

HEAD CLEANING BY LOADING HEADS AT LOW SPEED

BACKGROUND

Field of the Invention

The present invention relates to a data storage device having read/write
5 heads for accessing information on a storage medium and, more particularly, to cleaning
the heads by loading them onto the disk surface which is rotating at a low speed below
that at which the heads have pseudo contact.

Description of the Prior Art

Periodically, magnetic heads must be cleaned to prevent head degradation
10 due to contamination build-up on the surfaces of the heads. See "Head Load/Unload And
Cleaning In A Data Storage Device," Serial No. 08/324,895 filed October 18, 1994
(Attorney's Docket No. IOM-8771).

Recently, disk drives have been developed using hard disk technology.
"Velocity Control for a Disk Drive Actuator," Serial No. 08/517,836, filed August 22,
15 1995 (Attorney's Docket No. IOM-8782), which is incorporated herein by reference, and
related applications, show disk drives with a removable cartridge having a hard disk and
a type of head suspension referred to as "Winchester". The high performance of the hard
disk technology depends on a very clean interface between the head and the disk. Debris
may build up at the leading edge of the slider and may even cover up the gap. There is
20 intimate contact between the head and disk, sometimes referred to as pseudo-contact. In
order to maintain this critical pseudo-contact between head and disk, it is important that
the heads be clean.

- 2 -

The normal operating speed for the spinning disk is about 5600 rpm. At about 1900 rpm, the heads start to lift away from the disk surface. The head/disk interface pressure decreases as the speed increases.

Data storage devices, and in particular, data storage devices of the type that accept a removable cartridge containing a disk-shaped storage medium, usually employ either a linear actuator mechanism or a rotary arm actuator mechanism for positioning the read/write heads of the disk drive over successive tracks of the disk-shaped storage medium. In most disk drives, and particularly in those that receive removable disk cartridges, the linear or rotary arm actuators are moved to a retracted, or parked position when the disk drive is not in use. In such a retracted position, the read/write heads of the disk drive are removed off and away from the surface(s) of the storage medium in order to prevent damage to the head(s) and storage medium. In order to resume use of the disk drive, the read/write heads must once again be loaded onto the surface(s) of the storage medium so that the data transfer can begin. It is important that the head loading operations can be carried out in a controlled manner to prevent damage to the read/write heads.

It is an object of the present invention to perform routine head cleaning by loading the heads onto a storage disk which is turning at a low speed.

It is another object of the invention to periodically perform a more thorough cleaning cycle which is manually initiated.

Summary of the Invention

In accordance with the present invention, head cleaning is accomplished by rotating the disk at low speeds, below the operating rotational speed of the disk. At low speed, increased force between the head and disk is obtained. This cleans the heads.

In accordance with one aspect of the invention, the heads are routinely cleaned by loading them onto a slowly spinning data storage disk. As soon as the disk is detected to be spinning, the heads are loaded onto the disk. The disk speed is in the range of 400 rpm, well below the take-off speed. This causes intermittent contact between the head surface and the disk causing abrasion which keeps the head surface clean.

In accordance with another aspect of the invention, a more thorough cleaning operation is started manually. The eject button on the front of the disk drive is

- 3 -

pressed by the operator for longer than a specified period, for example, five seconds. This causes the disk drive to enter a cleaning mode. The LED indicator on the front of the disk drive flashes. This signals the operator to insert a cleaning cartridge. The cartridge contains disks which are mildly abrasive to the heads. The cleaning cartridge
5 is detected by the disk drive by the absence of a retroreflective marker which normally identifies the cartridge as one having information recorded thereon. For example, cartridges which have retroreflective markers thereon are suitable for use with the disk drive. In a cleaning mode, if the cartridge does not have such a marker, the heads are loaded by the disk drive while the disk is spinning at a low speed. As the disk starts to
10 spin, a low frequency is applied to the voice coil of the actuator to move the heads in a rapid radial motion on the disk surface. The disk is spun up to operating speed and then the low frequency is turned off. This cleaning cycle is repeated a number of times, for example, five times and then the cleaning cartridge is ejected.

The foregoing and other objects, features and advantages of the invention
15 will be better understood from the following more detailed description and appended claims.

Brief Description of the Drawings

Figure 1 is a flowchart depicting operation of the control systems in the performance of cleaning;

20 Figure 2 is a perspective view of a data storage device, or disk drive, in which the present invention may be employed;

Figure 2A is a perspective view of a portion of the disk drive of Figure 2 showing the mounting of an optical sensor and a gray scale pattern to produce a signal representing the position and velocity of the actuator;

25 Figure 2B shows the cartridge;

Figure 3 is a block diagram of control systems for controlling the position and velocity of the actuator, for controlling capstan speed and for controlling other operations in the cleaning cycle;

30 Figure 4 shows various positions of the suspension arms of the actuator during a head loading operation;

- 4 -

Figure 5 is a flowchart illustrating a method of controlling the velocity of the actuator of Figure 1 during the head loading operation; and

Figure 6 is a flowchart depicting operation of the control systems in a manually initiated cleaning operation.

5 Description of the Preferred Embodiment

Figure 1 is a flow sheet depicting the operation of the actuator control system and the capstan motor control system in performing the routine head cleaning operation of the present invention. As indicated at 10, the microprocessor 82 (Fig. 3) starts the rotation of the disk at a slow speed. A determination is made at 11 as to whether the disk is spinning. About 600 rpm is preferred. It is preferred to load the head onto a slowly spinning disk to prevent ringing. With presently used disks, if the head is loaded onto a stationary disk, ringing may cause the head to lock onto the disk.

If it is spinning, the Disk Spinning Signal applied to microprocessor 82 starts the head loading operation as indicated at 12. This loads the heads onto the slowly spinning disk. A determination is made as to whether the head is on the disk as indicated at 13. When this has been accomplished, a "Head On Disk Signal" from microprocessor 82 is applied to microprocessor 82. In response, microprocessor 82 controls spindle motor 29 to spin up to operating speed as indicated at 14. In this manner, the disk is rotated at a low speed with the heads in intermittent contact with the disk. This removes contamination build-up on the head surface thereby preventing head degradation. The take-off velocity is about 1900 rpm. Below that speed, the intermittent contact causes cleaning. Before describing the manually initiated head cleaning operation, the disk drive and its control systems will be described.

As shown in Figure 2, the disk drive 20 comprises a chassis 21 on which a number of disk drive components are mounted. A front panel 24 of the disk drive 20 has a substantially horizontal opening 22 for receiving a removable disk cartridge. An LED 27 indicates status of the drive. An eject button 26 is provided on the front panel for ejecting a disk cartridge from the disk drive 20. A spindle motor 29 is mounted on the chassis 21 to provide a means for rotating the storage media within a disk cartridge.

An actuator arm 32, which forms part of a rotary arm voice coil actuator, is pivotally mounted to the drive chassis 21 at 38. The actuator arm 32 has a plurality of

- 5 -

suspension arms 34 at its distal end that each carry a respective read/write head 36 for recording and reading information to and from the surfaces of the storage media of a disk cartridge. A head loading mechanism 35 facilitates loading of the magnetic heads onto the storage media. The head loading mechanism comprises a pair of load ramp structures 5 46, 48 upon which the suspension arms 34 of the actuator arm 32 ride during head loading/unloading operations. Further details concerning a head loading mechanism of the type shown at 35 can be found in co-pending, commonly assigned, U.S. Patent Application No. 08/438,254, entitled "Head Loading Mechanism for a Disk Drive," filed May 10, 1995 (Attorney's Docket No. IOM-8781), which is incorporated herein by
10 reference in its entirety.

Figure 2A is a perspective view of a portion of the disk drive 20 of Figure 2, illustrating the mounting of an optical sensor 54 and gray-scale pattern 52. Gray-scale pattern 52 is attached to the lower surface of the voice coil 42. The voice coil 42 is mounted to a forked member at the end of the actuator arm 32. The optical sensor 54 is
15 rigidly mounted to a surface of the disk drive 20 below the voice coil 42. An upper surface of the optical sensor 54 is disposed in facing relation to the gray-scale pattern 52.

Figure 2B is a perspective view of a disk cartridge 10 that may be used with the removable cartridge disk drive 20 of Figure 2. The disk cartridge 10 comprises an outer casing consisting of upper and lower shells 10a, 10b, respectively. In accordance
20 with the present invention, the disk cartridge 10 contains two disk-shaped mediums 60, 62 that are attached, in stacked relation, to a hub assembly rotatably mounted within the outer casing. In accordance with one aspect of the invention, the cartridge contains cleaning disks. The cleaning medium is mildly abrasive to the head.

A retroreflective marker 11 normally identifies the cartridge as being the
25 correct cartridge for the drive. See "Retroreflective Marker For Data Storage Cartridges," Serial No. 08/388,242 filed February 14, 1995 (Attorney's Docket No. IOM-8779), which is incorporated herein by reference. In accordance with the present invention, the absence of a retroreflective marker identifies the cartridge as being a cleaning cartridge.

A door 12 on the casing provides access to the recording disks by the
30 read/write heads of a disk drive. When the disk cartridge 10 is inserted into the disk drive 20, the actuator arm 32 will rotate counter-clockwise (as viewed in Fig. 2) causing the

- 6 -

suspension arms 34 of the actuator to move off the load ramp structures 46, 48, thereby loading the read/write heads 36 onto the disk surfaces within the cartridge 10.

Figure 3 is a block diagram of closed-loop control systems for control of the actuator and spindle motor during the cleaning cycle. In the manually initiated
5 cleaning cycle, the depression of the eject button 26 is detected by microprocessor 82. If the eject button is held for longer than five seconds, microprocessor 82 intermittently flashes the LED 27 and a cleaning cycle is entered.

The spindle motor 29 has a control system which includes power amplifier 63 and digital analog converter 65 which is in turn controlled by the microprocessor 82.
10 The engagement of the spindle motor 29 with the cartridge is more fully described in "Disk Drive Having An Automatic Spindle Motor Loading Mechanism," Serial No. 08/438,255 filed May 10, 1995 (Attorney's Docket No. IOM-8772), which is incorporated herein by reference.

Marker detection circuitry 67 detects whether a retroreflective marker 11
15 is present on the cartridge. The marker detection circuitry is fully disclosed in "Retroreflective Marker For Data Storage Cartridge," Serial No. 08/388,242 filed February 14, 1995 (Attorney's Docket No. IOM-8779).

The actuator control system comprises the low-pass filter 78 and microprocessor 82. The low-pass filter 78 conditions the output of the optical sensor 54
20 for input to the integrated analog-to-digital converter 84 of the microprocessor 82. The position signal is sampled at a predetermined rate and then processed in accordance with a selected velocity control algorithm implemented by the microprocessor 82. The microprocessor 82 outputs a control signal, which in the present embodiment may take the form of a series of discrete pulses, to a pulse-width modulation digital-to-analog converter
25 (PWMDAC) 88 via line 86. The PWMDAC 88 converts the pulses of the control signal into an analog control signal and provides the analog control signal to an amplifier 92 via line 90. The amplified control signal drives the voice-coil motor of the disk drive via line 94.

When the heads are loaded onto the cleaning disk, a low-frequency source
30 89 is turned on by microprocessor 82. Low-frequency source 89 causes the heads to vibrate in a radial direction at a frequency of about 175 to 200 hertz.

- 7 -

Figure 4 illustrates various positions of the suspension arms 34 of the actuator arm 32 as they move over the surface of the load ramp structures 46, 48 during a head loading operation. As shown, the suspension arms move along the load ramp structures 46, 48 from "Position 1", through "Position 2" to "Position 3". At "Position 3", the suspension arms 34 begin to move down the respective ramped surfaces of the load ramp structures 46, 48. As the suspension arms 34 move down the ramped surfaces of the load ramp structures 46, 48, the read/write heads 36 (not shown) at the distal ends of the respective suspension arms 34 move toward the respective surfaces of the storage media 60 and 62. When the suspension arms 34 reach "Position 4", the read/write heads 36 are fully loaded onto the surfaces of the media 60, 62. The term "loading" means to bring the read/write heads of the disk drive into normal operating position with respect to the surfaces of the storage media.

Figure 5 illustrates the operation of the actuator control system of Figure 3 during the head loading sequence illustrated in Figure 4. As a head loading operation is initiated, microprocessor control passes to step 64 where the microprocessor samples the position signal received from the optical sensor 54 to determine the position of the actuator arm, and hence, the suspension arms 34. If the suspension arms are determined to be between "Position 1" and "Position 2", control passes to step 66 where the microprocessor 82 begins processing the incoming samples of the position signal in accordance with a first velocity control algorithm. The first velocity control algorithm is described in greater detail in the aforementioned application (IOM-8782), referred to therein as the "initial push control."

As the suspension arms 34 move past position 2, control passes to step 68 where the microprocessor switches to a second velocity control algorithm that, in the preferred embodiment, comprises a closed loop velocity PID compensation and a nonlinear braking control.

Once the suspension arms 34 reach "Position 4", the head loading operation is complete, and control passes to step 72 where the microprocessor initiates acquisition of the servo track information on the surfaces of the media 60, 62.

The operation of the disk drive in performing a manually initiated, periodic head cleaning operation of the present invention is depicted in Figure 6. Microprocessor 82 detects whether the eject button 26 (Figure 2) has been held for more than 5 seconds

- 8 -

as indicated at 101 in Figure 1. If the eject button has been held for more than 5 seconds, the LED 27 is caused to flash intermittently, indicated by the step 102 in Figure 1.

Cartridge insertion is detected as indicated at 103. If a cartridge has been inserted, a determination is made as to whether the cartridge has a retroreflective marker.

5 This determination is indicated at 104 in Figure 1. If the cartridge has a retroreflective marker, it is ejected as indicated at 105. Then, the same head cleaning operation of Fig. 1 is performed. The disks are rotated as indicated at 10 and a determination is made as to whether the disks are spinning as indicated at 11. At very low speeds, the heads are loaded onto the disk with a high force between the heads and the disks.

10 As indicated at 12, the heads are loaded. A determination is made as to whether the heads are on the disk, as indicated at 13. The heads are moved to the ID, the extreme inner most usable diameter of the disk, indicated by the step 106. Then, the low frequency source 89 is energized to induce a low frequency motion of the heads as they engage the disks. The performance of this step is indicated at 108. The disks are spun
15 up to operating speed as indicated at 14. As the speed increases, the force decreases. In the disk drive under consideration, speeds at about 600 rpm apply enough force for cleaning. The disks are spun up to a speed of about 5600 rpm which is the speed for reading and writing data.

Then, the high frequency source 89 is turned off as indicated by the step
20 110. The spindle motor is turned off to bring the disks down to zero rpm as indicated at 111. This head cleaning cycle is repeated five times as indicated at 112. Then, the cleaning cartridge is ejected as indicated at 113.

While a particular embodiment of the invention has been shown and described, modifications may be made. The head may be loaded with the disk stationary
25 if the disk surface is appropriate. The disk is rotated at a low speed to clean the heads. Or, the head may be loaded at any speed below take-off speed.

The following claims cover all such modifications within the true spirit and scope of the invention.

**It is claimed:**

1. A data storage device for reading and writing information to and from a rotatable medium, said data storage device having an actuator for moving a read-write head over a surface of a rotating medium and a motor for rotating said medium, said
5 storage device further comprising:
an actuator control system for controlling the loading and unloading of said head on said surface;
a motor control system for controlling the speed of rotation of said
medium; and
10 microprocessor means for loading said head onto said surface and rotating said medium at a low speed below take-off speed so that said head contacts said medium with a force which cleans said heads.
2. The data storage device recited in claim 1 wherein said
15 microprocessor further comprises:
means for rotating said disk before loading said head onto said surface.
3. The data storage device recited in claim 1 further comprising:
means for manually initiating a cleaning cycle.
- 20 4. The data storage device recited in claim 3 further comprising:
a cleaning cartridge having a rotatable medium with a surface which is mildly abrasive to said head.
5. The data storage device recited in claim 4 further comprising:
means for detecting insertion of said cleaning cartridge.
- 25 6. The data storage device recited in claim 5 further comprising:
means for distinguishing said cleaning cartridge from a data storage cartridge by the presence or absence of a marker.





7. The data storage device recited in claim 6 further comprising:
means in said storage device for detecting the absence of said
marker; and
means to eject said cartridge if said marker is present.
- 5 8. The data storage device recited in claim 7 further comprising:
means for applying a low frequency to said actuator to vibrate said
heads radially when they are engaged with said medium.
9. The data storage device recited in claim 8 further comprising:
means for rotating said data storage medium up to a speed at which
10 said heads have decreased force of engagement with said storage medium.
10. The data storage device recited in claim 9 further comprising:
means for repeating said cleaning cycle a plurality of times.
11. The data storage device recited in claim 1 wherein said
microprocessor means thereafter rotates said medium at a higher speed at which said head
15 has pseudo contact with said surface of said storage medium.
12. The data storage device recited in claim 1 further comprising:
means producing a position signal indicating the position of said
actuator with respect to said surface of said storage medium;
said actuator control system being responsive to said position signal
20 for controlling the loading and unloading of said head on said surface.



AMENDED CLAIMS

[received by the International Bureau on 24 March 1997 (24.03.97);
original claims 1 and 8 amended; remaining claims unchanged (2 pages)]

1. A data storage device for reading and writing information to and
from a rotatable medium, said data storage device having an actuator for moving a read-
write head over a surface of a rotating medium and a motor for rotating said medium, said
5 storage device further comprising:
an actuator control system for controlling the loading and unloading
of said head on said surface;
a motor control system for controlling the speed of rotation of said
medium; and
10 a microprocessor having:
means for controlling said actuator control system to load said head
on to said surface means for controlling said motor control system so that said head is
loaded onto said medium at a speed below take-off speed so that said head contacts said
medium with a force which cleans said heads.; and
15 means for thereafter increasing said speed to the operating speed for
reading and writing information to and from said medium.
2. The data storage device recited in claim 1 wherein said
20 microprocessor further comprises:
means for rotating said disk before loading said head onto said
surface.
3. The data storage device recited in claim 1 further comprising:
means for manually initiating a cleaning cycle.
- 25 4. The data storage device recited in claim 3 further comprising:
a cleaning cartridge having a rotatable medium with a surface which
is mildly abrasive to said head.
5. The data storage device recited in claim 4 further comprising:
means for detecting insertion of said cleaning cartridge.



* C L M S *

- 12 -

6. The data storage device recited in claim 5 further comprising:
means for distinguishing said cleaning cartridge from a data storage
cartridge by the presence or absence of a marker.
7. The data storage device recited in claim 6 further comprising:
5 means in said storage device for detecting the absence of said
marker; and
means to eject said cartridge if said marker is present.
8. The data storage device recited in claim 7 further comprising:
means for applying a low frequency to said actuator to vibrate said
10 head radially when engaged with said medium.
9. The data storage device recited in claim 8 further comprising:
means for rotating said data storage medium up to a speed at which
said heads have decreased force of engagement with said storage medium.
10. The data storage device recited in claim 9 further comprising:
15 means for repeating said cleaning cycle a plurality of times.
11. The data storage device recited in claim 1 wherein said
microprocessor means thereafter rotates said medium at a higher speed at which said head
has pseudo contact with said surface of said storage medium.
12. The data storage device recited in claim 1 further comprising:
20 means producing a position signal indicating the position of said
actuator with respect to said surface of said storage medium;
said actuator control system being responsive to said position signal
for controlling the loading and unloading of said head on said surface.

