DEFECT DETECTION EQUALIZATION OF HARD DISK DRIVE MEDIA TEST PROCESS USING VARIABLE BIAS IMPLEMENTATION IN TOUCH DOWN SENSOR RESPONSE

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DEFECT DETECTION EQUALIZATION OF HARD DISK DRIVE MEDIA TEST PROCESS USING VARIABLE BIAS IMPLEMENTATION IN TOUCH DOWN SENSOR RESPONSE

ABSTRACT

The drive to satisfy the ever increasing need for digital storage capacity today has brought about various advances from a technological stand point in the design and manufacture of high speed and high capacity hard disk drives. Efforts to increase the areal density of the magnetic media disk within the hard disk drive forced designers to push the envelope of the read/write head's flying height clearance using Thermal or Dynamic Fly Height Control (DFH) down to the sub–nanometer region, thus giving birth to the need for improved magnetic media disk manufacturing processes. In order to fly the heads ever closer to the magnetic media surface, the media needed to be free of any protrusion or asperity type defects that could prove fatal to the drive, which in turn, was achieved through the use of the Touch Down Sensor. This research paper aims to address the variation that is present within the Touch Down Sensor application that employs the fixed bias implementation in the magnetic media test environment through the use of a variable bias solution. The amplitude response variation within the current implementation is scrutinized, and an alternative technique using a variable bias solution that is derived using an extrapolation of the amplitude response curve is discussed. The variable bias solution demonstrated that the variation of the Touch Down Sensor could be significantly be reduced by 36.7% and established a foundation where future research into this implementation could be explored further.

Penyamaan isyarat pengesanan kecacatan di dalam proses pemeriksaan media pemacu cakera keras melalui implementasi pincangan bolehubah terhadap tindak balas sensor "Touch Down"

ABSTRAK

Keperluan yang kian meningkat untuk kapasiti penyimpanan data digital telah mendorong pelbagai kemajuan dari segi teknologi serta reka bentuk pemacu cakera keras berkelajuan dan berkapasiti tinggi. Usaha untuk meningkatkan ketumpatan permukaan media magnet dalam pemacu cakera keras telah memacu pereka untuk merekabentuk peranti membaca/menulis data yang mampu untuk terbang hanya beberapa nanometer dari permukaan media cakera keras tersebut dengan menggunakan kawalan suhu "Thermal / Dynamic Fly Control (DFH)" pada peranti tersebut. Ini telah melahirkan keperluan yang nyata bagi proses pembuatan media magnet yang bebas dari sebarang kecacatan yang timbul dari permukaan media tersebut yang boleh secara langsung merosakkan cakera keras itu sekaligus. Kebolehan pengesanan kecacatan ini dicapai dengan penggunaan sensor "Touch Down" bagi memastikan bahawa permukaan media bebas dari sebarang kecacatan yang timbul pada permukaan media. Fokus kertas penyelidikan ini adalah untuk menangani variasi isyarat yang tinggi dalam pengunaan sensor "Touch Down" yang menggunakan pelaksanaan pincangan tetap dalam akitivi pemeriksaan cakera magnet. Penyelesaian terhadap variasi ini dicapai melalui perlaksanaan pincangan bolehubah. Kadar perubahan tindakbalas amplitud yang didapati menerusi pelaksanaan pincangan tetap diteliti dan disiasat, dan dibandingkan dengan teknik pincangan bolehubah. Data yang diperolehi menggunakan kaedah ekstrapolasi daripada lengkungan amplitud digunakan untuk memperolehi nilai pincangan baru. Penyelesaian menggunakan pincangan bolehubah menunjukkan bahawa variasi isyarat sensor “Touch Down” menurun sebanyak 36.7%. Kajian ini juga membuka peluang untuk penerokaan applikasi pincangan bolehubah pada sensor “Touch Down” yang lebih mendalam pada masa akan datang.

CHAPTER 1

INTRODUCTION

1.1 Project Overview

In this digital age, digital media storage has become a vital element that helps both individuals and organizations store various vital digital content, which as a result has caused an exponential growth in the need for high capacity, high speed and highly reliable storage solutions. This requirement has been the primary driver in Hard Disk Drive (HDD) capacity and density technology where the 3.5inch desktop drives has been the industrial standard since the early 1980s until now. The key components and the layout of a standard HDD is shown in Figure 1.1. An essential enabler to a high areal density drive is the Head Media Spacing (HMS), which is basically the distance from the bottom of the read element on the flying head to the top of the magnetic medium on the rotating disk in the drive [1]. This increase in the areal density has been duly achieved by decreasing the Head Media Spacing which in turn allows for the size of the bits on the magnetic media to be also significantly reduced.

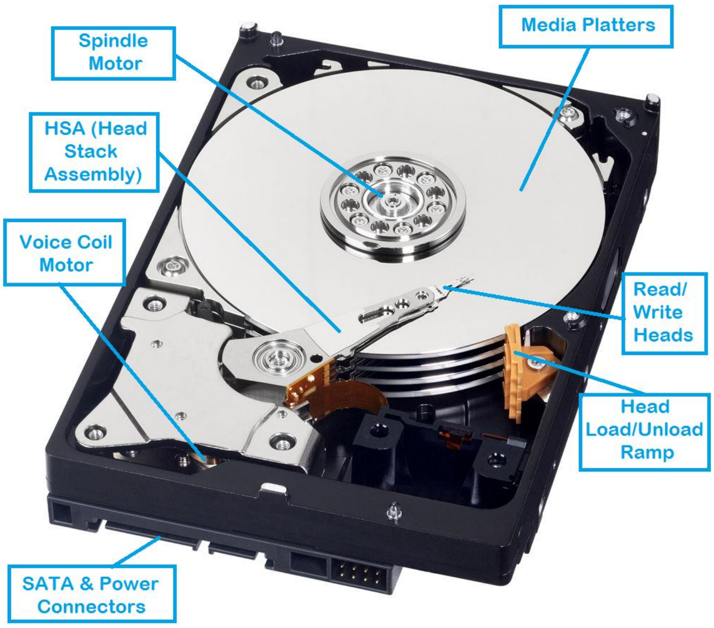

Figure 1.1 : Anatomy of a typical Hard Disk Drive (HDD) showing key components [2].

In the early 1990s, Head Media Spacing in a typical HDD was at around 200nm, today this space has shrunk to a mere 2nm only. This extremely narrow gap has a major impact on the physics of the drive reliability, failure and usage metrics [3]. A key challenge for the HDD industry resulting from the advent of smaller Read/Write (RW) Heads and the narrowed spacing is to ensure that the magnetic media surface doesn't have any asperities, mounds or imperfections that protrude from the surface of the media which can grossly damage the heads. This in turn has led to the requirement of magnetic media suppliers having to test and verify the magnetic media so that it is assembled into a HDD with no high asperities that could potentially damage the Read/Write Head.

Read/Write Heads in the HDD today have the ability to change the spacing between the heads and magnetic media through the implementation of Thermal Fly

Height Control or Dynamic Fly Height Control through resistive heating, which allows the heads to be flown over the media surface in two modes; the unactuated mode which is typically around 10nm and the actuated mode of around 2nm. Figure 1.2 illustrates these two modes which allows HDD drives today to fly over protrusions which are detected on the magnetic media surface during pre-test in the HDD assembly. These defects and protrusions are mapped out and the Read/Write heads will be unactuated as they fly over the defects in order to ensure that the life of the Read/Write Heads in the drive are maximized.

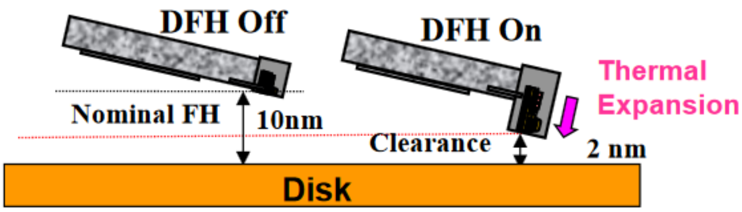

Figure 1.2 : Thermal or Dynamic Fly Height Control showing thermal expansion of the Dynamic Fly Height [3].

In short all the magnetic media that is tested prior to being installed into a hard drive needs to be verified to ensure that there are no such protrusions above 10nm as these defects would spell the end of the drive. In the magnetic media test environment in Western Digital (WD), the technology of detecting nano-asperities or protrusions on the magnetic media surface was introduced back in 2012 which allowed the detection of bumps and protrusions down to 2nm. This sensor which is called the Touch Down Sensor (TDS) is a thermal based sensor which is configured to convert heat to a voltage signal which can then be used to determine the physical properties of the defect detected [4], this in turn allows the magnetic media test process to detect and screen out the defects that would be detrimental to the drive.

In the real world variation is evident in any process and it cannot be eliminated completely, however, variation can be controlled and minimized in order to mitigate the effects of variation that can seriously affect the quality or reliability of the product. Similarly, variation between drive heads is common and is naturally anticipated in the magnetic media test process as there will always be head to head variation amongst HDD drives. In order to control this, the heads are calibrated and normalized to minimize the variation effects to produce a reliable test process. Likewise, in any similar Test process using TDS sensors, head detection variation has been found to be evident and can potentially be a serious problem to the drive reliability, thus, highlighting the need to have a better control of the detection variation in the test process itself.

The TDS sensor which is basically a sensitive resistive thermal based contact sensor is located between the read and write elements of a head [5]. The sensor relies on the bias voltage or current that is used to drive the sensor, whereby, the resultant sensor resistance changes proportionately with the change in the sensor temperature. Utilizing this varying change in the resistance of the sensor, the consequential voltage change is then captured and processed in order to decipher the detected defect. Variation in the voltage change across a defect amongst different heads has proven to be a serious challenge in ensuring that the detected defect is reported out accurately.

1.2 Problem Statement

The TDS sensor used in the WD magnetic media test process today is achieved using a fixed bias which is accomplished using a DAC controlled driver. This setup although is capable of supplying the high input required to bias the large sensor on the Read/Write Head which cannot be achieved purely by the existing driver of the Head Pre-amplifier chip on its own, is not intelligent enough to vary the bias in order to achieve the sensitivity required to detect defects consistently between different heads. The current open loop setup on the Pre-Amplifier Card (PAC) Printed Circuit Board Assembly does not have the ability to make changes to accommodate the head to head TDS sensor sensitivity variation which the primary target of this study. In other words, the inability of the current setup to resolve the intrinsic head to head variation that is evident in the WD test process will be investigated and addressed to achieve the desired defect detection variation distribution.

Research Questions

In order to understand the existing head to head variation and the required solution to normalize the defect detection capability of the TDS sensors, the research questions below have been outlined;

1. What is the current head to head defect detection variation in the TDS Test process in WD today?

2. What are the key variables that effect the detection variation and how these variables can be best controlled?

3. How effective is the Bias control in normalizing the defect detection capability of multiple heads?

1.3 Research Objectives

The principal aim of this research is to critically examine the effectiveness of implementing an auto variable bias control as opposed to the existing fixed bias TDS sensor which has variation in its detection sensitivity in order to equalize head to head defect detection performance. In order to achieve the aims of this research, the following objectives have been outlined:

1. To critically analyze the current head to head defect detection variation in the WD Magnetic media TDS Test process.

2. To investigate the key variables that effect the detection variation, primarily the Bias and how these variables can be best controlled.

1.4 Scope of Research

The scope of this research project will encompass the WD Magnetic media TDS test with particular focus on investigating and resolving the Touch Down Sensor defect detection variation, in an effort to equalize the defect detection capability of multiple heads. In addition to that, other possible variables that may be a factor towards the head to head variation will also be studied, finally culminating in a proposed solution which is aimed at providing a capable defect detection system that would allow the equalization of the defects detected.

Although the Touch Down Sensor used in the standard hard disk drive is typically similar in design, the focus of this research will be on the implementation and results of the specialty Touch Down Sensor which is a proprietary design used for WD Media Test. In short, the scope of this project will be limited to this Touch Down Sensor defect detection capability of the magnetic media in the WD test environment only.

1.5 Dissertation Outline

This research paper is essentially divided into five major chapters that will encompass the entire study with the general details of each chapter covered as below.

The first chapter of this study will cover the introduction of this research which concentrates primarily on the background of this research and an overview of the Touch Down Sensor. Following that, in this chapter as well the research problem statement is clearly defined and the corresponding research questions that will be addressed are highlighted. Finally, the specific research aims and objectives of this research are identified and followed up with the overall scope of the study undertaken.

The second chapter of this dissertation covers a comprehensive literature review of prior research on the subject matter, which puts forth relevant data, research outcomes and conclusions of studies done by the industry's content experts and developers on the Touch Down Sensor and all related matter. An overview of the

Touch Down Sensor test process together with a detailed review of the factors that contribute to the detection variation will be presented and discussed as well.

Chapter three will focus on the research methodology, where the research questions and objectives identified will be addressed in terms of the proposed experiments and tests. A clear framework of the how the data will be acquired and the measurement techniques used in the analyses of the compiled data is detailed in this chapter. Additionally, the research limitations and any other potential issues that may be encountered during this study will be discussed. Following this, a clear plan on the proposed solution to normalize the head variation and equalization of the detected defects will be put forth.

Chapter four will draw attention to the analysis of the various data collected and how the proposed solution or design together with any proposed algorithm for the new test process will be implemented, where it includes the discussion of the research observations and its relevance to the objectives, the validity of the research and the results of the proposed solution in order to improve the test process.

Lastly, the final chapter of this study will emphasize the conclusions that have been derived from the outcome of this research, and the proposed new solution in achieving the target objective of having a solid variation free test process for the detection of defects on magnetic media for HDD drives. This will be then followed by a comprehensive set of design recommendations that may be utilized by WD Media management in their effort to resolve this test head to head detection variation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The evolution of HDD technology at the turn of the century has brought about a multitude of technological advances that have allowed the overall capacity of the HDD today to have such a large storage capacity. This advancement in storage capacity, data transfer speed and reliability was enabled through the various technological improvements of all the key elements of the HDD, namely the magnetic media platters and the Read/Write heads. In order to further understand the significance of the magnetic media platters and the Read/Write heads towards the growth of the HDD, one needs to also understand that the interaction between these elements are the primary factor of the drive and its ability to store more data today.

2.2 Magnetic Media Platter

A key element in the large storage capacity can best be described by the areal density of the drive magnetic platters. Areal density, as defined by Computer History Museum is the number of bits of information or data that can be stored on the surface area of a magnetic recording medium [6]. Based on the desktop 3.5 inch drive size that has today become a worldwide standard, the capacity of data per square inch or areal density has grown tremendously throughout the last 50 years. Figure 2.1 shows the areal density improvement throughout the last 50 years, whereby the growth rate of areal density has been found to vary from 25% to 100% over this period and is now at around 25-40% [6].

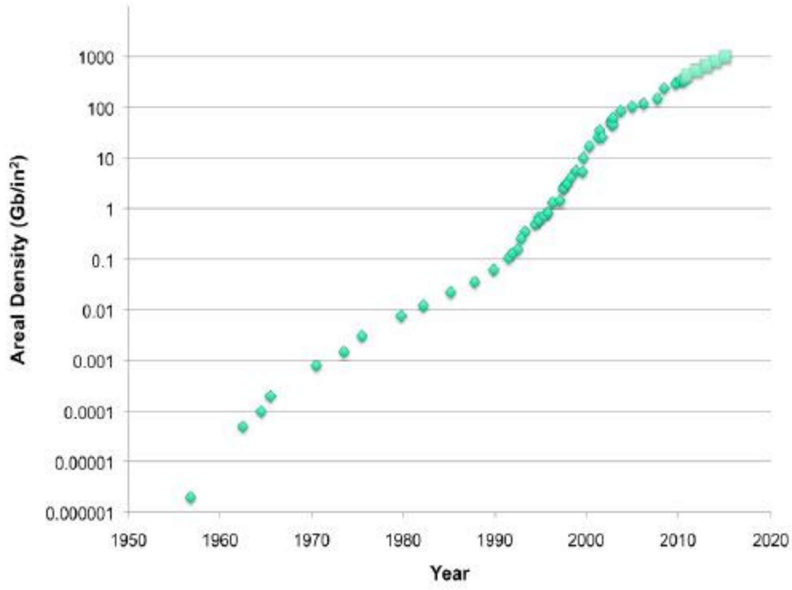

Figure 2.1 : Areal density trend of the HDD Magnetic Media from year 1950 to 2015 [7].

The increase in capacity and areal density in the HDD was achieved in part through the reduction of the Head Media Spacing, by employing smaller Read/Write heads to read and write the smaller magnetic bits, which in turn forced the heads to be flown lower and lower. As a result of the need for the increased areal density, the reduced spacing between the magnetic head and disk has today reached sub-1-nm regime, where such an ultra-low spacing between the heads and media inadvertently introduces great challenges to tribological reliability in the head–disk interface (HDI) [8].

A direct result of the reduced Head Media Spacing for the HDD drives in this day is the need for a magnetic media platter surface that is ultra-smooth and asperity or protrusion free. Figure 2.2 gives us an insight to what the actual drive surface looks like under an electron microscope. In short, with the Read/Write heads flying at 1nm spacing from the media surface, the standards and requirements for media that is defect free, smooth and flat cannot be overemphasized, thus warranting the need for better defect detection of the defects and protrusions on a high end drive media platter.

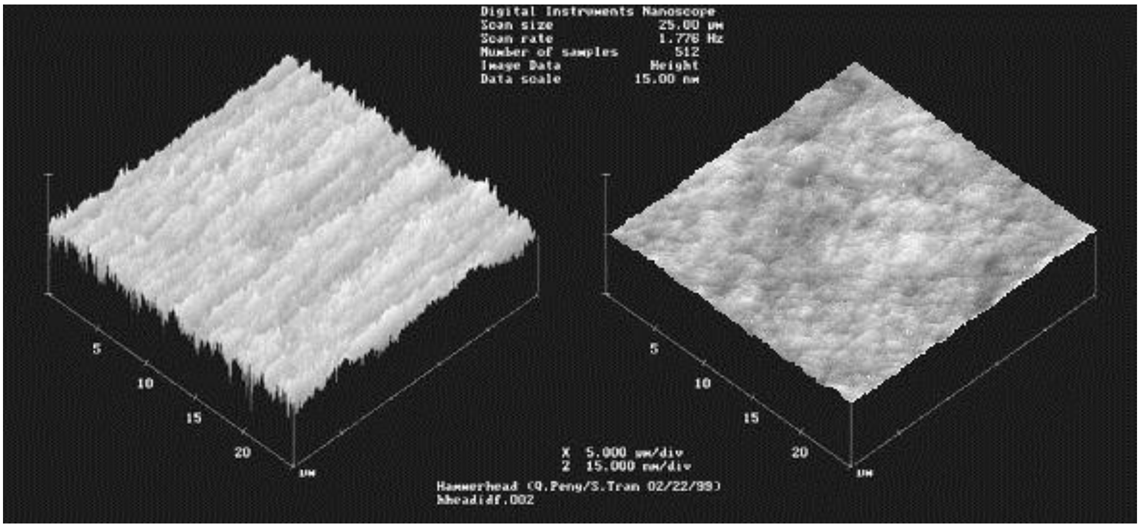

Figure 2.2 : Hard disk platters under a scanning electron microscope showing the surface of an aluminum alloy platter (left) and a glass platter (right) [9].

2.3 Read/Write Heads

HDD Read/Write Heads constitute the joint top most critical element in a hard drive besides the magnetic media platter. The improvements over time in HDD to bring the Head Media Spacing lower could not have been achieved with just a smoother magnetic media platter, but through the technological advances in head slider design which allows for the ability of the heads to fly in a stable and consistent manner in order for the reader and writer elements to effectively store and retrieve data from the media. Read/Write heads in the HDD are mounted on a Head Stack Assembly (HSA), as shown in Figure 2.3, where one head is allocated per media surface in order to fully utilize both magnetic surfaces in the drive.

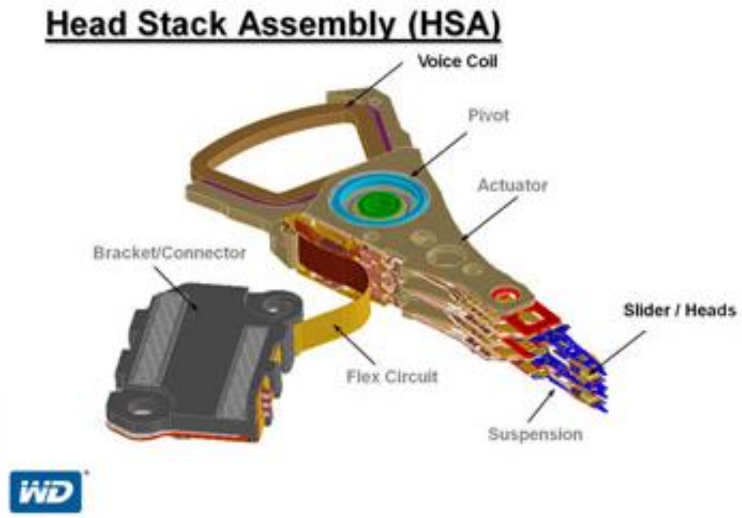

Figure 2.3 : Components of a Head Stack Assembly (HSA) [10].

The Read/Write Head is also known as the Head Gimbal Assembly (HGA) which consists of the Head Suspension and the Slider which houses the Read and Write elements, and since the read and write elements are extremely small, the elements are built into the center of the Slider. It is common for people to be fooled into thinking that the slider is the actual HDD head, on the contrary, a slider in fact is not a head, but it's a wing which helps read and write elements fly over the magnetic media platter, whereby the slider's surface is designed with aero dynamical grooves that allow it to fly at a certain height above the media surface in a stable manner [11]. As the media is spun at a high velocity, air flowing at high speed under the slider forms an Air Bearing Surface (ABS), and it is this Air Bearing Surface that allows the slider to fly almost parallel to the magnetic media platter's surface [11]. Figure 2.4 shows the slider position on a Read/Write Head.

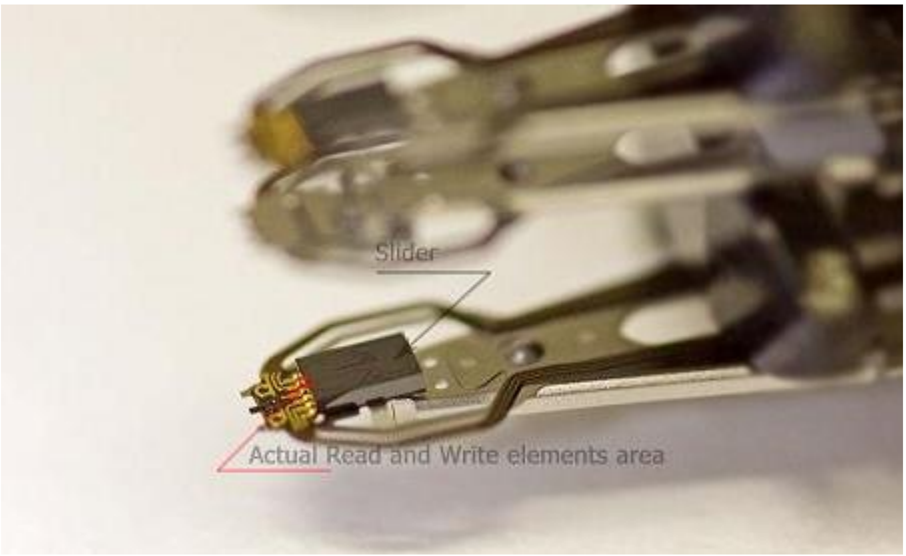

Figure 2.4 : Slider mounted on a Head Gimbal Assembly (HGA) showing the electrical connections and the Read/Write Element position [11].

The Read/Write elements which are basically coils that generate a magnetic field are built into the slider which allows for the reading and writing of data through the change in the polarity of the magnetic bit on the media platter. This control over the read and write elements is achieved through a Pre-Amplifier chip located at the end of the Head Stack Assembly arm. In recent years the addition of a Touch Down Sensor element has also been incorporated into the slider, thus giving the HDD designers an option to detect the flying height of the slider in the drive in an effort to control the Head Media Spacing requirement of high density HDD drives today.

2.4 Dynamic Fly Height

One of the two key technologies in the effort to achieve higher areal density in hard drives is the reduction of the clearance between the read/write element on the head and the magnetic recording media; while the other being the minimization of flying height variations to maintain a low bit error rate in the drive [12]. Hard Drive heads need to be flying consistently above the spinning magnetic media in order to be able to read and write the data transmitted to and from the hard disk drive. The advancement of technology today and the need for higher capacity hard drives has brought about the need to fly the heads lower and lower, thus presenting head designers the challenge of not only flying the heads in a stable manner, but also to be able to do so with high precision. The Read/Write elements in the heads of the hard drives today fly only nanometers from the surface, it is only through this close proximity can the bit sizes of the magnetic media be reduced to meet the areal density requirements of the drives today.

The need to fly closer to the magnetic media gave birth to the idea of actively controlling the fly height way back in 1990, whereby the proposed design was based on a piezo element that allowed for the dynamic adjustment of the head to media spacing in the hard drives. This technique however was found to be cumbersome and not cost effective if mass produced, thus leading to the design and implementation of using thin-film micro-heaters embedded within the slider that was first introduced by Machtle et al in 2001 [13]. These micro-heaters that are built-in into the sliders transfer thermal energy into the sliders which causes the sliders to expand non-uniformly and results in the deformation of the air-bearing surface on the slider which allows the slider to fly closer to the magnetic media surface [14].

The high precision control of the flying height of the slider from the magnetic media surface is also known as the Dynamic Flying Height (DFH) of the heads. This precision control of the flying height or clearance from the magnetic media surface is achieved through a series of incremental power applied to a heater coil within the head slider to a small region around the read/write transducer that will cause it to thermally expand towards the disk, thus achieving the spacing gap desired. This technique of thermal expansion and retraction of the protrusion on the slider allows for the flying height or gap of the head's Read/Write elements from the magnetic media to be adjusted flexibly [8]. Figure 2.5 shows the relative position of the micro-heater element embedded within the slider, and the resultant expansion of the slider towards the magnetic media surface.

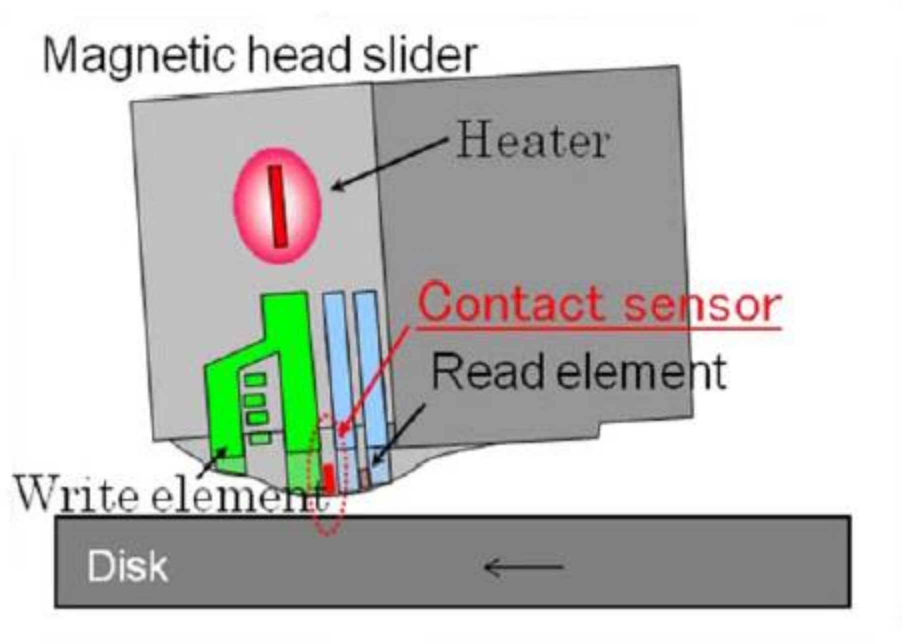

Figure 2.5 : Slider with the thermal protrusion of the slider flying above the Magnetic Disk/Media [15].

An important second reason for dynamic fly height control stems from the write element and write function on the head itself. The write element on the head also causes some degree of pole tip protrusion during write cycles to happen which is inevitable but undesirable nonetheless. In order to mitigate this effect during separate read and write cycles, the micro-heater is positioned in close proximity to the read and write elements on the slider, typically in the trailing edge of the slider where the read, write and also Touch Down Sensor (TDS) elements are located [12]. Additionally, positioning the micro-heater, read, write and TDS elements at the trailing edge of the slider provides the closest possible position for the read and write elements to have a consistent interaction with the magnetic media surface during the read and write process. Figure 2.6 shows the location of the read and write elements on a slider air bearing surface and the trailing edge of the slider.

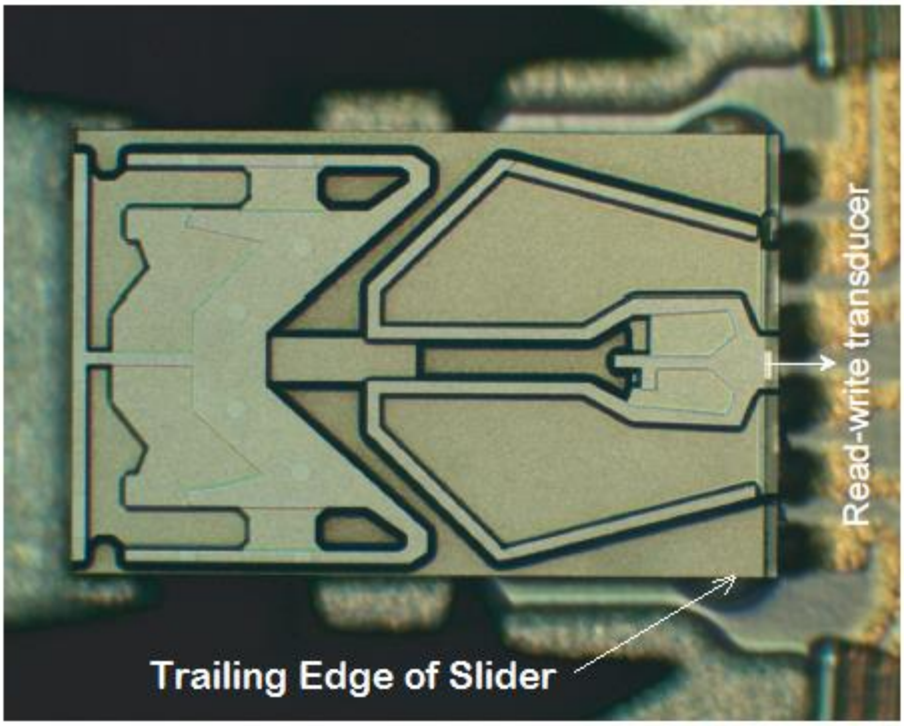

Figure 2.6 : Slider Air Bearing Surface showing the Read and Write Elements on the Trailing Edge of the slider [16].

The thermal protrusion on a slider which is normally achieved through the application of power to the micro-heater element within the slider is controlled by the pre-amplifier chip within the drive. The amount of protrusion from the slider is typically linear in proportion to the amount of power injected into the micro-heater element by the pre-amplifier chip as detected by the Touch Down Sensor. This has been proven whereby the sensitivity of the Touch Down Sensor voltage response as a function of the heater power applied on a test spin-stand magnetic media showed that the standard deviation of the TDS sensor voltage is nearly linear for heater powers up to 130mW. This response is illustrated in Figure 2.7, which reveals this constant increase in heater power versus the sensor voltage. However, this linear response does not hold true to heater powers beyond 130mW, where a sudden increase in the sensor standard deviation is observed [5].

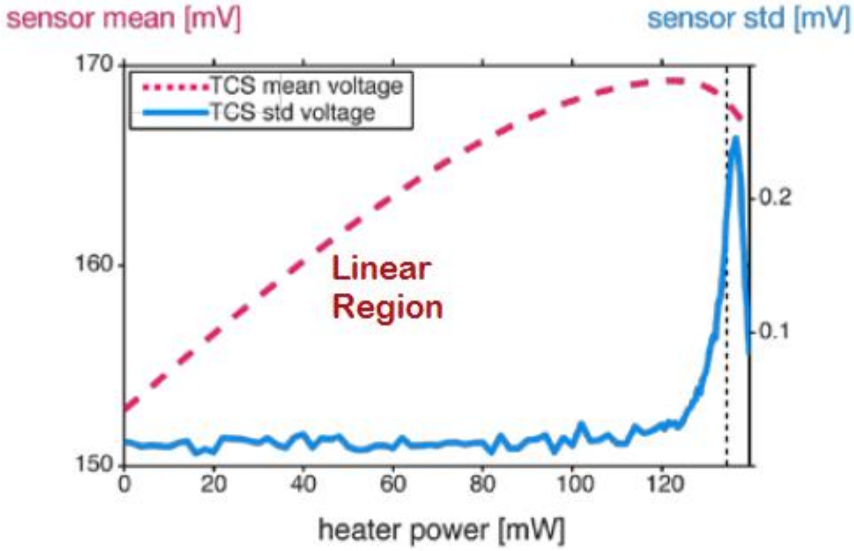

Figure 2.7 : Touch Down Sensor voltage response versus heater input power [5].

2.5 Slider Flying Height

The read/Write heads in the drive are designed to behave like an airfoil that uses the high speed wind generated by a spinning magnetic media in order to achieve lift and practically glide over the disk surface. The Air Bearing Surface of the slider is designed to allow the air travelling below it to lift the slider and maintain its fly height as the head moves across the magnetic media during the read and write cycles of the hard disk drive.

The flying height of the slider of the read/write heads from the magnetic media surface has significantly reduced over the years as the areal density requirements of the hard drive has forced the industry to design the heads to fly closer to the magnetic media in order to read and write the smaller magnetic bits. The original Fly Height of a slider is defined as the slider's flying-height with the micro-heater element turned off, and the adjusted Fly Height is the slider's flying-height with the micro-heater element turned on. The actuated Fly Height of the slider on the other hand is defined as the delta between the original Fly Height and the adjusted Fly Height of the slider [17]. Figure 2.8 shows these two conditions with the micro-heater element on and off, and the delta between these two conditions known as the Actuated Fly Height.

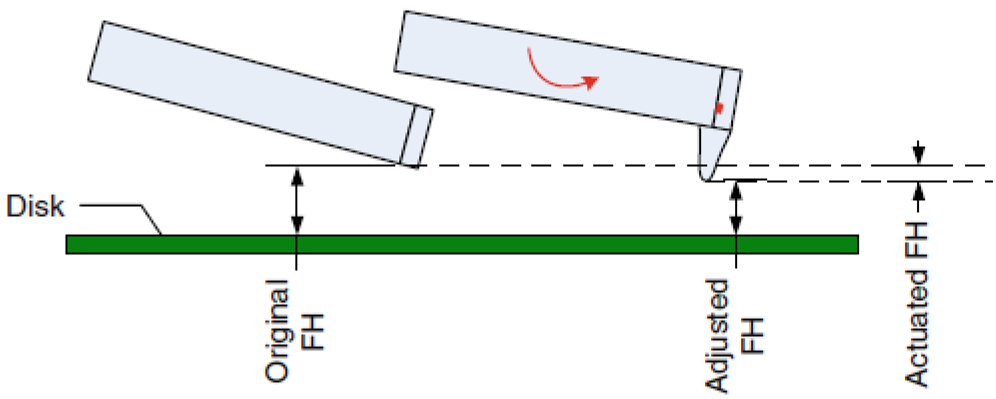

Figure 2.8 : Read/Write Head slider's original Fly Height, adjusted Fly Height and the Actuated Fly Height [17].

The sliders used in the hard disk drives today are distinctly designed to not only provide lift which allows the slider to glide across the magnetic media, but also fly in a stable manner with minimal or almost zero flying height variations. A typical slider today has three distinct areas with intricate cut outs and shapes that allows the slider to achieve a consistent head to media spacing across the entire disk, as well as minimal height variations under various types of conditions. The first of these three areas is the Shallow Etch area which generally is a stepped air inlet allowing airflow which creates the positive air pressure under the second area, which is the Air Bearing Surface that lifts the slider higher as the air flow increases underneath the slider, as shown in Figure 2.9. The third area known as the Deep Etch area on the other hand creates a negative pressure pocket of vacuum which is designed to pull the slider closer to the disk [18].

This special combination of both positive and negative air pressures on the slider is aimed at balancing the two opposing forces generated by the air flow against that of the Read/Write Head suspension arm pushing the slider toward the disk, while keeping the slider flying at the preferred height from the magnetic media surface. This intricate balance of both the positive and negative air pressures on the slider helps to stabilize the slider fly height variations which was a serious issue found in older slider designs [18]. This fact was also concurred by Yang Juan et al., who highlighted that it takes both the negative and positive air pressure distribution balance coupled with the applied down force load of the head suspension arm to determine the flying attitude of the slider which includes the overall height, pitch and roll, and other important characteristics, including air bearing stiffness and damping [19].

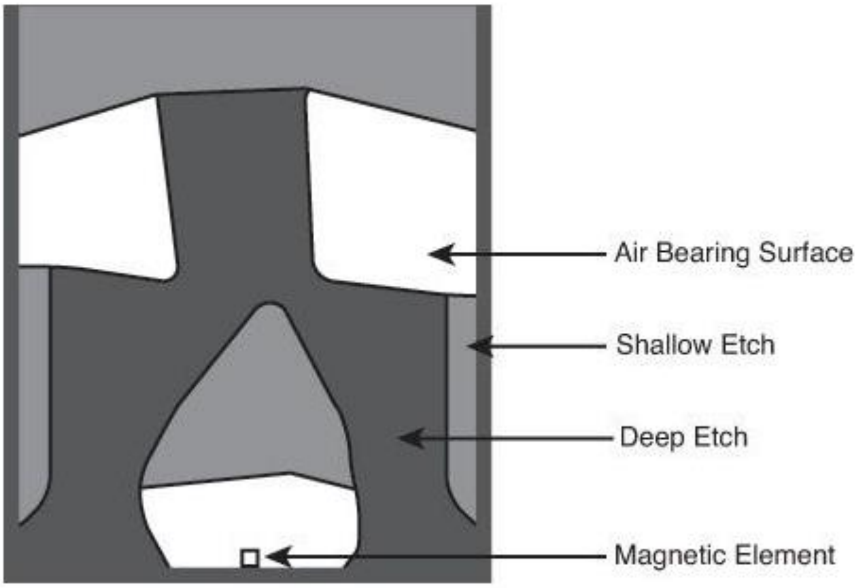

Figure 2.9 : Typical Femto Slider air-bearing slider surface design [18].

One other alternative design approach that has been found to be effective and is able to minimize changes in fly height is to design sub cavities etched into the existing deep etched area of the slider. Each sub cavity that is created by an additional etching step creates small regions within the deep etched cavity area creating a pocket of negative air pressure that is even lower. This method although proven to be successful in improving fly height stability has the disadvantage of higher manufacturing costs due to the additional process step involved [20].

2.6 Magnetic Media Defects

Understanding the types of defects and the morphology of these defects that are inherent process variations in the magnetic media manufacturing process is vital, where this insight will be key in order to have a clear idea on what type of detection is necessary to detect and reject these defects which are potentially fatal to the Hard disk drive. In order to identify the potential defects that can be created from the manufacturing process of the magnetic media, the manufacturing steps of the magnetic media needs to be understood. The general magnetic media manufacturing process starts with the base substrate material, followed by media texture, wash, sputtering, lubrication, tape burnishing and the final testing to ensure the magnetic media is manufactured to the required specifications for the drive. Figure 2.10 shows the process flow of the magnetic media manufacturing process and the potential defects that can be generated from those individual processes [21].

Process	Description	Potential Types of Defects
Substrate	Cut and polished bare Aluminium Ally or Glass Base material	1. Polish scratches 2. Embedded particles
Texture	Texturing of fine grain patterned groove for magnetic layer deposition process	1. Polish scratches 2. Embedded particles
Wash	Chemical and ultrasonic cleaning process	1. Unremoved particles 2. Chemically etched pits
Sputter	Vapor deposition of multiple layers of magnetic material done in vacuum chambers.	1. Uneven deposition 2. Embedded particles
Lubrication	A layer of a special lubrication solvent to protect the surface and reduce head and media wear	1. Uneven lubrication 2. Lubrication blobs
Tape Burnish	A non-abrasive wiping of the lubricated surface to remove any unwanted particles	1. Burnish scratches 2. Embedded particles
Final Test	Comprehensive test to determine product quality	1. Test Head scratch 2. Lubrication surface distortion

Figure 2.10 : Process flow for manufacturing of Magnetic Recording Media [21].

The magnetic media disk is in fact a rigid disk or platter that is made from a base material which typically consists of an Al-Mg alloy or glass substrate at the core, whereby providing a sturdy, light and stable foundation for the magnetic media. This base substrate has several layers of material deposited on it, namely the undercoat layer, Soft Underlayer, a magnetic multilayer and it is topped off with a carbon overcoat that is protected by a very thin layer of specialized lubrication material [22]. Figure 2.11 shows the layering of a general magnetic recording media disk used in the hard disk drives today.

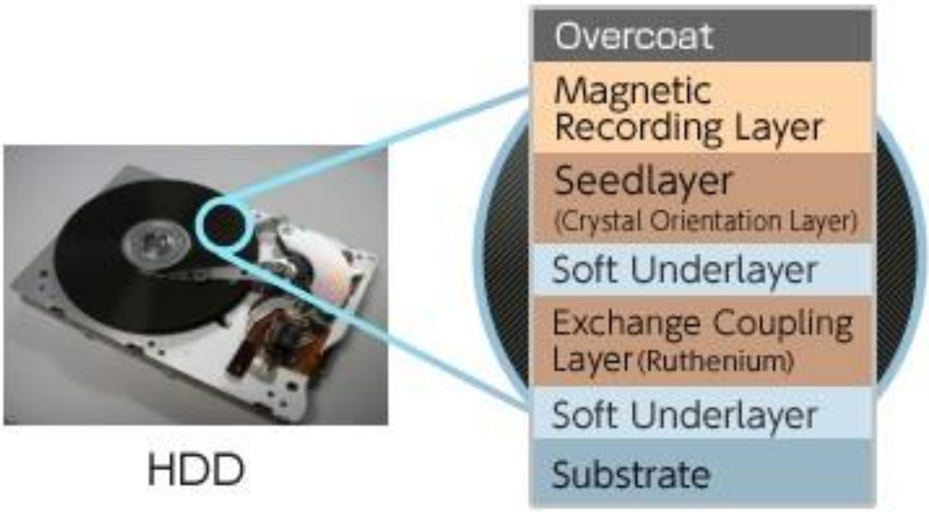

Figure 2.11 : Layers of a magnetic recording media of hard disk [23].

Magnetic media defects can be generated or encountered on every single process step of the magnetic media manufacturing process. Once these defects are encountered in a process, it may get covered by the various layers of magnetic material