

## MAGNETIC-DISK EVALUATING APPARATUS AND METHOD

### Field of the Invention

The present invention relates to a magnetic disk evaluating apparatus (i.e., a spin stand) and a method for evaluating temporary servo signals previously written to a magnetic disk for use in the self servo writing method for magnetic disk apparatuses.

### Background of the Invention

Hard disk drives (HDD) are commonly used as information storage devices, and position their heads on the basis of servo signals written to a magnetic disk. Fig. 1 is a schematic diagram of a standard HDD. A magnetic disk 1 in the HDD is rotated at several thousand rpm by a spindle motor 2, so that an air flow above the magnetic disk 1 causes a slider 4 located at the tip of a rotary positioner 3 to float slightly above the magnetic disk. A magnetic head 5 is located at an end of the slider 4. Servo signals are magnetically written on the magnetic disk 1 and are detected by the magnetic head 5, amplified by a preamplifier 6, and demodulated by a servo demodulating circuit 7 to obtain track information (indicating on which track the magnet head is lying) and a PES (Position Error Signal, which indicates how far the head is separated from the center of a track).

The HDD determines the current head position by using the magnetic head 5 to read the servo signals, and positions the magnetic head 5 on a track (target track) with desired information written thereto by using a voice coil motor (VCM) 8 to drive the rotary positioner 3. That is, the difference between the target track position and the head position is detected as the PES, which is input to a compensator 9. Then, the compensator 9 generates a drive command to the rotary positioner 3 on the basis of the

PES and transmits this drive command to the voice coil motor (VCM) 8 through a power amplifier 10; the voice coil motor thus drives the rotary positioner 3. Thus feeding back the PES serves to reduce the positional difference between the target track and the head position. In addition, in terms of absolute coordinates, the target track position varies in accordance with rotational cycles due to eccentricity of the disk.

The magnetic disk 1 used in the HDD has the above servo signals and data recorded thereon and reproduced therefrom by the magnetic head 5. In this case, a defect in the magnetic disk 1 would prevent proper recording or reproduction. Thus, the magnetic disk 1 must be tested before integration (that is, the magnetic disk 1 is clamped to the spindle motor 2) into the HDD to ascertain that the unitary magnetic disk 1 can provide minimum required performance. In general, this test consists of using a magnetic head to be tested to sequentially check the magnetic disk 1 for its gliding property, certify property, and contact start stop (CSS) property. The gliding property check consists of checking the number of projections on the magnetic disk 1, the certify property check consists of checking the magnetic disk 1 for its electric properties and defects, and the CSS property check consists of checking the durability of the magnetic disk 1. An apparatus used to evaluate the performance of the magnetic disk is generally called a "spin stand."

Fig. 2 is a schematic diagram of a common spin stand. The spin stand consists of a base 11 as a support table for the apparatus, a spindle motor 12 provided on the base 11 to rotate, at an arbitrary rotation speed, the magnetic disk 1 to be evaluated, an evaluating magnetic head 13 for reproducing and recording signals on and from the magnetic disk 1 in order to evaluate the magnetic disk 1, a carriage 14 to which the evaluating magnetic head 13 is attached, a  $\theta$  stage 15 for adjusting the carriage 14 to an arbitrary angle, and a stage 16 that is movable in at least one direction (the stage 16 is movable in the horizontal direction of Fig. 2 along a guide 17) in order to freely vary the

positional relationship between the spindle motor 12 and the evaluating magnetic head 13.

The standard HDD based on the head positioning method using the rotary positioner driven by the voice coil motor (VCM) has the advantage of having a compact structure but also has a drawback in that the head skew angle varies with the track. The head skew angle relates to the flying head height of the magnetic head and causes variations in the reproduction output from the magnetic head. Accordingly, the same skew angle as that in the HDD must be used in conducting the above described gliding, certify, and CSS property checks in order to evaluate the performance of the magnetic disk 1. Thus, for these checks, the positional relationship between the spindle motor 12 and evaluating magnetic head 13 of the spindle stand must be adjusted to be identical to that in the HDD, so that commonly used spin stands include a positioning mechanism based on the directly moving stage 16, the rotary  $\theta$  stage 15, or similar parts.

The checks are then carried out using this spin stand and if the magnetic disk 1 is determined to be acceptable, it is clamped to the spindle motor 2, which is then assembled into the HDD. With the magnetic disk 1 integrated into the HDD (that is, the magnetic disk 1 is clamped to the spindle motor 2), a device called a "servo track writer (STW)" is used to write servo signals to the magnetic disk 1.

Fig. 3 shows an example of a configuration in which the servo track writer (STW) is used to produce servo tracks. The servo track writer (STW) conventionally presses a pin 19, accurately positioned by an external actuator 18, against the rotary positioner 3 inside the HDD via a link 20 for positioning, while setting the head position on the basis of a scale inside the actuator 18 using a fine feeding mechanism. Since the servo signals are each written to a corresponding one of the tracks on the magnetic disk 1, the servo track writer (STW) must write the servo signals to all the tracks on the magnetic

disk 1 while executing accurate positioning via the link 20.

Since the recent increase in recording density has increased the number of tracks while reducing the track width, the servo track writer (STW) must execute more accurate positioning on a larger number of tracks. Realization of accurate positioning requires a rigid and expensive mechanical positioning mechanism as well as a large amount of time for writes. Consequently, multiple servo track writers (STW) must be provided for parallel processing, thus requiring a larger space in the clean rooms in which the servo track writers (STWs) are arranged, as well as increased costs.

#### Problems to be Solved by the Invention

Thus, considerable effort has been put into developing a method for omitting the above described servo track writers (STWs) and causing the hard disk drive (HDD) to execute self servo writing. Fig. 4 shows an example of this self servo writing method. Temporary servo signals 21 have already been written to the magnetic disk 1 (the servo signals can be written thereto substantially faster than with the servo track writers (STWs) by, for example, using a technique such as magnetic printing to copy a magnetic pattern from a master to the magnetic disk), and the magnetic disk 1 is integrated into the HDD, which then writes only actual servo signals 22 to the disk 1 on the basis of the temporary servo signals 21.

Subsequently, the magnetic head is positioned on the basis of the servo signals 22, and it is confirmed that the HDD operates correctly. If the HDD cannot operate correctly due to any defect in the servo signals 22 or temporary servo signals 21, the positioner section must be disassembled so that the magnetic disk can be replaced with a new one, to which the temporary servo signals 21 and the servo signals 22 are then

rewritten.

Further, the servo signals are stored on the unitary magnetic disk, so that when the magnetic disk 1 is chucked on the spindle motor 12 of the spin stand, the central position of the tracks 21 formed from recorded servo signals may be offset from the central position of the spindle motor 12 by several ten to thousand micrometers, as shown in Fig. 5. Consequently, signals reproduced from the tracks are observed to be eccentric to the rotational center of the magnetic disk (in Fig. 5, eccentricity of a maximum size A occurs). Thus, following up the servo signals requires the formation of a control system that takes this eccentricity into account.

However, although the object of the conventional method is to reduce the amount of time required by the servo track writers (STWs), as described previously, and to reduce costs, the quality of the servo signals cannot be evaluated before writing the actual servo signals 22 to the magnetic disk. Consequently, this method requires the same operation to be performed twice and is thus inefficient in terms of costs and time. Thus, if the servo signals have already been recorded on the unitary magnetic disk, evaluation of the unitary magnetic disk is conducted, then before the magnetic head is integrated into the HDD, it must be furthermore determined on the basis of the temporary servo signals 21 previously recorded on the magnetic disk that the actual servo signals 22 can be used in order to evaluate the unitary magnetic disk and to position the magnetic head.

#### **Summary of Invention**

The present invention is provided in consideration of these points, and it is an object thereof to provide a magnetic-disk evaluating apparatus and a method that can determine whether the temporary servo signals are acceptable without writing the

actual servo signals to the magnetic disk.

#### Object of the Invention

To attain the above object, the aspect of the present invention set forth in Claim 1 is a magnetic disk evaluating apparatus having the same configuration as that of an actual hard disk drive and comprising a base as a support table for the apparatus, a spindle motor provided on the base to rotate, at an arbitrary rotation speed, the magnetic disk to be evaluated, a magnetic head for recording and reproducing signals on and from the magnetic disk in order to evaluate the magnetic disk, a thin suspension for supporting the magnetic head, a thick rotary positioner for supporting the suspension, a voice coil provided at an end of the rotary positioner located opposite to the magnetic head, a rotating shaft installed so as to protrude from the base, for supporting the magnetic head, the suspension and the rotary positioner, and a pair of magnets sandwiching the voice coil therebetween, the apparatus being characterized by comprising control means being operative before evaluating performance of temporary servo signals previously written to the magnetic disk, to control driving of the rotary positioner on the basis of the temporary servo signals so that the magnetic head is positioned on a concentric circle in the center of the spindle motor, measurement means for measuring displacement of the magnetic head in a seek direction, detection means for detecting displacement of the tip of the magnetic head on the basis of the displacement in the seek direction which has been measured by the measurement means, and determination means for determining whether the temporary servo signals are acceptable, on the basis of the displacement detected by the detection means.

The magnetic-disk evaluating apparatus may be characterized in that the apparatus consists of fixation means for temporarily fixing the rotary positioner so that the magnetic head is located at an arbitrary position on the magnetic disk, positioner

rotating stage for supporting the fixation means and the rotary positioner and moving the rotary positioner, fixed by the fixation means, to an arbitrary position on the magnetic disk, and a measuring rotating arm rotating around the same rotating center as that of the positioner rotating stage and depending on a movement angle of the positioner rotating stage, and in that the measurement means is installed on the measuring rotating arm.

The magnetic-disk evaluating apparatus may also be characterized in that the measurement means is a laser Doppler vibrometer for measuring the displacement of the magnetic head in the seek direction by irradiating a side of the magnetic head with laser beams to receive light reflected therefrom.

The magnetic-disk evaluating apparatus may also be characterized in that the control means consists of storage means for storing eccentricity of the magnetic disc measured on the basis of a signal from the magnetic head reading the temporary servo signals while the rotary positioner is fixed by the fixation means, cancel means for canceling the eccentricity of the magnetic disk in the signal from the magnetic head by receiving a feed forward input of the eccentricity stored in the storage means, and feedback compensating means for generating a signal for feedback-controlling of the rotary positioner, from the signal sent from the cancel means and having the eccentricity canceled.

To attain the above object, the aspect of the present invention set forth in Claim 5 is a magnetic evaluation method in a magnetic-disk evaluating apparatus having the same configuration as that of an actual hard disk drive and comprising a base as a support table for the apparatus, a spindle motor provided on the base to rotate, at an arbitrary rotation speed, the magnetic disk to be evaluated, a magnetic head for recording and reproducing signals on and from the magnetic disk in order to evaluate the magnetic

disk, a thin suspension for supporting the magnetic head, a thick rotary positioner for supporting the suspension, a voice coil provided at an end of the rotary positioner located opposite to the magnetic head, a rotating shaft installed so as to protrude from the base, for supporting the magnetic head, the suspension and the rotary positioner, and a pair of magnets sandwiching the voice coil, the method being characterized by consisting of a control step being operative before evaluating performance of temporary servo signals previously written to the magnetic disk, in order to control driving of the rotary positioner on the basis of the temporary servo signals so that the magnetic head is positioned on a concentric circle in the center of the spindle motor, a measurement step of measuring displacement of the magnetic head in a seek direction, a detection step of detecting displacement of the tip of the magnetic head on the basis of the displacement in the seek direction measured by the measurement step, and a determination step of determining whether the temporary servo signals are acceptable, on the basis of the displacement detected by the detection step.

#### Operation

With the above configuration, the present invention makes it possible to determine whether the temporary servo signals are acceptable without writing the actual servo signals to the magnetic disk.

Furthermore, in the present invention, even if the magnetic head is moved to various positions, the measuring instrument moves correspondingly and thus need not be adjusted, facilitating measurement of the positional settlability of the magnetic head.

#### Brief Description of the Drawings

Fig. 1 is a schematic diagram showing a configuration of a standard HDD.

Fig. 2 is a schematic view showing a configuration of a conventionally common spin stand.

Fig. 3 is a view showing an example of a configuration in which a servo track writer (STW) is used to produce servo tracks.

Fig. 4 is an explanatory representation of self servo writing.

Fig. 5 is an explanatory representation showing how the central position of tracks 21 formed of recorded servo signals is offset from the central position of a spindle motor 12 of the spin stand when a magnetic disk 1 is chucked on the spindle motor 12.

Fig. 6 is a top view showing a magnetic-disk evaluating apparatus according to one embodiment of the present invention.

Fig. 7 is a front view of the magnetic-disk evaluating apparatus in Fig. 6.

Fig. 8 is an enlarged top view showing an evaluation section 50, shown in Figs. 6 and 7.

Fig. 9 is a top view showing the state of the magnetic-disk evaluating apparatus in Fig. 8 observed before the start of evaluation.

Fig. 10 is a top view showing the magnetic-disk evaluating apparatus in Fig. 8 executing a servo evaluation.

Fig. 11(a) is a top view showing an inner radius portion of a magnetic disk 1 being measured according to one embodiment of the present invention, and Fig. 11(b) is a top view showing an outer radius portion of a magnetic disk 1 being measured according to this embodiment of the present invention.

Fig. 12 is a flow chart showing the process of evaluating the performance of temporary servo signals according to one embodiment of the present invention.

Fig. 13 is a block diagram showing a configuration of a servo system according to one embodiment of the present invention.

Fig. 14 is a diagram representative of a servo simulation model according to one embodiment of the present invention.

Figs. 15(a) and (b) are charts representative of results of the servo simulation in Fig. 14.

## Detailed Description of the Preferred Embodiment

An embodiment of the present invention will be described below with reference to the drawings.

### Configuration

Figs. 6 to 12 are views representative of features of the present invention. Fig. 6 is a general top view of a magnetic-disk evaluating apparatus according to one embodiment of the present invention. Fig. 7 is a general front view of the magnetic-disk evaluating apparatus. The same components as those shown in the prior art (Figs. 1 to 5) are denoted by the same reference numerals and detailed description thereof is omitted; only the characteristic parts of this example will be explained.

The magnetic-disk evaluating apparatus of the present invention is composed of an evaluation section 50 having the same configuration as that of an actual hard disk drive, a measuring rotating arm 51 located under the evaluation section 50, a measurement plate 52 fixed on the measuring rotating arm 51, and a laser Doppler vibrometer 53 mounted on the measurement plate 52. Reference numeral 11 denotes a base.

First, a configuration of the evaluation section 50 will be described in detail. Fig. 8 is an enlarged top view showing only the evaluation section 50. Like the conventional spin stand, the magnetic-disk evaluating apparatus according to this embodiment has a spindle motor 12 for rotating a magnetic disk 1, a directly moving stage 16 for adjusting the positional relationship between the spindle motor and an evaluating magnetic head so that it is identical to that in a hard disk drive (HDD), both being provided on the base 11. Further, the stage 16 has a positioner rotating stage 100 composed of a half-moon-shaped plate and from which a lock pin 101 protrudes.

Furthermore, the positioner rotating stage 100 has a magnetic head 102 for recording and reproducing signals on and from the magnetic disk in order to evaluate the magnetic disk 1, a thin suspension 103 for supporting the magnetic head, a thick rotary positioner 104 for supporting the suspension, a voice coil 105 provided at an end of the rotary positioner 104 located opposite to the magnetic head 102, and a rotating shaft 106 directly installed so as to protrude from the positioner rotating stage 100, for supporting the magnetic head 102, the suspension 103, the rotary positioner 104, and the voice coil 105.

Moreover, the voice coil 105 is sandwiched between a magnet 107b directly installed on the positioner rotating stage 100 and a magnet 107a installed on the positioner rotating stage 100 via a magnet mounting jig 108 (see Fig. 7), thereby constituting a voice coil motor (VCM) that can drive the rotary positioner 104 around the rotating shaft 106 (the direction of the arrow a in Fig. 8).

Further, the positioner rotating stage 100 may be rotated around the rotating shaft 106 in the same manner as the rotary positioner 104 (the direction of the arrow b in Fig. 8), so that the lock pin 101 installed on the stage 100 so as to protrude therefrom may be rotated to an arbitrary position around the rotating shaft 106. The rotary

positioner 104 has a stopper 109 at an end thereof closer to the voice coil 105 so that the lock pin 101 and the stopper 106 abut each other depending on the position of the lock pin 101 to regulate the position of the rotary positioner 104.

Likewise, as shown in Figs. 6 and 7, the measuring rotating arm 51 may be rotated around the rotating shaft 106 (the direction of the arrow c in Fig. 6), so that the measurement plate 52 and laser Doppler vibrometer 53 mounted on the arm 51 may be rotated to an arbitrary position around the rotating shaft 106. Further, a measurement point of the laser Doppler vibrometer 53 is aligned with a side of the magnetic head 102 (that is, so that the side of the magnetic head 102 is irradiated with laser beams from the laser Doppler vibrometer from a vertical direction), enabling measurement of the fluctuation (settability) of the magnetic head 102 in a seek direction.

#### Operation

An evaluation method executed by the magnetic-disk evaluating apparatus configured as described above will now be explained with reference to the state diagrams in Figs. 9 to 11 and the flow chart in Fig. 12. In Figs. 9 to 11, however, the upper magnet 107a is not illustrated for the sake of simplification and the voice coil 105 is exposed.

Fig. 9 is a state diagram of the magnetic-disk evaluating apparatus prior to the start of evaluation. In this diagram, the magnetic disk 1 to be evaluated is clamped to the spindle motor 12. The magnetic disk 1 has temporary servo signals previously written thereto.

First, the spindle motor 12 is activated to rotate the magnetic disk 1, and the magnetic head 102 of the rotary positioner 104 is loaded on the magnetic disk 1 (no

diagram of loading process is shown). Since the apparatus has already been powered on to conduct the current through the voice coil 105 in one direction, the rotary positioner 104 rotates in the direction of an arrow i in Fig. 9 to abut the stopper 109 of the rotary positioner 104 against the lock pin 101 to thereby locate the rotary position 104 at its initial position.

In this state, the positioner rotating stage 100 is driven to an arbitrary position around the rotating shaft 106 to rotate the stopper 109 of the rotary positioner 104 together with the lock pin 101, thereby enabling the magnetic head 102 to move to an arbitrary position with a mechanism positioning accuracy (the positioning accuracy of the positioner rotating stage 100) without the need to control the magnetic head 102.

In this state, the configuration of the magnetic disk apparatus servo system shown in Figs. 13 to 15, described later, is used to cause the magnetic head 102 to read the temporary servo signals previously written on the magnetic disk 1 and to measure eccentricity caused by the chucking of the magnetic disk or the like, and to store it in memory.

Then, as shown in Fig. 10, the positioner rotating stage 100 in the state in Fig. 9 is rotated in the direction of the arrow j in Fig. 10 around the rotating shaft 106 to free the rotary positioner 104, thereby initiating a servo state. In the servo state, the positioner rotating stage 100 is rotated and at the same time, the current flowing through the voice coil 105 of the rotary positioner 104 in the one direction is cut off. Then, the position of the magnetic head 102 on the magnetic disk 1 is detected on the basis of the temporary servo signals reproduced from the magnetic head 102, so that positioning control is executed on the basis of the position detecting signal.

Since this position detecting signal contains the eccentricity of the magnetic disk 1, the eccentricity based on eccentricity data obtained and stored in the memory in the state in the above-described Fig. 9 is fed forward to cancel the eccentricity of the magnetic disk 1 in the position detecting signal. Only the resulting head position signal is fed back for positioning control. This enables the magnetic head 102 to be held on a concentric circle in the center of the spindle motor 12.

At this time, the displacement of the magnetic head 102 in the seek direction is measured using a measuring instrument such as the above-described laser Doppler vibrometer 53, in order to evaluate the settlability (displacement or fluctuation) of the tip of the measured magnetic head. Thus, the quality of the temporary servo signals can be numerically checked on the basis of the settlability to determine whether the temporary servo signals previously written to the magnetic disk 1 are acceptable. Whether the magnetic head can be positioned can be determined using actual servo signals, with the result of the determination of the acceptability of the temporary servo signals, before the magnetic disk is integrated into the HDD.

Furthermore, with the above-described laser Doppler vibrometer 53, a vibrating surface of a measuring target is irradiated with laser beams such as He-Ne laser beams so that reflected light obtained is utilized for measurements, thus requiring sufficient focusing. In the above evaluation method, however, the measured surface is the side of the magnetic head 102, so that the measured area is too small to facilitate the focusing of irradiation light. If the magnetic disk 1 is evaluated from its inner periphery to its outer periphery, the focusing operation is required for each evaluation; this is disadvantageous in terms of working efficiency. The operation shown in Fig. 11, however, resolves these problems.

Fig. 11(a) shows an example of the measurement of an inner radius portion of the magnetic disk 1, and Fig. 11(b) shows an example of measurement of an outer radius portion of the magnetic disk 1. The rotary positioner 104 is initially positioned at the position in Fig. 11(a), and the positioner rotating stage 100 is then rotated in the direction of the illustrated arrow k around the rotating shaft 106 to move the rotary positioner 104 to an outer radius portion as shown in Fig. 11(b).

At this time, the moving angle of the positioner rotating stage 100 is stored in the memory so that the measuring rotating arm 51 is then rotated through the same moving angle in the same direction as the positioner rotating stage (the direction of the arrow l in Fig. 11(b)) to correspondingly move the laser Doppler vibrometer 53. Accordingly, if measuring adjustment is executed once in the initial state in Fig. 11(a), the measuring position is automatically adjusted in Fig. 11(b), relieving the operator from the burden of readjustment.

In the servo state, however, the positioner rotating stage 100 actually rotates around the rotating shaft 106 in order to free up the rotary positioner 104, as described above.

Thus, as shown in the flow chart in Fig. 12, the following sequence is executed:

① while current is flowing through the voice coil 105 in one direction to rotate the rotary positioner 104, the measuring rotating arm 51 is moved through the same angle in the same direction as the positioner rotating stage 100 (steps S1→S2→S3→S5→S1)

② if the rotary positioner 104 is in the servo state to move the positioner rotating stage 100 in order to free the rotary positioner 104, then the moving direction and angle of the positioner rotating stage 100 are stored in memory (steps S1→S2→S6→S7→S2) so that when current flows through the voice coil 105 in one direction again, the measuring rotating arm 51 is moved using the moving direction and angle stored in the memory

(steps S3→S4→S5).

Subsequently, once the evaluation is finished, current starts to flow through the voice coil 105 in one direction to rotate the rotary positioner 104 in one direction, while rotating the positioner rotating stage 100 with the lock pin 101 installed thereon to carry the rotary positioner 104 to its unload position. Similarly, the evaluating magnetic head 102 is unloaded by executing the above described measuring method in the reverse order. Then, the spindle motor stops its rotation, and the stage 16 moves to its evaluation end position, thereby completing the series of servo tests.

#### Servo Method

Fig. 13 is a block diagram showing a configuration of a servo system relating to a servo method according to one embodiment of the present invention. In this embodiment, the magnetic disk 1 has temporary servo signals previously written thereto, as described above. After the magnetic disk 1 has been rotated and the rotary positioner 104 has been loaded thereon, the magnetic head 102 is held at an arbitrary position on the magnetic disk using the lock pin 101. In this state, the temporary servo signals are read by means of the magnetic head 102. In addition, the eccentricity caused by the chucking of the magnetic disk or the like is measured by means of an eccentricity measuring instrument 207, and the measured eccentricity is recorded in a memory 202. The eccentricity can be determined from track information and a PES (Position Error Signal, which indicates how far the head is separated from the center of a track) obtained by the servo demodulating circuit on the basis of detection signals for the above-described temporary servo signals.

Subsequently, the rotary positioner 104 is now free to enter the servo state. A position detecting section 206 detects the position of the rotary positioner 104 (that is,

the position of the magnetic head) on the basis of a signal from the magnetic head 102. This detection signal contains the eccentricity of the magnetic disk 1. An eccentricity  $d^*$  in the initial state obtained from the memory 202 is feed-forward-compensated to cancel the eccentricity  $d^*$  of the magnetic disk 1 contained in a position-detecting signal  $x+d$  from the position detecting section 206, so that the signal for the difference between the resulting head position signal and eccentricity is fed back to the rotary positioner 104 via a feedback compensator 203 and the power amplifier 10 for positioning control.

The feedback compensator 203 determines a drive signal to the rotary positioner 104 from an estimated speed value  $v^*$  obtained by a speed observer 204 and the above difference signal. The speed observer 204 can be easily composed of a gain compensator (gain  $K$ ) and an integrator (integral value  $1/s$ ) as follows:

[Equation 1]

$$v^* = K \times 1/s \times i \dots (1)$$

where

$$K = K_{AMP} \times K_t \times R_h/J \dots (2)$$

( $K_{AMP}$ : power amplifier gain,  $K_t$ : torque/current constant,  $R_h$ : positioner arm length,  $J$ : positioner inertia moment)

For simplification, the speed observer 204 may be omitted to limit feed back to the difference signal.

Fig. 14 shows a simulation model of a servo block, and Fig. 15 shows the simulation results. In Fig. 14, the rotary positioner 104 and the speed observer 204 are represented as functional blocks.

The speed observer 204 is composed of an arithmetic device 204b as the gain compensator (gain  $K$ ), an integrator 204c having an integral value  $1/s$ , and an amplifier

204a having the same gain as the power amplifier 10, which are connected in a series to implement the above-described equation (1).

The rotary positioner 104 consists of a well-known secondary delay system + a high-order resonance model; it is composed of the arithmetic devices 104a, 104b, and 104c that each perform a corresponding one of the illustrated operations, two integrators 104d and 104e, an adder 104f, and a high-order resonance model 104g to output a signal  $x$  indicative of the absolute position of the magnetic head.

An adder 208 adds the signal  $x$  to a value  $d$  corresponding to the eccentricity of the magnetic disk. That is, the eccentricity signal  $d$  is added to the signal  $x$  indicative of the absolute position of the positioner, to simulate a position signal obtained from the temporary servo signal. An adder 209 adds the value  $x+d$  to a value  $-d^*$  for canceling the eccentricity, to cancel the eccentricity of the magnetic disk.

The adder as the feedback compensator 203 adds the output  $x + (d - d^*)$  from the adder 209 and the output  $v^*$  from the speed observer 204 together via feedback gain amplifiers 210 and 211 to determine a positioner driving input. This driving input is supplied to the rotary positioner 104 for positioning the magnetic head, via the power amplifier 10 for converting the driving input into a current command and via a limiter 212 for limiting the current command obtained by the conversion, to a definite value.

For example, the input eccentricity  $d^*$  has a phase delayed by  $30^\circ$  relative to the eccentricity  $d$ . The feedback gains (position and speed feedback gains) of the feedback gain amplifiers 210 and 211 are determined using the pole placement method.

Fig. 15(a) represents the above eccentricity signal  $d$ , and Fig. 15(b) represents the signal  $x$  representative of the absolute position of the positioner as the output from the

rotary positioner 104 . A servo signal containing an eccentricity of  $\pm 100 \mu\text{m}$  of the value in Fig. 15(b) can be used to determine if the magnetic head 102 is held on a concentric circle (accuracy:  $0.1 \mu\text{m}$  or less).

Having described preferred embodiments of the invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications may be effected therein by one skilled in the art without departing from the scope or spirit of the invention as defined in the appended claims.

#### **Advantageous Effects of the Invention**

As described above, the present invention provides the following effects:

- (1) Whether the temporary servo signals are acceptable can be determined without writing the actual servo signals to the magnetic disk.
- (2) Whether the temporary servo signals are acceptable can be easily determined even if the magnetic head is moved to various positions.



## Claims

1. A magnetic-disk evaluating apparatus having the same configuration as that of an actual hard disk drive and comprising:

a base as a support table for the apparatus;

a spindle motor provided on said base to rotate, at an arbitrary rotation speed, the magnetic disk to be evaluated;

a magnetic head for recording and reproducing signals on and from said magnetic disk in order to evaluate the magnetic disk;

a thin suspension for supporting said magnetic head;

a thick rotary positioner for supporting said suspension;

a voice coil provided at one end of said rotary positioner located opposite to said magnetic head;

a rotating shaft installed so as to protrude from said base, for supporting said magnetic head, said suspension, and said rotary positioner; and

a pair of magnets sandwiching said voice coil, the apparatus being characterized by comprising:

control means being operative before evaluating performance of temporary servo signals previously written to said magnetic disk, to control driving of said rotary positioner on the basis of said temporary servo signals so that the magnetic head is positioned on a concentric circle in the center of said spindle motor;

measurement means for measuring displacement of said magnetic head in a seek direction;

detection means for detecting displacement of the tip of said magnetic head on the basis of the displacement in said seek direction measured by said measurement means; and

determination means for determining whether said temporary servo signals are acceptable, on the basis of said displacement detected by said detection means.



2. The magnetic-disk evaluating apparatus according to Claim 1, characterized in that the apparatus comprises:

fixation means for temporarily fixing said rotary positioner so that said magnetic head is located at an arbitrary position on said magnetic disk;

positioner rotating stage for supporting said fixation means and said rotary positioner and moving said rotary positioner, fixed by said fixation means, to an arbitrary position on said magnetic disk; and

a measuring rotating arm rotating around the same rotating center as that of said positioner rotating stage and depending on a movement angle of the positioner rotating stage, and in that:

said measurement means is installed on said measuring rotating arm.

3. The magnetic-disk evaluating apparatus according to Claim 1 or 2, characterized in that said measurement means is a laser Doppler vibrometer for measuring the displacement of said magnetic head in the seek direction by irradiating a side of said magnetic head with laser beams to receive light reflected therefrom.

4. The magnetic-disk evaluating apparatus according to Claim 2, characterized in that said control means comprises:

storage means for storing the eccentricity of said magnetic disc measured on the basis of a signal from said magnetic head reading said temporary servo signals while said rotary positioner is fixed by said fixation means;

cancel means for canceling the eccentricity of said magnetic disk in the signal from said magnetic head by receiving a feed forward input of the eccentricity stored in said storage means; and

feedback compensating means for generating a signal for feedback-controlling of said rotary positioner, from the signal sent from said cancel means and having the eccentricity canceled.



5. In a magnetic-disk evaluating apparatus having the same configuration as that of an actual hard disk drive and comprising a base as a support table for the apparatus, a spindle motor provided on said base to rotate, at an arbitrary rotation speed, the magnetic disk to be evaluated, a magnetic head for recording and reproducing signals on and from said magnetic disk in order to evaluate the magnetic disk, a thin suspension for supporting said magnetic head, a thick rotary positioner for supporting said suspension, a voice coil provided at an end of said rotary positioner located opposite to said magnetic head, a rotating shaft installed so as to protrude from said base, for supporting said magnetic head, said suspension, and said rotary positioner, and a pair of magnets sandwiching said voice coil, a magnetic-disk evaluating method being characterized by comprising:

a control step being operative before evaluating performance of temporary servo signals previously written to said magnetic disk, to control driving of said rotary positioner on the basis of said temporary servo signals so that the magnetic head is positioned on a concentric circle in the center of said spindle motor;

a measurement step of measuring displacement of said magnetic head in a seek direction;

a detection step of detecting displacement of the tip of said magnetic head on the basis of the displacement in said seek direction measured by said measurement means; and

a determination step of determining whether said temporary servo signals are acceptable, on the basis of said displacement detected by said detection means.

6. The magnetic-disk evaluating method according to Claim 5, characterized in that said measurement step comprises of detecting the displacement of said magnetic head by irradiating a side of said magnetic head with laser beams to receive light reflected therefrom.



7. The magnetic-disk evaluating method according to Claim 5 or 6, characterized in that said control step comprises:

a storage step of storing the eccentricity of said magnetic disc measured on the basis of a signal from said magnetic head reading said temporary servo signals while said rotary positioner is fixed;

a cancel step of canceling the eccentricity of said magnetic disk in the signal from said magnetic head by receiving a feed forward input of the eccentricity stored in said storage means; and

a feedback compensating step of generating a signal for feedback-controlling of said rotary positioner, from the signal having the eccentricity canceled at said cancel step.