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A Failure Analysis Tool for HDD Analysis

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***Abstract*—**The study of piezoelectric materialin the past wasin T-Domain form; however, no one has studied piezoelectric material in the S-Domain form. This paper willpresent the piezoelectric material in the transfer function or S-Domain model.S-Domain is a well known mathematical model, used for analyzing the stability of the material and determining thestability limits.By using S-Domain in testing stability of piezoelectric material, it willprovide a new toolfor the scientific world to study this material in various forms.

***Keywords*—**Hard disk drive, failure analysis, tool, time

I. INTRODUCTION

THE HDD is one of the important devices, and the most significant component, of the personal computer (PC). It is estimated that over 90% of all new information produced in the world is being stored on magnetic media, mostly on hard disk drive [1-2]. The HDD is a highly complex, mass-produced, electro-mechanical device that utilizes principles of magnetic recording for data storage. As fundamental elements of modern computer systems and consumer electronic devices, HDDs have managed to combine a steady increase in storage density and capacity with a concomitant decrease in the cost per megabyte. The HDD combines the most recent achievements in the science and technology of magnetic recording, material science and digital signal processing. [3]

The general, HDDs in factories - before sent to user handle - must “pass” several reliability and quality tests. These tests are highly complex throughout every step of the process to ensure product quality. Thus, some produced HDDs are not accepted - failed. These failed drives are removed and afterwards, sent to analyze their cause of failure. [4]

Section II describes about the general HDD, from the beginning of 'What‘s is a HDD?', to components of the HDD and read/write operation of the HDD. The entire FA process is explained in section III, as this software is produced as a FA tool. Section IV will describe the details of this tool. And the step by step method is given in section V. This paper is proposed to support first analysis of HDD.

We assume the FA operating and usage time support in the FA works as a basis. This tool can be used to help reduce the time.

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II. THE HARD DISK DRIVE

The HDD is a random access digital data storage device. It features rotating rigid platters on a motor-driven spindle within a protective enclosure. The data is magnetically read from and written to the platter by read/write heads that float on a film of air above the platters. [5]

The component of the HDD, consist head (read/write), disk (platter) spindle, actuator (arm and axis) and connector (IDE and power) as shown in Fig. 1.

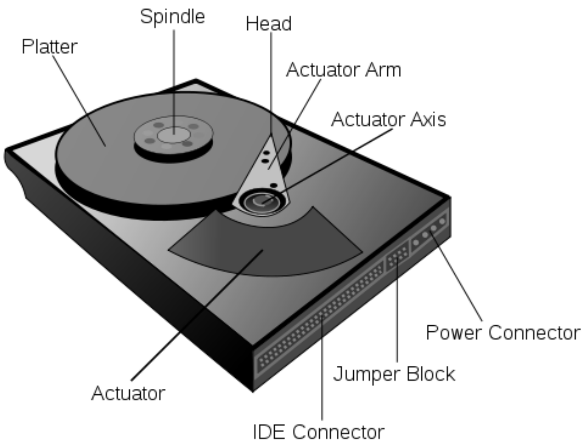


Fig. 1 The component of the HDD

The HDDs record data by magnetizing ferromagnetic material directionally. Sequential changes in the direction of magnetization represent patterns of binary data bits. The data are read from the disk by detecting the transitions in magnetization and decoding the originally written data.

A typical hard disk drive has two electric motors; a disk motor that spins the disks and an actuator (motor) that positions the read/write head assembly across the spinning disks.

The disk motor has an external rotor attached to the disks; the stator windings are fixed in place.

Opposite tothe actuator at the end of the head support arm is the read-write head (near center in photo); thin printed-circuit cables connect the read-write heads to amplifier electronics mounted at the pivot of the actuator. A flexible, somewhat U-shaped, ribbon cable, seen edge-on below and to the left of the actuator arm continues the connection to the controller board on the opposite side.

The capacity of an HDD may appear to the end user to be a different amount than the amount stated by a drive or system manufacturer due to many things; different units of measuring capacity, capacity consumed in formatting the drive for use by an operating system and/or redundancy.

In modern HDDs, spare capacity for defect management is not included in the published capacity. However, in many early HDDs a certain number of sectors were reserved for spares, thereby reducing capacity available to end users.

In some systems, there may be hidden partitions used for system recovery that reduce the capacity available to the end user.

Because modern disk drives appear to their interface as a contiguous set of logical blocks, their gross capacity can be calculated by multiplying the number of blocks by the size of the block. This information is available from the manufacturers' specification and from the drive itself through use of special utilities invoking low level commands.

III. The HDD Functionality

The HDD is used by a computer to store the operating system (OS) and the user's data. The HDD is one of the most important component of the modern PC: no application will run reasonably without the hard drive. [6]

A. The Magnetic Recording Basics

The reading process includes excitation of the current in the head coil when the head "senses" changes in the magnetic flux. The read voltage pulses at the flux transitions are then translated into sequences of bits equal to 0 and 1. The so-called Wallace's spacing loss factor postulates that the loss of magnetic signal power will be proportional to the media - head separation. This requires magnetic heads to fly as close to the disk surface as possible. That is shown in Fig. 2.

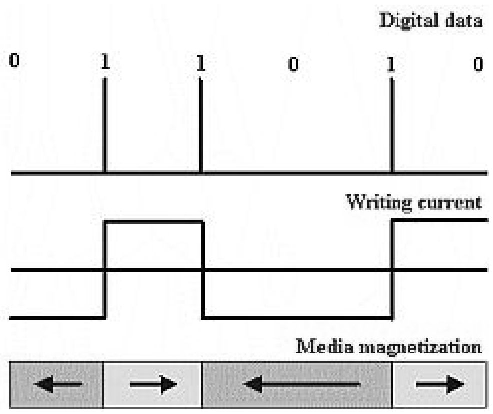


Fig. 2 TheMagnetic Recording Basics.

Now, the magnetic head typically consists of an MR (magneto-resistive) or GMR (giant MR) reading head and a thin-film inductive write head.

The MR head design is based on the ability of metals to change their resistivity in the presence of a magnetic field. This effect was first found in 1857.

The alloy of Ni and Fe (81%/19%) is widely used in MR heads and is called Perm alloy. MR heads are suitable for extremely high bit density and have superior signal-to-noise ratio when compared to inductive read heads. Inductive thin film heads generate strong magnetic fields at the gap between the poles, thereby magnetizing areas of the media. The physical read/write on the media is shown in Fig. 3.

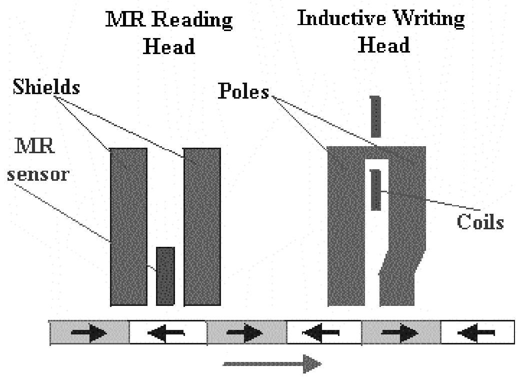


Fig. 3 The MR read/write operating on the media.

Continuous improvement of the head design allowed extremely high densities of magnetic recording with magnetic bits getting smaller and smaller. But, the head is only one component of the magnetic recording system, with magnetic media being extremely important as well.

The first magnetic media was called "particulate media" because it included particles of iron oxide (as the magnetic medium) and aluminum oxide (for abrasive resistance). Modern magnetic media is called "thin-film media" and consists of very thin layers with a total thickness of about 500 angstroms or 50 nm. The next figure presents a not-to-scale sketch of one of the kinds of thin-film media.

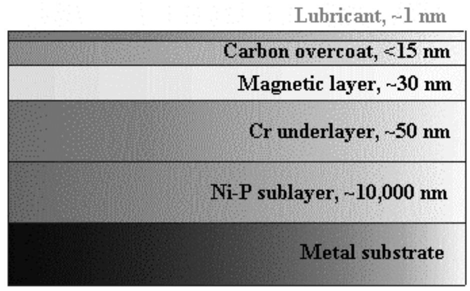


Fig. 4 The physical layer on the media

This thin sandwich is usually deposited by physical vapour deposition (when the atoms of different materials are formed on the surface with the minimum of chemical reaction involved) on the metal disk. Magnetic layer is needed to store the data. The reasons for having a thin carbon layer are simple: it increases mechanical durability of the disk and slows down corrosion of the magnetic layer. This carbon is sometimes called a diamond-like carbon (DLC) since it has similar chemistry to the diamond (both are mostly carbon), it is very hard (Diamond is VERY hard!), and it provides low friction.

A thin layer of lubricant on the top is used to minimize the wear of the carbon layer. The all layers are shown in Fig. 4.

Amazingly, year after year, this super-thin structure gets thinner and thinner to keep the magnetic head flying lower and lower to decrease that magnetic spacing loss

B. The Basic hard disk drive concepts

These are descriptions to accompany drive physical and logical organization as shown in Fig. 5.

Track

A concentric set of magnetic bits on the disk is called a track. Each track is divided into 512 bytes (usually) sectors.

Sector

A part of each track defined with magnetic marking and an ID number. Sectors have a sector header and an error correction code (ECC). In modern drives, sectors are numbered sequentially.

Cylinder

A group of tracks with the same radius is called a cylinder (red tracks on the picture belong to one cylinder).

Data addressing

There are two methods for data addressing: CHS (cylinder-head-sector) and LBA (logical block address). CHS is used on most IDE drives, while LBA is used on SCSI and enhanced IDE drives.

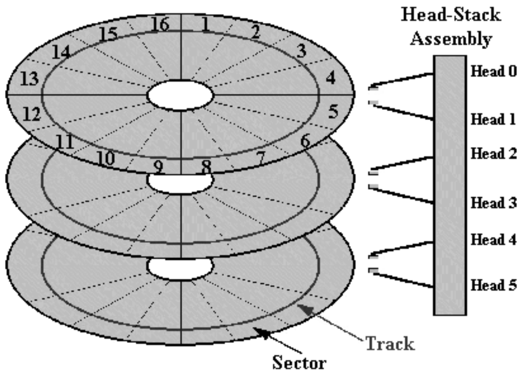


Fig. 5 The drive physical and logical

The CHS addresses data by simply specifying the cylinder (radius), head (platter side), and sector (angular position). LBA assigns each sector of the drive a sequential number, which is simpler.

If you look into your BIOS, you will find listed; the number of cylinders, heads, and sectors for each drive you have. Modern operating systems access data using LBA directly without the help of the BIOS. This reduces incompatibilities.

To improve performance and increase data rate, HDDs utilize a small amount of fast solid-state memory to store the most frequently used data. This memory is called 'cache' or 'buffer'. There are two types of cache memory organization: look-ahead and write / read.

In the failed locations, the C/H/S is told in detail. This may be useful for searching these positions quickly for future analyzing.

IV. The Failure Analysis

In computing, HDD failure occurs when the HDD malfunctions and the stored information cannot be accessed with a properly configured computer. A disk failure may occur in the course of normal operation, or due to an external factor such as exposure to fire or water or high magnetic waves, or suffering a sharp impact or environmental contamination, which can lead to a head crash[7].

The most cause of HDD failure is a head crash, where the internal read-and-write head of the device touches a platter, or a magnetic data-storage surface. A head crash usually incurs severe data loss, and data recovery attempts may cause further damage if not done by a specialist with proper equipment. The HDD platters are coated with an extremely thin layer of non-electrostatic lubricant, so that the read-and-write head will simply glance off the surface of the platter should a collision occur. However, this head hovers mere nanometers from the platter's surface which makes a collision an acknowledged risk. Another cause of failure is a faulty air filter. The air filters on today's hard drives equalize the atmospheric pressure and moisture between the HDD enclosure and its outside environment. If the filter fails to capture a dust particle, the particle can land on the platter, causing a head crash if the head happens to sweep over it. After the HDD crash, each particle from the damaged platter and head media can cause a bad sector. These, in addition to platter damage, will quickly render a hard drive useless. The HDD also includes controller electronics, which occasionally fail. In such cases, it may be possible to recover all data.

Since the HDD are mechanical devices, they will all eventually fail. While some may not fail prematurely, many hard drives simply fail because of worn out parts. Many hard-drive manufacturers include a Mean Time Between Failures figure on product packaging or in promotional literature. These are calculated by constantly running samples of the drive for a short amount of time, analyzing the resultant wear and tear upon the physical components of the drive, and extrapolating to provide a reasonable estimate of its lifespan. Since this fails to account for phenomena such as the aforementioned head crash, external trauma (dropping or collision), power surges, and so forth, the Mean Time Between Failures number is not generally regarded as an accurate estimate of a drive's lifespan. The HDD failures tend to follow the concept of the bathtub curve. The HDD typically fail within a short time if there is a defect present from manufacturing. If the HDD proves reliable for a period of a few months after installation, the HDD has a significantly greater chance of remaining reliable. Therefore, even if a hard drive is subjected to several years of heavy daily use, it may not show any notable signs of wear unless closely inspected. On the other hand, the HDD can fail at any time in many different situations.

The HDD failure can be catastrophic or gradual. The former typically presents as a drive that can no longer be detected by CMOS setup, or that fails to pass BIOS POST so that the operating system never sees it. Gradual hard-drive failure can be harder to diagnose, because its symptoms, such as corrupted data and slowing down of the PC (caused by gradually failing areas of the hard drive requiring repeated read attempts before successful access), can be caused by many other computer issues, such as malware. A rising number of bad sectors can be a sign of a failing HDD, but because the HDD automatically adds them to its own growth defect table, they may not become evident to utilities such as Scandisk unless the utility can catch them before the HDD's defect management system does, or the backup sectors held in reserve by the internal HDD defect management system run out. A cyclical repetitive pattern of seek activity such as rapid or slower seek-to-end noises can be indicative of HDD problems.

An overall FA process must hold responsibility to provide an effective system for cataloguing, tracking and data collection required for failure analysis. Such analysis is performed on all failed drives received.

The FA can be distributed in four levels [8], first level (Electrical Analysis or Isolation) means error definition is chargeable or non-chargeable, this important issue is given first priority. Second level (Electrical Analysis or Identify symptom) means a symptom and possible root cause identification. Next level (Mechanical Analysis) means a root cause identification into component parts related to a failure symptom. And final level (Component Analysis) means a root cause identification of material and a major component (Head, Disk and PCBA). All levels are combined into one issue; time used in throughout all analysis is long. Most of the time is lost in the analysis done in DOS command (In first analyze, it will interface between drive and tools with DOS command). Thus, we develop a tool to shorten this time duration,it will help to reduce the time in half of all processes. This is described detailed in the next section.

V. THE FA SOFTWARE TOOL

The primary objective of this tool is reducing the time for analysis. It can help speed the initial drive's information retrieval rather quickly. Flowchart of this tool is shown in Fig. 6.First, retrieve the basic drive's information in order to seek for the failed positions. After that, analyze at that position. We find the root cause of failure at this position. If no cause is apparent, we re-analyze around the failed position initially retrieved for data. Finally, if enough data is attained, summarize to report the root failure cause. All steps (from flowchart) is the general concept or basic FA form. Practical (real operation) usage has much more detailed specifics, which are not further explained here in this paper.

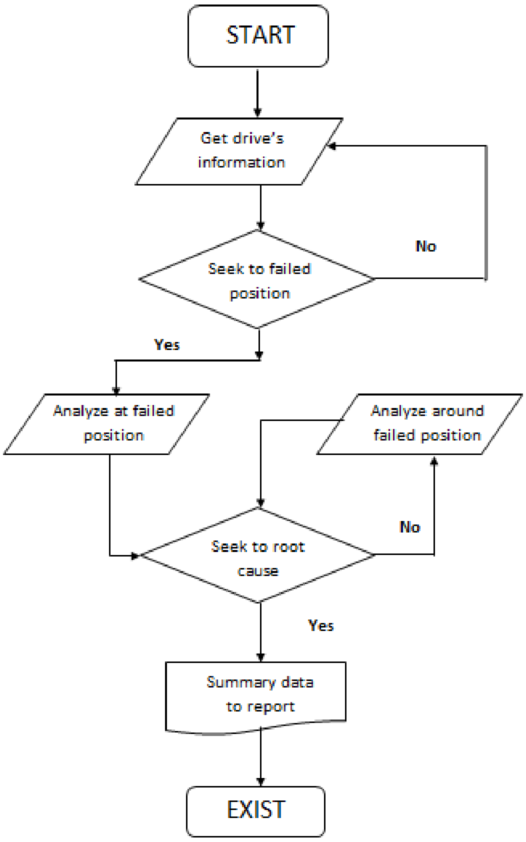
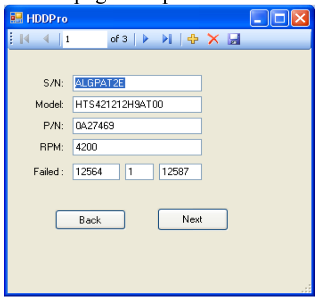


Fig. 6 The flowchart of the FA software tool

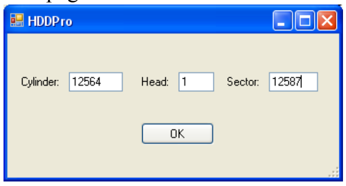
VI. THE PROCEDURE'S GUIDE

The general user can use this tool by the following guide: First, Open the software "HDD Pro", At first page see insert block "Please input HDD serial number". You can type the serial number of HDD product and press "OK" (see Fig. 7 (a)). If input serial number is incorrect, the message "Not found" will be shown. Please input the correct serial number. Next, the detail of this product will be shown. "Serial number", "Model", "Product number", "RPM", and "Failed Position" (see Fig. 7 (b)).Now, we know the failed position. Input that (cylinder-head-sector) into theblock and press "OK" (see Fig. 7 (c)). It will show the failed position (red-failed) as bit flip, the table form of data in HDD (see Fig. 7 (d)). And the last page, will show waveform and some additional data (see Fig. 7 (e)). Notice:This software is a referencemodel to a future product. It cannot provide all information of drive, due to confidentiality.

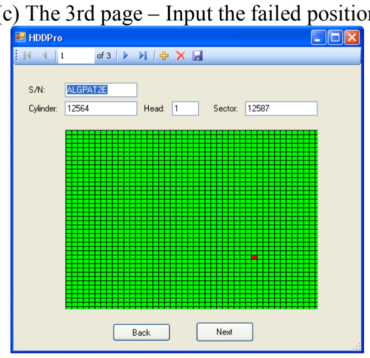
(a) The 1st page. – Input serial number.



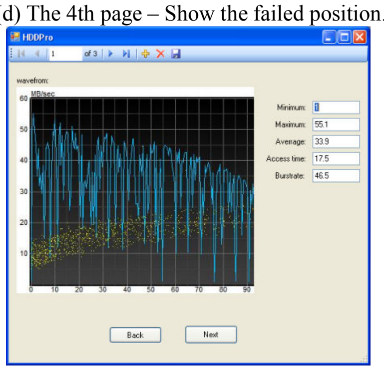
(b) The 2nd page– Show the basic drive's information.



(c) The 3rd page – Input the failed position



(d) The 4th page – Show the failed position.



(e) The 5th page of HDD Pro. – Show the performance waveform

Fig. 7 The procedure's guide of the software tool

VII. Conclusion

This software tool is a model based on the assumption that FA operating and usage time support in the FA works. It can be used to help analyze the basic problems of the HDD in operating systems effectively and accurately. It can reduce the time to analyze problems from retrieved drive information and other useful data in the FA operation. In the future, FA can utilize usage of this tool ranging from very basic analyzes to more advanced usage.

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