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TITLE OF THE INVENTION

HEAD POSITION CALCULATION METHOD IN MAGNETIC DISC
APPARATUS

BACKGROUND OF THE INVENTION

5 The present invention relates to a magnetic disc apparatus such as a hard disc apparatus and, more particularly, to a method of calculating a head position on the basis of burst data recorded in advance on a disc.

10 For example, a magnetic disc apparatus 10 such as a hard disc apparatus generally has an arrangement shown in FIG. 1.

 That is, the magnetic disc apparatus 10 of this type includes a motor 13, a medium 12 attached to the motor 13, a carriage 15, a head 14 attached to the carriage 15, and a voice coil motor 16. Information is written to the medium 12 using the head 14, and read from the medium 12 using the head 14. The head 14 is driven to move via the carriage 15 by the voice coil motor 16 on the basis of servo information 17 written on the medium 12. That is, the read/write head 14 can obtain the information pertaining to its current position on the medium 12 on the basis of the servo information 17.

25 BRIEF SUMMARY OF THE INVENTION

 It is an object of the present invention to provide a head position calculation method capable of

easily calculating a current head position on a medium with high precision.

In order to achieve the above object, the present invention takes the following means.

5 According to an embodiment of, the present invention, a method comprises calculating a position of a head in a magnetic disc apparatus which has each of annular tracks as a unit of a recording area on a disc, performs positioning control of the head within
10 a tack range on the basis of four burst data A, B, C, and D recorded in advance in the tracks, and records/plays back data in/from the tracks using the head. Note that each of the tracks includes a plurality of annular sub-tracks in combination. Each
15 of the sub-tracks always has only two of the burst data A, B, C, and D. The sub-track having the burst data A and D, the sub-track having the burst data A and C, the sub-track having the burst data B and C, and the sub-track having the burst data B and D are
20 repeatedly arranged in this order. In this case, in accordance with equations (1) and (2), a value of a constant n is determined within a range of 1.2 (inclusive) to 1.8 (inclusive) so as to obtain
25 linearity between a position in a radial direction of the disc and a position P of the head in the radial direction of the disc in the sub-track. The position P of the head is then calculated using the determined

constant n and equations 1 and 2:

$$P = (A - B) * |A - B|^{(n - 1)} / (|A - B|^n + |C - D|^n) \dots (1)$$

$$P = (C - D) * |C - D|^{(n - 1)} / (|A - B|^n + |C - D|^n) \dots (2)$$

Note that the constant n is determined for each length of a component which is parallel to the disc surface and along the disc radial direction of the head.

According to the present invention, a head position calculation method capable of calculating a current head position on a medium with high precision can be implemented using only one calculation expression, without depending on track position.

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 an embodiment of the invention, and together with the general description given above and the detailed description of the embodiment given

below, serve to explain the principles of the invention.

FIG. 1 is a schematic view showing a general arrangement of a magnetic disc apparatus;

5 FIG. 2 is a view showing an example of a burst pattern;

FIG. 3 is a conceptual view of a track format for explaining a head positioning process on a medium;

10 FIG. 4 is a graph showing an example of the output characteristic of an ideal burst signal;

FIG. 5 is a graph showing an example of the output characteristic of a burst signal with saturation and distortion;

15 FIG. 6 is a graph showing an example wherein linearity between a disc radial direction and a head position along the disc radial direction in a sub-track is not maintained;

FIG. 7 is a conceptual view showing annular tracks on the medium;

20 FIG. 8A is a view showing an example of a relationship between a track width and a head effective length;

25 FIG. 8B is a view showing an example of the relationship between the track width and the head effective length;

FIG. 9 is a view showing an example of the relationship between the track width and the head

effective length; and

FIG. 10 is a graph showing a relationship in which linearity between the disc radial direction and the head position along the disc radial direction in the sub-track is maintained.

DETAILED DESCRIPTION OF THE INVENTION

The best mode for carrying out the present invention will be described below with reference to the accompanying drawing.

Note that the same reference numerals in this embodiment denote the same parts as in FIG. 1.

On a medium 12 shown in FIG. 1, a burst data pattern shown in FIG. 2 is recorded in advance in each track T (... , $T(N - 1)$, $T(N)$, $T(N + 1)$, ...) to perform the positioning calculation of a head 14. This burst data pattern includes burst data A, B, C, and D. The track T includes a plurality of annular sub-tracks $\underline{t}$ (e.g., t_1 to t_3) in combination. Each of the sub-tracks $\underline{t}$ always has only two of burst data A, B, C, and D. The sub-track having burst data A and D, the sub-track having burst data A and C, the sub-track having burst data B and C, and the sub-track having burst data B and D are repeatedly arranged in this order. When performing the positioning process of the head 14, these burst data are read by the head 14, and a head position detection calculation is performed using the read burst signal, thereby detecting the

position of the head 14 along the disc radial direction $\underline{r}$ in the sub-track $\underline{t}$.

More specifically, for example, as disclosed in Jpn. Pat. Appln. KOKAI Publication No. 9-282818, as
5 shown in FIG. 3, a target track T to be positioned is assumed as a cylinder code (N). First, when a position range is (0), bit 0 of the cylinder code (N) is confirmed. When bit 0 is "0", the head position is determined to be an even cylinder, and a burst
10 calculation is performed using a calculation expression $(B - A)/(B + A)$. Alternatively, when bit 0 is "1", the head position is determined to be an odd cylinder, and the burst calculation is performed using a calculation expression $(D - C)/(D + C)$.

15 However, in this head position calculation, the following problem arises.

That is, in the head position calculation disclosed in Jpn. Pat. Appln. KOKAI Publication No. 9-282818, two types of calculation expressions
20 must be properly used depending on whether the head position is an even or odd cylinder.

As shown in FIG. 4, the burst data ideally has an output characteristic so as to form the triangular wave of the burst signal along the Y-axis with respect
25 to the disc radial direction (track direction) along the X-axis.

However, as shown in FIG. 5, the actual magnetic

disc apparatus has the output characteristics such as saturation S and distortion M by various factors.

When the positioning calculation of the head 14 is performed using the burst signal having these output characteristics, the position is influenced by the saturation S and distortion M. As shown in FIG. 6, linearity between the disc radial direction $\underline{r}$ along the X-axis and the head position along the Y-axis cannot be maintained at an off-track position.

Hence, depending on the position of the track T, the head position calculation precision can decrease, and the position of the head 14 can be misidentified.

Accordingly, in the head position calculation method according to the embodiment of the present invention, as shown in FIG. 7, each of the annular tracks T (T(1), T(2), ..., T(N - 1), T(N), T(N + 1), ...) on the medium 12 is used as a unit of a recording area. As shown in FIG. 2, the positioning control of the head 14 is performed in the range of the track T on the basis of the four burst data A, B, C, and D recorded in advance in the track T. The position of the head 14 in the magnetic disc apparatus which records/plays back the data in/from the track T using the head 14 is then calculated.

In this case, as shown in FIG. 2, the track T includes the plurality of annular sub-tracks t_1 , t_2 , and t_3 in combination. FIG. 2 shows an example

wherein the track T includes the three sub-tracks t_1 , t_2 , and t_3 from the inner peripheral portion of the disc. However, the present invention is not limited to this. The number of sub-tracks may be set to other
5 than three.

Each of the sub-tracks $\underline{t}$ always has only two of the burst data A, B, C, and D. The sub-track $\underline{t}$ (e.g., sub-track t_1 (N + 1)) having burst data A and D, the sub-track $\underline{t}$ (e.g., sub-track t_2 (N + 1)) having burst
10 data A and C, the sub-track $\underline{t}$ (e.g., sub-track t_3 (N + 1)) having burst data B and C, and the sub-track $\underline{t}$ (e.g., sub-track t_1 (N)) having burst data B and D are repeatedly arranged in this order from the inner peripheral side.

In accordance with equations 1 and 2, the value
15 of constant $\underline{n}$ falls within the range of 1.2 (inclusive) to 1.8 (inclusive) so as to obtain linearity between the position in the disc radial direction $\underline{r}$ and the head position P along the disc
20 radial direction $\underline{r}$ in the sub-track $\underline{t}$. The position P of the head 14 is then calculated using the determined constant $\underline{n}$ and equations 1 and 2:

$$P = (A - B) * |A - B|^{(n - 1)} / (|A - B|^n + |C - D|^n) \dots (1)$$

$$25 \quad P = (C - D) * |C - D|^{(n - 1)} / (|A - B|^n + |C - D|^n) \dots (2)$$

Note that the constant $\underline{n}$ is determined for each

length (head effective length) of the component which is parallel to a disc surface and along the disc radial direction $\underline{r}$ of the head 14. The reason for determining the constant $\underline{n}$ for each head effective length will be described as follows. That is, in order to obtain the ideal burst signal output characteristic as shown in FIG. 4, the head effective length $\underline{h}$ must be greater than the width t_w of one sub-track $\underline{t}$ as shown in FIG. 8A. For example, as shown in FIG. 8B, when the head effective length $\underline{h}$ is less than the width t_w of one sub-track $\underline{t}$, a region in which only the burst data in the single sub-track $\underline{t}$ can be read is generated. As a result, as shown in FIG. 5, the output value of the burst signal does not change even when the disc radial direction $\underline{r}$ changes, and the saturation S and distortion M are generated.

Alternatively, the head effective length $\underline{h}$ must be equal to or less than the width T_w of the track T. However, the more the head effective length $\underline{h}$ approximates to the width T_w of the track T, the more the data is influenced by the burst data in an adjacent track T. As a result, the position calculation precision decreases.

From the above viewpoint, actually, the head effective length $\underline{h}$ is designed to be greater than the sub-track width t_w , and less than 1.5 times the sub-track width t_w . Note that since the disc is annular

and the head 14 is rectangular, as shown in FIGS. 8A and 8B, the front surface of the head 14 is not always parallel to the disc radial direction $\underline{r}$ in the track T. As shown in FIG. 9, in a given track T, the head 14 tilts with respect to the disc radial direction $\underline{r}$, and the head effective length $\underline{h}$ decreases.

Accordingly, actually, in consideration of this tilt, the head effective length $\underline{h}$ is designed to be greater than the sub-track width t_w , and less than 1.5 times the sub-track width t_w in any track T.

In the head effective length $\underline{h}$, the value of the constant $\underline{n}$ falls within the range of 1.2 (inclusive) to 1.8 (inclusive) in equations 1 and 2. When the constant $\underline{n}$ is changed in this range to obtain the relationship between the disc radial direction $\underline{r}$ (track direction) and the head position P along the disc radial direction $\underline{r}$ in the sub-track $\underline{t}$, as shown in FIG. 10, the characteristic to maintain linearity between the disc radial direction $\underline{r}$ along the X-axis, and the head position P along the disc radial direction $\underline{r}$ in the sub-track $\underline{t}$ along the Y-axis can be obtained. Note that the characteristic shown in FIG. 10 is obtained under the condition that the sub-track width = t_w , the head effective length $\underline{h} = 4/3 t_w$, and the constant $\underline{n} = \sqrt{2}$.

As described above, since linearity between the disc radial direction $\underline{r}$ and the head position P along

the disc radial direction $\underline{r}$ in the sub-track $\underline{t}$ is
obtained, the head position detection can be stably
performed regardless of the track T wherein the head
14 is positioned. That is, the positioning process
5 can be stably performed regardless of the head
position (on-track, off-track).

As described above, in the head position
calculation method according to the embodiment, the
constant $\underline{n}$ is so determined as to obtain linearity of
10 the head position detection result using equations 1
and 2, and the head position is calculated using the
constant $\underline{n}$ in equations 1 and 2. As a result, the
head position can be calculated with high precision
regardless of the head position (on-track and off-
15 track), thus performing the stable head positioning
process.

Additional advantages and modifications will
readily occur to those skilled in the art. Therefore,
the invention in its broader aspects is not limited to
20 the specific details and representative embodiment
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 method of calculating a position of a head
in a magnetic disc apparatus which has each of annular
tracks as a unit of a recording area on a disc,
5 performs positioning control of the head within a
track range on the basis of four burst data A, B, C,
and D recorded in advance in the tracks, and
records/plays back data in/from the tracks using the
head, the method comprising:

10 when each of the tracks includes a plurality of
annular sub-tracks in combination, each of the sub-
tracks always has only two of the burst data A, B, C,
and D, and the sub-track having burst data A and D,
the sub-track having burst data A and C, the sub-track
15 having burst data B and C, and the sub-track having
burst data B and D are repeatedly arranged in an order
named, in accordance with equations 1 and 2,
determining a value of a constant n within a range of
1.2 (inclusive) to 1.8 (inclusive) so as to obtain
20 linearity between a position in a radial direction of
the disc and a position P of the head in the radial
direction of the disc in the sub-track, and
calculating the position P of the head using the
determined constant n and equations 1 and 2:

$$25 \quad P = (A - B) * |A - B|^{(n - 1)} / (|A - B|^n + |C - D|^n) \\ \dots (1)$$

$$P = (C - D) * |C - D|^{(n - 1)} / (|A - B|^n + |C - D|^n) \dots (2)$$

2. A method according to claim 1, further comprising determining the constant n for each length of a component which is parallel to a disc surface and
5 along the disc radial direction of the head.