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MAGNETLESS ACTUATOR FOR DISC DRIVE**Related Applications**

The present application claims benefit of the United States
10 provisional patent application number 60/235,612, filed September 27,
2000.

Field of the Invention

15 The present invention relates to data storage devices. More
particularly, it relates to movement of rotary actuators for disc drives.

Background of the Invention

20 Typically, a disc drive includes an actuator arm with a magnetic
read/write head for writing and reading data with respect to a track of a
rotating disc. The actuator arm is arranged to turn on a pivot. The
read/write head is located at one end portion of the actuator arm. The
opposite end of the actuator arm generally acts as the rotor of an electric
25 motor such as a voice coil motor.

Upon current being driven through the voice coil, the actuator arm
rotates about the pivot thereby causing the magnetic head to move across
the surface of the disc until it is positioned above a desired track in order
that data may be written to or read from the track in question.

30 A voice coil is generally comprised of numerous components
including a permanent magnet, coil, top pole, bottom pole, metal injection
molding latch and latch bumper. The voice coil is typically assembled by
means of adhesive and screws used to couple the components together.
The number of components and the high degree of accuracy with which

5 they must be positioned in order to properly assemble them together adds considerably to the overall expense of the finished product. Furthermore, a lengthy baking step is included in the production process to cure various epoxies or other adhesives used to assemble the prior art voice coil
10 actuators. The baking step is undesirable as it is time-consuming, is a high consumer of energy and generates pollutant gases.

Attempts have been made to effect actuator movement through other arrangements so as to eliminate some of the disadvantages associated with conventional voice coil motors. For example, some have used a stator
15 having a permanent magnet at an actuator pivot point, while magnetic coils on the actuator interact with the stator so as to move the actuator. Others have mounted magnets on a rotor so as to cooperate with a coil wound on an arcuate stator core at the actuator pivot.

These actuators have problems of their own. Because an air gap is required between the rotor and stator, and because the stator serves as a
20 pivot point for the actuator, they typically impart undesirable pitch and roll torques to the actuator arm, which undermine the performance of the finished disc drive or require special design features to counteract them.

What the prior art has been lacking is an actuator drive which eliminates the problems associated with conventional voice coil motors
25 while maintaining the rotational stability of these arrangements.

Summary of the Invention

A preferred embodiment of the present invention is directed to a
30 magnetless rotary actuator for carrying one or more read/write heads across a data bearing medium. The rotary actuator includes a stator and a rotor. The stator includes a plurality of independently controllable flux generating elements for directing flux towards the rotor, and the rotor includes discrete regions of low magnetic reluctance to interact with the

5 flux generating elements. The actuator supports one or more read/write heads over the surface of a disc, and is pivotally mounted, so as to allow transmission of operative torque from the rotor to the read/write head(s).

These and various other features as well as advantages which characterize the present invention will be apparent upon reading of the
10 following detailed description and review of the associated drawings.

Brief Description of the Drawings

FIG. 1 is a simplified and somewhat schematic top view of a disc
15 drive incorporating an actuator according to an embodiment of the present invention.

FIG. 2 is an enlargement of a portion of FIG. 1.

FIG. 3 is a view similar to that of FIG. 2 wherein the rotor has pivoted clockwise.

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Detailed Description

FIG. 1 is a simplified, and somewhat schematic, top view of a disc drive incorporating an actuator according to a preferred embodiment of the
25 present invention. The disc drive 1 comprises an actuator 3 and a rotatable disc 4, both mounted on a base 5. The actuator 3 includes an arm 12 rotatably mounted to the base 5 by means of pivot assembly 14. At one end of actuator arm 12 there is a suspension assembly 8 which supports a read/write head 6 for reading data encoded in circular tracks on disc 4.
30 The suspension assembly 8 is made of stainless steel or some other material that does not affect the read/write head 6.

The actuator arm 12 is continuous with, or coupled to, a rotor 18. The rotor 18 is formed of a material that is magnetically permeable but preferably not readily magnetized. In one embodiment, where the actuator

5 3 includes a plurality of arms 12 for accessing a plurality of disc surfaces,
the rotor 18 is preferably formed of a piece of stamped hard iron. In this
embodiment, the actuator arms 12 are preferably formed of a lightweight
material such as aluminum. In another embodiment, where the actuator 3
includes only a single arm 12 for accessing a single disc 4, the rotor 18 and
10 actuator arm 12 may be formed from a single piece of hard iron.

The actuator arm 12 acts as a torque coupler for transmitting
operative torque from the rotor 18 to the suspension assembly 8 and
read/write head 6. The pivot assembly 14 may take the form of any
conventional pivot such as a bearing cartridge (not shown) which is well-
15 known for use in disc drives. The pivot assembly 14 is arranged to allow
pivoting of the actuator 3 about a pivot point 17 that preferably coincides
with the center of gravity of the actuator 3.

Projecting along the outer periphery of the rotor 18 away from the
pivot point 14 are rotor teeth 20A,...,20F best seen in FIG. 2. Six teeth 20 are
20 shown in the illustrated embodiment, though it should be understood that
varying numbers of teeth 20 may be provided without departing from the
spirit of the invention. As will be explained below, in operation the rotor
teeth 20 present discrete regions of low magnetic reluctance to stator 22
relative to air gap portions which separate the rotor teeth 20 and have
25 much higher reluctance than the rotor teeth 20.

Stator 22 is formed of a material that is easily magnetisable, such as
soft iron. Stator core 22 is of a generally arcuate shape having an inner
periphery with teeth 24A,...,24H protruding inwards towards the pivot
point 14 as shown. Eight teeth 24 are shown in the illustrated
30 embodiment, though it should be understood that varying numbers of
teeth 24 may be provided without departing from the spirit of the
invention.

Both the inner periphery of the stator 22 and the outer periphery of
rotor 18 are generally arcuate and with common centers at pivot point 17.

5 Around each of the stator teeth 24 is wound a coil 26A,...,26H. For ease of assembly, the coils 26 may be wound on plastic bobbins, not shown, which fit over the stator teeth 24.

 With reference to FIG. 1, each of the coils 26 may be energized by closing a corresponding pole of eight-way switch 30, thereby placing a
10 selected coil 26 between a current limited voltage source V and ground. Switch 30 is controlled by control module 34. Switch 30 and control module 34 are typically implemented by means of integrated circuit semiconductor device logic.

 As will be explained, the stator teeth 24 and coils 26 act as
15 independently controlled flux generating elements for directing flux across the gap between stator 22 and rotor 18.

 Control module 34 is arranged to control switch 30 in order to energize the coils in a manner that causes the actuator arm 12 to pivot so that read/write head 6 may be maintained on a desired track, or caused to
20 seek out a particular track of disc 4.

 The operation of the actuator 3 will now be explained with reference to FIGs. 2 and 3.

 In order to make rotor 18 move in the direction indicated by arrow 28, coil 26C is energized by closing a corresponding pole of switch 30. As
25 will be noted in FIG. 2, rotor tooth 20B is initially at a position overlapping stator tooth 24C by about 30% of its width as indicated by arrows 25. Upon energizing coil 26C a current flows through coil 24C which induces magnetic flux to flow across the air gap between stator tooth 24C and rotor tooth 20B forming a magnetic flux circuit, the return path being back across
30 the air gap through neighboring rotor and stator teeth. In response to initiation of the magnetic flux, a directed force is generated that tends to move the rotor 18 to a position that minimizes the variable part of the flux path, in the presently described case, the air gap, thus causing a rotational torque that pivots the rotor 18 to the position shown in FIG. 3.

5 As shown in FIG. 3, the rotor comes to rest at a position where rotor tooth 20B is maximally aligned with the energized stator tooth 24C thereby minimizing the reluctance of the air gap adjacent the energized coil.

 In the event that it is now necessary to rotate the stator counter-clockwise in the direction shown by arrow 33 then coil 26C is de-energized
10 whereas coil 26F is energized generating magnetic flux in response to which the rotor pivots tooth 20E into maximal alignment with stator tooth 20F.

 For optimal operation the starting overlap of a rotor tooth 20 and opposing stator tooth 24 should be in the range of 25-33% of the width of
15 the teeth.

 It will be realized that the angular separation of the rotor teeth 20 must be different to that of the stator teeth 24 so that the situation where all the stator teeth 24 are maximally aligned with corresponding rotor teeth 20 does not occur. In the preferred embodiment, the angular separation and
20 spacing of the rotor teeth 20 is about 36 degrees and that of the stator teeth 24 is about 24 degrees.

 Alternatively, preferred embodiments of the present invention may be described in terms of a magnetless rotary actuator 3 that is configured for carrying one or more read/write heads 6 across a data bearing medium
25 4. The magnetless rotary actuator 3 includes a stator 22 having a number of stator teeth 24 projecting toward a pivot point 17, with each of the stator teeth 20 having wound thereon an independently energizable coil 26. The magnetless rotary actuator 3 further includes a rotor 18 having a number of rotor teeth 20 projecting away from the pivot point 17 towards the stator
30 teeth 24 thereby defining a gap therebetween. Forming part of the magnetless rotary actuator 3 is an actuator arm 12 that is pivotable about the pivot point 17. The actuator arm 12 is coupled to the rotor 18 at a first end and to the read/write head 6 at a second opposite end.

5 Optionally, the actuator arm 12 is formed integrally with the rotor
18. The actuator arm 12 and the rotor 18 may be formed from a single piece
of hard iron. There may be a pivot assembly 14 supporting the actuator
arm 12 at the center of gravity of an actuator arm assembly that includes
the actuator arm 12 and the rotor 18. The read/write head 6 may be
10 coupled to the actuator arm 12 by means of a suspension assembly 8. In a
preferred embodiment, the magnetless rotary actuator 3 is incorporated
into a memory device for storing data readable by a computational device.
The data bearing medium 4 may be a magnetic medium where the memory
device includes a disc drive. The disc drive 1 may further include controller
15 means 34 operative to separately energize the coils 26.

As will be realized by those skilled in the art, embodiments of the
invention other than the preferred embodiment described in detail herein
are possible. Accordingly the following claims are not to be read as limited
by the preferred embodiment.

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Claims

1. A magnetless rotary actuator for carrying one or more read/write heads across a data bearing medium, the rotary actuator comprising:
 - a stator including a plurality of independently controllable flux
 - 10 generating elements;
 - a rotor including discrete regions of low magnetic reluctance for interacting with the flux generating elements;
 - an actuator arm for transmitting operative torque from the rotor to the read/write head; and
 - 15 a pivot assembly for rotatably supporting the actuator.
2. The actuator of claim 1, in which each flux generating element comprises a separately energizable coil.
- 20 3. The actuator of claim 2, in which each flux generating element further comprises a stator tooth extending toward the rotor, each coil being wrapped around a corresponding stator tooth.
4. The actuator of claim 1, in which each discrete region of low magnetic
- 25 reluctance comprises a rotor tooth projecting towards the stator.
5. The actuator of claim 1, in which the actuator arm is formed integrally with the rotor.
- 30 6. The actuator of claim 1, in which the rotor and actuator arm are formed of a single piece of hard iron.
7. The rotary actuator of claim 1, in which the pivot assembly supports the actuator at a center of gravity of an actuator.



- 5 8. A disc drive, comprising:
a base; and
the rotary actuator of claim 1 mounted to the base.
9. The disc drive of claim 8, further comprising:
- 10 a controller operative to separately energize each of the flux
generating elements.
10. A disc drive, comprising:
a base;
15 a disc rotatably mounted to the base;
a rotary actuator for carrying a read/write head over a surface of the
disc, the actuator being mounted to the base for rotation
about a pivot point, the actuator comprising:
a stator having a number of stator teeth projecting toward the
20 pivot point, each of the teeth having wound thereon an
independently energizable coil;
a rotor including a number of rotor teeth projecting away
from the pivot point towards the stator teeth thereby
defining a gap therebetween; and
25 an elongate actuator arm pivotable about the pivot point, the
arm being coupled to the rotor at a first end and
configured to be coupled to the read/write head at a
second opposite end.
- 30 11. The disc drive of claim 10, in which the actuator arm is formed
integrally with the rotor.
12. The disc drive of claim 10, in which the actuator arm and the rotor are
formed from a single piece of hard iron.



- 5 13. The disc drive of claim 10, further comprising:
 controller circuitry coupled to each coil.
14. The disc drive of claim 10, in which the pivot point is located at a center
of gravity of the actuator.
- 10 15. The disc drive of claim 10, further comprising:
 a suspension assembly coupled to the actuator; and
 a read/write head coupled to the suspension assembly.
- 15 16. A disc drive comprising:
 a base;
 an actuator rotatably mounted to the base about a pivot point; and
 means for moving the actuator about the pivot point.
- 20 17. The disc drive of claim 16, the moving means comprising:
 a stator mounted to the actuator.
18. The disc drive of claim 16, the moving means comprising:
 a magnetically permeable element protruding away from the pivot
25 point.
19. The disc drive of claim 16, the moving means comprising:
 a flux generating element protruding toward the pivot point.
- 30 20. The disc drive of claim 16, the moving means comprising:
 a plurality of independently energizable flux generating elements.