DESCRIPTION

Magnetic disk drive, position controlling method of magnetic heads and recorded medium storing program of the method

TECHNICAL FIELD

The present invention relates to a magnetic disk drive and method for restoring a magnetic head brought into the off-track state by vibration or shock back to the on-track state.

BACKGROUND ART

In a magnetic disk drive, a magnetic head floats on a rotating magnetic disk, and reads or writes data. In this instance, the position of the magnetic head is controlled using magnetic head servo information (referred as servo information, below) which is recorded on the magnetic disk.

When the magnetic head has received from the outside vibration or shock exceeding a predetermined level to cause getting out of a track which data is to be written on or read from, the magnetic head is restored onto the original track by a control based on the servo information. The above-mentioned vibration or shock of the predetermined level to be treated in the present invention is not such strong one that, for example, the magnetic head collides with the magnetic

disk surface; but is assumed relatively mild one which occurs in the magnetic disk drive under normal use. In the present invention, "being in the on-track state" indicates that the magnetic head locates on the track which data is to be written into or read from, and "being in the off-track state" indicates that the magnetic head is out of the on-track state.

Specifically, a magnetic head brought into the off-track state is restored to the on-track state by the following procedure. When the servo information is not continuously detected, it is checked whether the magnetic disk drive has received vibration or shock exceeding a predetermined threshold from the outside. If the reception of such vibration or shock is found, it is concluded that the action of detecting the servo information is not being conducted in synchronization with the servo information or that the magnetic head has been moved onto an area without recorded servo information. In such case, the action of detecting the servo information is synchronized with the servo information. When it is detected that the servo information, the magnetic head is restored into the on-track state.

If the magnetic head is brought into an off-track state during the data write, the data write action is promptly stopped. Accordingly, the magnetic head in the off-track state is prevented from writing the data into the area not to be written. As such, the magnetic head in the off-

track state does not destroy the existing data on the magnetic disk.

Recently, track density is remarkably increasing for the purpose of increasing capacity of magnetic disks. That is, track pitch is remarkably narrowing. Besides, the amount of floating of magnetic heads is being reduced in order to improve the sensitivity of the magnetic heads. As a result, the magnetic heads are easily brought into the off-track state by slight vibration or shock from the outside. In particular, there is an increasing risk that the magnetic heads are brought into the off-track state during the data write, thereby destroying or failing to write the data on the disks.

To prevent such destruction or failing to write, a prior art large-capacity magnetic disk drive has the on-track range (a narrow area on the magnetic disk such that the magnetic head is assumed to be in the on-track state when the magnetic head is within the range) being set at a sufficient small. In addition, the threshold of vibration or shock detected by the shock sensor is set at a sufficient small. Therefore, with increasing capacity of the magnetic disk drive, the magnetic head stops to write at the case of occurrence of slight off-track state and for slight vibration or shock. In this way, the large-capacity magnetic disk drive prevents the magnetic head in the off-track state from destroying or failing to write the data on the magnetic disk.

However, the above-mentioned procedure to restore the magnetic head in the off-track state into the on-track state has generally required a time of a few seconds. The magnetic head can neither write nor read data during the period. Furthermore, in the large-capacity magnetic disk drive, the magnetic head frequently is brought into the off-track state. In such a magnetic disk drive, data reproduction is frequently discontinuous and the stop time of each reproduction is generally long. Therefore, in the reproduction of audio-video information by a prior art magnetic disk drive, there has been a large problem that the interruption is frequently experienced in the reproduced sounds or reproduced video.

On the other hand, under requirement of the enlargement in capacity and miniaturization of magnetic disk drives, it is difficult to suppress the vibration or shock from the outside to such a degree that the magnetic head is not substantially brought into the off-track state,.

In order to solve this problem, an object of the present invention is to shorten the time required to restore the magnetic head brought into the off-track state due to vibration or shock, back into the on-track state.

DISCLOSURE OF INVENTION

A magnetic disk drive in accordance with the present invention comprises:

a magnetic disk;

a magnetic head for writing and/or reading data on said magnetic disk;

a read/write circuit for controlling the write and/or read of data by said magnetic head;

an actuator for supporting said magnetic head;

an actuator drive for driving said actuator and moving said magnetic head to a predetermined position;

a magnetic head position detector for

a) detecting servo information read from said magnetic disk by said magnetic head,

b) calculating detected position information on the basis of said servo information when there is no fault in the detection of said servo information, and

c) outputting a servo information detecting fault signal when there is a fault in the detection of said servo information;

a shock sensor for detecting and measuring vibration or shock from the outside;

a vibration-shock detector for detecting that the degree of said vibration or shock exceeds a predetermined threshold, on the basis of the signal of vibration or shock from said shock sensor, and outputting an vibration-shock detection signal; and

a calculator of control value, comprising

A) an observer for estimating position-velocity

information of said magnetic head and

B) a selector for selecting either

a) normal position-velocity information from said magnetic head position detector or

b) estimated position-velocity information from said observer,

on the basis of said vibration-shock detection signal and said servo information detecting fault signal,

and for adopting the information selected by said selector as magnetic head position-velocity information and calculating a control value of said actuator on the basis of the information.

According to this configuration, the magnetic head position is controlled based on the estimated position-velocity information from the observer when there is a fault in the detection of said servo information. Accordingly, the restoration time of the magnetic head from the off-track state can be shortened.

In addition to the above-mentioned configuration of the magnetic disk drive according to the present invention, preferably

said observer may calculate an estimating error from said estimated position-velocity information and said detected position information; and

said selector may select said estimated position-velocity information as said magnetic head position-velocity

information when there is a fault in the detection of said servo information, or when the degree of said vibration or shock exceeds said threshold and the degree of said estimating error exceeds a predetermined threshold.

When the magnetic head position information can be detected but that the detected position information is probably a fault due to vibration or shock, the magnetic head position is controlled on the basis of the estimated position-velocity information from the observer instead of the detected position information. Accordingly, more reliable magnetic head position information is obtained, and hence, the magnetic head is restored more rapidly from the off-track state.

A position controlling method of magnetic heads in a magnetic disk drive according to the present invention comprises steps of:

detecting, with a shock sensor, that the degree of vibration or shock from the outside exceeds a predetermined threshold;

detecting servo information read by the magnetic head, checking a detection error in said servo information and calculating detected position information of said magnetic head;

calculating a control value for controlling an actuator driving necessary for moving said magnetic head to a predetermined position, comprising substeps of

a) estimating position-velocity information of said magnetic head by an observer and

b) selecting estimated position-velocity information from said observer when the degree of said vibration or shock exceeds said threshold, or there is a fault in the detection of said servo information; and

driving said actuator depending on said control value and moving said magnetic head to a predetermined position.

According to the position controlling method of magnetic heads of the present invention, the magnetic head position is controlled on the basis of the estimated position-velocity information from the observer when there is a fault in the detection of magnetic head position information. Accordingly, the restoration time of the magnetic head from the off-track state is shortened.

In addition to the above-mentioned steps, a position controlling method of magnetic heads according to the present invention may comprise steps of:

calculating an estimating error from said estimated position-velocity information and said detected position information by said observer; and

selecting said estimated position-velocity information when there is a fault in the detection of said servo information, or when the degree of said vibration or shock exceeds said threshold and said estimating error exceeds a predetermined threshold.

When the magnetic head position information can be detected and while the estimating error is large, that is, the detected position information is probably a fault due to vibration or shock, the magnetic head position is controlled on the basis of the estimated position-velocity information from the observer instead of the detected position information. Accordingly, more reliable magnetic head position information is obtained, and hence, the magnetic head can be restored more rapidly from the off-track state.

A position controlling program of magnetic heads according to the present invention comprises:

detecting, with a shock sensor, that the degree of vibration or shock from the outside exceeds a predetermined threshold;

detecting the servo information read by the magnetic head, checking a detection error in said servo information and calculating detected position information of said magnetic head;

calculating a control value for controlling an actuator driving necessary for moving said magnetic head to a predetermined position, comprising

a) by an observer estimating position-velocity information of said magnetic head, and

b) selecting said estimated position-velocity information from said observer when the degree of said vibration or shock exceeds said threshold, or there is a

fault in the detection of said servo information; and

driving said actuator depending on said control value and moving said magnetic head to a predetermined position.

The magnetic head position can be controlled on the basis of the estimated position-velocity information from the observer when there is a fault in the detection of magnetic head position information. Accordingly, the restoration time of the magnetic head from the off-track state can be shortened.

In addition to the above-mentioned procedure, a position controlling program of magnetic heads according to the present invention may comprise:

calculating an estimating error from said estimated position-velocity information and said detected position information by said observer; and

selecting said estimated position-velocity information when there is no fault in the detection of said servo information, or when the degree of said vibration or shock exceeds said threshold and said estimating error exceeds a predetermined threshold.

When the magnetic head position information can be detected and while the estimating error is large, that is, the detected position information is probably a fault due to vibration or shock, the magnetic head position is controlled on the basis of the estimated position-velocity information from the observer instead of the detected position

information. Accordingly, more reliable magnetic head position information is obtained, and hence, the magnetic head can be restored more rapidly from the off-track state.

Furthermore, the above-mentioned position controlling program of magnetic heads according to the present invention may be stored in the executable form on a recorded medium and the position controlling method of magnetic heads according to the present invention may be implemented in a prior art magnetic disk drive using a computer in which the recorded medium is incorporated.

While the novel features of the invention are set forth particularly in the appended claims, the invention, both as to organization and content, will be better understood and appreciated, along with other objects and features thereof, from the following detailed description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a block diagram of a calculator of control value 20 in an embodiment of the present invention;

FIG. 2 is a block diagram showing the hardware of a magnetic disk drive of an embodiment of the present invention;

FIG. 3 is a drawing showing the format of a track T and a recorded area of servo information 30 on the magnetic disk 22; Section (a) shows the ranges of the track T and the

recorded area of servo information 30 recorded on the magnetic disk 22; Section (b) is an enlarged view showing the format of the tracks T0--T3 and the recorded area of servo information 30 within the region encircled by the ellipse shown in Section (a);

FIG. 4 is a block diagram of an observer 16 in an embodiment of the present invention;

FIG. 5 is a block diagram of a vibration-shock detector 11 in an embodiment of the present invention;

FIG. 6 is a block diagram of a selector 15 in an embodiment of the present invention;

FIG. 7 is a table showing the signals which the selector 15 in an embodiment of the present invention selects respectively as the position-velocity information for the calculation of control value 108 and the position-velocity information for the observer 109, depending on e"or fals e" output of each of the vibration-shock detection signal 101, servo information detecting fault signal 103 and estimating error 106;

FIG. 8 is a flow chart of the vibration-shock detection process S0 in an embodiment of the present invention;

FIG. 9A is a flow chart showing Step S1 to Step S3 of the position control process of the magnetic head 23 in an embodiment of the present invention; and

FIG. 9B is a flow chart showing Step S4 to Step S8 of

the position control process of the magnetic head 23 in an embodiment of the present invention.

It will be recognized that some or all of the Figures are schematic representations for purposes of illustration and do not necessarily depict the actual relative sizes or locations of the elements shown.

BEST MODE FOR CARRYING OUT THE INVENTION

A preferred embodiment of the present invention is described with reference to FIG. 1 to FIG. 8.

FIG. 2 is a block diagram of the hardware of a magnetic disk drive of an embodiment of the present invention.

A spindle motor drive 26 supplies driving electric current to a spindle motor 25. The spindle motor 25 supplied with the electric current rotates a magnetic disk 22 at a predetermined revolution speed.

An actuator 13 supports a magnetic head 23 in the tip portion of an arm 13a. The arm 13a is driven by an electric motor for driving the actuator 24, and moves the magnetic head 23 onto a predetermined track (not shown) recorded on a magnetic disk 22.

The magnetic head 23 writes or reads data into or from the predetermined track.

The electric motor for driving the actuator 24 is, for example, a voice coil motor.

A read/write (R/W) circuit 21 controls writing and

reading conducted by the magnetic head 23 on the magnetic disk 22. Then the servo information 104 contained in the data read by the magnetic head 23 from the magnetic disk 22 is sent to a magnetic head position detector 14.

The magnetic head position detector 14 detects the servo information 104 in the data input from the R/W circuit 21 and, on the basis thereof, calculates the position of the magnetic head 23. Then the calculated result is sent as the detected position information 105 of the magnetic head to a calculator of control value 20. In case that there is a fault in the above-mentioned detection of servo information 104, the magnetic head position detector 14 sends a servo information detecting fault signal 103 to the calculator of control value 20.

A shock sensor 10 measures the acceleration of vibration or shock which the magnetic disk drive receives from the outside, and sends a signal of vibration or shock 100 indicating the direction and the degree of acceleration to a vibration-shock detector 11.

The vibration-shock detector 11 sends a vibration-shock detection signal 101 to the calculator of control value 20 when the degree of vibration or shock shown in the signal of vibration or shock 100 exceeds a predetermined threshold. In case that the degree of vibration or shock exceeds another predetermined threshold different from the above-mentioned threshold, the vibration-shock detector 11 sends a write-

fault signal 102 to the R/W circuit 21.

The calculator of control value 20 calculates a control value 110 for the actuator 13 on the basis of the detected position information 105, servo information detecting fault signal 103 and vibration-shock detection signal 101. The calculated control value 110 is sent to the actuator drive 12.

The actuator drive 12 supplies the electric motor for driving the actuator 24 with the electric current corresponding to the control value 110.

FIG. 3 shows the format of a track T and a recorded area of servo information 30 recorded on the magnetic disk 22. As shown schematically in Section (a) of FIG. 3, a plurality of tracks T is concentrically recorded on the magnetic disk 22. The recorded areas of servo information 30 are recorded radially at predetermined spaces on the magnetic disk 22.

Section (b) of FIG. 3 is an enlarged view showing the format of the tracks T0--T3 and the recorded area of servo information 30 within the region encircled by the ellipse shown in Section (a). Each of the tracks T0--T3 has an identical width. The magnetic head 23 writes and/or reads the data on the area with a predetermined width set in the central part of the track. The area in which the magnetic head 23 writes and/or reads data is called an on-track area. In Section (b) of FIG. 3, the on-track areas c0, c1, c2 and c3 of the tracks T0, T1, T2 and T3 are respectively shown

with broken lines. The width of on-track area is set at approximately 10% of the track width.

The recorded area of servo information 30 consists of the following four areas 31--34.

The first area 31 of the recorded area of servo information 30 records a synchronization signal for synchronizing the read action by the magnetic head 23 (see FIG. 2) and the servo information 104 on the magnetic disk 22 (see FIG. 2). The recorded areas of servo information 30 exist periodically in the tangential direction on the magnetic disk 22 as shown Section (a) of FIG. 3. Therefore, when the magnetic disk 22 revolves at a constant speed, the servo information 104 is transmitted to the magnetic head 23 as a signal having a predetermined frequency. The magnetic head 23 repeats the read action in synchronization with the period of this signal.

The second area 32 records a servo mark signal. The servo mark signal is a mark signal for the purpose that the magnetic head position detector 14 detects the servo information 104 in the data read by the magnetic head 23. If the magnetic head position detector 14 can not identify the servo mark signal, it concludes that the detection result is fault

The third area 33 records a track number signal indicating the physical track position in which the detected servo information 104 has been recorded. Using the track

number signal, the track number closest to the magnetic head 23 position is detected.

The fourth area 34 records four kinds of burst signals A--D. These burst signals A--D are used for the purpose of detecting the degree of shift of the magnetic head 23 in the radial direction of the magnetic disk 22 relative to the center line of a predetermined track (for example, the center line c1 for the predetermined track t1).

The fourth area 34 further consists of four areas 34a, 34b, 34c and 34d. The areas 34a, 34b, 34c and 34d record the burst signals A, B, C and D, respectively. The burst signals A--D are respectively recorded periodically along the radial direction of the magnetic disk 22. Each of the periods is equal to the track width. The burst signals A--D are recorded only in the half of each period. However, the respective phases of the recorded areas 34d, 34a, 34c and 34b are shifted in this order by $\pi/2$ each. That is, when the burst signal D is recorded on the (2n-1)-th track (where n is an integer grater than unity) counted from the inside of the magnetic disk 22, the burst signal A centers on the boundary between the (2n-1)-th track and the 2n-th track; the burst signal C locates on the 2n-th track; and the burst signal B centers on the boundary between the 2n-th track and the (2n+1)-th track. As such, the burst signals A--D are recorded in shifted way with each other. Therefore, the relative intensities of the respective burst signals A--D

contained in the detected servo information 104 inform the degree of shift of the magnetic head 23 from the on-track area, when the servo information 104 is read.

FIG. 1 is a block diagram of the calculator of control value 20. The calculator of control value 20 consists of an observer 16, a selector 15, a matrix divider 17, a matrix coupler 18 and a feedback gain 19.

The observer 16 models the actuator drive 12 and the actuator 13. The observer 16 receives the inputs of the control value 100 calculated in the preceding step and of the position-velocity information 109 to be used by the observer (referred as position-velocity information for the observer, below), and estimates the position and velocity of the magnetic head 23 on the basis thereof. The position-velocity information obtained by the estimation is output as the estimated position-velocity information 107b to the selector 15. Note that the position-velocity information is the information containing position, velocity and bias of the magnetic head 23. The bias is a disturbance continuously exerted on the actuator 13 including, for example, the friction acting on the rotary shaft of the electric motor for driving the actuator 24. The observer 16 compares the magnetic head detected position information 105 from the magnetic head position detector 14 with the estimated position-velocity information 107b, and calculates an estimating error 106. Furthermore, the observer 16 modifies

the estimated position-velocity information 107b on the basis of the estimating error 106, and the modified result is output as the modified position-velocity information 107a to the selector 15 together with the estimating error 106.

If the magnetic head position detector 14 can not find the servo mark signals (FIG. 3) in the data output by the R/W circuit 21, that is, if there is a fault in the detection of servo information 104, the magnetic head position detector 14 outputs a servo information detecting fault signal 103 to the selector 15. The vibration-shock detector 11 outputs a vibration-shock detection signal 101 to the selector 15 in response with the signal of vibration or shock 100 from the shock sensor 10.

The selector 15 selects, as the output to the matrix divider 17, either the detected position information 105 or the estimated position-velocity information 107b, on the basis of the servo information detecting fault signal 103 and vibration-shock detection signal 101. At the same time, the selector 15 selects, as the output to the observer 16, either the estimated position-velocity information 107b or modified position-velocity information 107a. The information selected as the output to the matrix divider 17 is the position-velocity information 108 to be used in the calculation of control value 110 (referred as position-velocity information for the calculation of control value, below). On the other hand, the information selected as the output to the observer

16 is the position-velocity information for the observer 109 mentioned above.

The matrix divider 17 divides the position-velocity information for the calculation of control value 108, and forms the three elements of magnetic head velocity information 112a, bias information 112b and magnetic head position information 112d. Note that the magnetic head position information 112d is either the detected position information 105 or the position information estimated by the observer 16 (referred as estimated position information, below) depending on the selection by the selector 15. The magnetic head velocity information 112a and bias information 112b are output to the matrix coupler 18, and the magnetic head position information 112d is to an adder 17a.

Information of a control target position of the magnetic head 23 (referred as target information 113, below) is input from an external input (not shown; for example, a picture reproducer) to the adder 17a. The adder 17a calculates the difference between the target information 113 and the magnetic head position information 112d (detected position information 105 or estimated position information), and outputs it as position error 112c to the matrix coupler 18.

The matrix coupler 18 couples the three elements of magnetic head velocity information 112a, bias information 112b and position error 112c, and generates the position-

velocity final information 111. The position-velocity final information 111 multiplied by the feedback gain 19 yields the control value 110. The control value 110 is output to the observer 16 and the actuator drive 12.

FIG. 4 is a block diagram showing the configuration of the observer 16. The observer 16 consists of a system matrix 43, an input matrix 40, an output matrix 42, a 1-sampling lag element 41, an observer gain 44 and three adders 40a, 40b and 40c.

The control value 110 input to the observer 16 is multiplied by the input matrix 40, and then, is output to the adder 40a. On the other hand, the position-velocity information for the observer 109 from the selector 15 is multiplied by the system matrix 43, and then, is output to the adder 40a. The adder 40a calculates the sum of the two inputs, and outputs it as the position-velocity information 400 to be used in the next estimation step (referred as position-velocity next-sampling information). The estimated position-velocity information 107b is obtained by multiplying the 1-sampling lag element 41 by the position-velocity next-sampling information 400. The estimated position information 401 of the magnetic head is obtained by multiplying the estimated position-velocity information 107b by the output matrix 42. The adder 40b calculates the difference between the magnetic head detected position information 105 from the magnetic head position detector 14 and the estimated position

information 401, and outputs the estimating error 106. The estimating error 106 is multiplied by the observer gain 44, and then is input to the adder 40c, and is added to the estimated position-velocity information 107b. As a result, the adder 40c outputs the modified position-velocity information 107a.

FIG. 5 is a block diagram of the vibration-shock detector 11. The vibration-shock detector 11 consists of an amplifier circuit 50, a low-pass filter 51, a comparator 52 and a detecting element 53. The shock sensor 10 measures the acceleration right after the magnetic disk drive receives vibration or shock from the outside. The shock sensor 10 supplies the vibration-shock detector 11 with the signal of vibration or shock 100 corresponding to the acceleration. The signal of vibration or shock 100 includes three signal components 100a, 100b and 100c corresponding to the respective three directional components of vibration or shock, which are orthogonal to each other. In the embodiment of the present invention, the signal components 100a, 100b and 100c of the signal of vibration or shock 100 correspond to the components of the vibration or shock in the radial direction, tangential direction and normal direction of the magnetic disk 22, respectively. The signal components 100a, 100b and 100c of the signal of vibration or shock 100 are respectively amplified by the amplifier circuit 50 and the wave forms thereof undergo a shaping process by the low-pass filter 51.

The comparator 52 determines whether each of the signal components 100a, 100b and 100c output by the low-pass filter 51 exceeds a predetermined write-fault level. When the comparator 52 concludes that at least one of the signal components 100a, 100b and 100c exceeds the write-fault level mentioned above, the detecting element 53 outputs a write-fault signal 102 to the read/write circuit 21. In addition, if the signal component 100c of the signal of vibration or shock 100 exceeds a predetermined threshold or a level of undetectable servo information, the detecting element 53 outputs a vibration-shock detection signal 101 to the selector 15. If the vibration or shock exceeding the level of undetectable servo information occurs in the normal direction of the magnetic disk 22, it is concluded that the gap between the magnetic head 23 and the magnetic disk 22 does not permit normal reading of the servo information 104. In an embodiment, the level of undetectable servo information is, for example, set at approximately $100m/s^2$ for a conventional magnetic disk drive.

FIG. 6 is a block diagram of the selector 15. The selector 15 consists of a divider 60, a coupler 61 and a selecting section 62. Further, the selecting section 62 consists of a first selecting section 62a and a second selecting section 62b.

The modified position-velocity information 107a is input from the observer 16 to the divider 60 and the second

selecting section 62b. On the other hand, the estimated position-velocity information 107b is input from the observer 16 to the first selecting section 62a and the second selecting section 62b.

The second selecting section 62b selects, as the position-velocity information for the observer 109, either the modified position-velocity information 107a or the estimated position-velocity information 107b, on the basis of the vibration-shock detection signal 101, the servo information detecting fault signal 103 and the estimating error 106.

The divider 60 generates the three elements of magnetic head velocity information, bias information and magnetic head position information in a similar way of the matrix divider 17 (see FIG. 1) mentioned above. The magnetic head velocity information and the bias information within the three elements are output to the coupler 61.

The coupler 61 receives the input of the magnetic head detected position information 105 from the magnetic head position detector 14. The coupler 61 couples the magnetic head velocity information, the bias information and the magnetic head detected position information 105, and outputs it as normal position-velocity information 600 to the first selecting section 62a in a similar way of the matrix coupler 18 (see FIG. 1) mentioned above. As such, the normal position-velocity information 600 is equivalent to a modified

position-velocity information 107a having its magnetic head position information replaced with the magnetic head detected position information 105.

The first selecting section 62a selects, as the position-velocity information for the calculation of control value 108, either the normal position-velocity information 600 or the estimated position-velocity information 107b, on the basis of the vibration-shock detection signal 101, the servo information detecting fault signal 103 and the estimating error 106.

In the embodiment of the present invention having the above-mentioned configuration, the position of the magnetic head 23 is controlled as described below.

FIG. 8 is a flow chart showing a vibration-shock detection process S0 with the shock sensor 10 and the vibration-shock detector 11. The vibration-shock detection process S0 is repeated independently of the position controlling process S1--S8 of the magnetic heads 23 described later. When the magnetic disk drive of the present invention receives vibration or shock from the outside, the vibration and shock are detected by the shock sensor 10. The shock sensor 10 outputs signals of vibration or shock corresponding to the directions and the degree of the vibration or shock to the vibration-shock detector 11. When the signal of vibration or shock exceeds the level of undetectable servo information, the vibration-shock detector 11 outputs "true"

output of the vibration-shock detection signal, and otherwise, outputs "false" output.

FIG. 9A and FIG. 9B are flow charts showing the position controlling process of the magnetic head 23. The position controlling process of the magnetic head 23 is divided into Step S1 to Step S8 and described below with reference to FIG. 9A and FIG. 9B. FIG. 9A shows the process from Step S1 to Step S3 and FIG. 9B from Step S4 to Step S8.

《First step S1》 (FIG. 9A)

The magnetic head position detector 14 detects the servo information 104 in the data read by the magnetic head 23. When there is no fault in the detection, the magnetic head position detector 14 calculates the magnetic head detected position information 105 from the track number signal and the burst signals A, B, C and D contained in the servo information 104. At the same time, the magnetic head position detector 14 outputs false" output of the servo information detecting fault signal 103. In contrast, when there is a fault in the detection of servo information 104, the magnetic head position detector 14 outputs "true" output of the servo information detecting fault signal 103.

《Second step S2》 (FIG. 9A)

The observer 16 calculates the estimated position-velocity information 107b and the estimated position information 401, and especially in a substep of Step S2, the estimating error 106 from the position-velocity next-sampling

information 400 by the following Eq. (1), Eq. (2) and Eq. (3), respectively:

$$Xb = Xbb / z \quad (1)$$

$$Xb1 = Hx \times Xb \quad (2)$$

$$Xerr = y - Xb1 \quad (3)$$

where Xb is the estimated position-velocity information 107b, Xbb is the position-velocity next-sampling information 400, Xb1 is the estimated position information 401, Hx is the output matrix 42, Xerr is the estimating error 106, and y is the detected position information 105.

《Third step S3》 (FIG. 9A)

The observer calculates the modified position-velocity information 107a by the following Eq. (4):

$$Xh = Xb + Lc \times Xerr \quad (4)$$

where Xh is the modified position-velocity information 107a and Lc is the observer gain 44.

《Fourth step S4》 (FIG. 9B)

FIG. 7 is a table showing the signals which the selector 15 selects respectively as the position-velocity information for the calculation of control value 108 and the position-velocity information for the observer 109, depending on e" or e" output of each of the vibration-shock detection signal 101, the servo information detecting fault signal 103 and the estimating error 106. There are three cases, CASE 1) to CASE 3), in the selection by the selector 15 as shown in FIG. 7.

CASE 1) of FIG. 7: When both of the servo information detecting fault signal 103 and the vibration-shock detection signal 101 are "false", the first selecting section 62a selects the normal position-velocity information 600 as the position-velocity information for the calculation of control value 108. On the other hand, the second selecting section 62b selects the modified position-velocity information 107a as the position-velocity information for the observer 109.

CASE 2) of FIG. 7: When the servo information detecting fault signal 103 is "true," both of the first selecting section 62a and the second selecting section 62b select the estimated position-velocity information 107b independently of e"or e" output of the vibration-shock detection signal 101.

CASE 3) of FIG. 7: When the servo information detecting fault signal 103 is "false" and when the vibration-shock detection signal 101 is "true," there are further the following two cases depending on the degree of estimating error 106.

CASE 3a) of FIG. 7: When the estimating error 106 exceeds the predetermined threshold, both of the first selecting section 62a and the second selecting section 62b select the estimated position-velocity information 107b.

CASE 3b) of FIG. 7: When the estimating error 106 does not exceed the predetermined threshold, the first selecting section 62a selects the modified position-velocity

information 107a. On the other hand, the second selecting section 62b selects the normal position-velocity information 600.

The selection by the selector 15 shown in FIG. 7 is illustrated in Step S4 of FIG. 9B. The selection result of substep S4a of Step S4 corresponds to the CASE 2) and CASE 3a) of FIG. 7; and the selection result of a substep S4b of Step S4 to the CASE 1) and CASE 3b) of FIG. 7.

《Fifth step S5》 (FIG. 9B)

The position-velocity information for the calculation of control value 108 selected in Step S4 is processed within the calculator of control value 20, thereby yielding the position-velocity final information 111.

《Sixth step S6》 (FIG. 9B)

The position-velocity final information 111 is multiplied by the feedback gain 19 in accordance with the following Eq. (5), thereby yielding the control value 110:

$$u = K \times X \qquad (5)$$

where u is the control value 110, K is the feedback gain 19 and X is the position-velocity final information 111. The actuator drive 12 drives the actuator 13 in accordance with the control value 110, thereby moving the magnetic head 23 to the position indicated by the target information 113.

《Seventh step S7》 (FIG. 9B)

In CASE 1) of FIG. 7, it is checked whether the magnetic head 23 is in the on-track state (referred as check

of on-track state, below) on the basis of the normally detected position of the magnetic head 23. Specifically, it is checked whether the position error 112c (see FIG. 1), or the difference between the target information 113 and the magnetic head position information 112d (the detected position information 105 or the estimated position information 401), falls within the predetermined range. As a result of the check, if the magnetic head 23 is in the on-track state, the magnetic head 23 writes and reads as usual. On the contrary, if the magnetic head 23 is in the off-track state, the magnetic head 23 does not write or read.

In CASE 2) of FIG. 7, the check of on-track state is not conducted and the magnetic head 23 does not write or read.

If the vibration-shock detection signal 101 is "false," the detection of servo information 104 is repeated predetermined times. As a result, if the servo information detecting fault signal 103 is continuously "true," a procedure is conducted for synchronizing the read action by the magnetic head 23 with the servo information 104. Specifically, the detection of servo information 104, or the detection of the synchronization signal recorded in the first area 31 (see Section (b) of FIG. 3) of the recorded area of servo information 30, is conducted for a time longer than normal condition.

If the vibration-shock detection signal 101 is "true," the magnetic head 23 keeps the state without write and read

until the vibration-shock detection signal 101 becomes "false," that is, until the vibration or shock cease.

In CASE 3a) of FIG. 7, the estimating error by the observer 16 exceeds the predetermined threshold. Thus, it is probable that the detected position information is inaccurate due to the influence of vibration or shock. Therefore, the check of on-track state is not conducted and the magnetic head 23 keeps the state without writing and reading until the vibration-shock detection signal 101 becomes "false," that is, until the vibration or shock cease.

In CASE 3b) of FIG. 7, since the estimating error by the observer 16 is smaller than the predetermined threshold, the detected position information is not affected severely by vibration or shock. Therefore, the check of on-track state is conducted on the basis of the detected magnetic head position information in the similar way of CASE 1) of FIG. 7 or the normal condition. Similarly to CASE 1) of FIG. 7, if the magnetic head 23 is in the on-track state, the magnetic head 23 writes and reads; but if the off-track state occurs, the magnetic head 23 does not write or read.

《Eighth step S8》 (FIG. 9B)

The observer 16 calculates the position-velocity next-sampling information 400 by the following Eq. (6):

$$Xbb = \Phi e \times Xe + \Gamma e \times u \qquad (6)$$

Where: Φe is the system matrix 43, Xe is the position-velocity information for the observer 109, and Γe is the

input matrix 40.

Repeating Step S1 to Step S8, the position of the magnetic head 23 is controlled.

In CASE 2) of FIG. 7, since there is a fault in the detection of servo information 104 conducted by the magnetic head position detector 14, the actual position of the magnetic head 23 is not detected. Accordingly, the position of the magnetic head 23 is controlled on the basis of the position of the magnetic head 23 estimated by the observer 16. While the estimated position-velocity information 117b contains a certain error, it approximates well the actual position and velocity of the magnetic head 23. Therefore, in general, the actual position of the magnetic head 23 is more rapidly re-detected than the conventional method in which the magnetic head 23 is kept stopping. As a result, the restoration time of the magnetic head 23 from the off-track state is substantially shortened in comparison with the conventional method.

In CASE 3a) of FIG. 7, detected servo information often does not correspond to the actual position of the magnetic head 23 due to the influence of vibration or shock. Accordingly, the position of the magnetic head 23 is controlled on the basis of the estimated position-velocity information 117b instead of the detected position information 105. When the vibration or shock cease and when the state changes into CASE 3b) or CASE 1) of FIG. 7, the check of on-

track state is conducted on the basis of the detected position information 105 as usual. Therefore, the restoration time of the magnetic head 23 from the off-track state is substantially shortened in comparison with the conventional method in which the magnetic head 23 is kept stopping.

The position controlling method of magnetic heads in accordance with the above-mentioned embodiment can be coded into a computer program in accordance with the flow charts shown in FIG. 9A and FIG. 9B. In particular, it should be easily understandable to a person skilled in the art that the calculator of control value 20 can be constructed as a software. As shown in FIG. 1, the configuration other than the calculator of control value 20 is common to that of a prior art magnetic disk drive. Thus, the calculator of control value 20 is constructed as a software and stored on a recorded medium in the executable form. Accordingly, using a computer incorporated with the recorded medium, the position controlling method of magnetic heads in accordance with the present invention can be implemented in a prior art magnetic disk drive. The recorded medium may be any of the data recording devices including a floppy disk, a CD-ROM, a DVD, a magneto-optical disk, a removable hard disk and a flash memory.

Although the present invention has been described in terms of the presently preferred embodiments, it is to be

understood that such disclosure is not to be interpreted as limiting. Various alterations and modifications will no doubt become apparent to those skilled in the art to which the present invention pertains, after having read the above disclosure.

Accordingly, it is intended that the appended claims be interpreted as covering all alterations and modifications as fall within the true spirit and scope of the invention.

INDUSTRIAL APPLICABILITY

In accordance with the present invention, the interruption in the audio-video information reproduced by a magnetic disk drive is alleviated. As such, since a magnetic disk drive adopting the position controlling method of magnetic heads in accordance with the present invention is of great advantage to reproduce the audio or video over a prior art magnetic disk drive, the magnetic disk drive has an industrial applicability.

CLAIMS

1. A magnetic disk drive comprising:

a magnetic disk;

a magnetic head for writing and/or reading data on said magnetic disk;

a read/write circuit for controlling the write and/or read of data by said magnetic head;

an actuator for supporting said magnetic head;

an actuator drive for driving said actuator and moving said magnetic head to a predetermined position;

a magnetic head position detector for

a) detecting servo information read from said magnetic disk by said magnetic head,

b) calculating detected position information of said magnetic head on the basis of said servo information when there is no fault in the detection of said servo information, and

c) outputting a servo information detecting fault signal when there is a fault in the detection of said servo information;

a shock sensor for detecting and measuring vibration or shock from the outside;

a vibration-shock detector for detecting that the degree of said vibration or shock exceeds a predetermined threshold, on the basis of signal of vibration or shock from

said shock sensor, and outputting an vibration-shock detection signal; and

a calculator of control value, comprising

A) an observer for estimating position-velocity information of said magnetic head, and

B) a selector for selecting either

a) normal position-velocity information from said magnetic head position detector or

b) estimated position-velocity information from said observer,

on the basis of said vibration-shock detection signal and said servo information detecting fault signal,

and for adopting the information selected by said selector as magnetic head position-velocity information and calculating a control value of said actuator on the basis of the information.

2. An magnetic disk drive in accordance with claim 1, wherein:

said observer calculates an estimating error from said estimated position-velocity information and said detected position information; and

said selector selects said estimated position-velocity information as said magnetic head position-velocity information when there is a fault in the detection of said servo information, or when the degree of said vibration or

shock exceeds said threshold and the degree of said estimating error exceeds a predetermined threshold.

3. A position controlling method of magnetic heads, comprising:

step of detecting, with a shock sensor, that the degree of vibration or shock from the outside exceeds a predetermined threshold;

step of detecting servo information read by the magnetic head, checking a detection error in said servo information and calculating detected position information of said magnetic head;

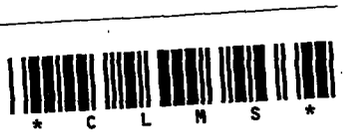
step of calculating a control value for controlling an actuator driving necessary for moving said magnetic head to a predetermined position, comprising

a) substep of estimating position-velocity information of said magnetic head by an observer, and

b) substep of selecting estimated position-velocity information from said observer when the degree of said vibration or shock exceeds said threshold, or there is a fault in the detection of said servo information; and

step of driving said actuator depending on said control value and moving said magnetic head to a predetermined position.

4. A position controlling method of magnetic heads in



accordance with claim 3, comprising:

step of calculating an estimating error from said estimated position-velocity information and said detected position-velocity information by said observer; and

step of selecting said estimated position-velocity information when there is a fault in the detection of said servo information, or when the degree of said vibration or shock exceeds said threshold and said estimating error exceeds a predetermined threshold.

5. A recorded medium storing a position controlling program of magnetic heads, said program comprising:

detecting, with a shock sensor, that the degree of vibration or shock from the outside exceeds a predetermined threshold;

detecting servo information read by the magnetic head, checking a detection error in said servo information and calculating detected position information of said magnetic head;

calculating a control value for controlling an actuator driving necessary for moving said magnetic head to a predetermined position, comprising

a) by an observer estimating position-velocity information of said magnetic head, and

b) selecting estimated position-velocity information from said observer when the degree of said vibration or shock

* C L M S *

exceeds said threshold, or there is a fault in the detection of said servo information; and

driving said actuator depending on said control value and moving said magnetic head to a predetermined position.

6. A recorded medium storing a position controlling program of magnetic heads in accordance with claim 5, said program comprising:

calculating an estimating error from said estimated position-velocity information and said detected position-velocity information by said observer; and

selecting said estimated position-velocity information when there is a fault in the detection of said servo information, or when the degree of said vibration or shock exceeds said threshold and said estimating error exceeds a predetermined threshold.

