TITLE OF THE INVENTION

DISK DRIVE SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to disk drive system, and more specifically, to a disk drive having a function for detecting the moving speed of the actuator equipped with heads based on the counter electromotive force induced in the voice coil motor (VCM).

As a conventional disk drive system, there is a hard disk drive (HDD). The hard disk drive has a mechanism of loading/unloading the slider equipped with a head (namely, a read/write unit) on the magnetic disk on which data is stored. In this mechanism, a component called "ramp" on which the head retracts is mounted beside the disk. The head retracts on the ramp when the rotation of the disk stops and data reading or writing is not under progress. This retractive movement is referred to as "unload". On the other hand, when the rotation of the disk begins and data reading/writing starts, the head moves from the ramp to a position over the disk. This movement of the heads onto the disk is referred to as "load".

During such head loading/unloading operation, the head moving speed is detected by a method which is different from that employed in the case of seek operation during data reading/writing. A head mounted on an actuator moves radially toward the center of the

disk, driven by a voice coil motor (VCM). The voice coil motor (VCM) moves the actuator with a driving current supplied from a VCM driver which is controlled by a microprocessor (CPU) in the drive.

During a loading/unloading operation, the speed of VCM, namely the moving speed of the actuator, is detected and identified with reference to a counter electromotive force which appears in the voice coil motor (VCM) during the driving operation. The moving speed of the actuator is controlled and stabilized through this speed detection, so that the head avoids collision with the disk during loading or the ramp during unloading.

As mentioned above, the movement of the actuator is controlled through the detection of the actuator moving speed during head loading/unloading, based on the magnitude of the counter electromotive force induced in VCM. In an ideal detection of the moving speed, the detected counter electromotive force should be zero when the moving speed is zero. In practical operation, however, the value of the detected counter electromotive force does not always show zero, affected by the driving current supplied to VCM, even if the speed of the voice coil motor (VCM) is zero. This leads to a detection error.

To solve this problem, a calibration is conducted to correct such detection error in HDDs employing the

loading/unloading mechanism. Calibration implies an operation for correcting the speed detection error. Its specific operation is to measure the counter electromotive force generated while the actuator moving speed is zero, on condition that the actuator is pressed onto a stopper mounted on the outer or inner edge of the disk and fixed on the stopper. In other words, calibration is an operation of clarifying the relationship between the current supplied to VCM and the induced counter electromotive force.

The electrical resistance of VCM changes with ambient temperature. It is, therefore, desirable to execute calibration frequently at a predetermined timing, for example, each time upon starting head loading, in order to raise accuracy in correcting the speed detection error. The amount of time taken for calibration, however, affects the time for loading/unloading and thereby drive performance.

BRIEF SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention is to provide a disk drive system that can minimize the number of times of calibration needed for detection of the actuator moving speed during head loading/unloading and thereby shorten the time for head loading/unloading, eventually improving disk performance.

Another object of the present invention is to

provide a disk drive that can raise accuracy in detecting the VCM moving speed and shorten the time for head loading/unloading by minimizing the number of times of calibration necessary for correction of the VCM moving speed detection error during head loading/unloading operation.

The present invention provides a disk drive system comprising:

a recording disk upon which data is stored;

a head for recording and reproducing data on the recording disk;

generating means for generating a driving signal;

actuator for carrying the head over the recording disk, which includes a driving motor for producing a moving force in accordance with the driving signal, the actuator being moved at a moving speed by the moving force and a counter electromotive force being induced in the driving motor;

detecting means for detecting the moving speed of the actuator based on the counter electromotive force;

sensing means for sensing an ambient temperature in the disk drive system; and

control means for controlling the generating means in response to the detected moving speed, which includes calibrating means for calibrating the detected moving speed at predetermined time intervals related to change in the ambient temperature in a period of

controlling the generating means.

In such disk drives, calibration is executed, not at each time a loading operation begins, but at predetermined time intervals. The length of this time interval corresponds to a lapse of time during which the electric resistance in VCM changes together with ambient temperature and then affects accuracy in detecting the VCM moving speed. In other words, this predetermined time is a period of time for monitoring the lapse of time between the preceding calibration and the following calibration. Therefore, calibration is not carried out during this predetermined time, even if the control of the actuator is executed according to loading/unloading operation. As a result, the number of times for calibration can be minimized, without causing deterioration of accuracy in detecting the actuator speed, and thereby the time required for loading/unloading operation is also shortened.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated

in and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

FIG. 1 is a block diagram of a disk drive (HDD) according to an embodiment of the present invention;

FIG. 2 is a block diagram illustrating the structure of the disk drive system of FIG. 1;

FIG. 3 is a flow chart illustrating a calibration operation conducted during a loading operation in the disk drive system of FIG. 1;

FIG. 4 is a flow chart illustrating a calibration operation conducted during a loading operation in the disk drive system of FIG. 1;

FIG. 5 is a flow chart illustrating a calibration operation conducted during an unloading operation in the disk drive system of FIG. 1; and

FIG. 6 is a flow chart illustrating a calibration operation conducted during an unloading operation in the disk drive system of FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

The hard disk drive having the loading/unloading mechanism according to embodiments of the present invention is described in detail below with reference to drawings.

(Structure of the disk drive system)

Referring now to FIG. 1, the hard disk drive has a disk 11 upon which data is stored, a slider 12 where a head for data reading/writing, namely read/write device, is mounted, and an actuator 13 where the head 12 is mounted. In FIG. 1, one disk 11 is shown and the head 12 is disposed on one side of the disk 11 for convenience. However, as widely known, conventional hard disk may be provided with a plurality of magnetic disk and heads may be disposed on both sides of each of the disks 11.

On the surface of each disk 11, a number of tracks are allocated almost concentrically. Each track has a plurality of servo areas in equal intervals where servo data for head 12 positioning control is written. The areas between servo areas in each track are used as data areas (areas set aside for user data), each of which is split into a plurality of data sectors. Servo data includes a track number, namely, track address indicating the cylinder code, and servo burst data used to identify the position inside each track.

As shown in FIG. 2, the head 12 is mounted on a rotary actuator 13. Actuator 13 has a suspension that supports the head 12 and is rotated by a driving force provided by a voice coil motor (VCM) 16. In this way, the head 12 is moved by the actuator 13 radially toward the center of the disk 11. The movement of the

actuator 13 is controlled, so that the head 12 is positioned on a target track on the disk 11. At the outer edge of the disk 11, there is a ramp 14 where the head 12 is retracted. The ramp 14 has a slope that supports a tub 120 mounted on the top of the suspension of actuator 13 when it retracts from the surface of the disk 11.

The disk 11 rotates at a high speed, driven by a spindle motor (SPM) 15. The SPM 15 is controlled by a driving current supplied from an SPM driver 17. The VCM 16 is controlled by a driving current supplied from a VCM driver 18. SPM driver 17 and VCM driver 18 have been integrated into one chip. A CPU 22 determines the magnitude of control signals for the driving currents supplied from drivers 17 and 18 to corresponding motors 15 and 16.

Head 12, after it is positioned on a target track on the disk 11 by the actuator 13, executes data reading/writing on the target data sector included in this target track. The head 12 is connected to a head amplifier 19 mounted on a flexible printed circuit (FPC). Head amplifier 19 amplifies the read signal read out by the head 12 and sends it to read channel 20. The head amplifier 19 also executes a predetermined signal processing on the read data output from the read channel 20 and then sends it to the head 12. The read channel 20, referred to as data channel or read/write

channel, is a circuit that processes read or write signals. The read channel 20 includes an automatic gain control (AGC) that holds the level of the read signal sent from the head amplifier 19 at a fixed value, a decoding circuit that decodes the read signal into data, for example, NRZ-code data, an encoding circuit that generates write data that will be stored in disk 11, and a servo circuit that extracts servo data from the read signal.

Based on a control program stored in memory 24, CPU (Central Processing Unit) 22 controls disk drive operations, such as head positioning, which is a servo control including loading/unloading operation. Based on servo data extracted by the read/write circuit 20, CPU 22 detects the position of the current track where the head 12 sits over the disk 11 and calculates the difference between the current position and the target track position. Based on the calculated difference, CPU 22 outputs a control signal needed for moving the head 12 for positioning and sets this signal in the VCM driver 18. At this moment, CPU 22 sets this control signal in the VCM driver 18 through a D/A converter 24.

When CPU 22 receives from a host system an order to stop SPM 15, it executes a usual unloading operation of retracting the head 12 to the ramp 14. CPU 22 executes a loading operation of moving the retracted head 12 onto the disk 11, when starting a read/write

operation by activating SPM 15.

The drive according to this embodiment of the invention has a temperature sensor 23 that detects temperature in a VCM control circuit 21 which controls the VCM 16 and the drive. The VCM control circuit 21 detects the counter electromotive force induced in VCM 16 and outputs it to CPU 22. The temperature sensor 23 measures temperature in the drive and outputs the measurements to CPU 22.

(Calibration)

Referring now to flow charts shown in FIGS. 3-6, the calibration process with which the counter electromotive force induced in VCM 16 is corrected will be described below.

(Timer mode)

Referring to the flow diagram of FIG. 3, calibration of a timer mode is explained with which calibration is carried out at predetermined time intervals. In this timer mode calibration, a timer (an internal timer in CPU 22) is activated upon the start of calibration and a lapse of time is monitored during a loading operation.

The flow diagram of FIG. 3 assumes a loading operation (YES in step S1) in which the head 12 is moved from the ramp 14 to a position over the disk 11 while the disk is turning. Prior to the start of a loading operation, CPU 22 determines whether the lapse

of time since the previous calibration has reached the predetermined value or not (step S2), referring to the time count conducted by the internal timer. This predetermined time is equivalent to a time interval that is considered long enough to affect the accuracy of actuator speed detection which is conducted by the VCM control circuit 21 based on the counter electromotive force induced in VCM. This amount of time, in other words, is a time interval at which it becomes necessary to monitor the lapse of time between the preceding calibration and the following calibration, related to a change in temperature.

If the predetermined time has passed since the preceding calibration, CPU 22 executes the current calibration (YES in step S3, S4). At this moment, CPU 22 initializes the internal timer and reactivates it. Unless the predetermined time has passed, CPU 22 conducts the current loading operation without calibration (NO in step S3, S5).

In calibration of the above timer mode, calibration is executed at predetermined time intervals. Calibration is not needed to conduct every time a loading operation is begun. Since calibration is conducted only when the predetermined time has passed, the number of times of calibration associated with loading operation can be minimized. As a result, the execution time of loading operation can be reduced and

then the drive performance is improved. Calibration is conducted at time intervals, namely, when the speed detection accuracy is considered to deteriorate due to change in the resistance in VCM caused by change in ambient temperature. CPU 22, therefore, can implement a stable loading operation by detecting the VCM speed, namely moving speed of actuator 13, with a high accuracy, based on the counter electromotive force induced in VCM 16.

(Temperature measurement mode)

Referring now to the flow chart of FIG. 4, calibration of a temperature measurement mode is explained wherein calibration is performed based on temperature measurement using a temperature sensor 23. Upon the start or end of calibration, CPU 22 saves the value of temperature measured with the temperature sensor 23 in a memory 24 and thereby detects a change in temperature during loading operation.

Also in this mode, take a loading operation (YES in step S11), for example, in which the head 12 moves from the ramp 14 to a position over the disk 11.

Prior to the start of a loading operation, CPU 22 compares the temperature value saved in memory 24 with the temperature measured with the temperature sensor 23. Namely, CPU 22 compares the change in temperature (comparative error) since the preceding calibration with the predetermined value (step S12). This

predetermined value is equivalent to a temperature limit that is considered large enough to affect the accuracy of actuator speed detection which is conducted by the VCM control circuit 21 based on the counter electromotive force induced in VCM.

CPU 22 carries out the current calibration (YES in step S13, S14), if it detects a temperature change since the preceding calibration which is equal to or larger than the predetermined value. At this moment, CPU 22 stores the temperature measurement data sent from the temperature sensor 23 in the memory 24 (step S15).

On the other hand, if the temperature change is smaller than the predetermined value, CPU 22 conducts the current loading operation without calibration (NO in step S13, S16).

In calibration of the above temperature measurement mode, temperature is monitored by the temperature sensor 23 prior to the start of a loading operation, and calibration is executed if the temperature change is equal to or larger than the predetermined value. Calibration is not necessary every time a loading operation is begun. Since calibration is conducted only when the temperature change is equal to or larger than the predetermined value, the number of times of calibration for loading operation can be thereby minimized. As a result, the

shorter execution time of loading operation leads to higher drive performance. During monitoring temperature, calibration is conducted when the speed detection accuracy is considered to deteriorate due to change in the resistance in VCM, affected by change in ambient temperature. Therefore, CPU 22 can implement a stable loading operation by detecting the VCM speed, namely moving speed of actuator 13, with a high accuracy, based on the counter electromotive force induced in VCM 16.

(Timer mode during unloading)

Referring to the flow chart of FIG. 5, another example of the timer mode calibration is explained in which calibration is conducted at predetermined time intervals. In this mode of calibration, a timer is activated upon the start of calibration and a lapse of time is monitored during unloading.

The flow diagram of FIG. 5 assumes an unloading operation (YES in step S21) in which the head 12 is moved from a position over the disk 11 to the ramp 14 while the disk is turning. Prior to the start of an unloading operation, CPU 22 determines whether the lapse of time since the previous calibration has reached the predetermined time or not (step S22), referring to the time count indicated by the internal timer.

If the predetermined time has passed since the

preceding calibration, CPU 22 executes the current calibration (YES in step S23, S24, S25) after the unloading operation is over. At this moment, CPU 22 initializes the internal timer and re-activates it.

Unless the predetermined time has passed, CPU 22 conducts the current unloading operation without calibration (NO in step S23, YES in step 26).

In calibration of the above timer mode, calibration is executed at predetermined time intervals. Calibration is not necessarily conducted every time an unloading operation is over. Instead, since calibration is conducted only when the predetermined time has passed, the number of times of calibration is minimized. As a result, the execution time to complete an unloading operation can be reduced and the drive performance is thereby improved. Calibration is conducted at the time interval, namely, when the speed detection accuracy is considered to deteriorate due to change in the resistance in VCM caused by change in ambient temperature. CPU 22, therefore, can implement a stable loading operation by detecting the VCM speed, namely, moving speed of actuator 13, with a high accuracy, based on the counter electromotive force induced in VCM 16.

(Temperature measurement mode during unloading)

Referring now to the flow diagram of FIG. 6, another example of calibration of the temperature

measurement mode is explained where calibration is performed with reference to the temperature measurement by a temperature sensor 23. Upon the start or end of calibration, CPU 22 saves the value of temperature measured with the temperature sensor 23 in a memory 24 and thereby detects a change in temperature during unloading operation.

The flow diagram of FIG. 6 assumes an unloading operation (YES in step S31) in which the head 12 is moved from a position over the disk 11 to the ramp 14 while the disk is turning. Prior to the start of an unloading operation, CPU 22 compares the temperature value saved in memory 24 with the temperature measured by the temperature sensor 23. Namely, CPU 22 judges whether the change in temperature (comparative error) since the preceding calibration is less than the predetermined value (step S32).

CPU 22 carries out the current calibration (YES in step S33, S34, S35) after the completion of the unloading operation, if the change in temperature since the preceding calibration is equal to or larger than the predetermined value. At this moment, CPU 22 stores the temperature measurement data sent from the temperature sensor 23 in the memory 24 (step S36).

On the other hand, if the temperature change is smaller than the predetermined value, CPU 22 conducts the current loading operation without calibration (NO

in step S33, YES in S37).

In calibration of the above temperature measurement mode, temperature is monitored by the temperature sensor 23 prior to the start of an unloading operation, and calibration is executed if the change in temperature is equal to or larger than the predetermined value. Calibration is not necessary every time an unloading operation is begun. Instead, since calibration is conducted only when the temperature change is equal to or larger than the predetermined value, the number of times of calibration associated with loading operation is minimized. As a result, the execution time of loading operation is reduced and thereby the drive performance is improved. During monitoring temperature, calibration is conducted when the speed detection accuracy is considered to deteriorate due to change in the resistance in VCM, affected by change in ambient temperature. Therefore, CPU 22 can implement a stable loading operation by detecting the VCM speed, namely moving speed of actuator 13, with a high accuracy, based on the counter electromotive force induced in VCM 16.

(Seek frequency monitoring mode)

As an alternative to the same embodiment, calibration of a seek frequency monitoring mode is described below in which CPU 22 executes calibration, monitoring the frequency of seeks per unit time, if the

frequency exceeds a predetermined value.

In general, during a seek operation in which the head 12 is moved to a target track on the disk 11, the temperature of VCM 16 rises because the actuator 13 is driven by a driving current supplied to VCM 16. Particularly when the frequency of seeks becomes high, the temperature of VCM 16 is likely to rise much enough to cause a change in the resistance of VCM and affect accuracy in detecting the actuator moving speed.

CPU 22, therefore, monitors the frequency of seeks per unit time and carries out calibration if the seek frequency exceeds the predetermined value. Note that it is desirable to conduct calibration at a time except during read/write operations, for example, during loading/unloading.

If calibration is conducted based on the seek frequency, the temperature sensor 23 is not necessary and it is possible to minimize the number of times for calibration, only using the internal counter and memory in CPU 22. With this function of monitoring the temperature of VCM based on the seek frequency, calibration can be ensured when necessary.

In the present invention described above in detail, it is possible to minimize the frequency of calibration, which is needed for correction of the VCM speed during loading/unloading, and carry out calibration as required. Accuracy in detecting the VCM speed is

thereby improved and the time for loading/unloading can be shortened which is particularly affected by the execution time of calibration. As a result, the performance of disk drives is enhanced.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.



WHAT IS CLAIMED IS:

1. A disk drive system comprising:

a recording disk on which data is stored;

a head for recording and reproducing data on said recording disk;

generating means for generating a driving signal;

actuator for carrying the head over the recording disk, which includes a driving motor for producing a moving force in accordance with the driving signal, said actuator being moved at a moving speed by the moving force and a counter electromotive force being induced in the driving motor;

detecting means for detecting the moving speed of the actuator based on the counter electromotive force;

sensing means for sensing an ambient temperature in the disk drive system; and

controlling means for controlling said generating means in response to the detected moving speed, which includes calibrating means for calibrating the detected moving speed at a predetermined time interval related to change in the ambient temperature in a period of controlling said generating means.

2. The disk drive system according to claim 1, wherein said controlling means including comparing means for comparing the predetermined time interval with the lapse of time since the preceding calibration, causing the calibrating means to conduct the following



calibration if the lapse of time is over the predetermined time interval and preventing the calibrating means from conducting the calibration if the lapse of time is within the predetermined time interval.

3. The disk drive system according to claim 2, wherein said controlling means includes a timer which is activated upon or after the execution of said calibration and means for determining the lapse of the predetermined time interval by monitoring the timer prior to the start of said loading operation.

4. The disk drive system according to claim 1, wherein said controlling means includes comparing means for comparing the predetermined time interval with the lapse of time since the preceding calibration at the time of an unloading operation in which the head is unloaded from a reading position on the recording disk to a predetermined retraction position, causing the calibration means to conduct the following calibration if the lapse of time is over the predetermined time interval, and prevent the calibrating means from conducting the calibration if the lapse of time is within the predetermined time interval.

5. A disk drive system comprising:

a recording disk on which data is stored;

a head for recording and reproducing data on said recording disk;

generating means for generating a driving signal;

actuator for carrying the head over the recording disk, which includes a driving motor for producing a moving force in accordance with the driving signal, said actuator being moved at a moving speed by the moving force and a counter electromotive force being induced in the driving motor;

detecting means for detecting the moving speed of the actuator based on the counter electromotive force;

sensing means for sensing an ambient temperature around said driving motor; and

controlling means for controlling said generating means in response to the detected moving speed, which includes calibrating means for calibrating the detected moving speed and comparing means for comparing the sensed ambient temperature with a predetermined temperature in a period of controlling said generating means, the calibrating means being activated if the ambient temperature exceeds the predetermined temperature, and the calibrating means being prevented from being activated if the ambient temperature is equal to or lower than the predetermined temperature.

6. The disk drive system according to claim 5, wherein said controlling means includes storing means for storing the sensed temperatures as measurement data provided from said sensing means after the calibration and means for determining, at start of the calibration,



whether the change in the ambient temperature exceeds the predetermined temperature which is determined with comparing the sensed temperature with the measurement data.

7. The disk drive system according to claim 5, wherein said controlling means includes means for causing the calibrating means to be activated if the change in the ambient temperature exceeds the predetermined value, and preventing the calibrating means from being activated if the change in the ambient temperature is equal to or lower than the predetermined value, at the start of a loading operation in which the head is loaded onto the recording disk.

8. The disk drive system according to claim 5, wherein said control means includes means for causing the calibrating means to be activated if the change in the ambient temperature exceeds the predetermined value after an unloading operation in which the head is unloaded from a position on the recording disk to a predetermined retraction position, and preventing the calibrating means from being activated if the change in the ambient temperature is equal to or lower than the predetermined value.

9. A disk drive system comprising:

a recording disk on which data is stored;

a head for recording and reproducing data on said recording disk;

generating means for generating a driving signal;

actuator for carrying the head over the recording disk, which includes a driving motor for producing a moving force in accordance with the driving signal, said actuator being moved at a moving speed by the moving force and a counter electromotive force being induced in the driving motor;

detecting means for detecting the moving speed of the actuator based on the counter electromotive force;

measuring means for measuring a seek frequency per unit time resulting from the movement of the actuator; and

control means for controlling said generating means in response to the detected moving speed, which includes calibrating means for calibrating the detected moving speed if the measured seek frequency exceeds a predetermined value.

10. The disk drive system according to claim 9, wherein the calibrating means calibrates the detected moving speed at a predetermined time interval at which the electrical resistance of the driving motor is changed, along with the ambient temperature, to affect accuracy in detecting the speed.

11. A disk drive system comprising:

a head for recording and reproducing data on a disk;

means for actuating the head over the disk, said

actuating means having a driving motor for producing a moving force, and being moved at a moving speed by the moving force and a back electromotive force being induced in the driving motor;

means for detecting the moving speed of said actuating means based on the back electromotive force;

means for sensing a temperature in the disk drive system; and

means for calibrating the detected moving speed at a predetermined time interval related to change of the temperature.