk drives. These sliders feature a small resistance heater element close to the read and write elements. The heater allows adjusting the head-medium spacing in the region where the read write element is located. In future disk drives, the flying height will have to be dynamically adjustable in order to meet the lower flying height requirements and prevent the head from severe disk contact during operation. Approaches to dynamically adjusting the flying height have been made [1, 2]. The main requirements for dynamic control are an accurate head-medium spacing measurement and an accurate dynamic model of the thermal actuator. The model should be estimated on HDD-level to compensate for manufacturing tolerances and adapt to changing operational and environmental conditions.

A number of different ways to measure the head-disk clearance have been reported in the literature. The most popular technique among them is the triple harmonics method [2, 3] which will be one of the techniques used in this paper. Recently, a modified harmonics method that uses the servo information from the servo sectors was proposed [4]. Here, the clearance measurement sampling frequency is limited to the position error signal (PES) sampling frequency. We will show in this study how both methods can yield a 2nd order model that approximates the heater response very well.

II. EXPERIMENTAL RESULTS

All experiments were performed on a spin stand (Microphysics) at 7200rpm, radius of 25mm and 2 degrees skew angle. Fig. 1 shows a touch down experiment using the triple harmonics method for relative head-disk clearance measurement. It can be seen that the flying height decreases almost linearly as the heater power increases. In the close-contact regime, the static gain (slope of the curve)

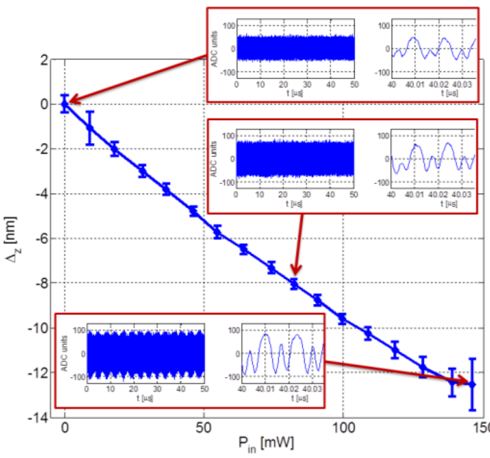

Fig. 1. Touch-down experiment: Relative head-medium spacing measurement (20 averages) and variance plotted with three corresponding read back signals.

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decreases drastically and the variance of the averaged measurement increases. At this critical flying height, slider vibrations at the air bearing frequency of 300 kHz can be observed in the read back signal (Fig.1). The dynamic measurements are performed in the region between 3nm to 7nm below the initial (at zero heater voltage) flying height. To identify the dynamics of the heater element a voltage step input of 2 volts was applied to the heater element for different bias voltages. Figure 2 shows the response measured using the servo sectors [4] at 15.36 kHz and Fig. 3 shows the response measured using the data sectors at 380 kHz. A dynamic model of the thermal actuator was estimated using a realization algorithm [5]. The simulated response using estimated 2nd order models can be seen in Fig. 2 and 3 as the solid lines. It can be seen that the estimated models are

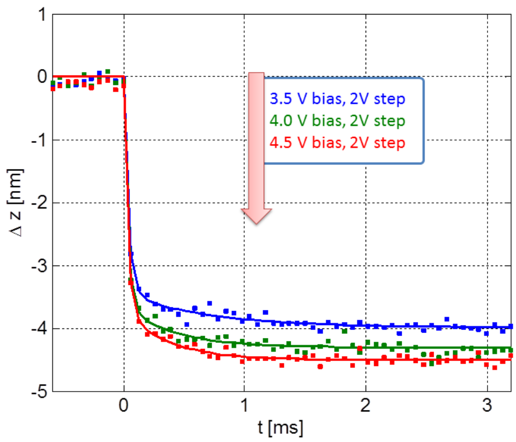

Fig. 2. Dynamic response of the relative flying height to voltage step inputs measured using the servo sectors [7] at a sampling rate of 15.36 kHz and estimated 2nd order model (solid lines).

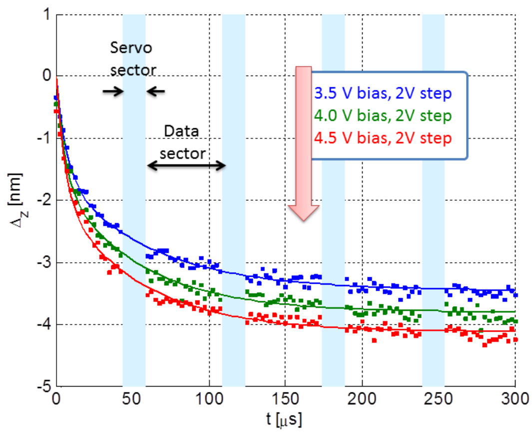

Fig. 3. Dynamic response of the relative flying height to voltage step inputs measured using the data sectors at an effective sampling rate of 380 kHz and estimated 2nd order models (solid lines).

in excellent agreement with the measurements. The Bode plots of the resulting continuous-time models assuming zero-order-hold are shown in Fig. 4. It can be observed that there is a small gain difference between both models at low frequencies due to the fact that after the 5 acquired data sectors (Fig. 3), the response has not completely settled (compare to Fig. 2). Furthermore, model sampled at higher frequency captures dynamics that are beyond the first Nyquist frequency at 7.68 kHz.

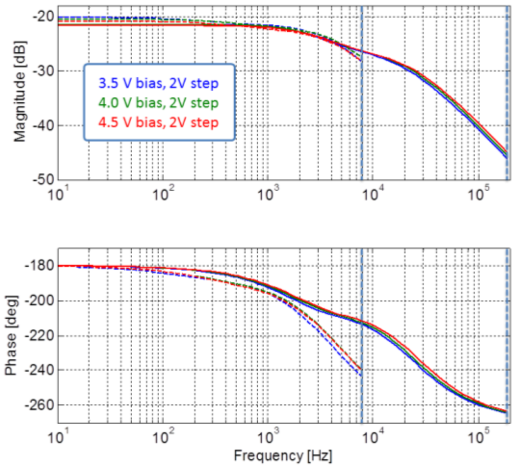

Fig. 4. Bode response of the resulting 2nd order continuous-time models assuming zero-order-hold for the 15.36 kHz (dashed lines) and 380 kHz (solid lines) estimated discrete-time models.

III CONCLUSION

In the close-contact regime the slider that was used in this study vibrates presumably at the air bearing resonance frequency. This feature can be helpful for contact detection. Furthermore, it was found that a second order model of the thermal actuator seems to be sufficient to capture the dynamics of the actuator. The fixed step number realization algorithm is straightforward and could be implemented in the firmware of the HDD. Based on the estimated models, the heater element seems to be capable for dynamic flying height control up to the several kHz regimes. Adaptive feed forward control is likely the most promising approach for dynamic flying height adjustment since the flying height variations appear very repeatable.

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