# Exhibit
# A

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(12) **United States Patent**
**Abe**

(10) **Patent No.: US 8,737,017 B1**
(45) **Date of Patent: May 27, 2014**

(54) **SPINDLE MOTOR AND DISK DRIVE APPARATUS**

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(72) Inventor: **Hiroyuki Abe**, Kyoto (JP)

(73) Assignee: **Nidec Corporation**, Kyoto (JP)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/804,726**

(22) Filed: **Mar. 14, 2013**

**Related U.S. Application Data**

(60) Provisional application No. 61/727,886, filed on Nov. 19, 2012.

(30) **Foreign Application Priority Data**

Nov. 19, 2012 (JP) ................................ 2012-252876

(51) **Int. Cl.**
***G11B 19/20*** (2006.01)

(52) **U.S. Cl.**
USPC ........................................................ **360/99.08**

(58) **Field of Classification Search**
CPC ........................................................ G11B 5/39
USPC ........................................................ 360/99.08
See application file for complete search history.

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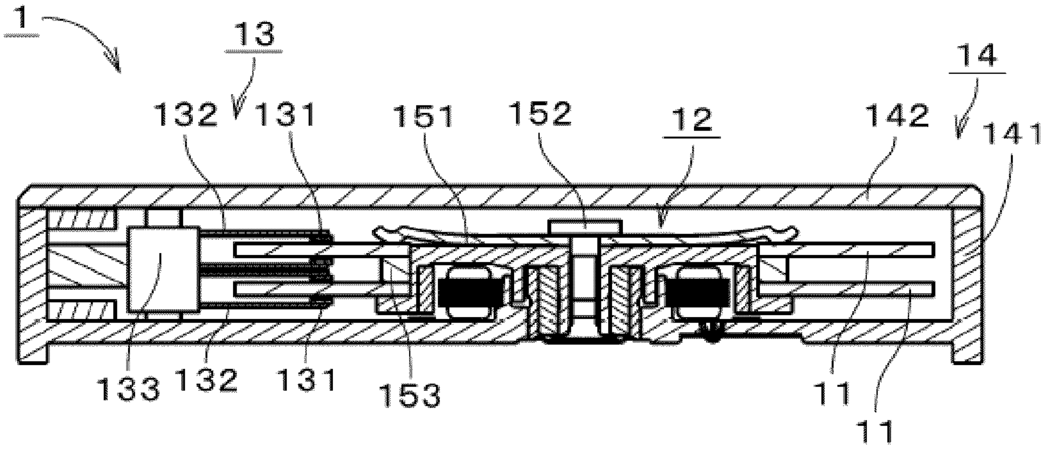
*Primary Examiner* — Mark Blouin
(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

A spindle motor of a disk drive apparatus includes a base unit, a stator core, a covered cylindrical rotor hub, a rotor magnet, and a bearing mechanism. The height of the stator core in an axial direction is about 50% or more and about 70% or less of the height of the stator. A torque constant Kt of torque generated between a stator and a rotor magnet is about 4 mN·m/A or more and about 6 mN·m/A or less. A motor constant Km is about 2 mN·m/(A·√Ω) or more and about 4 mN·m/(A·√Ω) or less.

**16 Claims, 28 Drawing Sheets**



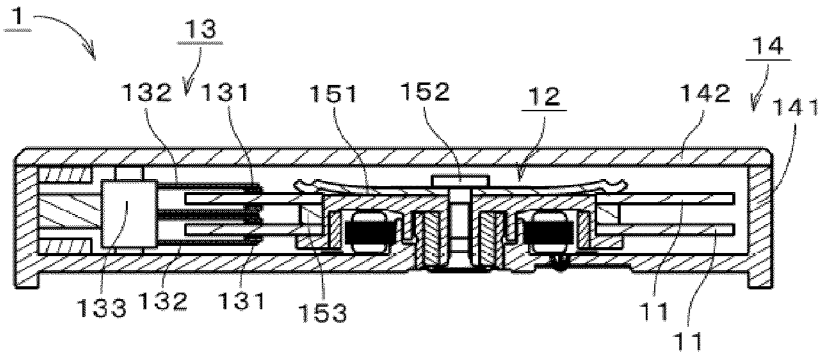
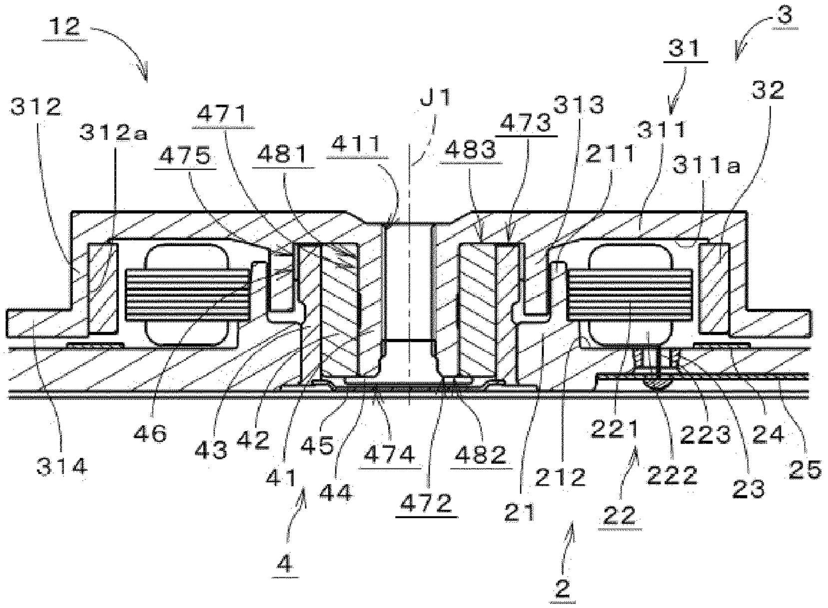


Fig. 1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471
J1
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311a
46
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42
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474
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212
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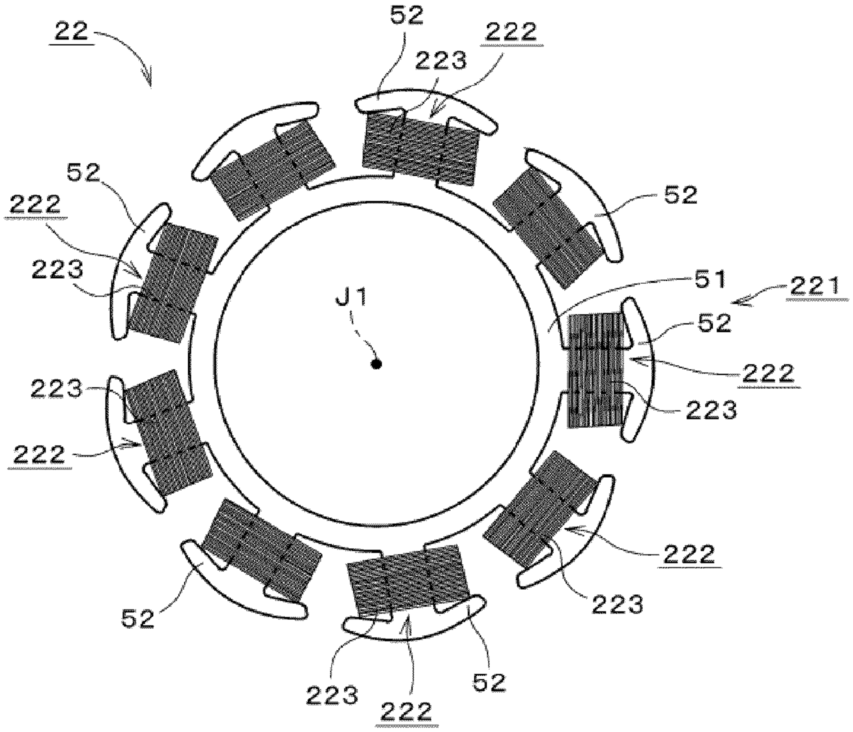
25
23
472
21
22
4
2

Fig. 2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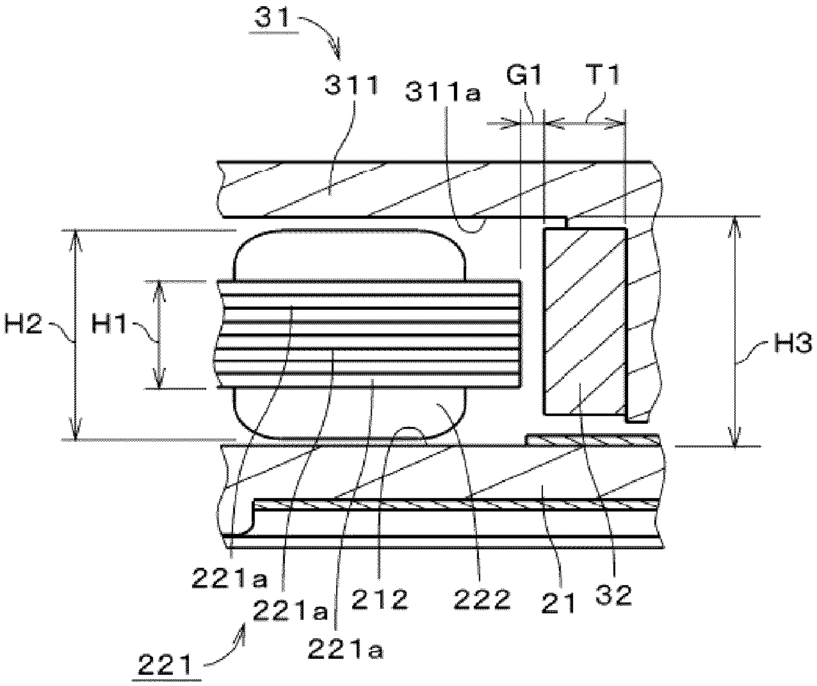
222
52

Fig. 3



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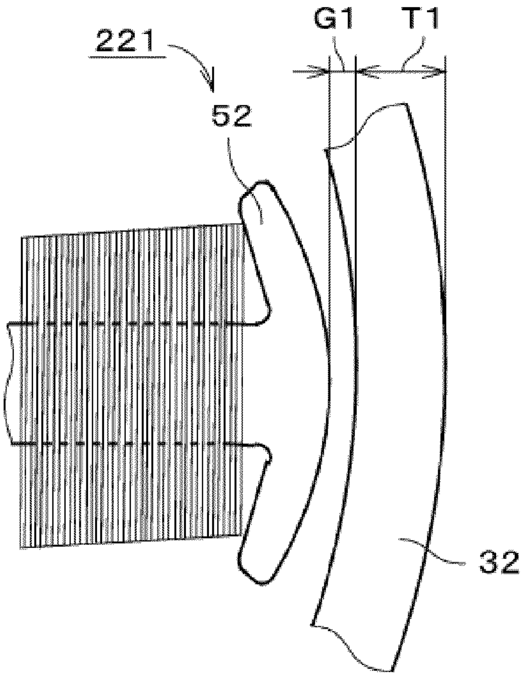

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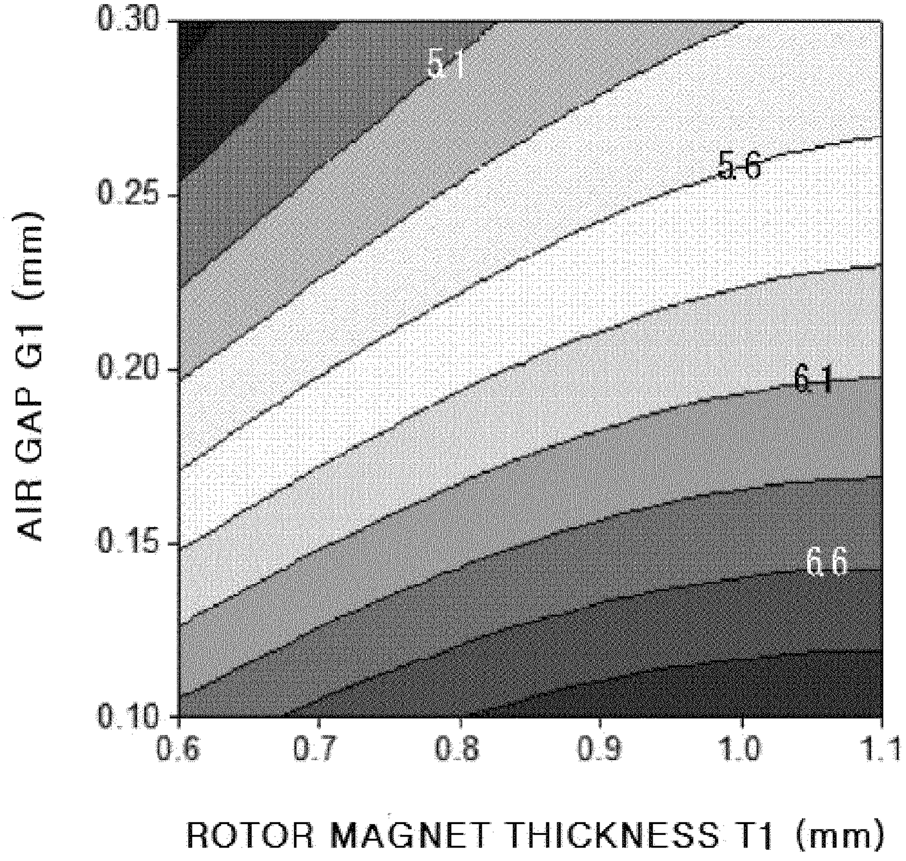
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0.10
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5.1
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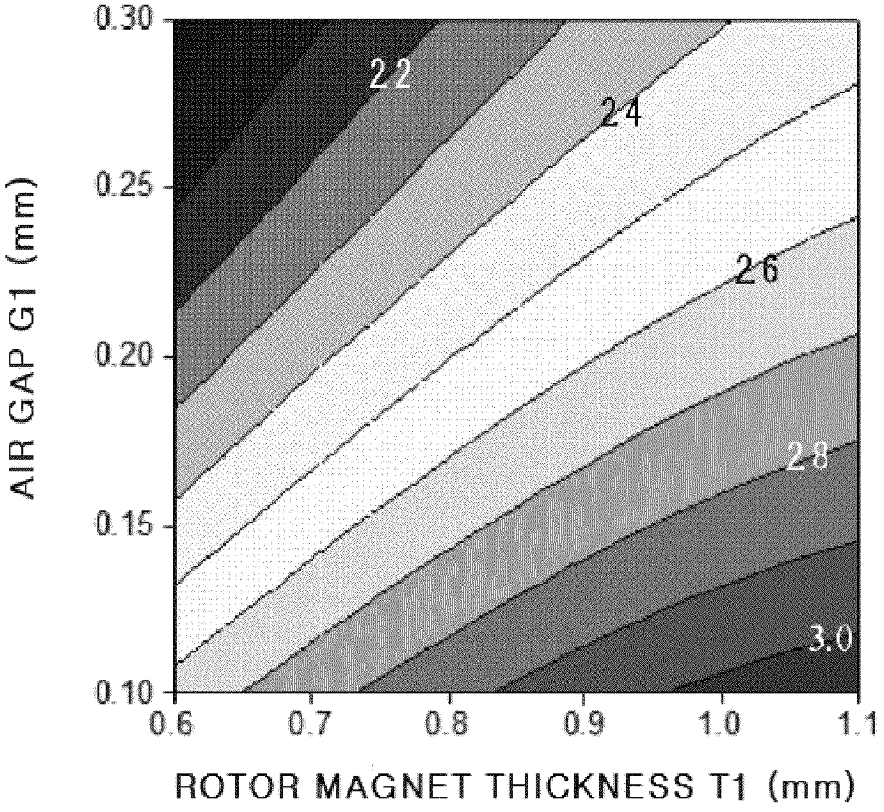
0.8
0.9
1.0
1.1
ROTOR MAGNET THICKNESS T1 (mm)

Fig. 6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0.25
0.20
0.15
0.10
AIR GAP G1 (mm)
2.2
2.4
2.6
2.8
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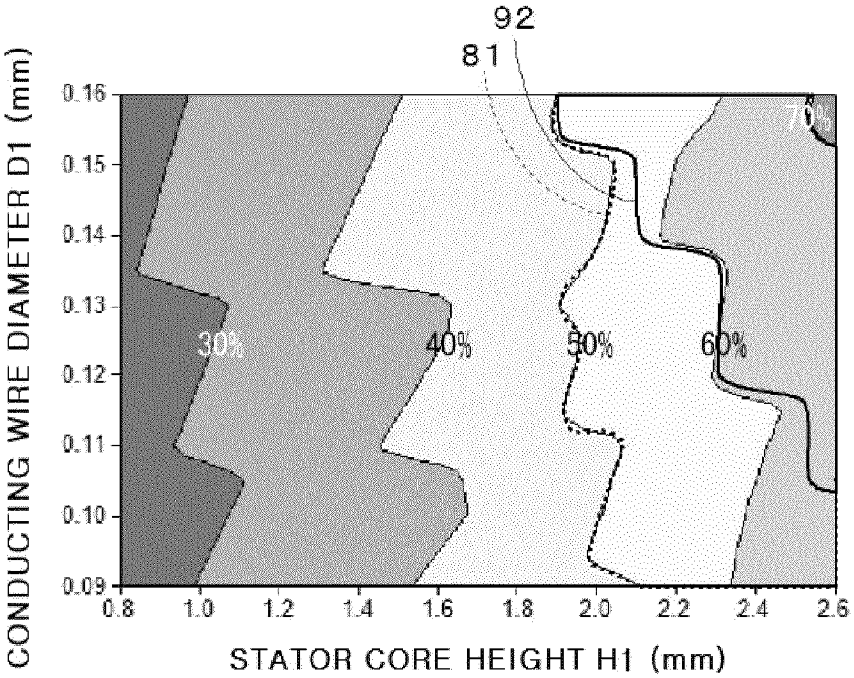
0.6
0.7
0.8
0.9
1.0
1.1
ROTOR MAGNET THICKNESS T1 (mm)

Fig. 7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81
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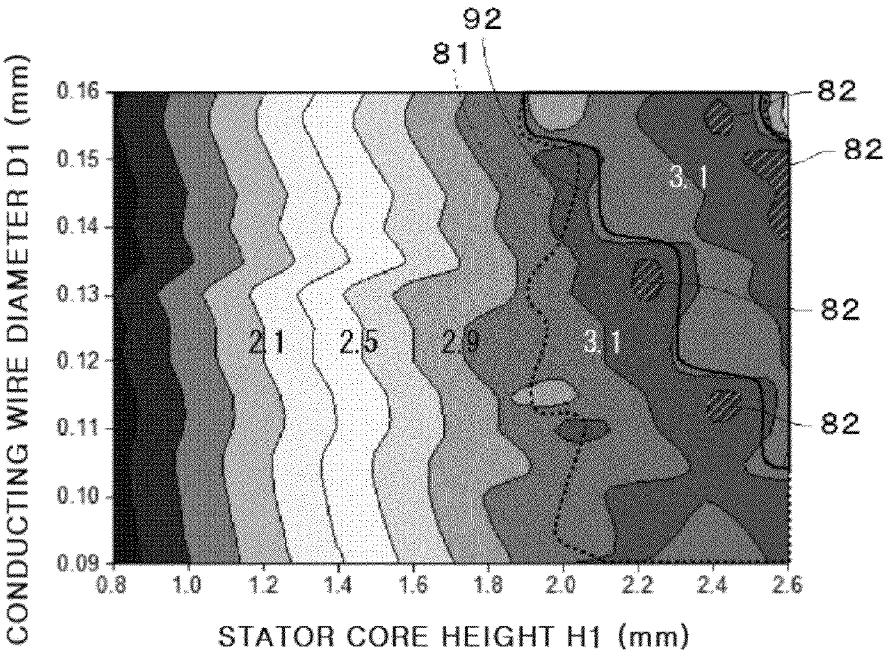
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
STATOR CORE HEIGHT H1 (mm)
30%
40%
50%
60%
70%

Fig. 8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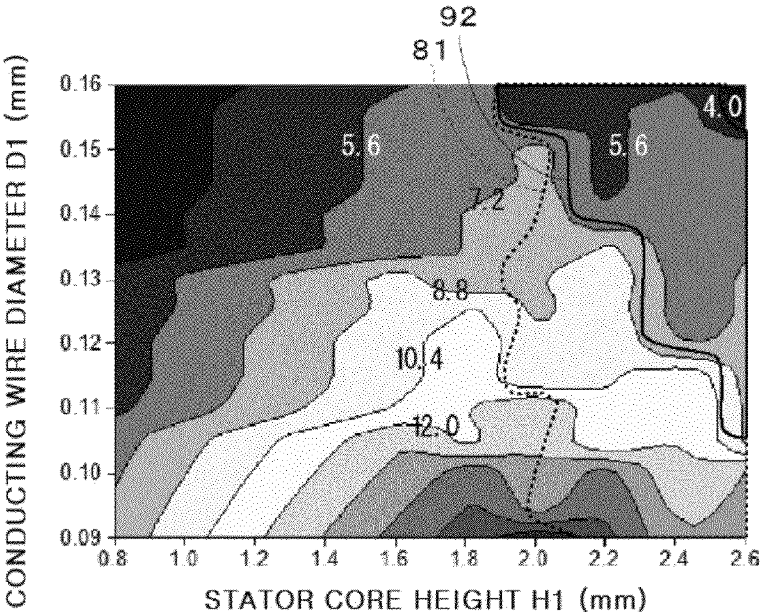
0.12
0.11
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
CONDUCTING WIRE DIAMETER D1 (mm)
STATOR CORE HEIGHT H1 (mm)

Fig. 9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0.15
0.14
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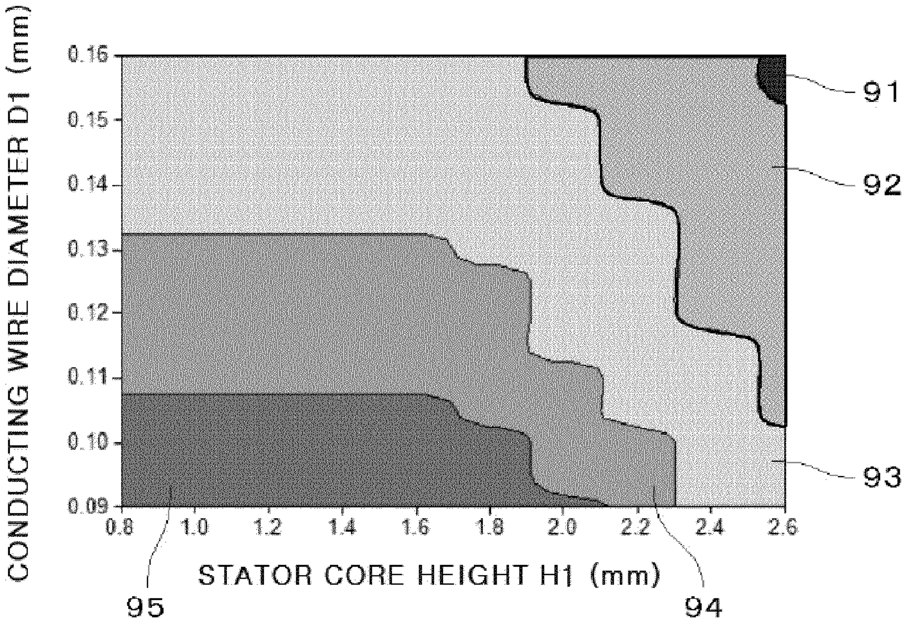
0.12
0.11
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
STATOR CORE HEIGHT H1 (mm)
CONDUCTING WIRE DIAMETER D1 (mm)

Fig. 10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0.14
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0.12
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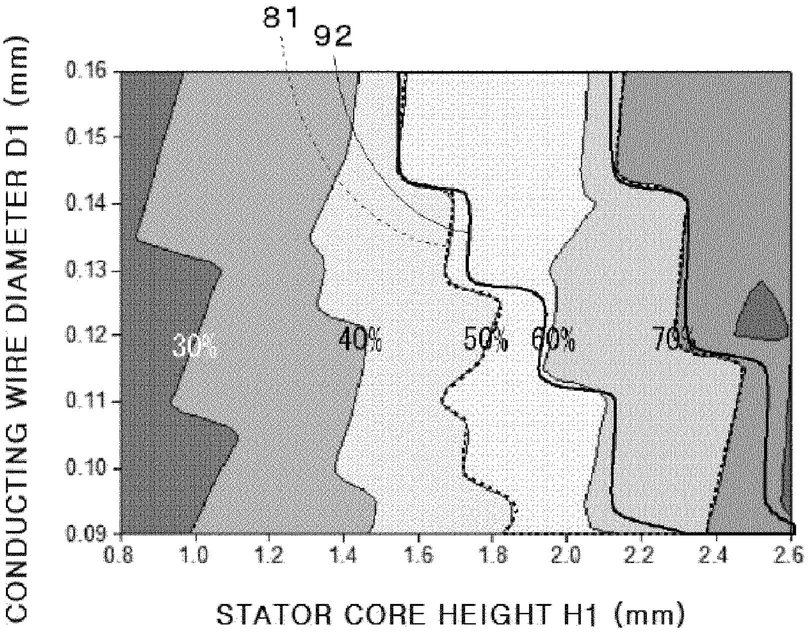
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
STATOR CORE HEIGHT H1 (mm)
91
92
93
94
95

Fig. 11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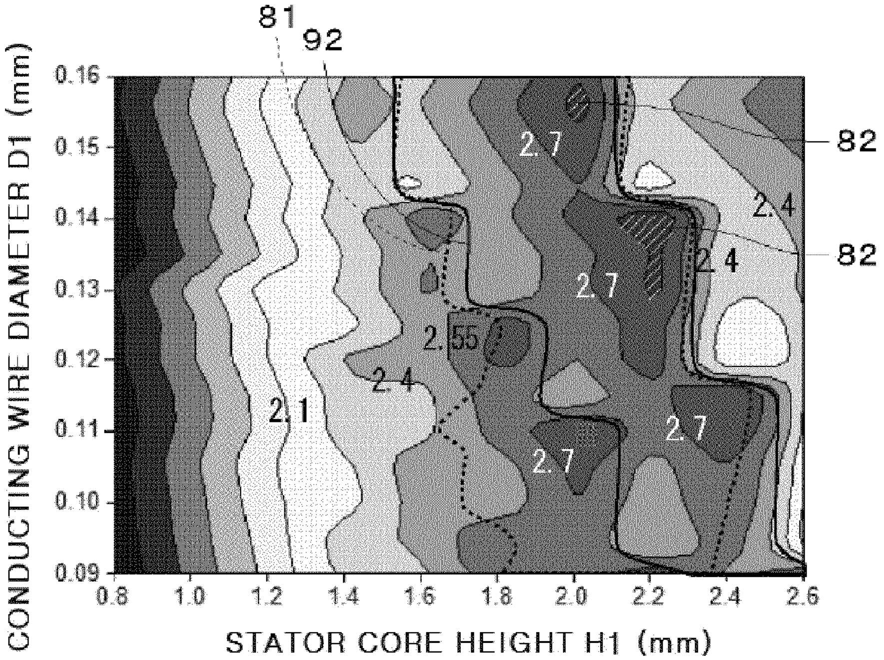
92
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
30%
40%
50%
60%
70%
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
CONDUCTING WIRE DIAMETER D1 (mm)
STATOR CORE HEIGHT H1 (mm)

Fig. 12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0.13
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0.11
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.1
2.4
2.55
2.7
2.7
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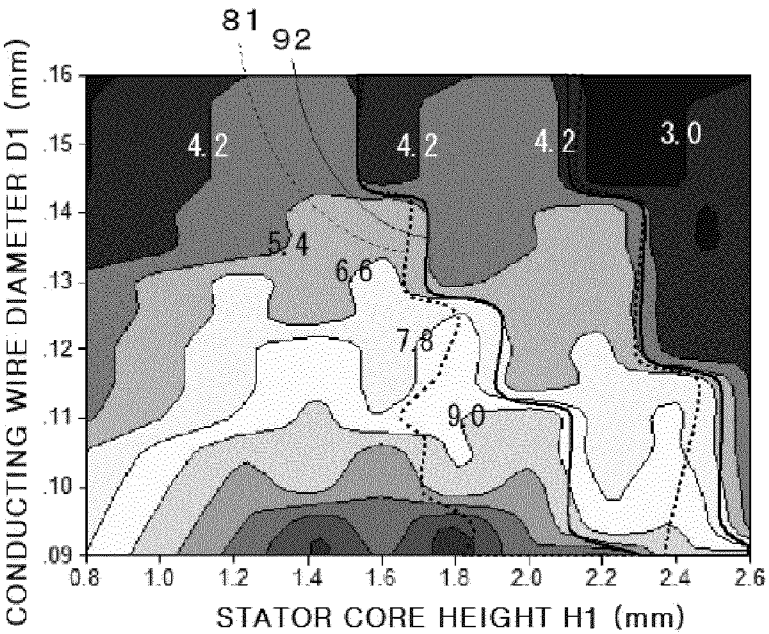
2.4
2.4
2.7
CONDUCTING WIRE DIAMETER D1 (mm)
STATOR CORE HEIGHT H1 (mm)

Fig. 13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92
4.2
4.2
4.2
3.0
5.4
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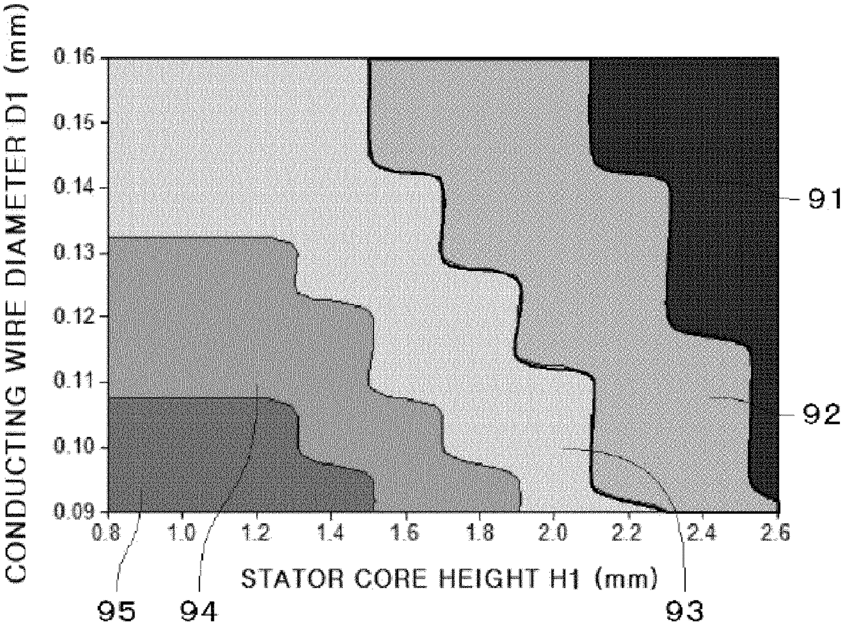
7.8
9.0
.16
.15
.14
.13
.12
.11
.10
.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
CONDUCTING WIRE DIAMETER D1 (mm)
STATOR CORE HEIGHT H1 (mm)

Fig. 14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0.14
0.13
0.12
0.11
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
STATOR CORE HEIGHT H1 (mm)
91
92
93
94
95

Fig. 15

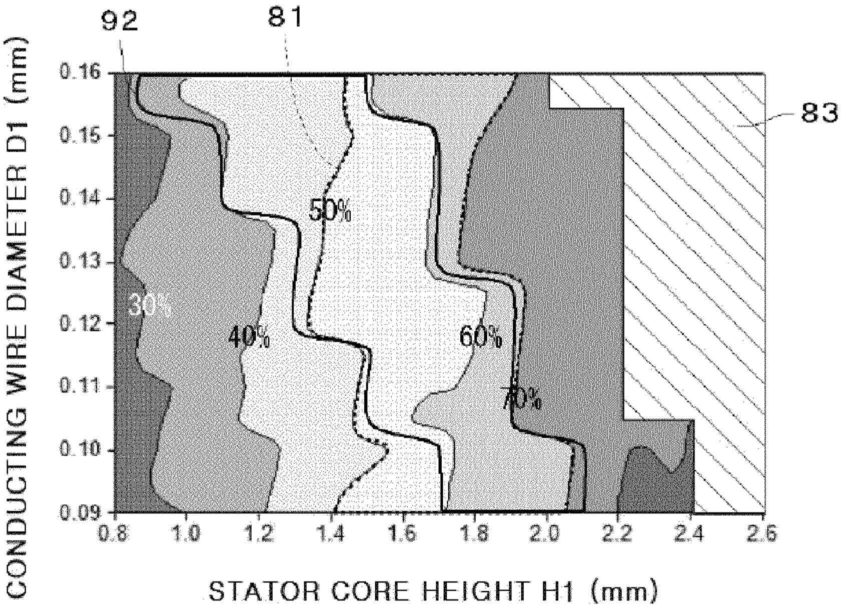
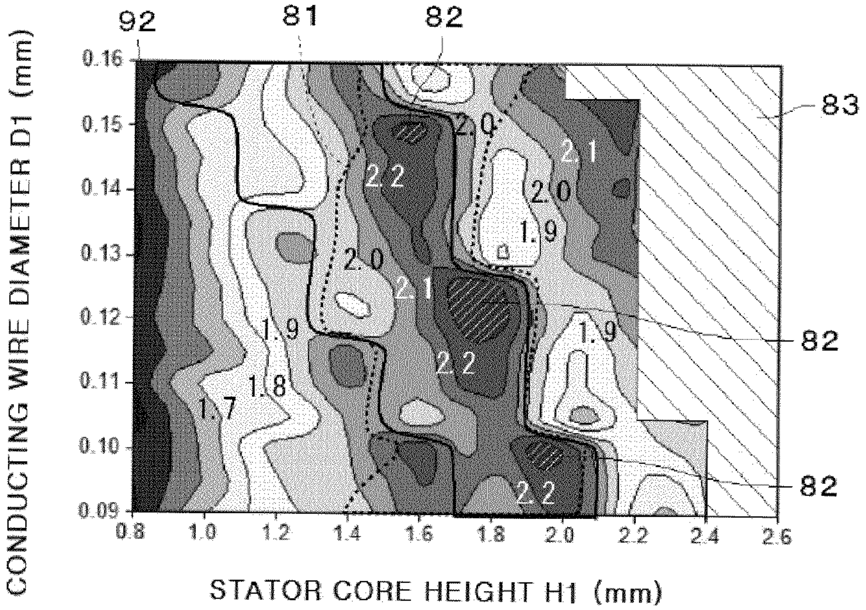

92
81
83
CONDUCTING WIRE DIAMETER D1 (mm)
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
30%
40%
50%
60%
70%
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
STATOR CORE HEIGHT H1 (mm)

Fig. 16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83
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0.13
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0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
1.7
1.8
1.9
2.0
2.1
2.2
2.0
2.1
2.0
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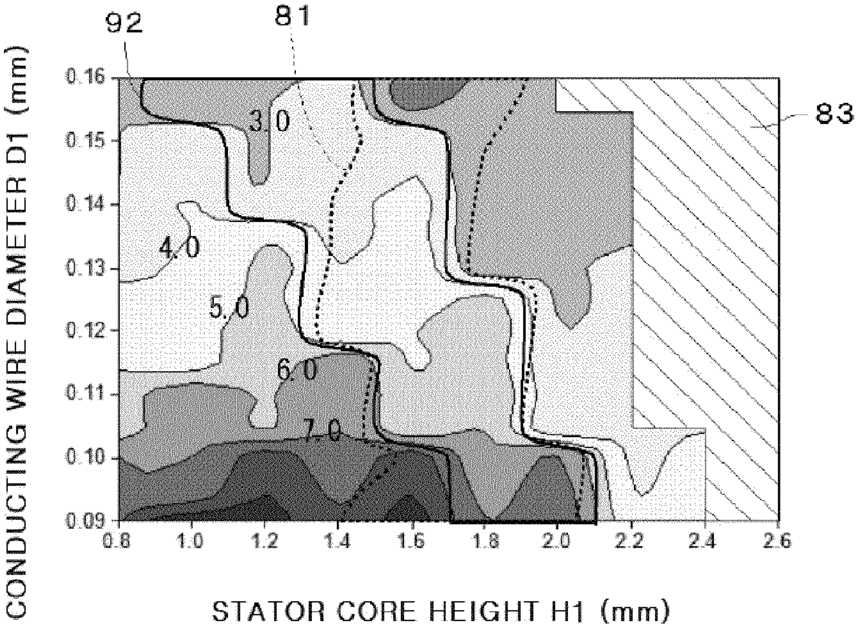
2.2
2.2
CONDUCTING WIRE DIAMETER D1 (mm)
STATOR CORE HEIGHT H1 (mm)

Fig. 17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3.0
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7.0
0.16
0.15
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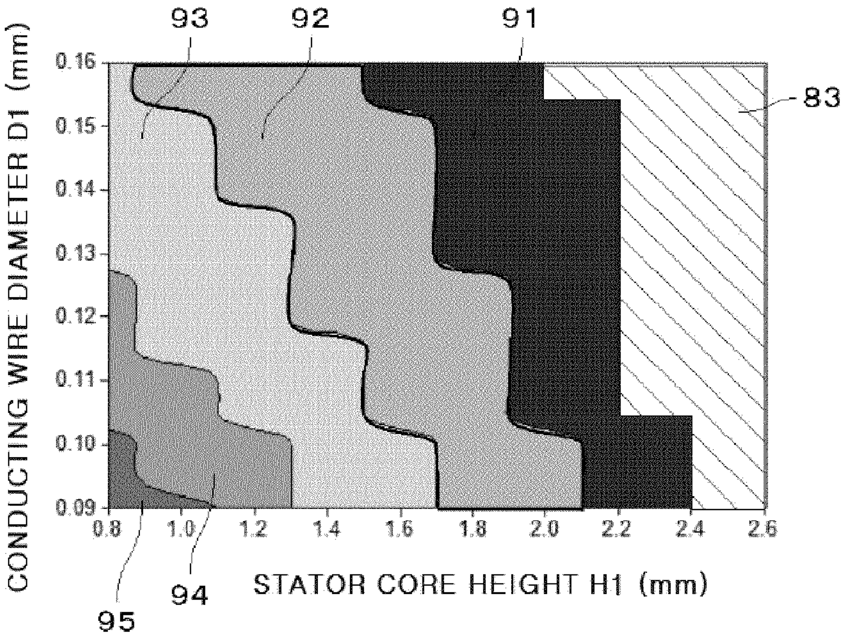
0.11
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
CONDUCTING WIRE DIAMETER D1 (mm)
STATOR CORE HEIGHT H1 (mm)

Fig. 18


93
92
91
83
CONDUCTING WIRE DIAMETER D1 (mm)
0.16
0.15
0.14
0.13
0.12
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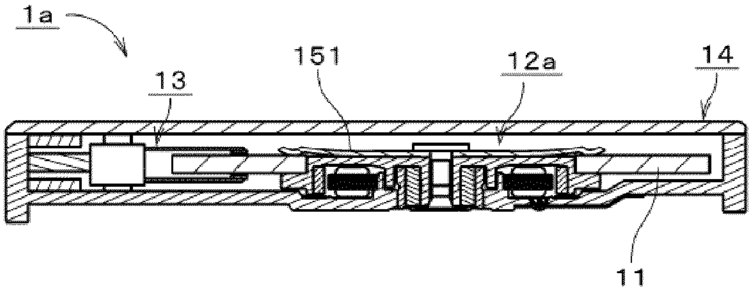
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
STATOR CORE HEIGHT H1 (mm)
94
95

Fig. 19



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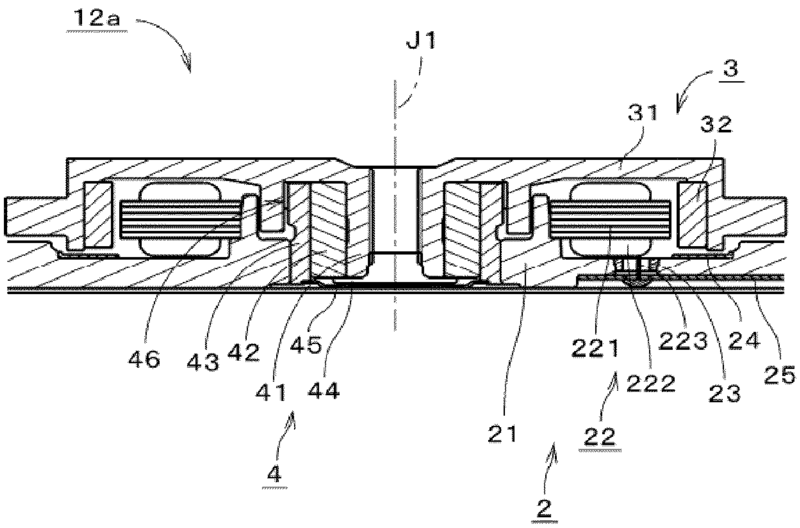


Fig. 21

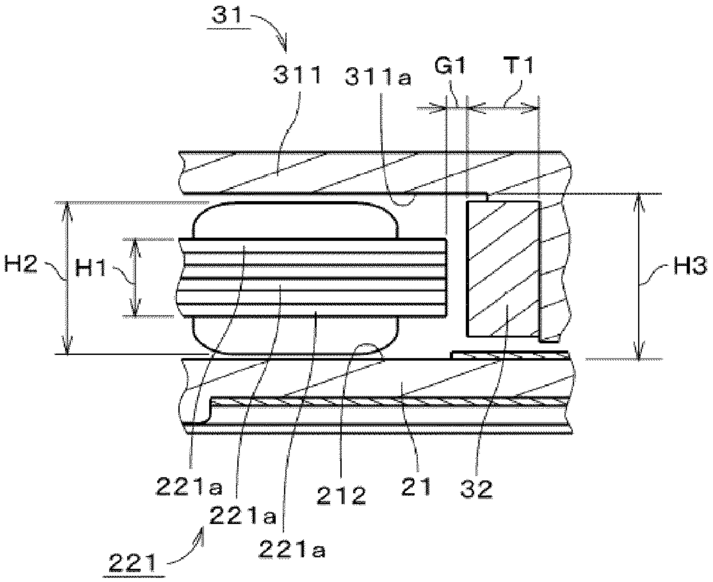
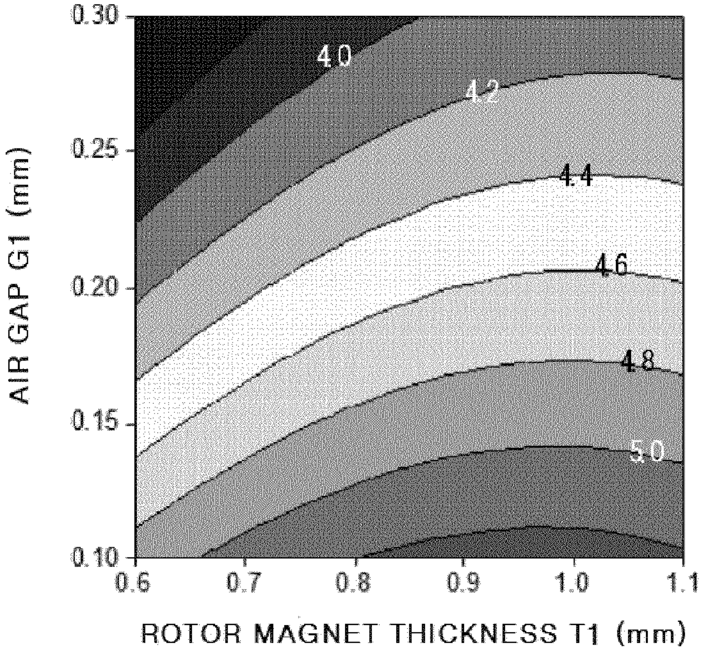


Fig. 22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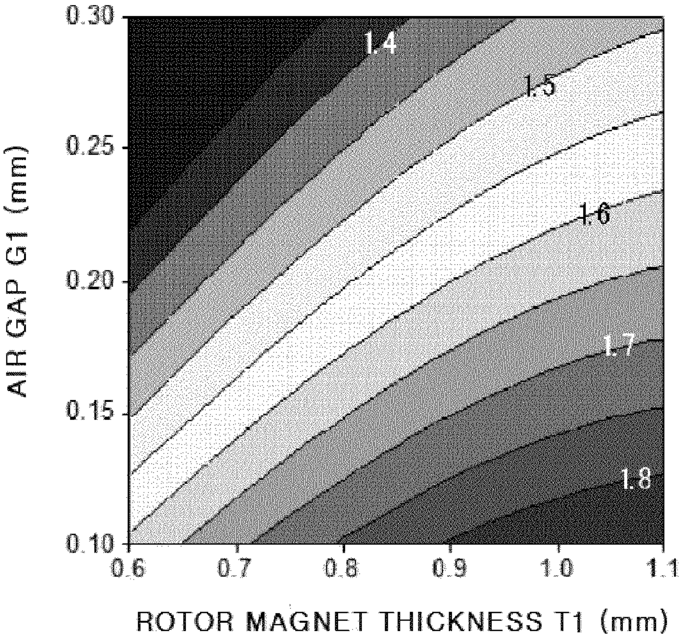
0.25
0.20
0.15
0.10
AIR GAP G1 (mm)
0.6
0.7
0.8
0.9
1.0
1.1
ROTOR MAGNET THICKNESS T1 (mm)

Fig. 23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AIR GAP G1 (mm)
1.4
1.5
1.6
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0.6
0.7
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0.9
1.0
1.1
ROTOR MAGNET THICKNESS T1 (mm)

Fig. 24

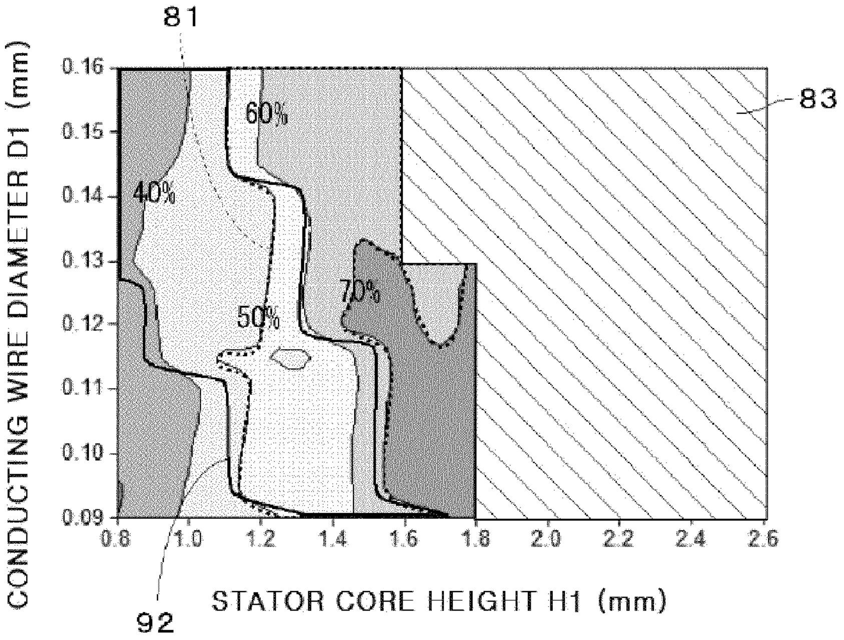
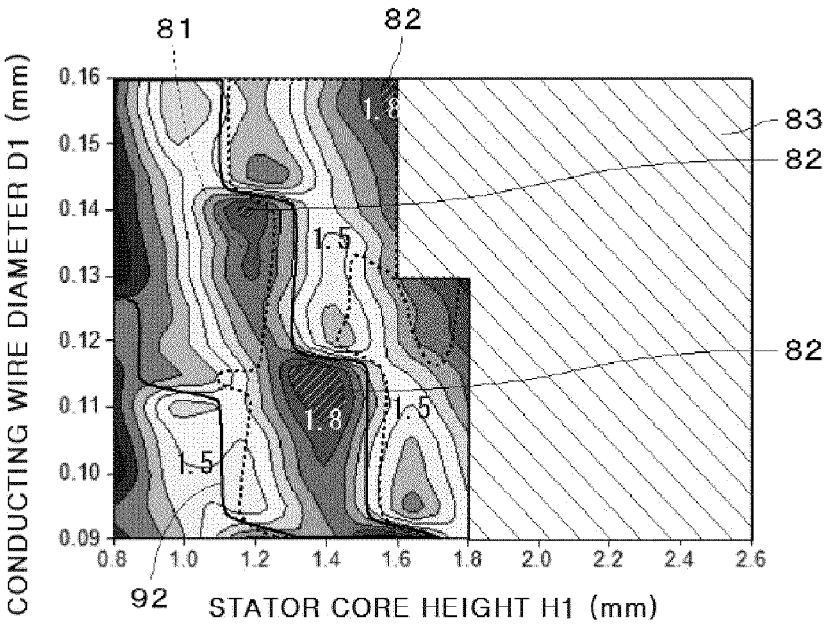

81
83
92
40%
50%
60%
70%
CONDUCTING WIRE DIAMETER D1 (mm)
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
STATOR CORE HEIGHT H1 (mm)

Fig. 25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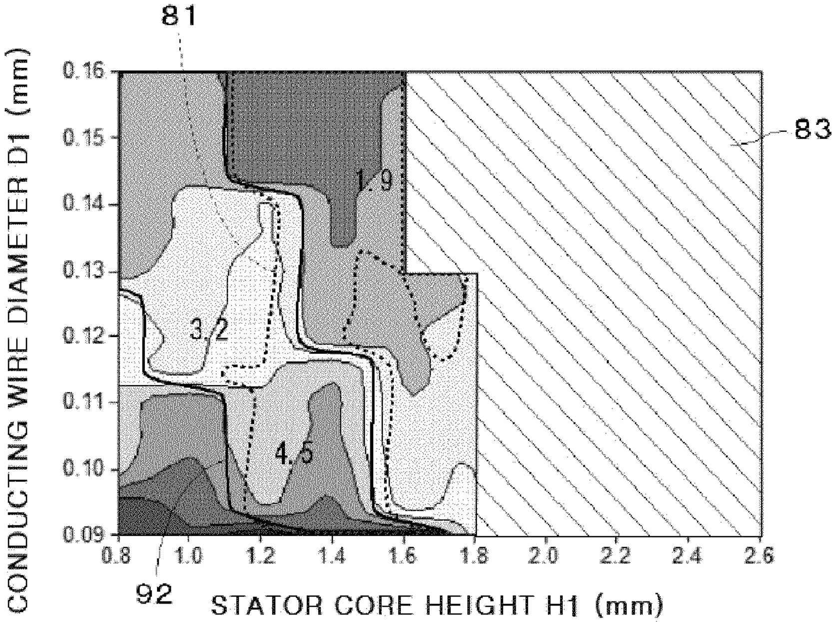
CONDUCTING WIRE DIAMETER D1 (mm)
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
STATOR CORE HEIGHT H1 (mm)

Fig. 26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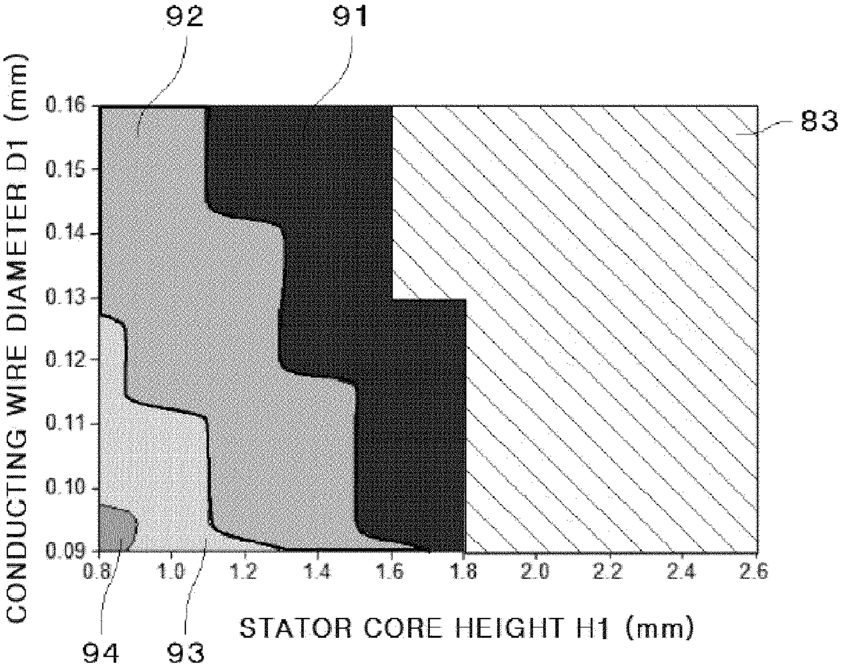
0.11
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
STATOR CORE HEIGHT H1 (mm)

Fig. 27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91
83
CONDUCTING WIRE DIAMETER D1 (mm)
0.16
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0.12
0.11
0.10
0.09
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
STATOR CORE HEIGHT H1 (mm)
94
93

Fig. 28

# SPINDLE MOTOR AND DISK DRIVE APPARATUS

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a spindle motor and more specifically to a spindle motor for a disk drive apparatus.

2. Description of the Related Art

In the related art, a spindle motor (hereinafter, simply referred to as a “motor”) is mounted in a disk drive apparatus such as a hard disk drive. In an outer rotor-type motor disclosed in JP-A-2004-135467, a rotor set includes a rotating hub body of a cup shape and a drive magnet. A stator set includes a stator core and a drive coil wound on the stator core. The drive magnet of the motor disclosed in JPA-2004-135467 is fixed to an inner circumferential surface of an annular standing wall part of the rotating hub body, and faces an outer circumferential surface of the stator core. When the motor is driven, a magnetic action is generated between the drive magnet and the drive coil. Further, JP-A-2008-97803 discloses a motor in which a permanent magnet is disposed to face an outer circumferential side of an electromagnet.

However, in recent years, as thinner disk drive apparatuses are demanded, it is necessary to further reduce the thickness of the motor mounted in the disk drive apparatus.

## SUMMARY OF THE INVENTION

According to an exemplary preferred embodiment of the present invention, a spindle motor of a disk drive apparatus includes a base unit, a stator, a rotor hub, a rotor magnet, and a bearing mechanism. The stator includes a stator core and a plurality of coils. The plurality of coils is mounted to the stator core. The stator is disposed above the base unit. The rotor hub includes a cover portion and a side wall portion, and has a covered cylindrical shape. The cover portion is positioned above the stator. The side wall portion extends downward from an outer edge of the cover portion. The rotor magnet is positioned outside the stator in a radial direction thereof and is fixed to an inner circumferential surface of the side wall portion of the rotor hub. The bearing mechanism supports the rotor hub and the rotor magnet to be rotatable with respect to the base unit and the stator. The rotor magnet is made of an Nd—Fe—B bond magnet. The height of the stator core in an axial direction is about 50% or more and about 70% or less than the height of the stator, for example. A torque constant Kt of torque generated between the stator and the rotor magnet is about 4 mN·m/A or more and about 6 mN·m/A or less, for example. A motor constant Km is about 2 mN·m/(A·√Ω) or more and about 4 mN·m/(A·√Ω) or less, for example.

According to another exemplary preferred embodiment of the present invention, a spindle motor of a disk drive apparatus includes a base unit, a stator, a rotor hub, a rotor magnet, and a bearing mechanism. The stator includes a stator core and a plurality of coils. The plurality of coils is mounted to the stator core. The stator is disposed above the base unit. The rotor hub includes a cover portion and a side wall portion, and has a covered cylindrical shape. The cover portion is positioned above the stator. The side wall portion extends downward from an outer edge of the cover portion. The rotor magnet is positioned outside the stator in a radial direction thereof and is fixed to an inner circumferential surface of the side wall portion of the rotor hub. The bearing mechanism supports the rotor hub and the rotor magnet to be rotatable with respect to the base unit and the stator. The rotor magnet is made of an Nd—Fe—B bond magnet. The height of the stator core in an axial direction is about 50% or more and about 70% or less than the height of the stator, for example. A torque constant Kt of torque generated between the stator and the rotor magnet is about 3 mN·m/A or more and about 4.5 mN·m/A or less, for example. A motor constant Km is about 1 mN·m/(A·√Ω) or more and about 2 mN·m/(A·√Ω) or less, for example.

According to various preferred embodiments of the invention, it is possible to generate sufficient torque and to shorten a startup time using a thin 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 with reference to the attached drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram illustrating a disk drive apparatus according to a first preferred embodiment of the present invention.

FIG. **2** is a cross-sectional view illustrating a spindle motor according to a preferred embodiment of the present invention.

FIG. **3** is a plan view illustrating a stator according to a preferred embodiment of the present invention.

FIG. **4** is an enlarged view of a portion of a spindle motor according to a preferred embodiment of the present invention.

FIG. **5** is an enlarged view of a portion of a spindle motor according to a preferred embodiment of the present invention.

FIG. **6** is a diagram illustrating the relationship between the thickness of a rotor magnet and an air gap and a torque constant according to a preferred embodiment of the present invention.

FIG. **7** is a diagram illustrating the relationship between the thickness of a rotor magnet and an air gap and a motor constant according to a preferred embodiment of the present invention.

FIG. **8** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a core height ratio according to a preferred embodiment of the present invention.

FIG. **9** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a motor constant according to a preferred embodiment of the present invention.

FIG. **10** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a torque constant according to a preferred embodiment of the present invention.

FIG. **11** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and the number of layers of the conducting wire according to a preferred embodiment of the present invention.

FIG. **12** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a core height ratio according to a preferred embodiment of the present invention.

FIG. **13** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a motor constant according to a preferred embodiment of the present invention.

FIG. **14** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a torque constant according to a preferred embodiment of the present invention.

FIG. **15** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and the number of layers of the conducting wire according to a preferred embodiment of the present invention.

FIG. **16** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a core height ratio according to a preferred embodiment of the present invention.

FIG. **17** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a motor constant according to a preferred embodiment of the present invention.

FIG. **18** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a torque constant according to a preferred embodiment of the present invention.

FIG. **19** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and the number of layers of the conducting wire according to a preferred embodiment of the present invention.

FIG. **20** is a diagram illustrating a disk drive apparatus according to a second preferred embodiment of the present invention.

FIG. **21** is a cross-sectional view illustrating a spindle motor according to a preferred embodiment of the present invention.

FIG. **22** is an enlarged view of a portion of a spindle motor according to a preferred embodiment of the present invention.

FIG. **23** is a diagram illustrating the relationship between the thickness of a rotor magnet and an air gap and a torque constant according to a preferred embodiment of the present invention.

FIG. **24** is a diagram illustrating the relationship between the thickness of a rotor magnet and an air gap and a motor constant according to a preferred embodiment of the present invention.

FIG. **25** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a core height ratio according to a preferred embodiment of the present invention.

FIG. **26** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a motor constant according to a preferred embodiment of the present invention.

FIG. **27** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and a torque constant according to a preferred embodiment of the present invention.

FIG. **28** is a diagram illustrating the relationship between the height of a stator core and the diameter of a conducting wire and the number of layers of the conducting wire according to a preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following description, an upper side of a motor in a central axis direction thereof in FIG. **1** is simply referred to as an "upper side", and a lower side thereof is simply referred to as a "lower side". A vertical direction does not represent a positional relationship or a direction when being assembled in an actual device. Further, a direction parallel or substantially parallel to a central axis is referred to as an "axial direction", a direction that is orthogonal or substantially orthogonal to the central axis with reference to the central axis is simply referred to as a "radial direction", and a circumferential direction with reference to the central axis is simply referred to as a "circumferential direction".

Further, in the following description, the "parallel" direction includes both a parallel and an approximately parallel direction. Further, in the following description, the "orthogonal" direction includes both an orthogonal and an approximately orthogonal direction.

FIG. **1** is a longitudinal sectional view illustrating a disk drive apparatus **1** that includes a spindle motor (hereinafter, simply referred to a "motor") according to a first exemplary preferred embodiment of the invention. The disk drive apparatus **1** is preferably a hard disk drive having a width of about 2.5" and a thickness of about 7 mm. The disk drive apparatus **1** preferably includes two disks **11**, a motor **12**, an access unit **13**, a housing **14**, and a clamper **151**. The motor **12** rotates the disk **11** that stores information. The access unit **13** performs at least one of reading and writing of information with respect to two disks **11**. The motor **12** is preferably a three-phase brushless motor.

The housing **14** preferably includes a first housing member **141** and a second housing member **142** of a plate shape. The disk **11**, the motor **12**, the access unit **13**, and the clamper **151** are accommodated inside the first housing member **141**. The second housing member **142** is inserted into the first housing member **141** to define the housing **14**. It is preferable that an inner space of the disk drive apparatus **1** be a clean space where dust or dirt is not present or is very minute.

Two disks **11** are vertically disposed above and below a spacer **153**, and are clamped to the motor **12** by the clamper **151**. The access unit **13** includes a head **131**, an arm **132**, and a head movement mechanism **133**. The head **131** moves close to the disk **11** to magnetically perform at least one of reading and writing of information. The arm **132** supports the head **131**. As the head movement mechanism **133** moves the arm **132**, the head **131** relatively moves with respect to the disk **11**. With such a configuration, the head **131** accesses a desired position of the disk **11** in a state where the head **131** moves close to the rotating disk **11**.

FIG. **2** is a longitudinal sectional view illustrating the motor **12** according to a preferred embodiment of the present invention. The motor **12** is preferably an outer rotor type, and includes a stationary portion **2** that is a fixed assembly, a rotating portion **3** that is a rotating assembly, and a bearing mechanism **4**. The stationary portion **2** preferably includes a base plate **21** that is a base unit having an approximate plate shape, the stator **22**, an insulating bushing **23**, a magnetic member **24**, and a wiring substrate **25**. The base plate **21** is a portion of the first housing member **141** in FIG. **1**. The stator **22** is disposed above the base plate **21**, and preferably includes a stator core **221** and a coil **222**. A portion of the stator core **221** in the radial direction is fixed around a cylindrical holder **211** of the base plate **21**. The magnetic member **24** has an annular shape with reference to a central axis J1, and preferably is fixed to an upper surface **212** of the base plate **21** by, for example, an adhesive. In the stationary portion **2**, a conducting wire **223** of the coil **222** is inserted together with the insulating bushing **23** into a through hole of the base plate **21** in the state of passing through the insulating bushing **23**. An end portion of the conducting wire **223** is preferably bonded to the wiring substrate **25** by soldering or the like.

The rotating portion **3** preferably includes a rotor hub **31** and a rotor magnet **32**. The rotor hub **31** has an approximately covered cylindrical shape. The rotor hub **31** preferably includes a cover portion **311**, a side wall portion **312**, a hub tube portion **313**, and a disk mounting portion **314**. The cover portion **311** is positioned above the stator **22**. The hub tube portion **313** has a cylindrical shape with reference to the central axis J1, and extends downward from a lower surface **311***a* of the cover portion **311** on the outside of the bearing mechanism **4**. The side wall portion **312** extends downward from an outer edge of the cover portion **311**. The disk drive apparatus **314** extends outward from the side wall portion **312** in the radial direction. The disk **11** in FIG. **1** is mounted on the disk mounting portion **314**.

The rotor magnet **32** is fixed to an inner circumferential surface **312***a* of the side wall portion **312**, and is positioned outside the stator **22** in the radial direction. The rotor magnet **32** is a tube portion made of, for example, a neodymium bond magnet (Nd—Fe—B BOND MAGNET). The magnet member **24** is positioned below the rotor magnet **32**. A magnetic attraction force is generated between the rotor magnet **32** and the magnetic member **24**.

Torque is generated between the stator **22** and the rotor magnet **32** when the motor **12** is driven. A torque constant Kt of the torque generated between the stator **22** and the rotor magnet **32** is preferably about 4 mN·m/A or more and about 6 mN·m/A or less for example. Further, a motor constant Km is preferably about 2 mN·m/(A·√Ω) or more and about 4 mN·m/(A·√Ω) or less, for example. The motor constant Km is defined as Km=Kt/√(R) using the torque constant Kt and a conducting wire resistance value R of the coil **222**.

The bearing mechanism **4** preferably includes a shaft portion **41**, a sleeve **42**, a sleeve housing **43**, a thrust plate **44**, a cap portion **45**, and a lubricant **46**. The shaft portion **41** extends downward from the inner portion of the cover portion **311** in the radial direction. The shaft portion **41** and the rotor hub **31** are preferably defined by a single connected monolithic member. A female screw portion **411** is preferably arranged inside the shaft portion **41** over its entire length. A male screw **152**, for example, shown in FIG. **1** is preferably screw-coupled with the female screw portion **411** at the center of the cover portion **311**. However, any other type of fastener other than the male screw **152** could be used if so desired. Thus, the clamper **151** is fixed to the motor **12**, and the disk **11** is clamped to the rotor hub **31**.

A hub clamping method other than the existing clamping method (hereinafter, referred to as a "center clamping method") may alternatively be used. In the hub clamping method, a plurality of female screw portions is defined in the upper surface of the cover portion of the rotor hub, male screws are screw-coupled with the female screw portions, and thus, the clamper is fixed to the motor. In the hub clamping method, since the male screws are fixed to the cover portion, it is preferable to lower the height of the cover portion as much as the height of the male screw. Further, since the male screws are provided in the hub, the hub becomes thick. In a thin motor used by the disk drive apparatus having a thickness of about 7 mm or a thickness of about 5 mm, to be described later, in order to secure a space between the lower surface of the cover portion and the upper surface of the base plate, the center clamping method is effectively used.

The shaft portion **41** is inserted inside the sleeve **42**. The sleeve housing **43** is positioned inside the hub tube portion **313**. The sleeve **42** is fixed to an inner circumferential surface of the sleeve housing **43**. The thrust plate **44** is fixed to a lower portion of the shaft portion **41** as the central male screw portion is screw-coupled with the female screw portion **411**. The cap portion **45** is fixed to a lower end of the sleeve housing **43**, and blocks a lower opening of the sleeve housing **43**.

In the motor **12**, the lubricant **46** preferably continuously fills a radial gap **471**, a first thrust gap **472**, and a second thrust gap **473**. The radial gap **471** is a gap between an inner circumferential surface of the sleeve **42** and an outer circumferential surface of the shaft portion **41**. The first thrust gap **472** is a gap between a lower surface of the sleeve **42** and an upper surface of the thrust plate **44**. The second thrust gap **473** is a gap between an upper surface of the sleeve **42** and an upper surface of the sleeve housing **43**, and the lower surface **311***a* of the cover portion **311**. Further, in the motor **12**, the lubricant **46** also preferably continuously fills a second thrust gap **474** and a sealing gap **475**. The third thrust gap **474** is a gap between a lower surface of the thrust plate **44** and an upper surface of the cap portion **45**. The sealing gap **475** is a gap between an inner circumferential surface of the hub tube portion **313** and an upper portion of an outer circumferential surface of the sleeve housing **43**.

A radial dynamic pressure groove sequence is provided on the inner circumferential surface of the sleeve **42**. Further, a thrust dynamic pressure groove sequence is provided on the upper surface and the lower surface of the sleeve **42**. In the radial gap **471**, a radial dynamic pressure bearing unit **481** is preferably configured by the radial dynamic pressure groove sequence. In the first thrust gap **472** and the second thrust gap **473**, a first thrust dynamic pressure bearing unit **482** and a second thrust dynamic pressure bearing unit **483** are preferably configured by the thrust dynamic pressure groove sequence, respectively. When the motor **12** is driven, the shaft portion **41** and the thrust plate **44** are supported in a non-contact manner with respect to the sleeve **42**, the sleeve housing **43**, and the cap portion **45** by the radial dynamic pressure bearing unit **481**, the first thrust dynamic pressure bearing unit **482**, and the second thrust dynamic pressure bearing unit **483**, that is, by the bearing mechanism **4**. Thus, the rotor hub **31** and the rotor magnet **32** are supported to be rotatable with respect to the base plate **21** and the stator **22**.

FIG. **3** is a plan view illustrating the stator **22**. The stator **22** includes the stator core **221** and the plurality of coils **222**. The plurality of coils **222** is preferably mounted on the stator core **221** by, for example, concentrated winding. The stator core **221** includes a central portion **51** that has a circular or approximately circular shape with reference to the central axis J1, and a plurality of teeth **52**. The number of the teeth **52** is preferably nine, for example. Each tooth **52** having an approximate T shape extends outward from the outer circumference of the central portion **51** in the radial direction, and also extends toward opposite sides in the circumferential direction at an end portion of the outside. The conducting wire **223** is wound on each tooth **52**, and thus, the coil **222** is provided.

The inner diameter of the stator core **221**, that is, the inner diameter of the central portion **51** is preferably about 8 mm or more and about 9 mm or less, for example. The number of turns of each coil **222** is preferably about 40 or more and about 80 or less, for example. The number of layers of the conducting wire **223** in each coil **222** is preferably four, for example. In other words, in an upper portion and a lower portion of the tooth **52**, the conducting wire **223** is respectively stacked into four layers. The diameter of the conducting wire **223** is preferably about 0.10 mm or more and about 0.15 mm or less, for example.

FIG. **4** is an enlarged view of the vicinity of the rotor magnet **32** in FIG. **2**. The coil **222** is preferably disposed between the lower surface **311***a* of the cover portion **311** of the rotor hub **31** and the upper surface **212** of the base plate **21**. A distance H3 in the axial direction between the lower surface **311***a* of the cover portion **311** of the rotor hub **31** and the upper surface **212** of the base plate **21** is approximately 4.0 mm, for example. Hereinafter, the distance H3 is referred to as an "inner height H3".

The stator core **221** is preferably obtained by stacking a plurality of magnetic steel plates **221***a*. The thickness of one magnetic steel plate **221***a* is preferably approximately 0.2

mm, for example. The number of the magnetic steel plates **221***a* is preferably eight to twelve, for example. In the present preferred embodiment, the number of the magnetic steel plates **221***a* is preferably eight, for example. In the axial direction, a height H**1** of the stator core **221** is preferably approximately 1.6 mm, for example. The height H**1** does not include the thicknesses of insulating films provided on an upper surface and a lower surface of the stator core **221**. In other words, the height H**1** is a height from a lower end of the plurality of stacked magnetic steel plates **221***a* to an upper end thereof. The height H**1** of the stator core **221** is preferably about 50% or more and about 70% or less than a height H**2** of the stator **22** in the axial direction. The height H**2** is a height from a lower end to an upper end of the coil **222**. In the present preferred embodiment, the height H**2** of the stator **22** is preferably approximately 3.78 mm, for example.

FIG. **5** is an enlarged view illustrating the vicinity of a tip end of the tooth **52** in FIG. **3**. A thickness T**1** of the rotor magnet **32** shown in FIGS. **4** and **5** in the radial direction is preferably about 0.7 mm or more and about 1.0 mm or less, for example. The thickness T**1** does not include the height of an insulating film provided on a front surface of the rotor magnet **32**.

The distance G**1** in the radial direction between the rotor magnet **32** and the stator core **221** (hereinafter, referred to as an "air gap") is preferably about 0.15 mm or more and about 0.20 mm or less, for example. The air gap G**1** is the shortest distance in the radial direction between an outer circumferential surface of the tooth **52** and an inner circumferential surface of the rotor magnet **32**. The outer circumferential surface of the tooth **52** refers to an outer surface of the plurality of stacked magnetic steel plates **221***a* in FIG. **4**. In a case where an insulating film is provided on the outer surface of the magnetic steel plate **221***a*, the thickness of the insulating film is included in the air gap G**1**. The inner circumferential surface of the rotor magnet **32** refers to an inner circumferential surface of the insulating film provided on the front surface of the rotor magnet **32**. The thickness of the insulating film of the rotor magnet **32** is not included in the air gap G**1**.

In the disk drive apparatus having the thickness of about 7 mm, even though a motor mounted in a disk drive apparatus having the thickness of about 9.5 mm is made thin according to the thickness of about 7 mm, it is difficult to secure sufficient torque constant Kt. For example, in a case where the height of the motor mounted in the disk drive having the thickness of about 9.5 mm is simply reduced by about 26%, the torque constant Kt decreases by half. By reducing the diameter of the conducting wire **223** to increase the number of turns of the coil **222**, it is possible to secure the torque constant Kt while making the motor thin, but in this case, the conducting wire resistance value R of the coil **222** increases. The motor in which the conducting wire resistance value R of the coil **222** is large has a small electric current at the time of startup in a case where the motor is driven with the same electric current, compared with a motor having a small conducting wire resistance R. As a result, torque when the motor starts up decreases, and thus, a startup time that is a time until the number of rotations of the motor reaches a rated speed increases. In the motor for the disk drive apparatus, it is preferable to secure sufficient torque and to set the startup time to a predetermined time or less.

Thus, in the motor **12** of the disk drive apparatus **1** having the thickness of about 7 mm, it is preferable to design the motor to generate sufficient torque and to shorten the startup time even with such a limited space. That is, it is preferable to design the motor to simultaneously increase the torque constant Kt and the motor constant Km in a desired range, instead

of increasing only the torque constant Kt. As described above, Km is a numerical value defined as $Kt/\sqrt{(R)}$. That is, instead of Kt/R or $Kt/R^2$, Km is an optimal index that expresses a suitable motor structure in a case where the motor is made thin. Specifically, in the motor **12**, in order to generate sufficient torque, the torque constant Kt is preferably designed to be about 4 mN·m/A or more and 6 about mN·m/A or less, for example. Further, in order to shorten the startup time, the motor is preferably designed so that the motor constant Km is about 2 mN·m/(A·√Ω) or more and about 4 mN·m/(A·Ω) or less, for example.

However, in order to generate sufficient torque in the limited space, it may be considered that the density of magnetic flux generated between the rotor magnet and the stator core is increased. However, if the thickness of the rotor magnet in the radial direction is simply increased in order to increase the magnetic flux density, the motor becomes larger in the radial direction. Further, if the magnetic flux density generated between the rotor magnet and the stator core is excessively increased, vibration or noise is generated. In order to prevent the generation of vibration or noise, it is preferable to increase the air gap in association with the increase in the thickness of the rotor magnet in the radial direction, and thus, the motor further becomes larger in the radial direction.

In the motor mounted in the disk drive apparatus having the thickness of about 9.5 mm, generally, the thickness T**1** of the rotor magnet in the radial direction is larger than about 0.93 mm and is equal to or less than about 1.04 mm, for example. Further, the air gap G**1** is larger than about 0.2 mm and is equal to or less than about 0.3 mm, for example.

On the other hand, in the motor **12**, as described above, the thickness T**1** of the rotor magnet **32** in the radial direction preferably is about 0.7 mm or more and about 1.0 mm or less, and the air gap G**1** preferably is about 0.15 mm or more and about 0.20 mm or less, for example. In the motor **12**, compared with the motor of the disk drive apparatus having the thickness of about 9.5 mm, it is possible to prevent the increase in the radial direction in the limited space, and to increase the density of the magnetic flux generated between the rotor magnet **32** and the stator core **221**. Consequently, it is possible to generate sufficient torque when the motor **12** is rotated in the limited space, and to shorten the startup time of the motor **12**.

FIG. **6** is a contour diagram illustrating the relationship between the thickness T**1** of the rotor magnet **32** of the motor **12** shown in FIG. **4** and the air gap G**1**, and the torque constant Kt. A plurality of curves in the figure represents contours of the torque constant Kt, and numerical values in the figure represent values of the torque constant Kt indicated by the contours. The torque constant Kt increases from the upper left to the lower right in FIG. **6**. The contours of the torque constant Kt are calculated by simulation while maintaining the outer diameter of the rotor magnet **32** constant and changing the thickness T**1** of the rotor magnet **32** and the air gap G**1**. In the simulation, the number of turns of the coil **222** is also changed according to the change in the thickness T**1** of the rotor magnet **32** and the air gap G**1**. For example, if the thickness T**1** of the rotor magnet **32** is constant and the air gap G**1** is increased, the outer diameter of the stator core **221** is decreased, and thus, the number of turns of the coil **222** is reduced. Further, similarly, in a case where the air gap G**1** is constant and the thickness T**1** of the rotor magnet **32** is increased, the outer diameter of the stator core **221** is decreased, and thus, the number of turns of the coil **222** is reduced.

According to FIG. **6**, if the thickness T**1** of the rotor magnet **32** is changed without change in the G**1** in a range where the air gap G**1** preferably is about 0.15 mm or more and about 0.20 mm or less, the torque constant Kt gradually increases as T**1** increases in a range where T**1** preferably is equal to or less than about 1.0 mm, for example. On the other hand, in a range where T**1** is larger than about 1.0 mm, the torque constant Kt does not remarkably increase even though T**1** increases. In other words, the increase ratio of the torque constant Kt to the increase of T**1** in a range where T**1** is larger than about 1.0 mm is smaller than the increase ratio of the torque constant Kt to the increase of T**1** in a range where T**1** is equal to or less than about 1.0 mm.

That is, by setting T**1** to about 1.0 mm or less, the magnetic flux density increased according to the increase of T**1** is effectively used in the increase of the torque constant Kt. Further, if T**1** is smaller than about 0.7 mm, the reduction ratio of Kt to the decrease of T**1** is relatively increased. Accordingly, by setting T**1** to about 0.7 mm or more and about 1.0 mm or less, it is possible to prevent the rotor magnet **32** from being increased in thickness and to efficiently increase the torque constant Kt.

FIG. **7** is a contour diagram illustrating the relationship between the thickness T**1** of the rotor magnet **32** of the motor **12** shown in FIG. **4** and the air gap G**1**, and the motor constant Km. A plurality of curves in the figure represents contours of the motor constant Km, and numerical values in the figure represent values of the motor constant Km indicated by the contours. The motor constant Km increases from the upper left to the lower right in FIG. **7**. The contours of the motor constant Km are calculated by the same method as in the contours of the torque constant Kt. Referring to FIG. **7**, if T**1** is changed without change in G**1** in a range where G**1** preferably is about 0.15 mm or more and about 0.20 mm or less, the motor constant Km gradually increases as T**1** increases in a range where T**1** preferably is about 0.7 mm or more and about 1.0 mm or less, for example. That is, the magnetic flux density increased according to the increase of T**1** is effectively used in the increase of the motor constant Km.

As described above, in the motor **12** shown in FIG. **4**, the thickness T**1** of the rotor magnet **32** preferably is about 0.7 mm or more and about 1.0 mm or less, and the air gap G**1** preferably is about 0.15 mm or more and about 0.20 mm or less, for example. In this way, by decreasing T**1** and G**1**, it is possible to prevent the motor **12** from being enlarged in the radial direction, and to increase the outer diameter of the stator core **221**. Thus, in the motor **12** in which the inner height H**3** is relatively small, it is possible to increase the upper limit of the number of turns of the coil **222**. Consequently, it is possible to easily realize the torque constant Kt and the motor constant Km of a desired size.

In the motor **12**, by setting the torque constant Kt to about 4 mN·m/A or more and about 6 mN·m/A or less, for example, it is possible to efficiently generate sufficient torque while suppressing the amount of electric current. Further, by setting the motor constant Km to about 2 mN·m/(A·√Ω) or more and about 4 mN·m/(A·√Ω) or less, for example, it is possible to shorten the startup time of the motor **12**.

FIGS. **8** to **11** respectively show results obtained by calculating the core height ratio Hr, the motor constant Km, the torque constant Kt, and the number of layers of the conducting wire **223** while variously changing the height H**1** of the stator core **221** and the diameter D**1** of the conducting wire **223** in a case where the inner height H**3** of the motor **12** shown in FIG. **4** is about 4.0 mm, for example. The core height ratio Hr represents the ratio of the height H**1** of the stator core **221** to the height H**2** of the stator **22**. The height H**2** of the stator **22** corresponds to the height thereof in a case where the conducting wire **223** is wound to the maximum in the inner space of the inner height H**3**. Further, the number of layers of the conducting wire **223** represents the number of layers in a case where the conducting wire **223** is wound to the maximum in the inner space of the inner height H**3**. The motor constant Km and the torque constant Kt are calculated by simulation. This is similarly applied to FIGS. **12** to **19** and FIGS. **25** to **28**.

FIG. **8** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the core height ratio Hr. A plurality of curves in the figure represents contours of the core height ratio Hr, and numerical values in the figure represent values of the core height ratio Hr indicated by the contours. This is similarly applied to FIGS. **12**, **16** and **25**. The core height ratio Hr increases from the left to the right in FIG. **8**. In FIG. **8**, a region where the core height ratio Hr is about 50% or more and about 70% or less is surrounded by a thick broken line with reference numeral **81**.

FIG. **9** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the motor constant Km. A plurality of curves in the figure represents contours of the motor constant Km, and numerical values in the figure represent values of the motor constant Km indicated by the contours. This is similarly applied to FIGS. **13**, **17** and **26**. Regions **82** indicated by parallel slanted lines in FIG. **9** represent regions in which the motor constant Km is the maximum. The motor constant Km is small on the left side in FIG. **9**, gradually increases from the lower left to the upper right, and becomes a peak in a range where H**1** is about 2.2 mm or more and about 2.5 mm or less. Further, if the motor constant Km passes the peak, the motor constant Km decreases once toward the upper right, and then increases again. A region surrounded by the thick broken line with reference numeral **81** represents a region where the core height ratio Hr is about 50% or more and about 70% or less, in a similar way to FIG. **8**, and includes the regions **82** where the motor constant Km is the maximum in FIG. **9**. In this way, by setting the core height ratio Hr to about 50% or more and about 70% or less, it is possible to efficiently increase the motor constant Km.

FIG. **10** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the torque constant Kt. A plurality of curves in the figure represents contours of the torque constant Kt, and numerical values in the figure represent values of the torque constant Kt indicated by the contours. This is similarly applied to FIGS. **14**, **18** and **27**. The torque constant Kt increases from the upper side to the lower side in FIG. **10**. A region surrounded by the thick broken line with reference numeral **81** represents a region where the core height ratio Hr is about 50% or more and about 70% or less, in a similar way to FIG. **8**. The region surrounded by the thick broken line **81** includes a region where the torque constant Kt is about 4 mN·m/A or more and about 6 mN·m/A or less.

As described above, the core height ratio Hr is the ratio of the height H**1** of the stator core **221** to the height H**2** of the stator **22** in a case where the conducting wire **223** is wound to the maximum in the inner space of the inner height H**3**. If the height H**1** of the stator core **221** and the diameter D**1** of the conducting wire **223** are changed, the number of layers of the conducting wire **223** in the coil **222** is also changed. Specifically, if the diameter D**1** of the conducting wire **223** is constant and the height H**1** of the stator core **221** increases, the core height ratio Hr increases, and the number of layers of the conducting wire **223** decreases. Further, if the height H**1** of the stator core **221** is constant and the diameter D**1** of the conducting wire **223** increases, the number of layers of the conducting wire **223** decreases. Since the number of layers of the conducting wire **223** is an even number, the minimum value of the number of layers is 2.

FIG. **11** is a diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the number of layers of the conducting wire **223**. Regions **91** to **95** that are arranged from the upper right to the lower left in FIG. **11** respectively represent regions where the number of layers of the conducting wire **223** is two, four, six, eight, and ten. In FIGS. **8** to **10**, the region **92** in which the number of layers of the conducting wire **223** is four is indicated by a thick solid line. As shown in FIG. **8**, in a case where the number of layers of the conducting wire **223** is four, the core height ratio Hr is about 50% or more and about 70% or less. As shown in FIGS. **9** and **10**, the region **92** includes the regions **82** in which the motor constant Km is the maximum in the figure, and includes a region where the torque constant Kt is about 4 mN·m/A or more and about 6 mN·m/A or less.

FIGS. **12** to **15** respectively show results obtained by calculating the core height ratio Hr, the motor constant Km, the torque constant Kt, and the number of layers of the conducting wire **223** while variously changing the height H**1** of the stator core **221** and the diameter D**1** of the conducting wire **223** in a case where the inner height H**3** of the motor **12** shown in FIG. **4** is about 3.5 mm.

FIG. **12** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the core height ratio Hr. In FIG. **12**, in a similar way to FIG. **8**, a region where the core height ratio Hr is about 50% or more and about 70% or less is surrounded by a thick broken line with reference numeral **81**.

FIG. **13** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the motor constant Km. Regions **82** indicated by parallel slanted lines represent regions where the motor constant Km is the maximum in FIG. **13**. The motor constant Km is small on the left side in FIG. **13**, gradually increases from the lower left to the upper right, and becomes a peak in a range where H**1** is about 2.0 mm or more and about 2.3 mm or less. Further, if the motor constant Km passes the peak, the motor constant Km decreases once toward the upper right, and then increases again. A region surrounded by a thick broken line with reference numeral **81** is a region where the core height ratio Hr is about 50% or more and about 70% or less, in a similar way to FIG. **12**, and includes the regions **82** where the motor constant Km in FIG. **13** is the maximum. In this way, by setting the core height ratio Hr to about 50% or more and about 70% or less, it is possible to efficiently increase the motor constant Km.

FIG. **14** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the torque constant Kt. The torque constant Kt increases from the upper side to the lower side in FIG. **14**. A region surrounded by a thick broken line with reference numeral **81** represents a region where the core height ratio Hr is about 50% or more and about 70% or less, in a similar way to FIG. **12**. A region surrounded by the thick broken line **81** includes a region where the torque constant Kt is about 4 mN·m/A or more and about 6 mN·m/A or less.

FIG. **15** is a diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the number of layers of the conducting wire **223**. Regions **91** to **95** that are arranged from the upper right to the lower left in FIG. **15** respectively represent regions where the number of layers of the conducting wire **223** is two, four, six, eight, and ten. In FIGS. **12** to **14**, the region **92** in which the number of layers of the conducting wire **223** is four is indicated by a thick solid line. As shown in FIG. **12**, in a case where the number of layers of the conducting wire **223** is 4, the core height ratio Hr is about 50% or more and about 70% or less. As shown in FIGS. **13** and **14**, a region where the region **92** and the region **81** where the core height ratio Hr is about 50% or more and about 70% or less are overlapped includes the regions **82** where the motor constant Km is the maximum, and includes the region where the torque constant Kt is about 4 mN·m/A or more and about 6 mN·m/A or less.

FIGS. **16** to **19** respectively show results obtained by calculating the core height ratio Hr, the motor constant Km, the torque constant Kt, and the number of layers of the conducting wire **223** while variously changing the height H**1** of the stator core **221** and the diameter D**1** of the conducting wire **223** in a case where the inner height H**3** of the motor **12** shown in FIG. **4** is about 3.0 mm.

FIG. **16** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the core height ratio Hr. In FIG. **16**, in a similar way to FIG. **8**, a region where the core height ratio Hr is about 50% or more and about 70% or less is surrounded by a thick broken line with reference numeral **81**. A region **83** indicated by parallel slanted lines on the right side in FIG. **16** represents a region where the coil **222** cannot be provided due to the relationship between the inner height H**3**, the height H**1** of the stator core **221** and the diameter D**1** of the conducting wire **223**. This is similarly applied to a region **83** in FIGS. **17** to **19**.

FIG. **17** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the motor constant Km. Regions **82** indicated by parallel slanted lines represent regions where the motor constant Km is the maximum in FIG. **17**. The motor constant Km is small on the left side in FIG. **17**, gradually increases from the lower left to the upper right, and becomes a peak in a range where H**1** is about 1.5 mm or more and about 2.0 mm or less. Further, if the motor constant Km passes the peak, the motor constant Km decreases once toward the upper right, and then increases again. A region surrounded by a thick broken line with reference numeral **81** represents a region where the core height ratio Hr is about 50% or more and about 70% or less, in a similar way to FIG. **16**, and includes the regions **82** where the motor constant Km in FIG. **17** is the maximum. In this way, by setting the core height ratio Hr to about 50% or more and about 70% or less, for example, it is possible to efficiently increase the motor constant Km.

FIG. **18** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the torque constant Kt. The torque constant Kt increases from the upper side to the lower side in FIG. **18**. A region surrounded by a thick broken line with reference numeral **81** represents a region where the core height ratio Hr is about 50% or more and about 70% or less, in a similar way to FIG. **16**. The region surrounded by the thick broken line **81** includes a region where the torque constant Kt is about 4 mN·m/A or more and about 6 mN·m/A or less.

FIG. **19** is a diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12** shown in FIG. **4** and the diameter D**1** of the conducting wire **223**, and the number of layers of the conducting wires **223**. Regions **91** to **95** that are arranged from the upper right to the lower left in FIG. **19** respectively represent regions where the number of layers of the conducting wire **223** is two, four, six, eight, and ten. In FIGS. **16** to **18**, the region **92** in which the number of layers of the conducting wire **223** is four is indicated by a thick solid line. As shown in FIG. **16**, in the region **92** where the number of layers of the conducting wire **223** is 4, the core height ratio Hr is about 50% or more and about 70% or less in a portion of about ⅔ from the right. As shown in FIGS. **17** and **18**, a region where the region **92** and the region **81** where the core height ratio Hr is about 50% or more and about 70% or less are overlapped includes the regions **82** where the motor constant Km is the maximum, and includes the region where the torque constant Kt is about 4 mN·m/A or more and about 6 mN·m/A or less.

In the disk drive apparatus **1** having the thickness of 7 mm, the inner height H**3** that can be realized is about 3.0 mm or more and about 4.0 mm or less, for example. As shown in FIG. **1**, in a case where two disks **11** are fixed to the motor **12**, the inner height H**3** shown in FIG. **4** is about 4.0 mm as described above, but in a case where one disk **11** is fixed to the motor **12**, the inner height H**3** may be about 3.0 mm or about 3.5 mm, for example.

As described with reference to FIGS. **8** to **19**, by setting the core height ratio Hr of the motor **12** to about 50% or more and about 70% or less, it is possible to efficiently increase the motor constant Km in the range of about 2 mN·m/(A·√Ω) or more and about 4 mN·m/(A·√Ω) or less while setting the torque constant Kt to about 4 mN·m/A or more and about 6 mN·m/A or less, for example.

As described above, in the motor **12**, by setting the torque constant Kt to about 4 mN·m/A or more and about 6 mN·m/A or less, for example, it is possible to efficiently generate sufficient torque while suppressing the amount of electric current. Further, by setting the motor constant Km to about 2 mN·m/(A·√Ω) or more and about 4 mN·m/(A·√Ω) or less, for example, it is possible to shorten the startup time of the motor **12**. In the motor **12**, by setting the number of layers of the conducting wire **223** to four, it is possible to easily set the core height ratio Hr to about 50% or more and about 70% or less, for example. Consequently, it is possible to efficiently generate sufficient torque while suppressing the amount of electric current, and to easily realize the motor **12** in which the startup time is short.

In the motor **12**, as described above, the inner diameter of the stator core **221** preferably is about 8 mm or more and about 9 mm or less, for example. By setting the inner diameter of the stator core **221** to about 9 mm or less, for example, it is possible to increase the length of the tooth **52** in the radial direction. Thus, it is possible to increase the upper limit of the number of turns of the coil **222** while preventing an increase of the inner height H**3** of the disk drive apparatus **1**. Further, by setting the inner diameter of the stator core **221** to about 8 mm or more, for example, it is possible to easily install the stator core **221** to the base plate **21**.

In the motor **12**, the diameter of the conducting wire **223** preferably is about 0.10 mm or more and about 0.15 mm or less, for example. The number of turns of each coil **222** preferably is about 40 or more and about 80 or less, for example. However, in the disk drive apparatus having the thickness of about 9.5 mm, generally, a conducting wire having a diameter larger than about 0.15 mm is preferably used, for example. The number of turns of the coil preferably is about 40 or more and about 60 or less, for example. In the motor **12**, compared with the motor of the disk drive apparatus having the thickness of about 9.5 mm, it is possible to increase the upper limit of the number of turns while suppressing an increase of the resistance value of the coil **222** in the limited space. Accordingly, it is possible to generate sufficient torque when the motor **12** is rotated in the limited space, and to shorten the startup time of the motor **12**.

In the stator **22**, by setting the number of the magnetic steel plates **221***a* to eight to twelve, it is possible to easily set the core height ratio Hr to about 50% or more and about 70% or less, for example. By using a magnetic steel plate having a thickness of about 0.2 mm, for example, that is easily available as the magnetic steel plate **221***a*, it is possible to reduce the manufacturing cost of the stator core **221**. In the stator core **221**, the magnetic steel plates **221***a* of various thicknesses and numbers may be used. The thickness of the magnetic steel plate **221***a* may be about 0.15 mm or about 0.3 mm, for example.

Further, the motor **12** is not only applied to the disk drive apparatus having the width of about 2.5" and the thickness of about 7 mm, but may also be applied to a disk drive apparatus having a width of about 2.5" and a thickness of about 6 mm, a width of about 2.5" and a thickness of about 5 mm, a width of about 2.5" and a thickness of about 4 mm, a width of about 2.5" and a thickness of about 3 mm, or the like, for example.

FIG. **20** is a longitudinal sectional view illustrating a disk drive apparatus **1***a* including a motor **12***a* according to a second exemplary preferred embodiment of the invention. The disk drive apparatus **1***a* is preferably a hard disk drive having a width of about 2.5" and a thickness of about 5 mm. The disk drive apparatus **1***a* includes the motor **12***a* that is thinner than the motor **12**, instead of the motor **12** shown in FIG. **1**. The other configuration is approximately similar to that of the disk drive apparatus **1** shown in FIG. **1**, and in the following description, the same reference numerals are given to corresponding components. The motor **12***a* preferably is a three-phase brushless motor.

The disk drive apparatus **1***a* preferably includes a disk **11**, an access unit **13**, a housing **14**, and a clamper **151**. The disk **11** is clamped to the motor **12***a* by the clamper **151**. The motor **12***a* rotates the disk **11** that records information. The access unit **13** performs at least one of reading and writing of information with respect to the disk **11**. The disk **11**, the motor **12***a*, the access unit **13**, and the clamper **151** are accommodated inside the housing **14**.

FIG. **21** is a longitudinal sectional view illustrating the motor **12***a*. The motor **12***a* preferably has approximately the same structure as that of the motor **12** shown in FIG. **2**, except that the thickness is reduced. The motor **12***a* includes a stationary portion **2**, a rotating portion **3**, and a bearing mechanism **4**. The stationary portion **2** preferably includes a base plate **21**, a stator **22**, an insulating bushing **23**, a magnetic member **24**, and a wiring substrate **25**. The stator **22** includes a stator core **221** and a coil **222**. The rotating portion **3** includes a rotor hub **31** and a rotor magnet **32**. The bearing mechanism **4** preferably includes a shaft portion **41**, a sleeve **42**, a sleeve housing **43**, a thrust plate **44**, a cap portion **45**, and a lubricant **46**.

When the motor **12***a* is driven, torque is generated between the stator **22** and the rotor magnet **32**. A torque constant Kt of the torque generated between the stator **22** and the rotor magnet **32** is preferably about 3 mN·m/A or more and about 4.5 mN·m/A or less, for example. Further, a motor constant Km is preferably about 1 mN·m/(A·√Ω) or more and about 2 mN·m/(A·√Ω) or less, for example.

The inner diameter of the stator core **221** with reference to a central axis J**1** is preferably about 8 mm or more and about 9 mm or less, for example. The number of turns of each coil **222** is preferably about 40 or more and about 80 or less, for example. The number of layers of a conducting wire **223** in each coil **222** is preferably four, for example. The diameter of the conducting wire **223** is preferably about 0.10 mm or more and about 0.15 mm or less, for example.

FIG. **22** is an enlarged view of the vicinity of the rotor magnet **32** in FIG. **21**. An inner height H**3** that is the distance in the axial direction between a lower surface **311***a* of a cover portion **311** of the rotor hub **31** and an upper surface **212** of the base plate **21** preferably is approximately 2.5 mm, for example. The stator core **221** is obtained by stacking a plurality of magnetic steel plates **221***a*. The thickness of one magnetic steel plate **221***a* preferably is approximately 0.2 mm, for example. The number of the magnetic steel plates **221***a* is preferably six or seven, for example. In the present preferred embodiment, the number of the magnetic steel plates **221***a* is preferably six, for example. A height H**1** of the stator core **221** in the axial direction preferably is approximately 1.2 mm, for example. The height H**1** does not include the thicknesses of insulating films provided on an upper surface and a lower surface of the stator core **221**. The ratio of the height H**1** of the stator core **221** to a height H**2** of the stator **22** in the axial direction, that is, the core height ratio Hr is preferably about 50% or more and about 70% or less, for example. The height H**2** is a height from a lower end to an upper end of the coil **222**. In the present preferred embodiment, the height H**2** of the stator **22** preferably is approximately 2.4 mm, for example.

A thickness T**1** of the rotor magnet **32** in the radial direction is preferably about 0.7 mm or more and about 1.0 mm or less, for example. The thickness T**1** does not include the thickness of an insulating film provided on a front surface of the rotor magnet **32**. An air gap G**1** that is the distance in the radial direction between the rotor magnet **32** and the stator core **221** is preferably about 0.15 mm or more and about 0.20 mm or less, for example. The air gap G**1** is the shortest distance in the radial direction between an outer circumferential surface of a tooth **52** and an inner circumferential surface of the rotor magnet **32**. The outer circumferential surface of the tooth **52** refers to an outer surface of the plurality of stacked magnetic steel plates **221***a*. In a case where the insulating film is provided on the outer surface of the magnetic steel plate **221***a*, the thickness of the insulating film is included in the air gap G**1**. The inner circumferential surface of the rotor magnet **32** refers to an inner circumferential surface of the insulating film provided on the front surface of the rotor magnet **32**. The thickness of the insulating film of the rotor magnet **32** is not included in the air gap G**1**.

In the motor **12***a* of the disk drive apparatus **1***a* having the thickness of about 5 mm, in a similar way to the disk drive apparatus **1** having the thickness of about 7 mm, it is preferably designed in a way so as to shorten the startup time while generating sufficient torque in the limited space. In order to generate sufficient torque, the motor **12***a* is preferably designed so that the torque constant Kt is about 3 mN·m/A or more and about 4.5 mN·m/A or less, for example. Further, in order to shorten the startup time, the motor **12***a* preferably is designed so that the motor constant Km is about 1 mN·m/(A·√Ω) or more and about 2 mN·m/(A·√Ω) or less, for example.

In the motor **12***a*, as described above, the thickness T**1** of the rotor magnet **32** in the radial direction preferably is about 0.7 mm or more and about 1.0 mm or less, and the air gap G**1** preferably is about 0.15 mm or more and about 0.20 mm or less, for example. In the motor **12***a*, compared with the motor of the disk drive apparatus having the thickness of about 9.5 mm, it is possible to increase the density of magnetic flux generated between the rotor magnet **32** and the stator core **221** while preventing an increase in size in the radial direction in the limited space. Consequently, it is possible to generate sufficient torque when the motor **12***a* is driven in the limited space, and to shorten the startup time of the motor **12***a*.

FIG. **23** is a contour diagram illustrating the relationship between the thickness T**1** of the rotor magnet **32** of the motor **12***a* shown in FIG. **22** and the air gap G**1**, and the torque constant Kt. A plurality of curves in FIG. **23** represents contours of the torque constant Kt, and the torque constant Kt increases from the upper left to the lower right in FIG. **23**. The contours of the torque constant Kt are calculated by the same simulation as in FIG. **6**.

Referring to FIG. **23**, if the thickness T**1** of the rotor magnet **32** is changed without change in G**1** in a range where the air gap G**1** is about 0.15 mm or more and about 0.20 mm or less, the torque constant Kt gradually increases as T**1** increases in a range where T**1** is about 1.0 mm or less. On the other hand, the torque constant Kt gradually decreases as T**1** increases in a range where T**1** is larger than about 1.0 mm. That is, by setting T**1** to about 1.0 mm or less, for example, the magnetic flux density increased according to the increase of T**1** is effectively used in the increase of the torque constant Kt. Further, if T**1** is smaller than about 0.7 mm, for example, the reduction ratio of Kt to the reduction of T**1** relatively increases. Accordingly, by setting T**1** to about 0.7 mm or more and about 1.0 mm or less, for example, it is possible to efficiently increase the torque constant Kt while preventing the rotor magnet **32** from being increased.

FIG. **24** is a contour diagram illustrating the relationship between the thickness T**1** of the rotor magnet **32** of the motor **12***a* shown in FIG. **22** and the air gap G**1**, and the motor constant Km. A plurality of curves in FIG. **24** represents contours of the motor constant Km, and the motor constant Km increases from the upper left to the lower right in FIG. **24**. The contours of the motor constant Km are calculated by the same method as in the contours of the torque constant Kt. According to FIG. **24**, if T**1** is changed without change in G**1** in a range where the G**1** is about 0.15 mm or more and about 0.20 mm or less, the motor constant Km gradually increases as T**1** increases in a range where the above-described T**1** is about 0.7 mm or more and about 1.0 mm or less, for example. That is, the magnetic flux density increased according to the increase of T**1** is effectively used in the increase of the motor constant Km.

As described above, in the motor **12***a* shown in FIG. **22**, the thickness T**1** of the rotor magnet **32** preferably is about 0.7 mm or more and about 1.0 mm or less, and the air gap G**1** preferably is about 0.15 mm or more and about 0.20 mm or less, for example. In this way, by reducing T**1** and G**1**, it is possible to increase the outer diameter of the stator core **221** while preventing an increase in the size of the motor **12***a* in the radial direction. Thus, even in the thin motor **12***a* in which the inner height H**3** is relatively small, it is possible to increase the upper limit of the number of turns of the coil **222**. Consequently, it is possible to easily realize the torque constant Kt and the motor torque Km of a desired size.

In the motor **12***a*, by setting the torque constant Kt to about 3 mN·m/A or more and about 4.5 mN·m/A or less, for example, it is possible to efficiently generate sufficient torque while suppressing the amount of electric current. Further, by setting the motor constant Km to about 1 mN·m/(A·√Ω) or more and about 2 mN·m/(A·√Ω) or less, for example, it is possible to shorten the startup time of the motor **12***a*.

FIGS. **25** to **28** respectively show results obtained by calculating the core height ratio Hr, the motor constant Km, the torque constant Kt and the number of layers of the conducting wire **223** while variously changing the height H**1** of the stator core **221** and the diameter D**1** of the conducting wire **223** in a case where the inner height H**3** of the motor **12***a* shown in FIG. **22** is about 2.5 mm, for example.

FIG. **25** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12***a* shown in FIG. **22** and the diameter D**1** of the conducting wire **223**, and the core height ratio Hr. In FIG. **25**, in a similar way to FIG. **8**, a region where the core height ratio Hr is about 50% or more and about 70% or less is surrounded by a thick broken line with reference numeral **81**. A region **83** indicated by parallel slanted lines on the right side in FIG. **25** represents a region where the coil **222** cannot be provided due to the relationship between the inner height H**3**, the height H**1** of the stator core **221**, and the diameter D**1** of the conducting wire **223**. This is similarly applied to a region **83** in FIGS. **26** to **28**.

FIG. **26** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12***a* shown in FIG. **22** and the diameter D**1** of the conducting wire **223**, and the motor constant Km. Regions **82** indicated by parallel slanted lines represent regions where the motor constant Km is the maximum in FIG. **26**. The motor constant Km is small on the left side in FIG. **26**, gradually increases from the lower left to the upper right, and becomes a peak in a range where H**1** is about 1.1 mm or more and about 1.5 mm or less. Further, if the motor constant Km passes the peak, the motor constant Km decreases once toward the upper right, and then increases again. A region surrounded by a thick broken line with reference numeral **81** represents a region where the core height ratio Hr is about 50% or more and about 70% or less, in a similar way to FIG. **25**, and includes the regions **82** where the motor constant Km in FIG. **26** is the maximum. In this way, by setting the core height ratio Hr to about 50% or more and about 70% or less, for example, it is possible to efficiently increase the motor constant Km.

FIG. **27** is a contour diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12***a* shown in FIG. **22** and the diameter D**1** of the conducting wire **223**, and the torque constant Kt. The torque constant Kt increases from the upper side to the lower side in FIG. **27**. A region surrounded by a thick broken line with reference numeral **81** represents a region where the core height ratio Hr is about 50% or more and about 70% or less, in a similar way to FIG. **25**. The region surrounded by the thick broken line **81** includes a region where the torque constant Kt is about 3 mN·m/A or more and about 4.5 mN·m/A or less.

FIG. **28** is a diagram illustrating the relationship between the height H**1** of the stator core **221** of the motor **12***a* shown in FIG. **22** and the diameter D**1** of the conducting wire **223**, and the number of layers of the conducting wires **223**. Regions **91** to **94** that are arranged from the upper right to the lower left in FIG. **28** respectively represent regions where the number of layers of the conducting wire **223** is two, four, six, and eight. In FIGS. **25** to **27**, the region **92** in which the number of layers of the conducting wire **223** is four is indicated by a thick solid line. As shown in FIG. **25**, in the region **92** where the number of layers of the conducting wire **223** is 4, the core height ratio Hr is about 50% or more and about 70% or less in a portion of about ½ from the right. As shown in FIGS. **26** and **27**, a region where the region **92** and the region **81** where the core height ratio Hr is about 50% or more and about 70% or less are overlapped includes the regions **82** where the motor constant Km is the maximum, and includes the region where the torque constant Kt is about 3 mN·m/A or more and about 4.5 mN·m/A or less.

In FIGS. **17** and **18** illustrating a case where the inner height H**3** preferably is about 3.0 mm, the region **81** includes the regions **82** where the motor constant Km is the maximum, and includes the region where the torque constant Kt is about 3 mN·m/A or more and about 4.5 mN·m/A or less, for example. Further, a region where the region **92** and the region **81** are overlapped also includes the regions **82** where the motor constant Km is the maximum, and includes the region the torque constant Kt is about 3 mN·m/A or more and about 4.5 mN·m/A or less, for example.

In the disk drive apparatus **1***a* having the thickness of about 5 mm, the inner height H**3** that can be realized is about 2.5 mm or more and about 3.0 mm or less, for example. As described with reference to FIGS. **16** to **19** and FIGS. **25** to **28**, by setting the core height ratio Hr of the motor **12***a* shown in FIG. **22** to about 50% or more and about 70% or less, it is possible to efficiently increase the motor constant Km in the range of 1 mN·m/(A·√Ω) or more and 2 mN·m/(A·√Ω) or less while setting the torque constant Kt to about 3 mN·m/A or more and about 4.5 mN·m/A or less, for example.

As described above, in the motor **12***a*, by setting the torque constant Kt to about 3 mN·m/A or more and about 4.5 mN·m/A or less, for example, it is possible to efficiently generate sufficient torque while suppressing the amount of electric current. Further, by setting the motor constant Km to about 1 mN·m/(A·√Ω) or more and about 2 mN·m/(A·√Ω)mN or less, for example, it is possible to shorten the startup time of the motor **12***a*. In the motor **12***a*, by setting the number of layers of the conducting wire **223** to four, it is possible to easily set the core height ratio Hr to about 50% or more and about 70% or less, for example. Consequently, it is possible to efficiently generate sufficient torque while suppressing the amount of electric current, and to easily realize the motor **12***a* in which the startup time is short.

In the motor **12***a*, as described above, the inner diameter of the stator core **221** preferably is about 8 mm or more and about 9 mm or less. By setting the inner diameter of the stator core **221** to about 9 mm or less, for example, it is possible to increase the length of the tooth **52** in the radial direction. Thus, it is possible to increase the upper limit of the number of turns of the coil **222** while preventing an increase of the inner height H**3** of the disk drive apparatus **1***a*. Further, by setting the inner diameter of the stator core **221** to about 8 mm or more, for example, it is possible to easily install the stator core **221** to the base plate **21**.

In the motor **12***a*, the diameter of the conducting wire **223** preferably is about 0.10 mm or more and about 0.15 mm or less, for example. The number of turns of each coil **222** preferably is about 40 or more and about 80 or less, for example. In the motor **12***a*, compared with the motor of the disk drive apparatus having the thickness of about 9.5 mm, it is possible to increase the upper limit of the number of turns while preventing an increase of the resistance value of the coil **222** in the limited space. Accordingly, it is possible to generate sufficient torque when the motor **12***a* is rotated in the limited space, and to shorten the startup time of the motor **12***a*.

In the stator **22**, by setting the number of the magnetic steel plates **221***a* to six or seven, it is possible to easily set the core height ratio Hr to about 50% or more and about 70% or less, for example. By using a magnetic steel plate having a thickness of about 0.2 mm, for example, that is easily available as the magnetic steel plate **221***a*, it is possible to reduce the manufacturing cost of the stator core **221**. In the stator core

**221**, the magnetic steel plate **221***a* having various thicknesses and numbers may be used. The thickness of the magnetic steel plate **221***a* may be about 0.15 mm or about 0.3 mm, for example.

Further, the motor **12***a* is not only applied to the disk drive apparatus having the width of about 2.5" and the thickness of about 5 mm, but may also be applied to a disk drive apparatus having a width of about 2.5" and a thickness of about 4 mm, a width of about 2.5" and a thickness of about 3 mm, or the like, for example.

The disk drive apparatuses **1** and **1***a* of the above described preferred embodiments of the present invention may be variously modified. For example, in the motor **12** and **12***a*, a base bracket installed to the first housing member **141** may be used as a base portion, instead of the base plate **21**. In the disk drive apparatuses **1** and **1***a*, a plurality of female screw portions may be defined in the cover portion **311** of the rotor hub **31** in the circumferential direction, and the clamper **151** may be fixed to the female screw portion.

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

The preferred embodiments of the present invention and modifications thereof may be used as a spindle motor of a disk drive apparatus, for example.

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 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.

What is claimed is:

**1**. A spindle motor of a disk drive apparatus, comprising:

a base unit;

a stator that includes a stator core and a plurality of coils mounted to the stator core and is disposed above the base unit;

a covered cylindrical rotor hub that includes a cover portion positioned above the stator and a side wall portion extending downward from an outer edge of the cover portion;

a rotor magnet that is positioned outside the stator in a radial direction thereof and is fixed to an inner circumferential surface of the side wall portion of the rotor hub; and

a bearing mechanism that supports the rotor hub and the rotor magnet to be rotatable with respect to the base unit and the stator; wherein

a height of the stator core in an axial direction is about 50% or more and about 70% or less than a height of the stator;

a torque constant Kt of torque generated between the stator and the rotor magnet is about 4 mN·m/A or more and about 6 mN·m/A or less; and

a motor constant Km is about 2 mN·m/(A·√Ω) or more and about 4 mN·m/(A·√Ω) or less.

**2**. The spindle motor of the disk drive apparatus according to claim **1**, wherein

the stator core is defined by a plurality of stacked magnetic steel plates; and

a number of the plurality of stacked magnetic steel plates is in a range of eight to twelve, and a thickness of each of the plurality of magnetic steel plates is about 0.2 mm.

**3**. The spindle motor of the disk drive apparatus according to claim **1**, wherein

a number of layers of a conducting wire in each of the plurality of coils is four; and

a diameter of a conducting wire of the plurality of coils is about 0.1 mm or more and about 0.15 mm or less.

**4**. The spindle motor of the disk drive apparatus according to claim **1**, wherein

a number of layers of a conducting wire in each of the plurality of coils is four;

a thickness of the rotor magnet in the radial direction is about 0.7 mm or more and about 1.0 mm or less, and

a distance in the radial direction between the rotor magnet and the stator core is about 0.15 mm or more and about 0.20 or less.

**5**. The spindle motor of the disk drive apparatus according to claim **1**, wherein an inner diameter of the stator core is about 8 mm or more and about 9 mm or less.

**6**. The spindle motor of the disk drive apparatus according to claim **1**, wherein a number of turns of each of the plurality of coils is about 40 or more and about 80 or less.

**7**. The spindle motor according to claim **1**, wherein the spindle motor is adapted for use in a disk drive apparatus having a width of about 2.5" and a thickness of about 7 mm or less.

**8**. A disk drive apparatus comprising:

the spindle motor according to claim **1** arranged to rotate a disk;

an access unit that performs at least one of reading and writing of information with respect to the disk;

a clamper that clamps the disk to the rotor hub; and

a housing that accommodates the disk, the spindle motor, the access unit and the clamper.

**9**. A spindle motor of a disk drive apparatus, comprising:

a base unit;

a stator that includes a stator core and a plurality of coils mounted to the stator core and is disposed above the base unit;

a covered cylindrical rotor hub that includes a cover portion positioned above the stator and a side wall portion extending downward from an outer edge of the cover portion;

a rotor magnet that is positioned outside the stator in a radial direction thereof and is fixed to an inner circumferential surface of the side wall portion of the rotor hub; and

a bearing mechanism that supports the rotor hub and the rotor magnet to be rotatable with respect to the base unit and the stator; wherein

a height of the stator core in an axial direction is about 50% or more and about 70% or less than a height of the stator;

a torque constant Kt of torque generated between the stator and the rotor magnet is about 3 mN·m/A or more and about 4.5 mN·m/A or less; and

a motor constant Km is about 1 mN·m/(A·√Ω) or more and about 2 mN·m/(A·√Ω) or less.

**10**. The spindle motor of the disk drive apparatus according to claim **9**, wherein

the stator core is defined by a plurality of stacked magnetic steel plates; and

a number of the plurality of stacked magnetic steel plates is one of six or seven, and a thickness of each of the plurality of magnetic steel plates is about 0.2 mm.

**11**. The spindle motor of the disk drive apparatus according to claim **9**, wherein

a number of layers of a conducting wire in each of the plurality of coils is 4; and

a diameter of the conducting wire of the plurality of coils is about 0.10 mm or more and about 0.15 mm or less.

**12**. The spindle motor of the disk drive apparatus according to claim **9**, wherein a number of layers of a conducting wire in each of the plurality of coils is 4;

a thickness of the rotor magnet in the radial direction is about 0.7 mm or more and about 1.0 mm or less; and

a distance in the radial direction between the rotor magnet and the stator core is about 0.15 mm or more and about 0.20 mm or less.

**13**. The spindle motor of the disk drive apparatus according to claim **9**, wherein an inner diameter of the stator core is about 8 mm or more and about 9 mm or less.

**14**. The spindle motor of the disk drive apparatus according to claim **9**, wherein a number of turns of each of the plurality of coils is about 40 or more and about 80 or less.

**15**. The spindle motor according to claim **9**, wherein the spindle motor is adapted for use in a disk drive apparatus having a width of about 2.5" and a thickness of about 5 mm or less.

**16**. A disk drive apparatus comprising:

the spindle motor according to claim **9** arranged to rotate a disk;

an access unit that performs at least one of reading and writing of information with respect to the disk;

a clamper that clamps the disk to the rotor hub; and

a housing that accommodates the disk, the spindle motor, the access unit and the clamper.

* * * * *

# Exhibit
# B

US009742239B2

(12) **United States Patent**
**Yoneda et al.**

(10) **Patent No.: US 9,742,239 B2**
(45) **Date of Patent: Aug. 22, 2017**

(54) **SPINDLE MOTOR AND DISK DRIVE APPARATUS**

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(72) Inventors: **Tomohiro Yoneda**, Kyoto (JP); **Hiroshi Kobayashi**, Kyoto (JP); **Masanobu Taki**, Kyoto (JP)

(73) Assignee: **NIDEC CORPORATION**, Kyoto (JP)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 350 days.

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(30) **Foreign Application Priority Data**

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| Feb. 25, 2015 | (JP) | 2015-035008 |

(51) **Int. Cl.**

| | |
|---|---|
| ***H02K 11/00*** | (2016.01) |
| ***H02K 5/10*** | (2006.01) |
| ***H02K 5/22*** | (2006.01) |
| ***H02K 11/33*** | (2016.01) |

(52) **U.S. Cl.**
CPC ................ ***H02K 5/10*** (2013.01); ***H02K 5/22*** (2013.01); ***H02K 11/33*** (2016.01)

(58) **Field of Classification Search**
CPC .............. H02K 3/28; H02K 5/10; H02K 5/22
USPC ............................ 310/71, 43, 90; 360/99.08
See application file for complete search history.

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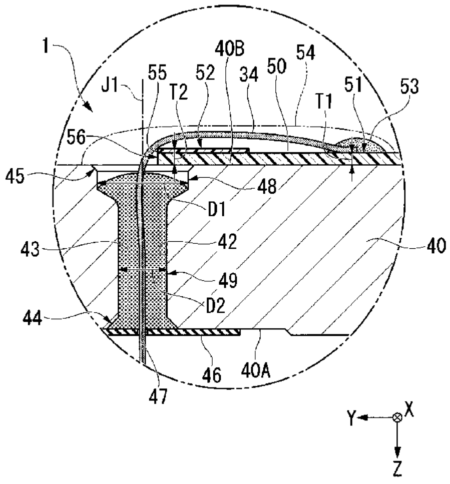
*Primary Examiner* — Hanh Nguyen
(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

A base portion made of a metal includes an upper surface, a lower surface, and a base portion through hole. An insulation sheet portion is located on the lower surface, and covers at least a portion of the base portion through hole. A lead wire is in contact with the insulation sheet portion. A spindle motor includes a first sealant located in the base portion through hole, and a second sealant which covers at least a portion of the base portion through hole. The first sealant has a coefficient of linear expansion greater than a coefficient of linear expansion of the base portion and smaller than a coefficient of linear expansion of the second sealant.

**15 Claims, 12 Drawing Sheets**



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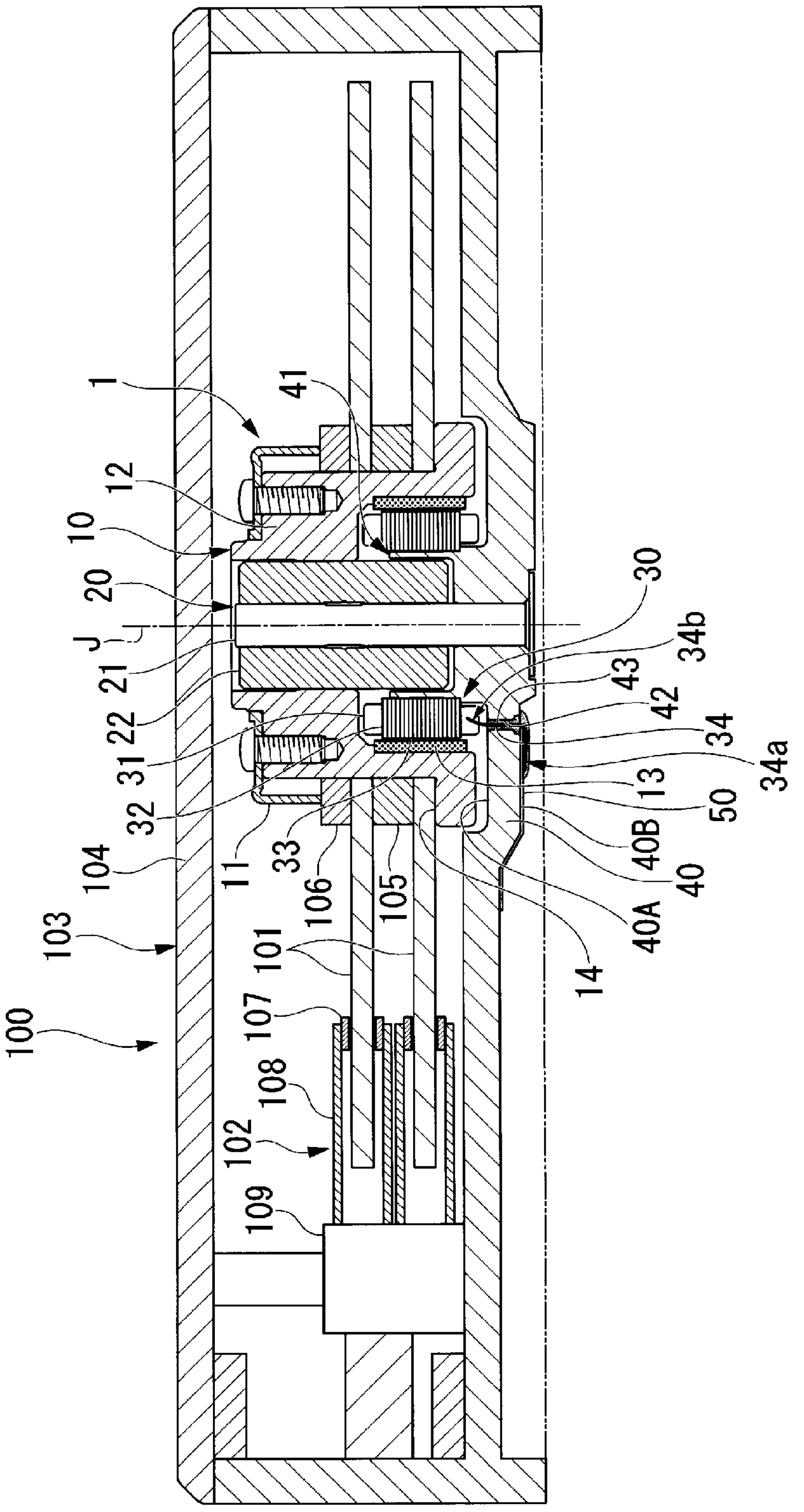
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Fig. 1

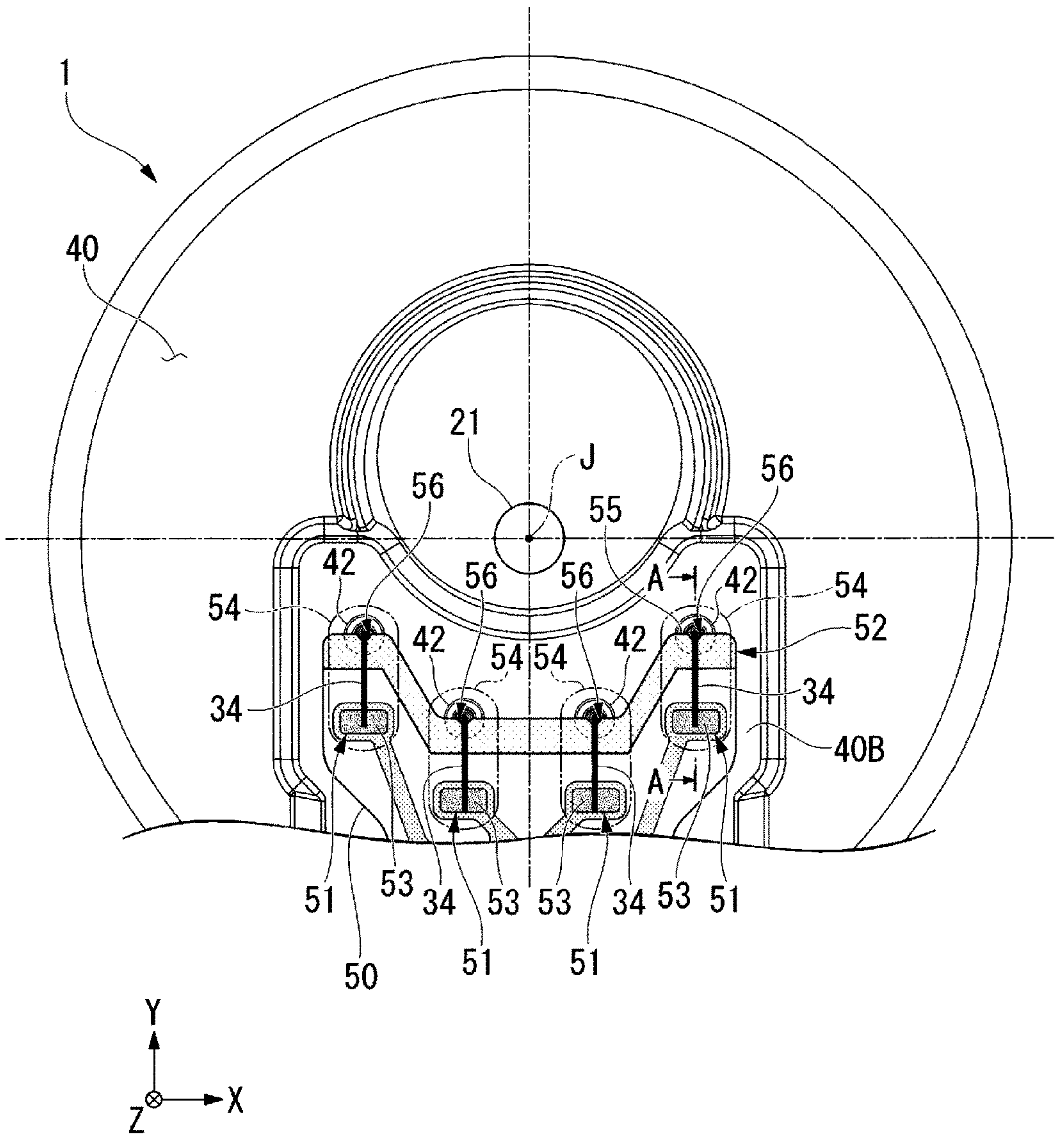
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Fig.2

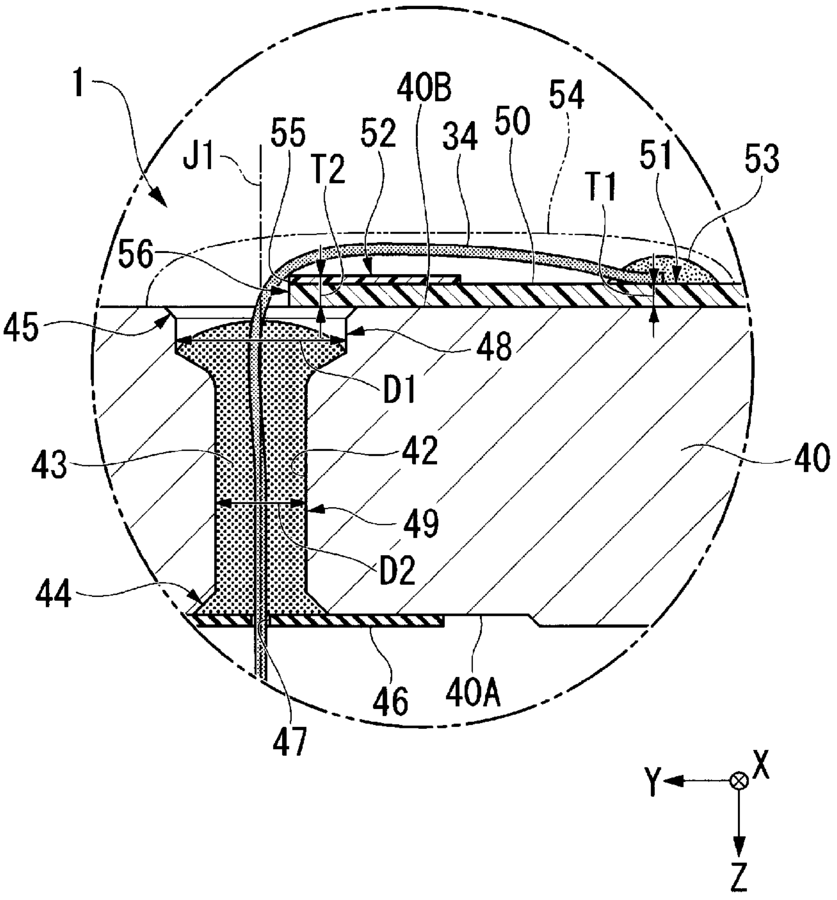
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Fig.3

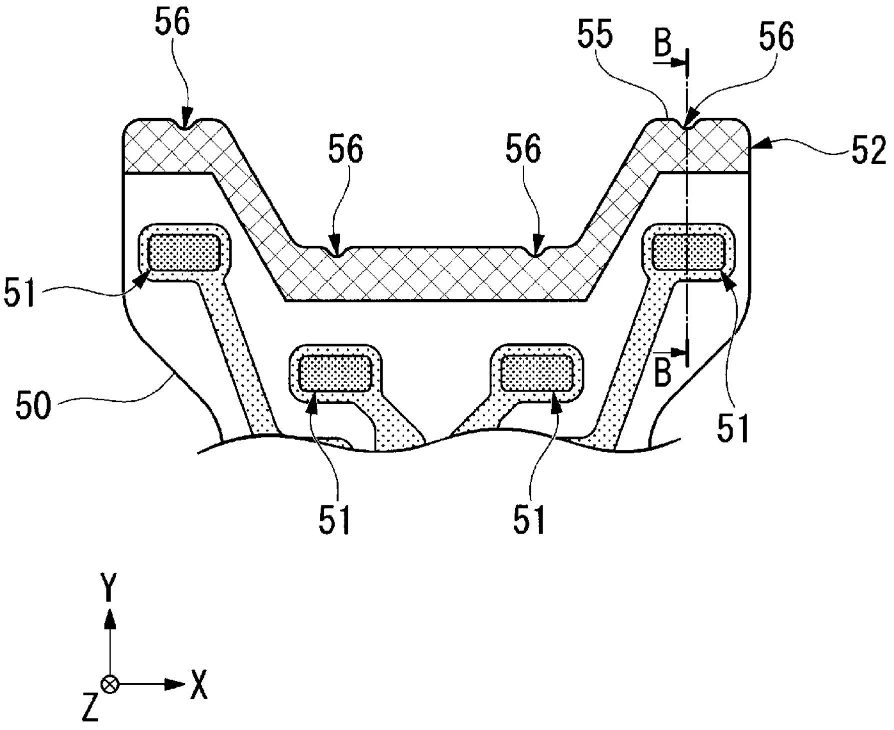

Fig.4

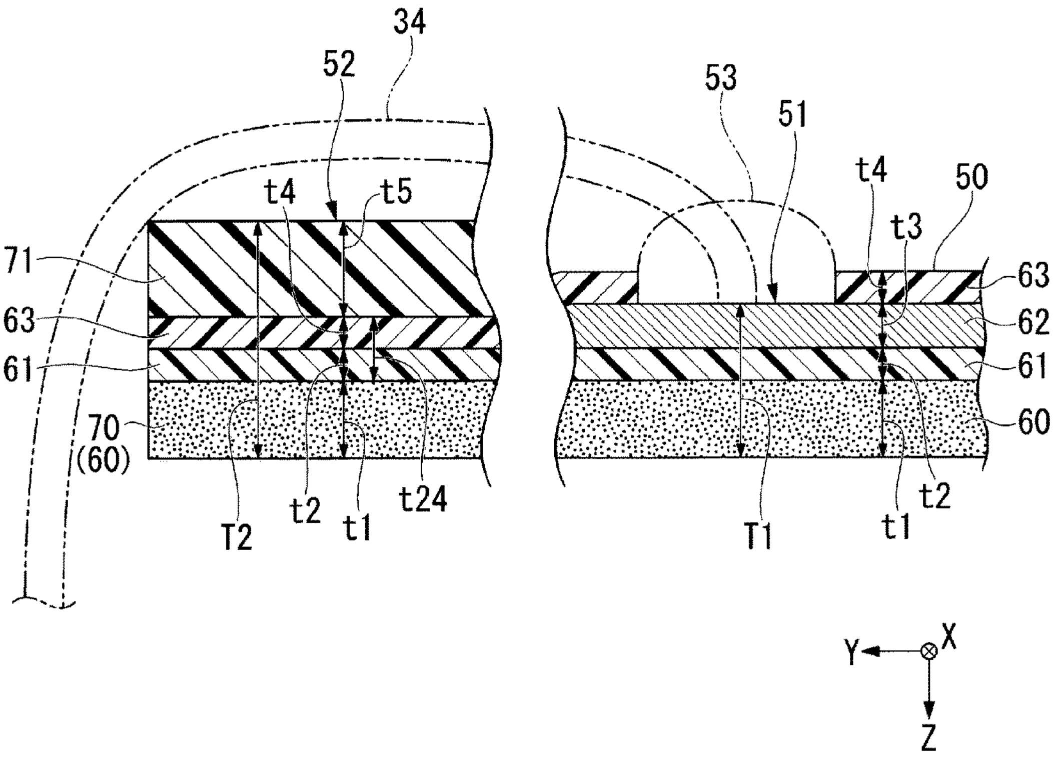
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Fig. 5

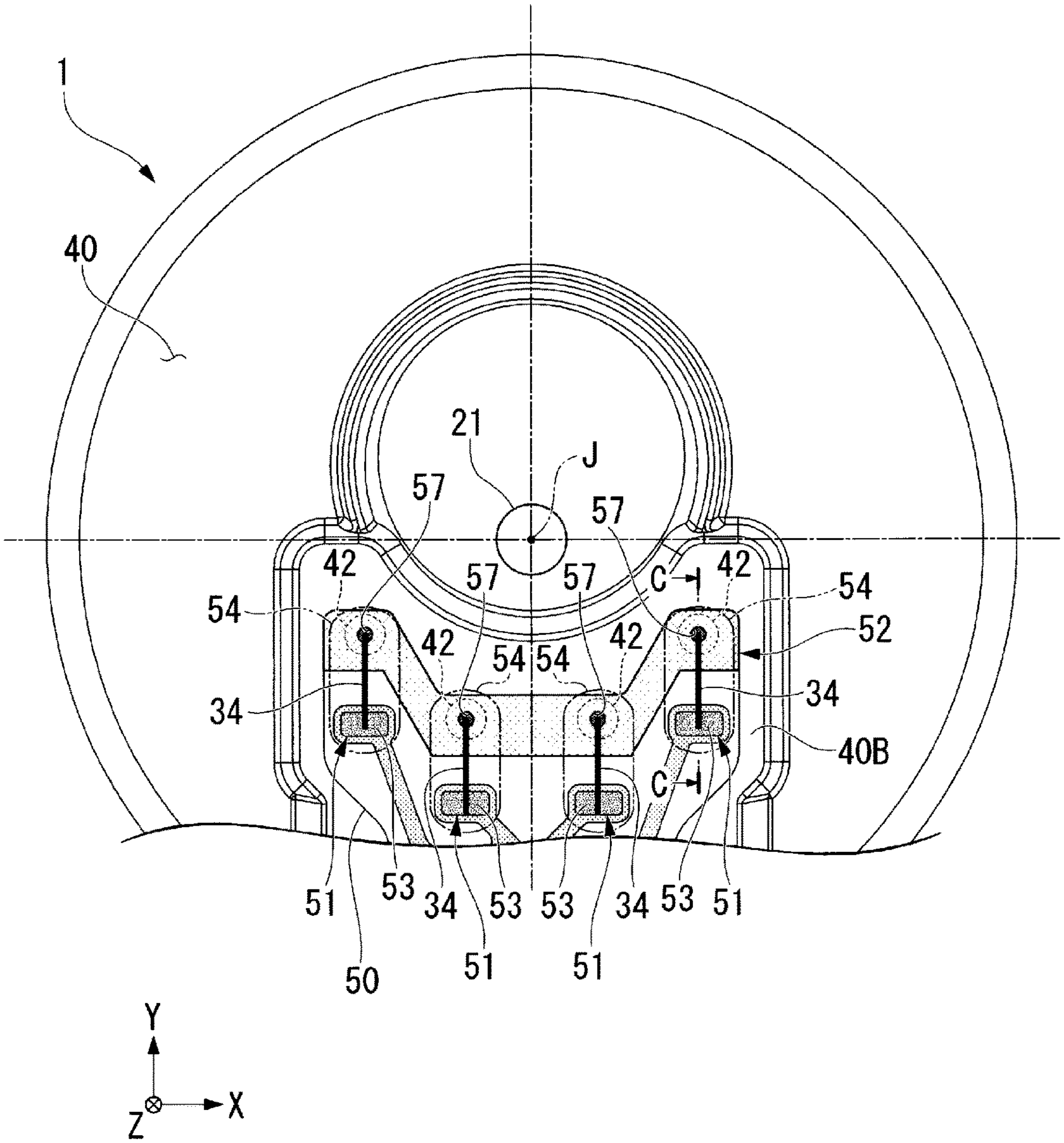
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Fig.6

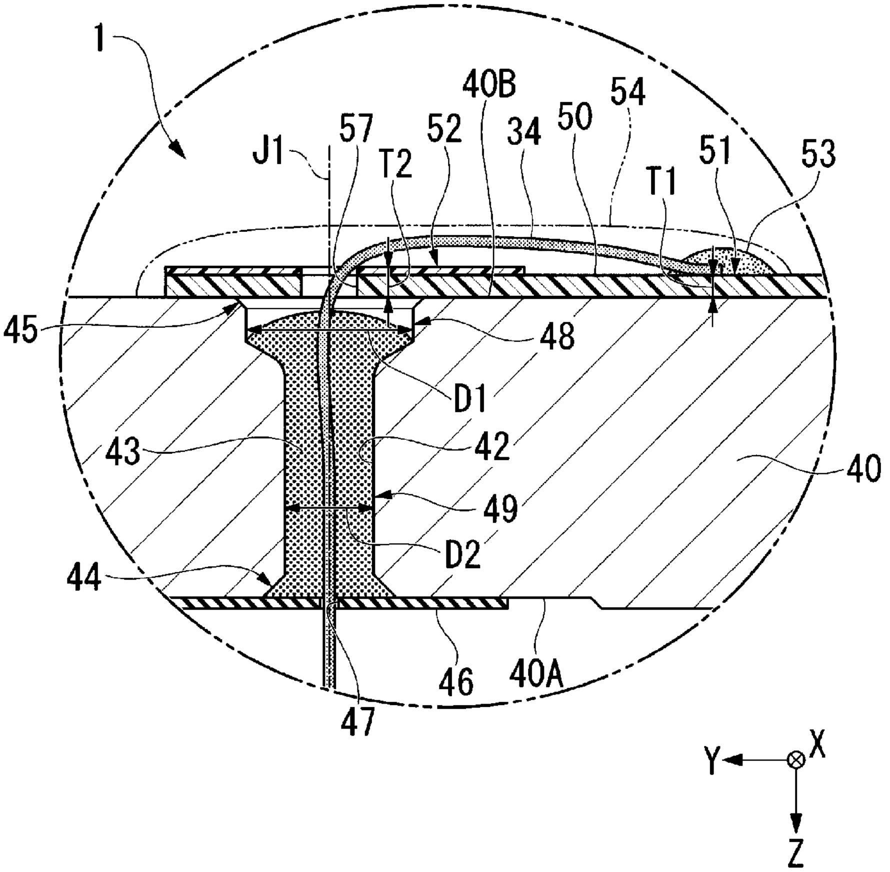
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Fig.7

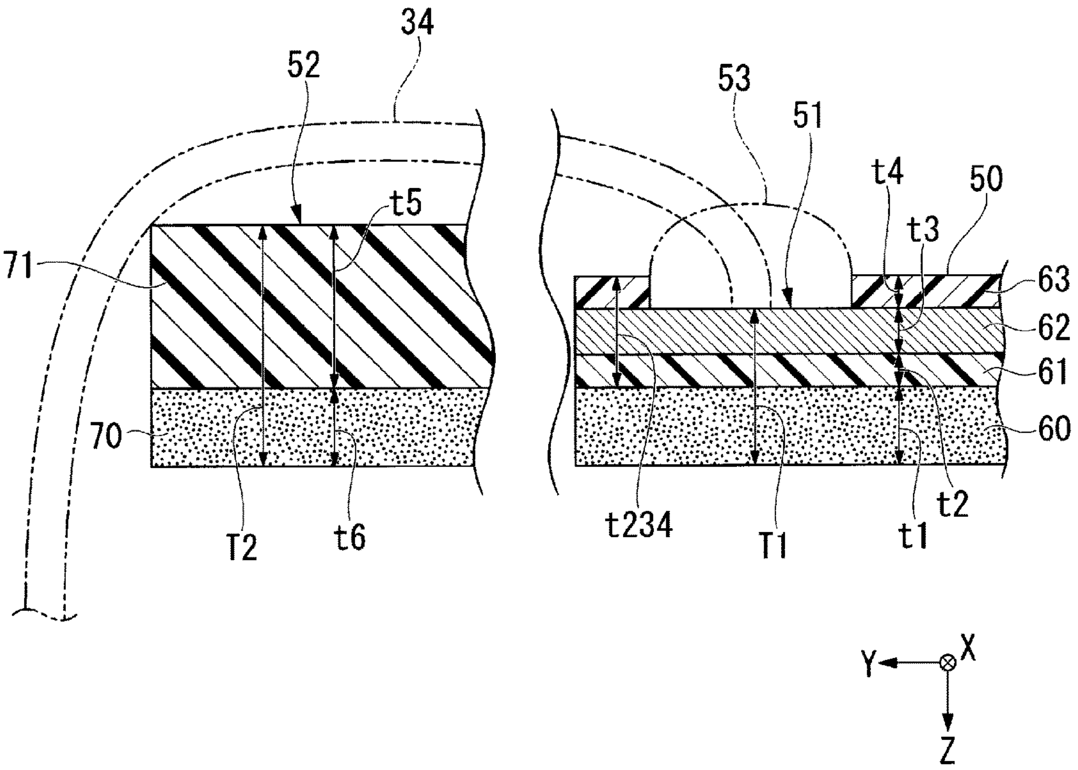

Fig.8

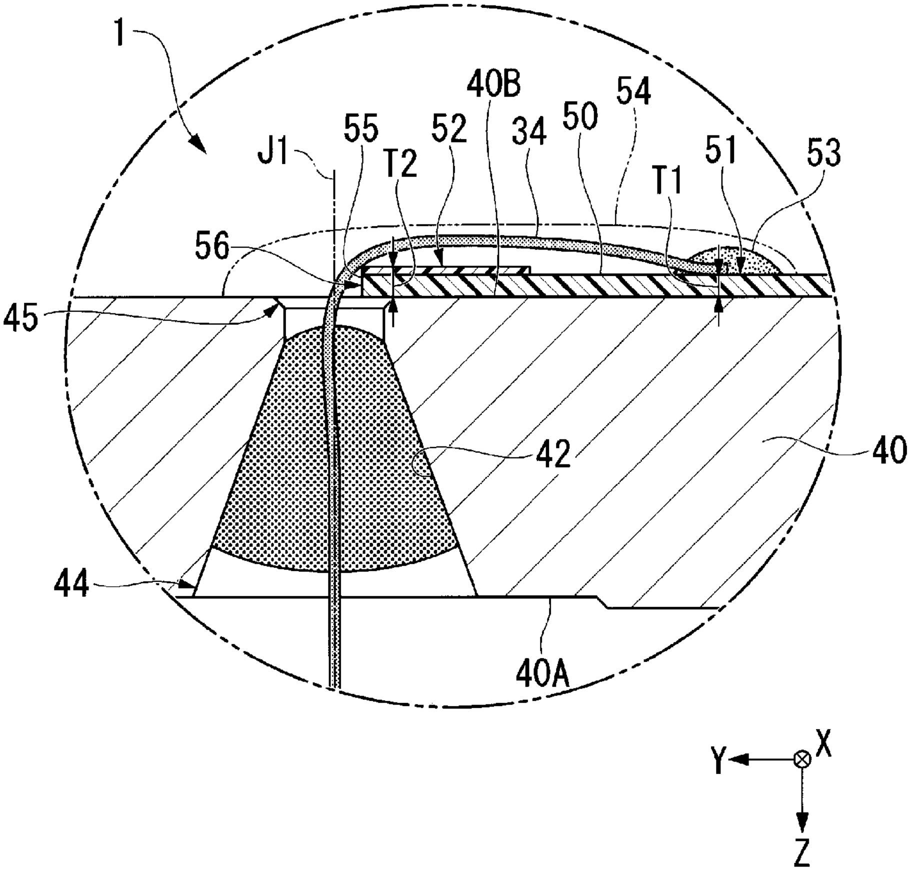

Fig.9

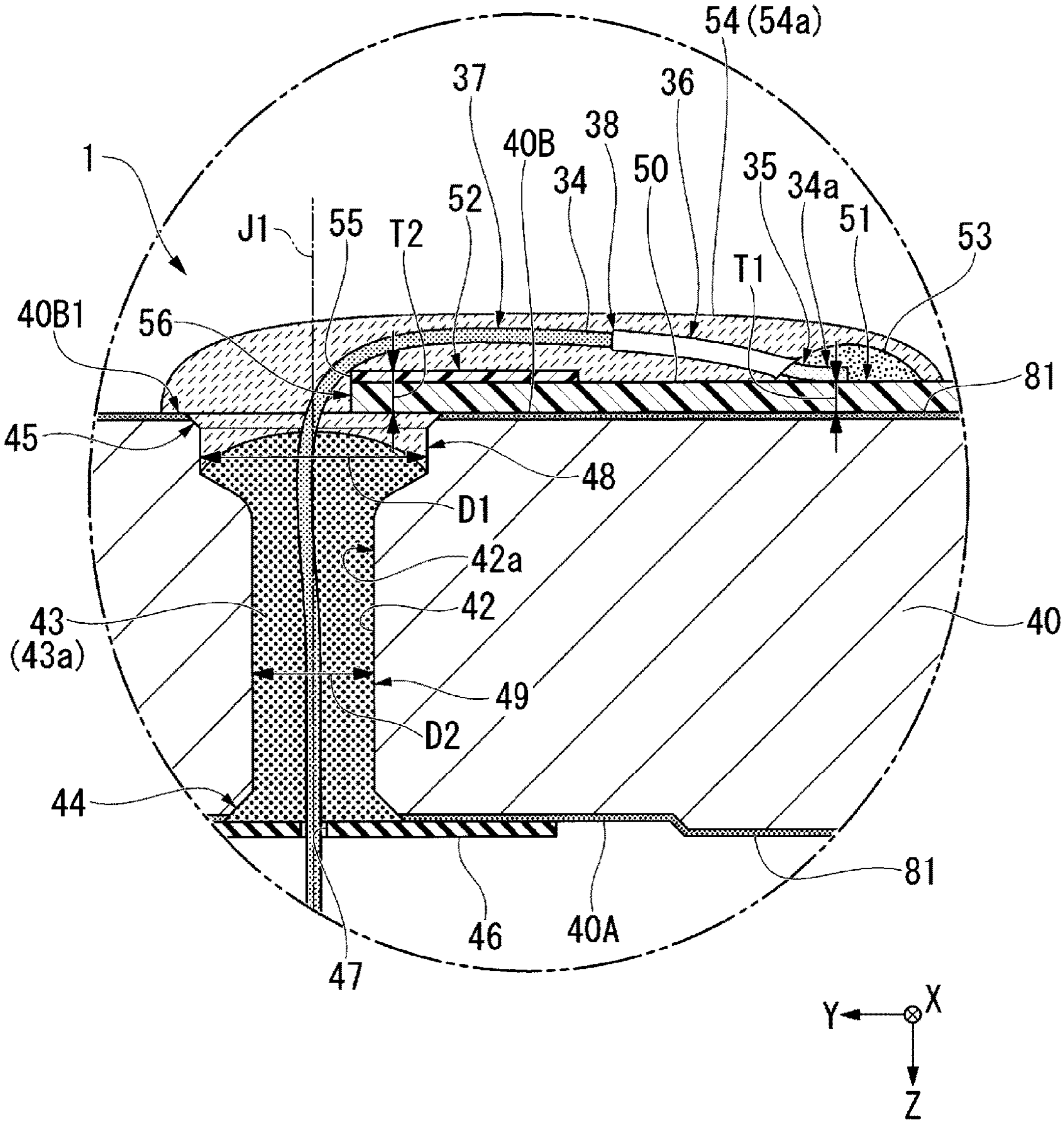
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Fig.10

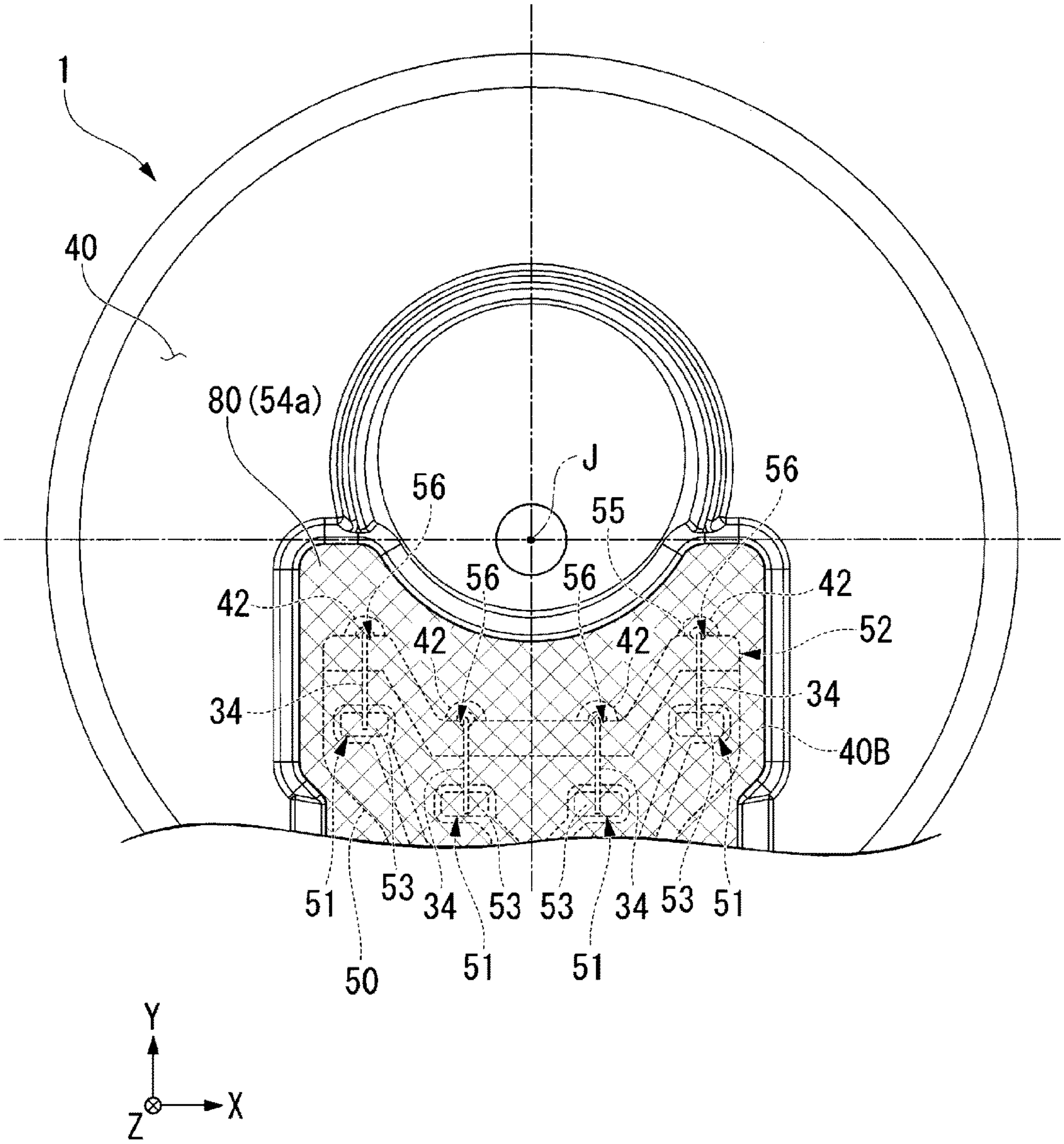
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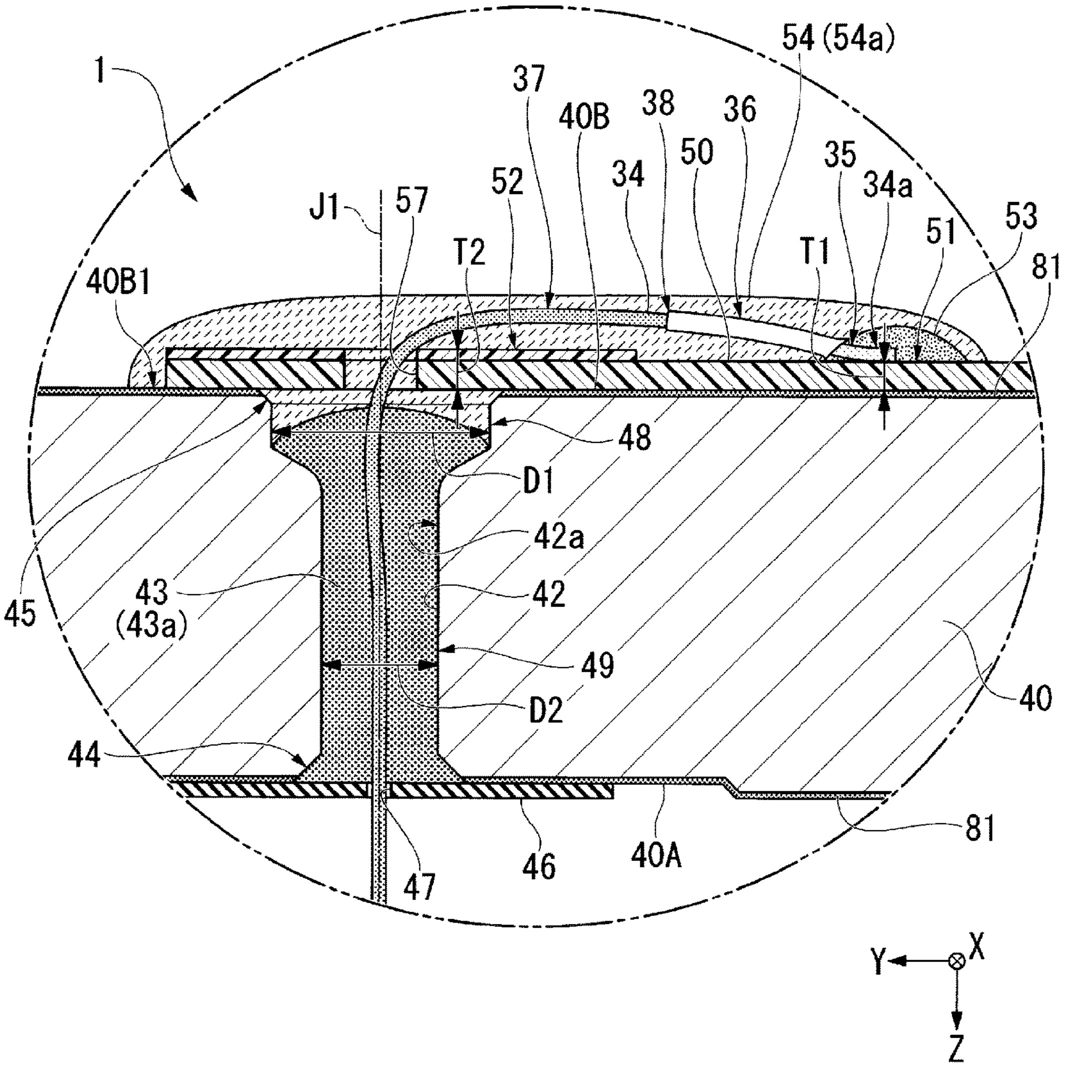
Fig. 11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D1
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D2
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44
81
46
40A
47
Y
X
Z

Fig.12

# SPINDLE MOTOR AND DISK DRIVE APPARATUS

## BACKGROUND OF THE INVENTION

1. Field of the Invention

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

2. Description of the Related Art

A disk drive apparatus, such as, for example, a hard disk drive, includes a spindle motor arranged to rotate a recording disk. A base of a spindle motor described in JP-A 2012-151940 includes a base draw-out hole. A lead wire from a coil passes through the base draw-out hole. The lead wire is soldered to a wiring member arranged on a lower surface of the base.

If the lead wire obliquely passes through the base draw-out hole, the lead wire is brought into contact with a hole edge of the base draw-out hole as illustrated in FIG. 3 of JP-A 2012-151940. If the lead wire is brought into contact with the hole edge, an insulating coating of the lead wire may be damaged. Damage to the coating of the lead wire may lead to defective insulation due to a portion of the coating being stripped off. Moreover, the lead wire, with a portion of the coating being stripped off, and the base may become electrically connected with each other, and a short circuit may occur.

In addition, gaps are defined between the lead wire and the base draw-out hole, and between the lead wire and the wiring member. When such a gap exists, gas may enter or exit from between an interior space of the disk drive apparatus and a space outside of the disk drive apparatus through the gap.

## SUMMARY OF THE INVENTION

A spindle motor according to a preferred embodiment of the present invention includes a rotor portion including a rotor magnet, a bearing portion, a base portion made of a metal, a stator portion, a circuit board, an insulation sheet portion, a first sealant, and a second sealant. The bearing portion is configured to support the rotor portion such that the rotor portion is rotatable about a central axis extending in a vertical direction. The base portion includes an upper surface, a lower surface, and a base portion through hole passing therethrough from the upper surface to the lower surface. The stator portion is located on the upper surface. The stator portion includes coils positioned opposite to the rotor magnet with a gap intervening therebetween. The circuit board is provided on the lower surface.

The coils include a lead wire drawn out from above the upper surface downwardly of the lower surface through the base portion through hole. The circuit board includes a land portion to which the lead wire is connected. The insulation sheet portion is located on the lower surface, covers at least a portion of the base portion through hole. The lead wire contacts the insulation sheet portion. The first sealant is provided in the base portion through hole. The second sealant covers at least a portion of the base portion through hole. The first sealant is has a coefficient of linear expansion greater than a coefficient of linear expansion of the base portion and smaller than a coefficient of linear expansion of the second sealant.

According to the above preferred embodiment of the present invention, the likelihood that the lead wire will make contact with an inner wall surface of the base portion which defines the base portion through hole is significantly reduced or prevented. According to the above preferred embodiment of the present invention, entering and exiting of gas through the base portion through hole is prevented. A spindle motor and a disk drive apparatus according to preferred embodiments of the present invention are provided.

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 with reference to the attached drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical cross-sectional view illustrating a disk drive apparatus according to a preferred embodiment of the present invention.

FIG. **2** is a bottom view illustrating a base portion according to a preferred embodiment of the present invention.

FIG. **3** is a cross-sectional view taken along line A-A in FIG. **2**.

FIG. **4** is a bottom view illustrating a circuit board according to a preferred embodiment of the present invention.

FIG. **5** is a cross-sectional view taken along line B-B in FIG. **4**.

FIG. **6** is a bottom view illustrating a base portion according to an example modification of the above preferred embodiment of the present invention.

FIG. **7** is a cross-sectional view taken along line C-C in FIG. **6**.

FIG. **8** is a vertical cross-sectional view illustrating an insulation sheet portion according to an example modification of the above preferred embodiment of the present invention.

FIG. **9** is a vertical cross-sectional view illustrating an inner wall surface of a base portion through hole according to an example modification of the above preferred embodiment of the present invention.

FIG. **10** is a more detailed version of FIG. **3**.

FIG. **11** is a bottom view illustrating a second sealant according to an example modification of the above preferred embodiment of the present invention.

FIG. **12** is a vertical cross-sectional view illustrating a second sealant according to an example modification of the above preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, with reference to the accompanying drawings, preferred embodiments of the present invention will be described below. Note that the scope of the present invention is not limited to the preferred embodiments described below, but includes any modification thereof within the scope of the technical ideas of the present invention. Also note that dimensions, scales, numbers, and so on of members or portions illustrated in the following drawings may differ from those of actual members or portions, for the sake of easier understanding of the members or portions.

FIG. **1** is a vertical cross-sectional view illustrating a disk drive apparatus **100** including a spindle motor **1** according to a preferred embodiment of the present invention.

The disk drive apparatus **100** is a hard disk drive. The disk drive apparatus **100** preferably includes the spindle motor **1**, disks **101**, and an access portion **102**. The spindle motor **1** is arranged to rotate the disks **101**, on which information is recorded, about a central axis J. The access portion **102** performs at least one of reading and writing of information from or to the disks **101**.

The disk drive apparatus **100** includes a housing **103**. The housing **103** preferably includes a base portion **40** of the spindle motor **1**, and a cover member **104**. The cover member **104** is fitted to an opening of the base portion **40** to define the housing **103**. The disks **101** and the access portion **102** are accommodated in the housing **103**. An interior space of the housing **103** is preferably filled with, for example, a helium gas. Note that the interior space of the housing **103** may alternatively be filled with a hydrogen gas, air, or the like.

The disk drive apparatus **100** includes the plurality of disks **101**. The disk drive apparatus **100** includes a spacer **105** arranged between the disks **101**. The plurality of disks **101** are supported by the spindle motor **1**. More specifically, the plurality of disks **101** are supported by a rotor portion **10** of the spindle motor **1**. The rotor portion **10** includes a clamp member **11** configured and located to support the plurality of disks **101**. The disk drive apparatus **100** includes a spacer **106** between the clamp member **11** and the disks **101**. The plurality of disks **101** are configured to rotate about the central axis J together with the rotor portion **10**.

The access portion **102** preferably includes heads **107**, arms **108**, and a head actuator mechanism **109**. Each of the heads **107** is in close proximity to a surface of one of the disks **101** to magnetically perform at least one of the reading and the writing of information. Each head **107** is supported by an associated one of the arms **108**. Each arm **108** is supported by the head actuator mechanism **109**.

The spindle motor **1** preferably includes the rotor portion **10**, a bearing portion **20**, a stator portion **30**, the base portion **40**, a circuit board **50**, and an insulation sheet portion **52**. The rotor portion **10** preferably includes the clamp member **11**, a rotor hub **12**, and a rotor magnet **13**.

The bearing portion **20** is configured to support the rotor portion **10** such that the rotor portion **10** is rotatable about the central axis J, which extends in a vertical direction. The bearing portion **20** preferably includes a shaft **21** and a sleeve **22**. The shaft **21** is fixed to the base portion **40**. The shaft **21** and the sleeve **22** are located opposite to each other with a gap therebetween. A fluid, such as, for example, a lubricating oil or a gas, is provided in the gap.

The stator portion **30** preferably includes coils **31** and a stator core **32**. Each coil **31** is located opposite to the rotor magnet **13** with a gap therebetween. The stator portion **30** includes the plurality of coils **31**. The plurality of coils **31** are supported by the stator core **32**. The stator core **32** is preferably a laminated structure defined by laminated magnetic bodies. The stator core **32** includes salient poles **33** each of which projects outwardly. One of the coils **31** is wound around each of the plurality of salient poles **33**.

The base portion **40** preferably includes an upper surface **40**A, a lower surface **40**B, and base portion through holes **42**. The upper surface **40**A is a surface facing an inside of the housing **103**. The base portion **40** is preferably, for example, molded by casting. The base portion **40** is preferably an aluminum die-casting. However, the base portion **40** may be made of any other desirable material and formed using any other desirable manufacturing method. The base portion **40** includes a stator support portion **41**. The stator support portion **41** is provided on the upper surface **40**A of the base portion **40**. The stator support portion **41** is preferably in the shape of, for example, a tube, a polygon, or the like. The stator core **32** is located outside of the stator support portion **41**.

Each base portion through hole **42** passes through the base portion **40** from the upper surface **40**A to the lower surface **40**B. The lower surface **40**B is a surface facing an outside of the housing **103**. Each base portion through hole **42** preferably extends parallel or substantially parallel to the central axis J. Lead wires **34** from the coils **31** pass through the base portion through holes **42**. The spindle motor **1** includes a sealant **43**. The sealant **43** fills a gap between each base portion through hole **42** and the lead wire **34**. The sealant **43** is preferably an adhesive, for example. The circuit board **50** is provided on the lower surface **40**B of the base portion **40**. The circuit board **50** is connected with the lead wires **34**, which are drawn out below the lower surface **40**B through the base portion through holes **42**.

FIG. **2** is a bottom view illustrating the base portion **40** according to a preferred embodiment of the present invention. FIG. **3** is a cross-sectional view taken along line A-A in FIG. **2**.

In the following drawings, an xyz coordinate system is shown appropriately as a three-dimensional orthogonal coordinate system. In the xyz coordinate system, a z-axis direction is assumed to be a direction parallel to the central axis J extending in a vertical direction in FIG. **1**. A y-axis direction is assumed to be a direction perpendicular to a z-axis and parallel to a direction in which each lead wire **34** is drawn in FIG. **2**. An x-axis direction is assumed to be a direction perpendicular to both the z-axis and a y-axis. Note that the wording "parallel direction" as used herein comprehends both parallel and substantially parallel directions. Also note that the wording "perpendicular" as used herein comprehends both "perpendicular" and "substantially perpendicular".

Also note that, in the following description, a positive side (i.e., a +z side) in the z-axis direction will be referred to as an "upper side", and a negative side (i.e., a −z side) in the z-axis direction will be referred to as a "lower side". It should be noted, however, that the above definitions of the vertical direction and the upper and lower sides are not meant to indicate relative positions and/or directions of different members or portions when those members or portions are actually installed in a device. Also note that, in the following description, the relative positions of different members or portions and/or positions of those members or portions will be defined based on a central axis J1 which passes through a center of the base portion through hole **42** illustrated in FIG. **3**. Unless otherwise specified, a direction parallel to the central axis J1 (i.e., the z-axis direction) will be simply referred to by the term "axial direction", "axial", or "axially", radial directions centered on the central axis J1 will be simply referred to by the term "radial direction", "radial", or "radially", and a circumferential direction about the central axis J1 will be simply referred to by the term "circumferential direction", "circumferential", or "circumferentially".

Referring to FIG. **2**, the base portion **40** includes the plurality of base portion through holes **42**. The number of base portion through holes **42** included in the base portion **40** is preferably four. The coils **31** include the plurality of lead wires **34**. The number of lead wires **34** included in the coils **31** is preferably four. One of the plurality of lead wires **34** is passed through each of the plurality of base portion through holes **42**. In other words, one of the lead wires **34** is passed through each one of the base portion through holes **42**. The size of each base portion through hole **42** can be reduced to a size which allows only one of the lead wires **34** to pass through the base portion through hole **42**, to achieve improved airtightness. In addition, since two or more of the lead wires **34** are not passed through each base portion through hole **42**, a failure in filling of the sealant **43** due to a contact of two or more of the lead wires **34** is prevented. The coils **31** are preferably defined by three coil groups. The three coil groups are a U phase group, a V phase group, and a W phase group, respectively. Note that the number of base portion through holes **42** is not limited to four, but may alternatively be one, two, three, or more than four. Also note that the number of lead wires **34** is not limited to four, but may alternatively be one, two, three, or more than four.

In each of the three coil groups, one conducting wire preferably defines two or more of the coils **31**. The conducting wire is preferably an enameled wire including an insulating coating. One end portion of each of the three conducting wires of the three coil groups is drawn out as one of the lead wires **34**. Meanwhile, opposite end portions of the three conducting wires of the three coil groups are twisted together and drawn out as a single common wire. Hereinafter, the common wire will also be referred to as one of the lead wires **34**. Thus, the four lead wires **34** are drawn out of the base portion **40**.

The circuit board **50** is preferably a flexible circuit board. The circuit board **50** is fixed to the lower surface **40**B of the base portion **40**. The circuit board **50** includes land portions **51** to which the lead wires **34** are connected. Each land portion **51** is preferably provided at a position spaced away from a corresponding one of the base portion through holes **42** in a radial direction (specifically, the y-axis direction). The land portion **51** is connected with the lead wire **34** which is drawn out from above the upper surface **40**A downwardly of the lower surface **40**B through the base portion through hole **42**.

The circuit board **50** includes the plurality of land portions **51**. The number of land portions **51** included in the circuit board **50** is preferably four, for example. One of the plurality of lead wires **34** is connected to each of the plurality of land portions **51**. In other words, one of the lead wires **34** is connected to each one of the land portions **51**. Each land portion **51** preferably is rectangular or substantially rectangular, including short sides extending in the y-axis direction and long sides extending in the x-axis direction. The lead wire **34** is connected to the land portion **51** through a solder **53**. The lead wire **34**, the land portion **51**, and the solder **53** are preferably covered with a molding member **54**. The molding member **54** is preferably made of a resin. The molding member **54** is, for example, a thermosetting adhesive. Note that the molding member **54** may not necessarily be an adhesive, and may be, for example, a sheet-shaped portion or a resin material which is not an adhesive.

Referring to FIG. **3**, each base portion through hole **42** preferably includes an upper opening portion **44** and a lower opening portion **45**. The upper opening portion **44** opens on the upper surface **40**A of the base portion **40**. The lower opening portion **45** opens on the lower surface **40**B of the base portion **40**. The upper opening portion **44** is preferably circular or substantially circular in a plan view. An inner wall surface of the base portion **40** which defines the upper opening portion **44** is preferably chamfered. Accordingly, the inner wall surface of the base portion **40** which defines the upper opening portion **44** is slanted to gradually decrease in inside diameter as it extends away from the upper surface **40**A toward the lower surface **40**B in an axial direction. Note that the inner wall surface of the base portion **40** which defines the upper opening portion **44** will be hereinafter referred to as an inner wall surface of the upper opening portion **44**. The lower opening portion **45** preferably is circular or substantially circular in a plan view. An inner wall surface of the base portion **40** which defines the lower opening portion **45** is chamfered. Accordingly, the inner wall surface of the base portion **40** which defines the lower opening portion **45** is slanted to gradually decrease in inside diameter as it extends away from the lower surface **40**B toward the upper surface **40**A in the axial direction. Note that the inner wall surface of the base portion **40** which defines the lower opening portion **45** will be hereinafter referred to as an inner wall surface of the lower opening portion **45**.

Referring to FIG. **3**, an opening area of the lower opening portion **45** is greater than an opening area of the upper opening portion **44**. An insulation sheet guide **46** is provided on the upper surface **40**A of the base portion **40**. The insulation sheet guide **46** is configured to position the lead wire **34** which is passed through the upper opening portion **44** at the upper surface **40**A of the base portion **40**. The insulation sheet guide **46** covers at least a portion of the upper opening portion **44**. The insulation sheet guide **46** includes a guide through hole **47**. The guide through hole **47** overlaps with the upper opening portion **44** in a plan view. Note that a lower surface of the insulation sheet guide **46** may be fixed to the upper surface **40**A of the base portion **40** through an adhesive layer.

An opening area of the guide through hole **47** is greater than a cross-sectional area of the lead wire **34**. Thus, the lead wire **34** is able to pass through the guide through hole **47**. In addition, the opening area of the guide through hole **47** is smaller than the opening area of the upper opening portion **44**. Accordingly, the guide through hole **47** is not in contact with the inner wall surface of the upper opening portion **44**. Thus, the likelihood that the insulating coating of the lead wire **34** will be damaged is significantly reduced or prevented. Moreover, even if the insulating coating of the lead wire **34** is damaged, the lead wire **34** does not contact the inner wall surface of the upper opening portion **44**. Therefore, a short circuit due to an electrical connection between the lead wire **34** and the inner wall surface of the upper opening portion **44** is prevented.

The insulation sheet guide **46** is preferably made of a resin. More specifically, the insulation sheet guide **46** is preferably thermoplastic. Polyethylene terephthalate (PET), polyamide (PA), polybutylene terephthalate (PBT), polyphenylene sulfide (PPS), or the like, for example, is preferably used for the insulation sheet guide **46**. The resin used for the insulation sheet guide **46** preferably has a melting point lower than a melting point of a metal of which the base portion **40** is made. After the insulation sheet guide **46** is provided on the upper surface **40**A of the base portion **40**, the guide through hole **47** is defined by fusion through light irradiation with a xenon lamp or the like.

Therefore, even when the insulation sheet guide **46** is not positioned with high accuracy, the guide through hole **47** is able to be provided at a position overlapping with the upper opening portion **44** with high accuracy. Use of the insulation sheet guide **46** contributes to reducing the opening area of the upper opening portion **44** and an area of the base portion through hole **42** when compared to, for example, the case where a cylindrical insulating bushing is located in the base portion through hole **42**. Accordingly, the likelihood that the helium gas provided in the interior space of the housing **103** will leak out of the housing **103** is reduced.

The base portion through hole **42** includes a first opening portion **48** and a second opening portion **49** between the lower opening portion **45** and the upper opening portion **44**. The first opening portion **48** is in communication with the lower opening portion **45**. In other words, the first opening portion **48** is located above (i.e., on the +z side of) the lower opening portion **45**. The second opening portion **49** is in communication with the first opening portion **48**. In other words, the second opening portion **49** is located above (i.e., on the +z side of) the first opening portion **48**. The upper opening portion **44** is in communication with the second opening portion **49**. In other words, the upper opening portion **44** is located above (i.e., on the +z side of) the second opening portion **49**.

An inner wall surface of the base portion **40** which defines each base portion through hole **42** is preferably tubular. In addition, an inner wall surface of the base portion **40** which defines the first opening portion **48** is preferably tubular. The inner wall surface of the base portion **40** which defines the first opening portion **48** will be hereinafter referred to as an inner wall surface of the first opening portion **48**. The first opening portion **48** has a first inside diameter D**1**. An inner wall surface of the base portion **40** which defines the second opening portion **49** is preferably tubular. The inner wall surface of the base portion **40** which defines the second opening portion **49** will be hereinafter referred to as an inner wall surface of the second opening portion **49**. The second opening portion **49** preferably has a second inside diameter D**2** smaller than the first inside diameter D**1**. The second inside diameter D**2** corresponds to the smallest inside diameter of the base portion through hole **42**. The gap between the base portion through hole **42** and the lead wire **34** is filled with the sealant **43** at least at the second opening portion **49**. The sealant **43** is preferably made of a resin. The sealant **43** is, for example, a thermosetting adhesive. Note that the sealant **43** may not necessarily be an adhesive, and may be, for example, a resin material which is not an adhesive.

Since the base portion through hole **42** includes the second opening portion **49**, which has an inside diameter smaller than that of the first opening portion **48**, which is in communication with the lower opening portion **45**, an improvement in airtightness is achieved. In addition, since the first opening portion **48** has an inside diameter greater than that of the second opening portion **49**, the first opening portion **48** defines and functions as a buffer to accommodate an extra portion of the sealant **43** when the sealant **43** is injected into the base portion through hole **42**.

Furthermore, since the gap between the base portion through hole **42** and the lead wire **34** is sealed with the sealant **43**, the airtightness is improved. Furthermore, the sealant **43** provided in the gap between the base portion through hole **42** and the lead wire **34** contributes to significantly reducing or preventing the likelihood that the lead wire **34** will make contact with an inner wall surface of the base portion through hole **42**.

Referring to FIG. **3**, the insulation sheet portion **52** is provided on the lower surface **40**B of the base portion **40**. The insulation sheet portion **52** covers at least a portion of each base portion through hole **42**. Each lead wire **34** contacts the insulation sheet portion **52**. An edge **55** of the insulation sheet portion **52** which covers at least a portion of each base portion through hole **42** preferably overlaps with the base portion through hole **42** in a plan view. The edge **55** will be hereinafter referred to as the edge **55** of the insulation sheet portion **52**. The edge **55** of the insulation sheet portion **52** is positioned radially inward of the base portion through hole **42**. More specifically, the edge **55** of the insulation sheet portion **52** is positioned radially inward of the inner wall surface of the second opening portion **49**.

The edge **55** of the insulation sheet portion **52** is located radially outward of (i.e., on a −y side of) a center of the base portion through hole **42**. Note that the edge **55** of the insulation sheet portion **52** may alternatively be located at the same or substantially the same position as that of the center of the base portion through hole **42**. The lead wire **34**, which makes contact with the edge **55** of the insulation sheet portion **52**, is drawn out along the central axis J1 of the base portion through hole **42**. Accordingly, the lead wire **34** is able to be drawn out in a direction parallel to the central axis J1 without allowing the lead wire **34** to make contact with the inner wall surface of the base portion through hole **42**.

Referring to FIG. **2**, the insulation sheet portion **52** covers at least a portion of each of the plurality of base portion through holes **42**. That is, the edge **55** of the insulation sheet portion **52** overlaps with each of the plurality of base portion through holes **42** in a plan view. Referring to FIG. **3**, the insulation sheet portion **52** preferably has a thickness T**2** greater than a diameter of the lead wire **34**. More specifically, the edge **55** of the insulation sheet portion **52** has a thickness greater than the diameter of the lead wire **34**. Thus, a contact of the lead wire **34** with the edge **55** does not easily cause a bending of the insulation sheet portion **52**. This contributes to maintaining a uniform distance between the lead wire **34**, which is pulled radially, and the inner wall surface of the base portion through hole **42**. This in turn contributes to significantly reducing or preventing the likelihood that the lead wire **34** from one of the coils **31**, which is passed through the base portion through hole **42**, will make contact with the inner wall surface of the base portion through hole **42**. The thickness T**2** of the insulation sheet portion **52** is preferably greater than a thickness T**1** of the land portion **51**.

FIG. **4** is a bottom view illustrating the circuit board **50** according to a preferred embodiment of the present invention.

Referring to FIG. **4**, the insulation sheet portion **52** is a portion of the circuit board **50**. The edge **55** of the insulation sheet portion **52** preferably includes cuts **56** each of which is recessed radially outward (i.e., to the −y side). Preferably, each cut **56** is substantially in the shape of a circular arc in a plan view. A radius of the cut **56** is greater than a radius of the lead wire **34**. The radius of the cut **56** is smaller than a radius of the lower opening portion **45**. The edge **55** of the insulation sheet portion **52** includes a plurality of such cuts **56**. The number of cuts **56** included in the edge **55** of the insulation sheet portion **52** is preferably four.

Referring to FIG. **3**, each lead wire **34** contacts an inner edge portion of the insulation sheet portion **52** which defines a corresponding one of the cuts **56**. The inner edge portion of the insulation sheet portion **52** which defines each cut **56** will be hereinafter referred to as an inner edge portion of the cut **56**. The inner edge portion of the cut **56** includes both a portion of an end surface of the insulation sheet portion **52** and an edge of the portion of the end surface of the insulation sheet portion **52**. In other words, the inner edge portion of the cut **56** includes both a portion of the end surface which is in the shape of a circular arc and which faces a radial center of the cut **56**, and an edge of the portion of the end surface which extends perpendicularly or substantially perpendicularly to the axial direction. Referring to FIG. **2**, one of the plurality of lead wires **34** contacts the inner edge portion of each of the plurality of cuts **56**. In other words, one of the lead wires **34** contacts the inner edge portion of each one of the cuts **56**.

A contact of the lead wire **34** with the inner edge portion of the cut **56** contributes to preventing the lead wire **34** from moving in a radial direction (specifically, in the x-axis direction) with respect to the edge **55** of the insulation sheet portion **52**. Accordingly, the lead wire **34**, which is drawn out below the lower surface **40**B of the base portion **40**, is positioned accurately with respect to the base portion through hole **42**. Therefore, the lead wire **34** is accurately positioned in the base portion through hole **42**. Since the lead wire **34** is able to be drawn out in the direction parallel or substantially parallel to the central axis J**1** from the base portion through hole **42** to the lower opening portion **45**, the likelihood that the lead wire **34** will make contact with the inner wall surface of the base portion through hole **42** is significantly reduced or prevented.

FIG. **5** is a cross-sectional view taken along line B-B in FIG. **4**.

As illustrated in FIG. **5**, the circuit board **50** preferably includes a board adhesive layer **60**, a base film layer **61**, a copper foil layer **62**, and a cover film layer **63**. The board adhesive layer **60** is fixed to the base portion **40**. The board adhesive layer **60**, the base film layer **61**, the copper foil layer **62**, and the cover film layer **63** are arranged in the order named.

The board adhesive layer **60** is provided on a lower side (i.e., the −z side) of the base portion **40**. The base film layer **61** is provided on the lower side (i.e., the −z side) of the board adhesive layer **60**. The copper foil layer **62** is provided on the lower side (i.e., the −z side) of the base film layer **61**. The cover film layer **63** is provided on the lower side (i.e., the −z side) of the copper foil layer **62**. Each of the base film layer **61** and the cover film layer **63** is preferably made of a resin. Polyimide (PI), for example, is used for each of the base film layer **61** and the cover film layer **63**. Note that, there is preferably no portion of the cover film layer **63** provided at each land portion **51**. This allows the lead wire **34** to be electrically connected to the copper foil layer **62** at the land portion **51**. Note that the term “board adhesive layer” **60** as used herein comprehends not only a glue layer but also, for example, an adhesive layer.

The insulation sheet portion **52** includes a sheet adhesive layer **70** fixed to the base portion **40**, and an increased thickness film layer **71** located on the lower side (i.e., the −z side) of the sheet adhesive layer **70**. The insulation sheet portion **52** is preferably a portion of the circuit board **50**. The insulation sheet portion **52** includes the base film layer **61**, the cover film layer **63**, and the board adhesive layer **60** as the sheet adhesive layer **70**. In the insulation sheet portion **52**, the board adhesive layer **60**, the base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71** are arranged in the order named. The above structure allows the board adhesive layer **60**, the base film layer **61**, and the cover film layer **63** in the insulation sheet portion **52** to be produced by the same process as in production of the circuit board **50**. Accordingly, the insulation sheet portion **52** preferably is produced by simple processes. In addition, since the circuit board **50** and the insulation sheet portion **52** is able to be fixed to the base portion **40** at one time, workability is improved. Note that the sheet adhesive layer **70** will be hereinafter referred to as the board adhesive layer **60** because the sheet adhesive layer **70** is preferably the same as the board adhesive layer **60**. Also note that, although the increased thickness film layer **71** preferably is a single layer, this is not essential to the present invention. The increased thickness film layer **71** may alternatively be a laminated body defined by a plurality of layers placed one upon another.

The board adhesive layer **60** is provided on the lower side (i.e., the −z side) of the base portion **40**. The base film layer **61** is provided on the lower side (i.e., the −z side) of the board adhesive layer **60**. The cover film layer **63** is provided on the lower side (i.e., the −z side) of the base film layer **61**.

The increased thickness film layer **71** is provided on the lower side (i.e., the −z side) of the cover film layer **63**. The increased thickness film layer **71** is preferably made of a resin. For the increased thickness film layer **71** according to a preferred embodiment of the present invention, polyimide (PI), which is preferably used for each of the base film layer **61** and the cover film layer **63** as well, is preferably used, for example. Note that, preferably, no portion of the copper foil layer **62** is located in the insulation sheet portion **52**.

The board adhesive layer **60** has a thickness t**1**. The base film layer **61** has a thickness t**2**. The copper foil layer **62** has a thickness t**3**. The cover film layer **63** has a thickness t**4**. The thickness T**1** of the land portion **51** corresponds to a thickness of the circuit board **50** excluding the cover film layer **63**. In other words, the thickness T**1** of the land portion **51** corresponds to a sum of the thickness t**1**, the thickness t**2**, and the thickness t**3**. The thickness T**2** of the insulation sheet portion **52** corresponds to a sum of a thickness of the increased thickness film layer **71** and a thickness of the circuit board **50** excluding the copper foil layer **62**. The increased thickness film layer **71** has a thickness t**5**. That is, the thickness T**2** of the insulation sheet portion **52** corresponds to a sum of the thickness t**1**, the thickness t**2**, the thickness t**4**, and the thickness t**5**.

Specifically, the thickness t**5** of the increased thickness film layer **71** is greater than a sum t**24** of the thickness t**2** of the base film layer **61** and the thickness t**4** of the cover film layer **63**. Since the increased thickness film layer **71** has a thickness greater than the sum t**24** of the thickness t**2** of the base film layer **61** and the thickness t**4** of the cover film layer **63**, the likelihood that a bending of the insulation sheet portion **52** will occur is able to be reduced by a simple structure. The thickness t**5** of the increased thickness film layer **71** is preferably about 1.5 or more times the combined thickness t**24** of the base film layer and the cover film layer **63**. Note that, preferably, the thickness t**2** of the base film layer **61** is equal or substantially equal to the thickness t**3** of the cover film layer **63**. In addition, the thickness t**5** of the increased thickness film layer **71** is preferably greater than the thickness t**3** of the copper foil layer **62**. The thickness t**5** of the increased thickness film layer **71** is preferably twice the thickness t**3** of the copper foil layer **62** or greater. Note that the thickness t**3** of the copper foil layer **62** is greater than the thickness t**2** of the base film layer **61**. As described above, the thickness T**2** of the insulation sheet portion **52** is greater than the thickness T**1** of the land portion **51**. Note that a gluing agent or an adhesive may be provided between the base film layer **61** and the cover film layer **63**. Also note that a gluing agent or an adhesive may be provided between the cover film layer **63** and the increased thickness film layer **71** as well.

Referring to FIG. **3**, the lead wire **34** from one of the coils **31** is passed through the base portion through hole **42** to be drawn out below the lower surface **40**B of the base portion **40**. After being drawn out below the lower surface **40**B of the base portion **40**, the lead wire **34** is soldered to a corresponding one of the land portions **51**, which is positioned away from the base portion through hole **42**. When the lead wire **34**, after being drawn out, is soldered thereto, the lead wire **34** is pulled in a radial direction (i.e., the y-axis direction) from the base portion through hole **42**. As a result of being pulled in the radial direction, the lead wire **34** approaches the inner wall surface of the base portion through hole **42**.

The spindle motor **1** includes the insulation sheet portion **52**, which covers at least a portion of each base portion through hole **42**. The insulation sheet portion **52** contacts the lead wire **34** when the lead wire **34** is pulled in the radial direction. The thickness T**2** of the insulation sheet portion **52** is greater than the thickness T**1** of the land portion **51**. Therefore, the insulation sheet portion **52** bends less easily than the circuit board **50**, and is able to support the lead wire **34** being pulled in the radial direction. This contributes to significantly reducing or preventing the likelihood that the lead wire **34** from one of the coils **31**, which is passed through the base portion through hole **42**, will make contact with the inner wall surface of the base portion through hole **42**. This in turn contributes to preventing a short circuit from occurring due to an electrical connection between the lead wire **34** and the inner wall surface of the base portion through hole **42**. In addition, a withstand voltage failure is prevented from occurring due to a contact between the lead wire **34** and the inner wall surface of the base portion through hole **42**.

In addition, each of the increased thickness film layer **71**, the base film layer **61**, and the cover film layer **63** is preferably made of a resin. Since all of the base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71** are made of a resin, each of the base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71** can be made of the same resin material only by varying the thickness. The base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71** is thus produced at a lower cost than in the case where the base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71** are made of different materials.

In addition, referring to FIG. **3**, the base portion through hole **42** preferably includes the upper opening portion **44** and the lower opening portion **45**. The upper opening portion **44** opens on the upper surface **40**A of the base portion **40**. The lower opening portion **45** opens on the lower surface **40**B of the base portion **40**. The opening area of the lower opening portion **45** is greater than the opening area of the upper opening portion **44**. This arrangement ensures a sufficient area of a portion of the lower opening portion **45** which is not covered with the insulation sheet portion **52** even when at least a portion of the base portion through hole **42** is covered with the insulation sheet portion **52**. This makes it easier to draw out the lead wire **34**, and also makes it easier to inject the sealant **43** through the lower opening portion **45**.

Note that structures described below may be adopted in other preferred embodiments of the present invention. In the following description, members or portions that have their equivalents in the above-described preferred embodiment are denoted by the same reference numerals as those of their equivalents in the above-described preferred embodiment, and descriptions thereof will be provided in brief or will be omitted.

Although the insulation sheet portion **52** discussed above preferably includes the sheet adhesive layer **70**, the base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71**, this is not essential to the present invention. The insulation sheet portion **52** may be modified in various manners as long as the thickness T**2** of the insulation sheet portion **52** is greater than the thickness T**1** of the land portion **51**.

For example, the increased thickness film layer **71** may be provided above the sheet adhesive layer **70** with the base film layer **61** and/or the cover film layer **63** being omitted. When this arrangement is adopted, the increased thickness film layer **71** preferably has a thickness still greater than the thickness t**5** illustrated in FIG. **5**.

Further, the thickness t**2** of the base film layer **61** and/or the thickness t**4** of the cover film layer **63** may be increased to define the insulation sheet portion **52**. When this configuration is adopted, the increased thickness film layer **71** may be omitted.

FIG. **6** is a bottom view illustrating a base portion **40** according to an example modification of the above-described preferred embodiment of the present invention. FIG. **7** is a cross-sectional view taken along line C-C in FIG. **6**.

Referring to FIG. **6**, an insulation sheet portion **52** may include sheet portion through holes **57** through each of which a lead wire **34** passes. Each sheet portion through hole **57** overlaps with a corresponding one of base portion through holes **42** in a plan view. The sheet portion through hole **57** preferably has an inside diameter smaller than a second inside diameter D**2** of a second opening portion **49**. The insulation sheet portion **52** covers almost the entire sheet portion through hole **57**.

This arrangement allows the lead wire **34** to be drawn out in a direction parallel or substantially parallel to a central axis J**1** without allowing the lead wire **34** to make contact with an inner wall surface of the base portion through hole **42**. In addition, referring to FIG. **6**, both radial and circumferential movement of the lead wire **34** is restricted. Accordingly, the lead wire **34**, which is drawn out below a lower surface **40**B of the base portion **40**, is able to be positioned accurately with respect to the base portion through hole **42**.

FIG. **8** is a vertical cross-sectional view illustrating an insulation sheet portion **52** according to an example modification of the above-described preferred embodiment of the present invention.

As illustrated in FIG. **8**, the insulation sheet portion **52** may be defined by a member separate from a circuit board **50**. The insulation sheet portion **52** includes a sheet adhesive layer **70** which is separate from a board adhesive layer **60**, and an increased thickness film layer **71** located on a lower side (i.e., the −z side) of the sheet adhesive layer **70**. A thickness t**5** of the increased thickness film layer **71** is greater than a combined thickness t**234** of a base film layer **61**, a copper foil layer **62**, and a cover film layer **63**. Note that a thickness t**6** of the sheet adhesive layer **70** may be equal or substantially equal to a thickness t**1** of the board adhesive layer **60**.

With the above arrangement, it is possible to make the insulation sheet portion **52** of materials different from those of the circuit board **50**. Because of this, it is possible to make the insulation sheet portion **52** of various materials. For example, a resin material used for the increased thickness film layer **71** may be different from a resin material used for the base film layer **61** and the cover film layer **63**. Note that, although the increased thickness film layer **71** is preferably a single layer, this is not essential to the present invention. The increased thickness film layer **71** may alternatively be a laminated body defined by a plurality of layers placed one upon another.

FIG. **9** is a vertical cross-sectional view illustrating an inner wall surface of a base portion through hole **42** according to an example modification of the above-described preferred embodiment of the present invention.

As illustrated in FIG. **9**, the inner wall surface of the base portion through hole **42** may have an angled slanting shape. The inner wall surface of the base portion through hole **42** preferably has a slanting shape that gradually decreases in inside diameter as it extends away from an upper surface **40**A toward a lower surface **40**B in the axial direction. The slanting shape may be, for example, in the shape of a cone, the shape of a quadrangular pyramid, or the shape of an n-gonal pyramid where n is not four.

According to the above arrangement, an opening area of an upper opening portion **44** is greater than an opening area of a lower opening portion **45**.

Note that the insulation sheet portion **52** may alternatively be in close contact with the lead wire **34** such that the base portion through hole **42** is entirely covered therewith.

Also note that the resin material used for the increased thickness film layer **71** may be an elastic elastomer, for example. Also note that the resin material used for the increased thickness film layer **71** may alternatively be a cured plastic, for example.

A structure as described below is preferably included in a preferred embodiment of the present invention.

FIG. **10** is a more detailed version of FIG. **3**.

Referring to FIG. **10**, the base portion **40** includes the upper surface **40**A, the lower surface **40**B, and the base portion through holes **42**. The base portion **40** is preferably made of a metal. More specifically, the base portion **40** is preferably made of an aluminum alloy or a ferrous metal. In the case where the base portion **40** is made of the aluminum alloy, the base portion **40** is preferably produced by casting. Meanwhile, in the case where the base portion **40** is made of the ferrous metal, the base portion **40** is preferably produced by press working or casting.

As the aluminum alloy, Japanese Industrial Standards (JIS) ADC12 (which has a coefficient of linear expansion of $21\times10^{-6}$ $K^{-1}$), JIS ADC10 (which has a coefficient of linear expansion of $22\times10^{-6}$ $K^{-1}$), or the like, for example, is preferably used. As the ferrous metal, JIS SPCC (which has a coefficient of linear expansion of $11.7\times10^{-6}$ $K^{-1}$), JIS SPCD, JIS SPCE, JIS SUS303 (which has a coefficient of linear expansion of $17.3\times10^{-6}$ $K^{-1}$), JIS SUS304 (which has a coefficient of linear expansion of $17.3\times10^{-6}$ $K^{-1}$), or the like, for example, is preferably used.

The base portion **40** includes a coating film **81** which covers a surface of the base portion **40**. The coating film **81** has an electrical insulating property. The coating film **81** is preferably an electrodeposition coating layer, for example. An inner wall surface of the base portion **40** which defines each base portion through hole **42** is a metal surface **42***a* where a metallic surface is exposed. The inner wall surface of the base portion **40** which defines the base portion through hole **42** will be hereinafter referred to as the inner wall surface of the base portion through hole **42**. The base portion through hole **42** is preferably defined by a cutting process after the base portion **40** is subjected to electrodeposition coating. Therefore, the inner wall surface of the base portion through hole **42** is not covered with the coating film **81**, and the metal surface **42***a* is exposed thereat.

The sealant **43** is preferably a first sealant **43***a* arranged in the base portion through hole **42**. The first sealant **43***a* is preferably a thermosetting adhesive. Specifically, the first sealant **43***a* is preferably an epoxy thermosetting adhesive. Note that the first sealant **43***a* may alternatively be an anaerobic and/or UV-curing adhesive. Also note that the adhesive of the first sealant **43***a* may not necessarily be an epoxy adhesive, but may alternatively be, for example, an acrylic adhesive. The first sealant **43***a* is in contact with the metal surface **42***a*. More specifically, the first sealant **43***a* is in contact with both the metal surface **42***a* and the lead wire **34**, and is also located between the metal surface **42***a* and the lead wire **34**. A contact of the first sealant **43***a* with the metal surface **42***a* contributes to preventing a contact between the lead wire **34** and the metal surface **42***a*.

The molding member **54** is preferably a second sealant **54***a* covering at least a portion of the base portion through hole **42**. The second sealant **54***a* is preferably a thermosetting adhesive. Specifically, the second sealant **54***a* is an epoxy thermosetting adhesive. Note that the second sealant **54***a* may be ultraviolet curable. A coefficient of linear expansion of the second sealant **54***a* is preferably in the range of about $40\times10^{-6}$ $K^{-1}$ to about $85\times10^{-6}$ $K^{-1}$, and more specifically, in the range of about $60\times10^{-6}$ $K^{-1}$ to about $80\times10^{\times6}$ $K^{\times1}$, for example.

Meanwhile, a coefficient of linear expansion of the first sealant **43***a* is preferably in the range of about $25\times10^{-6}$ $K^{-1}$ to about $35\times10^{-6}$ $K^{-1}$, and more specifically, in the range of about $28\times10^{-6}$ $K^{-1}$ to about $32\times10^{-6}$ $K^{-1}$, for example. That is, the coefficient of linear expansion of the first sealant **43***a* preferably is greater than the coefficient of linear expansion of the base portion **40** and smaller than the coefficient of linear expansion of the second sealant **54***a*. If an operating temperature of the spindle motor **1** increases while the spindle motor **1** is rotating, the first sealant **43***a* expands and becomes more closely adhered to the base portion through hole **42**. This contributes to preventing gas from entering or exiting through the base portion through hole **42**.

The first sealant **43***a* expands less than the second sealant **54***a*. Therefore, a thermal stress which occurs in the first sealant **43***a* is preferably small. This reduces the likelihood that any cracks will appear in the first sealant **43***a*, and also the likelihood that the first sealant **43***a* will come off the inner wall surface of the base portion through hole **42**. Note that, because the second sealant **54***a* is able to expand away from the base portion through hole **42**, a thermal stress which occurs in the second sealant **54***a* is small. This significantly reduces or prevented the likelihood that any cracks will appear in the second sealant **54***a*, and also the likelihood that the second sealant **54***a* will come off the surface of the base portion **40**.

A difference in the coefficient of linear expansion between the first sealant **43***a* and the base portion **40** is preferably about $10\times10^{-6}$ $K^{-1}$ or less, for example. When the coefficient of linear expansion of the first sealant **43***a* is close to the coefficient of linear expansion of the metallic base portion **40**, expansion of the first sealant **43***a* follows expansion of the base portion **40**. This significantly reduces or prevents the likelihood that a crack or the like will appear in the cured first sealant **43***a*, and also the likelihood that the cured first sealant **43***a* will come off the inner wall surface of the base portion through hole **42**.

The base portion **40** is preferably an aluminum alloy casting. As mentioned above, the coefficient of linear expansion of the first sealant **43***a* is preferably in the range of about $25\times10^{-6}$ $K^{-1}$ to about $35\times10^{-6}$ $K^{-1}$, for example. Further, the coefficient of linear expansion of the aluminum alloy is preferably in the range of about $21\times10^{-6}$ $K^{-1}$ to about $22\times10^{-6}$ $K^{-1}$, for example. Furthermore, the coefficient of linear expansion of the ferrous metal is preferably in the range of about $11.7\times10^{-6}$ $K^{-1}$ to about $17.3\times10^{-6}$ $K^{-1}$, for example. Therefore, the coefficient of linear expansion of the aluminum alloy is closer to the coefficient of linear expansion of the first sealant **43***a* than is the coefficient of linear expansion of the ferrous metal.

The second sealant **54***a* covers the edge **55** of the insulation sheet portion **52** and the entire base portion through hole **42**. The edge **55** is outward of the central axis J1 of the base portion through hole **42**. The second sealant **54***a* is in contact with an upper surface, a lower surface, and an end surface of the edge **55**. In addition, the second sealant **54***a* covers the entire lower opening portion **45**. The base portion through hole **42** is sealed with the first sealant **43***a* and the second sealant **54***a*. This contributes to preventing gas from entering or exiting through the base portion through hole **42**. Moreover, gas is prevented from entering or exiting through a gap between the lead wire **34** and the edge **55**.

In addition, the second sealant **54***a* is in contact with both the inner wall surface of the base portion through hole **42** and the first sealant **43***a*. Specifically, the second sealant **54***a* is in contact with both the inner wall surface of the first opening portion **48** and the inner wall surface of the lower opening portion **45**. Moreover, the second sealant **54***a* is in contact with a lower portion of the first sealant **43***a*. Thus, because the base portion through hole **42** is sealed with the second sealant **54***a* as well as with the first sealant **43***a*, gas is more effectively preventing from entering or existing through the base portion through hole **42**.

Referring to FIG. **2**, the base portion through hole **42**, the insulation sheet portion **52**, and the land portion **51** are arranged in the order named such that the base portion through hole **42** is the closest to the central axis J and the land portion **51** is the most distant from the central axis J. More specifically, the base portion through hole **42**, the insulation sheet portion **52**, and the land portion **51** are arranged in the order named along a direction parallel or substantially parallel to the y-axis direction such that the base portion through hole **42** is the closest to the central axis J and the land portion **51** is the most distant from the central axis J toward the −y side. Referring to FIG. **10**, the second sealant **54***a* is in contact with a lower surface **40**B**1**, which is a portion of the lower surface **40**B on a side of the base portion through hole **42** closer to the central axis J. This contributes to preventing gas from entering or existing into and from the base portion through hole **42** through the lower surface **40**B**1** on which no portion of the insulation sheet portion **52** is provided.

The second sealant **54***a* covers both the lead wire **34** and the land portion **51**. This prevents gas from entering or exiting through a gap between the lead wire **34** and the circuit board **50**. Referring to FIG. **2**, the coils **31** include the plurality of lead wires **34**. The base portion **40** preferably includes the plurality of base portion through holes **42**, and one of the lead wires **34** passes through each one of the base portion through holes **42**. The second sealant **54***a* which defines each molding member **54** covers one of the plurality of lead wires **34** individually. With this arrangement, a volume of each one of the second sealants **54***a* is reduced, and when heat is applied to the second sealant **54***a* to cure the second sealant **54***a*, any air bubbles within the second sealant **54***a* are able to easily escape out of the second sealant **54***a* through a surface of the second sealant **54***a*. As a result, airtightness of the second sealant **54***a* is improved. Moreover, any gas which exists in a space defined by the circuit board **50**, the lower portion of the first sealant **43***a*, the inner wall surface of the first opening portion **48**, and the inner wall surface of the lower opening portion **45** is able to easily escape out of the space through a gap between two adjacent ones of the second sealants **54***a*. As a result, the gas is easily replaced with the second sealant **54***a* in the aforementioned space, so that quality of the sealing of the base portion through hole **42** is improved.

Referring to FIG. **10**, the lead wire **34** preferably includes a conducting wire **35**, a solder film **36**, and an insulating coating **37**. The solder film **36** is defined during a process of soldering the lead wire **34**, for example. In the process of soldering the lead wire **34**, the lead wire **34** is first drawn out from an end portion of one of the coils **31**. Next, a portion of the lead wire **34** which has been drawn out is dipped in a molten liquid solder. A portion of the insulating coating **37** which has been dipped in the liquid solder is melted to expose the conducting wire **35**. Once the conducting wire **35** is pulled out of the liquid solder, a liquid solder attached to the conducting wire **35** is cured to define the solder film **36**.

One end portion **34***a* of the conducting wire **35** is connected to the land portion **51** through the solder **53**. A portion of the solder film **36** preferably defines the solder **53**. The solder film **36** extends from the solder **53** toward an opposite end portion **34***b* of the conducting wire **35** while covering a portion of the conducting wire **35**. Referring to FIG. **1**, the opposite end portion **34***b* is located above the upper surface **40**A of the base portion **40**. On the other hand, the one end portion **34***a* is located below the lower surface **40**B of the base portion **40**. The insulating coating **37** extends from the solder film **36** toward the opposite end portion **34***b* of the conducting wire **35** while covering a portion of the conducting wire **35**.

Referring to FIG. **10**, a boundary **38** between the solder film **36** and the insulating coating **37** is preferably positioned between the base portion through hole **42** and the land portion **51**. That is, the solder film **36** is arranged outward of the base portion through hole **42**. The solder film **36** has electrical conductivity. If the solder film were positioned at the base portion through hole, the solder film and the inner wall surface of the base portion through hole might make contact with each other, and the lead wire and the base portion might become electrically connected with each other to cause a short circuit. Arranging the boundary **38** between the solder film **36** and the insulating coating **37** at a position between the base portion through hole **42** and the land portion **51** preferably prevents the solder film **36** from being located at the base portion through hole **42**. Moreover, it is possible to recognize that the solder film **36** is outward of the base portion through hole **42** through visual inspection.

Note that structures described below may be adopted in preferred embodiments of the present invention. In the following description, members or portions that have their equivalents in the above-described preferred embodiment are denoted by the same reference numerals as those of their equivalents in the above-described preferred embodiment, and descriptions thereof will be provided in brief or will be omitted.

FIG. **11** is a bottom view illustrating a second sealant **54***a* according to an example modification of a preferred embodiment of the present invention.

Referring to FIG. **11**, the second sealant **54***a* may be a thermosetting sheet member **80**. The second sealant **54***a* is preferably configured to singly cover all of a plurality of lead wires **34**. The sheet member **80** is preferably, for example, a sealing sheet made of a thermosetting resin material. Once the sheet member **80** is heated, the sheet member **80** is closely adhered to the plurality of lead wires **34**, a lower surface **40**B of a base portion **40**, a circuit board **50**, land portions **51**, an insulation sheet portion **52**, and so on, and is cured. The above structure makes it possible to cover the plurality of lead wires **34** with the one second sealant **54***a*, achieving improved workability.

FIG. **12** is a vertical cross-sectional view illustrating a second sealant **54***a* according to an example modification of a preferred embodiment of the present invention.

Referring to FIG. **12**, the second sealant **54***a* may be provided in contact with an inner wall surface of an insulation sheet portion **52** which defines a sheet portion through hole **57**. Further, the second sealant **54***a* is in contact with an upper surface and a lower surface of the insulation sheet portion **52**. Moreover, the second sealant **54***a* is in contact with an inner wall surface of a base portion through hole **42** and a first sealant **43***a*. The above structure preferably prevents gas from entering or exiting through a gap between a lead wire **34** and the insulation sheet portion **52**.

Note that the thermosetting sheet member may not necessarily be one in number, but two or more thermosetting sheet members may alternatively be provided in a modification of the example modification of FIG. **11**. For example, each one of the base portion through holes may be covered with one separate sheet member. Also, two of the base portion through holes may be covered with one sheet member.

Also note that the second sealant may not necessarily be an adhesive or a sheet member, but may alternatively be another sealant.

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 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.

What is claimed is:

**1**. A spindle motor comprising:

a rotor portion including a rotor magnet;

a bearing portion configured to support the rotor portion such that the rotor portion is rotatable about a central axis extending in a vertical direction;

a base portion made of a metal, and including an upper surface, a lower surface, and a base portion through hole passing therethrough from the upper surface to the lower surface;

a stator portion located on the upper surface, and including coils arranged opposite to the rotor magnet with a gap intervening therebetween;

a circuit board located on the lower surface;

an insulation sheet portion;

a first sealant; and

a second sealant; wherein

the coils include a lead wire drawn out from above the upper surface downwardly from the lower surface through the base portion through hole;

the circuit board includes a land portion to which the lead wire is connected;

the insulation sheet portion is provided on the lower surface, and covers at least a portion of the base portion through hole;

the lead wire contacts the insulation sheet portion;

the first sealant is located in the base portion through hole;

the second sealant covers at least a portion of the base portion through hole; and

the first sealant has a coefficient of linear expansion greater than a coefficient of linear expansion of the base portion and smaller than a coefficient of linear expansion of the second sealant.

**2**. The spindle motor according to claim **1**, wherein

the first sealant is a thermosetting adhesive; and

a difference in the coefficient of linear expansion between the first sealant and the base portion is about $10\times10^{-6}$ $K^{-1}$ or less.

**3**. The spindle motor according to claim **2**, wherein the base portion is an aluminum alloy casting.

**4**. The spindle motor according to claim **2**, wherein

the base portion through hole, the insulation sheet portion, and the land portion are arranged in the order named such that the base portion through hole is a closest to the central axis and the land portion is a most distant from the central axis;

the insulation sheet portion includes an edge which covers at least a portion of the base portion through hole, and is located at a center of the base portion through hole or outward of the center of the base portion through hole; and

the second sealant covers the edge of the insulation sheet portion and the entire base portion through hole.

**5**. The spindle motor according to claim **1**, wherein

the base portion through hole, the insulation sheet portion, and the land portion are arranged in the order named such that the base portion through hole is a closest to the central axis and the land portion is a most distant from the central axis;

the insulation sheet portion includes an edge which covers at least a portion of the base portion through hole, and is located at a center of the base portion through hole or outward of the center of the base portion through hole; and

the second sealant covers the edge of the insulation sheet portion and the entire base portion through hole.

**6**. The spindle motor according to claim **5**, wherein the second sealant contacts the first sealant and an inner wall surface of the base portion which defines the base portion through hole.

**7**. The spindle motor according to claim **6**, wherein the second sealant contacts a portion of the lower surface on a side of the base portion through hole closer to the central axis.

**8**. The spindle motor according to claim **5**, wherein the second sealant is in contact with a portion of the lower surface on a side of the base portion through hole closer to the central axis.

**9**. The spindle motor according to claim **1**, wherein the second sealant covers both the lead wire and the land portion.

**10**. The spindle motor according to claim **1**, wherein

the coils include a plurality of lead wires;

the base portion includes a plurality of base portion through holes; and

one of the lead wires passes through each one of the base portion through holes.

**11**. The spindle motor according to claim **10**, wherein

the second sealant is a thermosetting adhesive; and

the second sealant covers each one of the plurality of lead wires individually.

**12**. The spindle motor according to claim **10**, wherein

the second sealant is a thermosetting sheet member; and

the second sealant singly covers all of the plurality of lead wires.

**13**. The spindle motor according to claim **1**, wherein

the land portion is located at a position spaced away from the base portion through hole in a radial direction;

the lead wire includes:

- a conducting wire including one end portion connected to the land portion through a solder;
- a solder film which extends from the solder toward an opposite end portion of the conducting wire while covering a portion of the conducting wire; and
- an insulating coating which extends from the solder film toward the opposite end portion of the conducting wire while covering a portion of the conducting wire; and

a boundary between the solder film and the insulating coating is positioned between the base portion through hole and the land portion.

**14**. The spindle motor according to claim **1**, wherein

the base portion includes a coating film which covers a surface of the base portion;

an inner wall surface of the base portion which defines the base portion through hole is a metal surface where a metallic surface is exposed; and

the first sealant is in contact with the metal surface.

**15**. A disk drive apparatus comprising:

the spindle motor according to claim **1**;

a disk supported by the spindle motor; and

an access portion configured to perform at least one of reading and writing of information from or to the disk.

* * * * *

# Exhibit
# C

US009935528B2

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**Yoneda et al.**

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(54) **SPINDLE MOTOR AND DISK DRIVE APPARATUS**

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(51) **Int. Cl.**

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| ***H02K 11/30*** | (2016.01) |
| ***H02K 5/22*** | (2006.01) |
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CPC ............. ***H02K 11/30*** (2016.01); ***H02K 5/225*** (2013.01); *F16C 2370/12* (2013.01); *H02K 5/12* (2013.01); *H02K 2203/06* (2013.01); *H02K 2211/03* (2013.01)

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USPC .......................................... 310/71; 360/99.08
See application file for complete search history.

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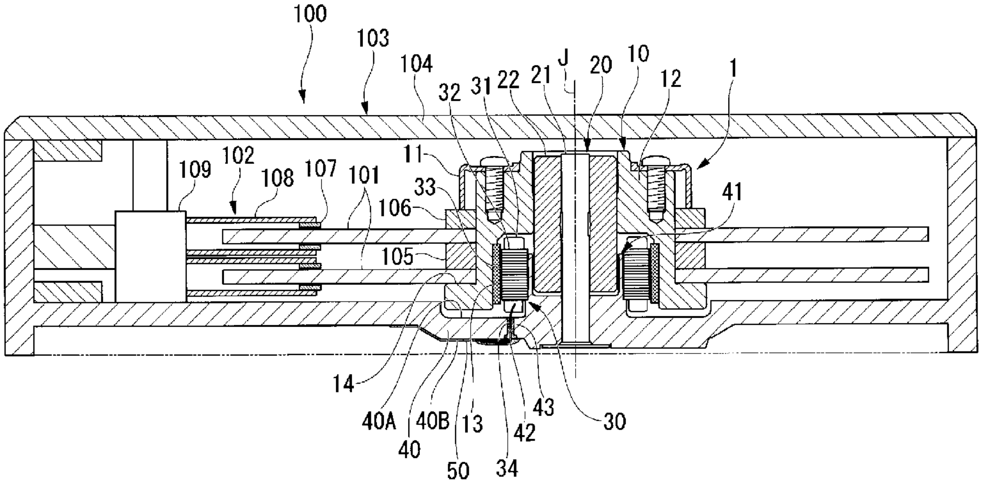
(57) **ABSTRACT**

A base portion of a spindle motor includes a base portion through hole passing therethrough from an upper surface to a lower surface thereof. Coils include a lead wire drawn out from above the upper surface downwardly from the lower surface through the base portion through hole. A circuit board includes a land portion to which the lead wire is connected. The spindle motor includes an insulation sheet portion configured to cover at least a portion of the base portion through hole and with which the lead wire is arranged to be in contact. A thickness of the insulation sheet portion is greater than a thickness of the land portion.

**16 Claims, 9 Drawing Sheets**



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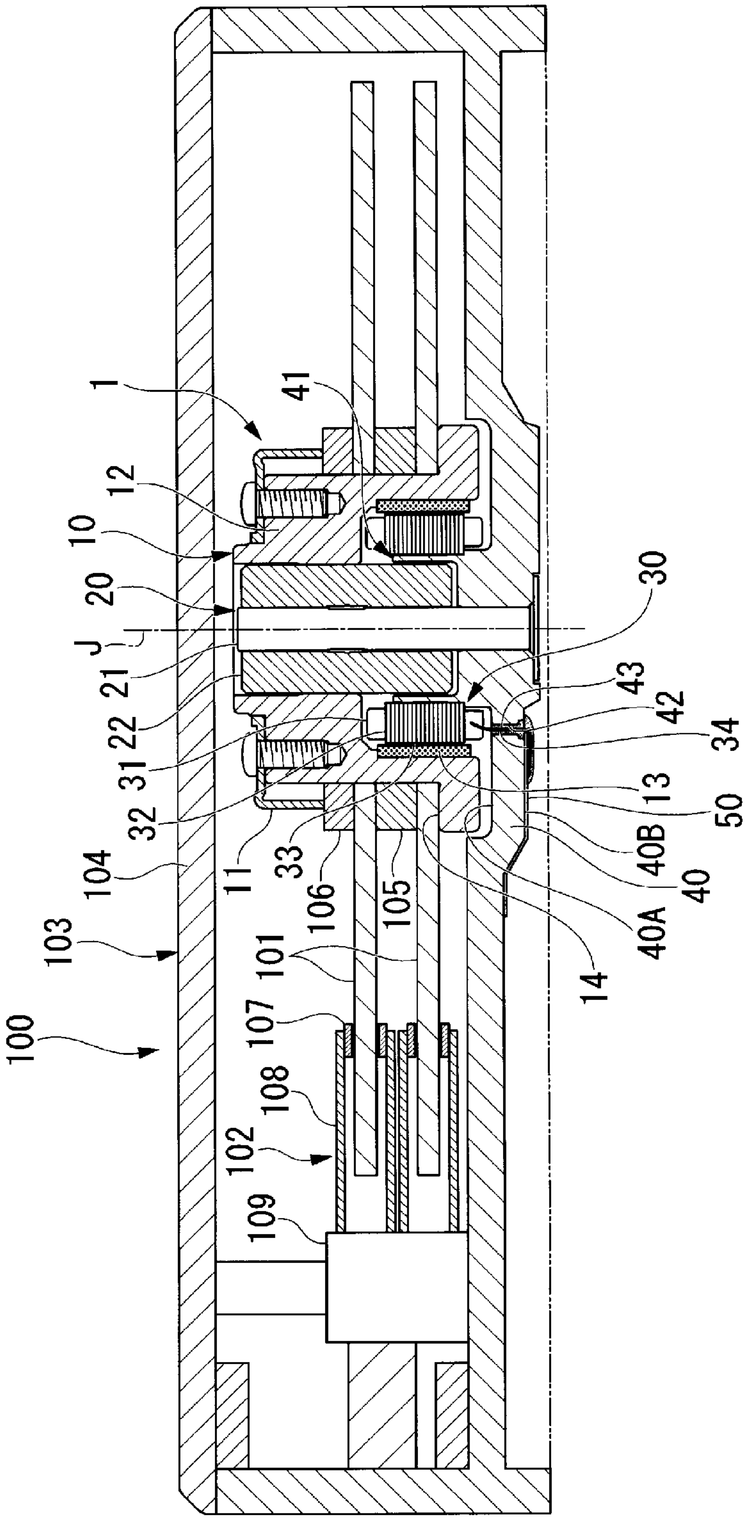
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30
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40B
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40A
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Fig.1

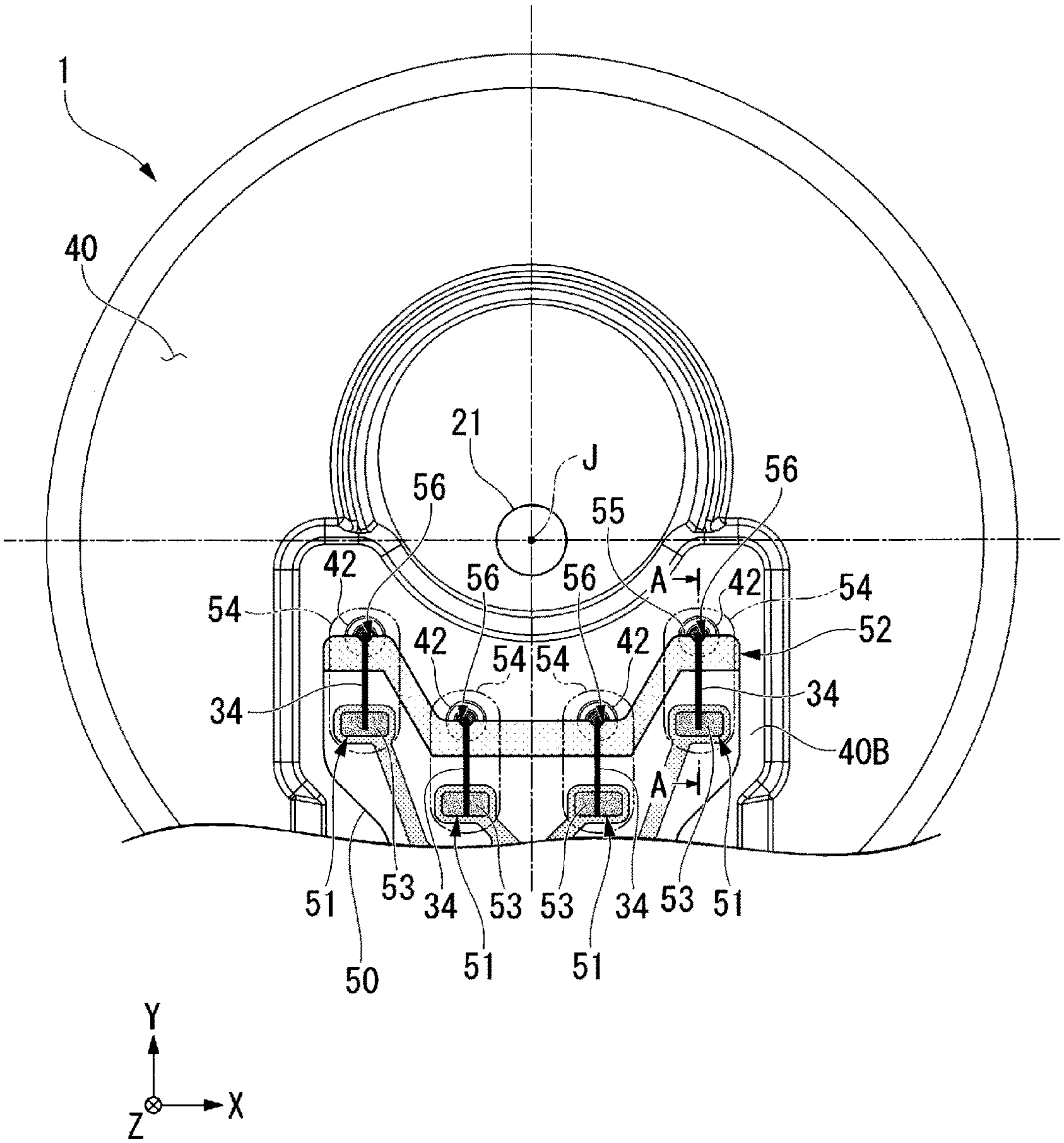
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Fig. 2

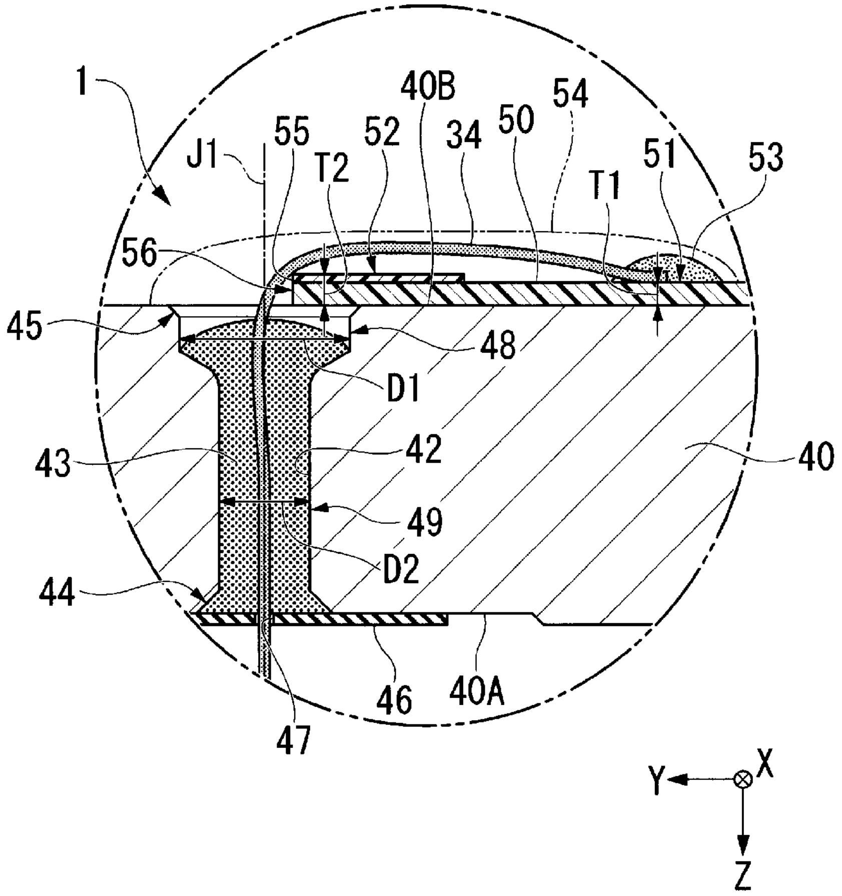
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Fig. 3

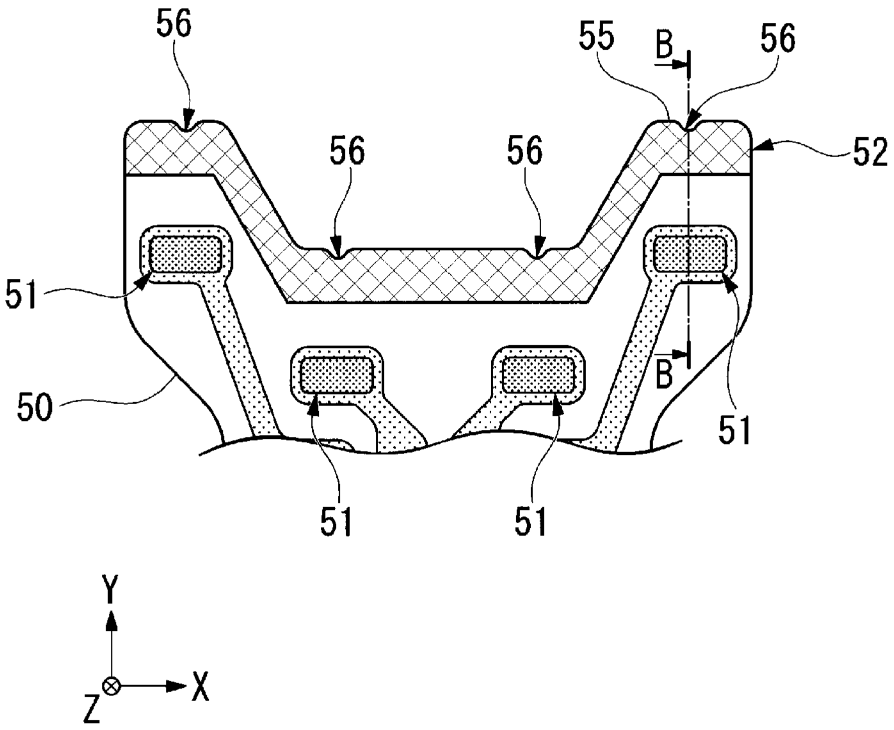

Fig.4

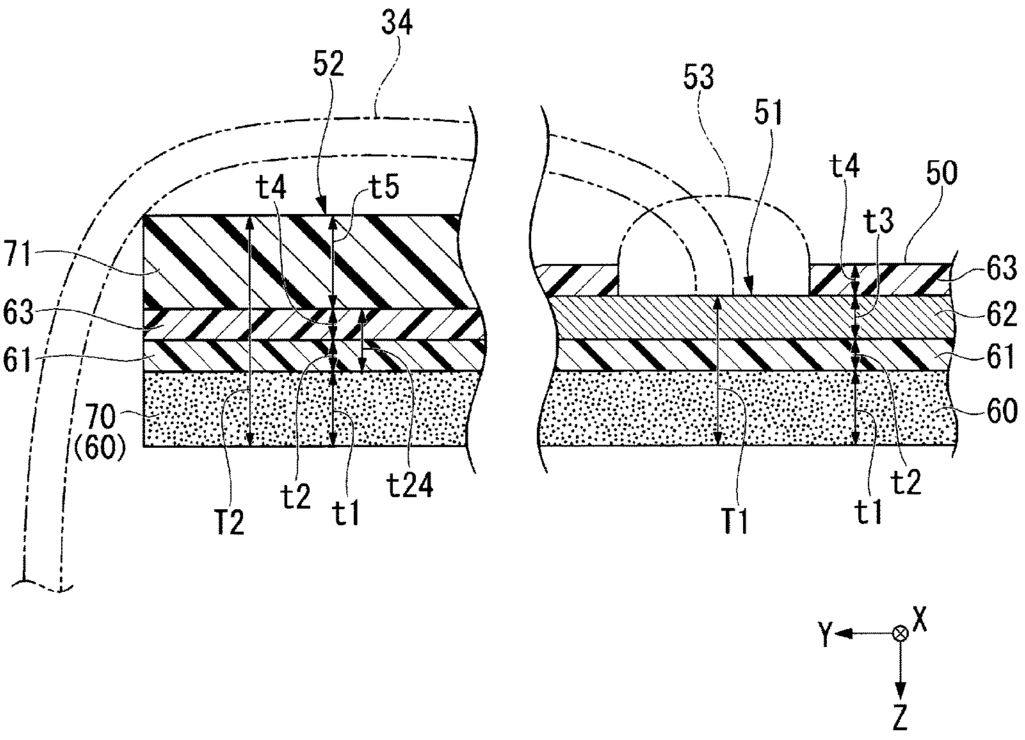
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Fig.5

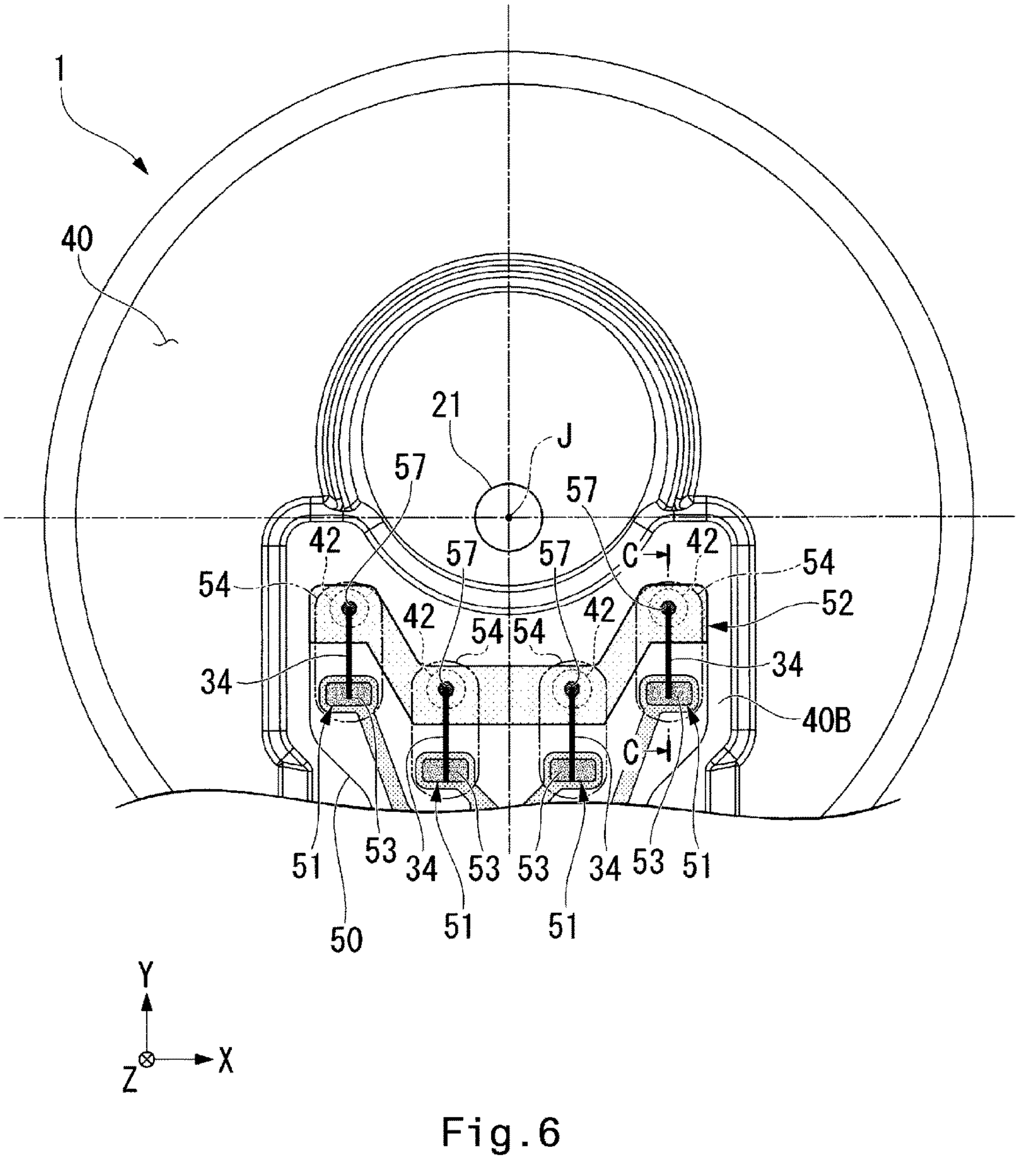
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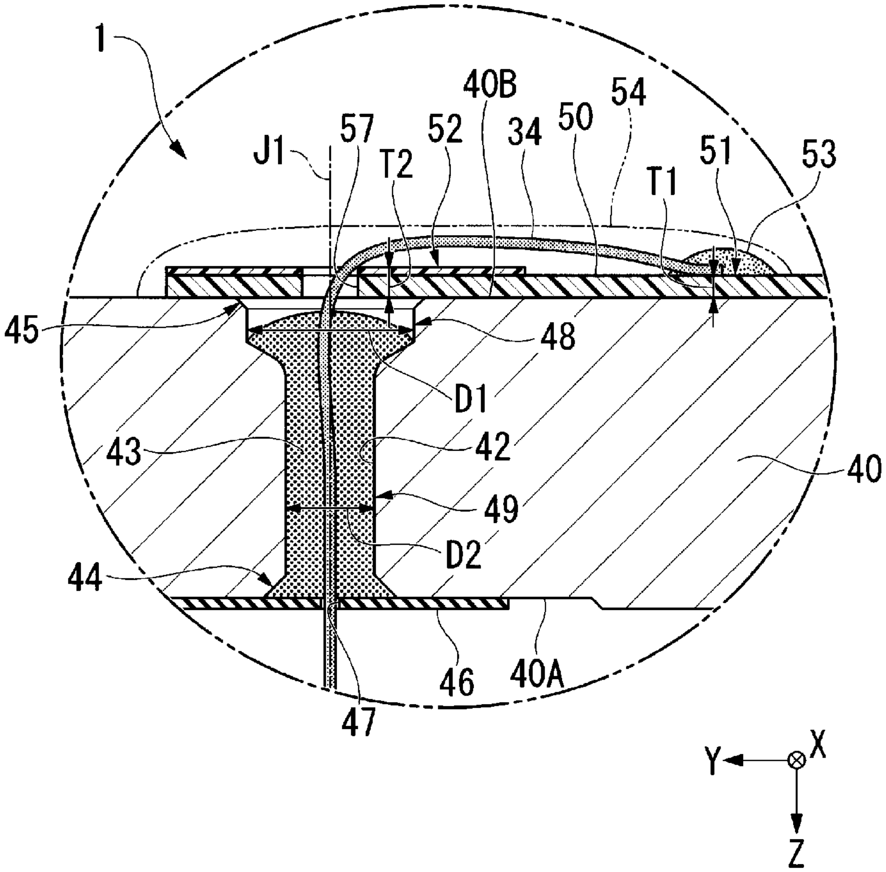
Fig.6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40A
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Y
X
Z

Fig.7

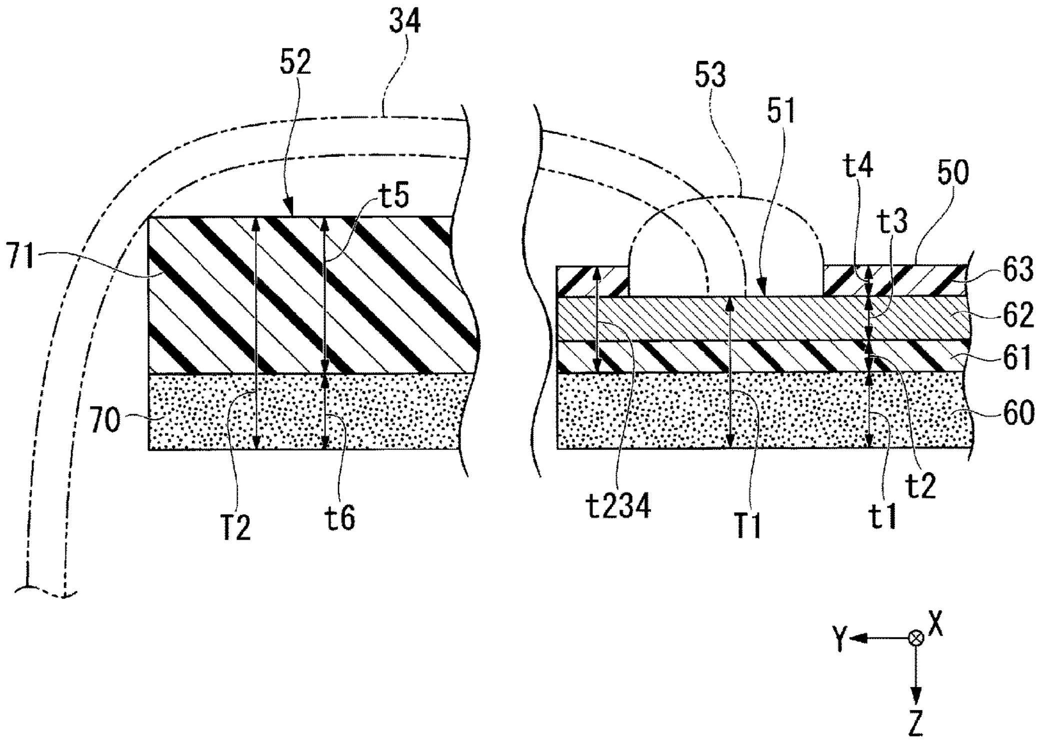

Fig.8

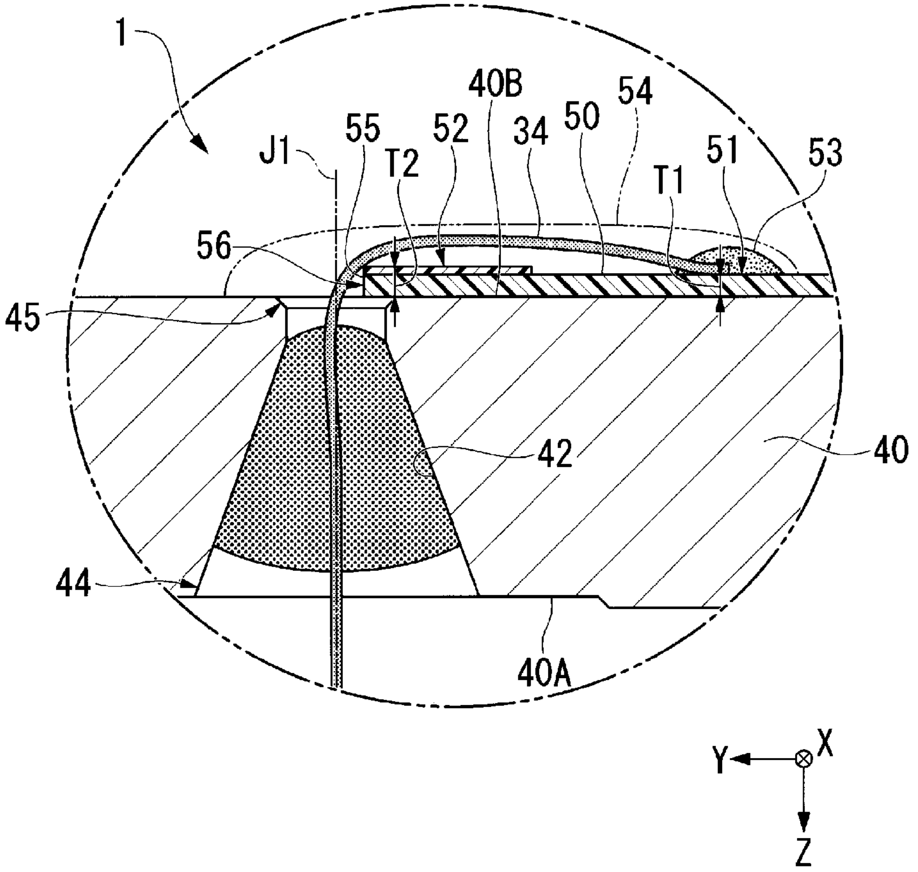

Fig.9

# SPINDLE MOTOR AND DISK DRIVE APPARATUS

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

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

### 2. Description of the Related Art

A disk drive apparatus, such as, for example, a hard disk drive, includes a spindle motor arranged to rotate a recording disk. A base of a spindle motor described in JP-A 2012-151940 includes a base draw-out hole. A lead wire from a coil passes through the base draw-out hole. The lead wire is soldered to a wiring member arranged on a lower surface of the base.

If the lead wire obliquely passes through the base draw-out hole, the lead wire is brought into contact with a hole edge of the base draw-out hole as illustrated in FIG. 3 of JP-A 2012-151940. If the lead wire is brought into contact with the hole edge, an insulating coating of the lead wire may be damaged. Damage to the coating of the lead wire may lead to defective insulation due to a portion of the coating being stripped off. Moreover, the lead wire, with a portion of the coating being stripped off, and the base may become electrically connected with each other, and a short circuit may occur.

## SUMMARY OF THE INVENTION

A spindle motor according to a preferred embodiment of the present invention includes a rotor portion including a rotor magnet, a bearing portion, a stator portion, a base portion, a circuit board, and an insulation sheet portion. The bearing portion is configured to support the rotor portion such that the rotor portion is rotatable about a central axis extending in a vertical direction. The stator portion includes coils located opposite to the rotor magnet. The base portion includes an upper surface, a lower surface, and a base portion through hole arranged to pass therethrough from the upper surface to the lower surface. The circuit board is provided on the lower surface of the base portion.

The coils include a lead wire drawn out from above the upper surface downwardly of the lower surface through the base portion through hole. The circuit board includes a land portion to which the lead wire is connected. The insulation sheet portion covers at least a portion of the base portion through hole. The lead wire contacts the insulation sheet portion. The insulation sheet portion has a thickness greater than a thickness of the land portion.

According to the above preferred embodiment of the present invention, the likelihood that the lead wire will make contact with an inner wall surface of the base portion which defines the base portion through hole is significantly reduced or prevented. A spindle motor and a disk drive apparatus according to preferred embodiments of the present invention are provided.

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 with reference to the attached drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical cross-sectional view illustrating a disk drive apparatus according to a preferred embodiment of the present invention.

FIG. **2** is a bottom view illustrating a base portion according to a preferred embodiment of the present invention.

FIG. **3** is a cross-sectional view taken along line A-A in FIG. **2**.

FIG. **4** is a bottom view illustrating a circuit board according to a preferred embodiment of the present invention.

FIG. **5** is a cross-sectional view taken along line B-B in FIG. **4**.

FIG. **6** is a bottom view illustrating a base portion according to an example modification of the above preferred embodiment of the present invention.

FIG. **7** is a cross-sectional view taken along line C-C in FIG. **6**.

FIG. **8** is a vertical cross-sectional view illustrating an insulation sheet portion according to an example modification of the above preferred embodiment of the present invention.

FIG. **9** is a vertical cross-sectional view illustrating an inner wall surface of a base portion through hole according to an example modification of the above preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, with reference to the accompanying drawings, preferred embodiments of the present invention will be described below. Note that the scope of the present invention is not limited to the preferred embodiments described below, but includes any modification thereof within the scope of the technical ideas of the present invention. Also note that dimensions, scales, numbers, and so on of members or portions illustrated in the following drawings may differ from those of actual members or portions, for the sake of easier understanding of the members or portions.

FIG. **1** is a vertical cross-sectional view illustrating a disk drive apparatus **100** including a spindle motor **1** according to a preferred embodiment of the present invention.

The disk drive apparatus **100** is a hard disk drive. The disk drive apparatus **100** preferably includes the spindle motor **1**, disks **101**, and an access portion **102**. The spindle motor **1** is arranged to rotate the disks **101**, on which information is recorded, about a central axis J. The access portion **102** performs at least one of reading and writing of information from or to the disks **101**.

The disk drive apparatus **100** includes a housing **103**. The housing **103** preferably includes a base portion **40** of the spindle motor **1**, and a cover member **104**. The cover member **104** is fitted to an opening of the base portion **40** to define the housing **103**. The disks **101** and the access portion **102** are accommodated in the housing **103**. An interior space of the housing **103** is preferably filled with, for example, a helium gas. Note that the interior space of the housing **103** may alternatively be filled with a hydrogen gas, air, or the like.

The disk drive apparatus **100** includes the plurality of disks **101**. The disk drive apparatus **100** includes a spacer **105** arranged between the disks **101**. The plurality of disks **101** are supported by the spindle motor **1**. More specifically, the plurality of disks **101** are supported by a rotor portion **10** of the spindle motor **1**. The rotor portion **10** includes a clamp member **11** configured and located to support the plurality of disks **101**. The disk drive apparatus **100** includes a spacer **106** between the clamp member **11** and the disks **101**. The plurality of disks **101** are configured to rotate about the central axis J together with the rotor portion **10**.

The access portion **102** preferably includes heads **107**, arms **108**, and a head actuator mechanism **109**. Each of the heads **107** is in close proximity to a surface of one of the disks **101** to magnetically perform at least one of the reading and the writing of information. Each head **107** is supported by an associated one of the arms **108**. Each arm **108** is supported by the head actuator mechanism **109**.

The spindle motor **1** preferably includes the rotor portion **10**, a bearing portion **20**, a stator portion **30**, the base portion **40**, a circuit board **50**, and an insulation sheet portion **52**. The rotor portion **10** preferably includes the clamp member **11**, a rotor hub **12**, and a rotor magnet **13**.

The bearing portion **20** is configured to support the rotor portion **10** such that the rotor portion **10** is rotatable about the central axis J, which extends in a vertical direction. The bearing portion **20** preferably includes a shaft **21** and a sleeve **22**. The shaft **21** is fixed to the base portion **40**. The shaft **21** and the sleeve **22** are located opposite to each other with a gap therebetween. A fluid, such as, for example, a lubricating oil or a gas, is provided in the gap.

The stator portion **30** preferably includes coils **31** and a stator core **32**. Each coil **31** is located opposite to the rotor magnet **13** with a gap therebetween. The stator portion **30** includes the plurality of coils **31**. The plurality of coils **31** are supported by the stator core **32**. The stator core **32** is preferably a laminated structure defined by laminated magnetic bodies. The stator core includes salient poles **33** each of which projects outwardly. One of the coils **31** is wound around each of the plurality of salient poles **33**.

The base portion **40** preferably includes an upper surface **40**A, a lower surface **40**B, and base portion through holes **42**. The upper surface **40**A is a surface facing an inside of the housing **103**. The base portion **40** is preferably, for example, molded by casting. The base portion **40** is preferably an aluminum die-casting. However, the base portion **40** may be made of any other desirable material and formed using any other desirable manufacturing method. The base portion **40** includes a stator support portion **41**. The stator support portion **41** is provided on the upper surface **40**A of the base portion **40**. The stator support portion **41** is preferably in the shape of, for example, a tube, a polygon, or the like. The stator core **32** is located outside of the stator support portion **41**.

Each base portion through hole **42** passes through the base portion **40** from the upper surface **40**A to the lower surface **40**B. The lower surface **40**B is a surface facing an outside of the housing **103**. Each base portion through hole **42** preferably extends parallel or substantially parallel to the central axis J. Lead wires **34** from the coils **31** pass through the base portion through holes **42**. The spindle motor **1** includes a sealant **43**. The sealant **43** fills a gap between each base portion through hole **42** and the lead wire **34**. The sealant **43** is preferably an adhesive, for example. The circuit board **50** is provided on the lower surface **40**B of the base portion **40**. The circuit board **50** is connected with the lead wires **34**, which are drawn out below the lower surface **40**B through the base portion through holes **42**.

FIG. **2** is a bottom view illustrating the base portion **40** according to a preferred embodiment of the present invention. FIG. **3** is a cross-sectional view taken along line A-A in FIG. **2**.

In the following drawings, an xyz coordinate system is shown appropriately as a three-dimensional orthogonal coordinate system. In the xyz coordinate system, a z-axis direction is assumed to be a direction parallel to the central axis J extending in a vertical direction in FIG. **1**. A y-axis direction is assumed to be a direction perpendicular to a z-axis and parallel to a direction in which each lead wire **34** is drawn in FIG. **2**. An x-axis direction is assumed to be a direction perpendicular to both the z-axis and a y-axis. Note that the wording “parallel direction” as used herein comprehends both parallel and substantially parallel directions. Also note that the wording “perpendicular” as used herein comprehends both “perpendicular” and “substantially perpendicular”.

Also note that, in the following description, a positive side (i.e., a +z side) in the z-axis direction will be referred to as an “upper side”, and a negative side (i.e., a −z side) in the z-axis direction will be referred to as a “lower side”. It should be noted, however, that the above definitions of the vertical direction and the upper and lower sides are not meant to indicate relative positions and/or directions of different members or portions when those members or portions are actually installed in a device. Also note that, in the following description, the relative positions of different members or portions and/or positions of those members or portions will be defined based on a central axis J1 which passes through a center of the base portion through hole **42** illustrated in FIG. **3**. Unless otherwise specified, a direction parallel to the central axis J1 (i.e., the z-axis direction) will be simply referred to by the term “axial direction”, “axial”, or “axially”, radial directions centered on the central axis J1 will be simply referred to by the term “radial direction”, “radial”, or “radially”, and a circumferential direction about the central axis J1 will be simply referred to by the term “circumferential direction”, “circumferential”, or “circumferentially”.

Referring to FIG. **2**, the base portion **40** includes the plurality of base portion through holes **42**. The number of base portion through holes **42** included in the base portion **40** is preferably four. The coils **31** include the plurality of lead wires **34**. The number of lead wires **34** included in the coils **31** is preferably four. One of the plurality of lead wires **34** is passed through each of the plurality of base portion through holes **42**. In other words, one of the lead wires **34** is passed through each one of the base portion through holes **42**. The size of each base portion through hole **42** can be reduced to a size which allows only one of the lead wires **34** to pass through the base portion through hole **42**, to achieve improved airtightness. In addition, since two or more of the lead wires **34** are not passed through each base portion through hole **42**, a failure in filling of the sealant **43** due to a contact of two or more of the lead wires **34** is prevented. The coils **31** are preferably defined by three coil groups. The three coil groups are a U phase group, a V phase group, and a W phase group, respectively. Note that the number of base portion through holes **42** is not limited to four, but may alternatively be one, two, three, or more than four. Also note that the number of lead wires **34** is not limited to four, but may alternatively be one, two, three, or more than four.

In each of the three coil groups, one conducting wire preferably defines two or more of the coils **31**. The conducting wire is preferably an enameled wire including an insulating coating. One end portion of each of the three conducting wires of the three coil groups is drawn out as one of the lead wires **34**. Meanwhile, opposite end portions of the three conducting wires of the three coil groups are twisted together and drawn out as a single common wire. Hereinafter, the common wire will also be referred to as one of the lead wires **34**. Thus, the four lead wires **34** are drawn out of the base portion **40**.

The circuit board **50** is preferably a flexible circuit board. The circuit board **50** is fixed to the lower surface **40**B of the base portion **40**. The circuit board **50** includes land portions **51** to which the lead wires **34** are connected. Each land portion **51** is preferably provided at a position spaced away from a corresponding one of the base portion through holes **42** in a radial direction (specifically, the y-axis direction). The land portion **51** is connected with the lead wire **34** which is drawn out from above the upper surface **40**A downwardly of the lower surface **40**B through the base portion through hole **42**.

The circuit board **50** includes the plurality of land portions **51**. The number of land portions **51** included in the circuit board **50** is preferably four, for example. One of the plurality of lead wires **34** is connected to each of the plurality of land portions **51**. In other words, one of the lead wires **34** is connected to each one of the land portions **51**. Each land portion preferably is rectangular or substantially rectangular, including short sides extending in the y-axis direction and long sides extending in the x-axis direction. The lead wire **34** is connected to the land portion **51** through a solder **53**. The lead wire **34**, the land portion **51**, and the solder **53** are preferably covered with a molding member **54**. The molding member **54** is preferably made of a resin. The molding member **54** is, for example, a thermosetting adhesive. Note that the molding member **54** may not necessarily be an adhesive, and may be, for example, a sheet-shaped portion or a resin material which is not an adhesive.

Referring to FIG. **3**, each base portion through hole **42** preferably includes an upper opening portion **44** and a lower opening portion **45**. The upper opening portion **44** opens on the upper surface **40**A of the base portion **40**. The lower opening portion **45** opens on the lower surface **40**B of the base portion **40**. The upper opening portion **44** is preferably circular or substantially circular in a plan view. An inner wall surface of the base portion which defines the upper opening portion **44** is preferably chamfered. Accordingly, the inner wall surface of the base portion which defines the upper opening portion **44** is slanted to gradually decrease in inside diameter as it extends away from the upper surface **40**A toward the lower surface **40**B in an axial direction. Note that the inner wall surface of the base portion **40** which defines the upper opening portion **44** will be hereinafter referred to as an inner wall surface of the upper opening portion **44**. The lower opening portion **45** preferably is circular or substantially circular in a plan view. An inner wall surface of the base portion **40** which defines the lower opening portion **45** is chamfered. Accordingly, the inner wall surface of the base portion which defines the lower opening portion **45** is slanted to gradually decrease in inside diameter as it extends away from the lower surface **40**B toward the upper surface **40**A in the axial direction. Note that the inner wall surface of the base portion **40** which defines the lower opening portion **45** will be hereinafter referred to as an inner wall surface of the lower opening portion **45**.

Referring to FIG. **3**, an opening area of the lower opening portion **45** is greater than an opening area of the upper opening portion **44**. An insulation sheet guide **46** is provided on the upper surface **40**A of the base portion **40**. The insulation sheet guide **46** is configured to position the lead wire **34** which is passed through the upper opening portion **44** at the upper surface **40**A of the base portion **40**. The insulation sheet guide **46** covers at least a portion of the upper opening portion **44**. The insulation sheet guide **46** includes a guide through hole **47**. The guide through hole **47** overlaps with the upper opening portion **44** in a plan view.

Note that a lower surface of the insulation sheet guide **46** may be fixed to the upper surface **40**A of the base portion **40** through an adhesive layer.

An opening area of the guide through hole **47** is greater than a cross-sectional area of the lead wire **34**. Thus, the lead wire **34** is able to pass through the guide through hole **47**. In addition, the opening area of the guide through hole **47** is smaller than the opening area of the upper opening portion **44**. Accordingly, the guide through hole **47** is not in contact with the inner wall surface of the upper opening portion **44**. Thus, the likelihood that the insulating coating of the lead wire **34** will be damaged is significantly reduced or prevented. Moreover, even if the insulating coating of the lead wire **34** is damaged, the lead wire **34** does not contact the inner wall surface of the upper opening portion **44**. Therefore, a short circuit due to an electrical connection between the lead wire **34** and the inner wall surface of the upper opening portion **44** is prevented.

The insulation sheet guide **46** is preferably made of a resin. More specifically, the insulation sheet guide **46** is preferably thermoplastic. Polyethylene terephthalate (PET), polyamide (PA), polybutylene terephthalate (PBT), polyphenylene sulfide (PPS), or the like, for example, is preferably used for the insulation sheet guide **46**. The resin used for the insulation sheet guide **46** preferably has a melting point lower than a melting point of a metal of which the base portion **40** is made. After the insulation sheet guide **46** is provided on the upper surface **40**A of the base portion **40**, the guide through hole **47** is defined by fusion through light irradiation with a xenon lamp or the like.

Therefore, even when the insulation sheet guide **46** is not positioned with high accuracy, the guide through hole **47** is able to be provided at a position overlapping with the upper opening portion **44** with high accuracy. Use of the insulation sheet guide **46** contributes to reducing the opening area of the upper opening portion **44** and an area of the base portion through hole **42** when compared to, for example, the case where a cylindrical insulating bushing is located in the base portion through hole **42**. Accordingly, the likelihood that the helium gas provided in the interior space of the housing **103** will leak out of the housing **103** is reduced.

The base portion through hole **42** includes a first opening portion **48** and a second opening portion **49** between the lower opening portion **45** and the upper opening portion **44**. The first opening portion **48** is in communication with the lower opening portion **45**. In other words, the first opening portion **48** is located above (i.e., on the +z side of) the lower opening portion **45**. The second opening portion **49** is in communication with the first opening portion **48**. In other words, the second opening portion **49** is located above (i.e., on the +z side of) the first opening portion **48**. The upper opening portion **44** is in communication with the second opening portion **49**. In other words, the upper opening portion **44** is located above (i.e., on the +z side of) the second opening portion **49**.

An inner wall surface of the base portion **40** which defines each base portion through hole **42** is preferably tubular. In addition, an inner wall surface of the base portion **40** which defines the first opening portion **48** is preferably tubular. The inner wall surface of the base portion **40** which defines the first opening portion **48** will be hereinafter referred to as an inner wall surface of the first opening portion **48**. The first opening portion **48** has a first inside diameter D1. An inner wall surface of the base portion **40** which defines the second opening portion **49** is preferably tubular. The inner wall surface of the base portion **40** which defines the second opening portion **49** will be hereinafter referred to as an inner wall surface of the second opening portion **49**. The second opening portion **49** preferably has a second inside diameter D**2** smaller than the first inside diameter D**1**. The second inside diameter D**2** corresponds to the smallest inside diameter of the base portion through hole **42**. The gap between the base portion through hole **42** and the lead wire **34** is filled with the sealant **43** at least at the second opening portion **49**. The sealant **43** is preferably made of a resin. The sealant **43** is, for example, a thermosetting adhesive. Note that the sealant **43** may not necessarily be an adhesive, and may be, for example, a resin material which is not an adhesive.

Since the base portion through hole **42** includes the second opening portion **49**, which has an inside diameter smaller than that of the first opening portion **48**, which is in communication with the lower opening portion **45**, an improvement in airtightness is achieved. In addition, since the first opening portion **48** has an inside diameter greater than that of the second opening portion **49**, the first opening portion **48** defines and functions as a buffer to accommodate an extra portion of the sealant **43** when the sealant **43** is injected into the base portion through hole **42**.

Furthermore, since the gap between the base portion through hole **42** and the lead wire **34** is sealed with the sealant **43**, the airtightness is improved. Furthermore, the sealant **43** provided in the gap between the base portion through hole **42** and the lead wire **34** contributes to significantly reducing or preventing the likelihood that the lead wire **34** will make contact with an inner wall surface of the base portion through hole **42**.

Referring to FIG. **3**, the insulation sheet portion **52** is provided on the lower surface **40**B of the base portion **40**. The insulation sheet portion **52** covers at least a portion of each base portion through hole **42**. Each lead wire **34** contacts the insulation sheet portion **52**. An edge **55** of the insulation sheet portion **52** which covers at least a portion of each base portion through hole **42** preferably overlaps with the base portion through hole **42** in a plan view. The edge **55** will be hereinafter referred to as the edge **55** of the insulation sheet portion **52**. The edge **55** of the insulation sheet portion **52** is positioned radially inward of the base portion through hole **42**. More specifically, the edge **55** of the insulation sheet portion **52** is positioned radially inward of the inner wall surface of the second opening portion **49**.

The edge **55** of the insulation sheet portion **52** is located radially outward of (i.e., on a −y side of) a center of the base portion through hole **42**. Note that the edge **55** of the insulation sheet portion **52** may alternatively be located at the same or substantially the same position as that of the center of the base portion through hole **42**. The lead wire **34**, which makes contact with the edge **55** of the insulation sheet portion **52**, is drawn out along the central axis J**1** of the base portion through hole **42**. Accordingly, the lead wire **34** is able to be drawn out in a direction parallel to the central axis J**1** without allowing the lead wire **34** to make contact with the inner wall surface of the base portion through hole **42**.

Referring to FIG. **2**, the insulation sheet portion **52** covers at least a portion of each of the plurality of base portion through holes **42**. That is, the edge **55** of the insulation sheet portion **52** overlaps with each of the plurality of base portion through holes **42** in a plan view. Referring to FIG. **3**, the insulation sheet portion **52** preferably has a thickness T**2** greater than a diameter of the lead wire **34**. More specifically, the edge **55** of the insulation sheet portion **52** has a thickness greater than the diameter of the lead wire **34**. Thus, a contact of the lead wire **34** with the edge **55** does not easily cause a bending of the insulation sheet portion **52**. This contributes to maintaining a uniform distance between the lead wire **34**, which is pulled radially, and the inner wall surface of the base portion through hole **42**. This in turn contributes to significantly reducing or preventing the likelihood that the lead wire **34** from one of the coils **31**, which is passed through the base portion through hole **42**, will make contact with the inner wall surface of the base portion through hole **42**. The thickness T**2** of the insulation sheet portion **52** is preferably greater than a thickness T**1** of the land portion **51**.

FIG. **4** is a bottom view illustrating the circuit board **50** according to a preferred embodiment of the present invention.

Referring to FIG. **4**, the insulation sheet portion **52** is a portion of the circuit board **50**. The edge **55** of the insulation sheet portion **52** preferably includes cuts **56** each of which is recessed radially outward (i.e., to the −y side). Preferably, each cut **56** is substantially in the shape of a circular arc in a plan view. A radius of the cut **56** is greater than a radius of the lead wire **34**. The radius of the cut **56** is smaller than a radius of the lower opening portion **45**. The edge **55** of the insulation sheet portion **52** includes a plurality of such cuts **56**. The number of cuts **56** included in the edge **55** of the insulation sheet portion **52** is preferably four.

Referring to FIG. **3**, each lead wire **34** contacts an inner edge portion of the insulation sheet portion **52** which defines a corresponding one of the cuts **56**. The inner edge portion of the insulation sheet portion **52** which defines each cut **56** will be hereinafter referred to as an inner edge portion of the cut **56**. The inner edge portion of the cut **56** includes both a portion of an end surface of the insulation sheet portion **52** and an edge of the portion of the end surface of the insulation sheet portion **52**. In other words, the inner edge portion of the cut **56** includes both a portion of the end surface which is in the shape of a circular arc and which faces a radial center of the cut **56**, and an edge of the portion of the end surface which extends perpendicularly or substantially perpendicularly to the axial direction. Referring to FIG. **2**, one of the plurality of lead wires **34** contacts the inner edge portion of each of the plurality of cuts **56**. In other words, one of the lead wires **34** contacts the inner edge portion of each one of the cuts **56**.

A contact of the lead wire **34** with the inner edge portion of the cut **56** contributes to preventing the lead wire **34** from moving in a radial direction (specifically, in the x-axis direction) with respect to the edge **55** of the insulation sheet portion **52**. Accordingly, the lead wire **34**, which is drawn out below the lower surface **40**B of the base portion **40**, is positioned accurately with respect to the base portion through hole **42**. Therefore, the lead wire **34** is accurately positioned in the base portion through hole **42**. Since the lead wire **34** is able to be drawn out in the direction parallel or substantially parallel to the central axis J**1** from the base portion through hole **42** to the lower opening portion **45**, the likelihood that the lead wire **34** will make contact with the inner wall surface of the base portion through hole **42** is significantly reduced or prevented.

FIG. **5** is a cross-sectional view taken along line B-B in FIG. **4**.

As illustrated in FIG. **5**, the circuit board **50** preferably includes a board adhesive layer **60**, a base film layer **61**, a copper foil layer **62**, and a cover film layer **63**. The board adhesive layer **60** is fixed to the base portion **40**. The board adhesive layer **60**, the base film layer **61**, the copper foil layer **62**, and the cover film layer **63** are arranged in the order named.

The board adhesive layer **60** is provided on a lower side (i.e., the −z side) of the base portion **40**. The base film layer

**61** is provided on the lower side (i.e., the −z side) of the board adhesive layer **60**. The copper foil layer **62** is provided on the lower side (i.e., the −z side) of the base film layer **61**. The cover film layer **63** is provided on the lower side (i.e., the −z side) of the copper foil layer **62**. Each of the base film layer **61** and the cover film layer **63** is preferably made of a resin. Polyimide (PI), for example, is used for each of the base film layer **61** and the cover film layer **63**. Note that, there is preferably no portion of the cover film layer **63** provided at each land portion **51**. This allows the lead wire **34** to be electrically connected to the copper foil layer **62** at the land portion **51**. Note that the term "board adhesive layer" **60** as used herein comprehends not only a glue layer but also, for example, an adhesive layer.

The insulation sheet portion **52** includes a sheet adhesive layer **70** fixed to the base portion **40**, and an increased thickness film layer **71** located on the lower side (i.e., the −z side) of the sheet adhesive layer **70**. The insulation sheet portion **52** is preferably a portion of the circuit board **50**. The insulation sheet portion **52** includes the base film layer **61**, the cover film layer **63**, and the board adhesive layer **60** as the sheet adhesive layer **70**. In the insulation sheet portion **52**, the board adhesive layer **60**, the base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71** are arranged in the order named. The above structure allows the board adhesive layer **60**, the base film layer **61**, and the cover film layer **63** in the insulation sheet portion **52** to be produced by the same process as in production of the circuit board **50**. Accordingly, the insulation sheet portion **52** preferably is produced by simple processes. In addition, since the circuit board **50** and the insulation sheet portion **52** is able to be fixed to the base portion **40** at one time, workability is improved. Note that the sheet adhesive layer **70** will be hereinafter referred to as the board adhesive layer **60** because the sheet adhesive layer **70** is preferably the same as the board adhesive layer **60**. Also note that, although the increased thickness film layer **71** preferably is a single layer, this is not essential to the present invention. The increased thickness film layer **71** may alternatively be a laminated body defined by a plurality of layers placed one upon another.

The board adhesive layer **60** is provided on the lower side (i.e., the −z side) of the base portion **40**. The base film layer **61** is provided on the lower side (i.e., the −z side) of the board adhesive layer **60**. The cover film layer **63** is provided on the lower side (i.e., the −z side) of the base film layer **61**. The increased thickness film layer **71** is provided on the lower side (i.e., the −z side) of the cover film layer **63**. The increased thickness film layer **71** is preferably made of a resin. For the increased thickness film layer **71** according to a preferred embodiment of the present invention, polyimide (PI), which is preferably used for each of the base film layer **61** and the cover film layer **63** as well, is preferably used, for example. Note that, preferably, no portion of the copper foil layer **62** is located in the insulation sheet portion **52**.

The board adhesive layer **60** has a thickness t**1**. The base film layer **61** has a thickness t**2**. The copper foil layer **62** has a thickness t**3**. The cover film layer **63** has a thickness t**4**. The thickness T**1** of the land portion **51** corresponds to a thickness of the circuit board **50** excluding the cover film layer **63**. In other words, the thickness T**1** of the land portion **51** corresponds to a sum of the thickness t**1**, the thickness t**2**, and the thickness t**3**. The thickness T**2** of the insulation sheet portion **52** corresponds to a sum of a thickness of the increased thickness film layer **71** and a thickness of the circuit board **50** excluding the copper foil layer **62**. The increased thickness film layer **71** has a thickness t**5**. That is, the thickness T**2** of the insulation sheet portion **52** corresponds to a sum of the thickness t**1**, the thickness t**2**, the thickness t**4**, and the thickness t**5**.

Specifically, the thickness t**5** of the increased thickness film layer **71** is greater than a sum t**24** of the thickness t**2** of the base film layer **61** and the thickness t**4** of the cover film layer **63**. Since the increased thickness film layer **71** has a thickness greater than the sum t**24** of the thickness t**2** of the base film layer **61** and the thickness t**4** of the cover film layer **63**, the likelihood that a bending of the insulation sheet portion **52** will occur is able to be reduced by a simple structure. The thickness t**5** of the increased thickness film layer **71** is preferably about 1.5 or more times the combined thickness t**24** of the base film layer and the cover film layer **63**. Note that, preferably, the thickness t**2** of the base film layer **61** is equal or substantially equal to the thickness t**3** of the cover film layer **63**. In addition, the thickness t**5** of the increased thickness film layer **71** is preferably greater than the thickness t**3** of the copper foil layer **62**. The thickness t**5** of the increased thickness film layer **71** is preferably twice the thickness t**3** of the copper foil layer **62** or greater. Note that the thickness t**3** of the copper foil layer **62** is greater than the thickness t**2** of the base film layer **61**. As described above, the thickness T**2** of the insulation sheet portion **52** is greater than the thickness T**1** of the land portion **51**. Note that a gluing agent or an adhesive may be provided between the base film layer **61** and the cover film layer **63**. Also note that a gluing agent or an adhesive may be provided between the cover film layer **63** and the increased thickness film layer **71** as well.

Referring to FIG. **3**, the lead wire **34** from one of the coils **31** is passed through the base portion through hole **42** to be drawn out below the lower surface **40**B of the base portion **40**. After being drawn out below the lower surface **40**B of the base portion **40**, the lead wire **34** is soldered to a corresponding one of the land portions **51**, which is positioned away from the base portion through hole **42**. When the lead wire **34**, after being drawn out, is soldered thereto, the lead wire **34** is pulled in a radial direction (i.e., the y-axis direction) from the base portion through hole **42**. As a result of being pulled in the radial direction, the lead wire **34** approaches the inner wall surface of the base portion through hole **42**.

The spindle motor **1** includes the insulation sheet portion **52**, which covers at least a portion of each base portion through hole **42**. The insulation sheet portion **52** contacts the lead wire **34** when the lead wire **34** is pulled in the radial direction. The thickness T**2** of the insulation sheet portion **52** is greater than the thickness T**1** of the land portion **51**. Therefore, the insulation sheet portion **52** bends less easily than the circuit board **50**, and is able to support the lead wire **34** being pulled in the radial direction. This contributes to significantly reducing or preventing the likelihood that the lead wire **34** from one of the coils **31**, which is passed through the base portion through hole **42**, will make contact with the inner wall surface of the base portion through hole **42**. This in turn contributes to preventing a short circuit from occurring due to an electrical connection between the lead wire **34** and the inner wall surface of the base portion through hole **42**. In addition, a withstand voltage failure is prevented from occurring due to a contact between the lead wire **34** and the inner wall surface of the base portion through hole **42**.

In addition, each of the increased thickness film layer **71**, the base film layer **61**, and the cover film layer **63** is preferably made of a resin. Since all of the base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71** are made of a resin, each of the base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71** can be made of the same resin material only by varying the thickness. The base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71** is thus produced at a lower cost than in the case where the base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71** are made of different materials.

In addition, referring to FIG. **3**, the base portion through hole **42** preferably includes the upper opening portion **44** and the lower opening portion **45**. The upper opening portion **44** opens on the upper surface **40**A of the base portion **40**. The lower opening portion **45** opens on the lower surface **40**B of the base portion **40**. The opening area of the lower opening portion **45** is greater than the opening area of the upper opening portion **44**. This arrangement ensures a sufficient area of a portion of the lower opening portion **45** which is not covered with the insulation sheet portion **52** even when at least a portion of the base portion through hole **42** is covered with the insulation sheet portion **52**. This makes it easier to draw out the lead wire **34**, and also makes it easier to inject the sealant **43** through the lower opening portion **45**.

Note that structures described below may be adopted in other preferred embodiments of the present invention. In the following description, members or portions that have their equivalents in the above-described preferred embodiment are denoted by the same reference numerals as those of their equivalents in the above-described preferred embodiment, and descriptions thereof will be provided in brief or will be omitted.

Although the insulation sheet portion **52** discussed above preferably includes the sheet adhesive layer **70**, the base film layer **61**, the cover film layer **63**, and the increased thickness film layer **71**, this is not essential to the present invention. The insulation sheet portion **52** may be modified in various manners as long as the thickness T2 of the insulation sheet portion **52** is greater than the thickness T1 of the land portion **51**.

For example, the increased thickness film layer **71** may be provided above the sheet adhesive layer **70** with the base film layer **61** and/or the cover film layer **63** being omitted. When this arrangement is adopted, the increased thickness film layer **71** preferably has a thickness still greater than the thickness t**5** illustrated in FIG. **5**.

Further, the thickness t**2** of the base film layer **61** and/or the thickness t**4** of the cover film layer **63** may be increased to define the insulation sheet portion **52**. When this configuration is adopted, the increased thickness film layer **71** may be omitted.

FIG. **6** is a bottom view illustrating a base portion **40** according to an example modification of the above-described preferred embodiment of the present invention. FIG. **7** is a cross-sectional view taken along line C-C in FIG. **6**.

Referring to FIG. **6**, an insulation sheet portion **52** may include sheet portion through holes **57** through each of which a lead wire **34** passes. Each sheet portion through hole **57** overlaps with a corresponding one of base portion through holes **42** in a plan view. The sheet portion through hole **57** preferably has an inside diameter smaller than a second inside diameter D**2** of a second opening portion **49**. The insulation sheet portion **52** covers almost the entire sheet portion through hole **57**.

This arrangement allows the lead wire **34** to be drawn out in a direction parallel or substantially parallel to a central axis J**1** without allowing the lead wire **34** to make contact with an inner wall surface of the base portion through hole **42**. In addition, referring to FIG. **6**, both radial and circumferential movement of the lead wire **34** is restricted. Accordingly, the lead wire **34**, which is drawn out below a lower surface **40**B of the base portion **40**, is able to be positioned accurately with respect to the base portion through hole **42**.

FIG. **8** is a vertical cross-sectional view illustrating an insulation sheet portion **52** according to an example modification of the above-described preferred embodiment of the present invention.

As illustrated in FIG. **8**, the insulation sheet portion **52** may be defined by a member separate from a circuit board **50**. The insulation sheet portion **52** includes a sheet adhesive layer **70** which is separate from a board adhesive layer **60**, and an increased thickness film layer **71** located on a lower side (i.e., the −z side) of the sheet adhesive layer **70**. A thickness t**5** of the increased thickness film layer **71** is greater than a combined thickness t**234** of a base film layer **61**, a copper foil layer **62**, and a cover film layer **63**. Note that a thickness t**6** of the sheet adhesive layer **70** may be equal or substantially equal to a thickness t**1** of the board adhesive layer **60**.

With the above arrangement, it is possible to make the insulation sheet portion **52** of materials different from those of the circuit board **50**. Because of this, it is possible to make the insulation sheet portion **52** of various materials. For example, a resin material used for the increased thickness film layer **71** may be different from a resin material used for the base film layer **61** and the cover film layer **63**. Note that, although the increased thickness film layer **71** is preferably a single layer, this is not essential to the present invention. The increased thickness film layer **71** may alternatively be a laminated body defined by a plurality of layers placed one upon another.

FIG. **9** is a vertical cross-sectional view illustrating an inner wall surface of a base portion through hole **42** according to an example modification of the above-described preferred embodiment of the present invention.

As illustrated in FIG. **9**, the inner wall surface of the base portion through hole **42** may have an angled slanting shape. The inner wall surface of the base portion through hole **42** preferably has a slanting shape that gradually decreases in inside diameter as it extends away from an upper surface **40**A toward a lower surface **40**B in the axial direction. The slanting shape may be, for example, in the shape of a cone, the shape of a quadrangular pyramid, or the shape of an n-gonal pyramid where n is not four.

According to the above arrangement, an opening area of an upper opening portion **44** is greater than an opening area of a lower opening portion **45**.

Note that the insulation sheet portion **52** may alternatively be in close contact with the lead wire **34** such that the base portion through hole **42** is entirely covered therewith.

Also note that the resin material used for the increased thickness film layer **71** may be an elastic elastomer, for example. Also note that the resin material used for the increased thickness film layer **71** may alternatively be a cured plastic, for example.

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 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.

What is claimed is:

**1**. A spindle motor comprising:

a rotor portion including a rotor magnet;

a bearing portion configured to support the rotor portion such that the rotor portion is rotatable about a central axis extending in a vertical direction;

a stator portion including coils located opposite to the rotor magnet;

a base portion including an upper surface, a lower surface, and a base portion through hole passing therethrough from the upper surface to the lower surface;

a circuit board located on the lower surface of the base portion; and

an insulation sheet portion; wherein

the coils include a lead wire drawn out from above the upper surface downwardly from the lower surface through the base portion through hole;

the circuit board includes a land portion to which the lead wire is connected;

the insulation sheet portion covers at least a portion of the base portion through hole;

the lead wire contacts the insulation sheet portion; and

the insulation sheet portion has a thickness greater than a thickness of the land portion.

**2**. The spindle motor according to claim **1**, wherein

the circuit board includes a board adhesive layer fixed to the base portion, a base film layer, a copper foil layer, and a cover film layer;

the board adhesive layer, the base film layer, the copper foil layer, and the cover film layer are arranged in an order named;

the insulation sheet portion includes a sheet adhesive layer fixed to the base portion, and an increased thickness film layer located on a lower side of the sheet adhesive layer; and

the increased thickness film layer has a thickness greater than a sum of a thickness of the base film layer and a thickness of the cover film layer.

**3**. The spindle motor according to claim **2**, wherein each of the increased thickness film layer, the base film layer, and the cover film layer is made of a resin.

**4**. The spindle motor according to claim **3**, wherein

the insulation sheet portion is a portion of the circuit board;

the insulation sheet portion includes the base film layer, the cover film layer, and the board adhesive layer as the sheet adhesive layer; and

the board adhesive layer, the base film layer, the cover film layer, and the increased thickness film layer are arranged in an order named.

**5**. The spindle motor according to claim **3**, wherein the insulation sheet portion is defined by a member separate from the circuit board.

**6**. The spindle motor according to claim **1**, wherein the insulation sheet portion includes an edge configured to cover at least a portion of the base portion through hole, and located at a center of the base portion through hole or radially outward of the center of the base portion through hole.

**7**. The spindle motor according to claim **6**, wherein

the edge of the insulation sheet portion includes a cut recessed radially outward; and

the insulation sheet portion includes an inner edge portion arranged to define the cut, and the lead wire contacts the inner edge portion.

**8**. The spindle motor according to claim **1**, wherein

the insulation sheet portion includes a sheet portion through hole through which the lead wire passes; and

the sheet portion through hole is configured to overlap with the base portion through hole in a plan view.

**9**. The spindle motor according to claim **1**, wherein

the base portion through hole includes an upper opening portion which opens on the upper surface of the base portion, and a lower opening portion which opens on the lower surface of the base portion; and

an opening area of the lower opening portion is greater than an opening area of the upper opening portion.

**10**. The spindle motor according claim **9**, wherein the base portion includes an inner wall surface configured to define the base portion through hole, the inner wall surface being tubular or slanted.

**11**. The spindle motor according to claim **9**, wherein the base portion through hole includes:

a first opening portion in communication with the lower opening portion, and having a first inside diameter; and

a second opening portion in communication with the first opening portion, and having a second inside diameter smaller than the first inside diameter.

**12**. The spindle motor according claim **11**, wherein the base portion includes an inner wall surface defining the base portion through hole, the inner wall surface being tubular or slanted.

**13**. The spindle motor according to claim **1**, wherein

the coils include a plurality of lead wires;

the base portion includes a plurality of base portion through holes; and

one of the lead wires passes through each one of the base portion through holes.

**14**. The spindle motor according to claim **1**, wherein the insulation sheet portion has a thickness greater than a diameter of the lead wire.

**15**. The spindle motor according to claim **1**, further comprising a sealant which fills a gap between the base portion through hole and the lead wire.

**16**. A disk drive apparatus comprising:

the spindle motor according to claim **1**;

a disk supported by the spindle motor; and

an access portion configured to perform at least one of reading and writing of information from or to the disk.

* * * * *

# Exhibit
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(12) **United States Patent**
**Sakurada et al.**

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(54) **BASE PLATE, HARD DISK DRIVE, AND METHOD OF MANUFACTURING BASE PLATE**

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(51) **Int. Cl.**

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| ***G11B 5/73*** | (2006.01) |
| ***C23C 18/31*** | (2006.01) |
| ***G11B 5/84*** | (2006.01) |
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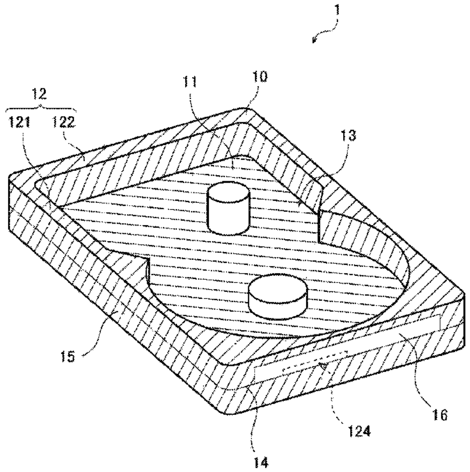
(57) **ABSTRACT**

A base plate is arranged to define a portion of a housing of a hard disk drive, and includes a base body defined by casting, and an electrodeposition coating film arranged to cover a surface of the base body. The surface of the base body includes a coated surface covered with the electrodeposition coating film, and a flat worked surface exposed from the electrodeposition coating film. The worked surface may include a gate position to which a gate has been connected at the time of the casting. At least a portion of the worked surface is covered with an impregnant.

**12 Claims, 12 Drawing Sheets**



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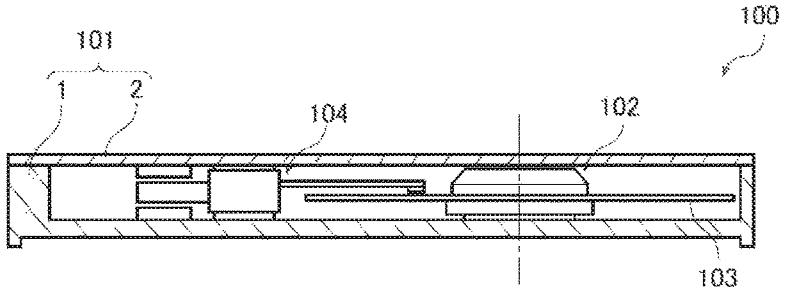

Fig. 1

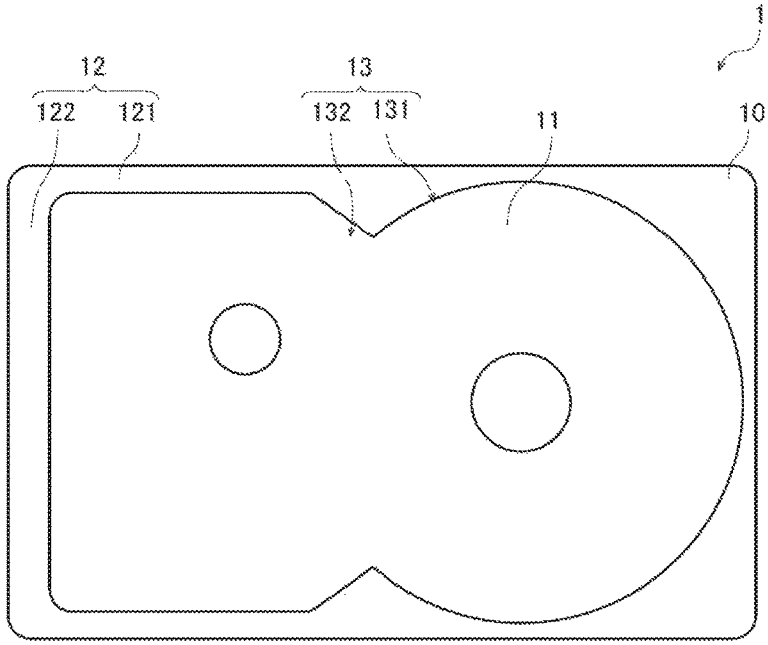

Fig. 2

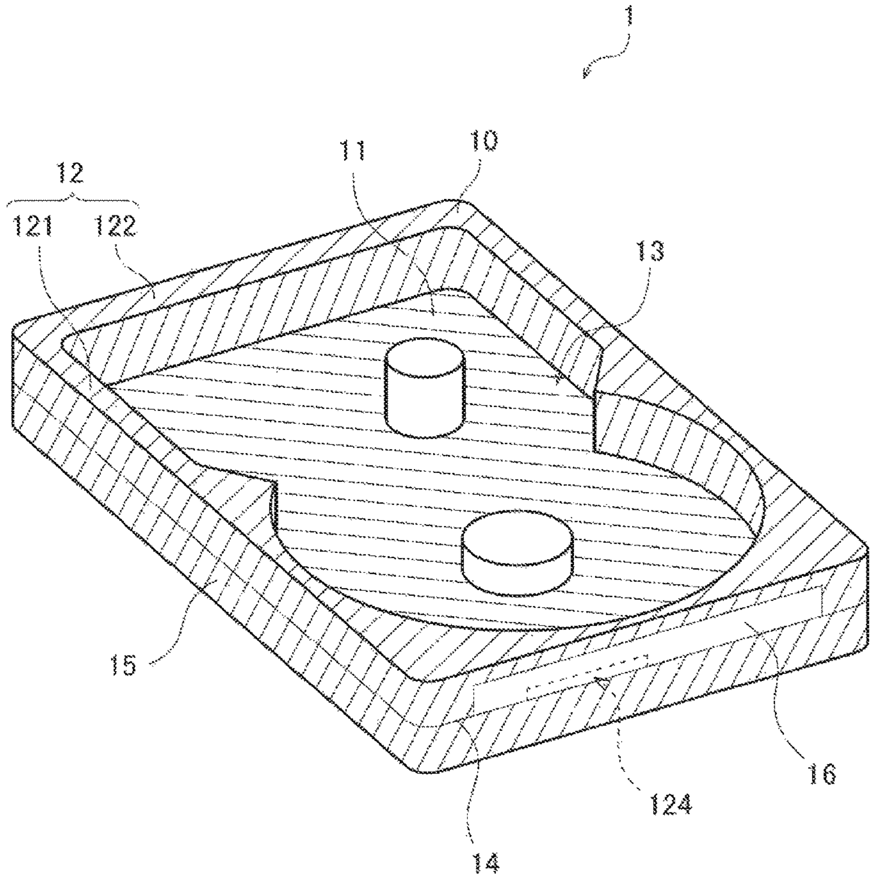

Fig. 3

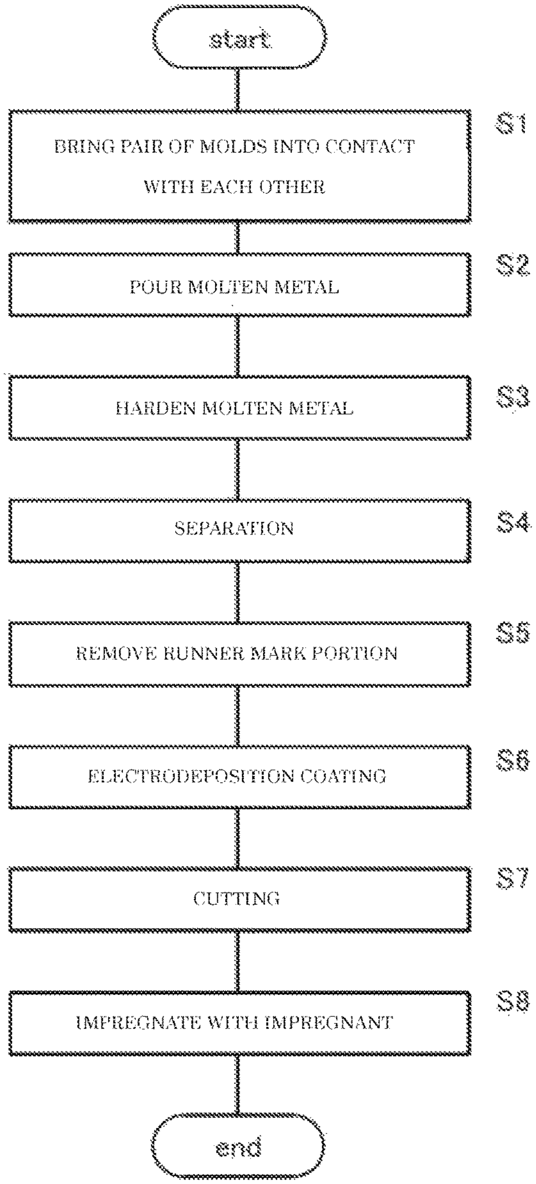
start
BRING PAIR OF MOLDS INTO CONTACT WITH EACH OTHER
S1
POUR MOLTEN METAL
S2
HARDEN MOLTEN METAL
S3
SEPARATION
S4
REMOVE RUNNER MARK PORTION
S5
ELECTRODEPOSITION COATING
S6
CUTTING
S7
IMPREGNATE WITH IMPREGNANT
S8
end

Fig. 4

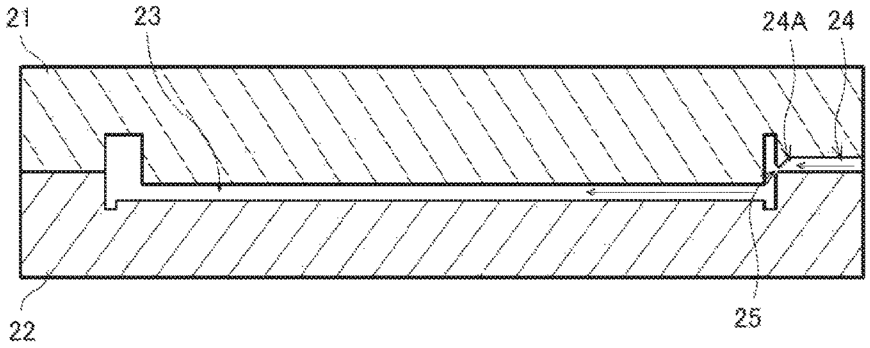

Fig. 5

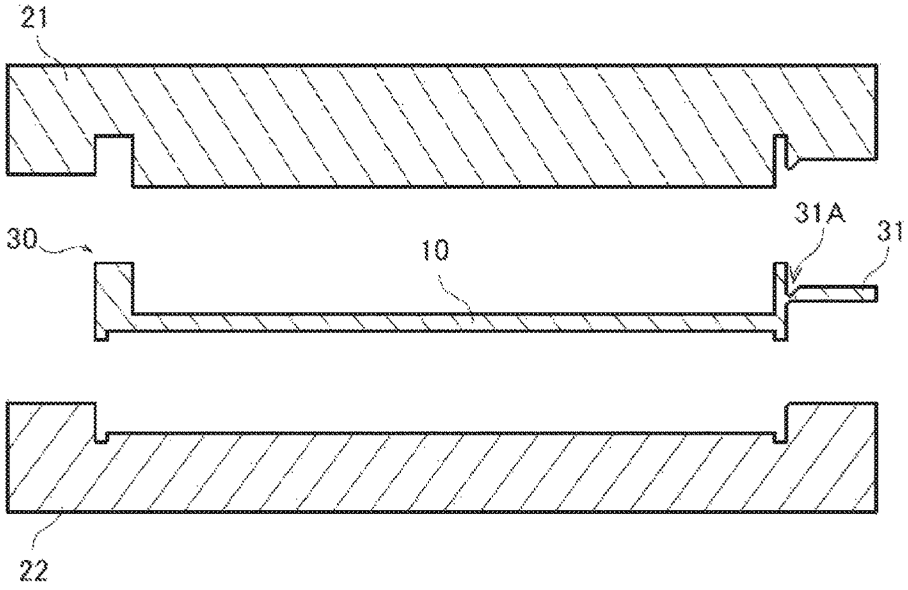

Fig. 6

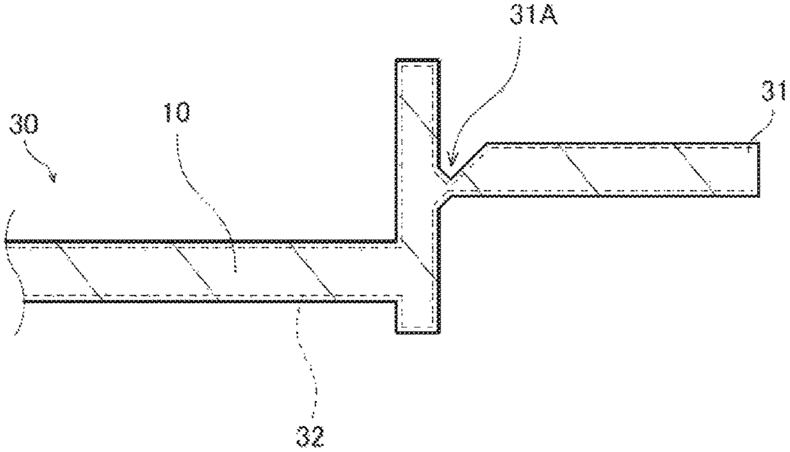

Fig. 7

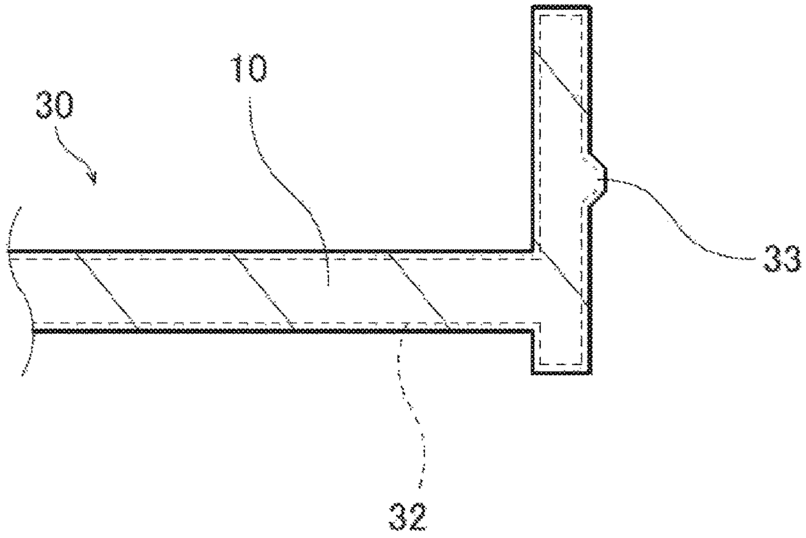

Fig. 8

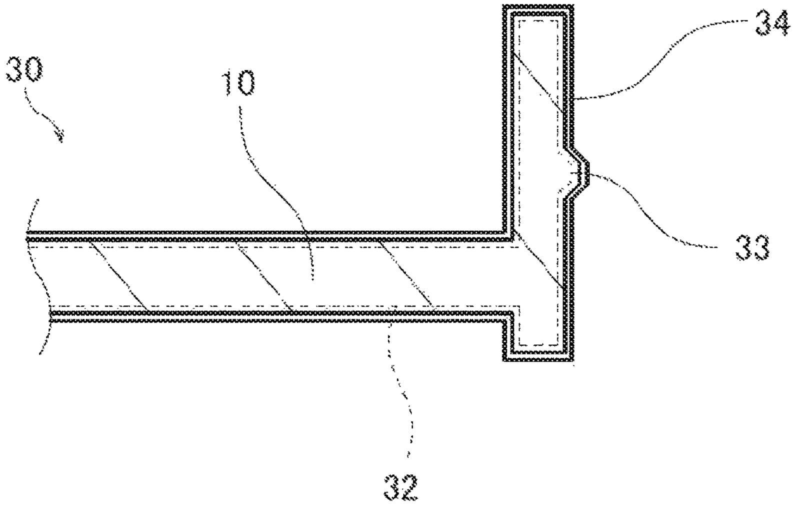

Fig. 9

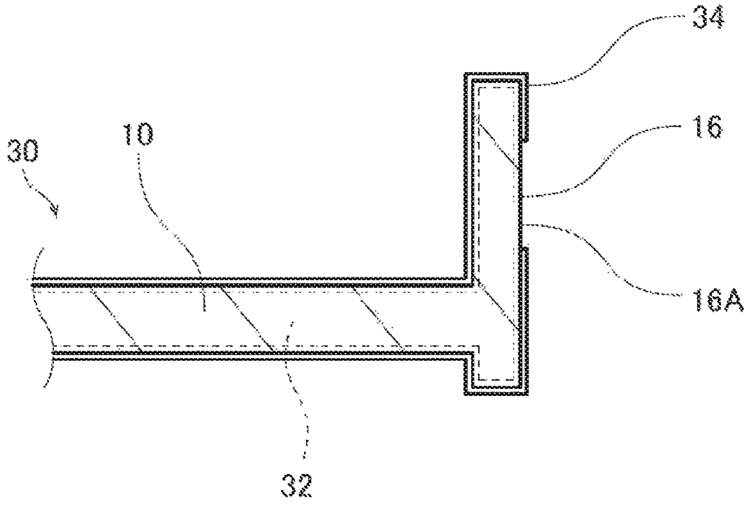

Fig. 10

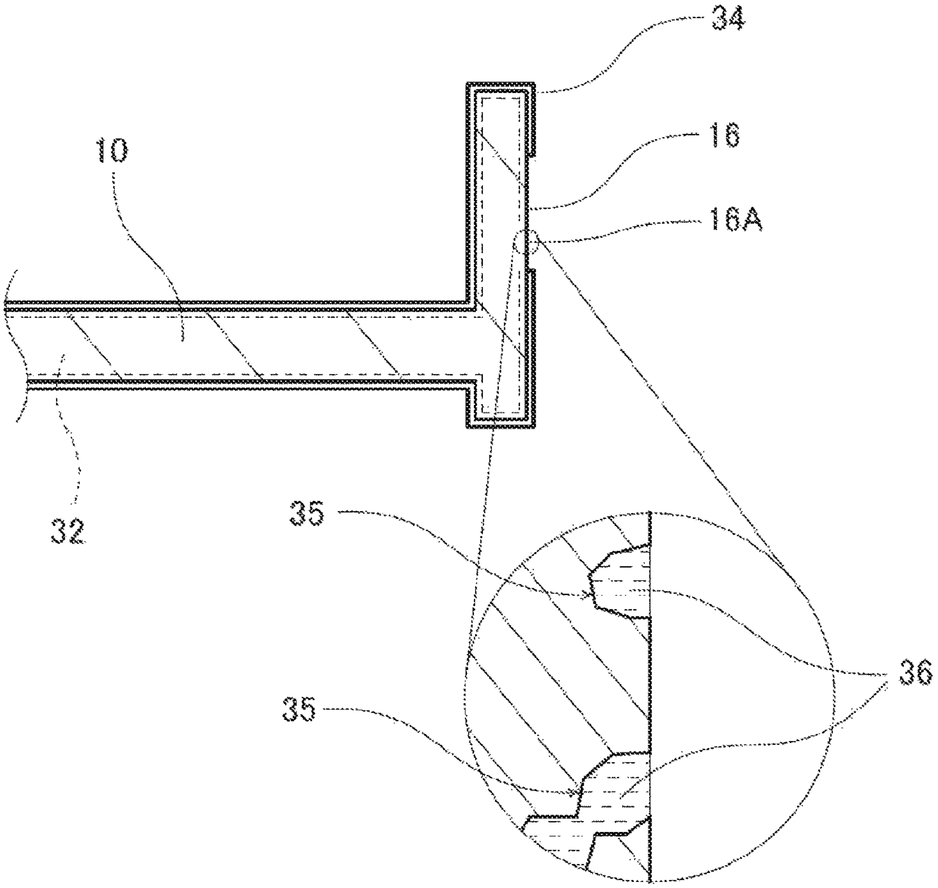

Fig. 11

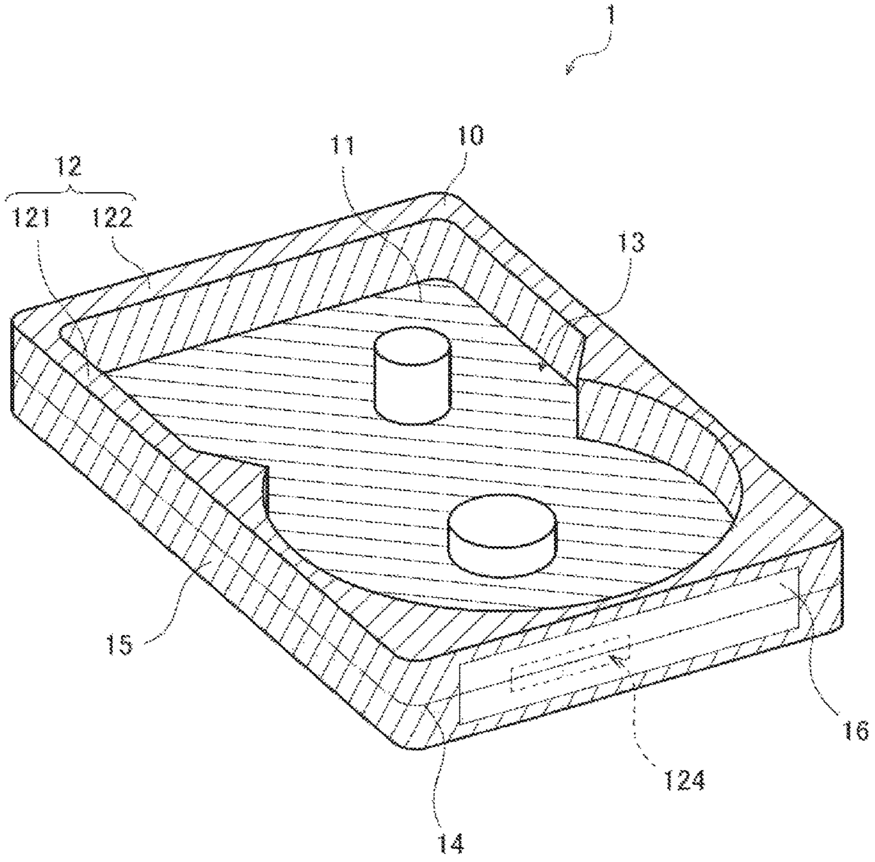

Fig. 12

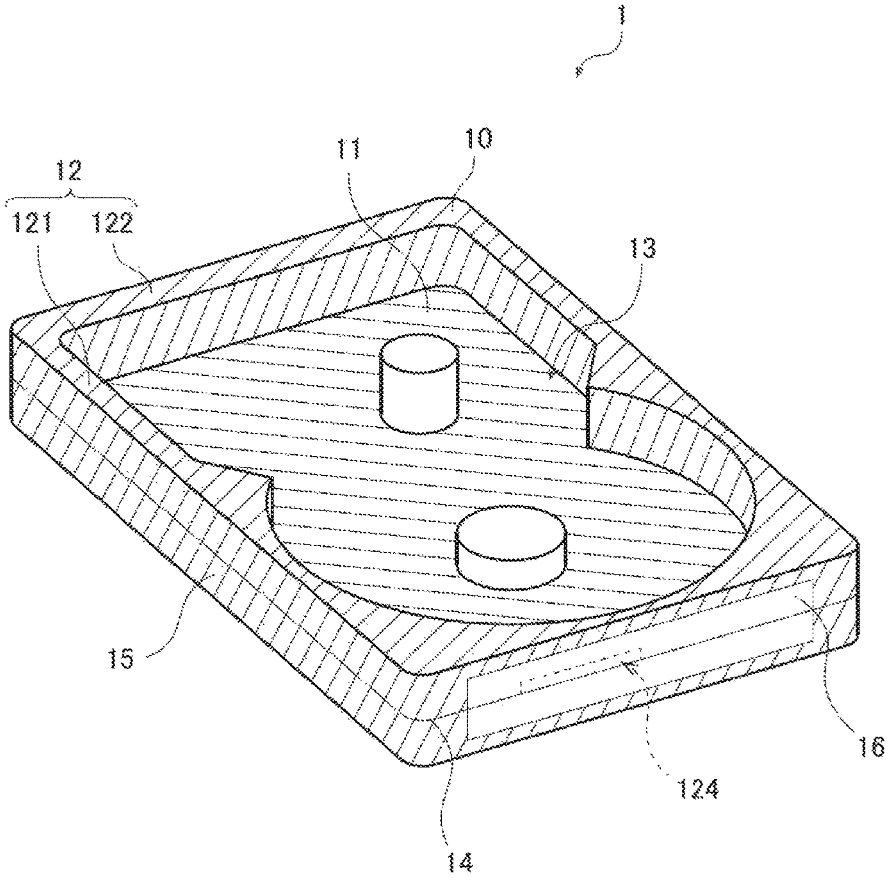

Fig. 13

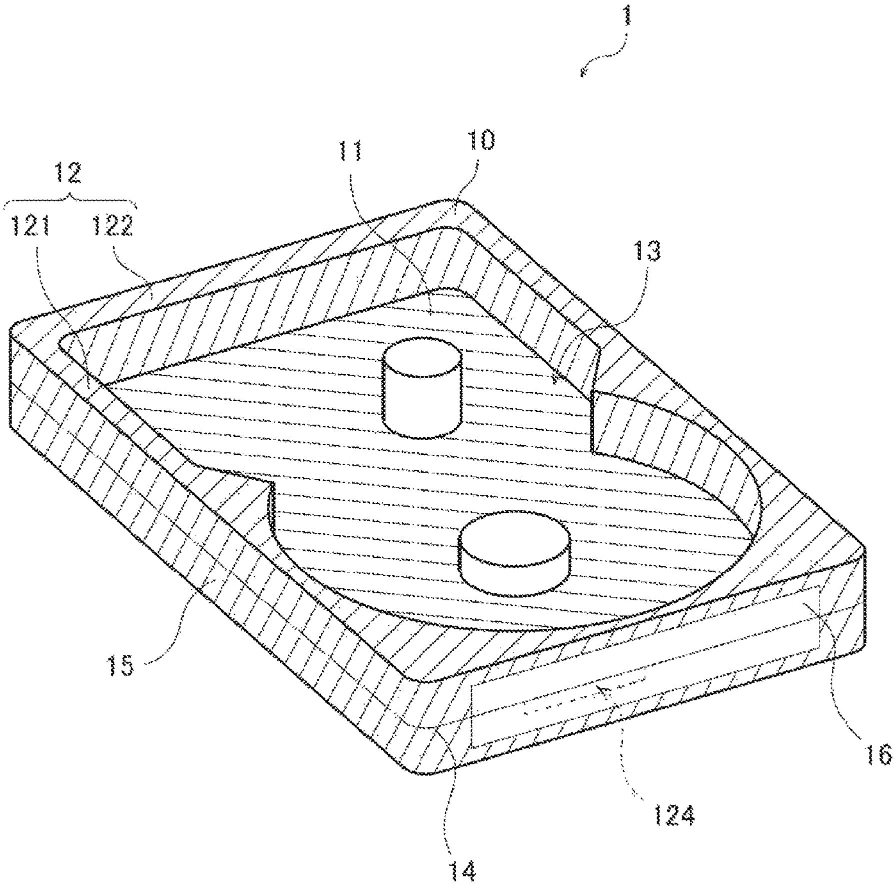

Fig. 14

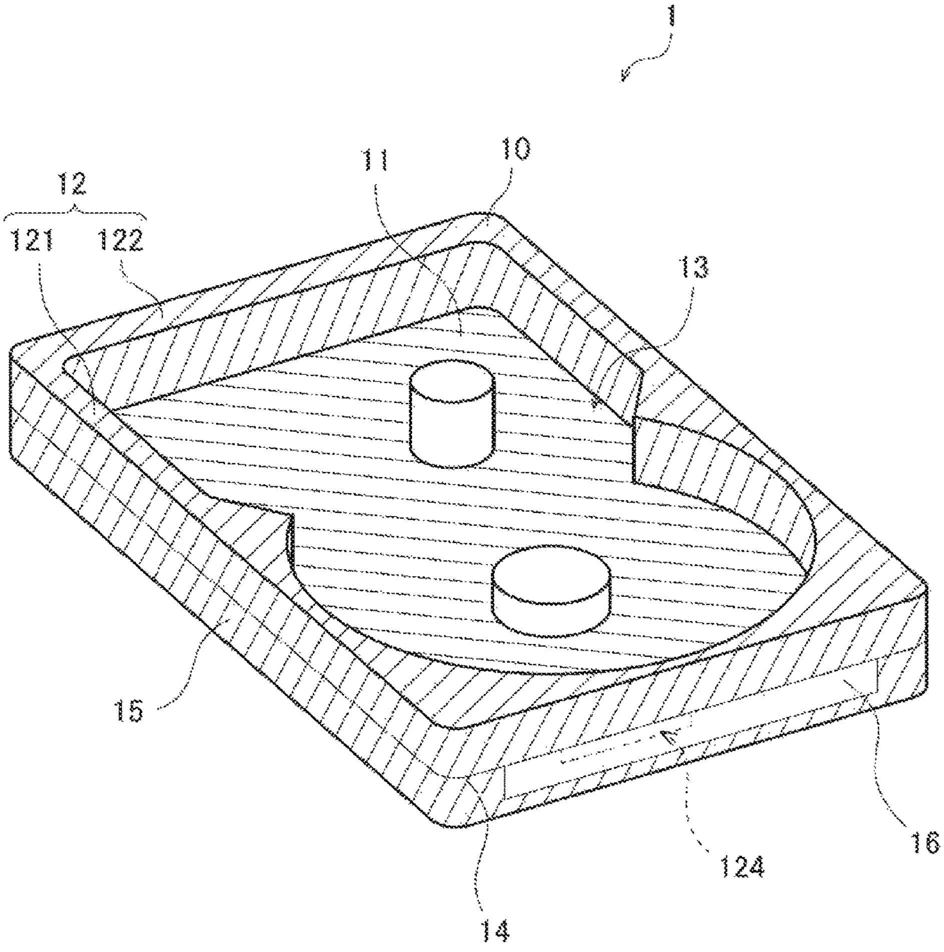

Fig. 15

# BASE PLATE, HARD DISK DRIVE, AND METHOD OF MANUFACTURING BASE PLATE

## CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority to Japanese Patent Application No. 2017-181974 filed on Sep. 22, 2017. The entire contents of this application are hereby incorporated herein by reference.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to a base plate, a hard disk drive, and a method of manufacturing the base plate.

### 2. Description of the Related Art

A disk drive apparatus, such as, for example, a hard disk drive, has been known. The disk drive apparatus is typically arranged to realize high-speed access to a desired location on a disk while rotating the disk at a high speed. Meanwhile, high-speed rotation of the disk causes problems of noise, an increase in a power consumption due to windage, etc. Thus, a technique of filling an interior space of a disk device with a gas having a density lower than that of air, such as, for example, a helium gas, to achieve a reduced windage loss has been known. An enclosed magnetic disk device filled with a low-density gas, such as, for example, a helium gas, is described in, for example, JP-A 2007-280555.

A base of the disk device described in JP-A 2007-280555 is molded by an aluminum die casting process. In the molding by the die casting process, a molten metal is poured into a cavity in a pair of molds fitted to each other, and is hardened therein, and then, the molds are removed from the hardened metal to complete the molded base. A gate through which the molten metal is poured into the cavity, an overflow through which an air bubble is removed from the cavity, or the like is defined at a boundary between the pair of molds fitted to each other.

In the molding of the base, when the molten metal is hardened, a portion of the molten metal which remains in the gate or the overflow is also hardened. Then, a cast portion is molded in the gate or the overflow together with the casting of the base. The cast portion in the gate or the overflow is cut off from the base, and a surface of the base from which the cast portion has been cut off has a low metal density. The low metal density may make it difficult to maintain airtightness of an interior space of a housing using the base.

## SUMMARY OF THE INVENTION

In view of the above problem, the present invention has been conceived to provide a base plate, a hard disk drive, and a method of manufacturing the base plate which are able to achieve an improvement in airtightness of an interior space of a housing using the base plate.

A base plate according to a preferred embodiment of the present invention is arranged to define a portion of a housing of a hard disk drive. The base plate includes a base body defined by casting, an electrodeposition coating film arranged to cover a surface of the base body, and an impregnant. The surface of the base body includes a coated surface covered with the electrodeposition coating film, and a flat worked surface exposed from the electrodeposition coating film. The impregnant is arranged to cover at least a portion of the worked surface.

According to the above preferred embodiment of the present invention, when the surface of the base body includes a portion having a low metal density, this portion is covered with the impregnant in place of the electrodeposition coating film. This leads to an improvement in airtightness of an interior space of the housing. In particular, the worked surface can be satisfactorily impregnated with the impregnant because minute cavities in the base body are exposed to an outside at the worked surface.

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 with reference to the attached drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view of a disk drive apparatus according to a preferred embodiment of the present invention.

FIG. **2** is a top view of a base plate according to a preferred embodiment of the present invention.

FIG. **3** is a perspective view of the base plate.

FIG. **4** is a flowchart illustrating a process of manufacturing the base plate according to a preferred embodiment of the present invention.

FIG. **5** is a vertical sectional view illustrating how casting is performed according to a preferred embodiment of the present invention.

FIG. **6** is a vertical sectional view illustrating how the casting is performed according to a preferred embodiment of the present invention.

FIG. **7** is a diagram illustrating a section of a portion of a base workpiece separated from molds according to a preferred embodiment of the present invention in an enlarged form.

FIG. **8** is a diagram illustrating a section of a portion of the base body with a runner mark portion removed therefrom according to a preferred embodiment of the present invention in an enlarged form.

FIG. **9** is a diagram illustrating a section of a portion of the base body after being subjected to electrodeposition coating according to a preferred embodiment of the present invention in an enlarged form.

FIG. **10** is a diagram illustrating a section of a portion of the base body after being subjected to a cutting process according to a preferred embodiment of the present invention in an enlarged form.

FIG. **11** is a diagram illustrating a section of a portion of the base body after being impregnated with an impregnant according to a preferred embodiment of the present invention in an enlarged form.

FIG. **12** is a perspective view of a base plate according to a modification of the above preferred embodiment of the present invention.

FIG. **13** is a perspective view of a base plate according to a modification of the above preferred embodiment of the present invention.

FIG. **14** is a perspective view of a base plate according to a modification of the above preferred embodiment of the present invention.

FIG. **15** is a perspective view of a base plate according to a modification of the above preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a sectional view of a disk drive apparatus **100** according to a preferred embodiment of the present invention.

The disk drive apparatus **100** is a hard disk drive. The disk drive apparatus **100** includes a housing **101**, a spindle motor **102**, a disk **103**, and an access portion **104**. The spindle motor **102**, the disk **103**, and the access portion **104** are housed in the housing **101**.

The spindle motor **102** is supported by a base plate **1** of the housing **101**. The base plate **1** will be described below. The spindle motor **102** is arranged to rotate the disk **103** while holding the disk **103**. The disk **103** is a medium on which information is recorded. The access portion **104** is arranged to make an approach to a surface of the disk **103** to magnetically perform at least one of reading of information recorded on the disk **103** and writing of information to the disk **103**.

The housing **101** includes the base plate **1** and a cover **2**. The base plate **1** includes an opening, and the cover **2** is fitted to the opening to define the housing **101** together with the base plate **1**. The base plate **1** and the cover **2** are combined so as to maintain airtightness of an interior space of the housing **101**. The interior space of the housing **101** is filled with a gas having a density lower than that of air, e.g., a helium gas. Note that the interior space of the housing **101** may alternatively be filled with a hydrogen gas, air, or the like.

FIG. **2** is a top view of the base plate **1**. FIG. **3** is a perspective view of the base plate **1**.

The base plate **1** includes a base body **10**. The base body **10** is a casting, and is defined by casting in a process of manufacturing the base plate **1**, which will be described below. The base body **10** includes a rectangular bottom plate portion **11** and a wall portion **12** arranged to extend from an edge portion of the bottom plate portion **11** perpendicularly to the bottom plate portion **11**. The edge portion of the bottom plate portion **11** is rectangular, and has long sides and short sides each of which is shorter than each of the long sides. The wall portion **12** includes long-side wall portions **121** each of which is arranged to extend from a separate one of the long sides of the edge portion of the bottom plate portion **11**, and short-side wall portions **122** each of which is arranged to extend from a separate one of the short sides of the edge portion of the bottom plate portion **11**.

The base body **10** has a space **13** surrounded by the bottom plate portion **11** and the wall portion **12**. The space **13** includes a motor accommodating portion **131** and an access portion accommodating portion **132**. The spindle motor **102** and the disk **103** are accommodated in the motor accommodating portion **131**. The access portion **104** is accommodated in the access portion accommodating portion **132**.

An outside surface of the wall portion **12** includes a parting line **14** extending along long sides and short sides thereof. The parting line **14** is a mark of a boundary between a pair of molds used at the time of the casting, which will be described below.

A surface of the base body **10** includes a coated surface **15**, which is indicated by hatching in FIG. **3**, and a worked surface **16**.

The coated surface **15** is a surface of the base body **10** which is covered with an electrodeposition coating film **34**. The electrodeposition coating film **34** is, for example, an insulating film made of an epoxy resin. The worked surface **16** is a surface of the base body **10** which is exposed from the electrodeposition coating film **34** and at least a portion of which is covered with an impregnant **36**. The impregnant **36** is, for example, an epoxy resin. The worked surface **16** is defined by covering a portion of the surface of the base body **10** which has a low metal density with the impregnant **36** at the time of the casting, which will be described below. Minute cavities in the worked surface **16** are sealed by being covered with the impregnant **36**. This results in an improvement in the airtightness of the interior space of the housing **101**, which is defined by the base plate **1** and the cover **2**.

The worked surface **16** is flat. The worked surface **16** is defined in an outside surface of one of the short-side wall portions **122**. In addition, the worked surface **16** is arranged to extend along the parting line **14** on an opposite side of the parting line **14** with respect to the bottom plate portion **11**. Further, the worked surface **16** is defined at a position to which a gate has been connected at the time of the casting, which will be described below. In other words, the worked surface **16** includes a gate position **124** to which the gate has been connected at the time of the casting, which will be described below. The gate position **124** is arranged to extend along the parting line **14** on the opposite side of the parting line **14** with respect to the bottom plate portion **11**.

FIG. **4** is a flowchart illustrating the process of manufacturing the base plate **1**. Each of FIGS. **5** and **6** is a vertical sectional view illustrating how the casting is performed.

First, as illustrated in FIG. **5**, opposed surfaces of a pair of molds **21** and **22** are brought into contact with each other to define a cavity **23** (step S**1**). The cavity **23** is arranged to have a shape corresponding to the shape of the base body **10**. In addition, once the pair of molds **21** and **22** are brought into contact with each other, a runner **24** extending along the opposed surfaces of the molds **21** and **22** is defined at the boundary between the molds **21** and **22**.

The runner **24** is a channel for a molten metal arranged to bring a space outside of the molds **21** and **22** into communication with the cavity **23**. The runner **24** includes, at a junction with the cavity **23**, a neck portion **24**A arranged to first gradually decrease and then increase in opening size with decreasing distance from the cavity **23**. Hereinafter, an opening portion of the runner **24** which is joined to the cavity **23** will be referred to as a gate **25**.

Next, the molten metal is poured into the defined cavity (step S2). The molten metal is, for example, molten aluminum. At step S2, the molten metal is poured into the cavity **23** through the runner **24** and the gate **25** as indicated by arrows in FIG. **5**. Although not shown in the figure, at the boundary between the molds **21** and **22**, a runner other than the runner **24** is defined along the opposed surfaces of the molds **21** and **22**. Once the molten metal is poured into the cavity **23**, the molten metal including gas or the like or air in the cavity **23** is pushed out of the cavity **23** into the runner that is not shown. This allows the molten metal having a high quality to spread throughout the cavity **23**. An opening at a junction between the runner that is not shown and the cavity **23** is an example of an “overflow” of the present application.

After the molten metal spreads throughout the cavity **23**, the molten metal is cooled and hardened (step S**3**). Once the molten metal is hardened, a base workpiece **30**, which will be described with reference to FIG. **6**, is defined. Thereafter, the pair of molds **21** and **22** are opened, and the base workpiece **30** is separated from the molds **21** and **22** (step S**4**).

FIG. **7** is a diagram illustrating a section of a portion of the base workpiece **30** separated from the molds **21** and **22** in an enlarged form.

The base workpiece **30** includes the base body **10** and a runner mark portion **31** positioned outside of the surface of the base body **10**. The runner mark portion **31** is a cast portion resulting from a portion of the molten metal staying in the runner **24** being hardened when the molten metal is hardened. The runner mark portion **31** includes a narrow portion **31**A defined by the neck portion **24**A.

In addition, a chill layer **32**, which is indicated by a broken line in FIG. **7**, is defined on a surface of the base workpiece **30**. The chill layer **32** is defined where the molten metal is in contact with the molds **21** and **22** and is hardened more quickly than in other places. The chill layer **32**, where the molten metal was hardened more quickly than in other places, contains fewer impurities and has a higher metal density than a remaining portion of the base workpiece **30**. Accordingly, the chill layer **32** defined on the surface of the base body **10** leads to an improvement in the airtightness of the interior space of the housing **101**.

Next, the runner mark portion **31** is removed from the base body **10** (step S**5**). At this time, the runner mark portion **31** is cut at the narrow portion **31**A to be removed from the base body **10**.

FIG. **8** is a diagram illustrating a section of a portion of the base body **10** with the runner mark portion **31** removed therefrom in an enlarged form. A projection **33** is defined in the surface of the base body **10** as a result of the runner mark portion **31** being cut at the narrow portion **31**A. The position of the projection **33** corresponds to the gate position **124**.

Thereafter, the surface of the base body **10** is subjected to electrodeposition coating (step S**6**). FIG. **9** is a diagram illustrating a section of a portion of the base body **10** after being subjected to the electrodeposition coating in an enlarged form. At this time, the base body **10** is, for example, immersed in a coating material, e.g., an epoxy resin, and an electric current is passed between the coating material and the base body **10** to adhere the coating material to the surface of the base body **10**. As a result, the electrodeposition coating film **34** is defined on the surface of the base body **10**.

Next, a portion of the surface of the base body **10** which is required to have a particularly high degree of accuracy, and which includes the projection **33**, is subjected to a cutting process (step S**7**). FIG. **10** is a diagram illustrating a section of a portion of the base body **10** after being subjected to the cutting process in an enlarged form. At step S**7**, a portion of the surface of the base body **10**, the portion including the position of the projection **33**, and a portion of the electrodeposition coating film **34** which is defined on that portion, are removed by the cutting process to define the flat worked surface **16**.

The chill layer **32** is defined on the surface of the base body **10**, which is in contact with the molds **21** and **22**. Therefore, a region **16**A from which the projection **33** has been cut off has no chill layer **32** defined thereon. That is, immediately after the cutting process, the worked surface **16** is a surface of the base body **10** which is exposed from the electrodeposition coating film **34** and which includes the region **16**A on which no chill layer **32** is defined.

Next, the surface of the base body **10**, with the worked surface **16** defined therein, is impregnated with the impregnant **36** (step S**8**). FIG. **11** is a diagram illustrating a section of a portion of the base body **10** after being impregnated with the impregnant **36** in an enlarged form. The impregnant **36** is, for example, an epoxy resin, and has a viscosity lower than that of the material of the electrodeposition coating film **34** before being hardened. At step S**8**, the base body **10** is immersed in the impregnant **36**.

Here, when the base body **10** is cast, minute cavities are defined in the base body **10**. The electrodeposition coating film **34** is provided on a remaining portion of the surface of the base body **10** excluding the worked surface **16**, that is, the coated surface **15** illustrated in FIG. **3**, and contributes to preventing air from penetrating the coated surface **15**, that is, contributes to maintaining the airtightness of the interior space of the housing **101**.

Meanwhile, the worked surface **16** includes the region **16**A on which no chill layer **32** is defined. Therefore, the worked surface **16** has a low metal density. Specifically, the worked surface **16** has minute cavities **35** as illustrated in FIG. **11**. These cavities **35** are defined when the base body **10** is cast. As a result of the immersion of the base body **10** in the impregnant **36** at step S**8**, the impregnant **36** infiltrates the cavities **35**. At this time, because the electrodeposition coating film **34** has been cut off from the worked surface **16**, the impregnant **36** is able to satisfactorily infiltrate the cavities **35** without the infiltration of the impregnant **36** into the cavities **35** being hindered by the electrodeposition coating film **34**. In addition, when any cavity exists in a region of the worked surface **16** other than the region **16**A, the impregnant **36** infiltrates that cavity as well. Thus, the impregnant **36** contributes to preventing air from penetrating the worked surface **16**, and maintaining the airtightness of the interior space of the housing **101**.

After the base body **10** is impregnated with the impregnant **36**, the base body **10** is cleaned and is dried by heating, so that manufacture of the base plate **1** is completed. At this time, the impregnant **36** which has permeated the electrodeposition coating film **34** is washed away when the base body **10** is cleaned, but if any minute cavity exists in the electrodeposition coating film **34**, the impregnant **36** will remain in that cavity.

As described above, when the surface of the base body **10** includes a portion having a low metal density, this portion is covered with the impregnant **36** in place of the electrodeposition coating film **34**. This leads to an improvement in the airtightness of the interior space of the housing **101**. In particular, the worked surface **16** can be satisfactorily impregnated with the impregnant **36** because the minute cavities **35** in the base body **10** are exposed to the outside at the worked surface **16**.

While a preferred embodiment of the present invention has been described above, it is to be understood that the present invention is not limited to the above-described preferred embodiment.

In the above-described preferred embodiment, the worked surface **16** is provided at a position including the gate position **124**. Note, however, that the worked surface **16** may also be provided at a position including the position of an overflow. The position of the overflow refers to a position to which the runner for removing air or the molten metal from the cavity **23** has been connected at the time of the casting.

Also note that the positions of the worked surface **16** and the gate position **124** are not limited to the positions according to the above-described preferred embodiment, but may be modified appropriately. For example, the worked surface **16** is defined in the outside surface of one of the short-side wall portions **122** in the present preferred embodiment, but may alternatively be defined in an outside surface of one of the long-side wall portions **121**. Also note that the number of gate positions **124** may be more than one. Also note that the worked surface **16** may be arranged to have any desirable size.

Each of FIGS. **12**, **13**, **14**, and **15** is a perspective view of a base plate according to a modification of the above-described preferred embodiment.

In the modification illustrated in FIG. **12**, the worked surface **16** is defined in the outside surface of one of the short-side wall portions **122**. In addition, the worked surface **61** is arranged to extend along the parting line **14** on both sides of the parting line **14**. The gate position **124** is arranged to extend along the parting line **14** on both sides of the parting line **14**.

In the modification illustrated in FIG. **13**, the worked surface **16** is defined in the outside surface of one of the short-side wall portions **122**. In addition, the worked surface **61** is arranged to extend along the parting line **14** on both sides of the parting line **14**. The gate position **124** is arranged to extend along the parting line **14** on the opposite side of the parting line **14** with respect to the bottom plate portion **11**.

In the modification illustrated in FIG. **14**, the worked surface **16** is defined in the outside surface of one of the short-side wall portions **122**. In addition, the worked surface **61** is arranged to extend along the parting line **14** on both sides of the parting line **14**. The gate position **124** is arranged to extend along the parting line **14** on a side of the parting line **14** on which the bottom plate portion **11** lies.

In the modification illustrated in FIG. **15**, the worked surface **16** is defined in the outside surface of one of the short-side wall portions **122**. In addition, the worked surface **61** is arranged to extend along the parting line **14** on the side of the parting line **14** on which the bottom plate portion **11** lies. The gate position **124** is arranged to extend along the parting line **14** on the side of the parting line **14** on which the bottom plate portion **11** lies.

While a preferred embodiment of the present invention and several modifications thereof have been described above, it should be noted that features of the above-described preferred embodiment and the modifications thereof may be combined appropriately as long as no conflict arises.

Preferred embodiments of the present invention are applicable to, for example, base plates, hard disk drives, and methods of manufacturing the base plates.

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 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.

What is claimed is:

**1**. A base plate arranged to define a portion of a housing of a hard disk drive, the base plate comprising:
- a base body defined by casting;
- an electrodeposition coating film arranged to cover an external surface of the base body; and
- an impregnant; wherein
- the external surface of the base body includes:
  - a coated surface covered with the electrodeposition coating film; and
  - a worked surface exposed from and encircled by the electrodeposition coating film, the worked surface including at least one minute cavity defined therein; and
- the impregnant is arranged to cover at least a portion of the worked surface, and infiltrates into the at least one minute cavity.

**2**. The base plate according to claim **1**, wherein the worked surface includes at least one of a gate position to which a gate has been connected at a time of the casting, and a position of an overflow.

**3**. The base plate according to claim **1**, wherein
- the base body includes:
- a rectangular bottom plate portion; and
- a wall portion arranged to extend from an edge portion of the bottom plate portion perpendicularly to the bottom plate portion; and
- the worked surface is defined in an outside surface of the wall portion.

**4**. The base plate according to claim **3**, wherein
- the base body further includes a parting line being a mark of a boundary between a pair of molds used at the time of the casting; and
- the worked surface is arranged to extend along the parting line on an opposite side of the parting line with respect to the bottom plate portion.

**5**. The base plate according to claim **4**, wherein
- a material of the electrodeposition coating film is a resin; and
- the impregnant is a resin having a viscosity lower than that of the material of the electrodeposition coating film before being hardened.

**6**. The base plate according to claim **5**, wherein each of the material of the electrodeposition coating film and the impregnant is an epoxy resin.

**7**. A hard disk drive comprising:
- the base plate of claim **1**;
- a cover arranged to define the housing together with the base plate;
- a spindle motor supported by the base plate; and
- a disk caused by the spindle motor to rotate in the housing.

**8**. The hard disk drive according to claim **7**, wherein an interior space of the housing is filled with a gas having a density lower than that of air.

**9**. A base plate arranged to define a portion of a housing of a hard disk drive, the base plate comprising:
- a base body defined by casting;
- an electrodeposition coating film arranged to cover a surface of the base body; and
- an impregnant; wherein
- the surface of the base body includes:
  - a coated surface covered with the electrodeposition coating film; and
  - a flat worked surface exposed from the electrodeposition coating film; and
- the impregnant is arranged to cover at least a portion of the worked surface;
- the base body includes:
  - a rectangular bottom plate portion; and
  - a wall portion arranged to extend from an edge portion of the bottom plate portion perpendicularly to the bottom plate portion; and
- the worked surface is defined in an outside surface of the wall portion;
- the edge portion of the bottom plate portion is rectangular, and has long sides and short sides;
- the wall portion includes:
  - long-side wall portions each of which is arranged to extend from a separate one of the long sides; and
  - short-side wall portions each of which is arranged to extend from a separate one of the short sides; and

the worked surface is defined in an outside surface of one of the short-side wall portions.

**10**. A method of manufacturing a base plate arranged to define a portion of a housing of a hard disk drive, the method comprising the steps of:

a) defining a base body by casting;

b) defining an electrodeposition coating film on a surface of the base body;

c) removing a portion of the surface of the base body and a portion of the electrodeposition coating film which is defined on that portion by a cutting process to define a worked surface encircled by the electrodeposition coating film, the worked surface including at least one minute cavity defined therein; and

d) impregnating at least a portion of the worked surface with an impregnant such that the impregnant infiltrates into the at least one minute cavity.

**11**. The method according to claim **10**, wherein, in step c), of the surface of the base body, a projection defined at a gate of a mold at a time of the casting is removed by the cutting process.

**12**. The method according to claim **11**, further comprising the step of e), between steps a) and b), removing a runner mark portion defined in a runner of the mold at the time of the casting from the base body; wherein

the runner mark portion includes a narrow portion outside of the surface of the base body; and

in step e), the narrow portion is cut to define the projection.

* * * * *

# Exhibit
# E

US010460767B2

(12) **United States Patent**
**Yoneda et al.**

(10) **Patent No.: US 10,460,767 B2**
(45) **Date of Patent: Oct. 29, 2019**

(54) **BASE MEMBER INCLUDING INFORMATION MARK AND INSULATING COATING LAYER, AND DISK DRIVE APPARATUS INCLUDING THE SAME**

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(73) Assignee: **NIDEC CORPORATION**, Kyoto (JP)

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(30) **Foreign Application Priority Data**

Nov. 8, 2017 (JP) ................................ 2017-215333

(51) **Int. Cl.**

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| ***G11B 23/03*** | (2006.01) |
| ***G11B 23/38*** | (2006.01) |
| ***G11B 25/04*** | (2006.01) |

(52) **U.S. Cl.**
CPC ........ ***G11B 33/022*** (2013.01); ***G11B 23/0326*** (2013.01); ***G11B 23/38*** (2013.01); ***G11B 25/043*** (2013.01)

(58) **Field of Classification Search**
CPC ... G11B 33/022; G11B 23/0326; G11B 23/38; G11B 25/043
See application file for complete search history.

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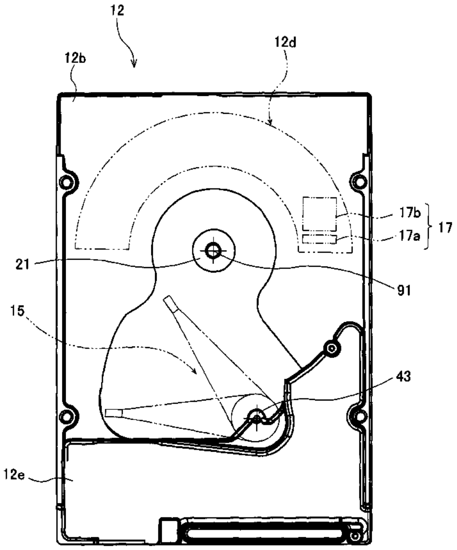
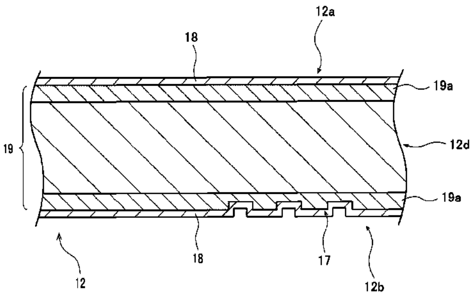
(57) **ABSTRACT**

A base member is structured to define a portion of a casing in which a gas with a density lower than that of air is to be sealed and to support a motor to be housed in the casing. The base member includes a base body made of a cast material, an information mark, and an insulating coating layer. The information mark includes casting information and is located on a portion of a surface of the base body. The insulating coating layer is defined on the surface of the base body and covers the information mark.

**10 Claims, 4 Drawing Sheets**





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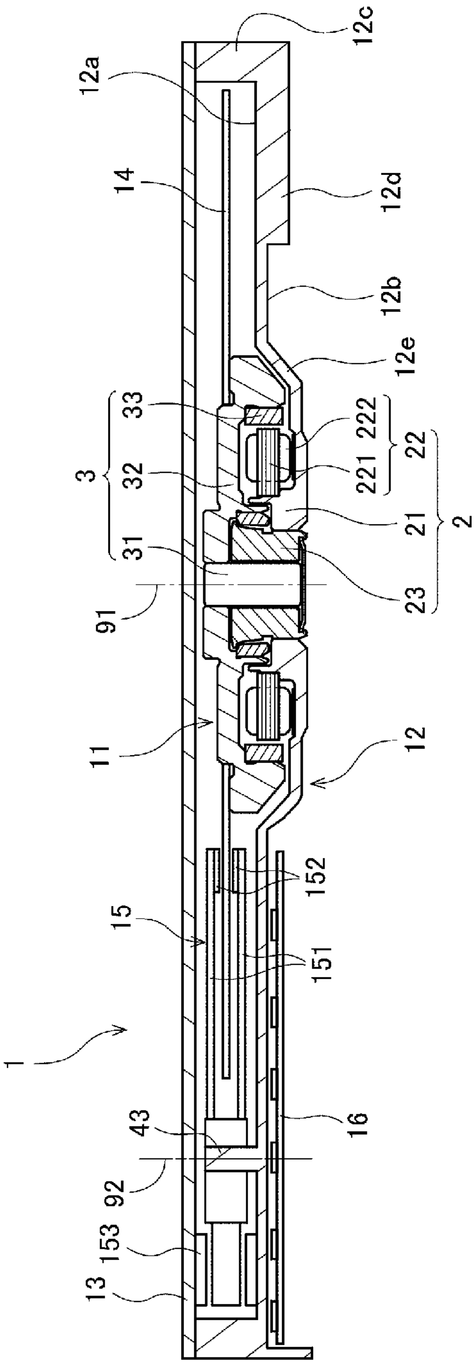
12c
12a
14
12d
12b
12e
3
33
32
31
222
221
22
21
2
23
91
11
12
152
15
151
1
16
43
92
153
13

Fig. 1

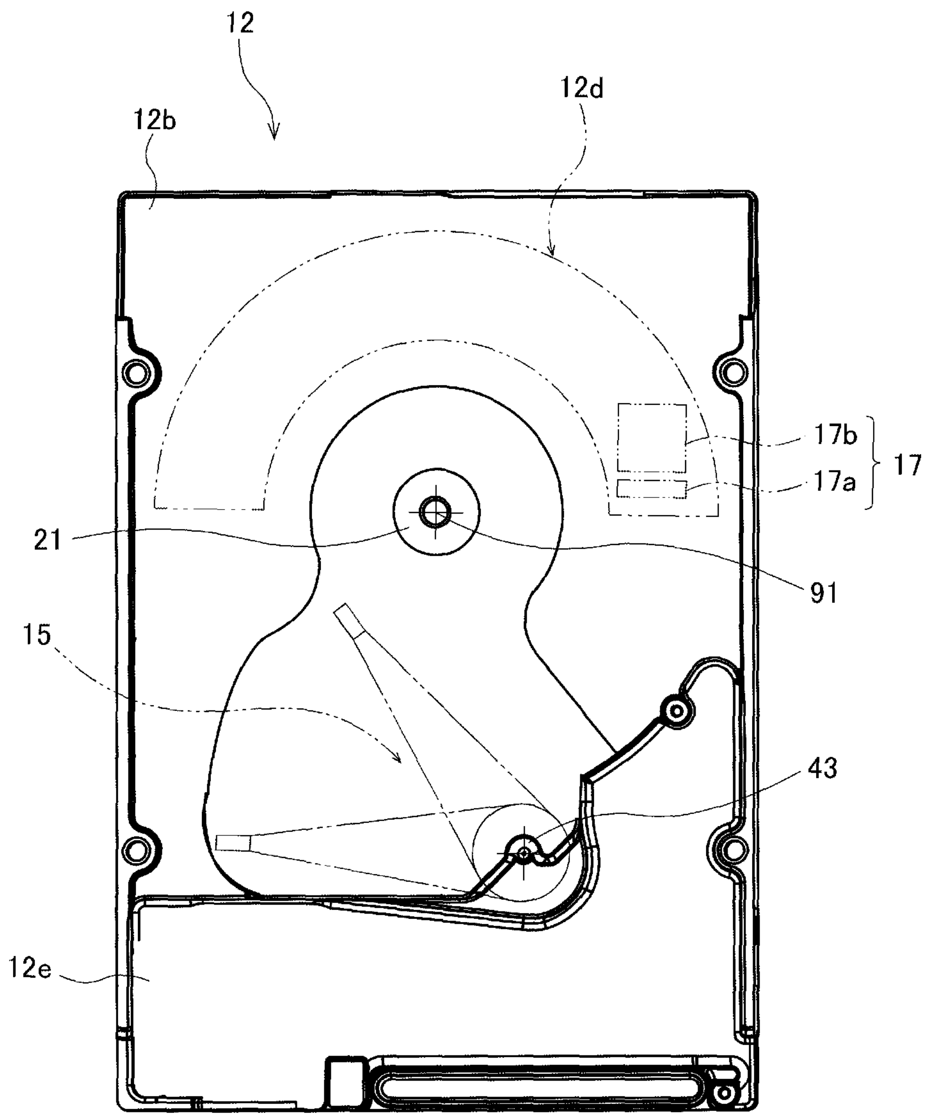

Fig. 2

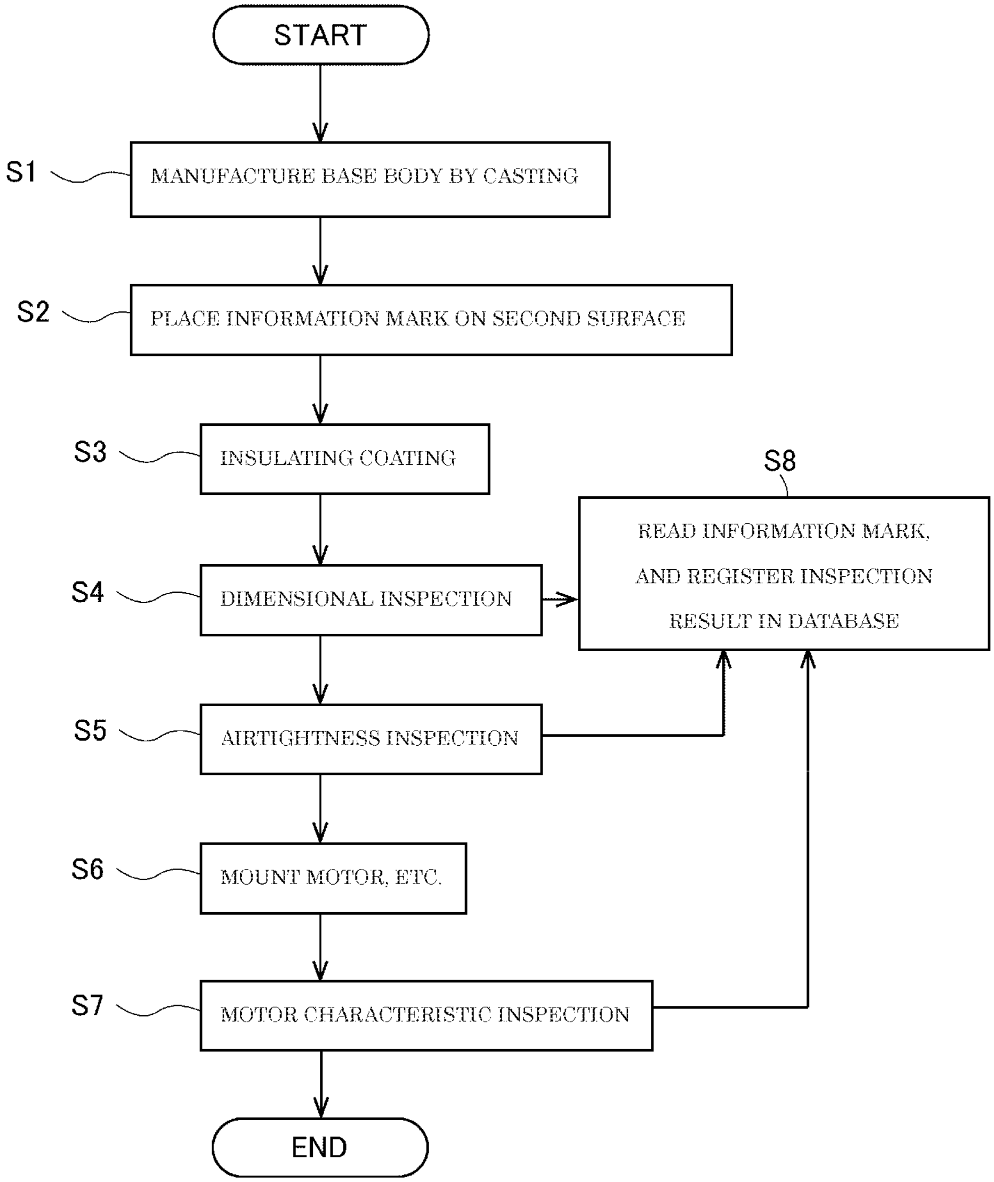
START
S1
MANUFACTURE BASE BODY BY CASTING
S2
PLACE INFORMATION MARK ON SECOND SURFACE
S3
INSULATING COATING
S4
DIMENSIONAL INSPECTION
S5
AIRTIGHTNESS INSPECTION
S6
MOUNT MOTOR, ETC.
S7
MOTOR CHARACTERISTIC INSPECTION
S8
READ INFORMATION MARK, AND REGISTER INSPECTION RESULT IN DATABASE
END

Fig. 3

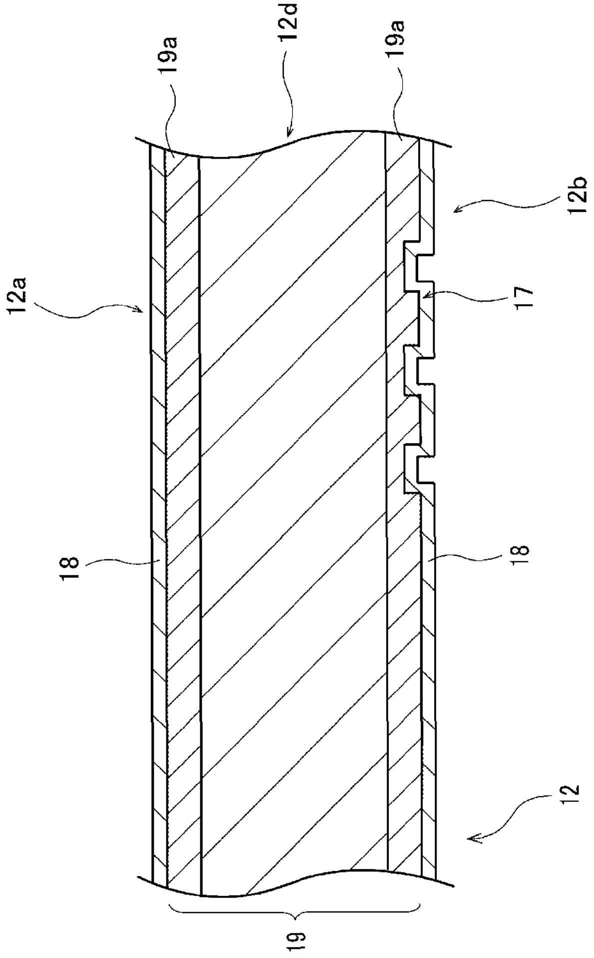

Fig. 4

# BASE MEMBER INCLUDING INFORMATION MARK AND INSULATING COATING LAYER, AND DISK DRIVE APPARATUS INCLUDING THE SAME

## CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority to Japanese Patent Application No. 2017-215333 filed on Nov. 8, 2017. The entire contents of this application are hereby incorporated herein by reference.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to a base member, and a disk drive apparatus including the same.

### 2. Description of the Related Art

A base member including an inner surface on which a motor is to be installed, and which defines a portion of a casing in which the motor is to be housed, has been known. JP-A 2009-211740 describes a base plate, which is a base member of this type.

The base plate described in JP-A 2009-211740 defines a portion of a casing of a hard disk drive. A spindle motor, an actuator, and so on, which are housed in the casing, are installed on the base plate. The base plate is obtained by, for example, precision machining a blank obtained by an aluminum die casting process using a machining center or the like.

In more detail, in a process of manufacturing the base plate described in JP-A 2009-211740, the blank is molded by casting, and then, the blank is provided with an insulating coating, and is subjected to inner surface processing, outer surface processing, etc., to complete the base plate. After manufacture of the base plates, nonconforming products are eliminated, and thereafter, two-dimensional bar codes representing manufacturing information are written on conforming products. In a process of producing a disk drive apparatus including the base plate described in JP-A 2009-211740, after a pre-shipment inspection, a production lot number, a date, processing machine information, etc., which are read from the two-dimensional bar code representing the manufacturing information, are finally checked and are registered in a production management database. This arrangement presumably allows management of the production of individual base plates.

Here, it is difficult to determine whether a casting process has a problem immediately after the blank, which is to define a main body of the base plate, is manufactured by the casting process. It is quite possible that a problem of the casting process will be found as a result of a dimensional inspection or an airtightness inspection performed after the inner surface processing and the outer surface processing in subsequent stages, for example. In particular, in the case where a gas having a low density, such as, for example, helium, is sealed in the casing defined by the base plate, airtightness should be realized with high accuracy, and it is desirable that any possible improvement in the casting process would be quickly known.

However, in the case of the base plate described in JP-A 2009-211740, a problem in the casting process might be noticed by a manufacturer only at a later time. Moreover, even if a problem in the casting process is noticed early, it will still be difficult to identify a cause for the abnormality among a number of casting conditions. This may result in a reduced yield, and an increased cost of scrapping nonconforming items.

## SUMMARY OF THE INVENTION

In view of the above circumstances, preferred embodiments of the present invention achieve an improved yield and a reduced cost of scrapping nonconforming items.

According to a preferred embodiment of the present invention, a base member is structured to define a portion of a casing in which a gas with a density lower than that of air is to be sealed and to support a motor to be housed in the casing. The base member includes a base body made of a cast material, an information mark, and an insulating coating layer. The information mark includes casting information, and is located on a portion of a surface of the base body. The insulating coating layer is defined on the surface of the base body, and covers the information mark.

Preferred embodiments of the present invention achieve an improved yield and a reduced cost of scrapping nonconforming items.

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 with reference to the attached drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view of a disk drive apparatus including a base member according to a preferred embodiment of the present invention.

FIG. **2** is a diagram illustrating a rear surface of a base member according to a preferred embodiment of the present invention.

FIG. **3** is a diagram illustrating a procedure for manufacturing a disk drive apparatus according to a preferred embodiment of the present invention.

FIG. **4** is a diagram illustrating a section of a portion of an increased thickness portion of a base member according to a preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments of the present invention will be described with reference to the accompanying drawings. Note that, in the description of the present invention, a direction parallel to a rotation axis of a disk is sometimes referred to by the term “axial direction”, “axial”, or “axially”, that directions perpendicular to the rotation axis of the disk are each sometimes referred to by the term “radial direction”, “radial”, or “radially”, and that a direction along a circular arc centered on the rotation axis of the disk is sometimes referred to by the term “circumferential direction”, “circumferential”, or “circumferentially”. Also note that, in the description of the present invention, the shape of each member or portion and relative positions of different members or portions will sometimes be described assuming that an axial direction is a vertical direction, and a side on which a cover is arranged with respect to a base member is an upper side. It should be noted, however, that the above definitions of the vertical direction and the upper and lower sides are not meant to restrict in any way the orientation of a base member or a disk drive apparatus according to any preferred embodiment of the present invention when in use.

Also note that the term “parallel” as used herein includes both “parallel” and “substantially parallel”. Also note that the term “perpendicular” as used herein includes both “perpendicular” and “substantially perpendicular”.

Hereinafter, the overall structure of a disk drive apparatus **1**, which includes a base member **12** according to a preferred embodiment of the present invention, will be described with reference to FIG. **1**. FIG. **1** is a vertical sectional view of the disk drive apparatus **1** according to the present preferred embodiment.

The disk drive apparatus **1** according to the present preferred embodiment is an apparatus arranged to perform reading and writing of information from or to a disk-shaped magnetic disk (i.e., a disk) **14** including a circular hole in a center thereof while rotating the magnetic disk **14**. Referring to FIG. **1**, the disk drive apparatus **1** includes, as primary components thereof, a spindle motor (i.e., a motor) **11**, the base member **12**, a cover **13**, the magnetic disk **14**, an access portion **15**, and a circuit board **16**.

The spindle motor **11** is a device arranged to rotate the magnetic disk **14** about a first axis **91** while supporting the magnetic disk **14**. The spindle motor **11** includes a stationary portion **2** and a rotating portion **3**. The stationary portion **2** is arranged to be stationary relative to both the base member **12** and the cover **13**. A rotating magnetic field is generated in the stationary portion **2**. The rotating portion **3** is supported to be rotatable with respect to the stationary portion **2**. The rotating portion **3** is arranged to rotate through interaction between magnetic flux of the rotating portion **3** and magnetic flux of the stationary portion **2**.

The stationary portion **2** includes a stator support portion **21**, a stator **22**, and a bearing unit **23**. The stator support portion **21** is arranged to extend in an axial direction to assume a cylindrical shape around the first axis **91**. The stator support portion **21** defines a portion of the spindle motor **11** and a portion of the base member **12**. The stator **22** includes a stator core **221**, which is a magnetic body, and a plurality of coils **222**. The stator core **221** is fixed to an outer circumferential surface of the stator support portion **21**. The stator core **221** includes a plurality of teeth arranged to project radially outward. Each of the coils **222** is defined by a conducting wire wound around a separate one of the teeth. The bearing unit **23** is fixed to an inner circumferential surface of the stator support portion **21**. The bearing unit **23** is arranged to rotatably support a shaft **31**, which is included in the rotating portion **3**. A fluid dynamic bearing mechanism, for example, is used as the bearing unit **23**.

The rotating portion **3** includes the shaft **31**, a hub **32**, and a rotor magnet **33**. The shaft **31** is a columnar member arranged to extend along the first axis **91**. A lower end portion of the shaft **31** is housed inside of the bearing unit **23**. The hub **32** is arranged to extend radially outward from a peripheral portion of an upper end portion of the shaft **31**. The magnetic disk **14** is fixed to the hub **32** while being oriented perpendicular to the first axis **91**. The rotor magnet **33** is fixed to the hub **32** radially outside of the stator **22**. The rotor magnet **33** is arranged radially opposite to the teeth of the stator core **221** with a gap therebetween. A magnet in the shape of a circular ring, for example, is used as the rotor magnet **33**. An inner circumferential surface of the rotor magnet **33** includes north and south poles arranged to alternate with each other in a circumferential direction.

Once electric drive currents are supplied to the coils **222** in the spindle motor **11** having the above-described structure, magnetic flux is generated around each of the teeth of the stator core **221**. Then, a circumferential torque is produced by interaction between the magnetic flux of the teeth and magnetic flux of the rotor magnet **33**, so that the rotating portion **3** is caused to rotate about the first axis **91** with respect to the stationary portion **2**. The rotation of the rotating portion **3** causes the magnetic disk **14**, which is fixed to the hub **32**, to rotate about the first axis **91** along with the hub **32**.

The base member **12** illustrated in FIG. **1** is a substantially plate-shaped member arranged to support the spindle motor **11** and the access portion **15**. The base member **12** defines a portion of a casing arranged to house the spindle motor **11** and the access portion **15**. The base member **12** is manufactured by subjecting a base body **19** (see FIG. **4**, which will be described below), which is molded by pouring a molten metal into a mold and hardening the molten metal, to appropriate processes. The detailed structure of the base member **12** and a procedure for manufacturing the base member **12** will be described below.

The cover **13** is supported by an upper end surface of a side wall portion of the base member **12**. An upper opening of the base member **12** is closed by the cover **13**. The base member **12** and the cover **13** are fixed to each other through, for example, screwing, so that an enclosed space is defined therein. The casing arranged to house the spindle motor **11** and the access portion **15** is defined by the base member **12** and the cover **13**. A gas (in the present preferred embodiment, helium) having a density lower than that of air is sealed in the casing according to the present preferred embodiment. This contributes to keeping resistance against rotation of the magnetic disk **14** low.

The access portion **15** includes arms **151**, heads **152** arranged at tips of the arms **151**, and an actuator mechanism **153**. Each arm **151** is attached to a pivot spot **43** of the base member **12** through a bearing. The actuator mechanism **153** is a mechanism to cause each of the arms **151** and the heads **152** to swing. Once the actuator mechanism **153** is driven, the arm **151** is caused to swing on a second axis **92**. The associated head **152** is thus arranged to move along a recording surface (i.e., a recording layer including a metal film) of the magnetic disk **14**. The heads **152** are arranged opposite to an upper surface and a lower surface of the magnetic disk **14**, and are arranged to perform reading and writing of information from or to the magnetic disk **14**.

Note that each head **152** may alternatively be arranged to perform only one of the reading and the writing of information from or to the magnetic disk **14**. Also note that the disk drive apparatus **1** may alternatively be arranged to include two or more magnetic disks **14**. Also note that the disk drive apparatus **1** may alternatively be an apparatus arranged to rotate an optical disk.

The circuit board **16** is fixed to a lower surface of a bottom plate portion of the base member **12**. A so-called rigid board, which has a small degree of flexibility, for example, is used as the circuit board **16**. An electrical circuit needed for an operation of the disk drive apparatus **1** is mounted on the circuit board **16**. The electrical circuit may be a circuit for an operation of the spindle motor **11**, a circuit for an operation of the actuator mechanism **153**, or a circuit for detecting various signals. A plurality of electronic components used to form the electrical circuit are mounted on an upper surface of the circuit board **16**. The circuit board **16** is connected to the coils **222** of the spindle motor **11** through a so-called flexible printed circuit board, which is highly flexible.

A more specific structure of the base member **12** according to the present preferred embodiment will now be described below with reference to FIGS. **1** and **2**. FIG. **2** is a diagram illustrating a rear surface (i.e., a second surface) **12***b* of the base member **12**.

A cylindrically projecting portion of the stator support portion **21** and the pivot spot **43** are defined at an inner surface (i.e., a first surface) **12***a* of the base member **12**. In other words, projecting portions to allow installation of the spindle motor **11** and the access portion **15** are defined at the inner surface **12***a*, which is a surface of the base member **12** on a side on which the spindle motor **11** is arranged. In addition, at the inner surface **12***a* of the base member **12**, a disk shroud **12***c* is defined along an outer circumference of the magnetic disk **14**. The disk shroud **12***c* is defined radially outside of an outer circumferential portion of the magnetic disk **14**, and is arranged to surround the outer circumferential portion of the magnetic disk **14**.

In addition, the base member **12** includes an increased thickness portion **12***d* having a relatively large axial thickness, and a decreased thickness portion **12***e* having a relatively small axial thickness. Referring to FIG. **1**, in an outer surface (i.e., the second surface) **12***b* of the base member **12**, a shoulder is defined between the increased thickness portion **12***d* and the decreased thickness portion **12***e*. Referring to FIGS. **1** and **2**, the increased thickness portion **12***d* lies inside of the disk shroud **12***c* when viewed in the axial direction.

As represented by a two-dot chain line in FIG. **2**, the increased thickness portion **12***d* is defined in the shape of a circular arc radially outside of a region centered on the first axis **91** and having a radius equal to a half of a distance from the first axis **91** to the outer circumference of the magnetic disk **14** when viewed in the axial direction. Viewed from another point of view, the increased thickness portion **12***d* is defined in the shape of a circular arc in a region extending from an inner circumferential portion of the recording layer, including the metal film, of the magnetic disk **14** to the outer circumferential portion of the magnetic disk **14** when viewed in the axial direction. Thus, in the base member **12** according to the present preferred embodiment, the region of the increased thickness portion **12***d* is arranged to be relatively narrow to prevent a blowhole from being defined in a thick portion of the base member **12**. This contributes to maintaining the sealing performance of the base member **12** at a high level.

Referring to FIG. **2**, an information mark **17** including casting information is placed on a portion of a portion of the rear surface of the base member **12** which corresponds to the increased thickness portion **12***d*. In the present preferred embodiment, the information mark **17** includes a numeric string portion **17***a*, which is visually readable by a human, and a two-dimensional image portion **17***b*, which is readable by a reading device.

The numeric string portion **17***a* illustrated in FIG. **2** is, for example, a string of numbers representing a casting machine number for identifying a casting machine used to mold the base body **19** of the base member **12**, and a casting date and time for identifying the date and time of the casting of the base body **19**. More specifically, the first two digits and the remaining, last six digits of the numeric string portion **17***a* may represent the casting machine number and the casting date and time, respectively, for example.

The two-dimensional image portion **17***b* illustrated in FIG. includes information of a minimum injection speed, a maximum injection speed, and a casting pressure, in addition to information of the casting machine number of the casting machine used to mold the base body **19** of the base member **12**, and the casting date and time. The minimum injection speed is the lowest speed at which the molten metal is poured into the mold. The maximum injection speed is the highest speed at which the molten metal is poured into the mold. The casting pressure is a pressure applied when the molten metal is forced into the mold. The two-dimensional image portion **17***b* according to the present preferred embodiment may be a two-dimensional bar code, for example.

As will be described in detail below, the information mark **17** is placed on the base body **19** by being engraved on the rear surface of the base body **19** using a laser marker after the molding of the base body **19** and before an insulating coating layer **18** is defined on a surface of the base body **19**. Accordingly, the information mark **17** is covered by the insulating coating layer **18** (see FIG. **4**).

The information mark **17** having the above-described structure is read at various times after the base body **19** is molded by casting and is provided with the insulating coating. Examples of such various times include times of various production processes, and a time when some abnormality has occurred in any stage after provision to the market. The readability of the casting information from the information mark **17** makes it possible to consider at various times whether a cause for an abnormality can be found in a casting process performed in an earlier stage.

Hereinafter, the procedure for manufacturing the base member **12** according to the present preferred embodiment, and, by extension, a procedure for manufacturing the disk drive apparatus **1**, will be described below with reference to FIGS. **3** and **4**. FIG. **3** is a flowchart illustrating the procedure for manufacturing the disk drive apparatus **1** including the base member **12**. FIG. **4** is a sectional view illustrating a portion of the molded base body **19** with the information mark **17** placed thereon and provided with the insulating coating.

First, the base body **19** is manufactured as a cast (step S**1**). Specifically, the molten metal, which is a material of the base body **19**, is poured into a cavity defined by a pair of molds. Aluminum or an aluminum alloy, for example, is used as the molten metal. Then, the molten metal is hardened in the molds. As a result, the base body **19** is defined. Thereafter, the molds are opened, and the base body **19** is separated from the molds.

At the time of this casting, for each individual base body **19**, various casting parameters are recorded in a production management database, with the various casting parameters being associated with the casting machine number for identifying the casting machine used for the casting, and the casting date and time for identifying the date and time of the casting. Here, the casting parameters include about 40 types of parameters concerning casting conditions, such as, for example, a temperature at the time of the casting, in addition to the minimum injection speed, the maximum injection speed, and the casting pressure mentioned above. At step S**1**, a chill layer **19***a* (see FIG. **4**) is defined at a portion which is in contact with surfaces of the molds when the molten metal is poured into the molds. In other words, the chill layer **19***a* is defined at a surface portion which is quickly cooled because of being in contact with the molds at the time of the casting.

After step S**1**, the information mark **17** is engraved on the rear surface of the base body **19** using the laser marker (step S**2**). Specifically, portions of the aforementioned chill layer **19***a* are shaved off by processing the rear surface of the base body **19** with the laser, so that the information mark **17** as illustrated in FIGS. **2** and **4** is engraved.

After step S2, the insulating coating layer **18** is defined on an outermost layer of the base body **19** (step S3). An epoxy resin, for example, is used as a material of the insulating coating layer **18**. At step S3, for example, the base body **19** is immersed in the epoxy resin in a liquid phase, and an electric current is passed between the epoxy resin and the base body **19**. As a result, the epoxy resin is adhered to the surface of the base body **19**. Thus, the insulating coating layer **18** is defined on the surface of the base body **19**. At this time, the information mark **17**, which was engraved at step S2, is covered by the insulating coating layer (see FIG. **4**).

After step S3, front and rear surfaces of the base body **19** are subjected to processes. As a result, the structure of details, such as, for example, a recess(es) and a projection(s) for installing the spindle motor **11** and the access portion **15** on the inner surface **12***a* of the base member **12** (the base body **19**), and a recess(es) and a projection(s) for attaching the circuit board **16** to the rear surface **12***b* of the base member **12**, is defined. In addition, other processes are performed, including processing of a mating surface of the base member **12** to enable the base member **12** to be fixed to the cover **13** so as to ensure airtightness.

Next, a dimensional inspection of the base member **12** is performed (step S4). Here, for example, only when a dimensional error is less than a specified value, a result of the dimensional inspection of the base member **12** is determined to be "passed", and control proceeds to the next step S5. At this time, the information mark **17** placed on the base member **12** is read through visual inspection and the reading device. Then, the result of the above dimensional inspection is registered in the production management database, with the casting information represented by the information mark **17** being associated with the result (step S8).

Meanwhile, when the dimensional error is equal to or higher than the specified value, the result of the dimensional inspection of the base member **12** is determined to be "failed", and control does not proceed to the next step S5. Even in this case, the information mark **17** placed on the base member **12** is read through visual inspection and the reading device. Then, the result of the above dimensional inspection is registered in the production management database, with the casting information represented by the information mark **17** being associated with the result (step S8).

If, as a result of the reading of the information mark **17** at step S8, it is found necessary to refer to more casting parameters, in addition to the casting parameters included in the two-dimensional image portion **17***b* of the information mark **17**, the aforementioned production management database is consulted. Thus, other casting information associated with the information of the casting machine number and the casting date and time of this base member **12** (the base body **19**) can be acquired.

Thus, it is possible to consider whether a cause for an abnormality can be found in the casting process performed at step S1, when the result of the dimensional inspection has been determined to be "failed". In more detail, for example, it is possible to accumulate information of the casting parameters of a plurality of cases for which the result of the dimensional inspection has been determined to be "failed", and to consider whether there is any casting parameter common to the cases. In addition, it is possible to compare the casting parameters of a plurality of cases for which the result of the dimensional inspection has been determined to be "passed" with the casting parameters of a plurality of cases for which the result of the dimensional inspection has been determined to be "failed" to find differences therebetween, and thus narrow down the casting parameters that may be a cause for an abnormality. If a casting parameter which is a cause for an abnormality is successfully identified, this casting parameter can be checked and modified as necessary to reduce the likelihood that the same cause will produce a "failed" result of the dimensional inspection in subsequent manufacturing processes.

If the result of the dimensional inspection at step S4 is determined to be "passed", an airtightness inspection of the base member **12** is next performed (step S5). Here, only when it has been found that airtightness of an interior of the base member **12** and the cover **13** fixed to each other will be maintained with high accuracy, a result of the airtightness inspection of the base member **12** is determined to be "passed", and control proceeds to the next step S6. At this time, the information mark **17** placed on the base member **12** is read. Then, the result of the above airtightness inspection is registered in the production management database, with the casting information represented by the information mark **17** being associated with the result (step S8).

Meanwhile, when it has been found that the airtightness of the interior of the base member **12** and the cover **13** fixed to each other will not be maintained with high accuracy, the result of the airtightness inspection is determined to be "failed", and control does not proceed to the next step S6. Even in this case, the information mark **17** placed on the base member **12** is read. Then, the result of the above airtightness inspection is registered in the production management database, with the casting information represented by the information mark **17** being associated with the result (step S8).

As described above, after the airtightness inspection, the casting parameters contained in the information mark **17** are acquired. In addition, the aforementioned production management database is consulted as necessary. Thus, it is possible to consider whether a cause for an abnormality can be found in the casting process performed at step S1, when the result of the airtightness inspection has been determined to be "failed". In addition, in accordance with a result of this consideration, the casting parameters can be checked and modified as necessary to reduce the likelihood that the same cause will produce a "failed" result of the airtightness inspection in subsequent manufacturing processes.

If the result of the airtightness inspection at step S5 is determined to be "passed", the spindle motor **11** is next mounted on the base member **12** (step S6). Then, the spindle motor **11** is experimentally driven, with the spindle motor **11** and so on installed on the base member **12**, to perform a motor characteristic inspection (step S7). Only when motor characteristics during the experimental operation of the spindle motor **11** have been found to be satisfactory, a result of the motor characteristic inspection is determined to be "passed", and control proceeds to a preparation for shipment. At this time, the information mark **17** placed on the base member **12** is read. Then, the result of the above motor characteristic inspection is registered in the production management database, with the casting information represented by the information mark **17** being associated with the result (step S8).

If the result of the motor characteristic inspection is determined to be "passed", an information mark (not shown) which is a two-dimensional image representing a serial number and manufacturing information of the spindle motor **11**, information of the result of the above motor characteristic inspection, etc., is, in the form of a sticker, for example, stuck onto an outermost layer of the rear surface **12***b* of the base member **12**.

If all the above inspections (steps S**4**, S**5**, and S**7**) have been passed, and assembly has been completed by the above-described procedure, an assembly including the spindle motor **11** and the base member **12** is shipped as a product.

Meanwhile, if the result of the motor characteristic inspection is determined to be “failed”, control does not proceed to the preparation for shipment. Even in this case, the information mark **17** placed on the base member **12** is read. Then, the result of the above motor characteristic inspection is registered in the production management database, with the casting information represented by the information mark **17** being associated with the result (step S**8**).

As described above, after the motor characteristic inspection, the casting parameters contained in the information mark **17** are acquired. In addition, the aforementioned production management database is consulted as necessary. Thus, it is possible to consider whether a cause for an abnormality can be found in the casting process performed at step S**1**, when the result of the motor characteristic inspection has been determined to be “failed”. In addition, in accordance with a result of this consideration, the casting conditions (i.e., the casting parameters) can be modified as appropriate to achieve an improvement in quality of the base member **12**. This will lead to an improved product yield.

In addition, although not shown in the figures, if some abnormality occurs after the aforementioned assembly is shipped as a product, the information mark **17** is read in a manner similar to that of the above-described step S**8**, and the casting parameters registered in the production management database are referred to as necessary. Thus, it is possible to consider whether a cause for the abnormality can be found in the casting process performed at an earlier step (i.e., step S**1**) even after the provision to the market.

It should be noted here that it is generally difficult to determine whether the casting process had any problem immediately after a cast, such as the base body **19**, is molded using a mold. However, this is not the case with the manufacturing procedure according to the present preferred embodiment. In the case of the manufacturing process according to the present preferred embodiment, if some abnormality occurs, for example, after various production processes (e.g., after the processing of the inner surface and the outer surface, after the airtightness inspection, after the mounting of the spindle motor **11**, etc.) or after the provision to the market, after the base body **19** molded by casting is provided with the insulating coating, it is possible to consider whether a cause for the abnormality can be found in the casting process performed at an earlier step by acquiring the casting information from the information mark **17**. In addition, it is possible to feed the result of this consideration back to the casting process, and, for example, modify the casting conditions (i.e., the casting parameters) as appropriate to achieve an improvement in the quality of the base member **12**.

In particular, in the case where the gas (in the present preferred embodiment, helium) having a density lower than that of air is sealed in the casing defined by the base member **12** and the cover **13**, it is necessary to maintain a high level of airtightness. Associating the result of the airtightness inspection (step S**5**) with the casting information after the airtightness inspection, for example, makes it possible to identify a casting parameter that may be a cause for poor airtightness. This will lead to an improved yield, and a reduction in a cost of scrapping nonconforming items.

In addition, in the present preferred embodiment, the information mark **17** is placed on the surface of the base body **19** before the insulating coating layer **18** is defined after the casting of the base body **19**. Accordingly, an information mark reflecting the casting information can be easily placed on each individual base body **19**.

Further, the numeric string portion **17***a* of the information mark **17** according to the present preferred embodiment includes the information of the casting machine number and the casting date and time. Accordingly, when some abnormality has occurred, it is possible to read the information of the casting machine number and the casting date and time of the base member **12** from the information mark **17** thereof. Additionally, it is possible to acquire other casting information associated with the information of the casting machine number and the casting date and time by consulting the production management database for the base member **12**, which is prepared separately, for example. Thus, it is possible to identify a casting parameter that may be a cause for the abnormality.

In addition, the information mark **17** is placed on the rear surface **12***b* of the base member **12** according to the present preferred embodiment. This makes it possible to easily read the information mark **17** from outside the casing to acquire the casting information, even after the spindle motor **11**, the cover **13**, and other members are mounted on the base member **12**. Accordingly, it is easy to consider whether a problem can be found in the casting process even at a later time.

As mentioned earlier, along with the information mark **17**, the information mark representing the serial number, the result of the motor characteristic inspection, etc., of the spindle motor **11** mounted on the base member **12** may be placed on the rear surface **12***b* of the base member **12**. This will make it possible to read the information mark of the spindle motor **11** in addition to the information mark **17**. This makes it easy to acquire motor information together with the casting information, which leads to improved working efficiency.

In addition, in the base member **12** according to the present preferred embodiment, the two-dimensional image portion **17***b* of the information mark **17** contains the information of the minimum injection speed, the maximum injection speed, and the casting pressure. This makes it possible to acquire more information concerning the casting, in addition to the casting machine number and the casting date and time, by reading the information mark **17**. This makes it possible to quickly identify a casting parameter that may be a cause for an abnormality.

In addition, in the base member **12** according to the present preferred embodiment, a portion of the information mark **17** is the two-dimensional image portion **17***b*, which enables the information mark **17** to contain much casting information using a limited space.

In addition, in the present preferred embodiment, the information mark **17** is placed on the rear surface of the base body using the laser marker, and thus, the placement of the information mark **17** can be accomplished in a relatively inexpensive and easy manner. Moreover, visibility of the information mark **17** even after the provision of the insulating coating can be ensured.

In addition, in the present preferred embodiment, the information mark **17** is placed on a portion of the rear surface **12***b* of the base body **19** (the base member **12**) which corresponds to the increased thickness portion **12***d*. This arrangement has the following advantages. That is, in the case where the information mark **17** is engraved and thereby placed on the rear surface of the base body **19** as in the present preferred embodiment, the chill layer **19***a* at the outermost layer of the base body **19** is partly shaved off in the engraved area (see FIG. **4**). Accordingly, in the present preferred embodiment, the information mark **17** is placed on the increased thickness portion **12***d*, and the above shaving off of portions of the chill layer **19***a* does not result in a failure to ensure the sealing of the gas in the casing because of the axial thickness of the material. Moreover, the information mark **17** can be placed on the increased thickness portion **12***d* by an easy process.

In addition, in the present preferred embodiment, the information mark **17** is placed on the increased thickness portion **12***d* inside of the disk shroud **12***c*, and thus, the information mark **17** is arranged in a reasonable place which can be easily processed.

In addition, regarding the disk drive apparatus **1** according to the present preferred embodiment, the improved quality of the base member **12** results in an improvement in quality of the disk drive apparatus **1** as a whole. This leads to an improved yield, and a reduction in a cost of scrapping nonconforming items.

While a preferred embodiment of the present invention has been described above, it is to be understood that the present invention is not limited to the above-described preferred embodiment.

In the above-described preferred embodiment, the information mark **17** includes the numeric string portion **17***a*, which is visually readable by a human, and the two-dimensional image portion **17***b*, which is readable by a reading device. Note, however, that this is not essential to the present invention. For example, the information mark may alternatively be made up of only the two-dimensional image portion **17***b* or only the numeric string portion **17***a*. Also note that the information mark may alternatively include a string of alphabetic characters or a one-dimensional bar code, in place of or in addition to any of the above.

In the above-described preferred embodiment, the information mark **17** is engraved on the rear surface **12***b* of the base member **12** (the base body **19**) using the laser marker. Note, however, that the placement of the information mark **17** may alternatively be achieved by any other desirable method. For example, the information mark **17** may alternatively be printed by a chemical etching process or a cutting process.

In the above-described preferred embodiment, the two-dimensional image portion **17***b* includes, in addition to the casting machine number and the casting date and time, the information of the minimum injection speed, the maximum injection speed, and the casting pressure as information of other casting parameters. Note, however, that this is not essential to the present invention. For example, the two-dimensional image portion **17***b* may include neither the casting machine number nor the casting date and time, because both the casting machine number and the casting date and time are included in the information of the numeric string portion **17***a*. Also note that the two-dimensional image portion **17***b* may include information other than the above three casting parameters, such as, for example, information of the temperature at the time of the casting.

In the above-described preferred embodiment, the information mark **17** includes the casting machine number and the casting date and time. Note, however, that this is not essential to the present invention. It may be sufficient if the information mark **17** includes information that can uniquely identify the base member **12** (the disk drive apparatus **1**) manufactured. For example, the information mark **17** may alternatively include a serial number that is sequentially issued to each individual base member **12** manufactured.

In the above-described preferred embodiment, the information mark **17** is placed on the rear surface **12***b* of the base member **12**. This arrangement has an advantage in that the information mark **17** can be easily read even at a later time. Note, however, that the information mark **17** may not necessarily be placed on the rear surface **12***b* of the base member **12**, but may alternatively be placed on a front surface or a side surface of the base member, for example.

In the above-described preferred embodiment, the information mark (not shown) representing the information concerning the spindle motor **11** is placed on the rear surface **12***b* of the base member **12** together with the information mark **17**. Note, however, that the information mark (not shown) representing the information concerning the spindle motor **11** may be omitted.

Note that the procedure for manufacturing the base member **12** and the disk drive apparatus **1** according to the above-described preferred embodiment is merely an example procedure, and that an additional process or processes may be included in the procedure. Examples of such additional processes include an annealing process, a precutting process, and an impregnating process.

In the above-described preferred embodiment, the results of the inspections (steps S**4**, S**5**, and S**7**) are registered in the production management database regardless of whether the results have been determined to be "passed" or "failed". Note, however, that this is not essential to the present invention. For example, the results of the inspections may alternatively be stored in the database only when the results have been determined to be "failed". Then, a casting parameter common to base members **12** with respect to which an abnormality has occurred may be searched for.

While a preferred embodiment of the present invention and several modifications thereof have been described above, it should be noted that features of the above-described preferred embodiment and the modifications thereof may be combined appropriately as long as no conflict arises.

Preferred embodiments of the present invention are applicable to, for example, base members and disk drive apparatuses including the base members.

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 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.

What is claimed is:

**1**. A base member structured to define a portion of a casing in which a gas with a density lower than that of air is to be sealed and to support a motor to be housed in the casing, the base member comprising:

a base body made of a cast material;

an information mark including casting information and located on a portion of a surface of the base body; and

an insulating coating layer defined on the surface of the base body; wherein

the insulating coating layer covers the information mark; and

the base body includes:

 a decreased thickness portion; and

 an increased thickness portion with a thickness greater than that of the decreased thickness portion; and the information mark is located on a surface of the increased thickness portion within the surface of the base body.

**2**. The base member according to claim **1**, wherein the casting information includes information of a casting machine number and a casting date and time.

**3**. The base member according to claim **2**, wherein the base body includes:

a first surface on which the motor is provided; and

a second surface defining a rear surface opposite to the first surface; and

the information mark is located on the second surface.

**4**. The base member according to claim **1**, wherein

the casting information includes at least one of a minimum injection speed, a maximum injection speed, and a casting pressure;

each of the minimum and maximum injection speeds is a speed at which a molten material is poured into a mold when the base body is cast; and

the casting pressure is a pressure applied when the molten material is forced into the mold.

**5**. The base member according to claim **1**, wherein the information mark includes a two-dimensional image.

**6**. The base member according to claim **1**, wherein the information mark is a laser-marked portion on the surface of the base body.

**7**. The base member according to claim **1**, further comprising a disk shroud extending along an outer circumference of a disk to be rotated by the motor; wherein

the disk is housed in the casing; and

the increased thickness portion is located inside of the disk shroud when viewed in an axial direction parallel or substantially parallel to a rotation axis of the motor.

**8**. The base member according to claim **7**, wherein the increased thickness portion has a shape of a circular arc radially outside of a region centered on the rotation axis and having a radius equal to about one half of a distance from the rotation axis to the outer circumference of the disk when viewed in the axial direction.

**9**. The base member according to claim **7**, wherein

the increased thickness portion has a shape of a circular arc in a region extending from an inner circumferential portion of a recording layer of the disk to an outer circumferential portion of the disk when viewed in the axial direction; and

the recording layer includes a metal film.

**10**. A disk drive apparatus comprising:

the base member of claim **1**;

a cover member defining a remaining portion of the casing excluding the portion defined by the base member;

a disk housed in the casing and to be rotated by the motor; and

an access portion housed in the casing and to perform at least one of reading and writing of information from or to the disk.

* * * * *

# Exhibit
# F

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# Unmatched Dependability.

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**Broadest 2.5-inch hard drive portfolio** with up to 5TB capacity and both 7mm and 15mm form factors suitable for a variety of compute applications.

**Thinnest and lightest 2.5-inch hard drive** with up to 2TB storage in a 7mm z-height, providing seamless upgrades of thin and light laptops and smaller form factor systems.

**Fast data rates of up to 140MB/s** enables superior PC end-user experience and snappier file transfers.

2.5-inch, 15mm z-height hard drives provide 3TB to 5TB in capacity, offering **the highest-capacity 2.5-inch hard drives** available for external or all-in-one storage.

**15mm z-height enables slimmer all-in-one desktop PC drives** while helping reduce system heat generation and vibration.

**Low startup current** configurations for 3TB to 5TB drives enable **use in legacy low-current systems** like USB-2 external boxes, while simultaneously lowering power consumption.

5TB drives can store more than **1.25 million songs and 600 hours of HD video.**[1]

[1] Quantitative usage examples for 5TB capacity drive

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| Specifications | 5TB | 4TB | 3TB | 2TB | 1TB |
|---|---|---|---|---|---|
| Capacity | 5TB | 4TB | 3TB | 2TB | 1TB |
| Model Numbers | ST5000LM000 | ST4000LM024 | ST3000LM024 | ST2000LM015 | ST1000LM049 |
| Bytes per Sector (logical/physical) | 512/4096 | 512/4096 | 512/4096 | 512/4096 | 512/4096 |
| Performance | | | | | |
| Interface | SATA 6Gb/s | SATA 6Gb/s | SATA 6Gb/s | SATA 6Gb/s | SATA 6Gb/s |
| Data Transfer Rate (MB/s) | Up to 140 | Up to 140 | Up to 140 | Up to 140 | Up to 160 |
| Cache (MB) | 128 | 128 | 128 | 128 | 128 |
| Spindle Speed (RPM) | 5400 | 5400 | 5400 | 5400 | 7200 |
| Recording Technology | SMR | SMR | SMR | SMR | SMR |
| Reliability/Data Integrity | | | | | |
| Load/Unload Cycles | 600,000 | 600,000 | 600,000 | 600,000 | 600,000 |
| Head-Rest Method | QuietStep™ Ramp Load | QuietStep Ramp Load | QuietStep Ramp Load | QuietStep Ramp Load | QuietStep Ramp Load |
| Nonrecoverable Read Errors per Bits Read, Max | 1 per 10E14 | 1 per 10E14 | 1 per 10E14 | 1 per 10E14 | 1 per 10E14 |
| Limited Warranty (years)[1] | 2 | 2 | 2 | 2 | 5 |
| Power Management | | | | | |
| Startup Current (+5V, A) | 1.2 | 1.2 | 1.2 | 1.0 | 1.0 |
| Read/Write Power, Average (W) | 1.9/2.1 | 1.9/2.1 | 1.9/2.1 | 1.7/1.8 | 1.9/1.7 |
| Idle Power, Average (W) | 1.1 | 1.1 | 1.1 | 0.5 | 0.7 |
| Environmental | | | | | |
| Temperature, Operating (°C) | 0°C – 60°C | 0°C – 60°C | 0°C – 60°C | 0°C – 60°C | 0°C – 60°C |
| Temperature, Nonoperating (°C) | -40°C – 70°C | -40°C – 70°C | -40°C – 70°C | -40°C – 70°C | -40°C – 70°C |
| Shock, Operating: 2ms (Gs) | 300 | 300 | 300 | 400 | 400 |
| Shock, Nonoperating: 1ms (Gs) | 650 | 650 | 650 | 1000 | 1000 |
| Acoustics, Idle, Typical (bels—sound power) | 2.6 | 2.6 | 2.6 | 2.2 | 2.2 |
| Acoustics, Seek, Typical (bels—sound power) | 2.7 | 2.7 | 2.7 | 2.4 | 2.4 |
| Physical | | | | | |
| Height (mm/in) | 15.0/0.59 | 15.0/0.59 | 15.0/0.59 | 7.0/0.276 | 7.0/0.276 |
| Width (mm/in) | 69.85mm/2.750in | 69.85mm/2.750in | 69.85mm/2.750in | 69.85mm/2.750in | 69.85mm/2.750in |
| Depth (mm/in) | 100.35mm/3.951in | 100.35mm/3.951in | 100.35mm/3.951in | 100.35mm/3.951in | 100.35mm/3.951in |
| Weight (g/lb, max) | 190g/0.42lb | 190g/0.42lb | 190g/0.42lb | 90g/0.198lb | 85g/0.187lb |
| Carton Unit Quantity | 40 | 40 | 40 | 50 | 50 |
| Cartons Per Pallet/Layer | 60/10 | 60/10 | 60/10 | 60/10 | 60/10 |
| Special Features | | | | | |
| Multi-Tier Caching Technology™ | Yes | Yes | Yes | Yes | Yes |
| Halogen Free | Yes | Yes | Yes | Yes | Yes |
| RoHS Compliance | Yes | Yes | Yes | Yes | Yes |

1 Extended warranty products available. Consult your distributor for details.

BARRACUDA
COMPUTE

| Specifications | 1TB | 500GB | 500GB |
|---|---|---|---|
| Capacity | 1TB | 500GB | 500GB |
| Model Numbers | ST1000LM048 | ST500LM034 | ST500LM030 |
| Bytes per Sector (logical/physical) | 512/4096 | 512/4096 | 512/1/4096 |
| Performance | | | |
| Interface | SATA 6Gb/s | SATA 6Gb/s | SATA 6Gb/s |
| Data Transfer Rate (MB/s) | Up to 140 | Up to 160 | Up to 140 |
| Cache (MB) | 128 | 128 | 128 |
| Spindle Speed (RPM) | 5400 | 7200 | 5400 |
| Recording Technology | SMR | SMR | SMR |
| Reliability/Data Integrity | | | |
| Load/Unload Cycles | 600,000 | 600,000 | 600,000 |
| Head-Rest Method | QuietStep Ramp Load | QuietStep Ramp Load | QuietStep Ramp Load |
| Nonrecoverable Read Errors per Bits Read, Max | 1 per 10E14 | 1 per 10E14 | 1 per 10E14 |
| Limited Warranty (years)[1] | 2 | 5 | 2 |
| Power Management | | | |
| Startup Current (+5V, A) | 1.0 | 1.0 | 1.0 |
| Read/Write Power, Average (W) | 1.6/1.7 | 1.9/1.7 | 1.6/1.7 |
| Idle Power, Average (W) | 0.45 | 0.7 | 0.45 |
| Environmental | | | |
| Temperature, Operating (°C) | 0°C – 60°C | 0°C – 60°C | 0°C – 60°C |
| Temperature, Nonoperating (°C) | -40°C – 70°C | -40°C – 70°C | -40°C – 70°C |
| Shock, Operating: 2ms (Gs) | 400 | 400 | 400 |
| Shock, Nonoperating: 1ms (Gs) | 1000 | 1000 | 1000 |
| Acoustics, Idle, Typical (bels—sound power) | 2.0 | 2.2 | 2.0 |
| Acoustics, Seek, Typical (bels—sound power) | 2.2 | 2.4 | 2.2 |
| Physical | | | |
| Height (mm/in) | 7.0/0.276 | 7.0/0.276 | 7.0/0.276 |
| Width (mm/in) | 69.85mm/2.75in | 69.85mm/2.750in | 69.85mm/2.75in |
| Depth (mm/in) | 100.35mm/3.951in | 100.35mm/3.951in | 100.35mm/3.951in |
| Weight (g/lb, max) | 90g/0.198lb | 85g/0.187lb | 90g/0.198lb |
| Carton Unit Quantity | 50 | 50 | 50 |
| Cartons Per Pallet/Layer | 60/10 | 60/10 | 60/10 |
| Special Features | | | |
| Multi-Tier Caching Technology™ | Yes | Yes | Yes |
| Halogen Free | Yes | Yes | Yes |
| RoHS Compliance | Yes | Yes | Yes |

[1] Extended warranty products available. Consult your distributor for details.

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# Exhibit G

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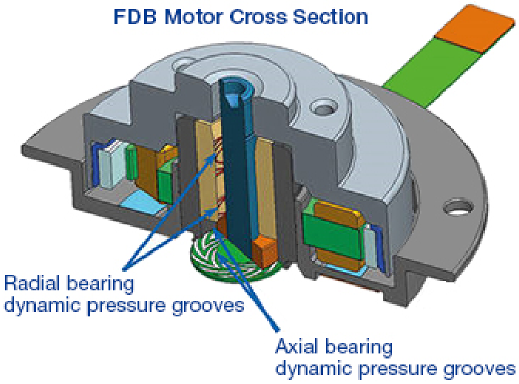
Features Data Application Contact Us

## Features



A BLDC motor is brushless, the commutation is done electronically. There is no need for brushes, as the torque is a function of the electronic action of the brushless motor on the commutator. This means is that a brushless motor has fewer parts that can wear out and there is never any need to be concerned about the condition of the brushes. A BLDC motor is longer lasting and more reliable than their brushed counterparts. It's a very effective motor with an optimized electromagnetic design for noise, vibration and jitter which last for the long-term.

The FDB (Fluid Dynamic Bearing) eliminates the limited precision of ball bearings, minimizing the non-repeatable run out, lowering acoustic noise level, and improving the reliability. The FDB was originally developed for hard disk drives and their ultra-precise mechanical requirements and long working life.

This hydrodynamic bearing system (FDB) is the right choice for your high precision application.

* The bearing which works by hydro dynamic pressure is generally expressed "Fluid Dynamic Bearing" or "FDB" in technical field.

### The BLDC FDB motor offers superior performance in terms of:

- extremely quiet and accurate running
- low vibration
- low run out (NRRO below 40 nm)
- low level of noise
- extremely long-lasting, since there a no wear parts
- high speed up to 15.000 rpm
- wobble error < 3"low
- energy consumption

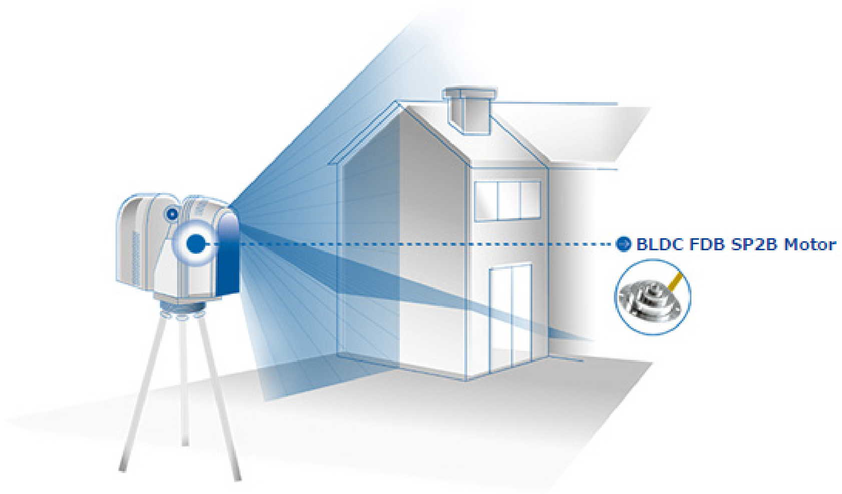
### Applications

- Hard Disk Drives

- LiDAR
- Virtual Reality: motion tracking
- 2D & 3D Scanner
- Fans
- DLP Projector
- Respiratory Equipment

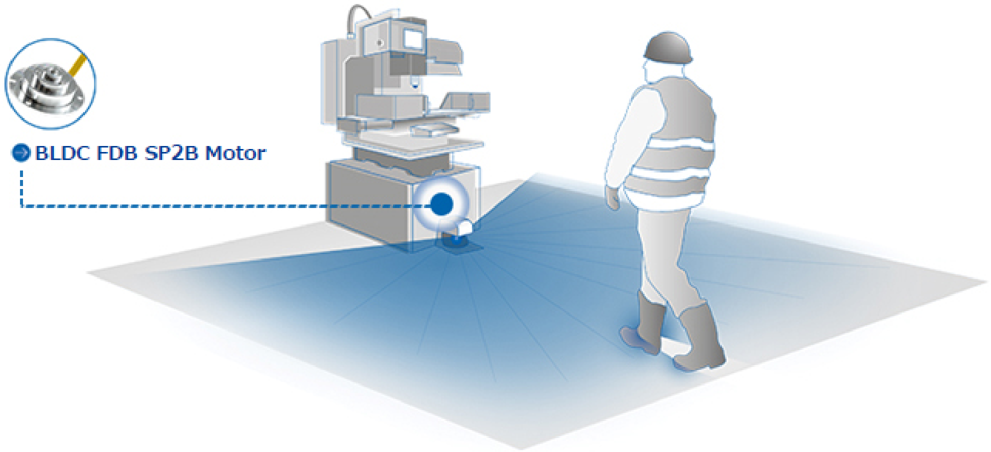
## Measurement Technology

With its wide temperature range, the BLDC FDB SP2B motor is ideally suited for indoor and outdoor applications. The FDB technology provides high density and accuracy. The small size and the high stiffness both fit perfectly when it comes to mobile application usage. Thanks to the combination of a brushless DC motor with the cutting-edge technology of fluid dynamic bearing, high running and scanning precision are guaranteed.



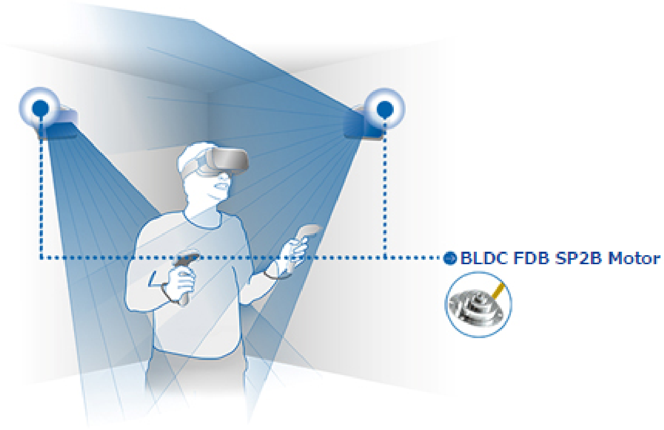
## Safety Technology

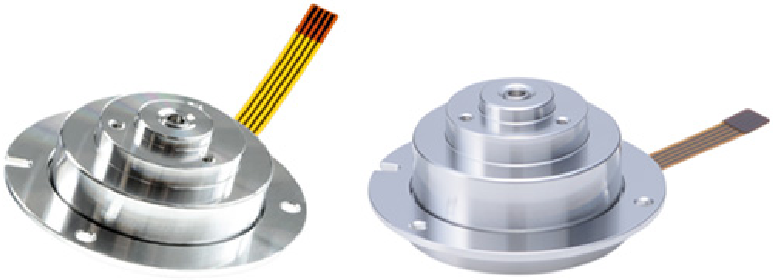
High accuracy, low vibration, a wide field of vision as well as high axial and radial stiffness are only a few of the numerous virtues of our FDB motor in the area of safety technology. The motor allows high density and a wide viewing angle. Thanks to the compact design also smaller constructions in this application area are possible. The fluid dynamic bearing comes without the limited precision of ball bearings and minimizes the non-repeatable run out to optimize the steadiness.



## Consumer Electronics

The BLDC FDB SP2B motor provides the link to the real world. Due to its extremely quiet running and its accuracy, the level of noise is minimized. Furthermore the FDB motor allows a high density and turns virtual content into reality. The fluid dynamic bearing fulfils the high precision standards in consumer electronics. Since there are no wear parts, a long service life is guaranteed.





## Product Data

| Item | Contents |
|---|---|
| Development | • MinebeaMitsumi Inc. Karuizawa Plant (Japan)<br>• MinebeaMitsumi Technology Center Europe GmbH (Germany) |
| Manufacturing | • NMB-Minebea Thai Ltd. Bang Pa-in Plant (Thailand) |
| Commenced Operation | in 2017 |

## Application

**Portable amusements**

**Projectors**

**Data projectors**

**Projectors for home theater systems**

**Medical Equipments**

**Security Cameras**

**LiDAR**

## Contact Us

**Japan [ Sales Headquarters MinebeaMitsumi Inc. ]**

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| | |
|---|---|
| FAX | 81-3-6758-6760 |

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# Exhibit
# H

IRONWOLF PRO NAS

SEAGATE

3.5 HDD DATA SHEET

# The Power of Agility for Creative Pro and SME NAS Enclosures

IronWolf™ Pro is designed for everything business NAS. Get used to tough, ready, and scalable 24×7 performance that can handle multi-drive environments across a wide range of capacities.

### Best-Fit Applications

- Commercial and enterprise network-attached storage (NAS)
- 1- to 24-bay network attached storage (NAS)
- Backup, archiving, and disaster recovery
- On-premise private cloud
- Virtual storage

Rescue DATA RECOVERY SERVICES

## Key Advantages

**Optimized for NAS with AgileArray™**. AgileArray enables dual-plane balancing and RAID optimization in multi-bay environments, with the most advanced power management possible.

**Actively protect your NAS with IronWolf Health Management** focusing on prevention, intervention, and recovery.[1]

**High performance means no lag time** or downtime for users during workload traffic for the NAS. Seagate leads the competition with the highest-performing NAS drive portfolio.[2]

**Rescue Data Recovery Services.**[3] IronWolf Pro comes with extra peace of mind for any mechanical, accidental, or natural disaster. With a 95% success rate of in-house recovery, Seagate has your back with a 3-year included Rescue Services plan.[4]

**Rotational Vibration (RV) sensors.** First in its class of drives to include RV sensors to maintain high performance in multi-drive NAS enclosures.[3]

**Range of capacities up to 18TB.** More capacity options means more choices that will fit within the budget. Seagate provides a scalable solution for any NAS use-case scenario.

**Do more in multi-user environments.** IronWolf provides a workload rate of 300TB/year. Multiple users can confidently upload and download data to the NAS server, knowing IronWolf can handle the workload, whether you are a creative professional or a small business.

**Designed for always on, always accessible 24×7 performance.** Access data on your NAS any time, remotely or on site.

**1.2M hours MTBF, 5-year limited warranty** represents an improved total cost of ownership (TCO) over desktop drives with reduced maintenance costs.

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1 Contact your Seagate sales representative for further information.

2 Performance may vary depending on user's hardware configuration and operating system.

3 Registration required to activate. Rescue Data Recovery Services not available in all countries. Contact your Seagate sales representative for further details.

4 Three-year coverage for product models shipped January 1, 2020, or later

IRONWOLF PRO NAS

| Specifications | 18TB | 16TB | 14TB | 12TB | 10TB |
|---|---|---|---|---|---|
| Capacity | 18TB | 16TB | 14TB | 12TB | 10TB |
| Standard Model Number[1] | ST18000NE000 | ST16000NE000 | ST14000NE0008 | ST12000NE0008 | ST10000NE0008 |
| Interface | SATA 6Gb/s | SATA 6Gb/s | SATA 6Gb/s | SATA 6Gb/s | SATA 6Gb/s |
| Features | | | | | |
| Drive Bays Supported | Up to 24-bay | Up to 24-bay | Up to 24-bay | Up to 24-bay | Up to 24-bay |
| Recording Technology | CMR | CMR | CMR | CMR | CMR |
| Drive Design (Air or Helium) | Helium | Helium | Helium | Helium | Helium |
| Workload Rate Limit (WRL) | 300 | 300 | 300 | 300 | 300 |
| Rotational Vibration (RV) Sensors | Yes | Yes | Yes | Yes | Yes |
| Hot-Plug Support[2] | Yes | Yes | Yes | Yes | Yes |
| Cache (MB) | 256 | 256 | 256 | 256 | 256 |
| Reliability/Data Integrity | | | | | |
| Mean Time Between Failures (MTBF, hours) | 1,200,000 | 1,200,000 | 1,200,000 | 1,200,000 | 1,200,000 |
| Reliability Rating @ Full 24×7 Operation (AFR) | 0.73% | 0.73% | 0.73% | 0.73% | 0.73% |
| Nonrecoverable Read Errors per Bits Read, Max | 1 per 10E15 | 1 per 10E15 | 1 per 10E15 | 1 per 10E15 | 1 per 10E15 |
| Power-On Hours (per year) | 8760 | 8760 | 8760 | 8760 | 8760 |
| Sector Size (Bytes per Logical Sector) | 512E | 512E | 512E | 512E | 512E |
| Rescue Data Recovery Services (years)[3] | 3 | 3 | 3 | 3 | 3 |
| Limited Warranty (years) | 5 | 5 | 5 | 5 | 5 |
| Performance | | | | | |
| Spindle Speed (RPM) | 7200 | 7200 | 7200 | 7200 | 7200 |
| Interface Access Speed (Gb/s) | 6.0, 3.0, 1.5 | 6.0, 3.0, 1.5 | 6.0, 3.0, 1.5 | 6.0, 3.0, 1.5 | 6.0, 3.0, 1.5 |
| Max. Sustained Transfer Rate OD (MB/s) | 260MB/s | 255MB/s | 255MB/s | 240MB/s | 240MB/s |
| Rotational Vibration @ 10-1500 Hz (rad/s$^2$) | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 |
| Power Consumption | | | | | |
| Startup Current, Typical (12V, A) | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Idle Power, Average (W) | 5.2 | 5.0 | 5.0 | 5.0 | 5.0 |
| Average Operating Power (W) | 8.0W | 7.6W | 7.6W | 7.8W | 7.8W |
| Standby Mode, Typical (W) | 1.25 | 1.0 | 1.0 | 1.0 | 0.8 |
| Sleep Mode, Typical (W) | 1.0 | 1.0 | 1.0 | 1.0 | 0.8 |
| Power Supply Requirements | +12 V and +5 V | +12 V and +5 V | +12 V and +5 V | +12 V and +5 V | +12 V and +5 V |
| Environmental/Temperature | | | | | |
| Operating (ambient, min °C) | 0 | 0 | 0 | 0 | 0 |
| Operating (drive reported temperature °C)[4] | 65 | 65 | 65 | 65 | 65 |
| Nonoperating (ambient, min °C) | -40 | -40 | -40 | -40 | -40 |
| Nonoperating (ambient, max °C) | 70 | 70 | 70 | 70 | 70 |
| Environmental/Acoustics | | | | | |
| Vibration, Nonoperating: 10Hz to 500Hz (Grms) | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 |
| Acoustics, Idle (typical, measured in Idle 1 state) | 2.8bels | 2.8bels | 2.8bels | 2.8bels | 2.8bels |
| Acoustics, Seek (typical) | 3.2bels | 3.2bels | 3.2bels | 3.2bels | 3bels |
| Environmental/Shock | | | | | |
| Shock, Operating 2ms (Read/Write) (Gs) | 50/50Gs | 50/50Gs | 50/50Gs | 50/50Gs | 70/40Gs |
| Shock, Nonoperating, 1ms and 2ms (Gs) | 200 | 200 | 200 | 200 | 250 |
| Physical | | | | | |
| Height (mm/in) | 26.11mm/1.028in | 26.11mm/1.028in | 26.11mm/1.028in | 26.11mm/1.028in | 26.11mm/1.028in |
| Width (mm/in, max) | 101.85mm/4.01in | 101.85mm/4.01in | 101.85mm/4.01in | 101.85mm/4.01in | 101.85mm/4.01in |
| Depth (mm/in, max) | 146.99mm/5.787in | 146.99mm/5.787in | 146.99mm/5.787in | 146.99mm/5.787in | 146.99mm/5.787in |
| Weight (g/lb, typical) | 670g/1.477lb | 670g/1.477lb | 670g/1.477lb | 670g/1.477lb | 690g/1.521lb |
| Carton Unit Quantity | 20 | 20 | 20 | 20 | 20 |
| Cartons per Pallet/Cartons per Layer | 40/8 | 40/8 | 40/8 | 40/8 | 40/8 |

[1] Seagate recommends validating your configuration with your HBA/RAID controller manufacturer to ensure full capacity capabilities.

[2] Supports Hot-Plug operation per Serial ATA Revision 3.3 specification.

[3] Rescue Data Recovery Services not available in all countries. Contact your Seagate sales representative for further details. Register an IronWolf Pro drive to activate your 3-year Rescue Services plan at seagate.com/register.

[4] Seagate does not recommend operating at sustained drive temperatures above 60C. Operating at higher temperatures may affect drive health.

# IRONWOLF PRO

NAS

| Specifications | 8TB | 6TB | 4TB |
|---|---|---|---|
| Capacity | 8TB | 6TB | 4TB |
| Standard Model Number[1] | ST8000NE001 | ST6000NE000 | ST4000NE001 |
| Interface | SATA 6Gb/s | SATA 6Gb/s | SATA 6Gb/s |
| Features | | | |
| Drive Bays Supported | Up to 24-bay | Up to 24-bay | Up to 24-bay |
| Recording Technology | CMR | CMR | CMR |
| Drive Design (Air or Helium) | Air | Air | Air |
| Workload Rate Limit (WRL) | 300 | 300 | 300 |
| Rotational Vibration (RV) Sensors | Yes | Yes | Yes |
| Hot-Plug Support[2] | Yes | Yes | Yes |
| Cache (MB) | 256 | 256 | 256 |
| Reliability/Data Integrity | | | |
| Mean Time Between Failures (MTBF, hours) | 1,200,000 | 1,200,000 | 1,200,000 |
| Reliability Rating @ Full 24×7 Operation (AFR) | 0.73% | 0.73% | 0.73% |
| Nonrecoverable Read Errors per Bits Read, Max | 1 per 10E15 | 1 per 10E15 | 1 per 10E15 |
| Power-On Hours (per year) | 8760 | 8760 | 8760 |
| Sector Size (Bytes per Logical Sector) | 512E | 512E | 512E |
| Rescue Data Recovery Services (years)[3] | 3 | 3 | 3 |
| Limited Warranty (years) | 5 | 5 | 5 |
| Performance | | | |
| Spindle Speed (RPM) | 7200 | 7200 | 7200 |
| Interface Access Speed (Gb/s) | 6.0, 3.0, 1.5 | 6.0, 3.0, 1.5 | 6.0, 3.0, 1.5 |
| Max. Sustained Transfer Rate OD (MB/s) | 240MB/s | 220MB/s | 220MB/s |
| Rotational Vibration @ 10-1500 Hz ($\text{rad/s}^2$) | 12.5 | 12.5 | 12.5 |
| Power Consumption | | | |
| Startup Current, Typical (12V, A) | 2.0 | 2.0 | 2.0 |
| Idle Power, Average (W) | 7.06 | 7.06 | 5.5 |
| Average Operating Power (W) | 9.2W | 8.1W | 9.0W |
| Standby Mode, Typical (W) | 1.0 | 1.0 | 1.0 |
| Sleep Mode, Typical (W) | 1.0 | 1.0 | 1.0 |
| Power Supply Requirements | +12 V and +5 V | +12 V and +5 V | +12 V and +5 V |
| Environmental/Temperature | | | |
| Operating (ambient, min °C) | 0 | 0 | 0 |
| Operating (drive reported temperature °C)[4] | 65 | 65 | 65 |
| Nonoperating (ambient, min °C) | -40 | -40 | -40 |
| Nonoperating (ambient, max °C) | 70 | 70 | 70 |
| Environmental/Acoustics | | | |
| Vibration, Nonoperating: 10Hz to 500Hz (Grms) | 2.27 | 3 | 3 |
| Acoustics, Idle (typical, measured in Idle 1 state) | 1.8bels | 2.7bels | 2.7bels |
| Acoustics, Seek (typical) | 2.8bels | 2.7bels | 2.8bels |
| Environmental/Shock | | | |
| Shock, Operating 2ms (Read/Write) (Gs) | 70/40Gs | 70/40Gs | 70/40Gs |
| Shock, Nonoperating, 1ms and 2ms (Gs) | 250 | 250 | 300 |
| Physical | | | |
| Height (mm/in) | 26.11mm/1.028in | 26.11mm/1.028in | 26.11mm/1.028in |
| Width (mm/in, max) | 101.85mm/4.01in | 101.85mm/4.01in | 101.85mm/4.01in |
| Depth (mm/in, max) | 146.99mm/5.787in | 146.99mm/5.787in | 146.99mm/5.787in |
| Weight (g/lb, typical) | 722g/1.59lb | 705g/1.55lb | 643g/1.42lb |
| Carton Unit Quantity | 20 | 20 | 20 |
| Cartons per Pallet/Cartons per Layer | 40/8 | 40/8 | 40/8 |

[1] Seagate recommends validating your configuration with your HBA/RAID controller manufacturer to ensure full capacity capabilities.

[2] Supports Hot-Plug operation per Serial ATA Revision 3.3 specification.

[3] Rescue Data Recovery Services not available in all countries. Contact your Seagate sales representative for further details. Register an IronWolf Pro drive to activate your 3-year Rescue Services plan at seagate.com/register.

[4] Seagate does not recommend operating at sustained drive temperatures above 60C. Operating at higher temperatures may affect drive health.

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