

TITLE

BRUSHLESS MOTOR AND DISK DRIVE APPARATUS

5 FIELD

The present invention relates to a brushless motor and a disk drive apparatus.

10 BACKGROUND

A hard disk device is equipped with a brushless motor for rotating a disk. A conventional brushless motor is disclosed in, e.g., SG185981. A permanent-magnet
15 synchronous motor of SG185981 includes a permanent magnet mounted to at least one of a top yoke and a bottom yoke and an armature arranged within an air gap between the permanent magnet and the other yoke.

A so-called axial gap structure in which an armature
20 and a permanent magnet are axially opposed to each other is sometimes more advantageous in thickness reduction than a so-called radial gap structure in which an armature and a permanent magnet are radially opposed to each other. However, the axial gap structure and the radial gap
25 structure essentially differ from each other in the arrangement of individual members within a motor. In order

to increase the drive efficiency of a motor, the axial gap structure needs to have a structural design differing from that of the radial gap structure.

5 SUMMARY

 A brushless motor in accordance with an illustrative first invention of the subject application includes a stationary unit and a rotary unit rotatably supported with
10 respect to the stationary unit through a bearing mechanism. The stationary unit includes an armature and a base member arranged to support the armature and a flat magnetic member. The flat armature lies radially outward of the bearing mechanism and extends in a direction orthogonal to a
15 vertically-extending center axis. The magnetic member makes contact with an upper surface of the armature and surrounding the center axis. The rotary unit includes a hub and a magnet. The hub includes a magnetic top plate portion and a magnetic hub protrusion portion extending downward
20 from the top plate portion. The magnet fixed to the hub and opposed to the upper surface of the armature. The armature includes a plurality of coil patterns arranged along a circumferential direction. The magnetic member has an outer peripheral portion arranged radially outward of an outer
25 circumferential surface of the magnet and the coil patterns.

 With the illustrative first invention of the subject

application, it is possible to prevent magnetic flux from being leaked radially outward beyond the magnetic member. The outer peripheral portion of the magnetic member is arranged radially outward of the outer circumferential surface of the magnet and the coil patterns. This restrains magnetic flux from being absorbed by the magnetic member. As a result, it becomes possible to increase the drive efficiency of the brushless motor.

A brushless motor in accordance with an illustrative second invention of the subject application includes a stationary unit and a rotary unit rotatably supported with respect to the stationary unit through a bearing mechanism. The stationary unit includes a flat armature and a base member arranged to support the armature. The armature lies radially outward of the bearing mechanism and extends in a direction orthogonal to a vertically-extending center axis. The rotary unit includes a hub, a magnet, and a rotor yoke. The hub includes a magnetic top plate portion and a magnetic hub protrusion portion extending downward from the top plate portion. The magnet is opposed to an upper surface of the armature. The rotor yoke is opposed to a lower surface of the armature. The bearing mechanism includes a lubricant existing between the stationary unit and the rotary unit. At least one of the stationary unit and the rotary unit includes a dynamic pressure groove array arranged to induce an axial dynamic pressure in the lubricant.

The base member includes a bottom plate portion, a substantially-cylindrical base protrusion portion, and a cylindrical surface. The bottom plate portion lies below the armature and extends in the direction orthogonal to the center axis. The base protrusion portion lies radially inward of the hub protrusion portion and extending upward from the bottom plate portion. The cylindrical surface is positioned radially outward of the rotor yoke. The lubricant has a liquid surface positioned radially inward of the hub protrusion portion. The rotor yoke is fixed to the hub protrusion portion. The base protrusion portion has an outer circumferential surface radially opposed to the hub protrusion portion or the rotor yoke through a first gap. The cylindrical surface is radially opposed to an outer peripheral portion of the rotor yoke through a second gap. The first gap has a radial dimension smaller than a radial dimension of the second gap.

With the illustrative second invention of the subject application, it is possible to restrain an air from flowing through the first gap. This reduces vaporization of the lubricant. As a result, it is possible to reduce rotation resistance in the bearing mechanism, thereby increasing the drive efficiency of the brushless motor.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description

of the preferred embodiments of the present invention with reference to the attached drawings.

BRIEF DESCRIPTION OF DRAWINGS

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Fig. 1 is a vertical section view showing a brushless motor according to a first preferred embodiment.

Fig. 2 is a vertical section view showing a disk drive apparatus according to a second preferred embodiment.

10 Fig. 3 is a vertical section view showing a brushless motor according to the second preferred embodiment.

Fig. 4 is a vertical section view showing a sleeve according to the second preferred embodiment.

15 Fig. 5 is a plan view of the sleeve according to the second preferred embodiment.

Fig. 6 is a partial vertical section view of the brushless motor according to the second preferred embodiment.

Fig. 7 is a partial vertical section view of the brushless motor according to the second preferred embodiment.

20 Fig. 8 is a plan view showing a stationary unit according to the second preferred embodiment.

Fig. 9 is a partial vertical section view showing a brushless motor according to one modified example.

25 Fig. 10 is a partial vertical section view showing a brushless motor according to another modified example.

DESCRIPTION OF EMBODIMENTS

Hereinafter, illustrative embodiments of the present invention will now be described with reference to the accompanying drawings. In the subject application, the direction parallel to the center axis of a brushless motor will be called "axial direction". The direction orthogonal to the center axis of the brushless motor will be referred to as "radial direction". The direction extending along an arc about the center axis of the brushless motor will be defined as "circumferential direction". In the subject application, the shape and positional relationship of the respective portions will be described under the assumption that the axial direction extends in the up-down direction and the permanent magnet is positioned at the upper side of the armature. However, the up-down direction is defined merely for the sake of convenience in description and is not intended to limit the direction in the manufacture and use of the brushless motor and the disk drive apparatus according to the present invention.

In the subject application, the term "parallel direction" is intended to include a substantially parallel direction. In the subject application, the term "orthogonal direction" is intended to include a substantially orthogonal direction.

<1. First Preferred Embodiment>

Fig. 1 is a vertical section view showing a brushless motor 11A according to a first preferred embodiment. As shown in Fig. 1, the brushless motor 11A includes a stationary unit 2A and a rotary unit 3A. The rotary unit 3A is rotatably supported with respect to the stationary unit 2A through a bearing mechanism 4A.

The stationary unit 2A includes a base member 21A, an armature 22A and a magnetic member 25A. The armature 22A is supported on the base member 21A. The armature 22A lies radially outward of the bearing mechanism 4A and extends in a plate-like shape in the direction orthogonal to the center axis 9A. The armature 22A includes a plurality of coil patterns 221A. The coil patterns 221A are arranged along the circumferential direction.

The base member 21A includes a bottom plate portion 51A, a base protrusion portion 52A and a cylindrical surface 55A. The bottom plate portion 51A lies below the armature 22A and extends in the direction orthogonal to the center axis 9A. The base protrusion portion 52A lies radially inward of a hub protrusion portion 62A to be described later and extends upward from the bottom plate portion 51A in a substantially cylindrical shape. The cylindrical surface 55A is positioned radially outward of a rotor yoke 35A to be described later.

The rotary unit 3A includes a hub 32A, a magnet 34A and a rotor yoke 35A. The hub 32A includes a magnetic top

plate portion 61A and a magnetic hub protrusion portion 62A. The hub protrusion portion 62A extends downward from the top plate portion 61A. The magnet 34A is fixed to the hub 32A. The magnet 34A is opposed to the upper surface of the armature 22A. The rotor yoke 35A is fixed to the hub protrusion portion 62A. The rotor yoke 35A is opposed to the lower surface of the armature 22A.

The magnetic member 25A is a flat member surrounding the center axis 9A. The magnetic member 25A makes contact with the upper surface of the armature 22A. The magnetic member 25A restrains magnetic flux from being leaked radially outward beyond the magnetic member 25A. In the brushless motor 11A, the outer peripheral portion of the magnetic member 25A is arranged radially outward of the outer circumferential surface of the magnet 34A and the coil patterns 221A. This restrains the magnetic member 25A from absorbing magnetic flux. As a result, it is possible to increase the drive efficiency of the brushless motor 11.

The bearing mechanism 4A includes a lubricant 41A existing between the members of the stationary unit 2A and the members of the rotary unit 3A. The liquid surface of the lubricant 41A is positioned radially inward of the hub protrusion portion 62A. At least one of the stationary unit 2A and the rotary unit 3A includes a dynamic pressure groove array 230A. When driving the brushless motor 11A, the dynamic pressure groove array 230A induces a dynamic

pressure in the lubricant 41A.

In the brushless motor 11A, the outer circumferential surface of the base protrusion portion 52A and the hub protrusion portion 62A or the rotor yoke 35A are radially opposed to each other through a first gap 81A. The cylindrical surface 55A and the outer peripheral portion of the rotor yoke 35A are opposed to each other through a second gap 82A. The radial dimension d1 of the first gap 81A is smaller than the radial dimension d2 of the second gap 82A. This restrains a gas from flowing through the first gap 81A. Accordingly, it is possible to restrain vaporization of the lubricant 41A. As a consequence, it becomes possible to reduce rotation resistance in the bearing mechanism 4A and to increase the drive efficiency of the brushless motor 11A.

Fig. 2 is a vertical section view showing a disk drive apparatus 1 according to a second preferred embodiment. The disk drive apparatus 1 performs information reading and writing tasks with respect to a magnetic disk 12 while rotating the magnetic disk 12. As shown in Fig. 2, the disk drive apparatus 1 includes a brushless motor 11, a magnetic disk 12, an access unit 13 and a cover 14.

The brushless motor 11 supports the magnetic disk 12 and rotates the magnetic disk 12 about the center axis 9. The brushless motor 11 includes a base member 21 extending radially at the lower side of the magnetic disk 12. The

rotary unit 3 of the brushless motor 11, the magnetic disk 12 and the access unit 13 are accommodated within a housing made up of the base member 21 and the cover 14. The access unit 13 displaces a head 131 along the recording surface of the magnetic disk 12 and performs information reading and writing tasks with respect to the magnetic disk 12. The base member 21 may be formed of a single member or an assembly including a plurality of members.

The disk drive apparatus 1 may include two or more magnetic disks 12. The access unit 13 may perform only one of information reading and writing tasks with respect to the magnetic disk 12.

Subsequently, description will be made on the configuration of the brushless motor 11. Fig. 3 is a vertical section view of the brushless motor 11. As shown in Fig. 3, the brushless motor 11 includes a stationary unit 2 and a rotary unit 3. The stationary unit 2 is kept stopped relative to the base member 21 and the cover 14. The rotary unit 3 is rotatably supported with respect to the stationary unit 2 through a bearing mechanism 4.

The stationary unit 2 of the present embodiment includes a base member 21, an armature 22, a sleeve 23, a cap 24 and a magnetic member 25.

The base member 21 supports the armature 22 and the sleeve 23. The base member 21 can be formed by casting metal, e.g., aluminum. As shown in Fig. 3, the base member

21 includes a bottom plate portion 51, a base protrusion portion 52, a base through-hole 53, an armature holding portion 54 and a cylindrical surface 55.

5 The bottom plate portion 51 lies below the armature 22 and extends in the direction orthogonal to the center axis 9. The base protrusion portion 52 extends upward in a substantially cylindrical shape from the inner periphery of the bottom plate portion 51. The base protrusion portion 52 is positioned radially inward of a hub protrusion portion 62
10 to be described later. The base through-hole 53 lies radially inward of the base protrusion portion 52 and extends in the up-down direction.

The armature holding portion 54 lies radially outward of a rotor yoke 35 to be described later and protrudes
15 upward from the bottom plate portion 51. The armature holding portion 54 includes a wall portion 541 and an annular surface 542. The wall portion 541 is radially opposed to the outer edge portion of the armature 22. The annular surface 542 extends radially inward from the lower
20 end of the wall portion 541. The armature 22 is arranged radially inward of the wall portion 541 and is supported on the annular surface 542. The outer edge portion of the armature 22 may be opposed to the wall portion 541 in a contacting relationship or in a radially spaced-apart
25 relationship with the wall portion 541.

The cylindrical surface 55 exists between the upper

surface of the bottom plate portion 51 and the annular surface 542 and extends axially in a substantially cylindrical shape. The cylindrical surface 55 is positioned radially outward of the rotor yoke 35 and is radially
5 opposed to the outer circumferential surface of a disc portion 71 to be described later.

The armature 22 is a flat circuit board extending in the direction orthogonal to the center axis 9. The armature 22 is arranged radially outward of the bearing mechanism 4,
10 below the magnet 34 to be described later and above the disc portion 71 of a rotor yoke 35 to be described later. The outer edge portion of the armature 22 is fixed to the armature holding portion 54 by a fixing means, e.g., an adhesive agent. The armature 22 includes a plurality of
15 electrically conductive coil patterns 221 arranged along the circumferential direction. Each of the coil patterns 221 is arranged in a helical shape about a coil axis extending in the axial direction.

The sleeve 23 extends axially in a substantially
20 cylindrical shape around a shaft 31 to be described later. The lower portion of the sleeve 23 is inserted into the base through-hole 53 and is fixed to the inner circumferential surface of the base protrusion portion 52. The inner circumferential surface of the sleeve 23 is radially opposed
25 to the outer circumferential surface of the shaft 31. The lower opening of the sleeve 23 is closed by the cap 24.

The rotary unit 3 of the present embodiment includes a shaft 31, a hub 32, an annular member 33, a plurality of magnets 34 and a rotor yoke 35.

5 The shaft 31 is a member extending in the axial direction. The shaft 31 is made of metal, e.g., stainless steel. The shaft 31 is supported on the sleeve 23 and the cap 24 through a lubricant 41 and is rotated about the center axis 9. The upper end portion of the shaft 31 protrudes upward beyond the upper surface of the sleeve 23.

10 The hub 32 includes a top plate portion 61, a hub protrusion portion 62 and a disk support portion 63. In the present embodiment, the hub 32 as a whole is made of a magnetic material. The top plate portion 61 lies above the armature 22 and extends radially and circumferentially. The radial inner edge portion of the top plate portion 61 is fixed to the upper end portion of the shaft 31. The hub protrusion portion 62 extends downward from the top plate portion 61 in a substantially cylindrical shape. The hub 32 may be formed of a single member or an assembly including a plurality of members.

15 The disk support portion 63 is arranged radially outward of the top plate portion 61 to support the magnetic disk 12. The disk support portion 63 includes a substantially cylindrical first support surface 631 and a second support surface 632 extending radially outward from the lower end of the first support surface 631. The inner

circumferential portion of the magnetic disk 12 makes contact with the first support surface 631. Thus the magnetic disk 12 is positioned in place in the radial direction. The lower surface of the magnetic disk 12 makes
5 contact with the second support surface 632. Accordingly, the magnetic disk 12 is positioned in place in the axial direction.

The annular member 33 is a circular ring-shaped member positioned radially inward of the hub protrusion portion 62.
10 The upper surface of the annular member 33 makes contact with the lower surface of the top plate portion 61. The radial outer surface of the annular member 33 is fixed to the inner circumferential surface of the hub protrusion portion 62 by press fit and/or by a fixing means such as an
15 adhesive agent.

A lubricant 41 exists between the combination of the sleeve 23 and the cap 24 and the combination of the shaft 31, the hub 32 and the annular member 33. The liquid surface of the lubricant 41 is positioned between the outer
20 circumferential surface of the sleeve 23 and the inner circumferential surface of the annular member 33. The shaft 31, the hub 32 and the annular member 33 are rotatably supported with respect to the sleeve 23 and the cap 24 through the lubricant 41. In the present embodiment, the
25 bearing mechanism 4 is made up of: the sleeve 23 and the cap 24 of the stationary unit 2; the shaft 31, the hub 32 and

the annular member 33 of the rotary unit 3; and the lubricant 41 existing therebetween. For example, polyol ester-based oil or diester-based lubricating liquid is used as the lubricant 41.

5 Fig. 4 is a vertical section view of the sleeve 23. As shown in Fig. 4, a radial dynamic pressure groove array 231 is provided on the inner circumferential surface of the sleeve 23. The radial dynamic pressure groove array 231 is formed into, e.g., a herringbone shape as shown in Fig. 4.
10 Upon driving the brushless motor 11, the radial dynamic pressure groove array 231 induces a radial dynamic pressure in the lubricant 41 existing between the sleeve 23 and the shaft 31. The shaft 31 is radially supported with respect to the sleeve 23 by the dynamic pressure thus induced.

15 Fig. 5 is a plan view of the sleeve 23. As shown in Fig. 5, a thrust dynamic pressure groove array 232 is provided on the upper surface of the sleeve 23. The thrust dynamic pressure groove array 232 is formed into, e.g., a herringbone shape. Upon driving the brushless motor 11, the
20 thrust dynamic pressure groove array 232 induces an axial dynamic pressure in the lubricant 41 existing between the sleeve 23 and the hub 32. The hub 32 is axially supported with respect to the sleeve 23 by the axial dynamic pressure thus induced. The thrust dynamic pressure groove array may
25 be, e.g., a spiral groove array for increasing a pressure at the radial inner side.

The radial dynamic pressure groove array 231 needs only to be provided on at least one of the inner circumferential surface of the sleeve 23 and the outer circumferential surface of the shaft 31. The thrust dynamic pressure groove array 232 needs only to be provided on at least one of the upper surface of the sleeve 23 and the lower surface of the top plate portion 61.

Referring back to Fig. 3, the magnets 34 are fixed to the lower surface of the top plate portion 61 of the hub 32 by means of, e.g., an adhesive agent. The magnets 34 are positioned above the armature 22. The lower surface of each of the magnets 34 is a magnetic pole surface axially opposed to each of the coil patterns 221 provided on the upper surface of the armature 22. The magnets 34 are arranged along the circumferential direction in such a way that the magnetic pole surfaces of N-pole and the magnetic pole surfaces of S-pole can be alternately arranged side by side. A single annular magnet alternately magnetized with N-poles and S-poles along the circumferential direction may be used in place of the magnets 34.

The rotor yoke 35 is a magnetic body rotating together with the hub 32 and the magnets 34. The rotor yoke 35 of the present embodiment includes a disc portion 71 and a yoke protrusion portion 72. The disc portion 71 is positioned below the armature 22, above the bottom plate portion 51 of the base member 21 and radially inward of the cylindrical

surface 55 of the base member 21. The disc portion 71 extends in a circular ring shape. The upper surface of the disc portion 71 is axially opposed to the lower surface of the armature 22. The yoke protrusion portion 72 lies
5 radially inward of the armature 22 and extends upward from the disc portion 71 in a substantially cylindrical shape. The yoke protrusion portion 72 is fixed to the hub protrusion portion 62.

In the brushless motor 11 described above, magnetic
10 flux axially penetrating the armature 22 is generated if a drive current is supplied to the coil patterns 221 of the armature 22. In addition, a magnetic circuit extending through the armature 22, the magnets 34, the hub 32 and the rotor yoke 35 is formed. Circumferential torque is
15 generated under the action of the magnetic flux. As a result, the rotary unit 3 is rotated about the center axis 9 with respect to the stationary unit 2. The magnetic disk 12 supported on the hub 32 is rotated about the center axis 9 together with the rotary unit 3.

20 Next, description will be made on the magnetic member 25.

Figs. 6 and 7 are partial vertical section views of the brushless motor 11. Fig. 8 is a plan view of the stationary unit 2. As shown in Figs. 6 and 8, the magnetic
25 member 25 is arranged on the upper surfaces of the base member 21 and the armature 22. The magnetic member 25 is a

flat member annularly surrounding the center axis 9. The magnetic member 25 is arranged in a substantially coaxial relationship with the center axis 9. The lower surface of the magnetic member 25 makes contact with the upper surface of the base member 21 and the upper surface of the armature 22.

The magnetic member 25 is made of a magnetic material such as iron or stainless steel. For that reason, a magnetic attraction force is generated between the magnetic member 25 and the magnets 34. The magnetic attraction force includes an axial component. The hub 32 is attracted toward the base member 21 by the magnetic attraction force generated between the magnetic member 25 and the magnets 34. As a result, the rotary unit 3 is stably supported with respect to the stationary unit 2.

Upon driving the brushless motor 11, the dynamic pressure induced by the thrust dynamic pressure groove array 232 applies an upwardly-acting pressure on the hub 32. The hub 32 is stably rotated under the influence of the upwardly-acting pressure applied by the dynamic pressure and the downwardly-acting magnetic attraction force applied by the magnetic member 25.

In case of a structure, e.g., the brushless motor 11, in which the armature 22 and the magnets 34 are axially opposed to each other, an axial magnetic attraction force and an axial magnetic repulsion force are alternately

generated between the armature 22 and the magnets 34. The magnetic attraction force and the magnetic repulsion force may cause vibration in the brushless motor 11. In the brushless motor 11 of the present embodiment, however, a
5 magnetic attraction force other than the magnetic attraction force and the magnetic repulsion force stated above is continuously generated between the magnetic member 25 and the magnets 34. This reduces vibration of the brushless motor 11.

10 As shown in Fig. 7, the sleeve 23 of the present embodiment includes a sleeve protrusion portion 233 protruding radially outward from the upper end portion of the sleeve 23. The lower surface of the sleeve protrusion portion 233 is axially opposed to the upper surface of the
15 annular member 33. As the hub 32 is attracted toward the base member 21 by the magnetic attraction force acting between the magnetic member 25 and the magnets 34, the upper surface of the annular member 33 and the lower surface of the sleeve protrusion portion 233 are restrained from making
20 contact with each other.

The magnetic member 25 restrains the magnetic flux generated between the armature 22 and the magnets 34 from being leaked radially outward beyond the magnetic member 25. If the leakage of the magnetic flux is restrained in this
25 manner, the magnetic flux is efficiently used between the armature 22 and the magnets 34. This increases the torque

constant representing the torque generation efficiency with respect to the drive current.

In the brushless motor 11, as shown in Fig. 6, the outer peripheral portion of the magnetic member 25 is arranged radially outward of the outer circumferential surfaces of the magnets 34 and the coil patterns 221. In other words, at least the outer peripheral portion of the magnetic member 25 does not exist between the lower surfaces of the magnets 34 and the coil patterns 221. This reduces the amount of magnetic flux absorbed by the magnetic member 25. Accordingly, the magnetic flux is efficiently used between the armature 22 and the magnets 34. This increases the torque constant of the brushless motor 11. In other words, it becomes possible to increase the drive efficiency of the brushless motor 11.

In the brushless motor 11, the minimum value of the distance between the lower surfaces of the magnets 34 and the upper surface of the magnetic member 25 is larger than the minimum value of the distance between the lower surfaces of the magnets 34 and the upper surfaces of the coil patterns 221. For that reason, the magnetic flux generated from the magnets 34 tends to flow toward the coil patterns 221 rather than toward the magnetic member 25. This further reduces the amount of magnetic flux absorbed by the magnetic member 25.

In the present embodiment, as shown in Figs. 6 and 8,

a portion of each of the coil patterns 221 is positioned radially outward of the inner peripheral portion of the magnetic member 25. This increases the area of the coil patterns 221. Thus it is possible to generate strong
5 magnetic flux in the coil patterns 221. Alternatively, the coil patterns 221 may be arranged only in the region existing radially inward of the inner peripheral portion of the magnetic member 25.

The magnetic member 25 of the present embodiment is a
10 member formed independently of the circuit board making up the armature 22. The magnetic member 25 extends over the upper surface of the base member 21 existing radially outward of the wall portion 541 and the upper surface of the armature 22. The magnetic member 25 is fixed to the upper
15 surface of the base member 21 and the upper surface of the armature 22 by means of, e.g., an adhesive agent. For that reason, the upward movement of the armature 22 is limited by the magnetic member 25.

In other words, the magnetic member 25 of the present
20 embodiment realizes a first function of attracting the rotary unit 3 downward, a second function of preventing radial outward leakage of the magnetic flux and a third function of restraining upward movement of the armature 22.

As shown in Fig. 6, the hub 32 of the present
25 embodiment includes a first lower surface 321, a second lower surface 322 and a step surface 323. The first lower

surface 321 lies above the magnets 34 and extends radially and circumferentially. The step surface 323 extends downward from the radial outer edge portion of the first lower surface 321 in a substantially cylindrical shape. The
5 second lower surface 322 extends radially outward from the lower end portion of the step surface 323. In other words, the second lower surface 322 is positioned radially outward of the first lower surface 321 and below the first lower surface 321.

10 The magnets 34 are fixed to the first lower surface 321 and the step surface 323 by an adhesive agent 80. In other words, the upper surfaces of the magnets 34 make contact with the first lower surface 321 through the adhesive agent 80. In addition, the outer circumferential
15 surfaces of the magnets 34 make contact with the step surface 323 through the adhesive agent 80.

In a hypothetical case that the lower surfaces of the magnets 34 are positioned higher than the second lower surface 322, the adhesive agent 80 is likely to spread
20 toward the lower surfaces of the magnets 34. In the present embodiment, however, the lower surfaces of the magnets 34 are positioned lower than the second lower surface 322. The adhesive agent 80 exists between the second lower surface 322 and the outer circumferential surfaces of the magnets 34.
25 This restrains the adhesive agent 80 from spreading toward the lower surfaces of the magnets 34.

In the brushless motor 11, the inner peripheral portion of the magnetic member 25 is positioned radially outward of the outer circumferential surfaces of the magnets 34. It is therefore possible to prevent contact between the magnets 34 and the magnetic member 25 while allowing the lower surfaces of the magnets 34 to protrude downward beyond the second lower surface 322. This makes it possible to have the armature 22 and the magnets 34 come close to each other in the axial direction. Accordingly, it is possible to increase the drive efficiency of the brushless motor 11. The second lower surface 322 may be positioned on at least one of the radial outer side and the radial inner side of the first lower surface 321.

As shown in Fig. 7, the outer circumferential surface of the base protrusion portion 52 and the inner circumferential surface of the hub protrusion portion 62 are radially opposed to each other through the first gap 81. The liquid surface 410 of the lubricant 41 exists in an internal space 83 surrounded by the upper surface of the base protrusion portion 52, the outer circumferential surface of the sleeve 23, the hub protrusion portion 62 and the annular member 33. A first gap 81 smaller in radial dimension than the internal space 83 exists between the internal space 83 and the external space of the brushless motor 11. This restrains a gas from flowing between the internal space 83 and the external space of the brushless

motor 11. As a result, it is possible to restrain vaporization of the lubricant 41.

If the vaporization of the lubricant 41 is restrained, the rotation resistance is hard to increase in the bearing mechanism 4. Moreover, the axial gap between the armature 22 and the magnets 34 becomes stable. Accordingly, it is possible to efficiently rotate the brushless motor 11. In other words, as compared with a case where the structure for restraining the vaporization of the lubricant 41 is absent, it is possible to increase the drive efficiency of the brushless motor 11.

On the other hand, as shown in Fig. 6, the cylindrical surface 55 of the base member 21 and the outer peripheral portion of the disc portion 71 of the rotor yoke 35 are radially opposed to each other through a second gap 82. In the brushless motor 11, the radial dimension $d1$ of the first gap 81 is smaller than the radial dimension $d2$ of the second gap 82. This restrains a gas from flowing through the first gap 81. It is therefore possible to restrain vaporization of the lubricant 41.

It is preferred that the radial dimension $d1$ of the first gap 81 be, 0.2 mm or less. In order to further restrain a gas from flowing through the first gap 81, it is preferred that the radial dimension $d1$ of the first gap 81 be, 0.15 mm or less.

In the present embodiment, the axial length $h1$ of the

first gap 81 shown in Fig. 7 is larger than the axial length h2 of the second gap 82 shown in Fig. 6. This further restrains a gas from flowing through the first gap 81.

5 In the present embodiment, as shown in Fig. 7, the annular member 33 is arranged radially inward of the hub protrusion portion 62. The liquid surface 410 of the lubricant 41 is positioned radially inward of the annular member 33. On the other hand, the first gap 81 is positioned radially outward of the outer circumferential
10 surface of the annular member 33. This increases the distance from the liquid surface 410 of the lubricant 41 to the first gap 81. As a result, the vaporization of the lubricant 41 is further restrained.

15 Features of the above-described preferred embodiments and the modifications thereof may be combined appropriately as long as no conflict arises.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those
20 skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

Fig. 9 is a partial vertical section view showing a
25 brushless motor 11B according to one modified example. In the example shown in Fig. 9, a magnetic member 25B is

embedded in a circuit board making up an armature 22B. In other words, the lower surface of the magnetic member 25B is positioned lower than the upper surface of the circuit board making up the armature 22B. This makes it possible to
5 reduce the axial thickness of the magnetic member 25B and the armature 22B as a whole. Accordingly, it is possible to further reduce the axial thickness of the brushless motor 11B.

Alternatively, the magnetic member may be formed
10 independently of the armature and may be arranged radially inward of the outer peripheral portion of the armature.

Fig. 10 is a partial vertical section view showing a brushless motor 11C according to another modified example. In the example shown in Fig. 10, a yoke protrusion portion
15 72C is arranged radially inward of a hub protrusion portion 62C. Thus a first gap 81C is provided between the base protrusion portion 52C and the yoke protrusion portion 72C. In other words, the outer circumferential surface of the base protrusion portion 52C and the inner circumferential
20 surface of the yoke protrusion portion 72C are radially opposed to each other through the first gap 81C.

This makes it possible to prevent the hub protrusion portion 62C from being displaced radially inward by the pressure applied when fixing the yoke protrusion portion 72C.
25 It is therefore possible to prevent radial inward displacement of the annular member 33C. By preventing

radial inward displacement of the annular member 33C, it is possible to accurately set the radial gap between the sleeve 23C and the annular member 33C near the liquid surface 410C of the lubricant 41C.

5 It is however preferred that, just like the second embodiment described above, the first gap 81 be provided between the outer circumferential surface of the base protrusion portion 52 and the inner circumferential surface of the hub protrusion portion 62. This is because variation
10 is hardly generated in the radial dimension of the first gap 81.

 The brushless motor of the present invention may be a so-called fixed-shaft motor in which a shaft belongs to a stationary unit and a sleeve belongs to a rotary unit. The
15 brushless motor and the disk drive apparatus of the present invention may be used to rotate a disk other than the magnetic disk, e.g., an optical disk.

 The specific shape of the respective members may differ from the shape shown in the respective figures of the
20 subject application.

 The respective elements appearing in the foregoing preferred embodiments and the modifications thereof may be combined appropriately as long as no conflict arises.

CLAIMS

1. A brushless motor, comprising:
a stationary unit; and
5 a rotary unit rotatably supported with respect to the stationary unit through a bearing mechanism,
wherein the stationary unit includes a flat armature lying radially outward of the bearing mechanism and extending in a direction orthogonal to a vertically-
10 extending center axis, a base member arranged to support the armature and a flat magnetic member making contact with an upper surface of the armature and surrounding the center axis,
the rotary unit includes a hub, which includes a
15 magnetic top plate portion and a magnetic hub protrusion portion extending downward from the top plate portion, and a magnet fixed to the hub and opposed to the upper surface of the armature,
the armature includes a plurality of coil patterns
20 arranged along a circumferential direction, and
the magnetic member has an outer peripheral portion arranged radially outward of an outer circumferential surface of the magnet and the coil patterns.
- 25 2. The brushless motor of claim 1, wherein the armature is a circuit board including the coil patterns, the magnetic

member being a member formed independently of the circuit board, the magnetic member extending over an upper surface of the base member and an upper surface of the circuit board.

- 5 3. The brushless motor of claim 1, wherein the armature is a circuit board including the coil patterns, the magnetic member being embedded in the circuit board.
4. The brushless motor of claim 1, wherein the hub includes a first lower surface making contact with an upper surface of the magnet and a second lower surface positioned on at least one of radial inner and outer sides of the first lower surface, the second lower surface is positioned lower than the first lower surface, the magnet having a lower surface positioned lower than the second lower surface, and an adhesive agent exists between the first lower surface and the magnet.
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5. The brushless motor of claim 1, wherein a minimum value of a distance between the magnet and the magnetic member is larger than a minimum value of a distance between the magnet and the coil patterns.
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6. The brushless motor of claim 1, wherein the magnetic member has a circular ring shape and is arranged in a
- 20

substantially coaxial relationship with the center axis.

7. The brushless motor of claim 1, wherein the bearing mechanism includes a lubricant existing between the stationary unit and the rotary unit, at least one of the stationary unit and the rotary unit including a dynamic pressure groove array arranged to induce an axial dynamic pressure in the lubricant.

8. A disk drive apparatus, comprising:
the brushless motor of claim 1;
an access unit arranged to perform at least one of information reading and writing tasks with respect to a disk supported on the rotary unit of the brushless motor; and
a cover making up a housing in cooperation with the base member, the rotary unit and the access unit being accommodated within the housing.

9. A brushless motor, comprising:
a stationary unit; and
a rotary unit rotatably supported with respect to the stationary unit through a bearing mechanism,
wherein the stationary unit includes a flat armature lying radially outward of the bearing mechanism and extending in a direction orthogonal to a vertically-extending center axis and a base member arranged to support

the armature,

the rotary unit includes a hub, which includes a magnetic top plate portion and a magnetic hub protrusion portion extending downward from the top plate portion, a
5 magnet opposed to an upper surface of the armature and a rotor yoke opposed to a lower surface of the armature,

the bearing mechanism includes a lubricant existing between the stationary unit and the rotary unit,

at least one of the stationary unit and the rotary
10 unit includes a dynamic pressure groove array arranged to induce an axial dynamic pressure in the lubricant,

the base member includes a bottom plate portion lying below the armature and extending in the direction orthogonal to the center axis, a substantially-cylindrical base
15 protrusion portion lying radially inward of the hub protrusion portion and extending upward from the bottom plate portion and a cylindrical surface positioned radially outward of the rotor yoke,

the lubricant has a liquid surface positioned radially
20 inward of the hub protrusion portion,

the rotor yoke is fixed to the hub protrusion portion,

the base protrusion portion has an outer circumferential surface radially opposed to the hub protrusion portion or the rotor yoke through a first gap,

25 the cylindrical surface is radially opposed to an outer peripheral portion of the rotor yoke through a second

gap, and

the first gap has a radial dimension smaller than a radial dimension of the second gap.

5 10. The brushless motor of claim 9, wherein the first gap has an axial length larger than an axial length of the second gap.

10 11. The brushless motor of claim 9, wherein the outer circumferential surface of the base protrusion portion is radially opposed to an inner circumferential surface of the hub protrusion portion through the first gap.

15 12. The brushless motor of claim 9, wherein the rotary unit further includes an annular member positioned radially inward of the hub protrusion portion,

the liquid surface of the lubricant is positioned radially inward of the annular member, and

20 the first gap is positioned radially outward of an outer circumferential surface of the annular member.

13. The brushless motor of claim 9, wherein the first gap has a radial dimension of 0.2 mm or less.

25 14. A disk drive apparatus, comprising:
the brushless motor of claim 9;

an access unit arranged to perform at least one of information reading and writing tasks with respect to a disk supported on the rotary unit of the brushless motor; and

5 a cover making up a housing in cooperation with the base member, the rotary unit and the access unit being accommodated within the housing.