

THE SUSPENSION STUDY FOR DECREASING THE CLEARANCE OF HEAD
GIMBAL ASSEMBLY



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หัวข้อวิทยานิพนธ์	การศึกษาการปรับระยะการประกอบสไลเตอร์บนซัสเพนชันเพื่อปรับลดระยะการบินระหว่างหัวบันทึกกับแผ่นบันทึกข้อมูล
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บทคัดย่อ

ในการศึกษานี้ จะทำการศึกษาผลกระทบ ของระยะแนวแกนนอนของดิมเพล (dimple location X) บน ซัสเพนชัน ที่ส่งผลต่อระยะการบินระหว่างหัวบันทึกกับแผ่นบันทึกข้อมูล (clearance) การทดลองนี้จะทำการปรับระยะการประกอบสไลเตอร์ไปบนซัสเพนชัน หรือเรียกอีกอย่างว่าระยะแนวแกนนอนของสไลเตอร์ (x-alignment)

เครื่องทดสอบที่ทำการตรวจวัดคุณสมบัติทางไฟฟ้า ของการเขียนและการอ่านของหัวบันทึกข้อมูลจะรวมอยู่ในกระบวนการทดสอบระยะห่างของการบินในครั้งนี้ ซึ่งหัวบันทึกข้อมูลจะทำการทดสอบภายใต้ห้องสะอาดที่คลาสหนึ่งพัน (จำนวนอนุภาคน้อยกว่าหนึ่งพันต่อคิวบิกฟุตต่อนาที) หน่วยของระยะบินระหว่างหัวบันทึกกับแผ่นบันทึกข้อมูลคือนาโนเมตร สำหรับเครื่องทดสอบพินาเคิล ใช้สำหรับตรวจสอบระยะแนวแกนนอนของระยะตำแหน่งของสไลเตอร์กับซัสเพนชัน หน่วยที่ใช้วัดคือ มิลลิเมตร

ผลการทดลองจะ แสดงระยะการอ่านค่าของระยะห่างระหว่าง หัวบันทึกกับแผ่นบันทึกข้อมูล ตามทิศทางของสไลเตอร์ในแนวแกนนอน ซึ่งจะมีระยะที่เพิ่มขึ้นเมื่อระยะแนวแกนนอนของสไลเตอร์เคลื่อนที่ไปในทิศทางบวก และจะลดลง เมื่อระยะดิมเพลเคลื่อนไปในทิศทางด้านลบ อย่างไรก็ตามทิศทางความสูงในเชิงมุมในแนวแกนตั้งแกนนอน (PSA) และทิศทางของความบิดเอียง (RSA) ไม่มีส่วนที่นำมาศึกษาในการทดลองนี้

Thesis Title: The Suspension Study For Decreasing The Clearance of Head Gimbal Assembly

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ABSTRACT

In this study, the effect of Dimple x-location on suspension to Clearance is experimentally investigated. The experiment is set by varying the location of slider placement along the suspension, called Slider x-Alignment. A Contact Spin Stand (CSS) tester is used to measure electrical parameter of read/write performance of Head Gimbal Assembly (HGA) which is included the clearance test. Head Gimbal Assembly (HGA) is tested at class 1000 cleanroom (< 1000 particles/cubic foot/minute). The unit of Clearance is "nanometer". The Pinnacle tester is used to confirm the Slider x-alignment position along the suspension, the unit of Slider x-alignment is "millimeter". The experimental results showed that the Clearance reading follows as Slider x-alignment direction, i.e., Clearance increases when the Slider x-alignment moves to the positive direction and the clearance decreases when the Dimple x-location moves to negative direction. However, Pitch Static Attitude (PSA) and Roll Static Attitude (RSA) are not contributed in this study.

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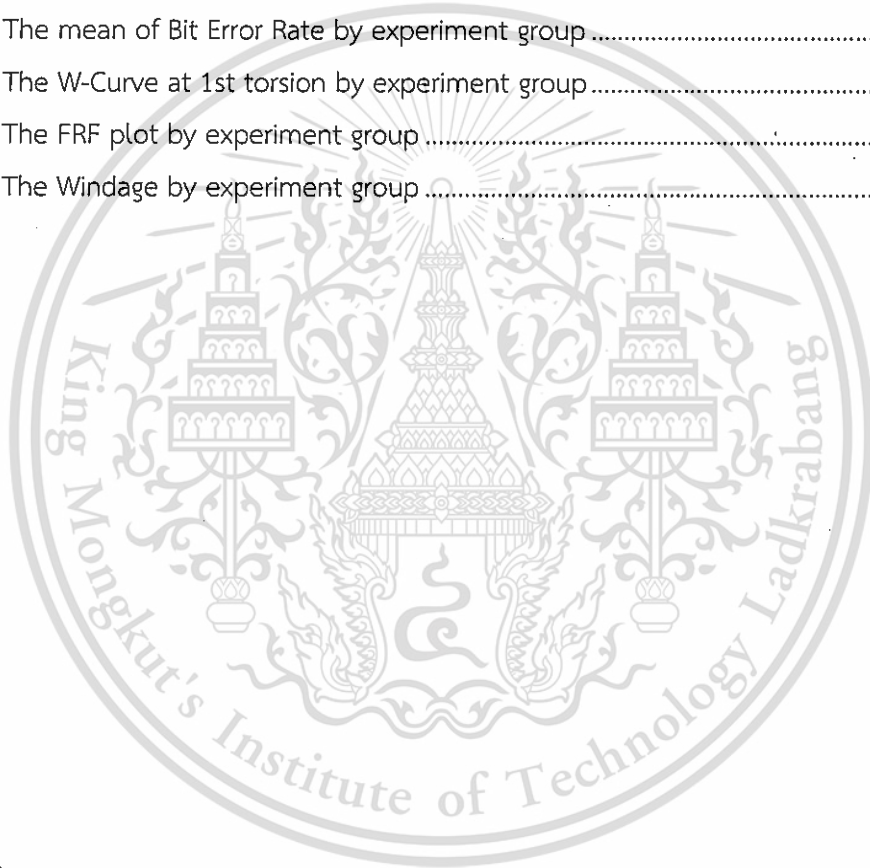
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CHAPTER 1

INTRODUCTION

1.1 Background and Problem Statement

Hard Disk Drive (HDD) is important equipment of data storage devices for computer and consumer electronic systems. In another words called ,“Hard Disk“, “Hard Drive” or ,“Disk Drive“. It has been used for storing and providing the quick access to large data on an electromagnetic charged surface or set of surfaces [7]. The components inside Hard Disk Drive (HDD) consist of a rotation disk, motor servo and Head Stack Assembly (HSA). The disk or platter is an imagination like a phonograph records which has data recorded electromagnetic in concentric circle or in another hand called “Tracks”. The Head Stack Assembly (HSA) is composed of the Actuator Arm and the Head. The Head Gimbal Assembly (HGA) is the subset of Head Stack Assembly (HSA), consisting of slider and stainless steel suspension. It was called ,“head“. A ,“head “was recorded (Write) or reads the information on the track of the disc. Each side of a disk has a head which reads or writes the data when the disk spins. The rotation spindle speed is varied from 5400 – 7200 rpm. When the disk rotates with spindle speed, the head is flying above the disk.

Figure 1.1 shows HDD structure focusing on the mechanical parts. Inside the HDD, there are platter or disk, spindle, actuator, actuator axis, actuator arm and the head.

Figure 1.2 shows the HDD innovation from the past to the current date. In the picture, it has a ruler (scale) to show the length of platter and the size of read/ write head. The HDD keeps small and smaller every year. It means, all components of HDD are physically decreased including the size of head [8].

As previous explanation, when the disk rotates with spindle speed, the head is flying above the disk. With this, the gap between the head and the disk is occurred, called “Clearance” or “Fly height” or “CHIRP (Contact Heater-Induced Reader Protrusion).

A gap between the head and the disk or in another hand called “clearance” is verified as one of various factors effected to the recording density, small gap reported high recording density while large gap was opposite direction.

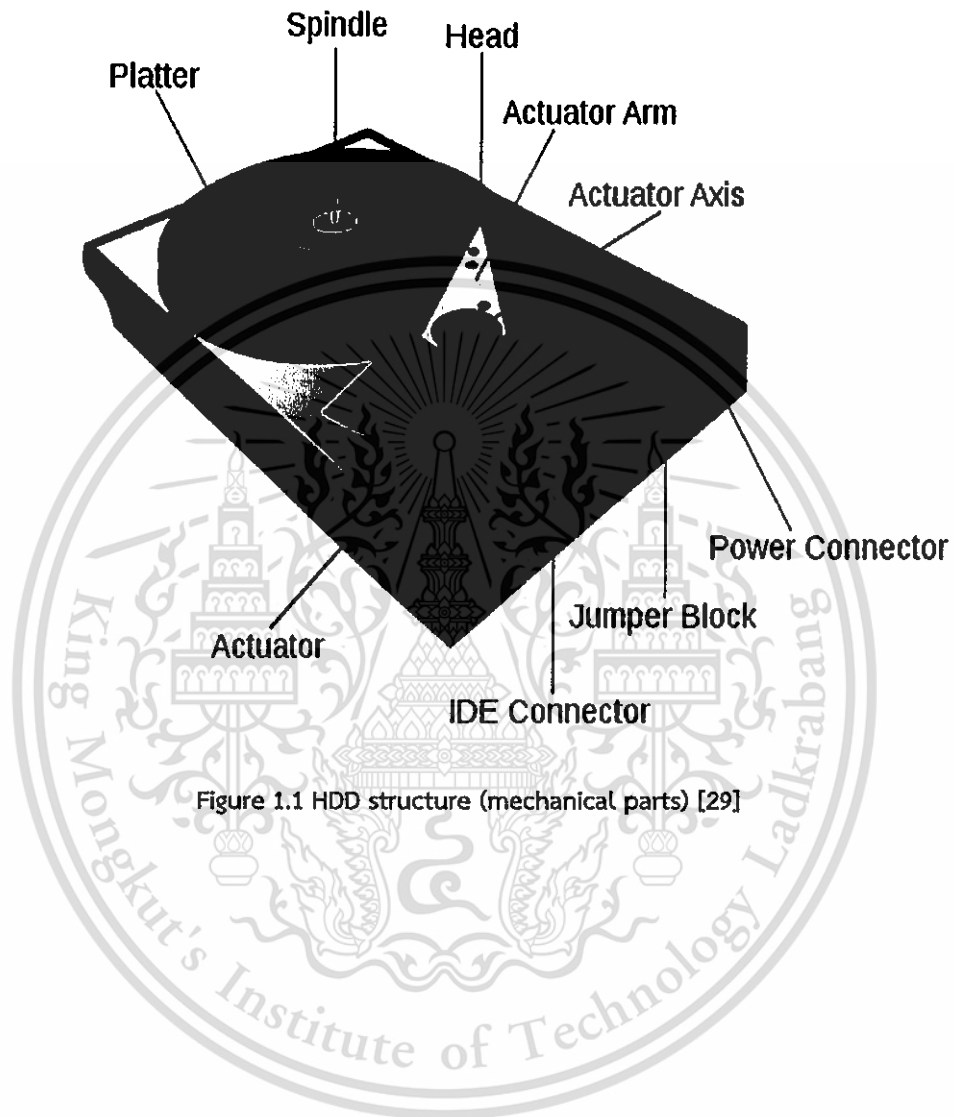


Figure 1.1 HDD structure (mechanical parts) [29]



Figure 1.2 8-, 5.25-, 3.5-, 2.5-, 1.8- and 1-inch HDDs, together with a ruler to show the length of platters and read-write heads [30]

1.1.1 What is Clearance?

Clearance is the minimum spacing between head and Disk as in Figure 1.3. To improve the read/ write ability, the spacing between head and disk must be reduce. However, the gap measurement is very important for Head Gimbal Assembly (HGA). Nowadays, the gap has been achieved in nanometer space. In the past, the Fly height measurement was tested with Dynamic test flying over the disk. With this measurement, it causes to physically scratches at the slider surface. The reason is shown in Figure 1.3 the roughness of disk can cause scratched slider surface.

To prevent the scratches of slider and disk, the new technology of clearance is explored and called “CHIRP”, (Contact Heater-Induced Reader Protrusion). It has been a static test. The new clearance concept is to apply the heater power into the head, when

heater on the writer and reader will be protrusion. It is measured when the close point is in contact with the disk.

In the other hand, the clearance is the distance of the reader protruded toward the disk before some parts of the transducer hit the disk. By this, it would help reducing overall part to part variation by allowing all heads to operate with more similar write and read Head Media Spacing (HMS).

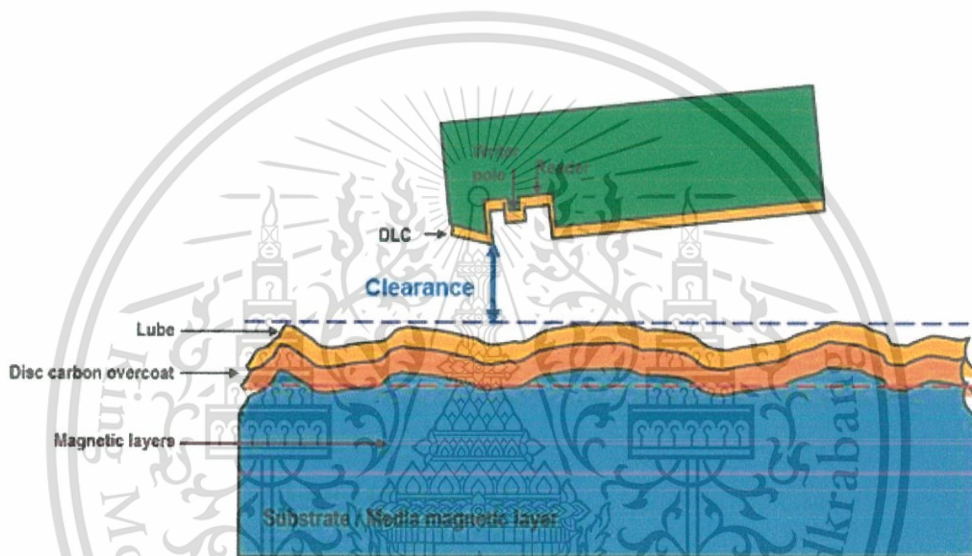


Figure 1.3 Cross section image of disk and head showing Clearance position [2]

Moreover, since the recording density of HDD keeps increasing every year. To increase the density rate, several studies have focused on head design and innovation of technology development. However, some studies have also physically focused on the mechanical side of Hard Disk Drive (HDD) system. The mechanism between Head Gimbal Assembly (HGA) and disk must be reduced until it eventually reaches contact recording. The mechanic lower gap becomes high signal ratio and results with high density [1]-[2]. The reduction between head and disk is critical for mechanical design which must have the gap less than 10 nm. The head which flies less than 3 nm causes scratches / damages on the disk and head degradation [3]. Simulation studies focusing on the suspension area to decrease the gap between head and disk have been reported [1]-[7].

The coupling vibration of air bearing slider and suspension system affecting the slider flying ability and head position have been investigated at several states[15],[17]. The contact/friction force on the dynamics of slider air bearing, the suspension vibration and the dimple gimbal interaction force are characterized and they affect surfing states. A new design was for reducing the interaction force at surfing states [4].

However, few studies have been completed on the suspension area for decreasing the clearance at Head Gimbal Assembly (HGA). Many components of suspension factors affect the clearance, including suspension stiffness, size of the dimple suspension and position of the dimple at suspension. Thus, the purpose of this study is to investigate the effect of dimple x-location of suspension area which may decrease the clearance of Head Gimbal Assembly (HGA). This study may lead to a better understanding of dimple x-location to the clearance at Head Gimbal Assembly (HGA). It is hoped that information from this study may be useful in the suspension design.

1.1.2 What is the Head Gimbal Assembly (HGA)?

Head Gimbal Assembly (HGA) is composed of stainless steel suspension and slider mounted together by using glue and gold. Physically, it uses to hold the read / write head on the disk. Electrically, it uses to carry the electrical signal from the head to the pre-amplifier and vice-versa. In the fly ability, it is the component which allows the head to follow the contours of disk without contacting it.

Figure 1.4 shows the overview of HGA separated by top side view and disk side view. The Flex circuit was used to connect into the gold bond pad of the slider to connect the electrical circuit for read/ write signal. The baseplate and load beam was made from stainless steel used for holding slider and flexure during hard disk operated.

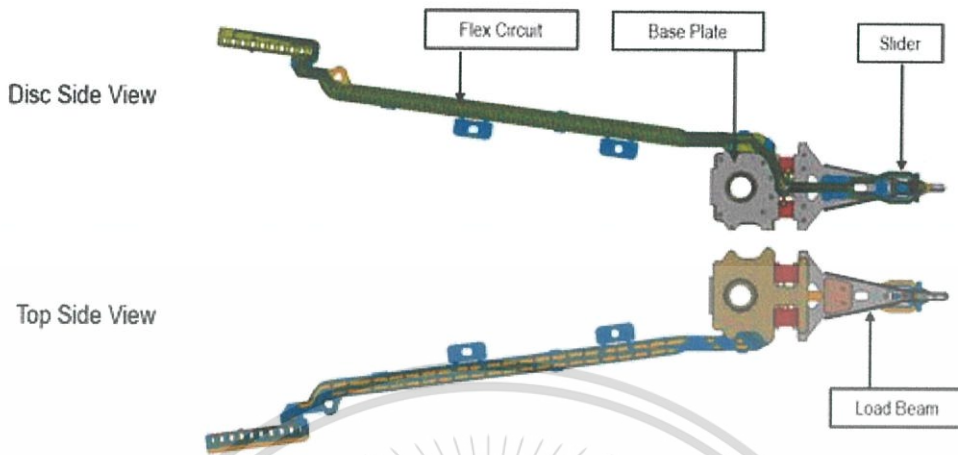


Figure 1.4 The image of Head Gimbal Assembly and Dimple position

1.1.3 What is the Dimple?

Figure 1.5 shows the overview of Head Gimbal Assembly (HGA), consisting of Slider, suspension (Flexure) and indicated location of dimple at the suspension. The dimple is located at the back side of slider, between slider and baseplate. The dimple transfers the load beam preload down to the slider through a point contact. The dimple is located at the center of slider to minimize any induced roll or pitch torque.

Figure 1.6 shows the dimple direction schematic of Head Gimbal Assembly (HGA), (a) down tab mean the head is located under the disk and (b) up tab mean the head is located above the disk.

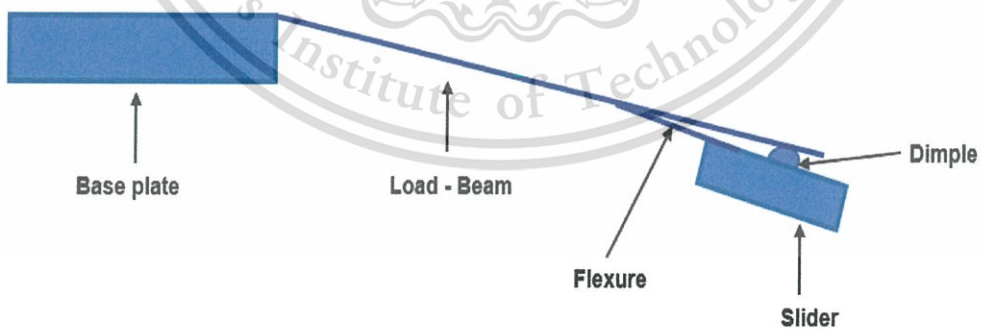


Figure 1.5 The image of Head Gimbal Assembly and Dimple position

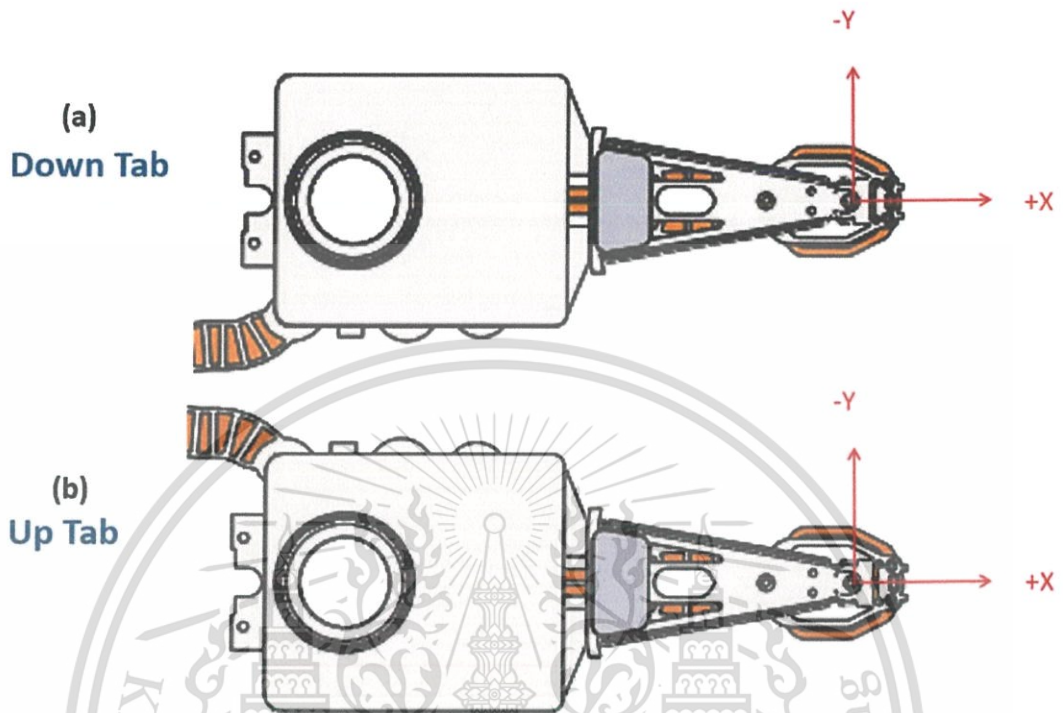


Figure 1.6 Typical Dimple Direction Definition Schematic, (a) head located under the disc (b) head located above the disk [2]

1.2 Objectives

1.2.1 To study the dimple location at the suspension can cause of the clearance of Head Gimbal Assembly (HGA) change.

1.2.2 To understand the relation between distance of dimple location and the clearance change.

1.3 Scope of work

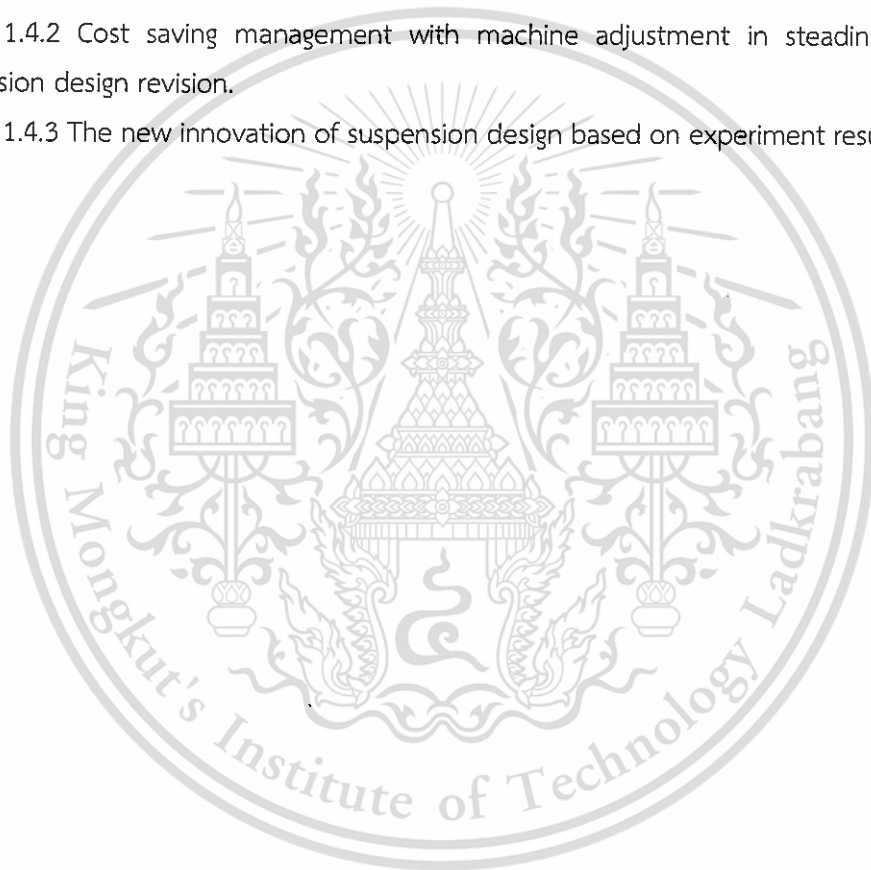
Focus on the dimple location of the suspension area of Head Gimbal Assembly (HGA) by varying the slider placement with different locations along an x-axis direction.

1.4 Expected Benefits

1.4.1 To understand the effect of dimple location at x-direction to clearance of Head Gimbal Assembly (HGA).

1.4.2 Cost saving management with machine adjustment in steading of new suspension design revision.

1.4.3 The new innovation of suspension design based on experiment results.



CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 Literature review

Literature review summarized the researches on the effect of the suspension to the clearance of Head Gimbal Assembly (HGA). There are several research papers that studied at the slider Advance Air Bearing (AAB) design to see the Fly height affected. As far as I can see, in term of suspension affected to the clearance of Head Gimbal Assembly (HGA), the researchers have been trying to study and focus on the vibration in various conditions. Moreover another group of researchers had proposed with new suspension design development.

In 2006, Kuwajima, Kita, Hashi, Miyamoto, Ueno and Matsuoka [9] proposed a novel shockproof head gimbal assembly (HGA) structure by using a “balanced-type head suspension” for 0.85-in hard disk drives (HDDs) with the size of 32 x 24 x 3.3 mm³, after then, they are investigated performance on external shock resistance during read/write operations of HDDs. It was used for supporting mobile device application. The comparison between conventional suspension and balanced- type suspension is shown in Figure 2.1. The concept for improving from conventional suspension to balance – type suspension is lighten the equivalent mass of the suspension and increase the spring mode of the suspension. In Figure 2.1(b), the balance-type suspension has three main characteristics:

- (1) The slider was supported by an actuator arm for substantially as a rigid body.
- (2) The actuator arm was pivoted on the pivot for providing the freedom of rotation in a direction out of the disk, the reaction force was generated by springs which can prove that it is large enough to support the arm under high shock.
- (3) The balance mass of VCM coil with resulting in the center of gravity of the movement part.

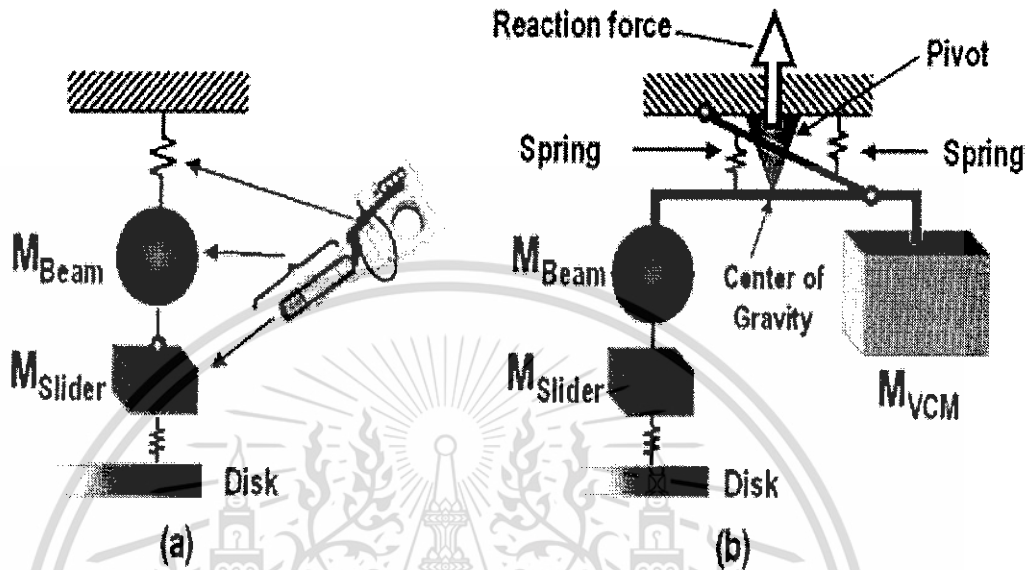


Figure 2.1 Fundamental dynamic models of (a) the conventional suspension and (b) the balanced-type suspension [9]

Figure 2.2 shows the design concept of the balanced – type suspension which considered of a mechanical can rotationally support the arm with high rigidity and a means for applying the spring load bias the arm by constantly toward the disk surface. Figure 2.2(a) shows load Free State, the leaf spring was flat without force bias applied. Figure 2.2(b) the pivot presses the arm downward, then, the pivot and leaf spring are relatively down and end of the head slider move down to the disk.

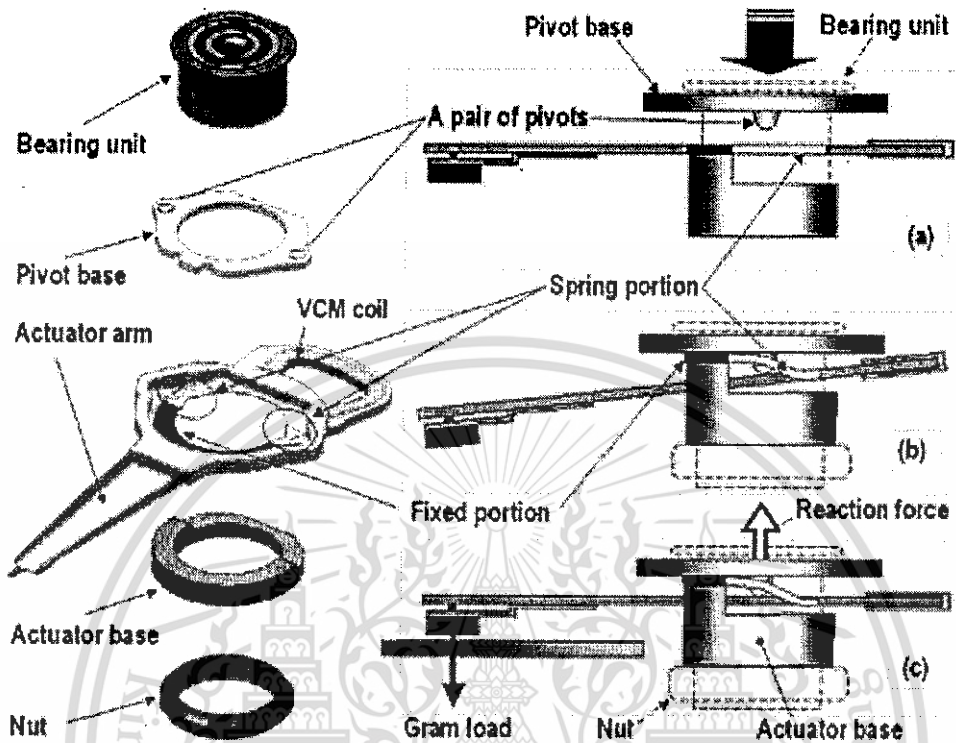


Fig. 2.2 Tangible configuration of the balanced-type suspension [9]

In Figure 2.3, it shows the result on the resonance mode using the finite-element method. All four modes, first - third bending mode and first torsion mode have high enough considering frequency responsibility.

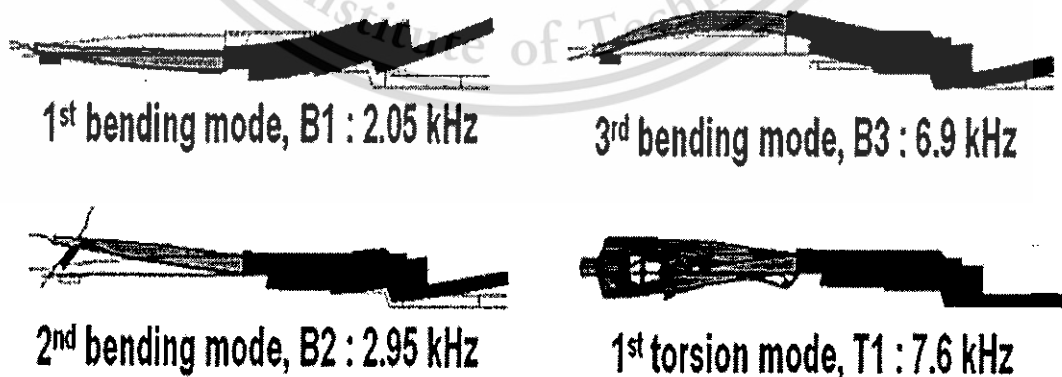


Figure 2.3 Resonance mode analysis [9]

In Figure 2.4, it shows the drop impact test, it was used to qualitatively confirm the arm behavior itself to external shock. The results showed that higher than 1.0 ms duration the tip portion is very small.

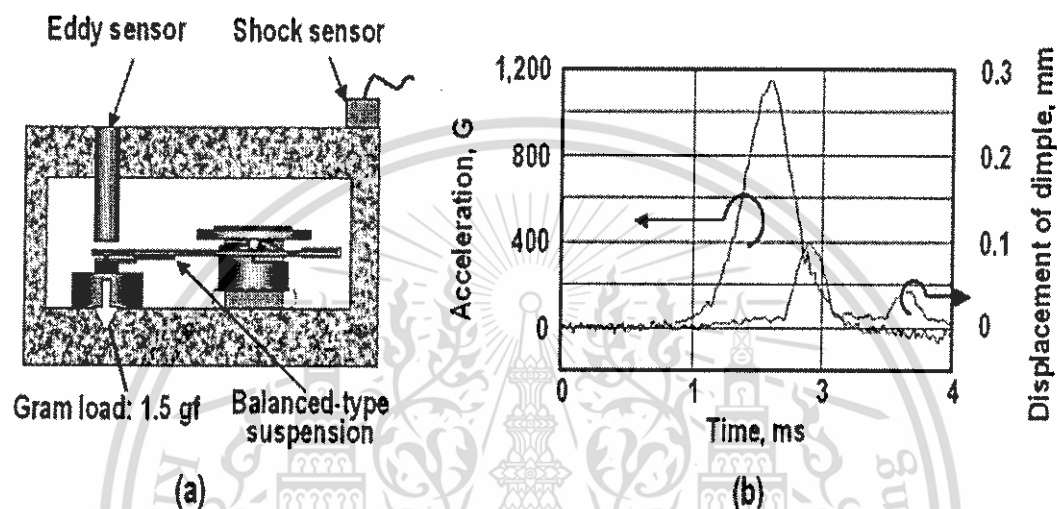


Figure 2.4 Drop impact test method at the actuator component device level. (a) Schematic illustration of a testing unit. (b) Example of detected acceleration and displacement of dimple.[9]

They concluded that the new suspension design did not induce any disk surface defects. They also strongly concluded that the main resonance frequency was found to be 8 kHz and had no serious problem to off-track performance.

In 2008, Shiramatsu, Atsumi, Kurita, Shimizu and Tanaka [10] developed a thermal flying-height control (TFC) slider with carrying a micro-thermal actuator. Previously, the TFC slider was controlled by a constant power supply for the heater. In their research, the focusing area was on the write current induced thermal protrusion which assumed that it was the largest obstacle in reducing the flying height. There are focused to demonstrate dynamic control of the TFC slider to compensate for high-speed magnetic signal modulation using feed-forward control methods as shown in Figure 2.5 for the concept of TFC.

Their experiment method was set up as Figure 2.6. There are the magnetic disk and head slider, set in a read/write spin stand that consists of spindle and read/write function unit. The magnetic signal of TFC was measured by a magnetic signal detector and an oscilloscope. The magnetic signal detector is a device used for measuring the fluctuation time of read back signal frequency.

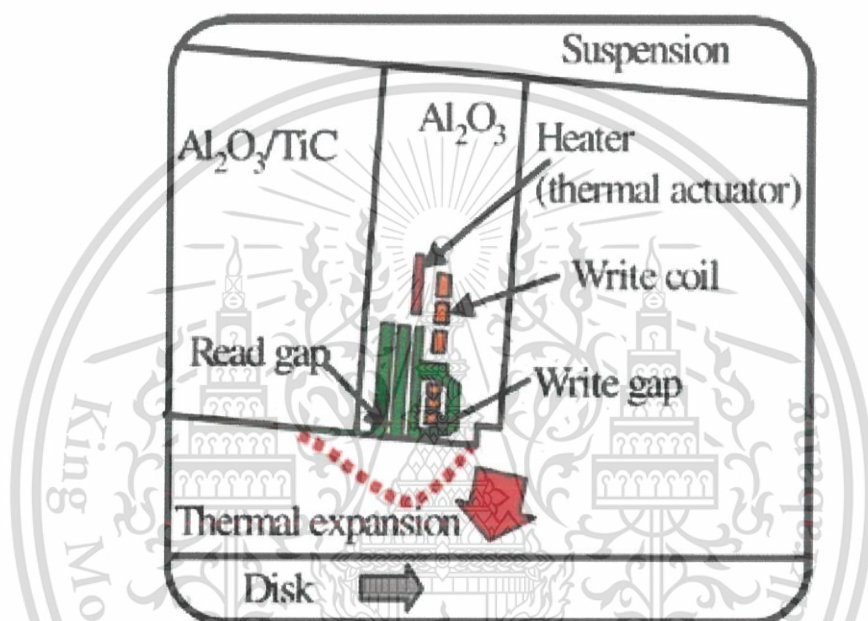


Figure 2.5 Concept of TFC [10]

An experiment was started from writing the magnetic pattern on the disk, then, measured the magnetic signal moderation without TFC compensation. After that, they calculated the heater input waveform by using the result from the without TFC compensation. For the final results, they measured the magnetic signal again with dynamic TFC compensation.

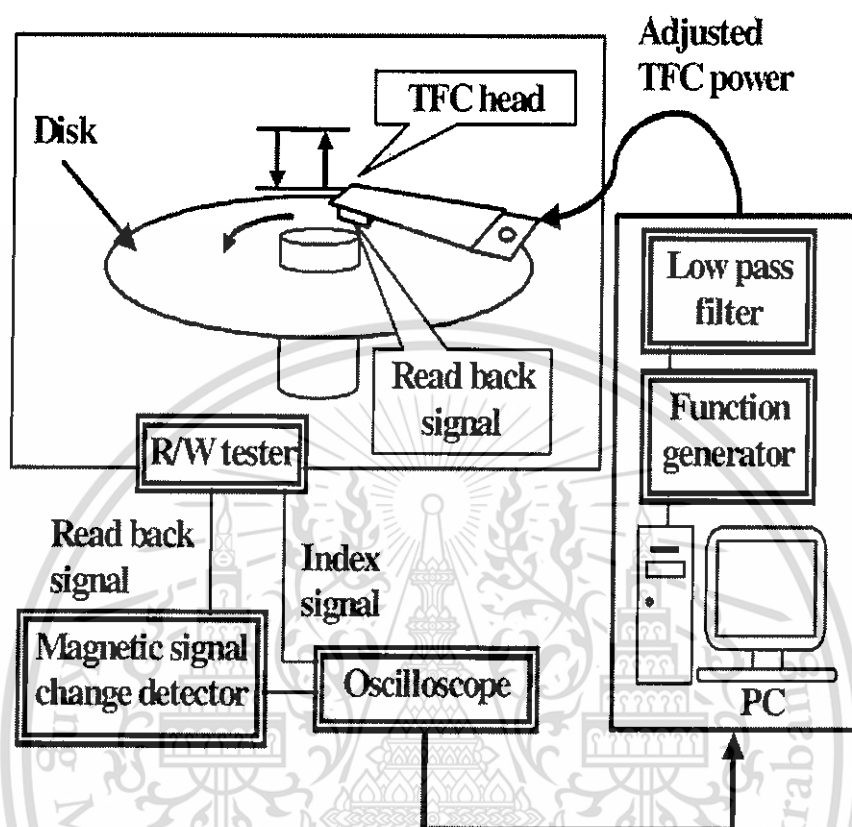


Figure 2.6 Experimental set up [10]

They have two methods for this studied. The first method, the TFC power was adjusted by using tune domain information. The second method, the TFC power was adjusted by using frequency domain information at addition to time domain information.

The results of their experiment were shown in Figure 2.7-2.9. They are focused on the average magnetic signal modulation at 3-sigma comparing each other. Figure 2.7 shows magnetic signal modulation without TFC compensation while Figure 2.8 and Figure 2.9 illustrate the first and second methods, respectively. They were concluded that the second method was better than the first method regarding to average of magnetic signal, which was reduced from 38 mV (without TFC compensation) and 22 mV (the first method) to 18 mV (the second method).

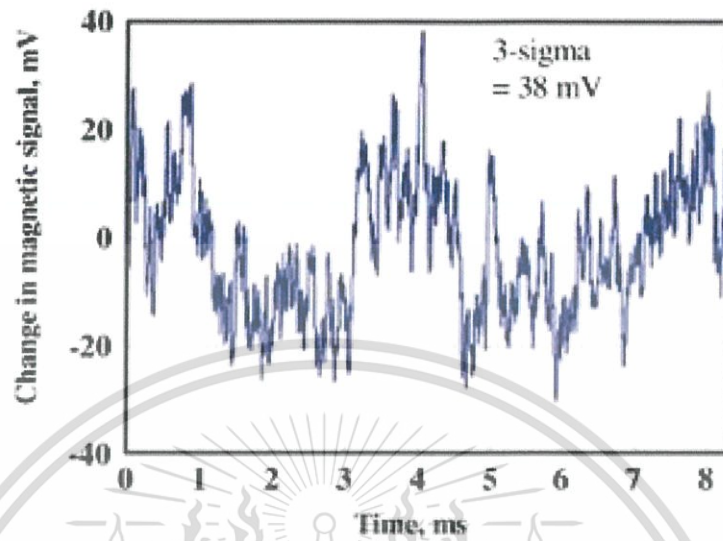


Figure 2.7 Magnetic signal modulation without TFC. [10]

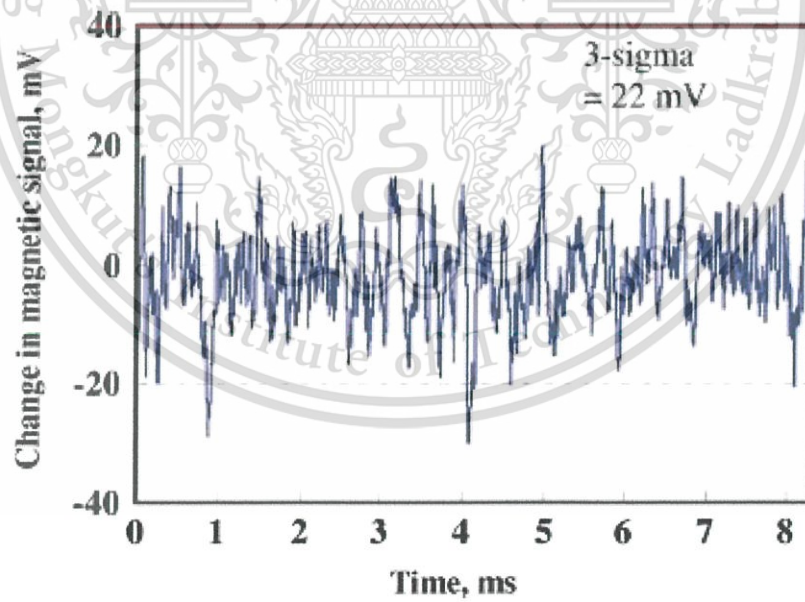


Figure 2.8 Magnetic signal modulation during the operation of first method. [10]

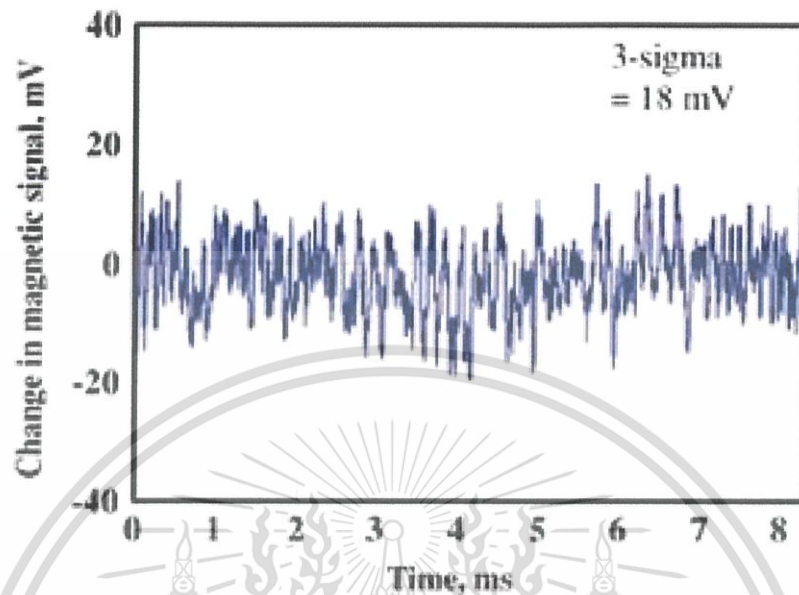


Figure 2.9 Magnetic signal modulation during the operation of second method.[10]

They were confirmed by using the FET analysis, the result is show in Figure 2.10 – 2.11. The results shows that second method was better reduction than the first method, especially in the frequencies from 2 to 5 kHz. They were concluded that the dynamically controlled TFC slider is possible to compensate kilohertz order magnetic signal modulation.

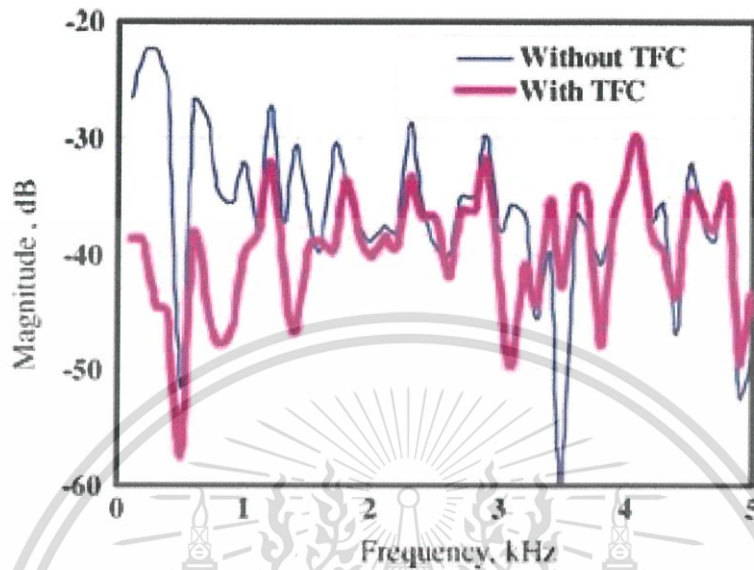


Figure 2.10 FET analysis of the first method [10]

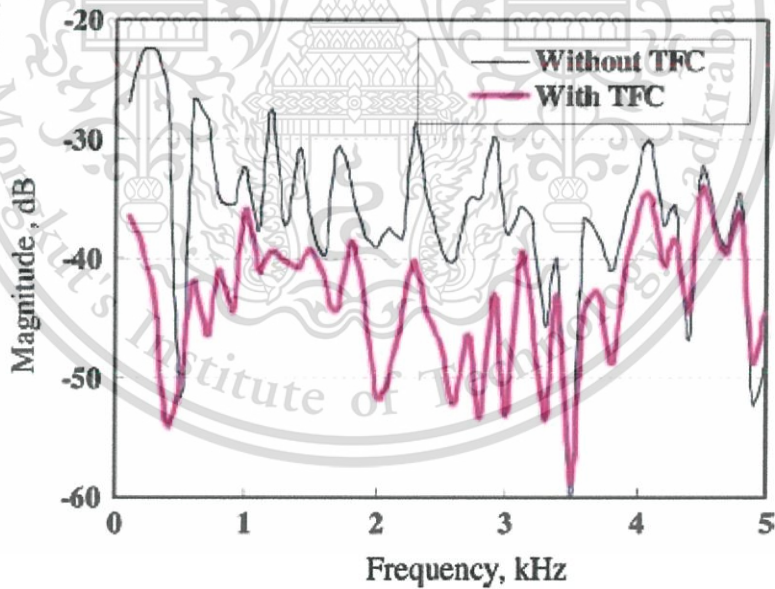


Figure 2.11 FET analysis of second method [10]

In 2010, Park, Lim, Park, and Park [12] studied the dimple – flexure slip phenomenon which was induced by the ramp contact of suspension that could affect the

load / unload performance and load / unload area. In these studies, they have focused on the reduction of load/ unload area at outer diameter (OD). They used finite element model for ramp contact in load / unload process and analyzed the sensitivity of dimple flexure slip phenomenon. The focused parameters are ramp contact position and suspension load beam stiffness. They fabricated ramp component with three kinds of material and characteristics of dimple flexure slip in according to different ramp material and angle study.

Their FE model is commercial software at 2.5 inch HDD head gimbal assembly (HGA). The length is 15.6 mm and the ramp contact position is far away 15.3 mm from pivot center of the HGA. They used the surface friction model for referencing the interaction between the dimple and the flexure. They applied the contact force at the ramp contact point instead of rotating HGA to simulate the ramp contact behavior of unloading process as shown in Figure 2.12. The contact force they applied are 24mgf in the off track and 80mgf in the vertical direction.

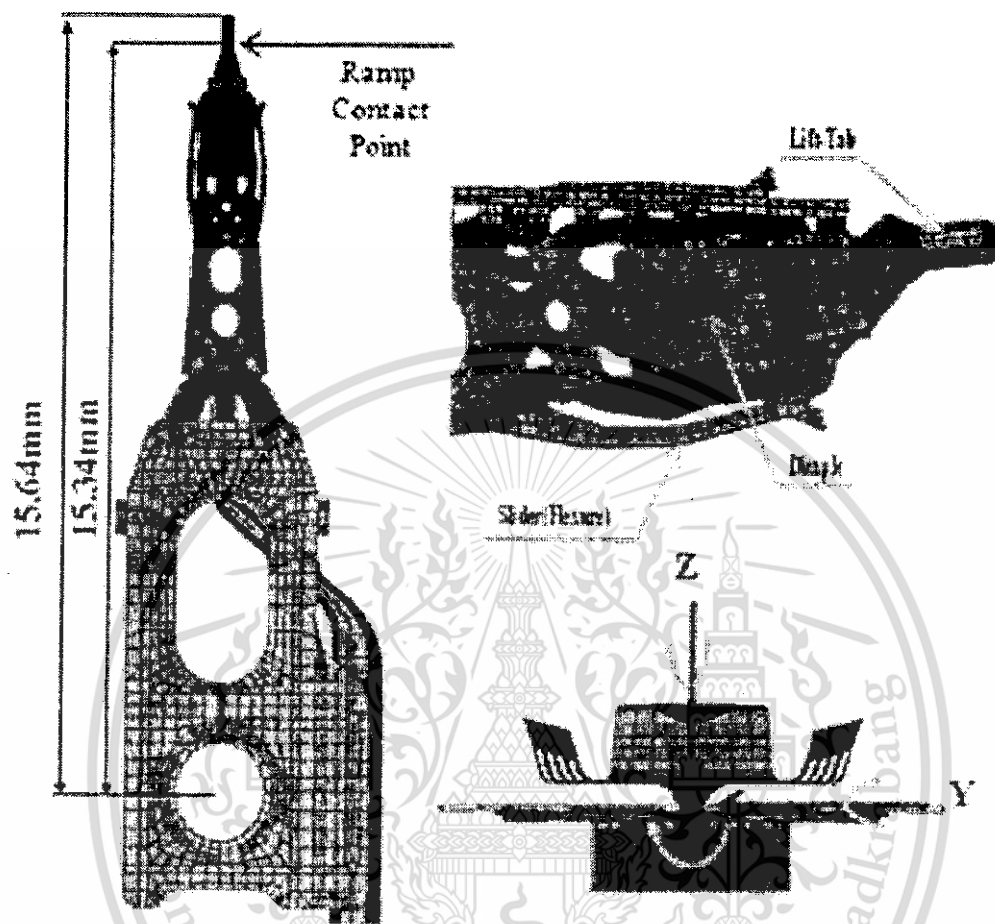


Figure 2.12 FE model for LUL process (2.5inch HDD) [12]

The simulated results showed that the vertical force did not affect the dimple flexure slip. Figure 2.13 shows that when the contact force increases, the dimple flexure become larger. Considering at the contact force becomes 50% smaller the displacement of dimple flexure decreases under 20 μm . They concluded that the small contact force can improve the load/unload performance and decrease the head -disk interface problems. By the way, they investigated the dominant factor to increase the dimple slip in HDD as shown in Figure 2.14. It showed that the smaller ramp contact duration, the larger dimple flexure slip happened.

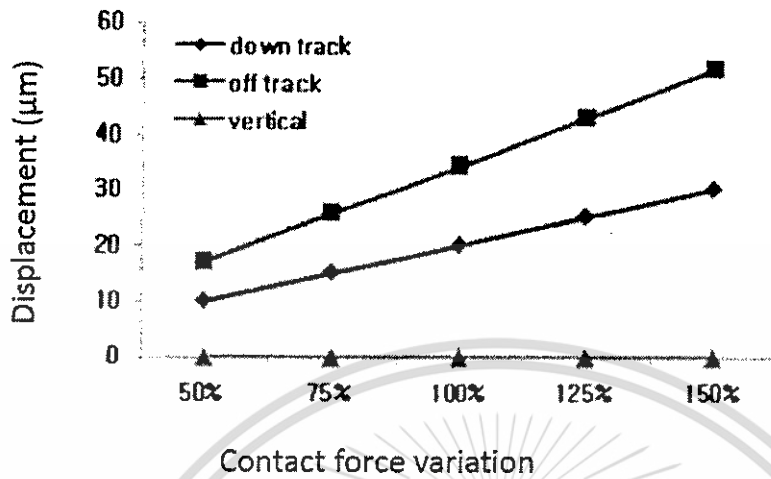


Figure 2.13 Dimple-flexure slip as a function of ramp contact force [12]

In this paper, they concluded that the characteristics of contact between ramp and suspension lip-tab is important parameter to determine the performance of load/unload. They can improve the characteristics of dimple flexure slip by the ramp material or load/unload speed.

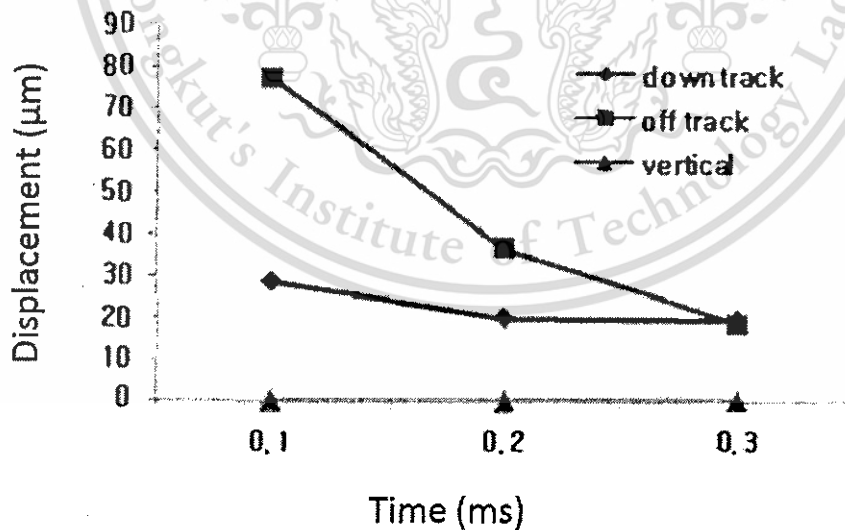


Figure 2.14 Dimple-flexure slip as a function of ramp contact duration [12]

In 2005, Nakamura, Aduma, Takahashi, Wakatsuki and Hagiya [15] studied the effect of the flow – induced vibration of Head Gimbal Assembly (HGA). They called windage. They measured windage under various conditions for better understanding the windage characteristics. They proved that windage is one of obstacle factors to increase track densities. Their previous experiment and numerical simulation studies have shown that sufficient damping, vibration-mode decoupling, and airflow control are important to reduce windage. Their report can prove that the windage can be reduced by miniaturizing the HGA and applying the Taguchi method to optimize the HGA –arm configuration.

Their experiment was used a laser Doppler vibrometer (LDV) for windage measuring. They are intended to avoid the results which may be effected from vibration by using the rigid STST arm for these measurements. They have two conditions of HGA, one condition was on the disk and another condition was between the disks. They assumed the nominal setting conditions, the HGA has a first bending mode of 3.7 kHz, a first torsion mode of 6.1 kHz, a sway mode of 11.6 kHz, and a secondary torsion mode of 14.5 kHz. Figure 2.15 shows the experimental setup used to measure windage. Figure 2.16 is a schematic view. This HGA has three main parts: the head suspension, head slider, and tail.

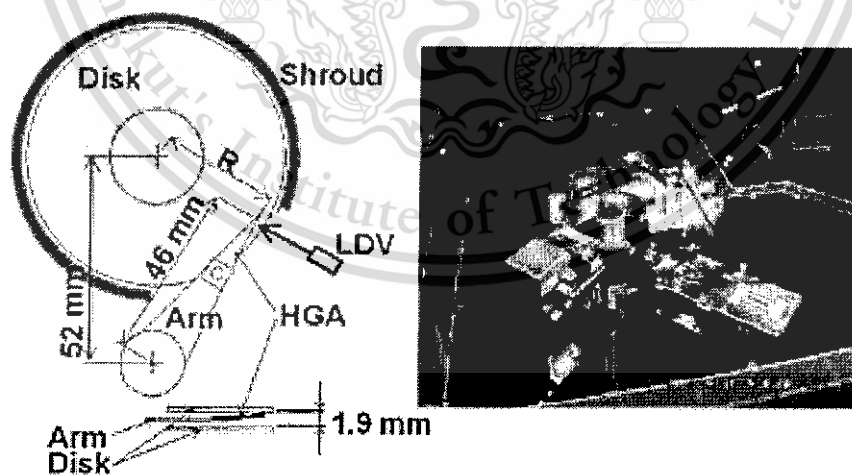


Figure 2.15 Experiment setup [15]

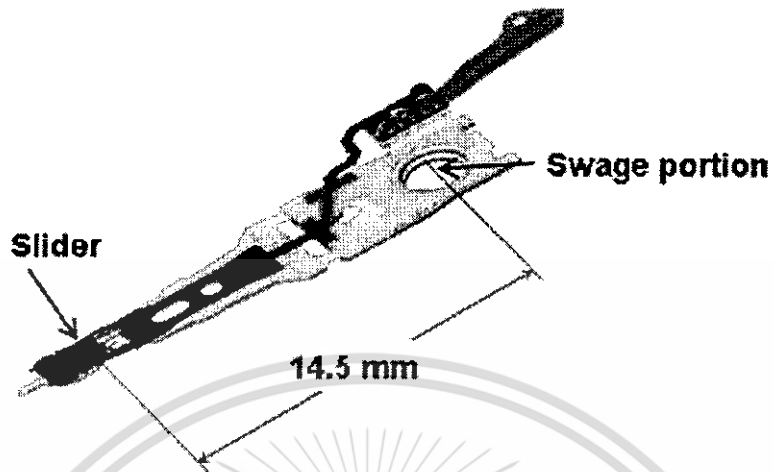


Figure 2.16 Test Samples [15]

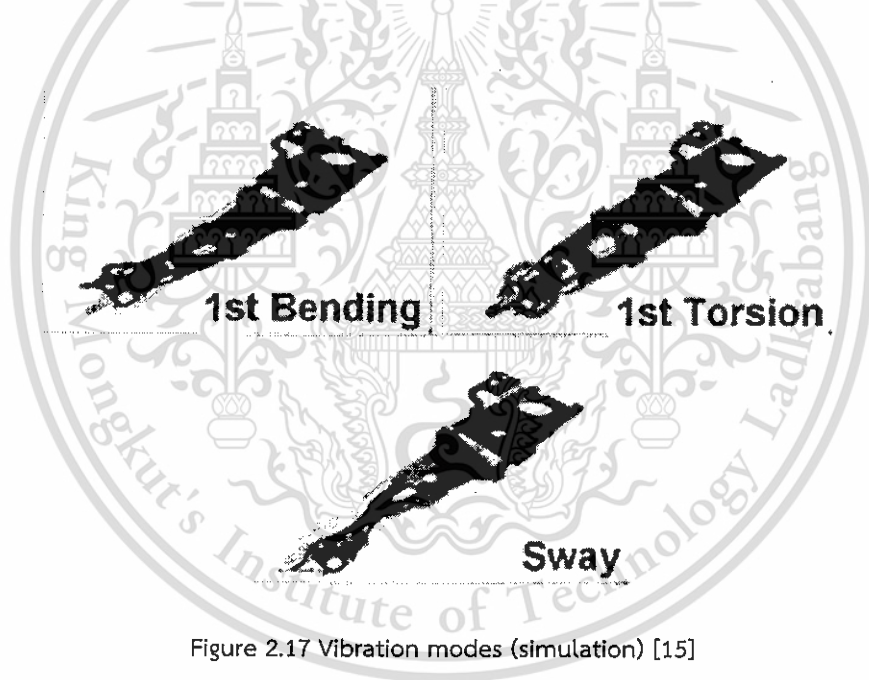


Figure 2.17 Vibration modes (simulation) [15]

Their experiment symptom was assumed the meaning of D1 and D2 as:

- D1 means the HGA was positioned on the disk.
- D2 means the HGA was positioned between the disks.

Their experiment results can be categorized the effect into five items by

1. Effect of HGA Position, the Shroud, and Slider Radius Position: The HGA positioned between disk has windage greater than when it was on the disk. Because when it

is positioned between the disks, the first bending mode (3.7 kHz) and the first torsion mode (6.1 kHz) were excited and peaks appeared.

2. Effect of Disk Rotational Speed: The results could not explain regarding to 4 HGAs of sample size cannot capture the vibration of 2 kHz.
3. Effect of Slider Radius Position: The result showed that when radius increased, the normalized amplitude of windage increased, but the trend was not correlated with disk rotation speed that was increased. It was proved that the inherent vibration of HGA itself must be reduced to realize the small windage which is important to control the wind hitting the HGA by application of a spoiler that can help for less flow induced vibration.
4. Effect of Temperature: The result showed that when the temperature increased, the oscillation amplitude increased. They concluded that this phenomenon was caused by the viscous elastic material (VEM) becoming less rigid than temperature then resulting in a lower rate of attenuation. To reduce this, the thickness and /or material of VEM and damper must be carefully selected.
5. Effect of Z Height: The result showed that when the z height is changed, the amplitude and resonance frequency of the windage change. It was proved that the Z Height is important to windage as shown in Figure 2.18

From the results, they concluded that the windage depended on how the wind hits the HGA and the Z height. Then to control the airflow in an HDD, it was important to reduce the Z height deviation and reduce vibration of the HGA itself.

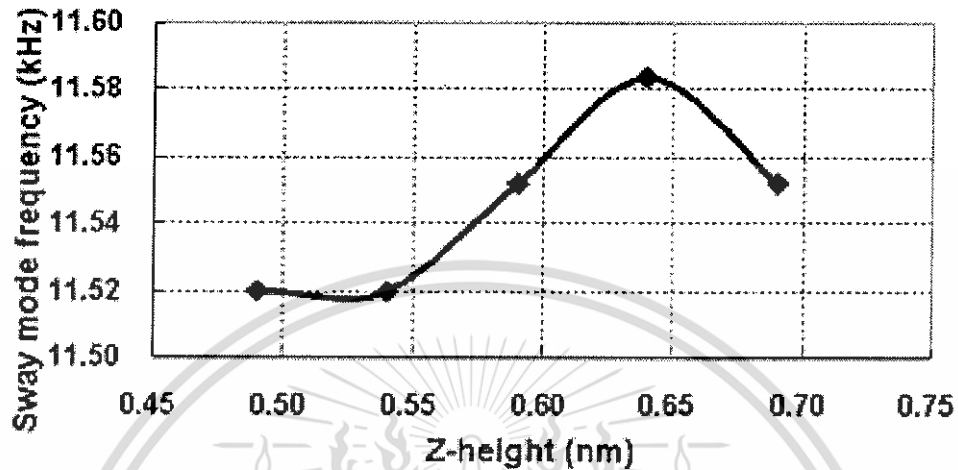


Figure 2.18 Effect of Z height (R = 38:8 mm) [15]

In 2013, Yuan, Du, Chow, Zhang, Yu and Liu [26] proposed the sensor array embedded on the slider for head disk contact detection. They were classified the HMS fly-contact into three categories as

1. Wear – in state meaning as the slider is in contact with the highest asperity.
2. Proximity state or ensuring state meaning as the state that certainly period of the wear – in state that can be further decreased and more asperities will come into contact.
3. The continuous surfing contact meaning as the final state that occurred when the HMS is reduced to level where the slider dips into the lubricant and stays in continuous light contact with the media.

They had compared between three techniques in the past, the traditional Acoustic Emission (AE), the Thermal asperity (TA) detection and the Variable Gain Amplifier (VGA). The AE was used to detect the head-disk contact and found that main disadvantage of AE is capable of only single head disk interface (HDI). For the VGA technique the occasional contact cannot be detected. The TA which actually has been used to calibrate the flying height for thermal fly height control (TFC) slider. But it cannot be used for high-frequency real time detection because the contact has to last

prolonged period of time. Their proposed is to integrate piezoelectric sensors onto the slider. They were expected to be able to detect the dynamics stress and head disk contact.

Their experiment used the Pico slider ($1.25 \times 1 \times 0.3 \text{ mm}^3$) with a piezoelectric sensor array. The sensor array consists of a common ground electrode (Au), a ZnO layer ($1 \text{ }\mu\text{m}$ thick), and three sensing pads (Au). The slider experiences elastic strain which converted to voltage through piezoelectricity of ZnO layer. The contact location can be identified by examining the output voltage of the left, central and right sensors. The air bearing was simplified into spring-damper systems which have the spring constant of $1.25 \times 10^5 \text{ N/m}$ and damping coefficient of 0.24 N-s/m . A force was applied on the trailing side of the slider to simulate head-disk contact as depicted in Figure 2.19-2.23.

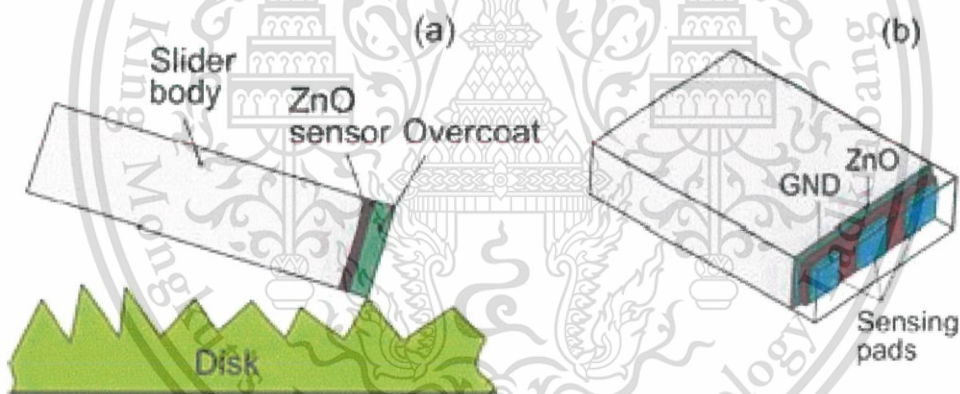


Figure 2.19 Slider design: (a) slider in contact with disk and (b) triple-sensor array [26]

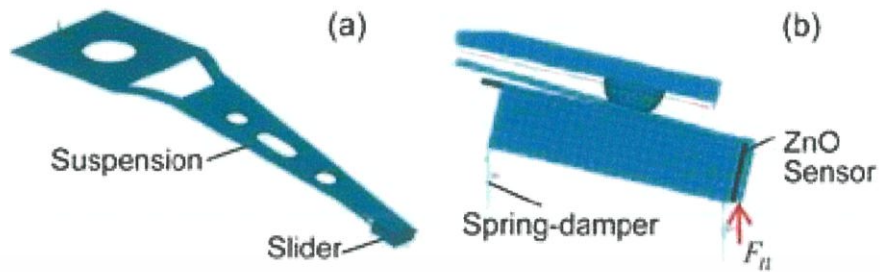


Figure 2.20 Finite element model: (a) sensor-slider-suspension assembly and (b) slider with ZnO sensor.

Their results showed that the output of the sensors array was in the millivolt level which correlates to the contact location of head disk contact. They concluded that in the final state (continuous light contact), the slider is highly excited by contact force with low amplitude and high frequency. As that, a result of output voltage is high due to induction by the wear – in and proximity contact. They were reported that the central sensor always has the highest response under continuous contact. The final concluded that the integrated piezoelectric ZnO sensor array on the trailing side is feasible design for detection of head – disk contact.

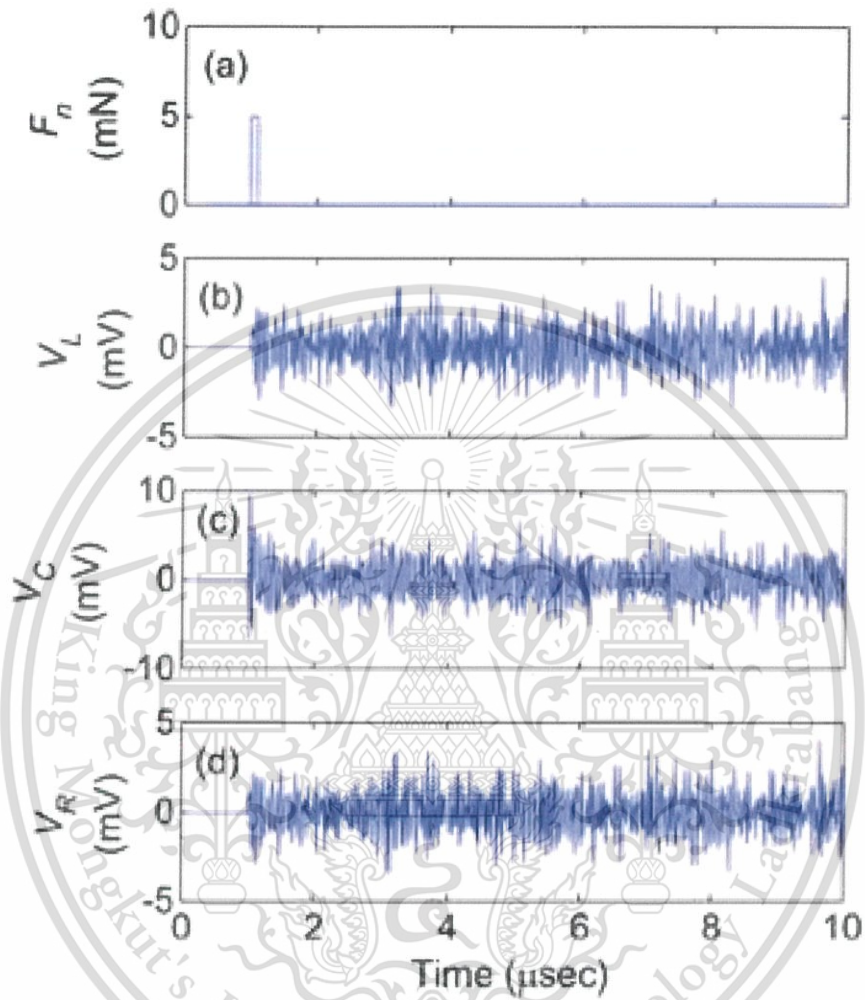


Figure 2.21 Transient response to a single asperity (Wear-In) contacting the rear ABS pad: (a) contact force; (b) voltage of left sensor; (c) voltage of central sensor; and (d) voltage of right sensor [26]

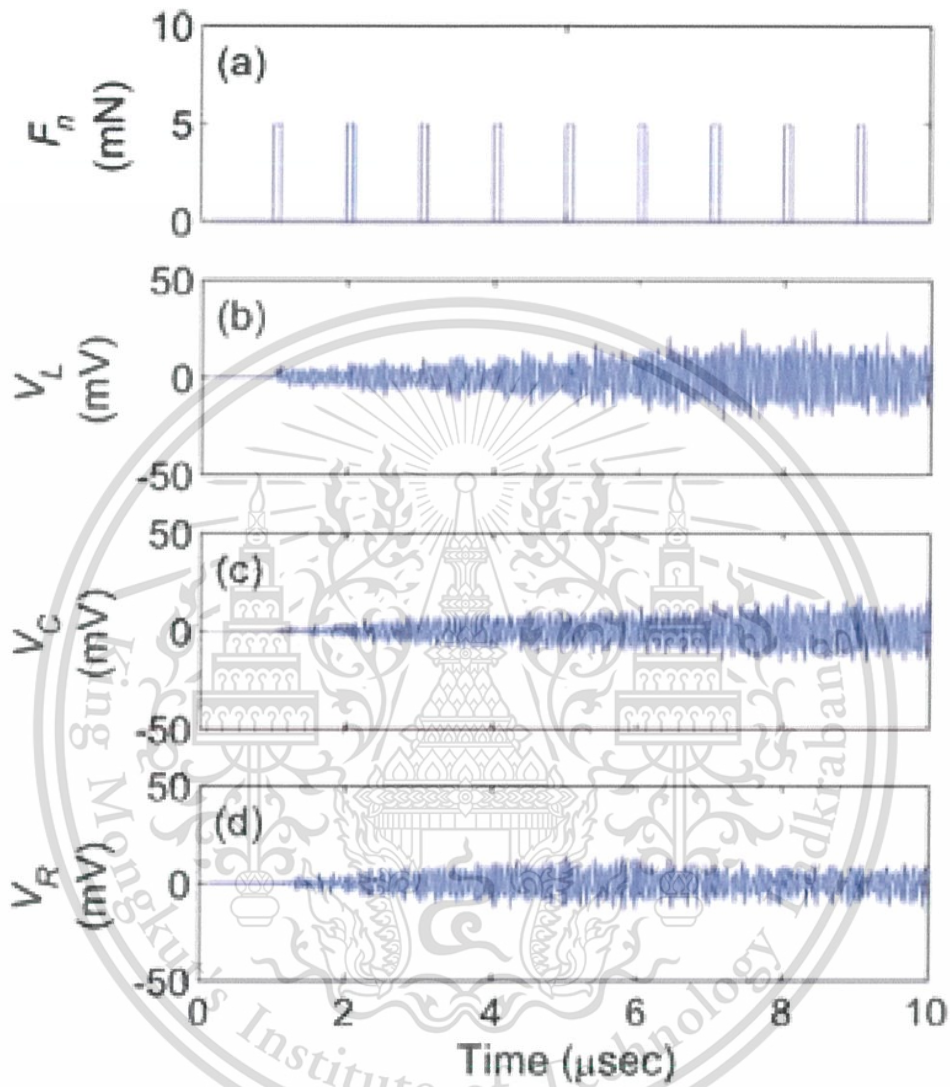


Figure 2.22 Transient response to multiple asperities contacting the left corner: (a) contact force; (b) voltage of left sensor; (c) voltage of central sensor; and (d) voltage of right sensor

[26]

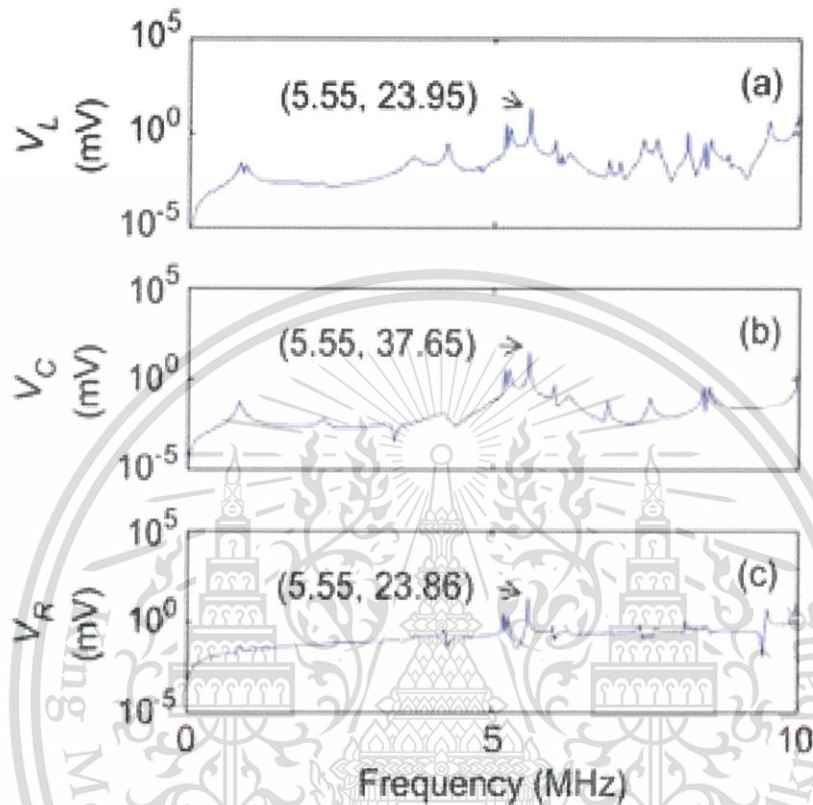


Figure 2.23 Harmonic response to continuous contact on the left corner: (a) voltage of left sensor; (b) voltage of central sensor; and (c) voltage of right sensor [26]

In 2013, Pan, Ovcharenko, Peng, Sanchez, Radicati and Yang [11] studied the effect of flying pitch angle and flying roll angle on lubricant transfer from the disk to the slider. They observed that when the slider flew close to the disk with distance of space between the disk and slider less than 2 nm, lubricant transfer from the disk to slider becomes more frequent because of the intermittent contact between the disk and slider. The lubricant transfer is effective on slider flying ability because the lubricant pickup can cause interaction between slider and lubricant on the disk which decrease slider flying ability. That mean, unstable flying of slider affects the reliability of the head disk interface. In the

other hand, lubricant transfer from the disk to slider can cause lubricant depletion on the disk.

From their experiment, they found that lubricant transfer occurred even without head to disk contact. It was assent to many researches which concluded that the effect of lubricant transfer increased with an increase in absolute humidity. The lubricant picked up by slider accumulates around the edges of air bearing surface pads and recession area. It was found that the amount of lubricant transferred from the disk to the slider can be decreased by minimizing the air bearing surface pad size. They also observed the amount of lubricant transfer increasing with the increase of slider pitch static angle, while non-zero slider roll static angle results in more lubricant transfer than zero slider roll static angle.

Their experiment used flying height tester (FHT) for measuring the flying pitch angle and flying roll angle. For the transparent glass disk, two types were used for this experiment; first one is coated with 3 Å lubricant film thickness and the second one is coated with 12 Å thickness. The Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) was used to analyze lubricant distribution on a slider. It was used to detect the distribution of C_2F_5 , a fragment of a lubricant molecule, on a slider surface. They assume that the existence of C_2F_5 on the slider surface can be indicates of lubricant transfer from the disk to slider. In order to track lubricant transfer from a disk to a slider in-situ, a charge-couple device (CCD) camera is placed above the disk. A schematic of measuring flying pitch and roll angles is shown in Figure 2.24, explaining a schematic of measuring flying pitch and roll angle (a) is laser focuses without slider, one at the top of disk and other one focus at bottom surface of the disk (b) is laser focused with slider, the reference laser still focus on the top surface while the other laser converges on the air bearing surface of the slider. Figure 2.25 shows the flying pitch and roll angle and measuring point on the slider air bearing surface (a) shows the schematic of the flying pitch angle, the angle between ABS and disk surface is defined as positive flying pitch angle (b) shows the positive flying roll angle which is considered in xz plane between ABS and disk surface (c) shows measurement point on the ABS which used to calculate flying pitch and roll slider with respect the disk surface.

Their experiment is set up under room temperature (22°C-24°C) and humidity (15% RH-20% RH). The first step of their experiment is by measuring slider flying height (FH), flying pitch angle, and flying roll angle using disks with 3Å mobile lubricant and taken the images of the slider at time 0 second, and after 30 seconds, 1 minute, 2 minutes, 3 minutes, and 4 minutes of flying using CCD camera. Then, did proceed the same at the 12 Å group, comparing results together.

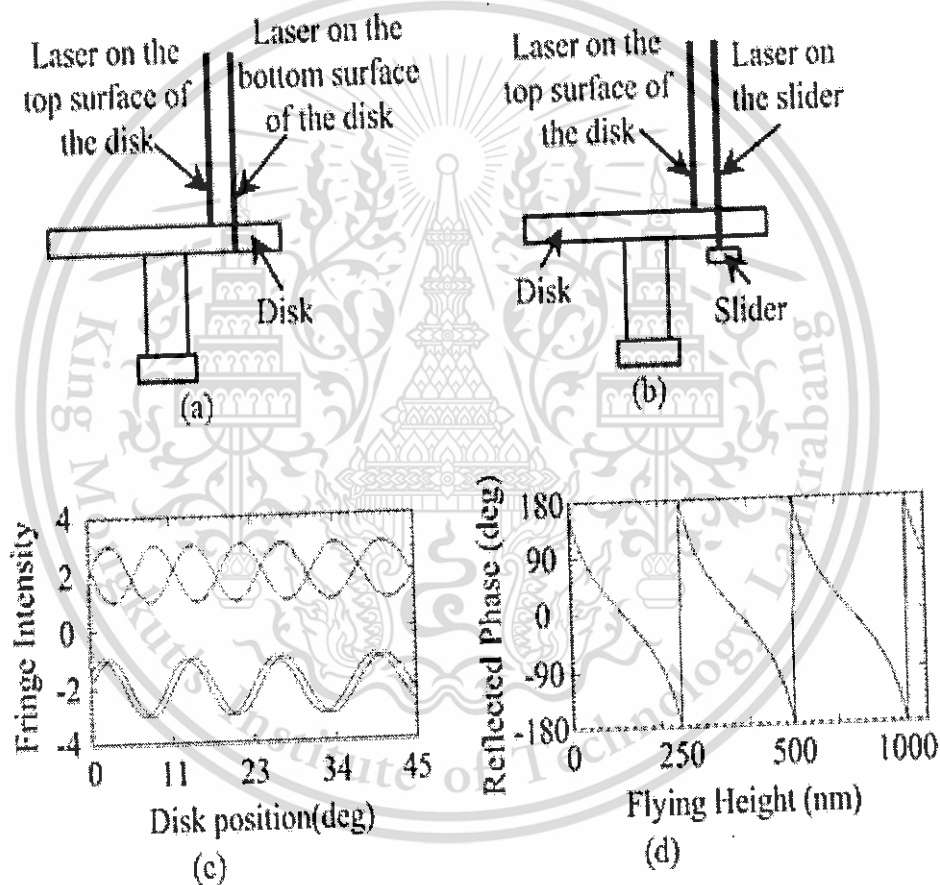


Figure 2.24 A schematic of measuring flying height. (a) both lasers are on disk, (b) one laser is on slider and the reference laser is on disk, (c) average phase difference, and (d) relationship between flying height and reflected phase [11]

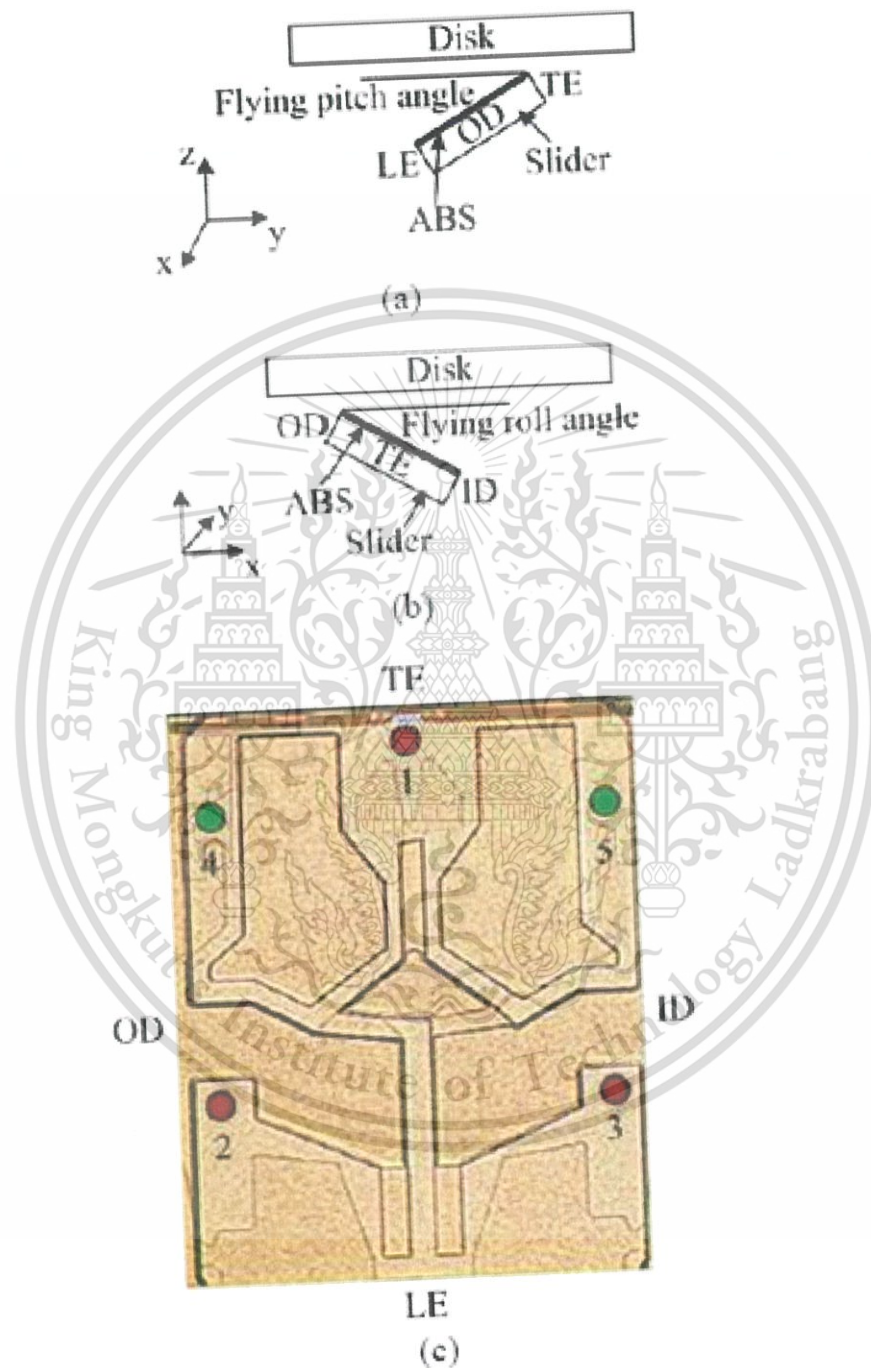


Figure 2.25 Schematic of flying pitch and roll angles and measuring points on a slider ABS. (a) schematic of positive flying pitch angle, (b) schematic of positive flying roll angle, (c) measurement points on the air bearing surface. (OD: outer diameter of the disk, ID: inner diameter of the disk, TE: trailing edge, LE: leading edge.) [11]

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The air flow on the slider surface consists of two components; one is poiseuille flow which is driven by the air bearing pressure gradient, forcing the lubricant to move from high pressure area to low pressure area. The other one is Couette flow which is driven by the disk velocity, making the lubricant flow follow the skew angle direction. They concluded that the Couette flow had more significant effect than the Poiseuille flow as shown in Figure 2.26.

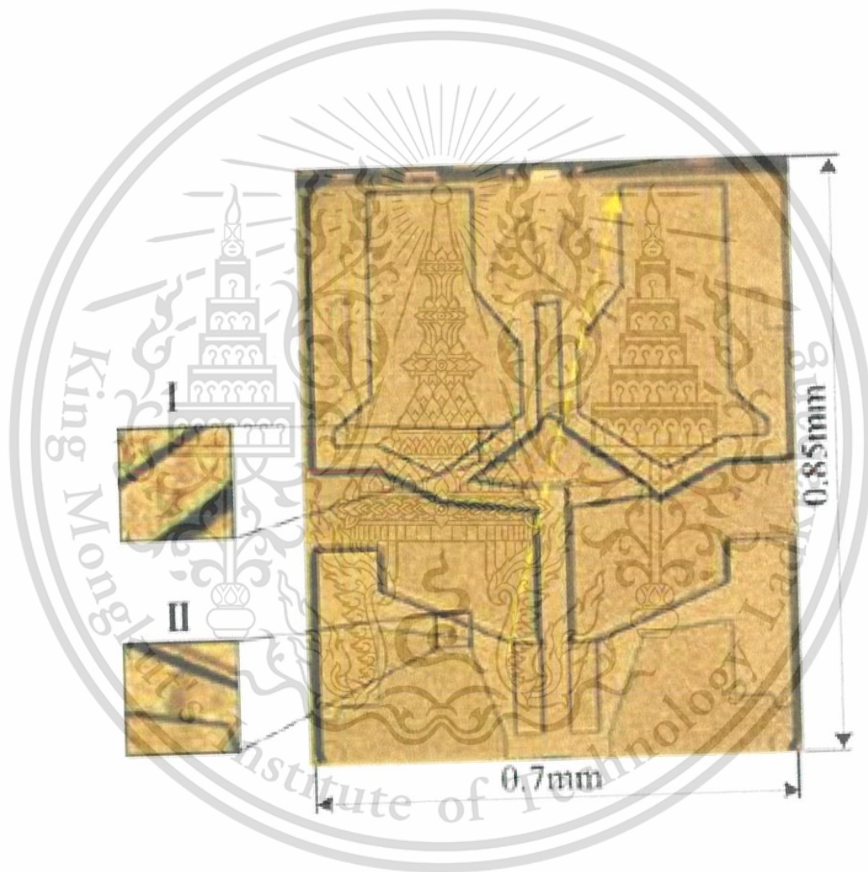


Figure 2.26 Posttest optical image of a slider which flew at the OD skew of the 3 Å lubricant disk using Combination 4 (PSA=2.8/RSA=0/G.L.=2.2) [11]

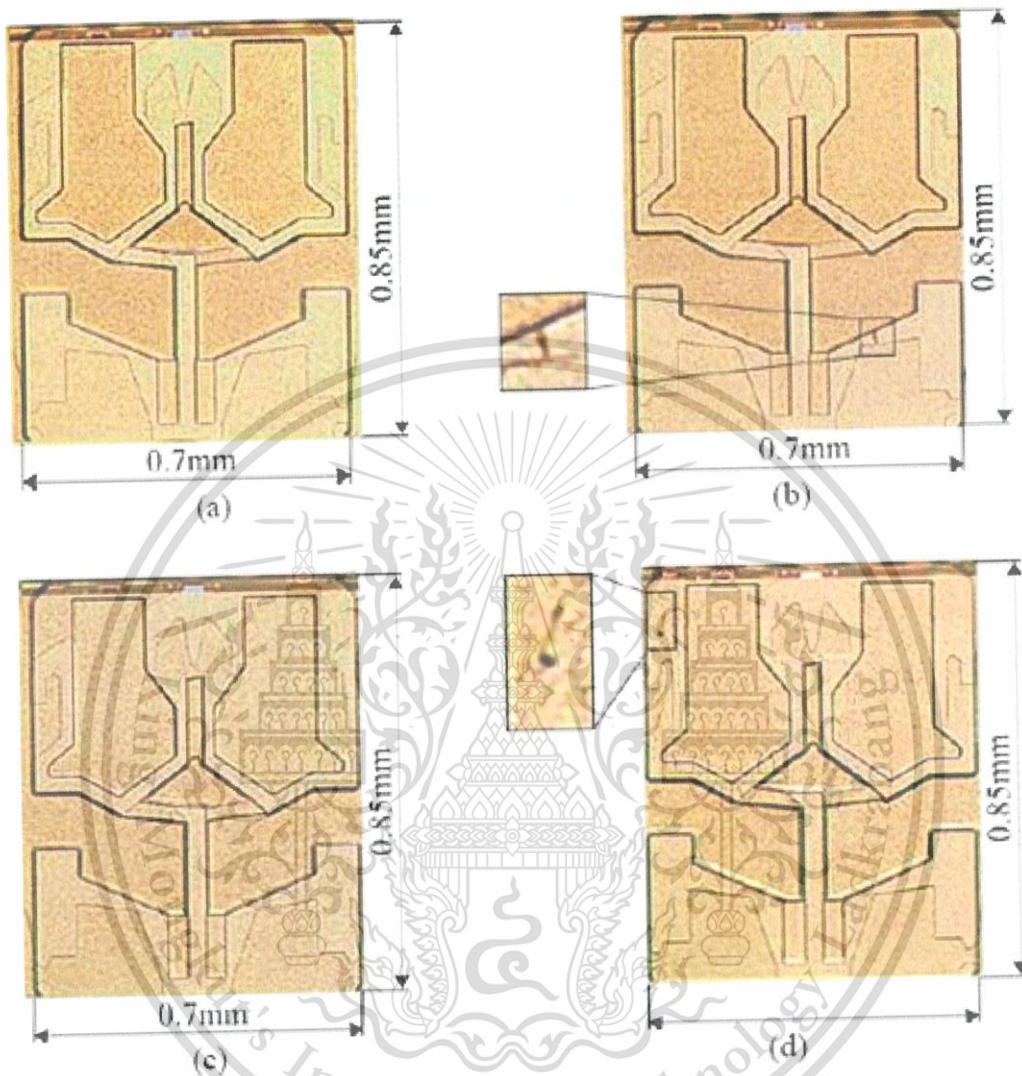


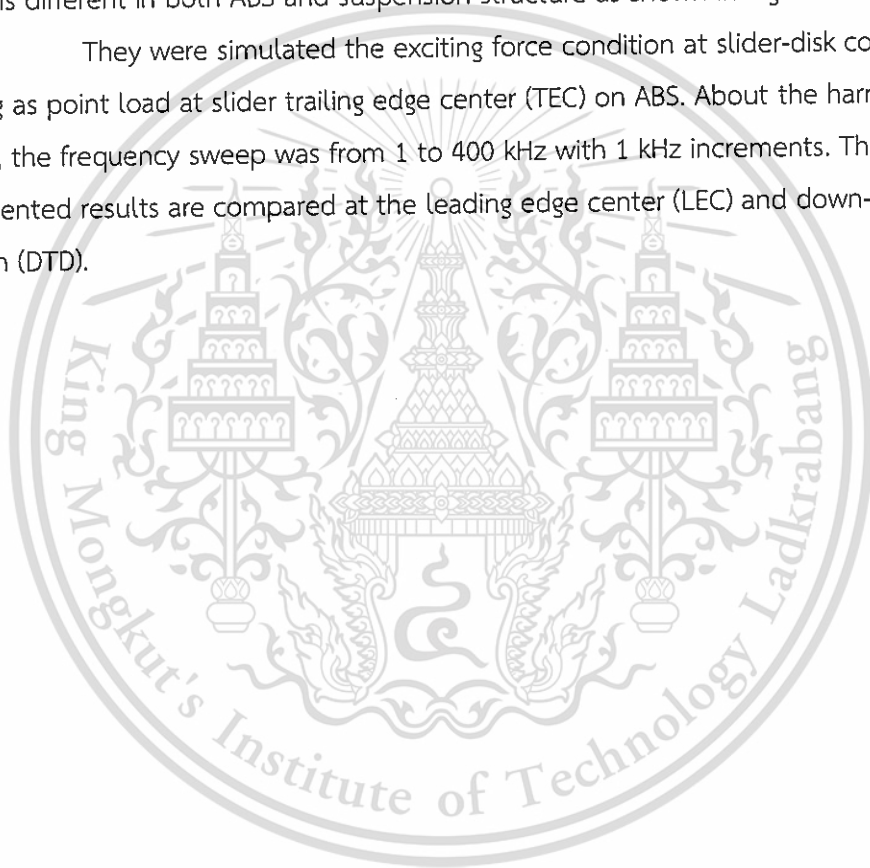
Figure 2.27 Posttest optical images of slider flying at the ID skew of the 12 Å lubricant disk, (a) Combination 1, (b) Combination 2, (c) Combination 3, and (d) Combination 4 [11]

From their experiment it can be concluded that lubricant flow follows the skew direction, going towards outer trailing edge of the slider at ID skew and towards inner trailing edge of the slider OD skew. Flying roll angle plays more dominant role than flying pitch angle on the lubricant transfer from the disk to slider.

In 2014, Chen, Peng and Bogy [13] investigated the stability of thermal fly height effects on the reliability of interface. Their reason of this study regarding to spacing of ~ 2 nm between disk and slider can cause instability in term of slider vibration and prominent

lubricant transfer. The experiment techniques and simulations are implemented to investigate the thermal protrusion induced slider – disk at contact proximities. The instability was used laser Doppler vibrometers (LDVs) for measuring at multiple locations of slider body to extract the dynamic content during contact. The simulations condition considered both air-bearing and suspension designs. They used the finite volume and finite element methods for experimentally simulating with two different designs of HGA. The sample is different in both ABS and suspension structure as shown in Figure 2.28.

They were simulated the exciting force condition at slider-disk contact by applying as point load at slider trailing edge center (TEC) on ABS. About the harmonic analysis, the frequency sweep was from 1 to 400 kHz with 1 kHz increments. The experimented results are compared at the leading edge center (LEC) and down-track direction (DTD).



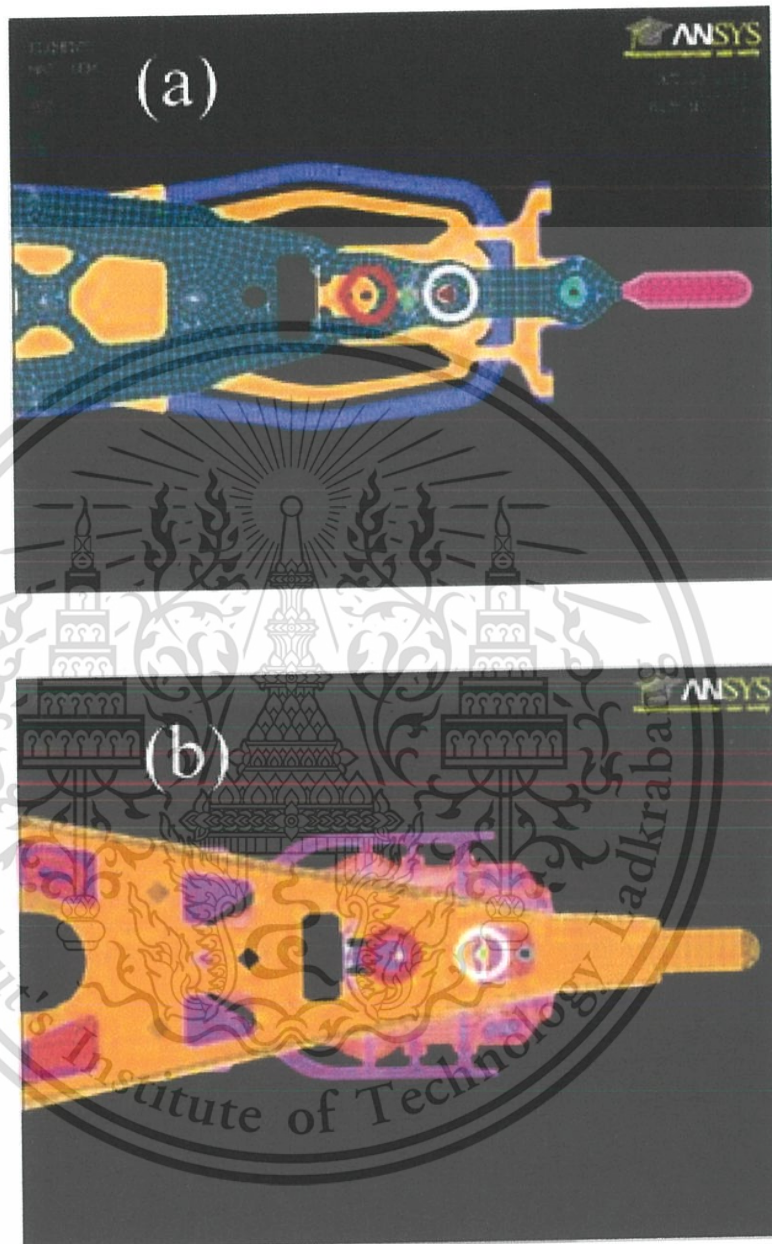


Figure 2.28 Suspension design of (a) HGA#1 and (b) HGA#2. TEC is circled in white and LEC is circled in red for both Figures [13]

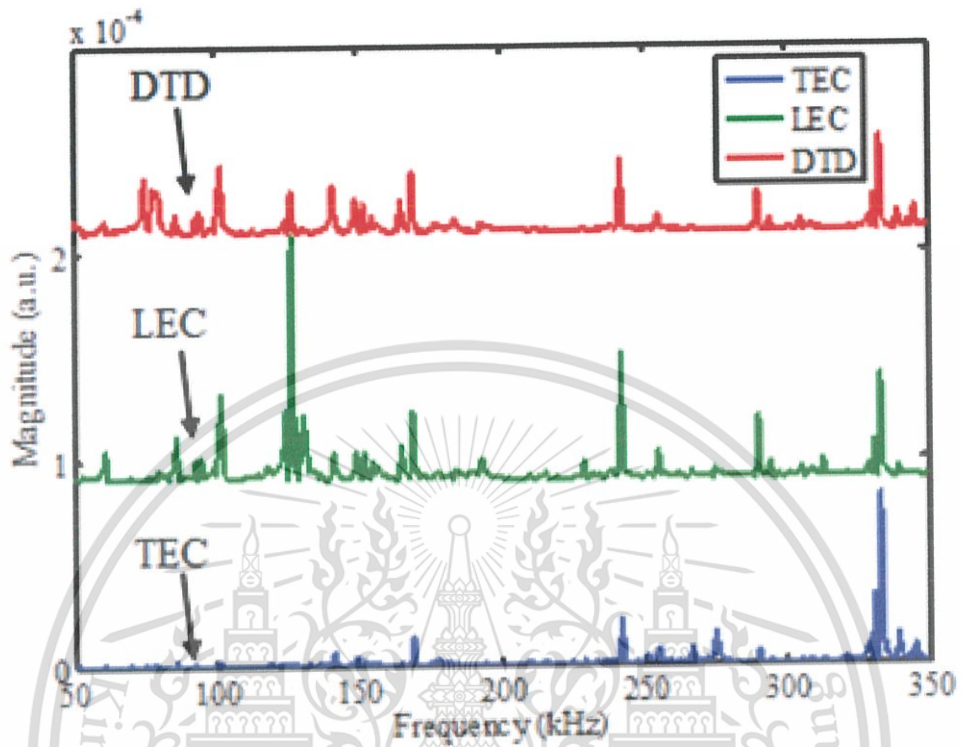


Figure 2.29 Frequency response of harmonic analysis for HGA#1 [13]

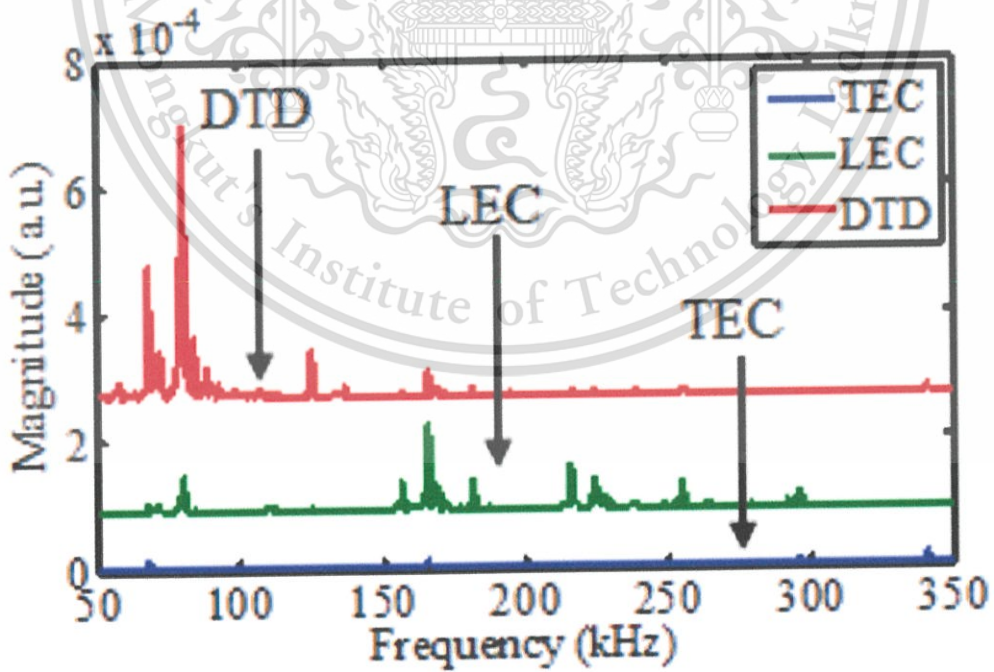


Figure 2.30 Frequency response of harmonic analysis for HGA#2 [13]

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The results shown in Figure 2.29 – 2.30 represent of HGA#1 & HGA#2 respectively. The HGA#1 result shows that the DTD trace features two prominent peaks at 75 and 79 kHz that are not seen on TEC and LEC. The HGA#2 result shows in Figure 2.30. With a different suspension and ABS design, HGA#2 shows less frequency contents above 100 kHz and dominant modes at 72 and 80 kHz, which are view of first pitch mode in the vertical direction seen in DTD mode. They were compared with HGA#1 on the DTD mode and concluded that the HGA#2 are mechanically coupled with LEC modes which given strong DTD modes as observed as first pitch mode vertical rather than roll modes. From their results, it can be concluded that at thermal protrusion induced contact proximity the in-plane force is most important excitation. It can be inferred from the similar DTD modes shared by the different HGA designs. The designing to reduce LEC coupling from DTD excitation is essential for slider instability.

Finally,as above from all researchers, review concerning the fly height of magnetic recording. No research has been done at the slider placement location on the suspension. However, this paper was focused at the slider placement location to see clearance effect. The JMP software was used for experimentally model prediction and data analysis.

2.2 Theory

The clearance is known as the distance between the slider and the disk. In the other hand, clearance is the distance of the reader protruded toward the disk before some parts of the transducer hit the disk as shown in Figure 2.31. It is very important for evolution of magnetic data storage technology requirement. The continual increase in areal density, now targeting 4 Tbit per square inch [7] has several new technologies such as shingled magnetic recording [3] and heat-assisted magnetic recording [4]. It has been recognized that to achieve and resolve the future data storage needs, all of these technologies have to be implemented altogether, and all technologies share a reliability concern related to head-disk interactions. The head-disk contact raises concerns of reliability at a minimum fly height of around 2 nm during a read-write process, and it is expected to be at sub nanometer values in the near future, regardless of which of the aforementioned technologies are used [13]. The closer of the slider or head to the disk is better the BER (Bit error rate) and signal to noise ratio which the distance is measured in Angstroms.

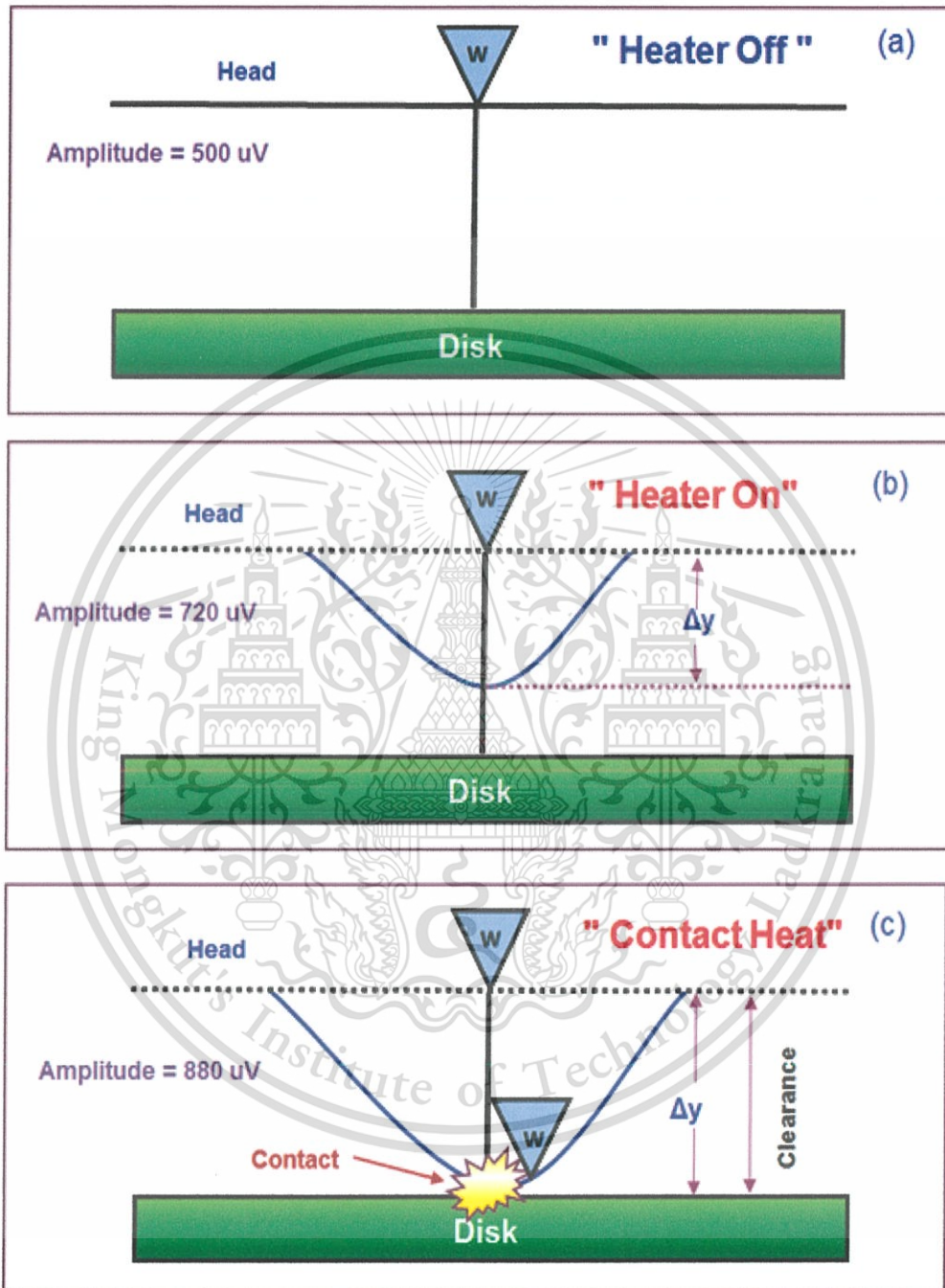


Figure 2.31 Schematic of heater protrusion and clearance describe (a) when heater off status (b) when heater on status (c) when contact heat

In the other hand, Figure 2.31 shows the schematic of heater protrusion and clearance. A measure of clearance by measuring the change in amplitude between passive fly and heater- induced contact and convert to be distance between head and disk. At first step shown in Figure 2.31(a) heater off, writer and reader staying at its position without any change. A track is written at a known frequency (and wavelength λ) and read in narrowband mode. The amplitude at (a) was 500 μ V for an example case, called reference amplitude. The second, shown at 2.31(b) when heater is turned on (during read), the reader gets closer to the disk by the distance, Δy , and amplitude increases by ΔV (in db). Then, measure ΔV and calculate Δy (clearance) by using Wallace spacing loss equation. In term of the power applied to head, it was applied into head with a step by step varying the power every 10 mW, start from zero to 200 mW, respectively. It means, heat is increased until contact is detected. The amplitude just before contact is used for calculating clearance as shown in Figure 2.31(c).

From above state, the Wallace spacing loss equation was used to correct harmonics and calculated the spacing from ratio of fundamentals after correction for the gap effect and transition width [29]. It was proved that fitting for confident accuracy equation in HDD, can be written as below

$$\Delta V = 20 \times \log_{10} (\text{Heat amplitude} \div \text{Reference amplitude}) \quad (2.1)$$

$$\Delta y = \lambda \div 54.6 \times \Delta V \quad (2.2)$$

So $\Delta y = \text{Clearance}$

Where

λ is the wavelength of the signal = linear velocity / frequency

And fixed λ as 75 nm

In Figure 2.31(b) when heat is turned on, the amplitude increased from 500 μ V to 720 μ V (an example number)

Then

$$\Delta y = 75 \text{ nm} \times 20 \times \log(720/500)/54.6 \quad (2.3)$$

$$\Delta y = 4.3 \text{ nm} \quad (2.4)$$

In Figure 2.31(c) heat is increased until contact is detected, the amplitude increased from 500 μV to 880 μV (an example number)

Then

$$\Delta y = 75 \text{ nm} \times 20 \times \log(880/500)/54.6 \quad (2.5)$$

$$\Delta y = 6.74 \text{ nm} \quad (2.6)$$

As the results of Δy , it would explain in term of amplitude change that, after apply heat into head. The reader and writer was protruded. With the protrusion, it caused the reader and writer move close to the disk. With the closure point as described, it becomes high signal to noise ratio which actually affected with high amplitude which high rates of data transfer require high frequency current in writer coil [34]. Mean that, high amplitude was better for read and write for HDD.

2.3 Clearance cause and effect Diagram

Nowadays in the HDD manufacturing, there are a lot of parameters determined for affecting to clearance as shown in Figure 2.33. The main contribute was indicated into the color rectangle such as slider, contamination, media / disk and TGA/ HGA. At the portion of TGA/HGA, there are four parameters focusing on this paper which determined as main contribution to cause clearance change. By the way, at the slider portion, it was contributed on this study.

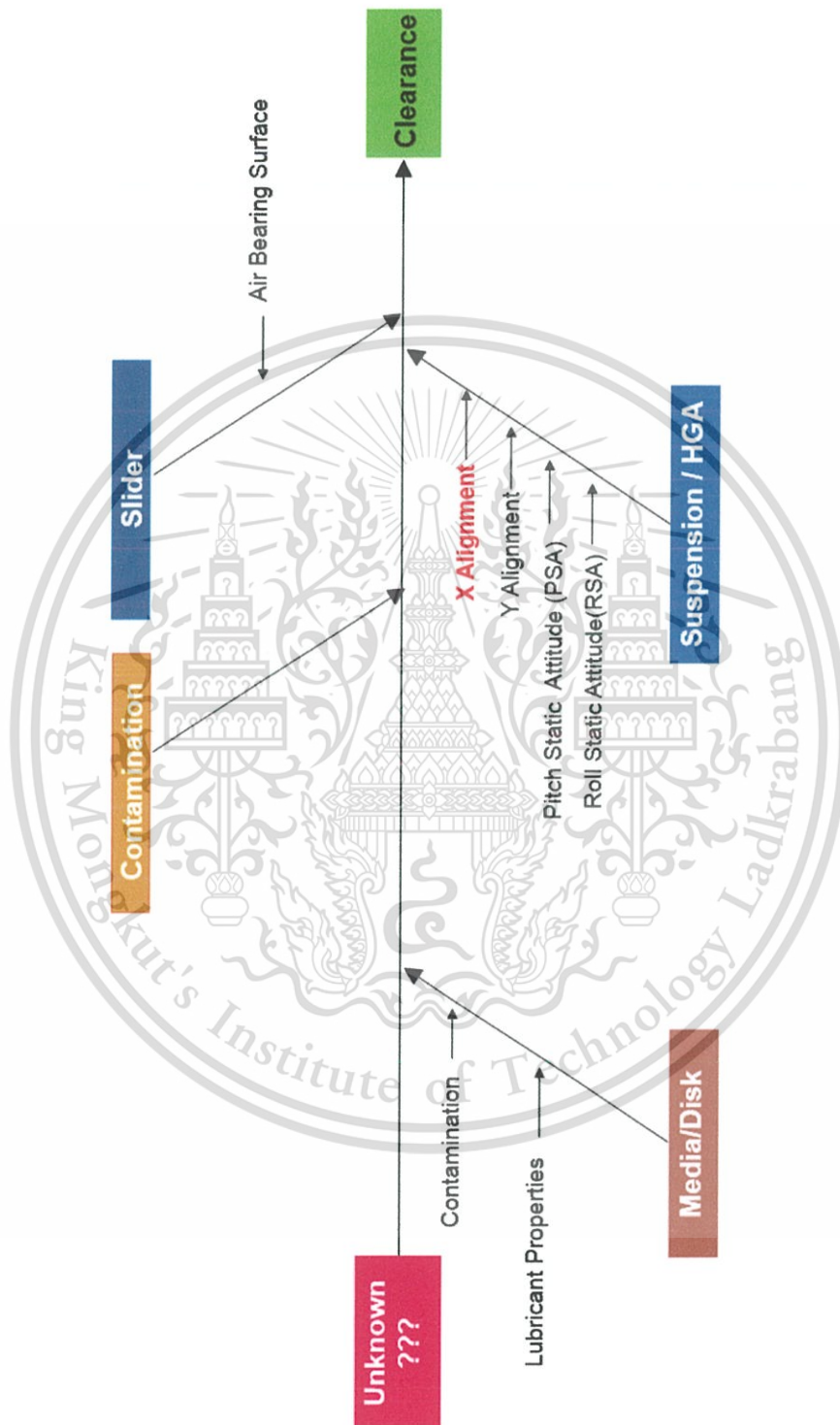


Figure 2.32 Clearance cause and effect diagram

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2.4 Clearance Prediction model

As previous by state, this paper was focused on the HGA at the slider x-alignment. The prediction model was calculated based on all population of HGA dataset. The dataset of sample size was more than 100,000 HGAs with including all parameters that might be concerned to clearance. The top four parameters were ranking with high potential effected to low or high clearance. The prediction model was created from JMP statistical discovery software, version 10. More details of how to create clearance prediction model in appendix B.

$$\begin{aligned} \text{Clearance} = & 9.56144243704604 + (21.9575654600966 \times A) + (15.8429228044625 \times \\ & B) + (-90.24934728951248 \times P) + (0.272132423967986 \times R) + [(A + \\ & 0.0172798362068966)^2 \times (-90.2493472895124)] + [(B + 00100501293103448)^2 \times \\ & 344.603702930111] + [(P - 2.56355693534483)^2 \times 0.366831814966094] + [(R + \\ & 0.516499310344828)^2 \times (-0.934901632221247)] \end{aligned} \quad (2.7)$$

Where

$A = X_{\text{alignment}}$

$B = Y_{\text{alignment}}$

$P = \text{PSA}$

$R = \text{RSA}$

Figure 2.34 shows the results of prediction model. An x-axis was $x_{\text{alignment}}$, $y_{\text{alignment}}$, PSA and RSA respectively. Y-axis was clearance number. The red dot line from all parameter means the movement line which can move up or down in every parameters by fixed $Y_{\text{alignment}}$, PSA and RSA. The $X_{\text{alignment}}$ was varied as number needed to see how clearance affected. Based on result in Figure 2.34, $x_{\text{alignment}}$ was given at 0.01916 mm, $y_{\text{alignment}}$ at zero mm, PSA gave at 2.1 degree and RSA gave at -0.5 degree, the clearance from given number was 8.99 nm.

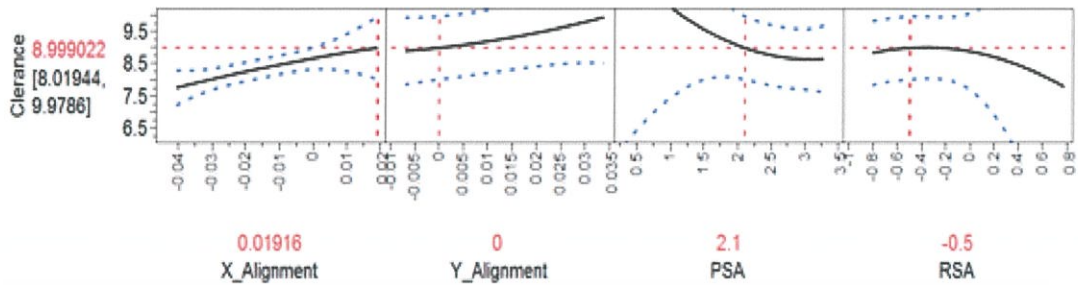


Figure 2.33 Clearance result of the prediction profiler model with fixed Y_alignment, PSA and RSA value but input X_alignment as 0.01916 μ inch

Based on result in Figure 2.34, x_alignment was given at 0.01916 mm, y_alignment at zero mm, PSA gave at 2.1 degree and RSA gave at -0.5 degree, the clearance from given number was 8.99 nm.

Based on result in Figure 2.35, x_alignment was given at 0.001842 mm, y_alignment at zero mm, PSA gave at 2.1 degree and RSA gave at -0.5 degree, the clearance from given number was 8.70 nm.

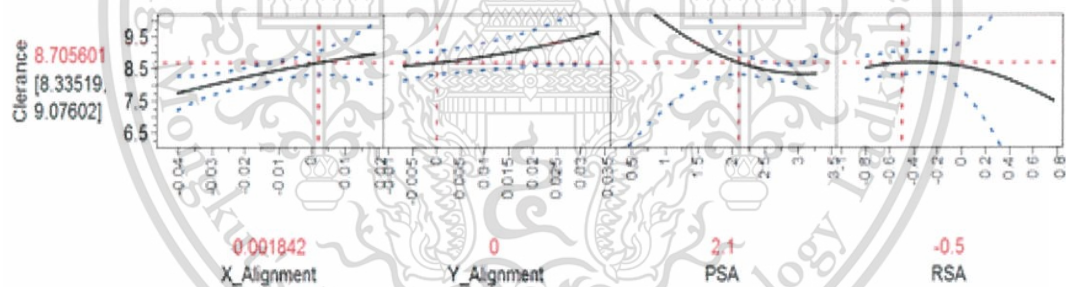


Figure 2.34 Clearance result of the prediction profiler model with fixed Y_alignment, PSA and RSA value but input X_alignment as 0.0010842 μ inch

Based on result in Figure 2.36, x_alignment was given at -0.013149 mm, y_alignment at zero mm, PSA gave at 2.1 degree and RSA gave at -0.5 degree, the clearance from given number was 8.40 nm.

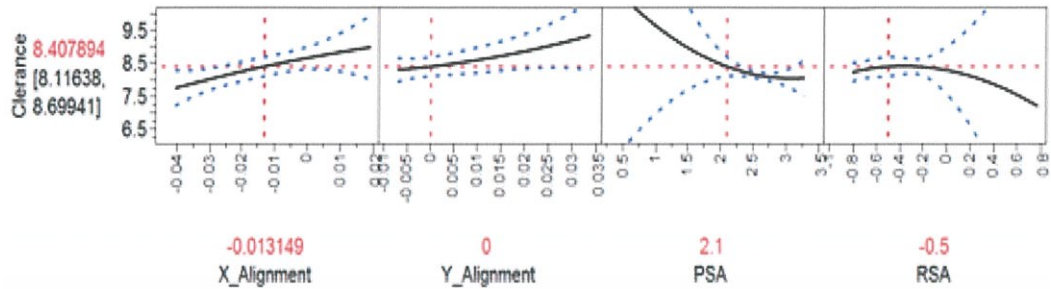


Figure 2.35 Clearance result of the prediction profiler model with fixed Y_alignment, PSA and RSA value but input X_alignment as
-0.013149 μ inch

2.5 Definition

2.5.1 Clearance : At electrical side of HDD, it means the protrusion distance at the contact point of reader after applying power into the head.

2.5.2 Gap : It is the space of head and disk during read / write operation of HDD.

2.5.3 Fly Height : It is the distance between head and disk while flying. Actually, at the Head Gimbal Assembly side, the fly height is represented at mechanical algorithm of flyability of the head without any protrusion of reader.

2.5.4 PSA (Pitch Static Attitude) : The pitch angle of the head after slider is mounted onto flexure of the suspension. The angle can greatly affect the magnitude of the pitch torque which is applied to slider when forced to align with disk.[31]

2.5.5 RSA (Roll Static Attitude) : The roll angle measurement of the head which can use same measurement tool as PSA.

2.5.6 Slider x-alignment : The distance of prototype setting of slider placement and real position of slider after placing onto the suspension on x-direction.

2.5.7 Slider y-alignment : The distance of prototype setting of slider placement and real position of slider after placing onto the suspension on y-direction.

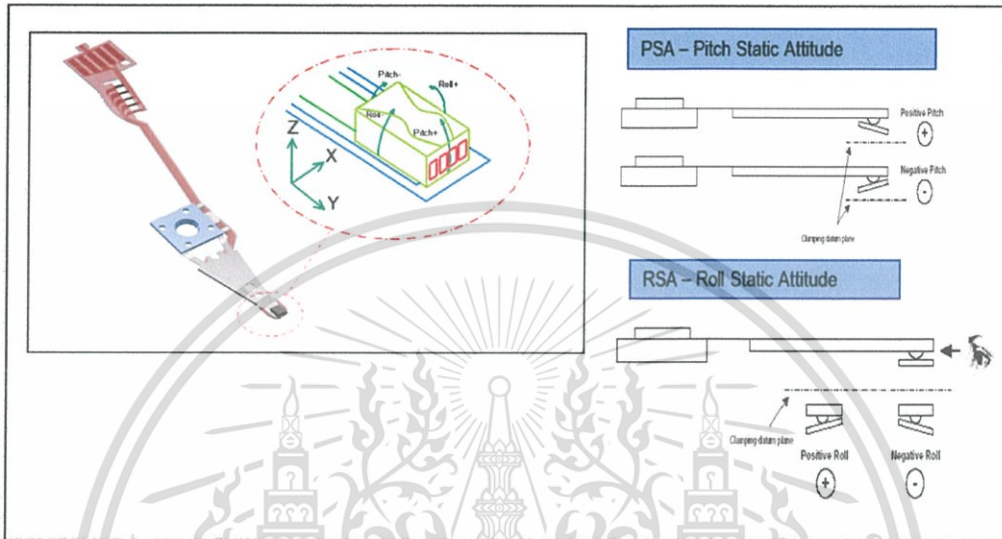


Figure 2.36 Indicated the PSA and RSA definition

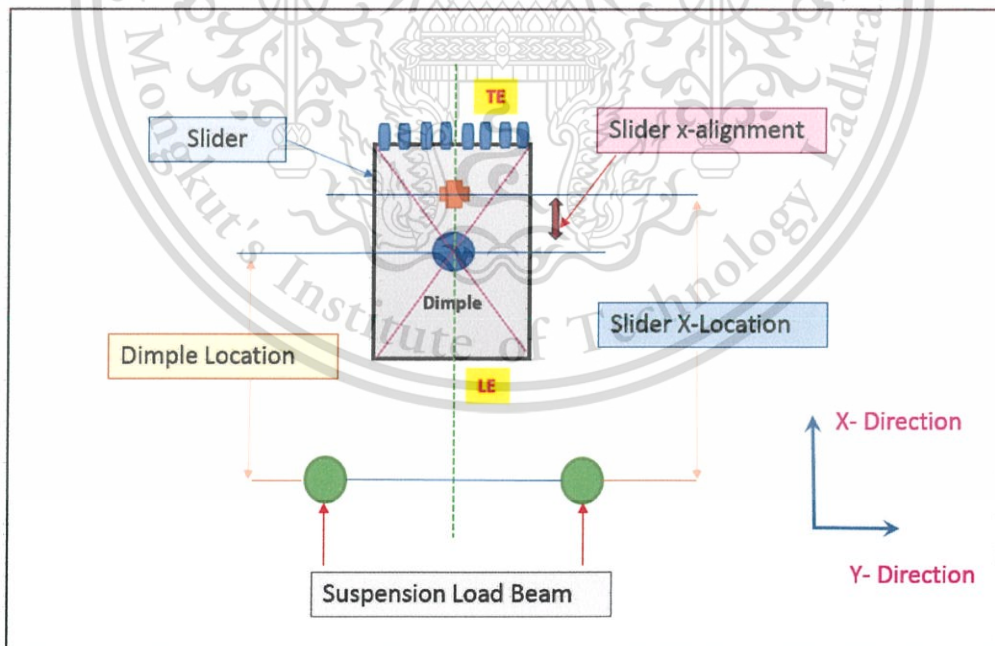


Figure 2.37 Indicated the slider x-alignment

CHAPTER 3

RESEARCH METHODOLOGY

3.1 The Slider Attach Tester

The Slider Attachment machine was used to support the experiment by attachment of the slider and the suspension together. The suspension was placed using the glue RTG1128 for attaching the slider and the suspension. Before placing the slider into the suspension, UV cure was applied with high energy to pre-cure the glue preparing for slider placement. In usual practice, the placing was focused at the center of Advance Air Bearing (AAB) of the slider and the dimple of the suspension. The slider attach algorithm was started from caption at the side edge of slider. It was caption into four positions along the edge of slider as Figure 3.2 b. After that, the machine vision system program will be calculated the center of slider by reference from four positions pointed and placed slider into the suspension by focusing at the center of slider and reference of suspension area, with this the slider can be fit for placing at the dimple area as in Figure 3.2 a.

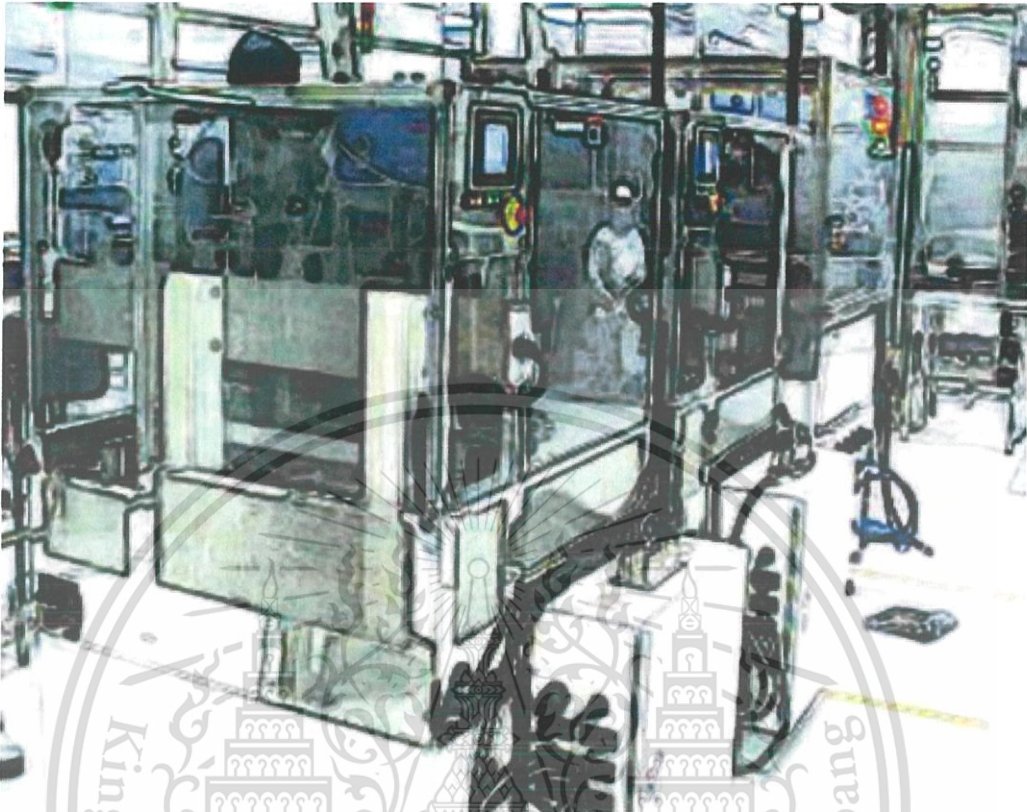


Figure 3.1 The slider attach machine [2]

After completely placing slider, the second UV cure was activated. Then, flexure circuit was connected with slider gimbal pad with Thermal Inter Connect machine (TIC). The gold wire was used to connect the suspension and the slider was melted with high energy power.

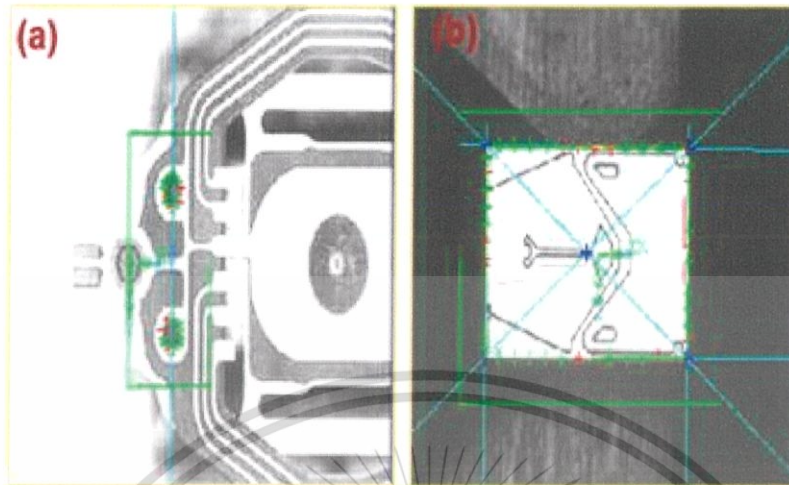


Figure 3.2 Vision recognition of slider attach machine for placing slider into suspension (a) Suspension recognition and (b) slider recognition [2]

3.2 The Pinnacle tester

The pinnacle tester was used for measuring the position of slider after completely mounted slider and suspension together at XYT-alignment direction. The machine was used the reference information set up and designed with uniqueness of own slider ABS itself. The reference information was created and measured by the ABS prototype with AUTOCAD program. The measurement algorithm is practical as same as slider attach machine, but, a bit different just at the resulting of report because the machine software read the real position from the sample and compare with reference information provided, after then, the software will calculate the distance of each parameter concerned, in this case is XYT_alignment.

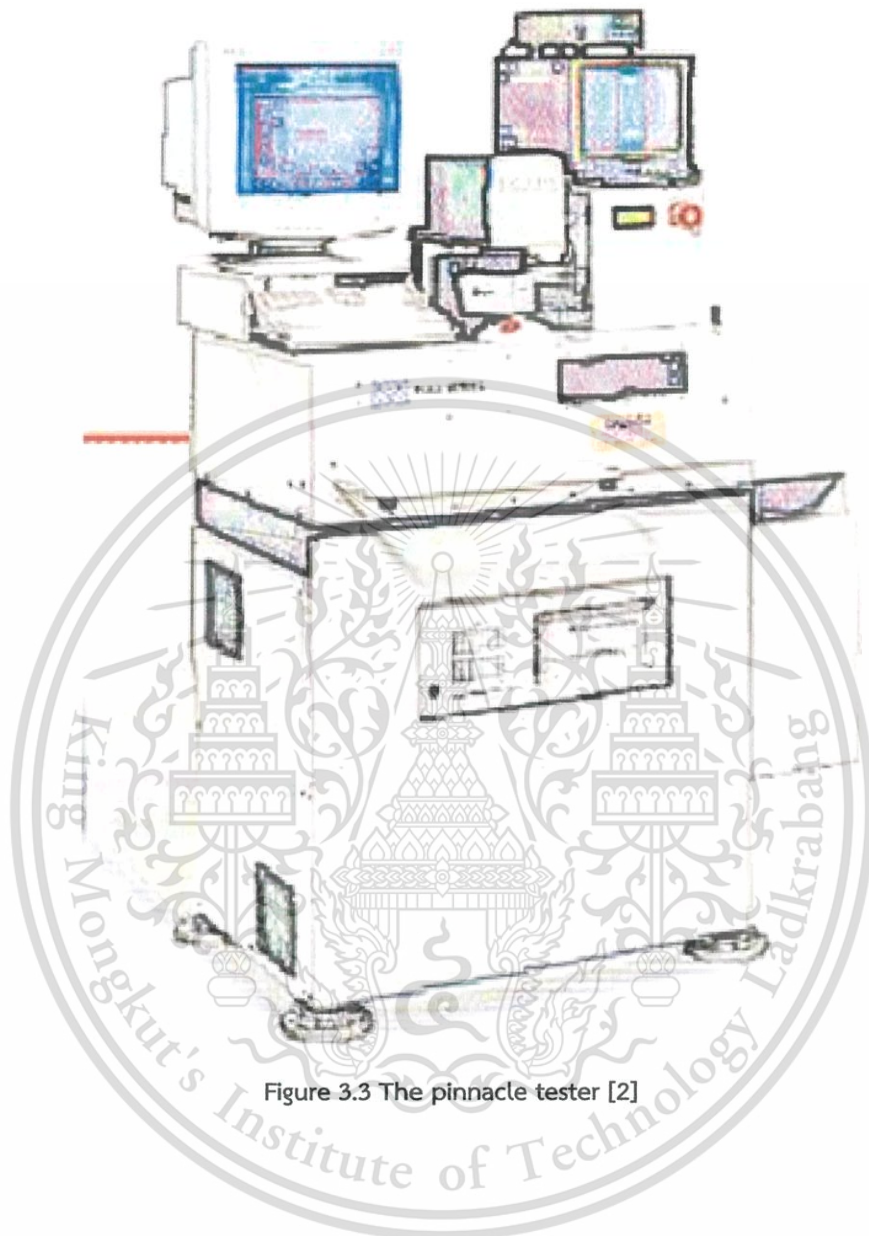


Figure 3.3 The pinnacle tester [2]

3.3 The Fly tester

Fly test is used to measure the distance between a glass disk and slider by using reflective light. The Fly Tester takes spot readings at numerous slider locations and calculates the following parameters:

1. ORTE = Outer Rail Trailing Edge
2. IRLE = Inner Rail Leading Edge
3. ORSLOPE = Outer Rail Slope = ORLE – ORTE

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4. ROLL = ORTE – IRTE

5. CP = Close Point

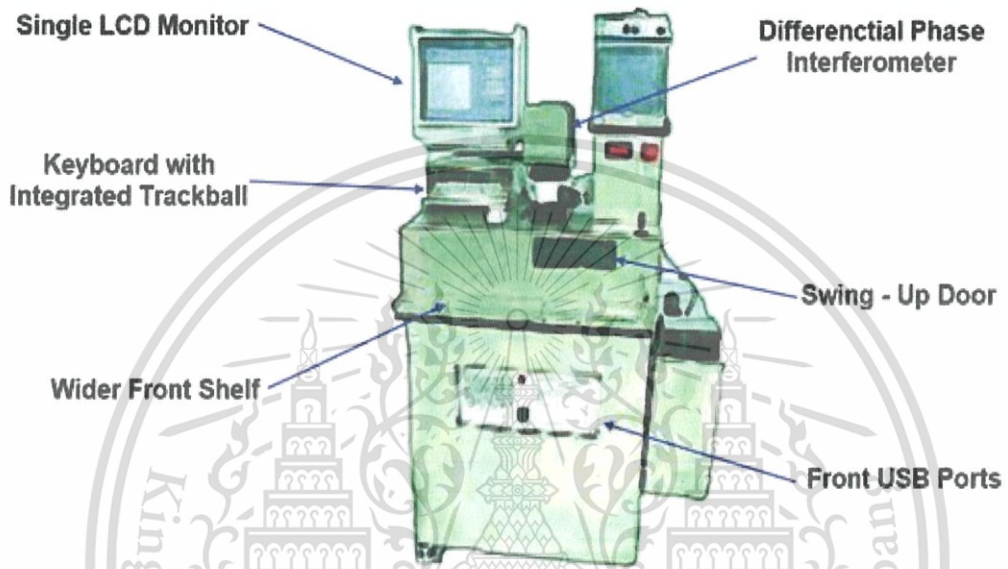


Figure 3.4 The Fly Tester [2]

Normally, the Fly was tested with five radius, ID1, ID2, MD, OD1 and OD2. Each radius has different skew angle, starting from -15° for ID1 and -5° for ID2 respectively as shown in Figure 3.5. The results of Fly test was reported by basing on the skew angle.

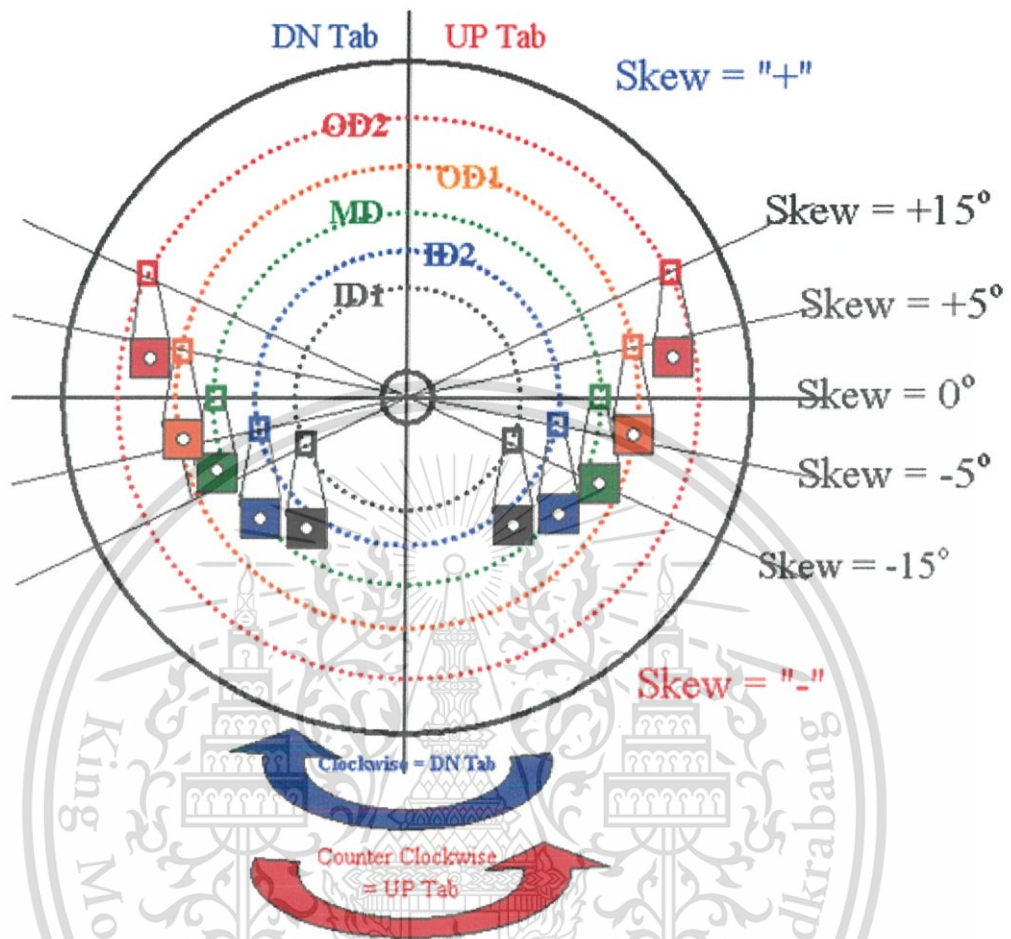


Figure 3.5 Fly test skew location identification [2]

3.4 The Contact Spin Stand Tester

The contact Spin Stand Tester is used for both electrical and mechanical test at HGA. The tester consists of disk, piezo, preamp assembly and channel board. It is used to quantify the performance of HGAs which intend to be capable of measuring as same as in HDD operation. With the same test approach can be used to understand media behavior and performance of other components of recording subsystem. This tester is a highly configurable test system that allows the user to place a head over a spin disk much like in the HDD, but with greater flexibility over the electrical and mechanical details. In term of electrical performance testing, it was covered on both reader and writer performance to more understand design point and head performance. In term of mechanical

performance testing, majority test was simulated the protrusion after apply heat into head and measure how far of head and disk then convert back to distance as presented in chapter 2.

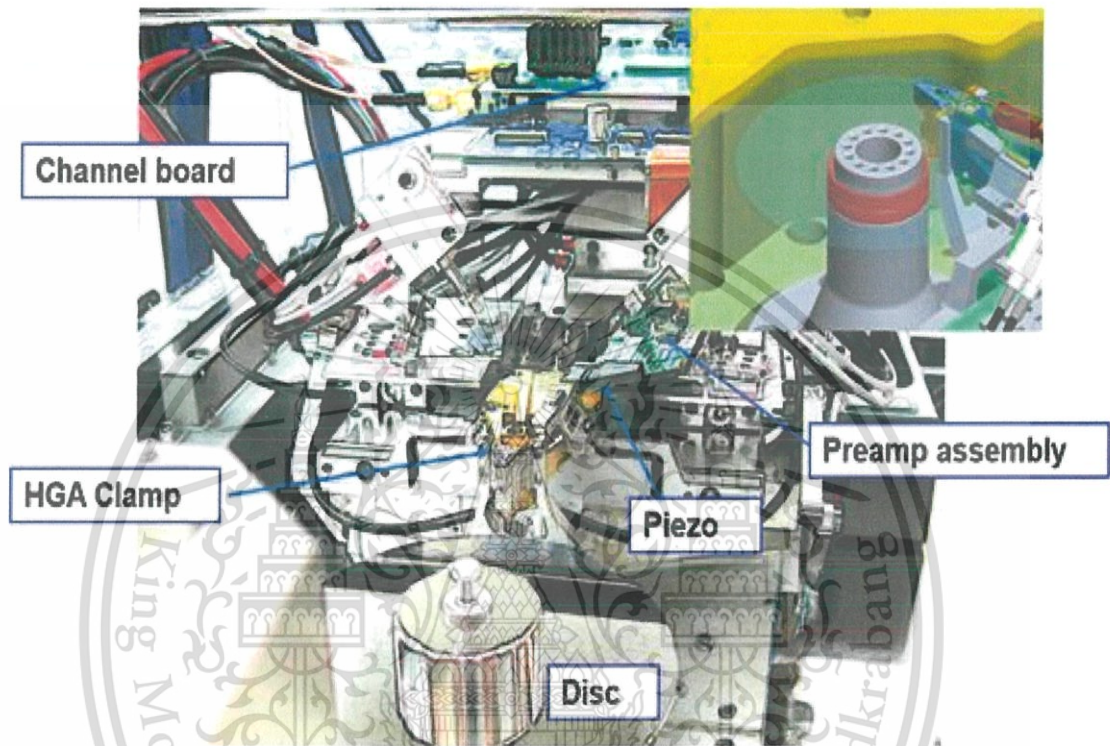
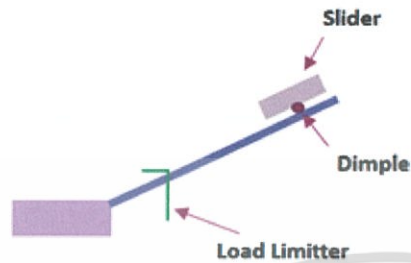


Figure 3.6 The Contact Spin Stand tester overview [2]

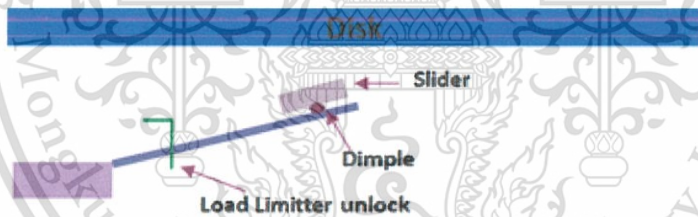
1. HGA prepare for test at Test Nest position and lock with Load Limitter



2. Tilt Down to adjust the angle before move to test under media



3. Tilt Up and unlock the Load Limitter (under media)



4. Test HGA (Under media) :: Dimple at center of the slider

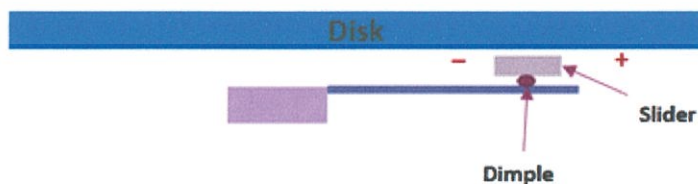


Figure 3.7 The simulation of head during test at Contact Spin Stand tester

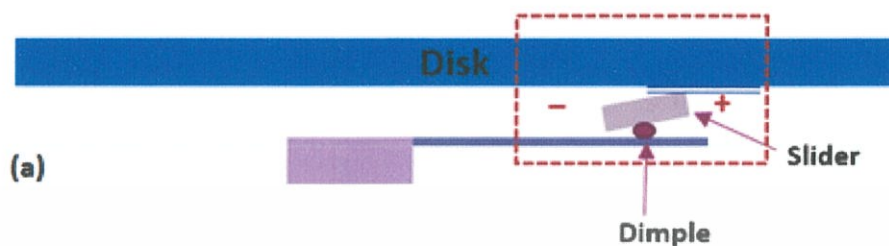
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In Figure 3.7, it shows the step by step of HGA measurement at Contact Spin Stand tester. In normal practice, the HGAs would sit at the nest waiting for picking to the slot test area. Then, the first step would be started by test nest position as and lock with load/unload limiter. Step two is tilt down the HGA into the position angle with safety before moving to test under disk. This process was intended to minimize the scratch at the end of suspension and disk which can be effected to head performance and cross failure for other HGAs test. Then, once HGAs was moved to under the disk the load limiter was unlocked, with these the HGAs will ready for step of testing. From step four, the HGAs stayed parallel to the disk during test, this is assumed with the dimple location and slider $x_{\text{alignment}}$ at the zero position. This tester was measured and tested the read/ write ability of head under the disk which was rotated with spindle speed between 5400 – 7200 rpm. The radius in this research is ID (Inner radius).

In Figure 3.8, it shows the simulation of slider under the disk during test with different slider $x_{\text{alignment}}$ directions. In Figure 3.8a, an $x_{\text{alignment}}$ at the (-) direction which means the dimple was not located at the center of slider, but it has some bevel slider position. Then, when it moves to under disk preparing for measurement the slider is not in parallel with disk. With this, the writer will be close to media as picture state which assumed that clearance will be low on this behavior moving. In the other hand, for the Figure 3.8b an $x_{\text{alignment}}$ at the (+) direction which means the dimple was not located at the center of slider but it has some bevel slider position. Then, when it moves to under disk preparing for measurement the slider is not in parallel with disk. With this, the writer will be fart from media which assumed that clearance will be high on this behavior moving.

HGA testing under media :: Dimple at "-" direction



HGA testing under media :: Dimple at "+" direction

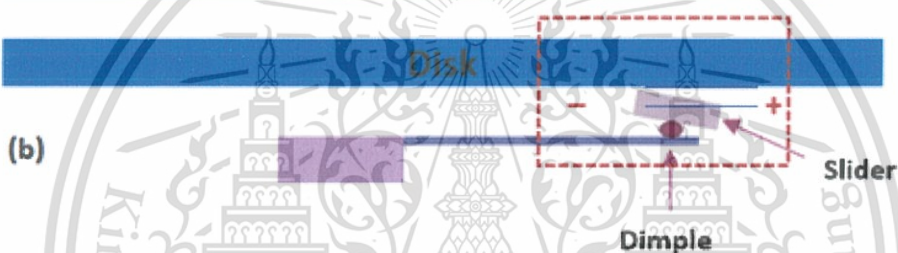


Figure 3.8 The simulation of head during test at Contact Spin Stand tester with moving slider $x_{\text{alignment}}$ into (-) and (+) direction

This research purposes the alternative approach to adjust the clearance reading prior to considering a new revision design of the suspension. As mentioned in chapter 1, the unit of slider $x_{\text{alignment}}$ is “millimeter”, hence, the machine adjustment is main factors in this research.

There are two main parts of experiment in this research. The first part called “The clearance impact from varying range of the slider $x_{\text{alignment}}$ ” is concerning the maximum adjustment on both higher side and lower side of the machine capability limitation. The second part is called “The clearance impact study from slider $x_{\text{alignment}}$ on the negative range adjustment”, this part was intended to study the machine efficiency adjustment and understand the clearance changed from this adjust.

3.5 Experiment flow of the clearance impaction from varying range of the slider x_alignment (part I)

In the part I, it was set the experiment into three groups as

1. Group1 as the lower group. This group is intended to move the slider x-alignment to the negative side, assumed as the slider x-alignment is low
2. Group2 as the center of dimple. This group is called normal which assumed the slider x-alignment is zero
3. Group3 as the higher group. This group is intended to move the slider x-alignment to the positive side, assumed as the slider x-alignment is high

To minimize the impact factors, the simulation of experimented environment was determined. The experiment was arranged under cleanroom environment of class 1000 condition (< 1000 particles/cubic foot/minute). The temperature inside the cleanroom environment was controlled. The room temperature was set between 17 – 27 °C and the relative humidity was set between 40-60%. All group of experiment are set by using slider of the same lot. The sample size was 120 HGAs per group. The manufacturing process was controlled to use the same tester measurement. The disk of contact spin stand tester was controlled by using only one surface. More detail of part I, the experiment flow is depicted in Figure3.7.

The clearance results are determined by using mean and sigma analysis. In this research, it uses JMP software for analyzing mean and sigma results.

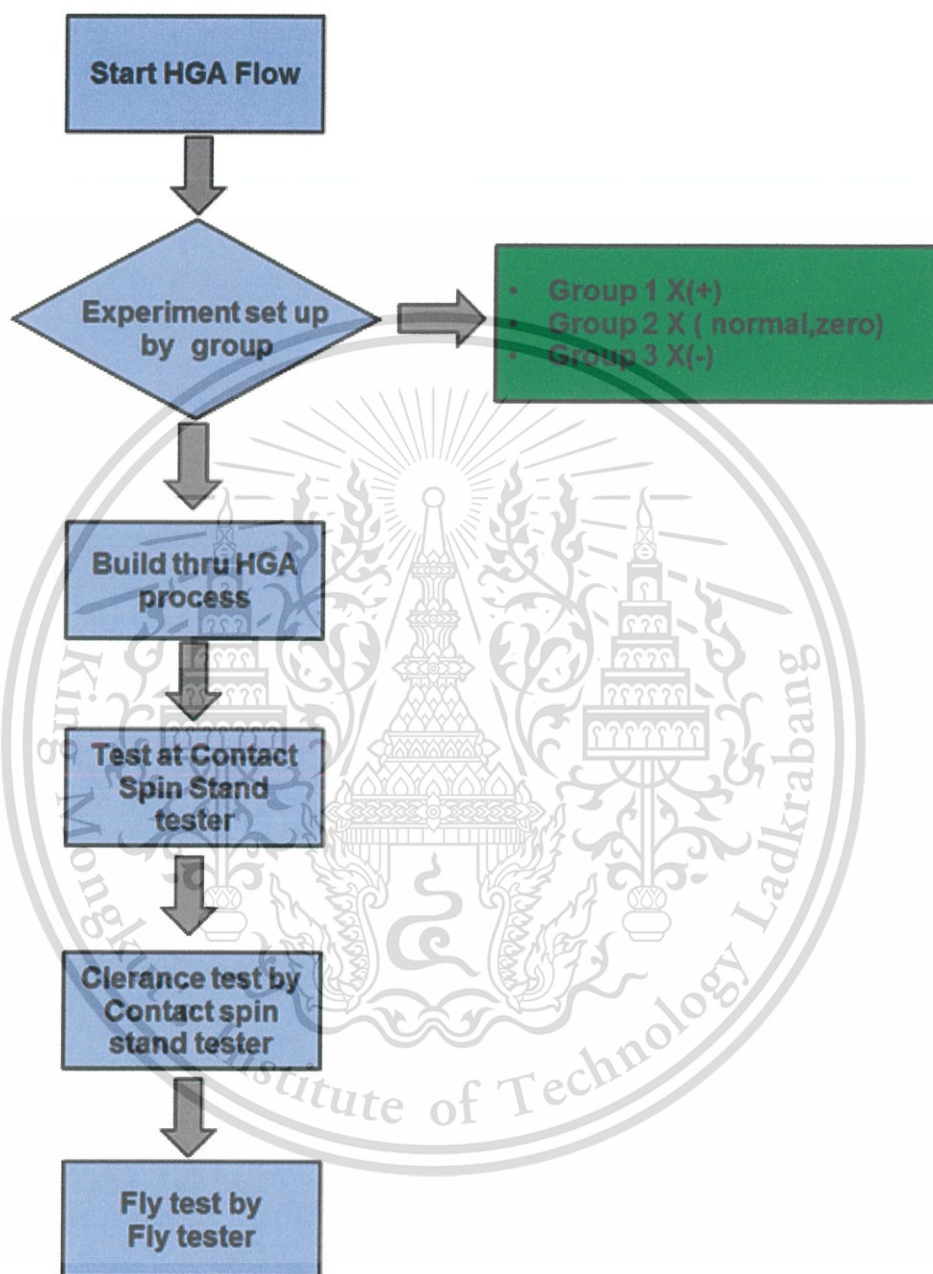


Figure 3.9 Experiment's flow chart of the clearance impactation from vary range of the slider $x_{\text{alignment}}$ (part I)

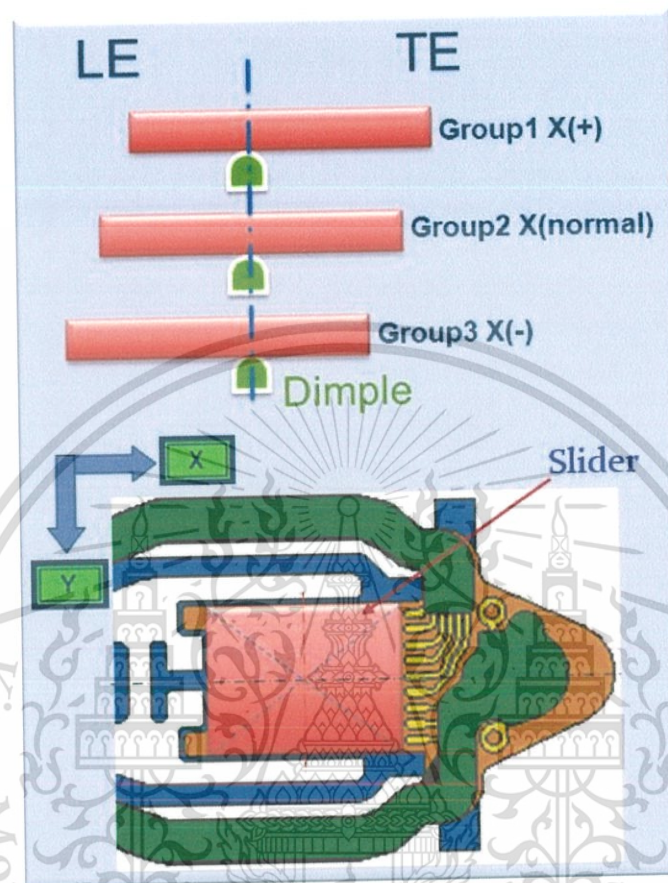


Figure 3.10 The top view image of slider and direction of slider x-alignment of each experiment group on suspension

Figure 3.10 illustrates the top view image of Slider and the direction of x-alignment of each group. The Trailing End (TE) is the top side of slider, containing Gold Bond Pad used for bonding slider and the suspension together. The Leading End (LE) is the bottom of slider, consisting of serial number of each individual of slider. The placement position of slider and the suspension was at the centered of both slider and dimple area, assumed as normal group. The placement of negative and positive directions was assumed as low and high group.

On the other hand, in Figure 3.11, it shows the schematic of side view of the slider and the dimple location. The 3.11a was slider x_alignment at zero location. This is baseline group which actually used for factory production so far and beyond. With the alignment

placing of slider at the center of dimple, this group would indicate with balance on both pitch and roll as well as HGA was paralleled to the disk. In Figure 3.11b and 3.11c, they indicated the location of slider which off from the dimple with different direction, negative (-) and positive (+).

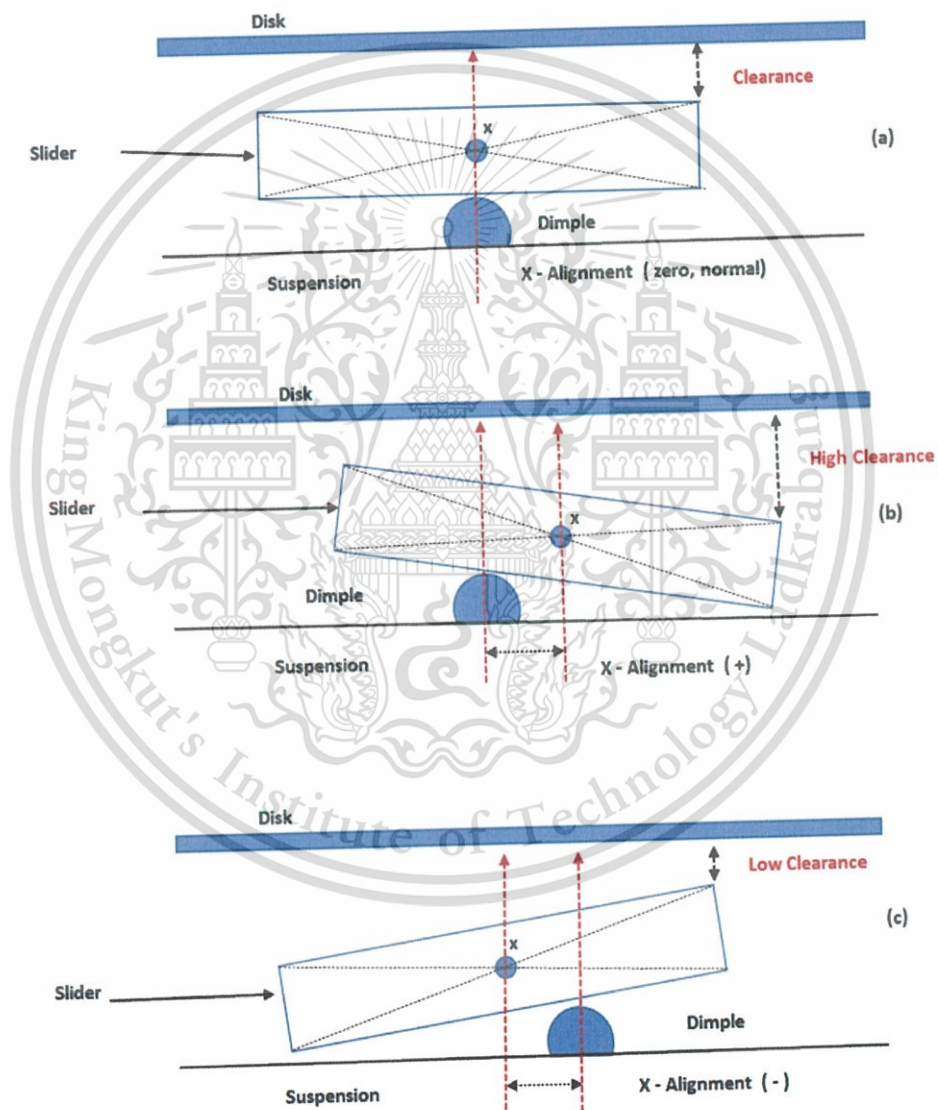


Figure 3.11 The schematic side view image of slider and direction of slider x-alignment of each experiment group during testing by Contact Spin Stand tester

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3.6 Experiment flow of the clearance impact study from slider x_alignment on the negative range adjustment (part II)

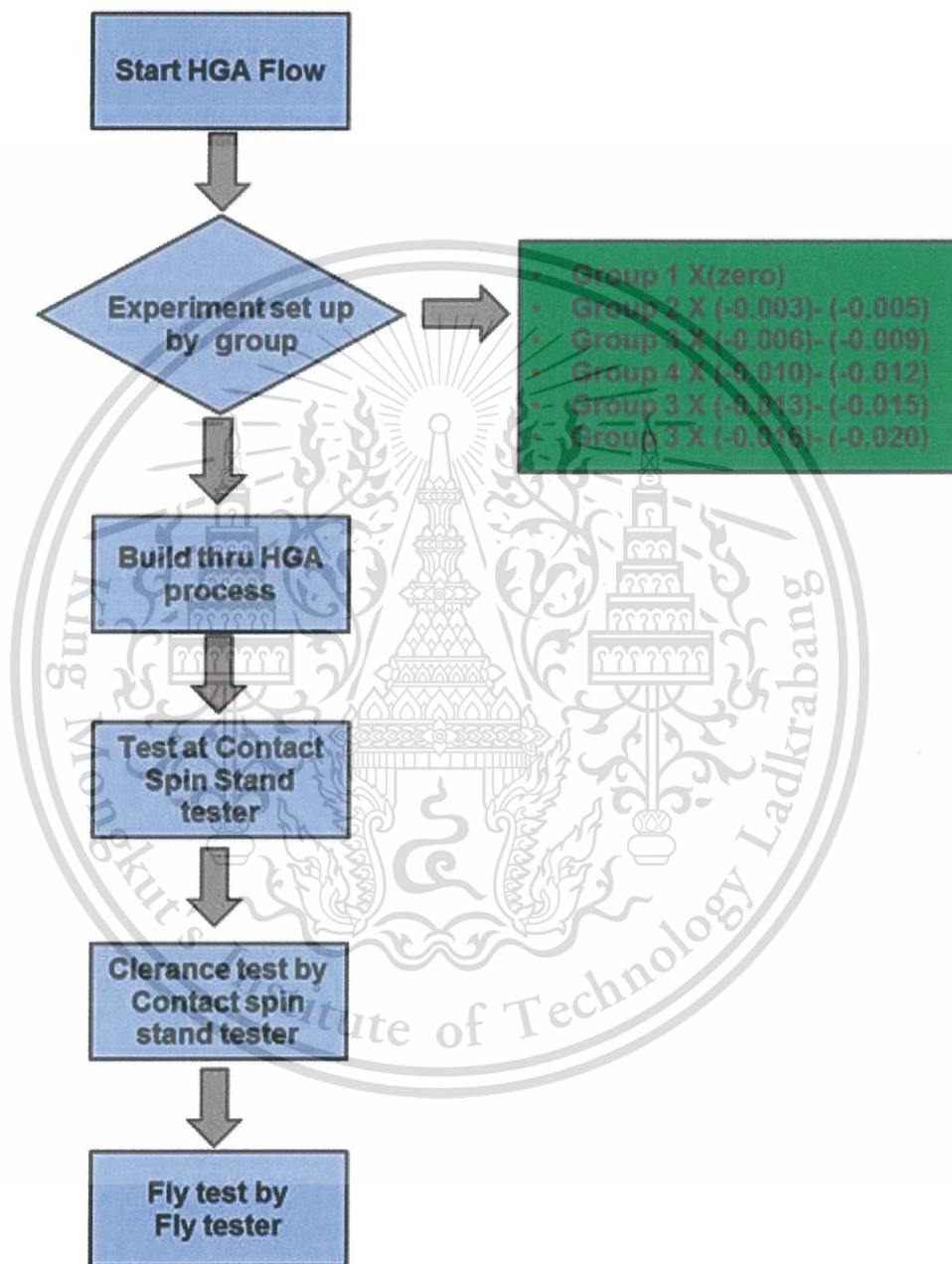


Figure 3.12 Experiment's flow chart of the clearance impact study from slider x_alignment on the negative range adjustment (part II)

In the part II, it was set the experiment into six groups and intended to study at the negative direction. The purpose of this experiment part was to study the machine minimizing adjustment and understand when clearance starting change after moving x_alignment. Based on machine adjustment limitation, in this research, it can move at minimum side only 0.003 mm as shown in Figure 3.12.



CHAPTER 4

EXPERIMENTAL RESULTS AND DISCUSSION

4.1 The clearance impact from varying range of the slider x_alignment (Part I) result

The results of part one, consisting of three groups of varying range of slider x_alignment impact to clearance, the results indicated that the Clearance keep changing when dimple location changes.

Figure 4.1 shows the result of clearance by experiment group. The Y-axis was clearance and the X-axis was experiment group, with three groups totally. This graph was plotted by an average value of each population data set of each group. The Figure 4.2 and 4.3 show the result of x_alignment and y_alignment by experiment group respectively. From the results of three Figures, at group one which is known as slider x_alignment was on the positive direction given x_alignment at 0.01916 mm. With this, the clearance on this group becomes an average at 9.07 nm. By the way, when comparing with group two (normal) which x_alignment on zero slider x_alignment position, it becomes that clearance result shows an average value at 8.43 nm (0.64 nm higher than group one). For the result of group three which is known as slider x_alignment at negative direction given slider x_alignment at -0.01315 mm. With this, the clearance on this group becomes an average value at 8.28 nm. Looking at the slider y_alignment results in Figure 4.3, the group one which is known as slider x_alignment at the positive side, this group is given slider y_alignment an average value at 0.00283 mm. The group two which is known as slider x_alignment at normal group, at zero position, this group is given slider y_alignment an average value at 0.00165 mm while the last one is known as group three which is known as slider x_alignment at negative side, this group is given slider y_alignment an average value at 0.00408 mm.

Additionally, the Figure 4.3 and Figure 4.4, Y_alignment and T_alignment respectively, have similarly trend Figure, group two is given lower than other while group three given higher than other. This trend was as expected. The reason was this study is

intended by varying the x_alignment along the suspension, but, it would be some chance, causing to y_alignment change. By the way, both of them were at the acceptable range since it was not out of specification. With this result, it would be reported that Y_alignment was comparable on three group experiments.

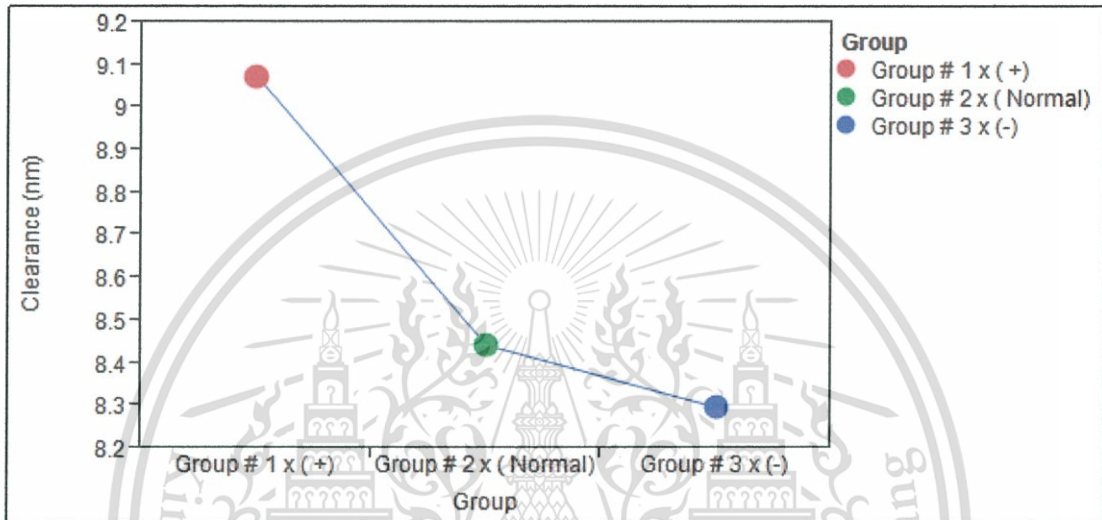


Figure 4.1 The mean of clearance by experiment group

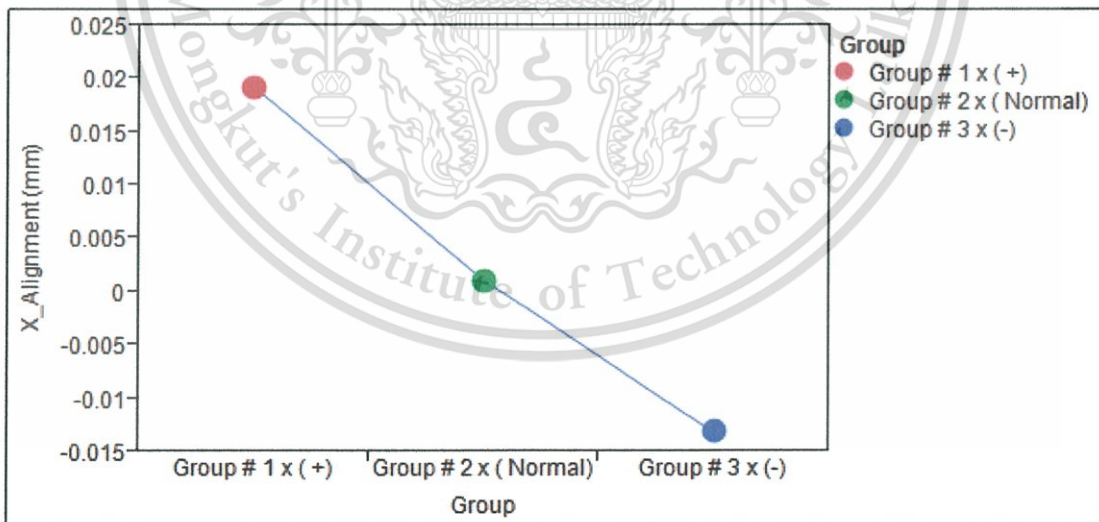


Figure 4.2 The mean of X_Alignment by experiment group, specification 0 ± 0.02235

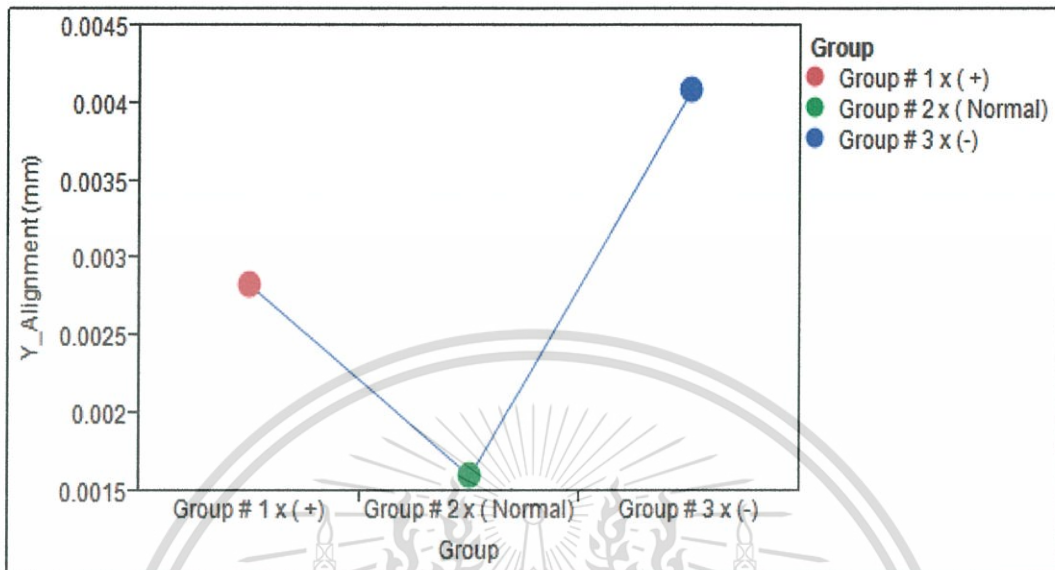


Figure 4.3 The mean of Y_Alignment by experiment group, specification 0 ± 0.02235

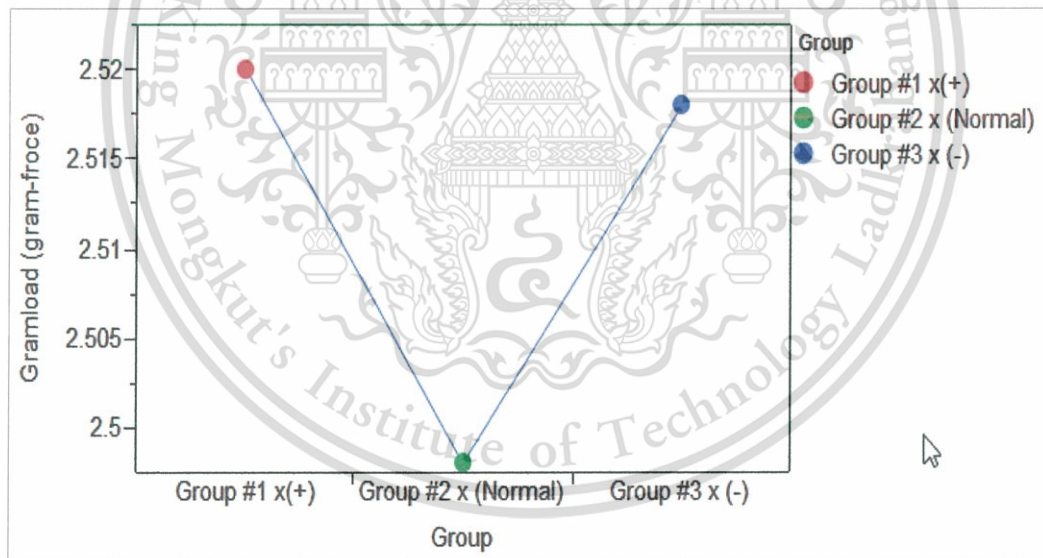


Figure 4.4 The mean of Gramload by experiment group, specification 2.5 ± 0.2

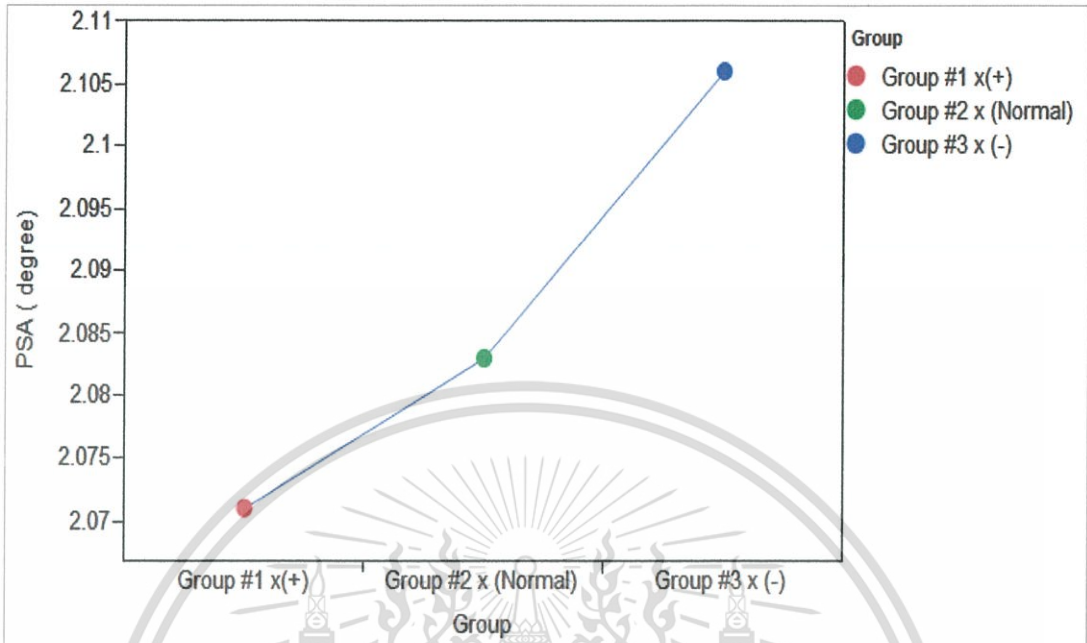


Figure 4.5 The mean of PSA by experiment group, specification 2.1 ± 0.2

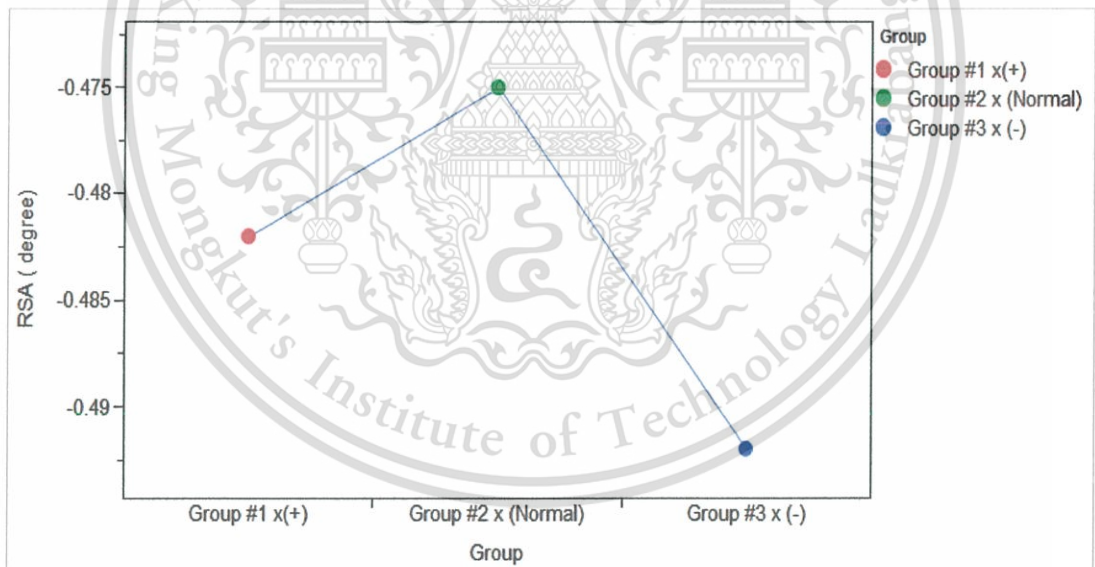


Figure 4.6 The mean of RSA by experiment group, specification -0.5 ± 0.6

Figure 4.4 shows the Gramload result of all three group experiment, an x-axis was identified by an experiment group with having three groups in total while y-axis is gramload value and the unit of gramload is gram-force. The spec of gramload is 2.5 ± 0.2 gram-force, from the chart shows that the group two given gramload value at 2.49 gram-force while

group one and group three are given gramload value at 2.52 and 2.51 gram-force respectively. In term of the spec and tolerance even group two was lower than other group but it was within spec, with this, this report would conclude that gramload was comparable. In the other hand, these experiments were assumed that along the slider body the gramload force holding was 2.5 gram-force and the result was as expected.

In the Figure 4.5, it shows the PSA (Pitch Static Attitude) result by experiment group. An x-axis was identify by an experiment group with having three groups in total while y-axis is PSA value and the unit of PSA is degree. Regarding the PSA results, it was converse trend when comparing with clearance chart. Based on the clearance sensitivity, getting low clearance if PSA trend is high and same practice with high clearance if PSA trend is low. In the Figure 4.6, group one get PSA value at 2.07 degree while clearance results in Figure 4.1 at 9.07nm, group two is baseline which gets PSA value at 2.08 degree while clearance results in Figure 4.1 at 8.43 nm and the last one is group three which get PSA value at 2.106 degree while clearance results in Figure 4.1 at 8.28 nm. In term of RSA (Roll Static Attitude) in Figure 4.6, an x-axis was identify by an experiment group with having three groups in total while y-axis is RSA value and the unit of RSA is degree. The results shows that group two was get low RSA than other group which getting RSA value at -0.475 degree while group one and group three get RSA value at -0.482 degree and -0.492 degree respectively. Regarding to the RSA spec and tolerance, it would reported that the result of three groups were comparable.

In Figure 4.7, it shows the trend of Fly testing, an x_axis was identified by skew angle of disk while y_axis was identified PTFH (Pole Tip Fly Height) value which the unit of PTFH was microinch. The experiment group was separated by colour and identified in the top of right hand side. It was dynamic test which uses to verify the flying characteristics of the head. There are three parameters interested at Fly test, PTFH, pitch and roll. The PTFH results were correlated with clearance result, when looking at the profile of each group, all group has same slope profile. But, when looking at the PTFH value by each experiment group and comparing to clearance value in Figure 4.1, all three groups were different flying profile which was significant correlated with clearance result, low clearance also fly height become low PTFH and high clearance was become high PTFH as well. By

the way, in term of each group result, the PTFH delta was only 0.1 microinch which would conclude that it is not significantly different in term of static theory. But, it can be indicated the flying feasibility of head. With this results it can be concluded that with the change at clearance (around 0.4-0.8 nm) would be affected to real fly of head stability. Therefore, fly height was most critical fly parameter in terms of electrical performance. Low fly height provides better electrical performance, too low causes HDI (Head Disk Interference) and becomes damages on both head and disk.

In Figure 4.8 show the pitch results. The result indicated that, all three groups were comparable on all skew angle range.

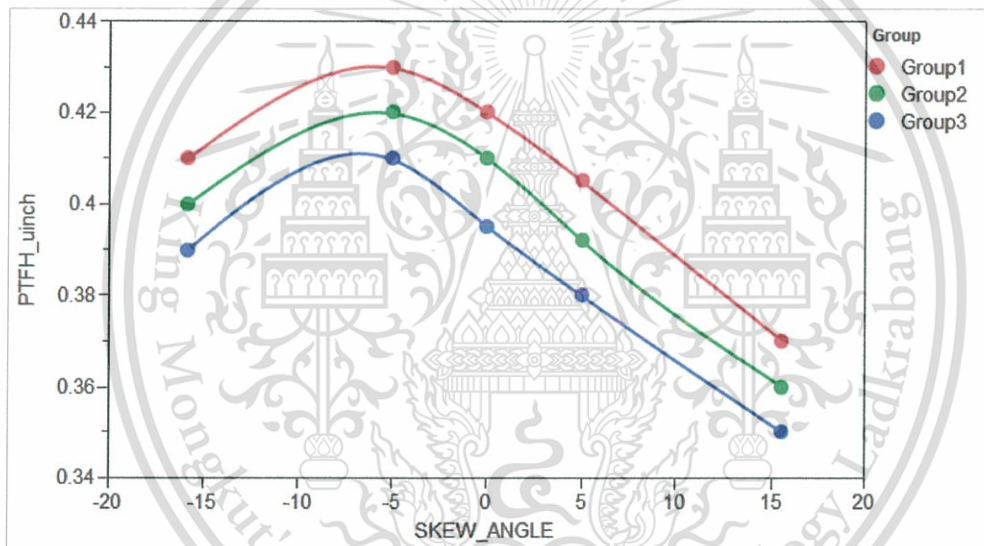


Figure 4.7 The mean of PTFH by experiment group

In Figure 4.9 show the roll results. The result indicated that, all three groups were comparable on all skew angle range. With the result of both pitch and roll, it was indicated that even the fly height profile looks different among three groups of experiment but pitch and roll does not change. Both pitch and roll performance can indicated that the slider and suspension were perform attached together with good balancing.

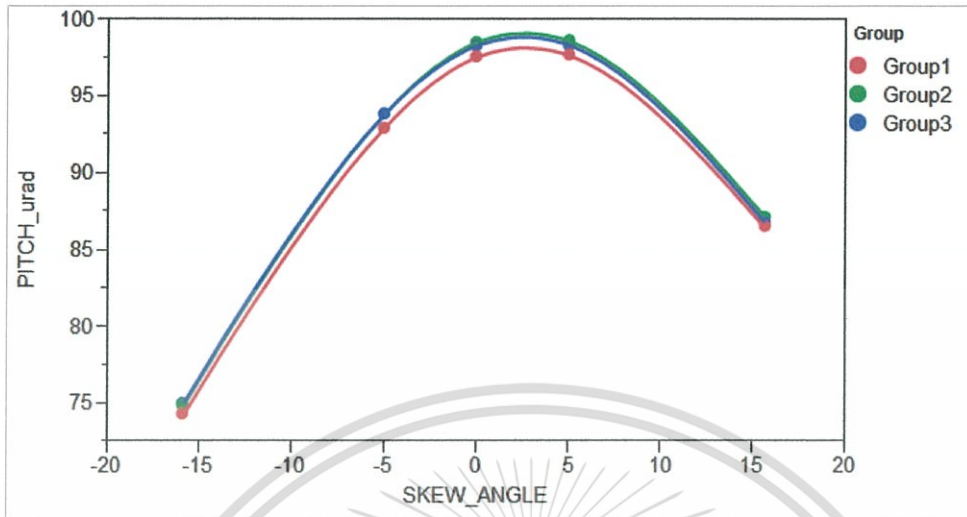


Figure 4.8 The mean of PITCH by experiment group

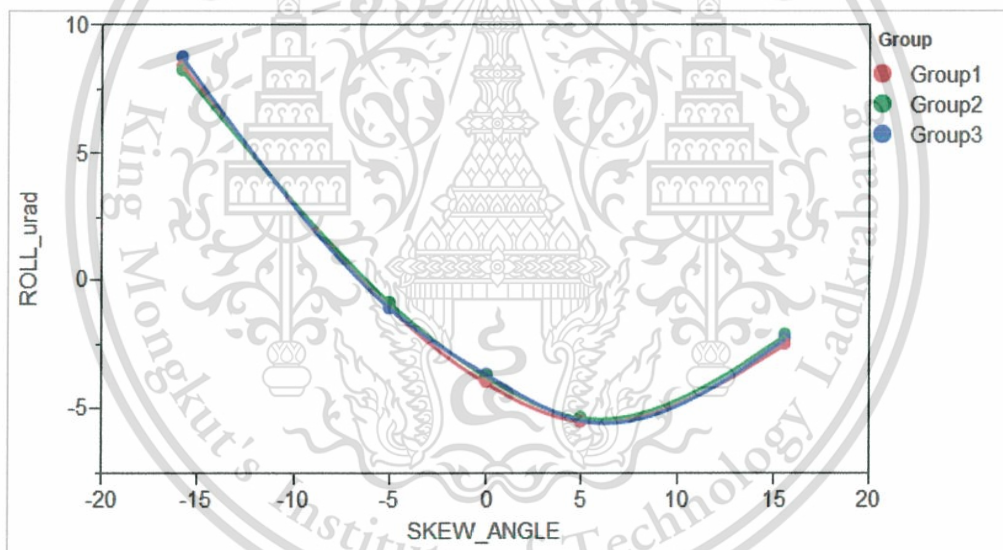


Figure 4.9 The mean of ROLL by experiment group

In Figure 4.10, it show the amplitude results; an x_axis was identified by experiment group while y_axis was identified amplitude value which the unit of amplitude was microvolt. The result indicated that, group one gets higher amplituder than other groups while group two gets lowest amplitude when compared with other group. The amplitude of group one was higher than group two by $400 \mu\text{V}$ and the amplitude of group three was higher than group two by $150 \mu\text{V}$.

In Figure 4.11, it shows the Bit Error Rate result; an x_axis was identified by experiment group while y_axis was identified amplitude value which the unit of Bit Error Rate was decade. The result indicated that, group one gets worst Bit Error Rate than other groups while group two gets better Bit Error Rate when compared with other groups. The Bit Error Rate of group one was poorer than group two by 0.07 decade and the Bit Error Rate of group three was poorer than group two by 0.02 decade.

From Figure 4.11 and 4.10 results, it can be concluded that, the amplitude and Bit Error Rate have no correlation to clearance. The reason of this phenomena came from the algorithm of electrical test of the contact spin stand tester. In this study, the contact spin stand software was programmed and focused at the target point of clearance, then, applied power into head with only two or three steps to hit contact point. It is important to keep in mind that in this study, the Pole Tip Flyheight (PTFH) result was the key parametric which can be preferred for head flying ability.

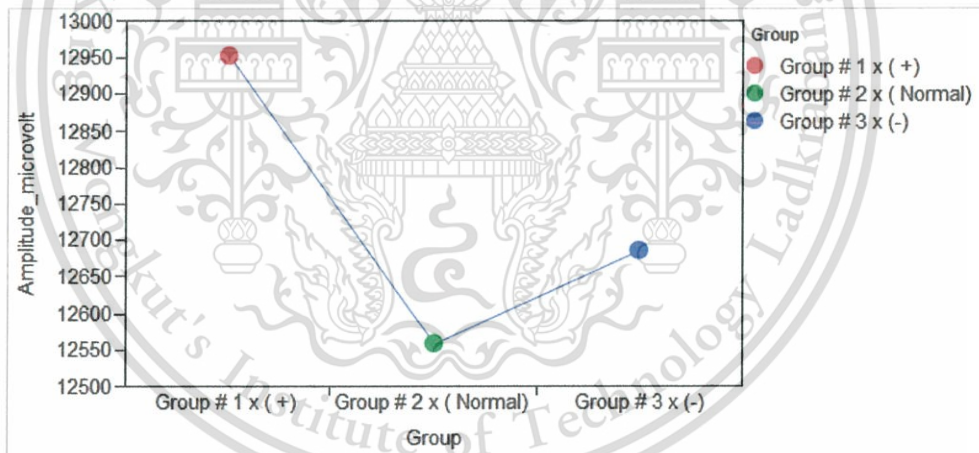


Figure 4.10 The mean of amplitude by experiment group

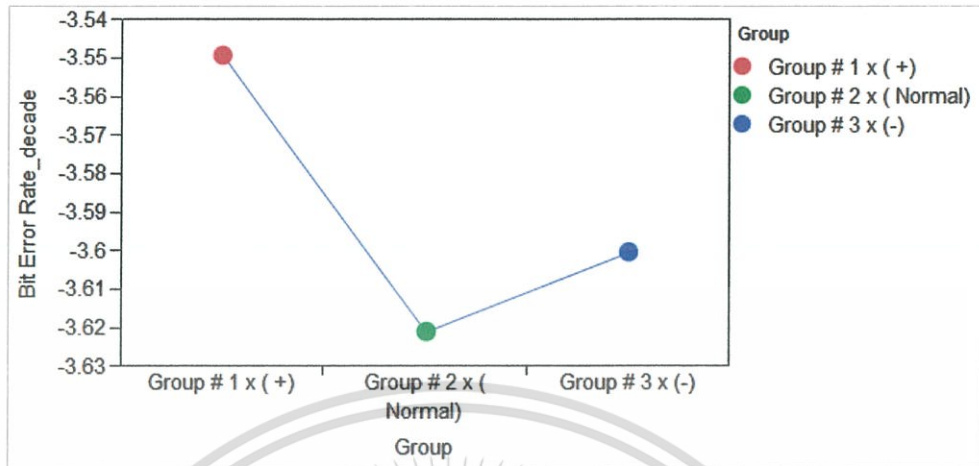


Figure 4.11 The mean of Bit Error Rate by experiment group

In Figure 4.12, it shows the W-curve at 1st torsion mode by an x_axis was Z-height range and separated by experiment group by color of line while y_axis was average gain of each experiment group by Z-height. The sample size was fifteen HGAs per experiment group. The result shows all experiment group which are comparable on all Z_height range.

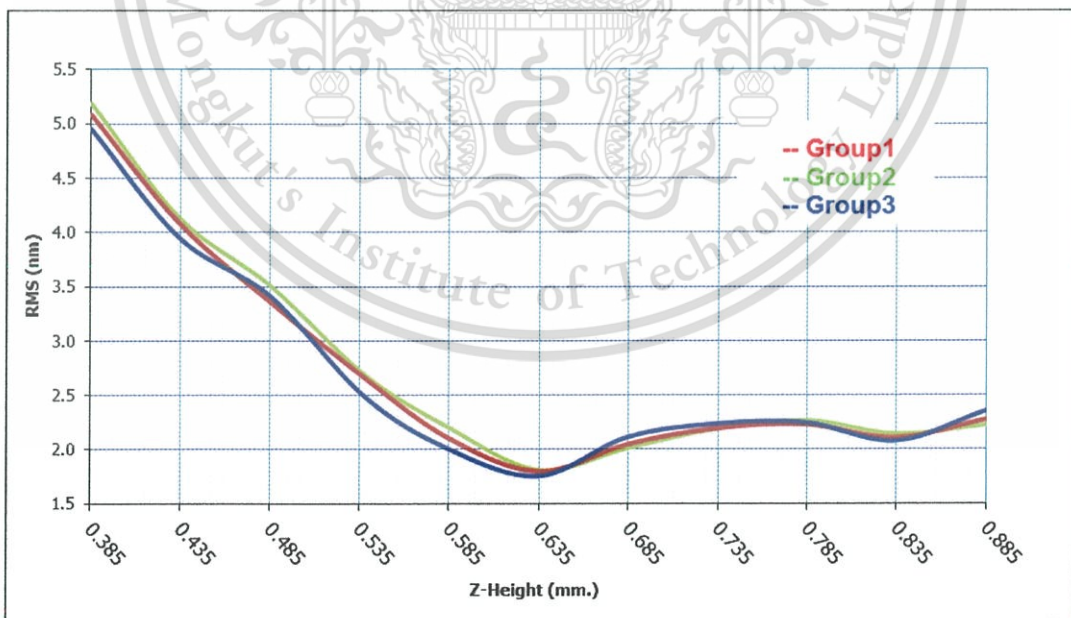


Figure 4.12 The W-Curve at 1st torsion by experiment group

In Figure 4.13, it shows the Frequency Response Functions (FRF) plot. An x_axis was frequency range while y_axis was the magnitude of gain which separate by an experiment group. Figure 4.11a, it shows the overall frequency from 1-100 kHz while Figure 4.11b was zoomed in the frequency from 1-50 kHz. The results shows all three groups of experiment got peak of gain were comparable on every frequency modes, first torsion, first sway and third torsion mode. But, in Figure 4.11a, observed the different peak at the frequency from around 65 kHz to 75 kHz. It was occurred on the group one (red line). By the way, this study was studied at Head Gimbal Assembly (HGA) which was focused at the frequency from range 1-40 kHz.

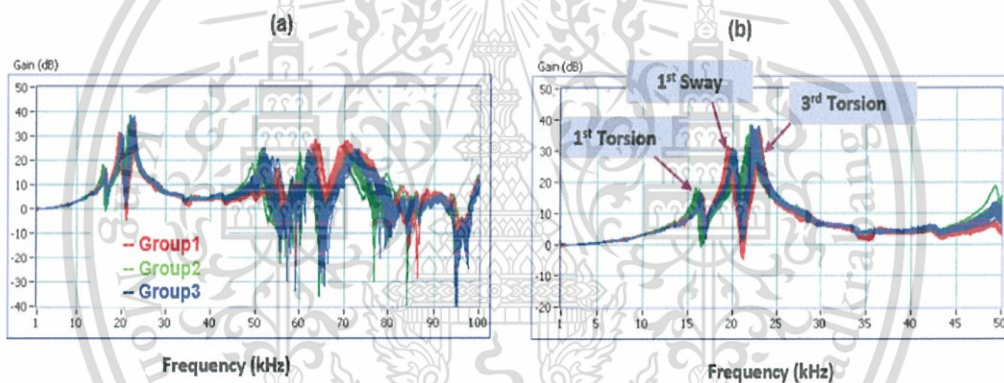


Figure 4.13 The Frequency Response Functions(FRF) plot by experiment group

In Figure 4.14, it shows the windage spectra plot. An x_axis was frequency range while y_axis was the magnitude of gain which was separated by an experiment group. Figure 4.18a, it shows overall frequency from 1-100 kHz while Figure 4.18b was zoomed in the frequency from 5-50 kHz. The results shows only two group of experiment (group two and group three) which were comparable on every frequency ranges except at the first Bending and gimbal torsion mode which seen group one higher peak than other group. With the phenomena of group two result, it was concluded that when varying the slider into the positive direction of x-alignment it become clearance to be higher. With the significant higher of clearance it may be cause of more ripple during the windage test.

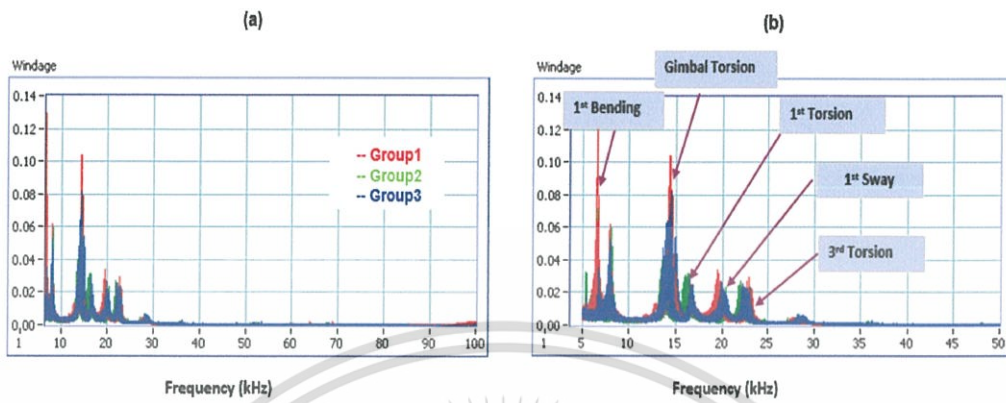


Figure 4.14 The windage spectra plot by experiment group

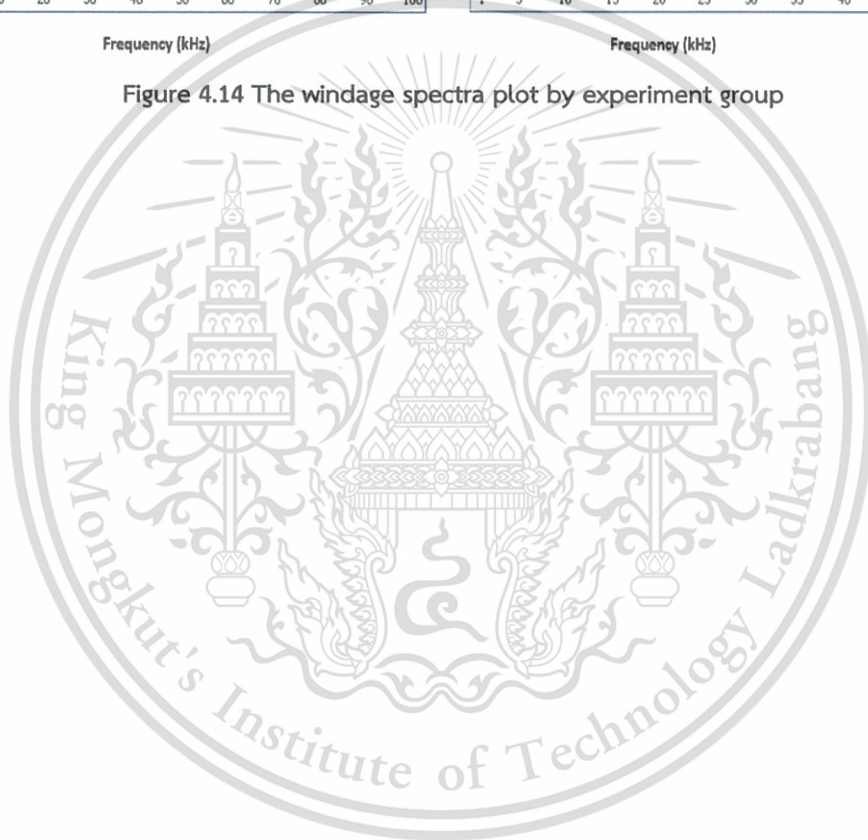


Table 1. The summary results of the clearance impaction from varying range of the slider x_alignment (part I)

Parameters	Spec	Group 1 X(+)	Group 2 X(normal)	Group 3 X(-)
X-Alignment (mm)	0 ± 0.02235	0.01916	0.00108	-0.01315
Y-Alignment (mm)	0 ± 0.02235	0.00283	0.00165	0.00408
PSA (degree)	2.1 ± 0.2	2.071	2.083	2.106
RSA (degree)	-0.5 ± 0.6	-0.482	-0.475	-0.492
Gramload (gram-force)	2.5 ± 0.2	2.52	2.498	2.518
Clearance (nm)	Min 3	9.07	8.43	8.28

4.2 The clearance impact study from slider $x_{\text{alignment}}$ on the negative range adjustment (Part II) result

Figure 4.15 shows the result of clearance by group of experiment, an x-axis was identify by an experiment group which contains six groups in total while y-axis was clearance mean which unit of clearance was nanometres. The results show as expected, starting from group one which is called “control group”, assumed slider $x_{\text{alignment}}$ at zero. With the reason needed to have better understanding in term of how many slider $x_{\text{alignment}}$ change can contribute to clearance starting change. This experiment was intended to study at the negative range of slider $x_{\text{alignment}}$ with only.

However, the results indicated that, group one which was control group got clearance value at 8.32 nm while got slider $x_{\text{alignment}}$ value at -0.0049 mm (would consider this is zero). Group two got clearance value at 8.24 nm while got slider $x_{\text{alignment}}$ value at -0.0111 mm. Group three got clearance value at 8.10 nm while got slider $x_{\text{alignment}}$ value at -0.0170 mm. Group four got clearance value at 7.98 nm while got slider $x_{\text{alignment}}$ value at -0.0193 mm. Group five got clearance value at 7.95 nm while got slider $x_{\text{alignment}}$ value at -0.0238 mm. The last one was group six got clearance value at 7.71 nm while got slider $x_{\text{alignment}}$ value at -0.0274 mm.

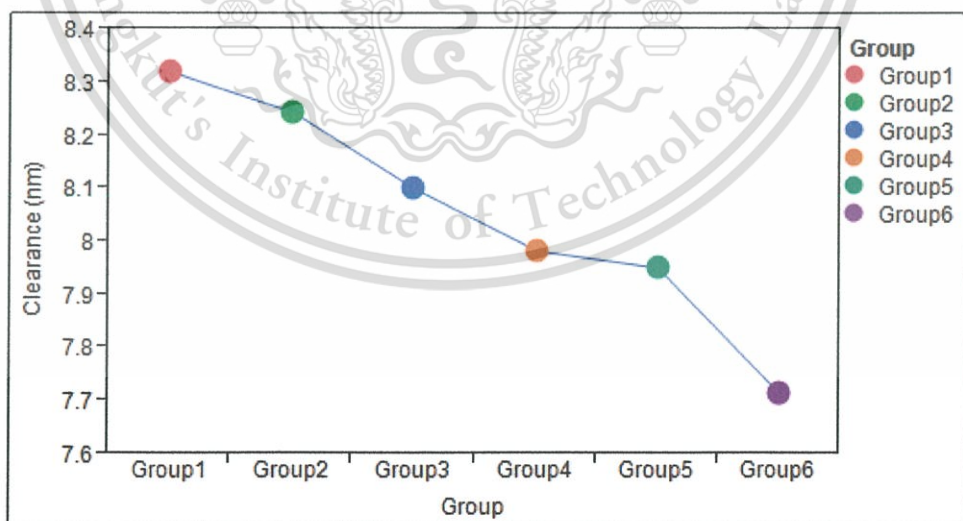


Figure 4.15 The mean of clearance by experiment group

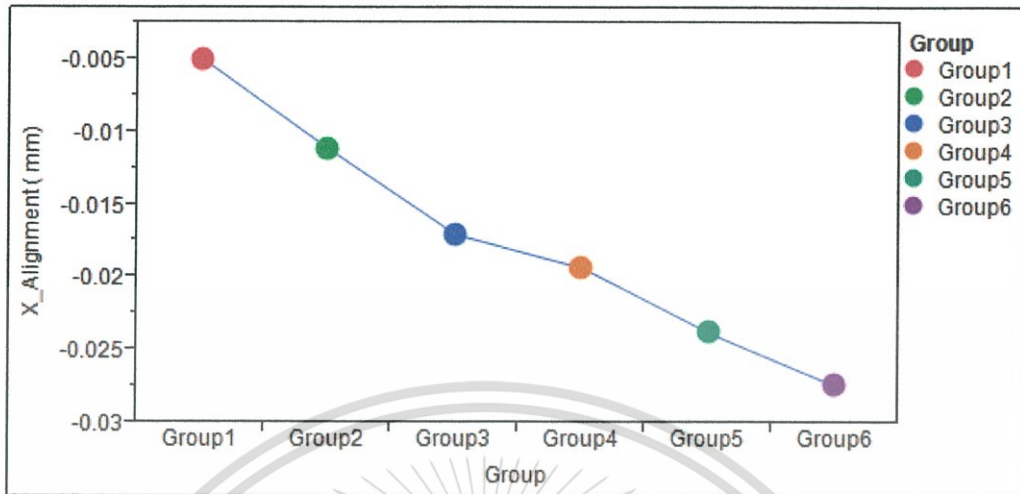


Figure 4.16 The mean of X_Alignment by experiment group, specification 0 ± 0.02235

In Figure 4.16, it shows the slider x_alignment value by experiment group, an x-axis was identified by an experiment group, having six groups in total while y-axis was slider x_alignment mean which unit of clearance was millimeters. The chart result shows that group one was higher slider x_alignment than other group. For the group two until group five given the x-alignment lower and lower till -0.03 millimeters respectively. As a matter of fact, it was as expected of this study.

In Figure 4.17, it shows the slider y_alignment value by experiment group, an x-axis was identified by an experiment group, having six groups in total while y-axis was slider y_alignment mean which unit of clearance was millimetres. The chart result shows that group one and group5 have higher slider y_alignment than other group. By the way, when comparing with slider y_alignment spec, there were comparable for all six groups experiment.

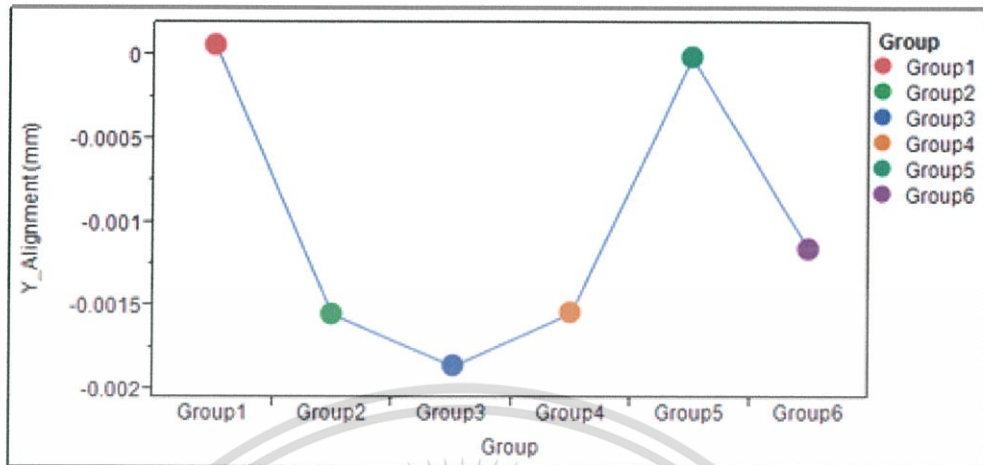


Figure 4.17 The mean of Y_Alignment by experiment group, specification 0 ± 0.02235

Figure 4.18 shows the PSA (Pitch Static Attitude) result by experiment group. An x_axis was identified by an experiment group while y_axis was identified PSA value which the unit of PSA was degree. The results of PSA starting from group one to group six keep increasing, group one was lower than other groups while group six was also higher PSA than other groups. The PSA trend when compared with Figure 4.13 and 4.14 looks opposite direction of slope. Therefore, this phenomenon was correlated with prediction model and clearance sensitivity. When taking about clearance and slider x_alignment sensitivity, the clearance keep higher when slider x_alignment keep higher (at positive direction range). As well as the clearance keep lower when slider x_alignment keep lower (at negative direction range). But for the PSA sensitivity, it was converse slope as clearance keep lower when PSA becomes higher and on the other hand, clearance keep higher when PSA becomes lower.

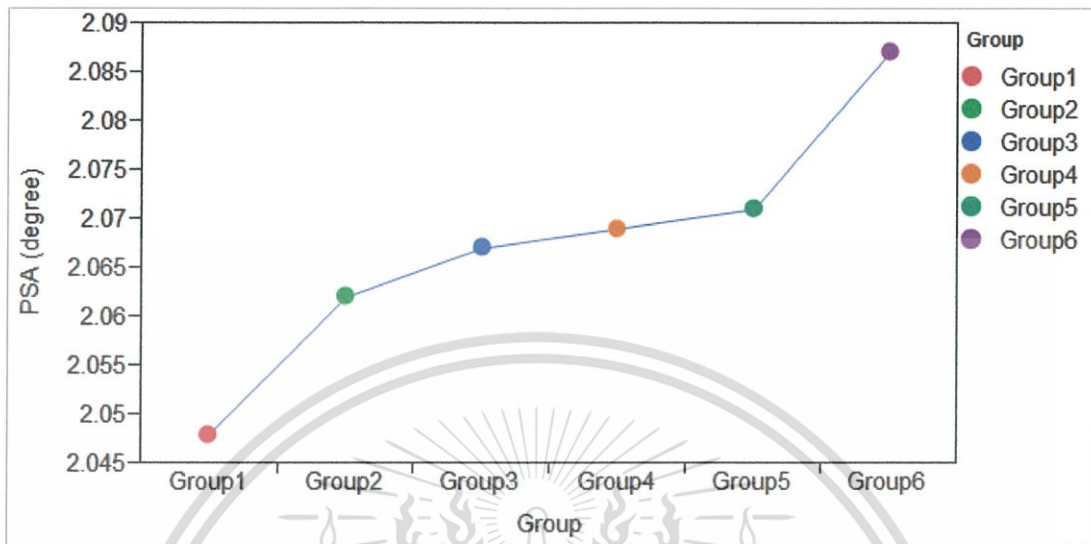


Figure 4.18 The mean of PSA by experiment group , specification 2.1 ± 0.2

In Figure 4.19, it shows the RSA (Roll Static Attitude), an x_axis was identified by an experiment group while y_axis was identified RSA value which the unit of PSA was degree. The results shows that group one and group six have higher RSA than other group. By the way, if looking at an RSA spec it would conclude that all six group are comparable. In the other hand, an RSA had less correlation to clearance on this study.

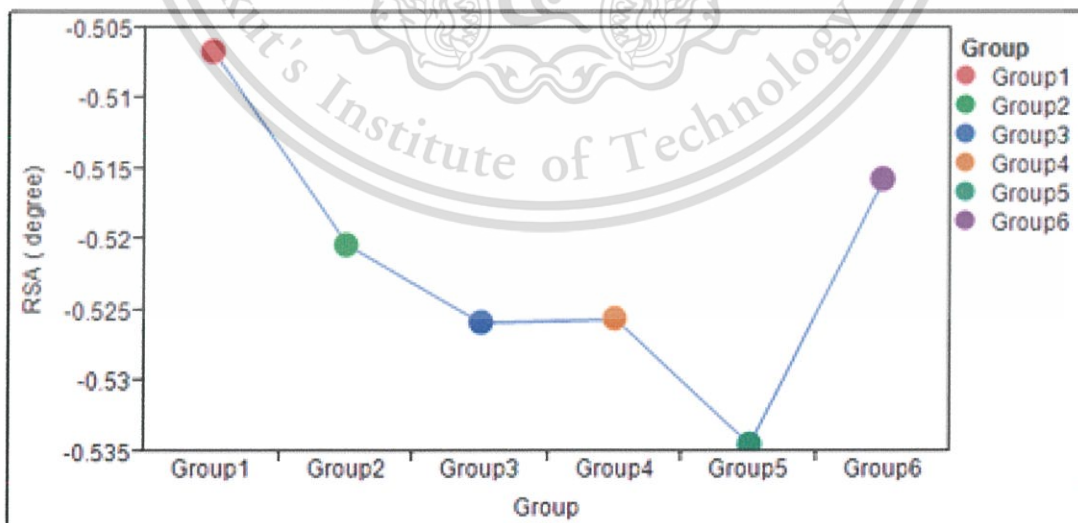


Figure 4.19 The mean of RSA by experiment group, specification -0.5 ± 0.6

In Figure 4.20, it shows the trend of Fly testing, an x_axis was identified by skew angle of disk while y_axis was identified PTFH (Pole Tip Fly Height) value which the unit of PTFH was microinch. The experiment group was separated by colour and identified in the top of right hand side. It was dynamic test which uses to verify the flying characteristics of the head. There are three parameters interested at Fly test, PTFH, pitch and roll. The PTFH results were correlated with clearance result, when looking at the profile of each group, all group has same slope profile. But, when looking at the PTFH value by each experiment group and comparing to clearance value in Figure 4.12, only group six was significant correlated with clearance result, low clearance also fly height become low PTFH as well. By the way, in term of group one and group two result, the PTFH delta was only 0.1 microinch which would conclude that it is not significantly different in term of static theory.

The Figure 4.21 shows the combined group of experiment into three groups, combined group one came from result of group one and group two, combined group two came from result of group three and group four and combine group three came from result of group five and group six. An important point is that, the Fly tester has variation sigma by 0.3 nm, it turned out with only 0.1 – 0.2 nm change of clearance cannot see PTFH significant difference. After combined, the result shows as same as PTFH profile of experiment part I, high clearance getting high PTFH and low clearance getting low PTFH.

With this results it can be concluded that small change at clearance (around 0.08 nm) would not be affected to real fly of head stability. Therefore, fly height was most critical fly parameter in terms of electrical performance. Low fly height provides better electrical performance, too low causes HDI (Head Disk Interference) and becomes damages on both head and disk.

In Figure 4.22 and 4.23 show the pitch results which Figure 4.22 represents overall scale and 4.23 represents the zooming one respectively. The result indicated that, group one and group six were correlated with clearance result in Figure 4.12 by, group one got high clearance value while at fly test got low pitch value. In the other word, the group six

got low clearance value while at fly test got high pitch value. By the way, the other group experiment, group two to group five look comparable.

In Figure 4.24, it shows roll result by skew angle and experiment group. Based on the result observed, group one and group three have same roll value on all skew angle while seen same phenomenon at group four and group five as well. By the way, group two and group six were have more significantly different than other group. Group two have higher PTFH when compare with other group and seen high on all skew angle. For the group six have lower PTFH when compare with other group and seen low on all skew angle. It was still unknown the root cause of these phenomenon of group two and group six due to they are no physical damage observed after inspection these parts.

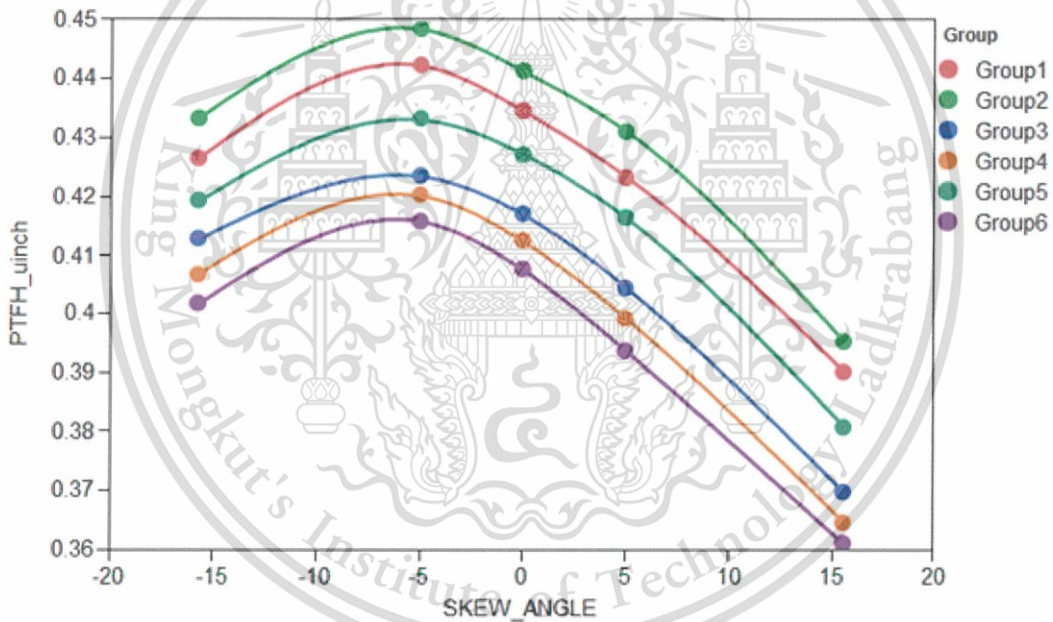


Figure 4.20 The mean of PTFH by experiment group

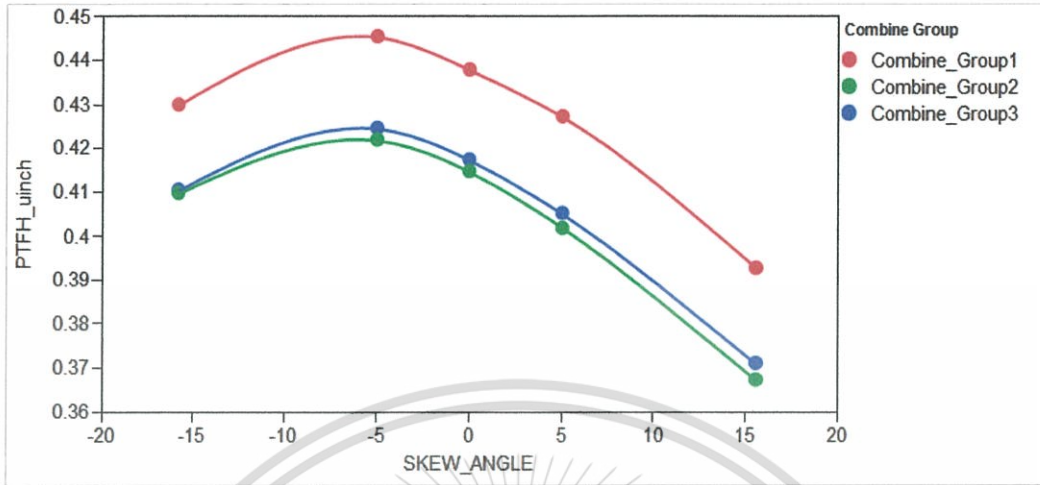


Figure 4.21 The mean of PTFH by experiment group after combine into three groups

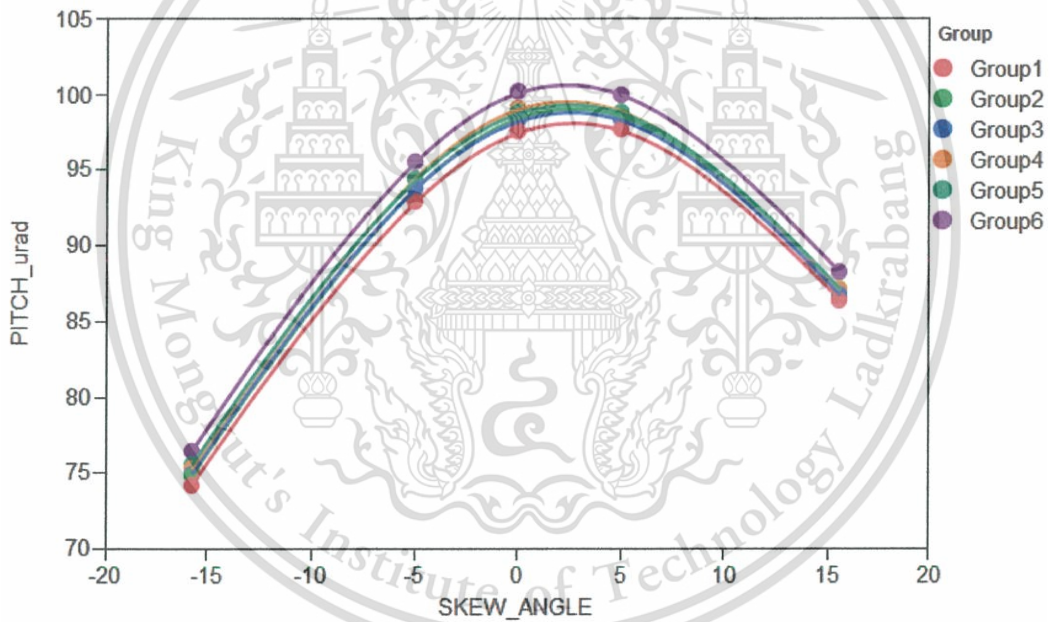


Figure 4.22 The mean of PITCH by experiment group

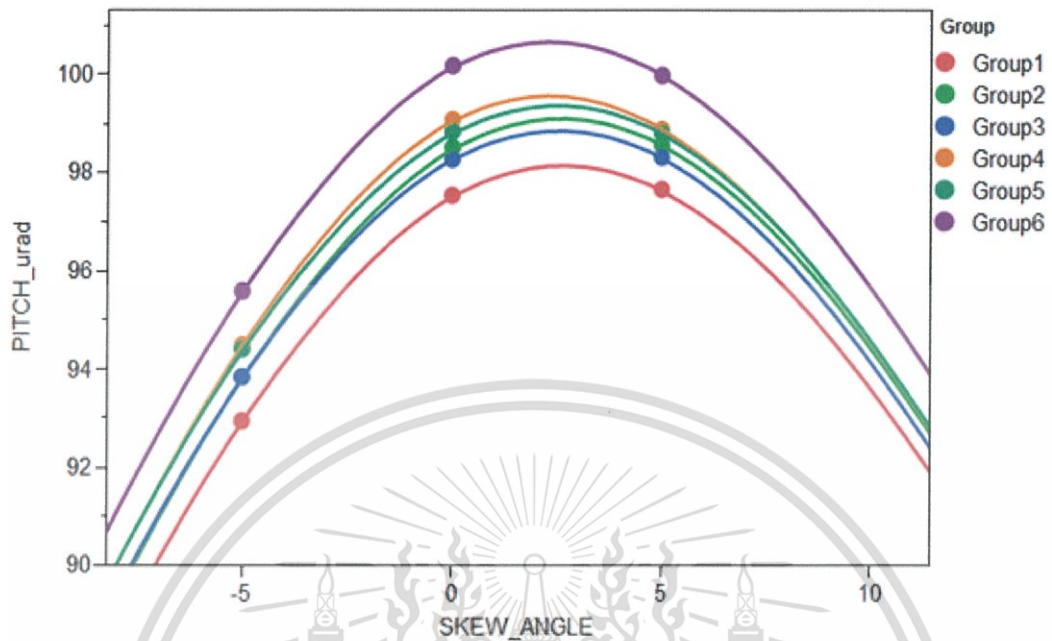


Figure 4.23 The mean of PITCH by experiment group (zoom in)

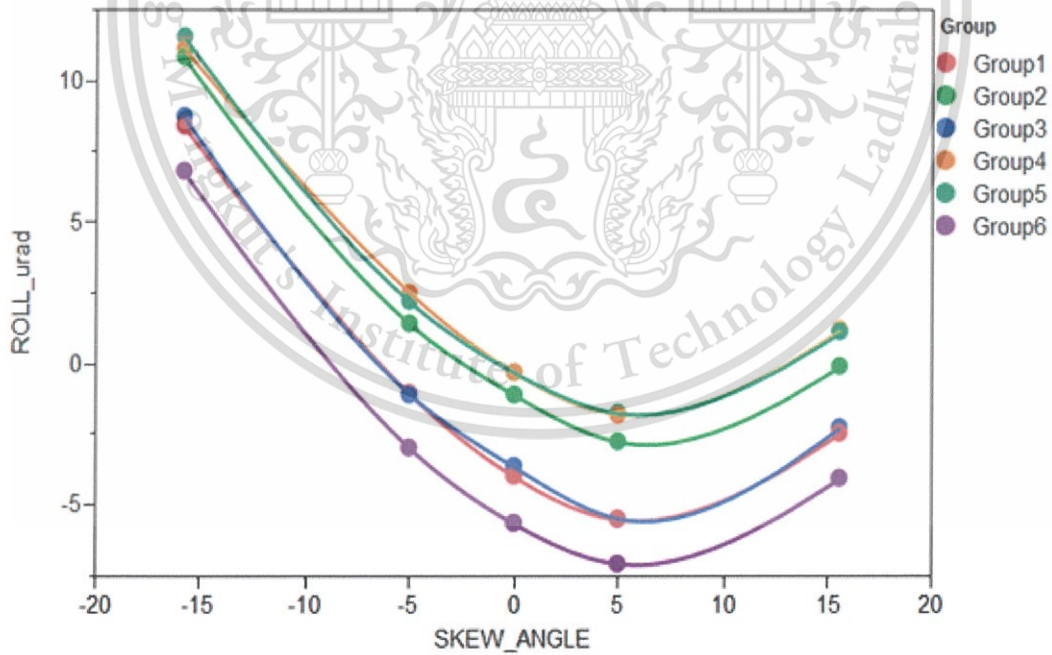


Figure 4.24 The mean of ROLL by experiment group

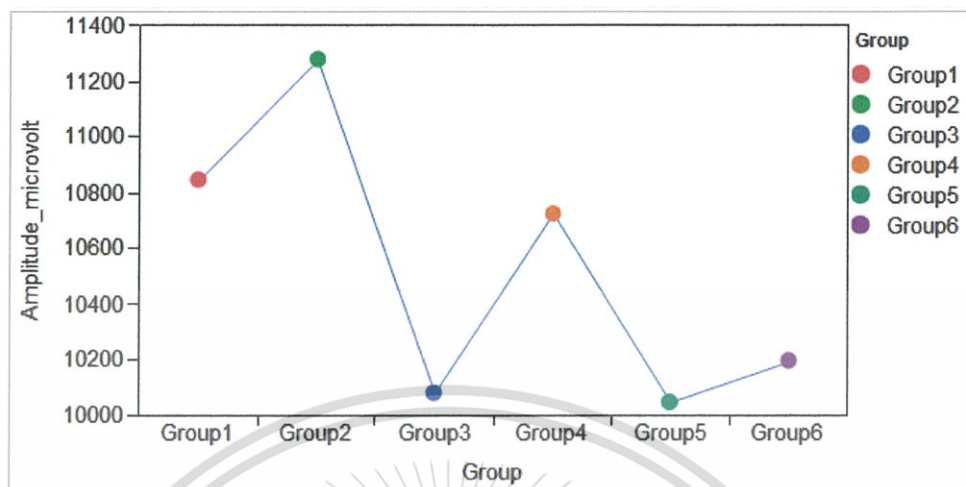


Figure 4.25 The mean of amplitude by experiment group

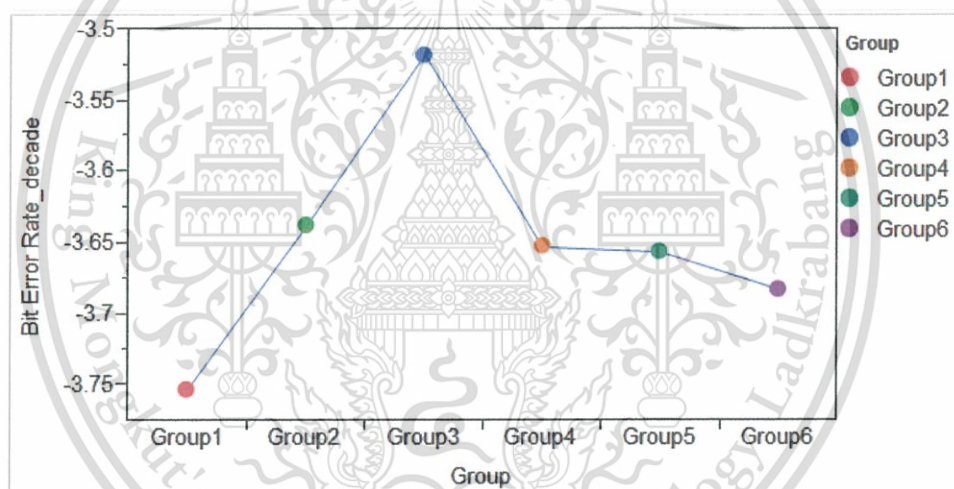


Figure 4.26 The mean of Bit Error Rate by experiment group

In Figure 4.25, it shows the amplitude results; an x_axis was identified by experiment group while y_axis was identified amplitude value which the unit of amplitude was microvolt. The result indicated that; all six groups get the amplitude with high variation value. The amplitude phenomena can be concluded as same as amplitude result of experiment at part I.

In Figure 4.26, it shows the Bit Error Rate result; an x_axis was identified by experiment group while y_axis was identified amplitude value which the unit of Bit Error

Rate was decade. The result indicated that; all six groups get Bit Error Rate with high variation value which can be concluded as same as amplitude phenomena.

From Figure 4.25 and 4.26 result, it can be concluded that, the amplitude and Bit Error Rate have no correlation to clearance as same as experiment part I with same reason. It is well known that; the Pole Tip Flyheight (PTFH) result was the key parameter which can be preferred for head flying ability.

In Figure 4.27, it shows the W-curve at 1st torsion mode by an x_axis was Z-height range and separated by experiment group by color of line while y_axis was average gain of each experiment group by Z-height. The sample size was ten HGAs per experiment group. The result shows all experiment group which are comparable on all Z_height range.

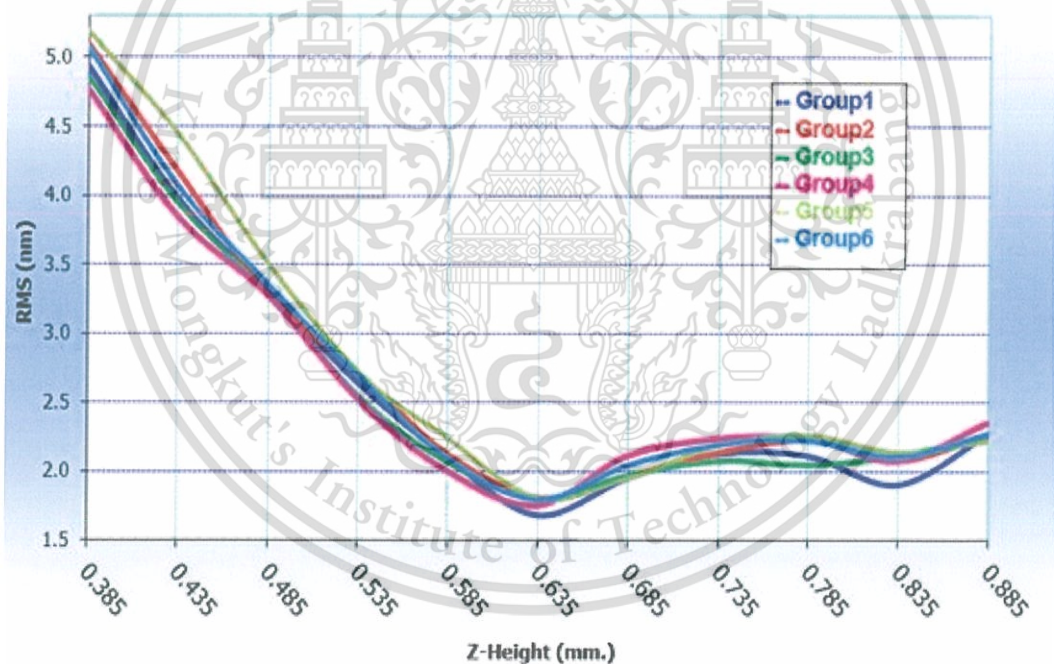


Figure 4.27 W-Curve at 1st torsion by experiment group

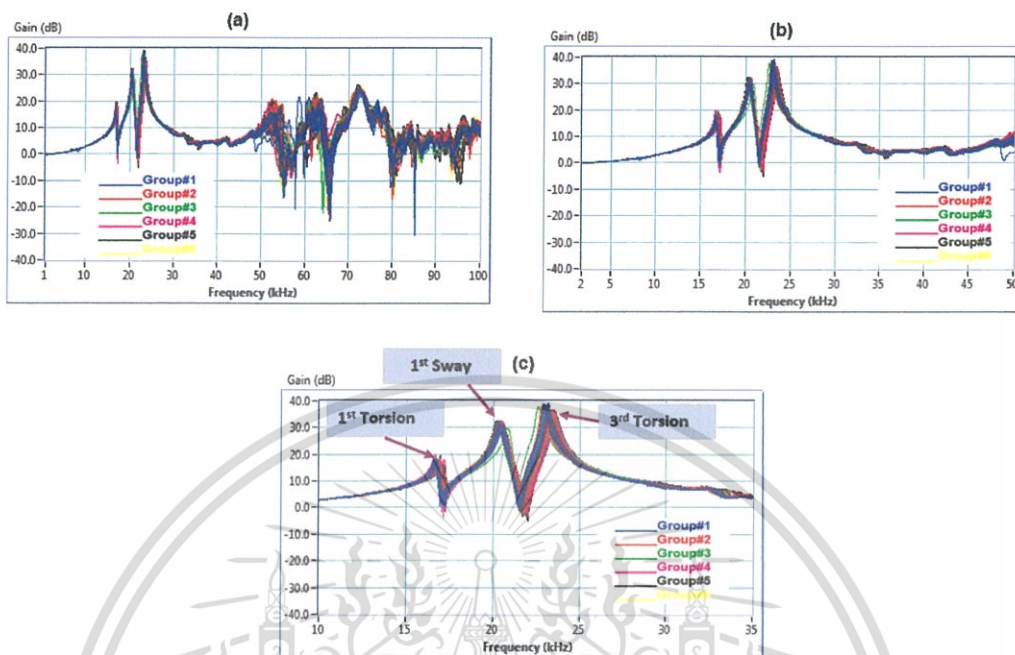


Figure 4.28 Frequency Response Functions (FRF) plot by experiment group

In Figure 4.28, it shows the Frequency Response Functions (FRF) plot. An x_axis was frequency range while y_axis was the magnitude of gain which separate by an experiment group. Figure 4.23a, it shows the overall frequency from 1-100 kHz while Figure 4.28b was zoomed in the frequency from 2-50 kHz and Figure 4.28c was zoomed in the frequency from 10-35 kHz. The results shows all six groups of experiment got peak of gain were comparable on every frequency modes, first torsion, first sway and third torsion mode.

In Figure 4.29, it shows the windage spectra plot. An x_axis was frequency range while y_axis was the magnitude of gain which was separated by an experiment group. Figure 4.29a, it shows overall frequency from 1-100 kHz while Figure 4.29b was zoomed in the frequency from 1-50 kHz. The results shows all six group of experiment which were comparable on every frequency ranges except at the first Bending mode which seen group two higher peak than other group.

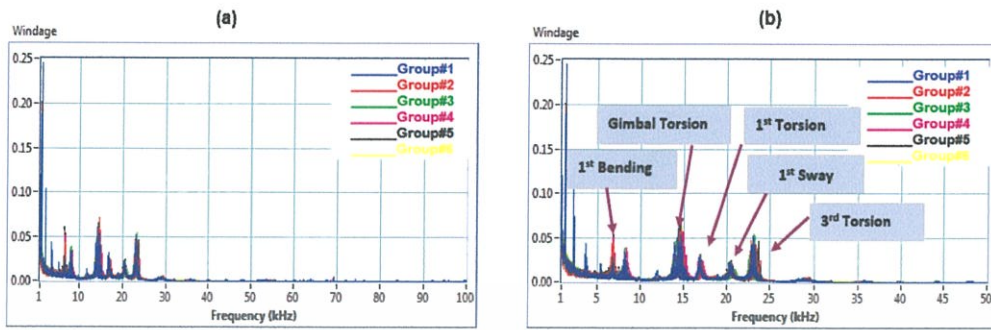


Figure 4.29 The windage spectra plot by experiment group



Table 2. The summary results of the clearance impact study from slider x_alignment on the negative range adjustment (Part II)

Parameters	Spec	Group 1 x (zero)	Group 2 x (-0.003)-(-0.005)	Group 3 x (-0.005)-(-0.009)	Group 4 x (-0.010)-(-0.012)	Group 5 x (-0.013)-(-0.015)	Group 6 x (-0.016)-(-0.020)
X-Alignment (mm)	0 ± 0.02235	-0.00495	-0.01112	-0.01703	-0.0193	-0.02378	-0.02741
Y-Alignment (mm)	0 ± 0.02235	0.00007	-0.00155	-0.00186	-0.00154	-0.00001	-0.00116
T-Alignment (degree)	0 ± 1.56	-0.02068	-0.01321	-0.01894	-0.03059	-0.01291	-0.01343
PSA (degree)	2.1 ± 0.2	2.048	2.062	2.067	2.045	2.071	2.029
RSA (degree)	-0.5 ± 0.6	-0.51	-0.52	-0.52	-0.52	-0.53	-0.52
Gramload (gram-force)	2.5 ± 0.2	2.51	2.49	2.5	2.5	2.51	2.51
Clearance (nm)	Min 3	8.32	8.24	8.1	7.98	7.95	7.71

CHAPTER 5

CONCLUSIONS AND SUGGESTION

5.1 Conclusions

This thesis proposed an alternative way for the minor adjustment of the clearance at Head Gimbal Assembly (HGA) by focusing on the suspension area at the dimple location instead of considering changing new suspension design. This method is called “slider placement delta x_alignment” which placed slider into suspension by Slider Attach Machine. In regularly practiced for placing the slider into the suspension, the focused area was at the center of dimple area on the suspension and the center of the slider body. In this method, it was intended to adjust the location of the slider x_alignment to place the slider while dimple location was not changed. The slider x_alignment was measured by the pinnacle machine. The clearance was measured by the contact spin stand machine (CSS) and Fly height was measured by Fly test machine.

The prediction model had great accuracy for predicting with variation around ± 0.1 - 0.2 nm. All parameters at Head Gimbal Assembly (HGA) that might be related to clearance was determined and put into the prediction model, but, only top four parameters which have high sensitivity to clearance were selected in this study.

The results from this study can be confirmed that the clearance range during 0.2 - 0.5 nm was possibly to adjust by tweak the slider x_alignment method. The Fly height profile was confirmed with no mechanical effect to head flying ability. Anyhow, an amplitude and Bit Error Rate have no correlation with clearance on this study regarding to the limitation of clearance target point of software at contact spin stand tester. Based on an experimental results of both part I and part II, Pole Tip Fly height (PTFH) was correlated with clearance result. It can be concluded that the low head flying with less than 7.7 nm can be possibly without Air Bearing Surface (ABS) scratch or defect.

In term of vibration concerning, resonance measurement method test was used for confirming the results which become comparable on all experiment group on both two parts of experiment. Thus, the adjustment of slider x_alignment at HGA is capable of practicing for helping clearance problem regarding to resonance that was not affected.

5.2 Future suggestion

This experiment study was based on the sample size of Head Gimbal Assembly (HGA) less than 500 pieces which has the clearance specification from 3 - 8 nm. It was quite confident that at the factory standpoint, the tweak of machine adjustment at the slider x_alignment will be helping for fastest action to solve either low or high clearance problems. Actually, for more stability of head while flying above the disk, it was necessary to make a change at suspension design regarding to robustness, vibration and other contribution concerns. By the way, in term of future technology and HDD innovation, it must be required very small spacing between head and disk to meet high recording density. Hence, it would be more adding up contribution factor to clearance. With this hoping that, the result from this experiment may be useful for even factory minor adjustment standpoint and suspension designing algorithm.



REFERENCES

- [1] S.J. Yoon, J.L. Lee, Y.P. Park and D.H. Choi, " Design of Optical Flying Head for Magneto-optical Recording", IEEE Transactions on Magnetics, vol.41,no.10, pp. 2851-2853, October 2005.
- [2] Head Gimbal Assembly class training, Seagate Technology, April 2002.
- [3] G. Sheng, Q. Chen, W. Hua and B. Liu," An Experiment Study of Dimple Separations and Head-Disk Impacts of Negative Pressure Slider in Unload Process",IEEE Transactions on Magnetics, vol.37,no.4, pp. 1859-1862, July 2001.
- [4] S. Yu, B. Liu, W. Hua, W. Zhou and C.H. Wong, "Dynamics of Fly-Contact Head Disk Interface", IEEE Transactions on Magnetics, vol.44,no.11, pp. 3683-3686, November 2008
- [5] R. Kant, "Mechatronics in Storage Technology", IEEE Transactions on Components, Packaging and Manufacturing Technology, vol.20,no.1, pp. 21-30, January 1997.
- [6] J.X. Xu, D.Huang, V.Venkataramanan, and T.C. Tuong Huynh,"Frequency-Shaping Optimal Compensation of Low Fly-Height Vibration in High Density HDD Servo Systems", IEEE International Conference on Control and Automation (ICCA), pp. 1343-1348, December 19-21, 2011.
- [7] B. Gu, D. Shu, Y. Fuji and B. Shi," Dynamic Force Measurement of a Head Arm Assembly of a Hard Disk Drive by Numerical Analysis and Experiments", IEEE Transactions on Magnetics, Vol. 45, No. 11, pp. 5034-5037,November 2009.

- [8] S. K. Yu, K. K. Ng, W. Hua, W. D. Zhou and B. Liu, "Dynamics of air bearing-slider-suspension system at surfing state", (A*STAR) Singapore, DP-7, September 2012.
- [9] H. Kuwajima, H. Kita, H. Hashi, M. Miyamoto, Y. Ueno, T. Ueno and K. Matsuoka, "Development of Balanced-Type High Shock Suspension for 0.85-in Hard Disk Drive", IEEE Transactions on Magnetics, Vol. 42, No. 2, pp. 255-260, February 2006
- [10] T. Shiramatsu, T. Atsumi, M. Kurita, Y. Shimizu and H. Tanaka, "Dynamically Controlled Thermal Flying-Height Control Slider", IEEE Transactions on Magnetics, Vol. 44, No. 11, pp 3695-3697, November 2008.
- [11] D. Pan, A. Ovcharenko, J.P. Peng, S. Sanchez, F. Radicati and M. Yang, "Effect of Flying Pitch and Roll angle on Lubricant Transfer between Disk and Slider ", IEEE Transactions on Magnetics, pp. 1-11, October 21, 2013.
- [12] K.S. Park, G. Lim, N.C. Park, and Y.P. Park, "Parametric Studies of dimple-flexure slip at the moment of ramp contact in unloading process", BP10, (MEST) (No. 2010-00(0769) and (No 2009-0076065), September, 2010.
- [13] Y. K.Chen, J.P. Peng and D. Bogy, " Experimental and Simulation Study of Thermal Protrusion-Induced Head-Disk Contact Instabilities in Hard Disk Drives ", IEEE Transactions on Magnetics, Vol. 50, No. 11, p. 3302805 ,November 2014.
- [14] Q. Zeng and D. Bogy, " Effects of Suspension Limiters on the Dynamic Load/Unload Process: Numerical Simulation", IEEE Transactions on Magnetics, Vol. 35, No. 05, pp. 2490-2492, September 1999.
- [15] S. Nakamura, R. Aduma, H. Takahashi, K. Wakatsuki and S. Hagiya, "Flow-Induced Vibration of a Head Gimbal Assembly Under Various Conditions", IEEE Transactions on Magnetics, Vol. 41, No. 02, pp. 769-773, February 2005.

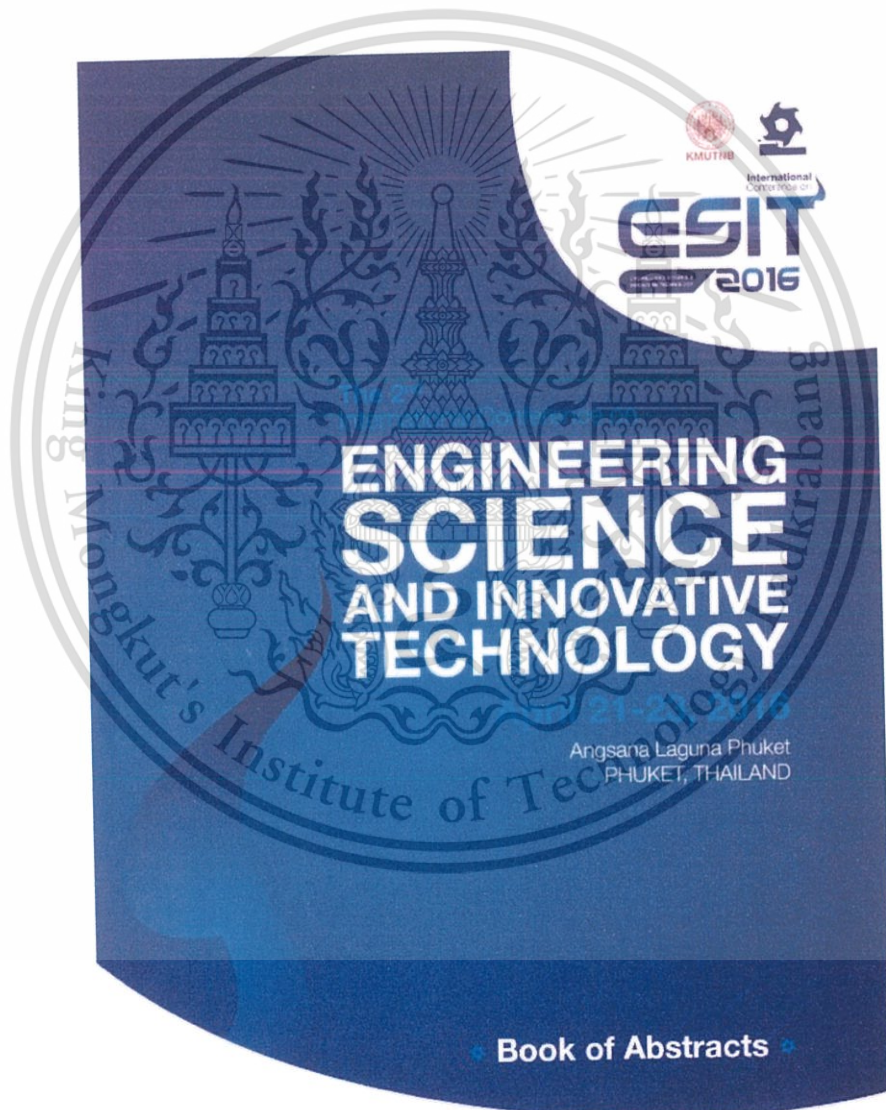
- [16] K. Aoki, T. Hoshino, T. Iwase, T. Imamura and K. Aruga, "Thermal Pole-Tip Protrusion Analysis of Magnetic Heads for Hard Disk Drives", IEEE Transactions on Magnetics, Vol. 141, No. 10, pp. 3043-3045, October 2005
- [17] J. Juang and D. Bogy, "Controlled-Flying Proximity Sliders for Head-Media Spacing Variation Suppression in Ultralow Flying Air Bearings", IEEE Transactions on Magnetics, Vol. 141, No. 10, pp. 3052-3054, October 2005
- [18] Y. Wang, X. Jin, S. Chen, X. Wei and K.L. Tsui, "Effect of Low-frequency Vibration in Z-direction (Out-of-plane) on Slider Dynamics", IEEE Transactions on Magnetics, 2013.
- [19] K.W. Ng, Z. Yuan and Bo Liu, "Spacing Fluctuation Induced by Disk Clamping Distortion", IEEE Transactions on Magnetics, Vol. 39, No. 05, pp. 2465-2467, September 2003.
- [20] B. Liu, S. Yu, M. Zhang, L. Gonzaga, H. Li, J. Liu and Y. Ma, "Air-Bearing Design Towards Highly Stable Head-Disk Interface at Ultralow Flying Height", IEEE Transactions on Magnetics, Vol. 43, No. 02, pp. 715-720, February 2007.
- [21] H. Tani, T. Mitsutome, D. Kamei and N. Tagawa, "Relationship of Adhesion/Friction Forces and Slider Vibration in Surfing-Recording HDI System", IEEE Transactions on Magnetics, Vol. 49, No. 07, pp. 3752-3755, July 2013.
- [22] A.I. Vakis, S.C. Lee and A.A. Polycarpou, "Dynamic Head-Disk Interface Instabilities With Friction for Light Contact (Surfing) Recording", IEEE Transactions on Magnetics, Vol. 45, No. 11, pp. 4966-4971, November 2009.
- [23] K. H. Kim, N.C. Park, Y.P. Park and K.S. Park, "Tolerance Analysis of the Pitch Static Attitude of a Thermally Assisted Magnetic Recording System With an Optical Fiber and Prism", IEEE Transactions on Magnetics, Vol. 47, No. 03, pp. 585-589, March 2011.

- [24] X. Liu, A. Li, W. Clegg, David F. L. Jenkins and Davey, "Head-Disk Spacing Variation Suppression via Active Flying Height Control", IEEE Transactions on Magnetics, Vol. 51, No. 05, pp. 897-901, October 2002.
- [25] Y. Hatamura, S. Yanabe, N. Ishimaru, T. Shinohara and M. Ito, "Development of a self-peeling suspension for non-crash, non-stick and low fly-height", IEEE Transactions on Magnetics, Vol. 26, No. 05, pp. 2484-2486, September 1990.
- [26] Y. Yuan, H. Du, K. S. Chow, M. Zhang, S. Yu and B. Liu, "Design and Analysis of a Slider-Level Piezoelectric Sensor Array for Head-Disk Contact Detection", IEEE Transactions on Magnetics, Vol. 49, No. 06, pp. 2574-2577, June 2013.
- [27] M. L. Mallery, R. Beauregard, M. Benakli, A. F. Torabi, and S. B. Marshall, "Measurement of Transition Shape, Width, and Total Magnetic Spacing", IEEE Transactions on Magnetics, Vol. 40, No. 4, pp. 2567-2569, July 2004.
- [28] B. Slutsky and H. N. Bertram, "Transition Noise Analysis of Thin Film Magnetic Recording Media", IEEE Transactions on Magnetics, Vol. 30, No. 5, pp. 2808-2817, September 1994.
- [29] http://en.wikipedia.org/wiki/File:Hard_drive-en.svg, 20 May 2016
- [30] <https://en.wikipedia.org/wiki/File:SixHardDriveFormFactors.jpg>, 20 May 2016
- [31] K.H. Kim, N.C. Park, Y.P. Park and K.S. Park, "Tolerance Analysis of the Pitch Static Attitude of a Thermally Assisted Magnetic Recording System With an Optical Fiber and Prism", IEEE Transactions on Magnetics, Vol. 47, No. 3, pp. 585-589, March 2011.

APPENDIX A

PUBLICATION

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Engineering Science and Innovative Technology

April 21-23, 2016, Angsana Laguna Phuket, Phuket, THAILAND

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Asst. Prof. Dr. Rattanakorn Phadungthin
Chair and Program Coordinator
ESIT Conference 2016

The Suspension Study for Decreasing the Clearance of Head Gimbal Assembly

Nongnoot Deetu^{1,3,a*} and Chaiyan Jettanasen^{2,b*}

Abstract

In this study, the effect of Dimple x-location on suspension to Clearance is experimentally investigated. The experiment is set by varying the location of slider placement along the suspension, called Slider x-Alignment. A Contact Spin Stand (CSS) tester is used to measure electrical parameter of read/write performance of Head Gimbal Assembly (HGA) which is included the clearance test. Head Gimbal Assembly (HGA) is tested at class 1000 cleanroom (< 1000 particles/cubic foot/minute). The unit of Clearance is "nanometer". The Pinnacle tester is used to confirm the Slider x-alignment position along the suspension, the unit of Slider x-alignment is "millimeter". The experimental results showed that the Clearance reading follows as Slider x-alignment direction, i.e., Clearance increases when the Slider x-alignment moves to the positive direction and the clearance decreases when the Dimple x-location moves to negative direction. However, Pitch Static Attitude (PSA) and Row Static Attitude (RSA) are not contributed in this study.

Keywords: Dimple location, Slider x- Alignment, Clearance, Suspension

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1. Introduction

Hard Disk Drive (HDD) is important part of data storage devices for computer and consumer electronic systems. The components inside Hard Disk Drive (HDD) consist of a rotation disk, servo motor and Head Stack Assembly (HSA). The Head Gimbal Assembly (HGA) is the subset of Head Stack Assembly (HSA), consisting of slider and stainless steel suspension. When the disk rotates with spindle speed of 7,200 rpm, the head flies above the disk.

A gap between the head and the disk is verified as one of various factors affecting to the recording density; small gap reports high recording density while large gap is opposite direction.

Moreover, the recording density of HDD keeps increasing every year. To increase the density rate, several studies have focused on head design and innovation of technology development. However, some studies have physically focused on the mechanical side of Hard Disk Drive (HDD) system. The mechanism between Head Gimbal Assembly (HGA) and disk must be reduced until it eventually reaches contact recording. The mechanical lower gap becomes high signal ratio and results with high density [1]-[2]. The reduction between Head and Disk is critical for mechanical design which must have the gap less than 10 nm. The head which flies less than 3 nm causes scratches/damages on the disk and head degradation [3]. Simulation studies focusing on the suspension area to decrease the gap between head and disk have been reported. The coupling vibration of air bearing slider and suspension system affecting the slider flying ability and head position have been investigated at several states. The contact/friction force on the dynamics of slider air bearing, the suspension vibration and the dimple gimbal interaction force are characterized and they affect surfing states. A new design has been to reduce the interaction force at surfing states [4].

However, few studies have been completed on the suspension area for decreasing the clearance at Head Gimbal Assembly (HGA). Many components of suspension factors affect the clearance, including suspension stiffness, size of the dimple suspension and position of the dimple at suspension. Thus, the purpose of this study is to investigate the effect of dimple x-location of suspension area which may decrease the clearance of Head Gimbal Assembly (HGA). This study may lead to a better understanding of dimple x-location to the clearance at Head Gimbal Assembly (HGA). It is expected that information from this study may be useful in the suspension design.

Fig.1 shows the overview of Head Gimbal Assembly (HGA) which is consisted of the Slider, and the suspension. The suspension itself comprises flexure, base plate, and load-beam. The dimple is indicated in the picture, and normally located at almost the end of the suspension. The slider is placed into flexure and dimple.



Fig. 1. The image of Head Gimbal Assembly and Dimple position

2. Experiment and Methodology

This study, focuses on the suspension area with a hypothesis that moving the dimple location along the x-axis of suspension might cause clearance change. The focusing area is on the Dimple location at the suspension.

To minimize the impact factors, the simulation of experiment environment was determined. The experiment

was arranged under cleanroom environment at class 1000 condition (< 1000 particles/cubic foot/minute). The temperature inside the cleanroom environment was controlled. The room temperature was set between 17 – 27 °C and the relative humidity was set between 40-60%.

The Slider Attach machine was used for the attachment of the slider and the suspension together. The suspension was placed using the glue RTG1128 for attaching the slider and the suspension. Before placing the slider into the suspension, UV cure was applied with high energy to pre-cure the glue preparing for slider placement. In usual practice, the placing was focused at the center of Advance Air Bearing (AAB) of the slider and the dimple of the suspension. The slider attach algorithm was started from caption at the side edge of slider. It was caption into four position along the edge of slider. After then, the machine vision system program will be calculated the center of slider by reference from four positions point and placed slider into the suspension by focusing at the center of slider and the dimple location.

The experiment had been arranged by varying the location for placing the slider into the suspension. The study's intention was moving the slider placed into the suspension along x-axis direction of dimple location, starting from the center of dimple location. It was assumed that the x-alignment is zero. The tolerance variation moved from zero to both positive and negative directions of x-alignment from the center of dimple determining zero location. The sample size was 120 pieces per each group. Totally, there are 3 groups: the center of dimple location as the control group, the positive direction as the higher group and the negative direction as the lower group.

After the placing of slider had been completed, the second UV cure was activated. Then, flexure circuit was connected with slider gimbal pad with Thermal Inter Connect machine (TIC). The gold wire was used to connect

the suspension and the slider which was melted with high energy power.

The pinnacle tester was used for measuring the position of slider after completely mounted slider and suspension together at XYT-alignment direction. The machine was used the reference information set up and designed with unique of own slider ABS itself. The reference information was created and measured by the ABS prototype with AUTOCAD program. The measurement algorithm is practical as same as slider attach machine, but, a bit different just at the resulting of report because the machine software read the real position from the sample and compare with reference information provided, after then, the software will calculate the distance of each parameter concern, in this case is XYT-alignment.

The Clearance of Head Gimbal Assembly was tested by Compact Spin Stand machine (CSS) with disk rotation of 7,200 rpm. The unit of Clearance was nanometer. The Statistical method was used to report the clearance results, especially on mean/sigma and histogram of each population group.

Fig.2 illustrates the top view image of Slider and the direction of x-alignment of each group. The Trailing End (TE) is the top side of slider, containing Gold Bond Pad used for bonding slider and the suspension together. The Leading End (LE) is the bottom of slider, consisting of serial number of each individual of slider. The placement position of slider and the suspension was at the centered of both slider and dimple area, assumed as normal group. The placement of negative and positive directions was assumed as low and high group.

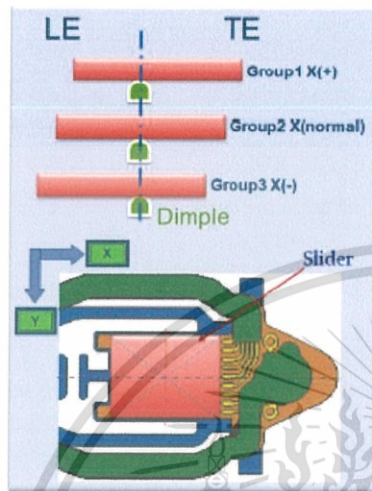


Fig. 2. The image of slider and direction of slider x-alignment of each experiment group

Fig.3 shows the experiment's flow chart. There are 3 groups with different directions of slider placement into the suspension. The sample size of each group was 120 pieces. The Slider was controlled by using the same lot to block the impact factor. The Contact Spin Stand tester (CSS) was controlled by using only one tester for minimizing the tester variation.

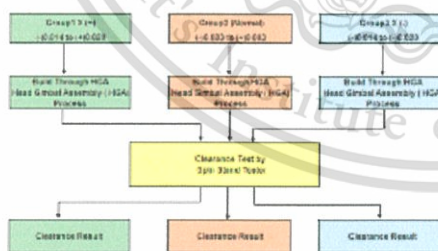


Fig. 3. Experiment's flow chart

3. Result and Discussion

Fig 4 and Fig. 5 show the following experimental results: an X-axis is identify by group of experiment and the Y-axis identify by clearance and x-alignment respectively.

Group 1 as high x-alignment (positive direction) given Clearance mean was 9.08 nanometers and given Clearance sigma was 1.11. Group 2 as zero, normal x-alignment (Normal baseline) given Clearance mean by 8.49 nanometers and Clearance sigma was 0.71. The Group 3 as low x-alignment (negative direction) given Clearance was 8.25 nanometers and given Clearance sigma was 0.92.

Fig. 6 show the Y-alignment result by group of experiment. An X-axis is identify the group of experiment and the Y-axis is identify the Y-alignment mean. With result, the group 3 was highest Y-alignment mean than group 1 and group 2 by 0.001 mm and 0.002 mm respectively. It can concluded that all three group looks comparable even mean was difference because it within one sigma of Y-alignment spec.

Fig. 7 show the T-alignment result by group of experiment. An X-axis is identify the group of experiment and the Y-axis is identify the T-alignment mean. With result, all three groups have T-alignment mean at 0.4 degree. It can concluded that even X & Y-alignment is changed, T-alignment was not affected. It was proved that the reading from pinnacle tester is accurate for this experiment.

Additionally, the table 1 presents the results of each experiment group of Slider XYT-alignment mean and Clearance mean with Clearance delta when comparing with normal group (baseline). The group 1 was higher Clearance than baseline by 0.65 nanometer, Slider x-alignment mean was 0.0191 micro inch. The group 3 was lower than baseline by 0.14 nanometer, Slider x-alignment mean was -0.0130 micro inch. In term of Y & T-alignment, the number of each group did not changed. Based on results, it was assumed that Y & T-alignment of three groups are comparable.

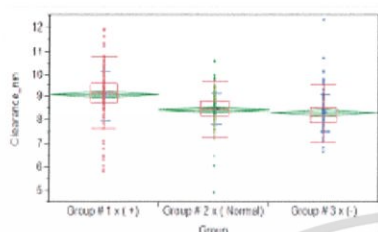


Fig. 4. The Oneway Analysis of Clearance results by experiment group

Fig. 6. The Oneway Analysis of Slider Y- Alignment results by experiment group

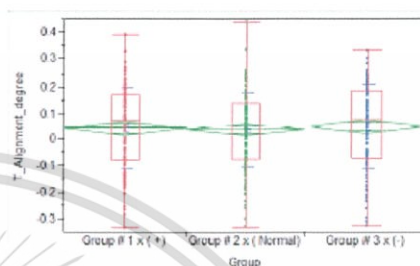


Fig. 7. The Oneway Analysis of Slider T- Alignment results by experiment group

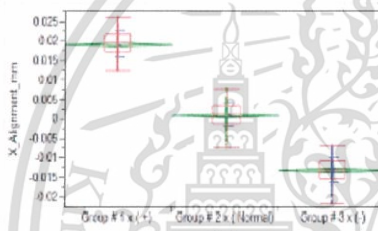


Fig. 5. The Oneway Analysis of Slider x- Alignment results by experiment group

Table 1 The summary result of Mean of Slider XYT-alignment and Clearance by experiment group

Experiment	Sample Size (N)	Y-alignment (Millimeter)	X-alignment (Millimeter)	T-alignment (Degree)	Clearance (Millimeter)	Remark
Group 1 (+)	117	0.0191	0.0121	0.0124	9.069	Higher than baseline by 0.64 mm
Group 2 (Normal)	119	0.0010	0.0015	0.0171	8.530	Baseline
Group 3 (-)	116	-0.0130	0.0041	0.0192	8.208	Lower than baseline by 0.15 mm

4. Conclusion

From the experimental results, the Clearance can decrease or increase with the change of Dimple x-location. The obtained results depended on which side of design intention. In case of increasing the clearance, the Dimple x-location should be changed into negative direction. On the other hand, if the design is intended to decrease the Clearance, the Dimple x-location should be changed into the positive direction.

However, this is only an experiment that we try to study the effect of Clearance & Slider x-alignment with simulation by moving slider along with distance of suspension itself. The further improvement would be considered the change at the suspension design point for the stability results.

- [6] Jian-Xin Xu, Deqing Huang, V. Venkataramanan, and T.C. Tuong Huynh, "Frequency-Shaping Optimal Compensation of Low Fly-Height Vibration in High Density HDD Servo Systems", IEEE International Conference on Control and Automation (ICCA), pp. 1343-1348, December 19-21, 2011

5. Acknowledgment

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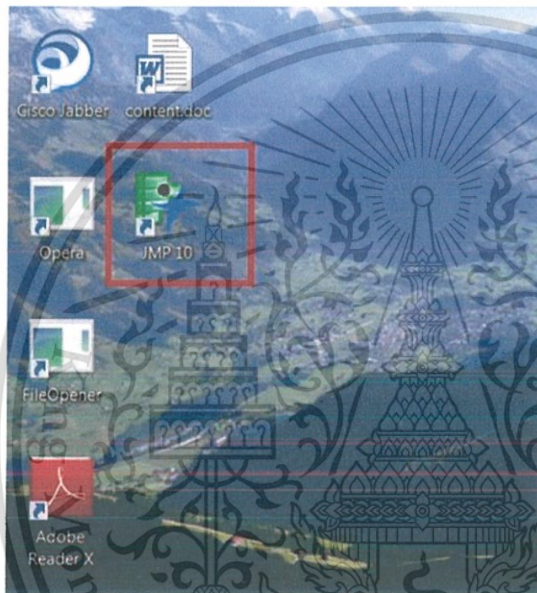
6. Reference

- [1] Sang-Joon Yoon, Jongsoo Lee, Young - Pil Park and Dong-Hoon Choi, " Design of Optical Flying Head for Magneto-optical Recording", IEEE Transactions on Magnetics, vol.41, no.10, pp. 2851-2853, October 2005
- [2] Shigeo Nakamura, Ryouhei Aduma, Haruhide Takahashi, Kousaku Wakatsuki and Shinobu Hagiya, " Flow - Induced Vibration of a Head Gimbal Assembly Under Various Conditions " IEEE Transactions on Magnetics, vol.41, no.2, pp. 769-773, February 2005
- [3] Gang Sheng, Qisuo Chen, Wei Hua and Bo Liu, " An Experiment Study of Dimple Separations and Head-Disk Impacts of Negative Pressure Slider in Unload Process", IEEE Transactions on Magnetics, vol.37, no.4, pp. 1859-1862, July 2001
- [4] Shengkai Yu, Bo Liu, Wei Hua, Weidong Zhou and Chee How Wong, "Dynamics of Fly-Contact Head Disk Interface", IEEE Transactions on Magnetics, vol.44, no.11, pp. 3683-3686, November 2008
- [5] Rishi Kant, "Mechatronics in Storage Technology", IEEE Transactions on Components, Packaging and Manufacturing Technology, vol.20, no.1, pp. 21-30, January 1997

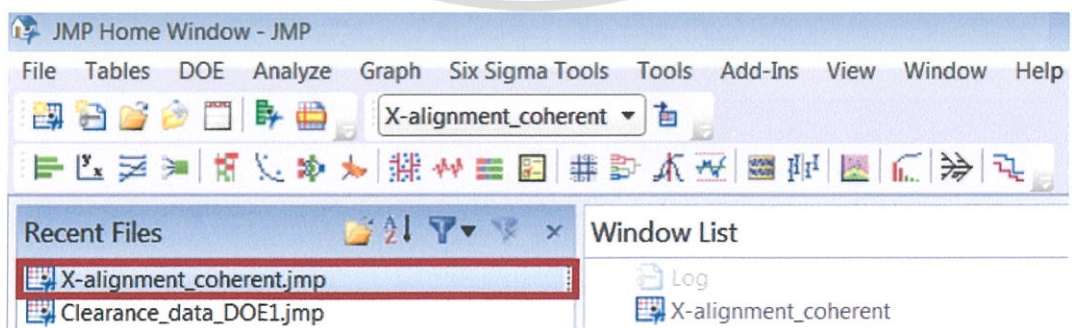
APPENDIX B

Prediction Model by JMP software

Step1 : Click to open JMP 10 software



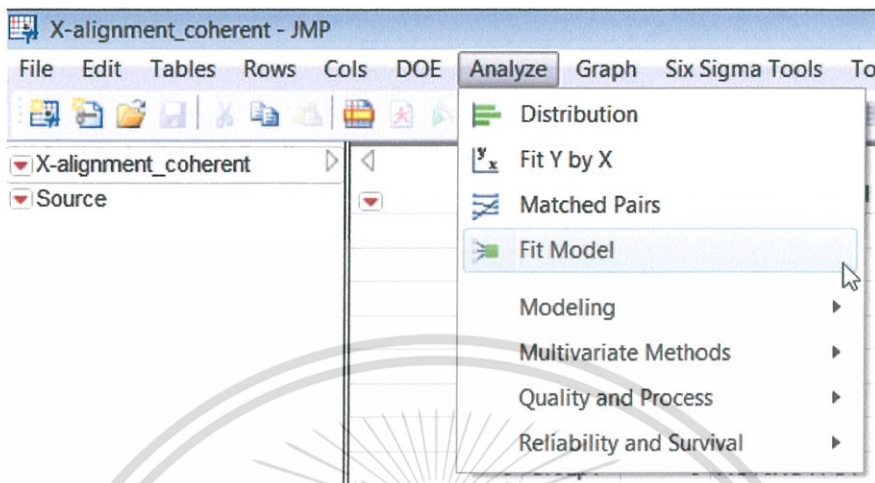
Step2 : At JMP Home Window, click open raw file of all data set interesting



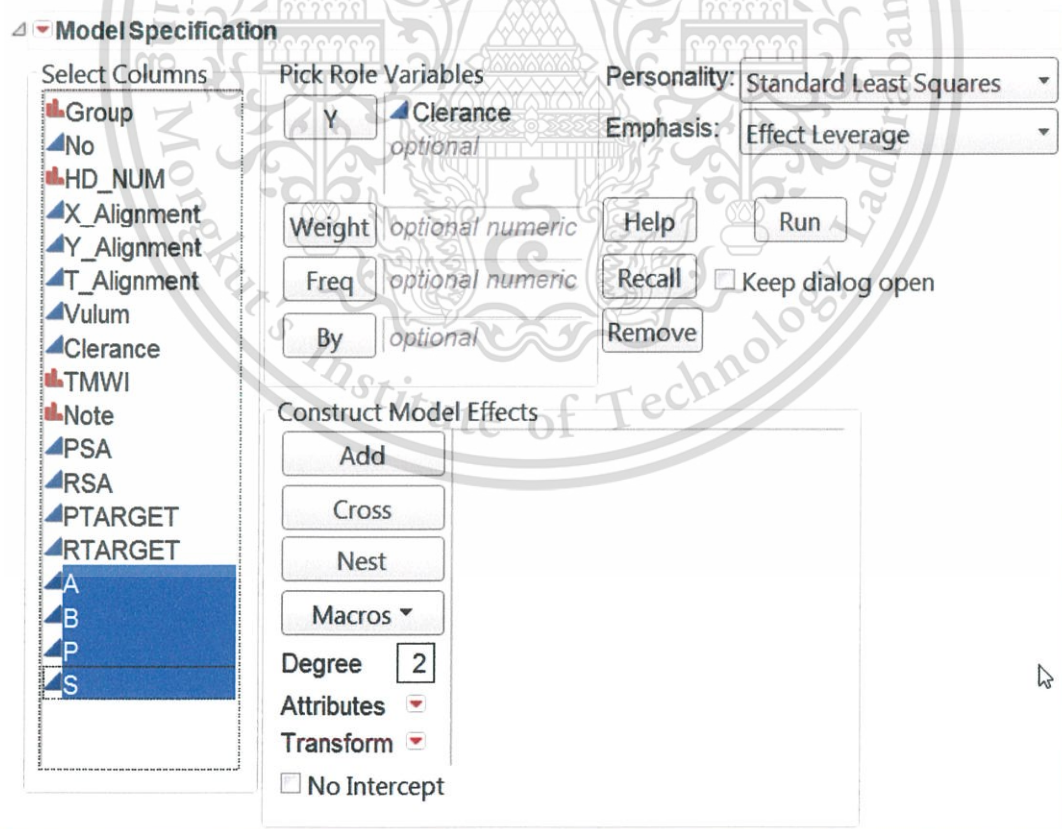
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Step3 : Click “Analyze” then go to “Fit Model”



Step4 : Select “Clarence” from Select Columns” in to Y-axis. Then, select the “visibility concern parameters” into “Add”, then click “Run”



Step5 : Then, select the “visibility concern parameters” again, then click “Macro” then “Polynomial to degree”, then “Run”

Model Specification

Select Columns

- Group
- No
- HD_NUM
- X_Alignment
- Y_Alignment
- T_Alignment
- Vulum
- Clerance
- TMWI
- Note
- PSA
- RSA
- PTARGET
- RTARGET
- A**
- B
- P
- S

Pick Role Variables

Y

▲ Clerance *optional*

Weight *optional numeric*

Freq *optional numeric*

By *optional*

Personality: Standard Least Squares

Emphasis: Effect Leverage

Help Run

Recall Keep dialog open

Remove

Construct Model Effects

Add A

Cross B

Nest P

Macros S

A*B*P*S

Full Factorial

Factorial to degree

Factorial sorted

Response Surface

Mixture Response Surface

Polynomial to Degree

Scheffe Cubic

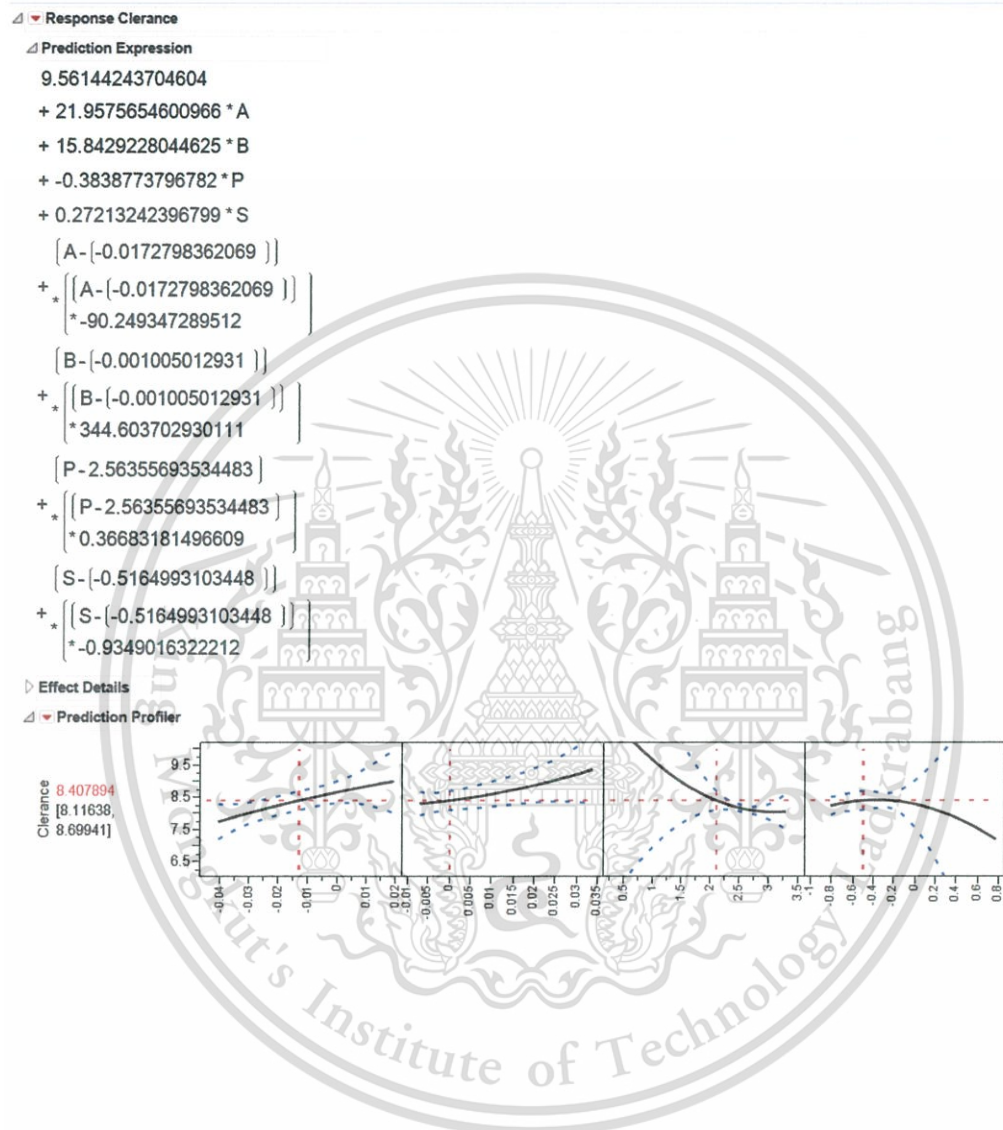
Radial

Add the selected columns (say, X) and their powers (X*X, X*X*X, etc.) up to the specified degree.

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Step6 : Results popping up, the prediction equation can got from Prediction expression and prediction profiler was the profile result of interesting parameters



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