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# An experiment study of head-to-media spacing sensitivity in ultra-high density magnetic recording systems

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**Abstract**

The decrease in flying height due to the higher recording areal density of hard disk drives (HDDs) has had a huge impact on data storage technology. The head protrusion that induced by ambient temperature can further reduce flying clearance by a few nanometers. However, the head-disk interface reliability should be also emphasized; since when the head flies too close to the media, the recording head may be burnished. To investigate the head-to-media spacing sensitivity, we use the spin stand tester and analyze the sensitivity through the measurement of overwrite (OVW), micro-track profile (MTP), and signal-to-noise ratio (SNR). The experiment results imply the significant relationship between the OVW and the heater-induced writer protrusion (H-IWP). Furthermore, we verify that the properly reduction of head-to-media spacing can also enhance the both of writability and readability.


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*Keywords:* Flying height, magnetic head slider; temperature-induced head protrusion (T-IHP); readability; writability

## 1. Introduction

Currently, the rapid growth of recording areal density of hard disk drives (HDDs) absolutely requires a reduction in the flying height of magnetic-head sliders (a spacing between head and disk), which is approximately 2 nm. At a

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very low head-disk clearance, variations of the flying height for a half nanometer have an influential effect on the magnetic recording performance [1-2]. Practically, the flying height variations can be produced from many parameters such as a tolerance stack-up in manufacturing processes, the head protrusion that induced by ambient temperature, and write current in the writing process. Due to the ambient temperature directly affects to the head-disk clearance; therefore, when the ambient temperature was varied, the clearance will be also changed. Moreover, the head-disk clearance alternation is due to temperature-induced head protrusion (T-IHP), which induced by differences in the rate of thermal expansion of head materials as explained in [1-2].

To achieve the accurately target head-media clearance during writing and reading processes, a slider that consists of a heater near the read/write elements should be adjustable to achieve the appropriate head-media clearance [3]. The head deformation can be induced with the heating from the heater, which can move the read/write elements closer to the media. It is called heater-induced head protrusion (H-IHP), which consists of heater-induced writer protrusion (H-IWP) that used for varying heater during write i.e., the read clearance target is fixed, and heater-induced reader protrusion (H-IRP) on during read i.e., the write clearance target is fixed. This protrusion can significantly improve the potentiality in both of writing and reading processes of the perpendicular magnetic recording (PMR) system, especially at high density recording.

In magnetic recording system; however, there is a tradeoff between read/write performance and head-disk interface reliability. If the head flies too close to the media, the recording head may be burnished. Then, the active fly-height (AFH) control and contact detection measurement needs to be highly accurate. In this study; therefore, we have investigated the sensitivity of head-to-media spacing to the electrical performance of recording subsystem using the spin stand tester through the measurement of overwrite (OVW), micro-track profile (MTP), and signal-to-noise ratio (SNR).

## 2. Experimental Setup

The spin stand tester is used for this studying. The samples are tunneling magneto-resistance (TMR) heads were selected for testing. It is important to note that the heads used in this experiment are built in a form of head gimbals assembly (HGA). The 20 TMR example heads was selected to study. Here, an inner diameter (ID) radius with 5400 rpm was used for measuring all parameters at spin stand tester, the skew angle was fixed at -13.5 degrees, and the linear velocity is 317 inches/s. The nominal linear density is 2036 kfci corresponding to an areal density of 750 Gbit/in$^2$. Then, a head-to-media spacing (HMS) versus applied heater power were measured using the spin stand tester. The testing results can lead to calculate a head protrusion rate *(*$\Delta HMS$) and the head-media clearance without AFH. In this paper, we measure the head protrusion or H-IHP relied on Wallace spacing loss method with harmonic ratio technique given as

$$\Delta HMS = -\frac{v}{109.2 f_0}(\Delta dB_3 - \Delta dB_1), \tag{1}$$

here $v$ is the velocity of the written track, $f_0$ is the fundamental frequency of the written signal, and ΔdB1 and ΔdB3 are the spectral amplitude of the 1st and 3rd harmonic, respectively [4].

In this experiment, we define head-media contact by using the off-track behavior observation. First, we determine the close proximity of head and media from the position error signal (PES). Then, the positive PES ($PES_P$) and negative PES ($PES_N$) are measured when the head began moving from its center track to the right or left for 25% of a track width, respectively. At a very small clearance between the head and media (i.e., the head almost contact with the media), the difference between the $PES_P$ and $PES_N$, ΔPES, is defined as

$$\Delta PES = PES_P - PES_N, \tag{2}$$

which is significantly different because the head is off the track due to a sideway-contact force. When its difference is above the threshold, the head-media contact will be defined. In addition, the flying height of each individual head at zero heater power is determined from $\Delta HMS$ when the head contacts to the media. Finally, the electrical performance i.e., OVW, MTP, and SNR are measured at different HMS to calculate the HMS sensitivity in both during writing and reading processes, separately.