

DESCRIPTION

BRUSHLESS DC MOTOR AND CEILING FAN USING SAME

5 TECHNICAL FIELD

[0001] The present disclosure relates to an air blower equipped with a brushless DC motor for driving fans such as a ceiling fan.

BACKGROUND ART

10 [0002] As an example of such type of conventional brushless DC motors, a brushless DC motor configured as disclosed in Patent Literature 1 has been known. Hereinafter, this brushless DC motor will be described with reference to FIG. 11. FIG. 11 is a longitudinal cross-sectional diagram of the conventional brushless DC motor.

15 [0003] As illustrated in FIG. 11, stator core 102 is fixed to bracket 101. Coil 104 is wound around bobbin 103 mounted onto stator core 102. Sensor 113 is configured to detect a magnetic pole by receiving a magnetic force of rotor magnet 106a constituting rotor 106. Sensor 113 includes three chip Hall ICs (magnetic sensors) 114 and printed circuit board 115 having Hall ICs 114 on
20 board.

[0004] Sensor 113 is inserted through opening 101a of bracket 101, and fixed to bracket 101 so as to be in a predetermined position relative to rotor magnet 106a.

[0005] Furthermore, a brushless DC motor disclosed in Patent Literature 2
25 has been known. FIG. 12A is a longitudinal cross-sectional diagram of a conventional brushless DC motor, and FIG. 12B is an enlarged view of a principal part of the conventional brushless DC motor.

[0006] Upper bearing 203 is pressed fit and fixed to motor case 202, and, together with lower bearing 212, rotatably supports shaft 201. Rotor frame 205 to which a cylindrical permanent magnet 204 adheres is fixed to shaft 201. Circuit board 209 has a driving circuit element, such as IC 210, on board.
5 Fixing member 211 is configured to fix a stationary armature to circuit board 209 and receive the thrust of shaft 201.

[0007] In circuit board 209, insulating layer 214 is formed on a surface of metal base 213. Conductive patterns 215a and 215b made of copper foil are formed on insulating layer 214. Here, conductive pattern 215a is connected to an
10 earth terminal. Lower bearing 212 is pressed fit into circuit board 209. Lower bearing 212 comes into contact with conductive pattern 215a, thereby being grounded, and also comes into contact with metal base 213, thereby causing metal base 213 to be grounded.

15 **Citation List**

[0008] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2002-315292

Patent Literature 2: Japanese Unexamined Patent Application Publication No. H6-38432

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SUMMARY

[0009] In a conventional brushless DC motor, sensor 113 including printed circuit board 115 having a chip Hall IC 114 on board is installed into bracket 101. With this configuration, the positioning of Hall IC 114 to be installed can
25 be surely effected.

[0010] However, since the positional relationship between stator core 102 and sensor 113 (Hall IC 114) is dependent on bracket 101, a misalignment

therebetween is caused by variations in components or variations in assembly.

In other words, in accordance with a position of rotor magnet 106a detected by sensor 113 and a position of stator core 102, a current passing through a winding needs to be controlled, and as a result, motor characteristics
5 deteriorate.

[0011] An object of the present disclosure is to achieve higher motor characteristics by accurate positioning of a Hall IC.

[0012] As described above, in the conventional brushless DC motor, lower bearing 212 is pressed fit into circuit board 209. Lower bearing 212 comes into
10 contact with conductive pattern 215a, thereby being grounded, and also comes into contact with metal base 213, thereby causing metal base 213 to be grounded. Therefore, it is difficult to detach lower bearing 212 from circuit board 209.

[0013] Another object of the present disclosure is to achieve a simply
15 configured connection between a circuit board and a shaft and simplify the disassembly of a brushless DC motor for ease of maintenance.

[00013a] In a first aspect, the present disclosure provides a brushless direct-current (DC) motor, comprising: a shaft; a stator core including a plurality of slots, and fixed to the shaft, the plurality of slots being arranged
20 along a periphery of the stator core; a rotor holder having an inner peripheral surface facing the stator core; a plurality of magnets arranged on the inner peripheral surface of the rotor holder along a peripheral of the rotor holder; and a control circuit board allowing the shaft to pass therethrough, and being adjacent, along a rotational axis of the shaft, to the stator core, wherein the
25 control circuit board includes at least one Hall element configured to detect magnetic forces of the plurality of magnets, and wherein the at least one Hall element is held by an element holder inserted into at least one of the slots of the

stator core, the Hall element standing on the control circuit board, and wherein the element holder includes protrusions protruding toward the stator core, the protrusions being inserted into the slots of the stator core to position the at least one Hall element with respect to the stator core.

5 [0013b] In a second aspect, the present disclosure provides a ceiling fan, including the brushless DC motor according to the first aspect.

[0013c] In a third aspect, the present disclosure provides a brushless DC motor, comprising: a shaft; a stator core fixed to the shaft; and a control circuit board including an opening allowing the shaft to pass therethrough, wherein
10 the control circuit board includes an earth section printed on a circumference of the opening in a top surface of the control circuit board.

[0013d] In a fourth aspect, the present disclosure provides a ceiling fan, including the brushless DC motor according to the third aspect.

[0014] An outer-rotor brushless DC motor according to one embodiment of the
15 present disclosure includes a shaft, a stator core, a rotor holder, a plurality of magnets, and a control circuit board. The stator core includes a plurality of slots, and is fixed to the shaft. The plurality of slots is arranged along a peripheral of the stator core. The rotor holder has an inner peripheral surface facing the stator core. The plurality of magnets are arranged on the inner
20 peripheral surface of the rotor holder along a peripheral of the rotor holder. The control circuit board allows the shaft to pass therethrough, and is adjacent, along a rotational axis of the shaft, to the stator core. The control circuit board includes at least one Hall element configured to detect the magnetic forces of the magnets. The Hall element is held by an element holder inserted into at

least one of the slots of the stator core.

[0015] A brushless DC motor according to another embodiment of the present disclosure includes a shaft, a stator core, and a control circuit board. The stator core is fixed to the shaft. The control circuit board includes an opening
5 through which the shaft passes. The control circuit board includes an earth section printed on the circumference of the opening in the top surface of the control circuit board.

[0016] According to the one embodiment of the present disclosure, the Hall element is held by the element holder to be inserted into the slot of the stator
10 core. Thus, a position of the Hall element is fixed with respect to the stator core, whereby positions of the magnets can be detected with high accuracy, and thus, higher motor characteristics can be achieved.

[0017] According to the other embodiment of the present disclosure, there is provided a brushless DC motor that makes it possible to achieve a simply
15 configured connection between the shaft and the circuit board, can be easily disassembled, and can surely establish grounding.

BRIEF DESCRIPTION OF DRAWINGS

[0018] FIG. 1 is an exploded perspective view of a brushless DC motor
20 according to a first embodiment of the present disclosure.

FIG. 2 is a cross-sectional diagram of the brushless DC motor.

FIG. 3 is a perspective view of a rotor holder of the brushless DC motor.

FIG. 4 is an external view of a control circuit board of the brushless DC
motor.

25 FIG. 5 is an exploded perspective view of a position sensing element of the brushless DC motor.

FIG. 6 is a perspective view of the position sensing element of the

brushless DC motor.

FIG. 7 is a schematic diagram of a stator core of the brushless DC motor.

FIG. 8 is a connection diagram of windings of the brushless DC motor.

5 FIG. 9 is an enlarged perspective view of a substrate holder support of the brushless DC motor.

FIG. 10 is an external view of a ceiling fan including the brushless DC motor.

10 FIG. 11 is a longitudinal cross-sectional diagram of a conventional brushless DC motor.

FIG. 12A is a partial longitudinal cross-sectional diagram of the conventional brushless DC motor.

FIG. 12B is a partial perspective view of the conventional brushless DC motor.

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DESCRIPTION OF EMBODIMENTS

[0019] Hereinafter, embodiments of the present disclosure will be described with reference to the drawings. The following embodiments are merely specific examples of the present disclosure, and do not limit the technical scope of the present disclosure. In all of the drawings, the same constituent elements are given the same reference numerals, respectively, and the repetition of the same descriptions thereof is avoided. Furthermore, in each of the drawings, detailed descriptions of constituent elements that are not directly related to the present disclosure are omitted.

25 [0020] (First Embodiment)

First, with reference to FIG. 1 and FIG. 2, a schematic configuration of brushless DC motor 9 according to a first embodiment of the present disclosure

is now described. FIG. 1 is an exploded perspective view of brushless DC motor 9.

[0021] As illustrated in FIG. 1 and FIG. 2, brushless DC motor 9 includes stator core 1, rotor holder 5, and rotor cover 8. Magnet 6 is mounted in rotor holder 5. Rotor holder 5 and rotor cover 8 are united to constitute a rotor.

[0022] Stator core 1 includes a plurality of teeth 1a disposed radially around shaft 3, and is in the shape of a disk as a whole. Shaft 3 passes through stator core 1 and is fixed to the center of stator core 1. Driving coil 2 is wound around each of teeth 1a of stator core 1 via a resin film (a slot insulator). By energizing driving coil 2, a magnetic field is generated. Note that stator core 1 can be designed to have any thickness. Therefore, in some cases, stator core 1 may be said to have a cylindrical shape.

[0023] In the upper part of shaft 3 along a rotational axis of shaft 3 (on the upper side of FIG. 1), inner ring 43 of bearing 4a (a first bearing) is disposed rotatably about shaft 3. In the lower part of shaft 3 along the rotational axis (on the lower side of FIG. 1), the lower part being located across stator core 1 from bearing 4a, inner ring 45 of bearing 4b (a second bearing) is disposed rotatably about shaft 3.

[0024] Position sensing element 7 configured to detect a magnetic flux of magnet 6 provided in the inner circumferential surface of rotor holder 5 is fixed to outer circumferential edge 1c of stator core 1.

[0025] Rotor holder 5 is in the shape of a bowl, more specifically, in the shape of a cylinder having top surface 51 and inner circumferential surface 52 connected to top surface 51. Shaft opening 53 (see FIG. 2) through which shaft 3 passes is provided at the center of top surface 51 of rotor holder 5. The diameter of the cylinder is reduced stepwise from the bottom surface of rotor holder 5 toward top surface 51, so that stepped portion 14a and stepped portion

14b are formed. Note that a plurality of magnets 6 is circumferentially mounted to cylinder-side inner circumferential surface 52 of rotor holder 5 at predetermined intervals. Rotor holder 5 accommodates stator core 1 in a space defined by top surface 51 and inner circumferential surface 52.

5 [0026] Rotor holder 5 has an opening at the bottom thereof. Rotor cover 8 covers the opening of the bottom of rotor holder 5. Thus, in brushless DC motor 9, an interior space of rotor holder 5 is closed. Rotor cover 8 has an approximately circular shape larger than the opening of the bottom of rotor holder 5. At the center of rotor cover 8, shaft opening 8a through which shaft 3
10 passes is provided. Rotor cover 8 may be removably attached to rotor holder 5 by a screw thread, a bolt and a nut, an elastically deformable hook, or other members.

[0027] Thus, brushless DC motor 9 is an outer-rotor brushless DC motor configured such that a rotor into which rotor holder 5 and rotor cover 8 are
15 united rotates along the outer circumference of stator core 1 fixed to shaft 3.

[0028] When the assembly of stator core 1, rotor holder 5, and rotor cover 8, each having the above-mentioned configurations, is performed, outer ring 44 of bearing 4a is fixed to rotor holder 5, while outer ring 46 of bearing 4b is fixed to rotor cover 8. With this state being kept, the upper part of shaft 3 passes
20 through shaft opening 53 of rotor holder 5, while the lower part of shaft 3 passes through shaft opening 8a of rotor cover 8. Magnets 6 arranged in inner circumferential surface 52 of rotor holder 5 face the outer circumferential curved surface, that is, a facing surface, of teeth 1a constituting stator core 1. In other words, brushless DC motor 9 is configured in such a way that rotor
25 holder 5 and rotor cover 8 envelop stator core 1.

[0029] In brushless DC motor 9, by the passage of a controlled current through driving coil 2, rotor holder 5 and rotor cover 8 integrally rotate on shaft 3

serving as a central axis. Note that a method of controlling a current is not directly related to the present disclosure, and therefore, detailed descriptions of the method are omitted herein.

[0030] The connection of shaft 3, stator core 1, and rotor holder 5 in the present embodiment is now described in detail.

[0031] Shaft 3 is in the shape of a hollow cylinder, and allows a power source wire for power supply and a control wire for rotation control to pass through the inside of shaft 3. In the upper part of shaft 3 along the rotational axis (on the upper side of FIG. 1), shaft 3 includes stepped portion 3a (a first stepped portion) in contact with inner ring 43 of bearing 4a. Stepped portion 3a is circularly formed along the outer circumference of shaft 3. The outer diameter of shaft 3 is larger at a portion positioned below stepped portion 3a along the rotational axis than at a portion positioned above stepped portion 3a along the rotational axis. The outer diameter of a portion of shaft 3, the portion being positioned above stepped portion 3a along the rotational axis, is smaller than the inner diameter of inner ring 43 of bearing 4a so that shaft 3 can be smoothly inserted into inner ring 43.

[0032] In the lower part of shaft 3 along the rotational axis, stepped portion 3b (a second stepped portion) is provided. Stepped portion 3b is circularly formed along the outer circumference of shaft 3. The outer diameter of shaft 3 is smaller at a portion positioned below stepped portion 3b along the rotational axis than at a portion positioned above stepped portion 3b along the rotational axis. In other words, the outer diameter (a third outer diameter) of a portion between stepped portion 3a and stepped portion 3b is larger than the outer diameter (a first outer diameter) of the portion positioned above stepped portion 3a along the rotational axis and the outer diameter (a second outer diameter) of the portion below stepped portion 3b along the rotational axis. The outer

diameter of a portion of shaft 3, the portion being positioned below stepped portion 3b along the rotational axis, is smaller than the inner diameter of inner ring 45 of bearing 4b so that shaft 3 can be smoothly inserted into inner ring 45. Thus, shaft 3 includes large-diameter section 36 (a third section) between
5 stepped portion 3a and stepped portion 3b. Shaft 3 further includes small-diameter section 34 (a first section) located above stepped portion 3a, and small-diameter section 35 (a second section) located below stepped portion 3b. The outer diameter of large-diameter section 36 of shaft 3 is larger than the inner diameter of inner ring 43 of bearing 4a, and larger than the inner
10 diameter of inner ring 45 of bearing 4b.

[0033] Stator core 1 is pressed fit and fixed to large-diameter section 36 of shaft 3.

[0034] Bearing 4a is fitted to shaft 3 from above along the rotational axis. Inner ring 43 of bearing 4a is held in a state of being in contact with stepped
15 portion 3a. Shaft 3 is inserted through shaft opening 53 of rotor holder 5. Outer ring 44 of bearing 4a is pressed fit into bearing holder 13 provided around shaft opening 53 of rotor holder 5.

[0035] Control circuit board 10 is provided below stator core 1 along the rotational axis. Control circuit board 10 is electrically and physically
20 connected to stator core 1 and configured to control driving of brushless DC motor 9. Control circuit board 10 includes substrate holder 10a and substrate 10b. Substrate holder 10a includes, at the center thereof, cylindrical section 10c through which shaft 3 is inserted. Substrate 10b includes, at the center thereof, an opening through which cylindrical section 10c and shaft 3 are
25 inserted. In the present embodiment, the opening provided at the center of substrate 10b communicates with the outer circumference of substrate 10b, and thus has what is called a notched shape. Substrate holder 10a further includes

holders 10d for the inner circumference and the outer circumference the holders 10d being configured to hold substrate 10b. Holder 10d for the inner circumference is configured to hold an inner circumferential portion of substrate 10b. Holder 10d for the outer circumference is configured to hold an outer circumferential portion of substrate 10b. Holder 10d for the outer circumference includes arm 10e protruding radially, and hook 10f configured to hook and hold substrate 10b mounted from below along the rotational axis. Holder 10d for the inner circumference includes arm 10e protruding downward along the rotational axis, and hook 10f configured to hook and hold substrate 10b mounted from below along the rotational axis.

[0036] As illustrated in FIG. 4, substrate 10b includes an opening (hereinafter, referred to as a center opening) 37 at the approximately center thereof, center opening 37 through which shaft 3 is inserted. Center opening 37 communicates with the outer circumference of substrate 10b, and accordingly, substrate 10b is externally shaped like a letter "C" of the alphabet. As illustrated in FIG. 2, substrate holder 10a holds the outer circumference of substrate 10b by holder 10d for the outer circumference (hook 10f), and holds center opening 37 of substrate 10b by holder 10d for the inner circumference (hook 10f). More specifically, hook 10f of holder 10d for the inner circumference is engaged with a communicating section between a center portion and an outer circumferential portion of the center opening of substrate 10b, the communicating section being located closer to the outer circumference than a portion through which shaft 3 passes.

[0037] Stator core 1 is provided with substrate holder support 18. Substrate holder support 18 includes a plurality of cylindrical walls standing downward below stator core 1, more specifically, standing downward on the substrate holder 10a side, on the radially outer side of shaft 3, and on the radially inner

side of driving coil 2. Substrate holder support 18 is molded using resin.

[0038] At a position at which inserted shaft 3 is fixed to substrate holder 10a, the upper edge of cylindrical section 10c along the rotational axis is in contact with stator core 1. In other words, cylindrical section 10c includes upper edge
5 10g (a third edge) in contact with stator core 1. Substrate holder 10a is in contact with the lower edge of substrate holder support 18.

[0039] Furthermore, with substrate 10b being mounted to shaft 3, elastic member 11 is fitted to shaft 3 from below along the rotational axis. The inner diameter of elastic member 11 is slightly larger than the outer diameter of shaft
10 3. More specifically, the inner diameter of elastic member 11 is larger than the outer diameter of large-diameter section 36 of shaft 3. Upper edge 11a (a first edge) of elastic member 11 along the rotational axis comes into contact with lower edge 10h (a fourth edge) of cylindrical section 10c of substrate holder 10a. Thus, the elastic force of elastic member 11 acts on stator core 1 via substrate
15 holder 10a on the upper edge 11a side. Note that, in the present embodiment, as elastic member 11, a spring is used, but use may be made of a wave washer, a rubber washer, or an urethane (rubber) sleeve, for example.

[0040] Bearing 4b is inserted in the lower end of shaft 3, or in the vicinity of the lower end thereof. In other words, bearing 4b is positioned at
20 small-diameter section 35 of shaft 3. Lower edge 11b (a second edge) of elastic member 11 is in contact with inner ring 45 of bearing 4b. Thus, the elastic force of elastic member 11 acts on inner ring 45 of bearing 4b on the lower edge 11b side. Bearing 4b is pressed fit and fixed to bearing mount 8b of rotor cover 8. More specifically, outer ring 46 of bearing 4b is pressed fit and fixed to
25 bearing mount 8b of rotor cover 8, while inner ring 45 is not in contact with bearing mount 8b.

[0041] With this configuration, control circuit board 10 is pressurized by elastic

member 11 and fixed between bearing 4b and stator cores 1. Elastic member 11 presses inner ring 45 of bearing 4b down, thereby causing a positional discrepancy along the rotational axis between inner ring 45 and outer ring 46 of bearing 4b. In other words, inner ring 45 of bearing 4b is positioned lower
5 along the rotational axis than outer ring 46. On the other hand, on an upper part along the rotational axis, a pressure from elastic member 11 having coming into contact with substrate holder 10a acts on the inner ring of bearing 4a via substrate holder 10a, stator core 1, and shaft 3. With a downward pressure from elastic member 11, bearing 4b is pressed downward, and rotor cover 8
10 fixed to bearing 4b and rotor holder 5 are pressed downward, accordingly. It can be said that this causes rotor holder 5 to press outer ring 44 of bearing 4a down. In other words, inner ring 43 of bearing 4a is positioned upper along the rotational axis than outer ring 44.

[0042] As described above, control circuit board 10 is held by being pressed
15 downward by elastic member 11 toward stator core 1 united to shaft 3. Therefore, by detaching rotor holder 5 from rotor cover 8, rotor cover 8 can be removed downward. Bearing 4b is not fixed to shaft 3, but fixed to rotor cover 8, therefore can be removed together with rotor cover 8. Elastic member 11 is merely fitted to shaft 3, not fixed to shaft 3. Elastic member 11 can also be
20 easily removed downward. When elastic member 11 is removed, an upward pressure on control circuit board 10 from elastic member 11 is removed. Control circuit board 10 can be removed downward by the removal of the upward pressure. Thus, stator core 1 united to shaft 3 can be easily detached from control circuit board 10. Note that the outer diameter of small-diameter
25 section 34 of shaft 3 is smaller than the inner diameter of inner ring 43 of bearing 4a. The outer diameter of small-diameter section 35 of shaft 3 is smaller than the inner diameter of inner ring 45 of bearing 4b. Therefore,

bearing 4a and bearing 4b can be easily removed from shaft 3.

[0043] The length of shaft 3 and the length of cylindrical section 10c along the rotational axis can be adjusted at a designing stage, and thus, a stroke of elastic member 11 can be appropriately secured. In other words, the magnitude of a pressure from elastic member 11 can be appropriately set. By the application of an appropriate pressure to bearing 4a and bearing 4b, heat generation from bearing 4a and bearing 4b can be substantially prevented, noise generation from bearing 4a and bearing 4b can be reduced, and as a result, the deterioration of bearing 4a and bearing 4b can be substantially prevented.

[0044] Next, rotor holder 5 and mounting of magnet 6 to rotor holder 5 will be described.

[0045] As illustrated in FIG. 3, fixing section 12 configured to couple rotor cover 8 to rotor holder 5 is provided at the bottom of rotor holder 5. Fixing section 12 protrudes outward at the bottom of rotor holder 5, and has a threaded hole through which a screw for fixing passes. Fixing section 12 may be in the shape of a flange into which fixing section 12 is circumferentially integrated, or may have a shape in which only a threaded hole portion protrudes as illustrated in FIG. 3.

[0046] Rotor holder 5 further includes holder outer frame 5a made of aluminum, and insert ring 5b provided inside holder outer frame 5a. As described above, holder outer frame 5a of rotor holder 5 has an approximately cylindrical shape, and the top of rotor holder 5 is top surface 51 having shaft opening 53, and the bottom of rotor holder 5 is an opening to be covered with rotor cover 8. The cylindrical shaped holder outer frame 5a is provided with two ring-shaped stepped portions (stepped portion 14a, stepped portion 14b) so that the diameter of the cylindrical shaped holder outer frame 5a becomes smaller towards the top, that is, top surface 51. Stepped portion 14a is located

lower than stepped portion 14b. Balance-weight insertion hole 41 configured to allow balance weight 40 to be inserted thereinto is circularly provided at a position closer to the bottom than stepped portion 14a. Bearing holder 13 is provided in top surface 51 located upper than stepped portion 14b.

5 [0047] As illustrated in FIG. 2 and FIG. 3, insert ring 5b is provided to cover a region between stepped portion 14a and stepped portion 14b in the inner circumferential surface of holder outer frame 5a. The top surface of insert ring 5b is arranged to come into contact with stepped portion 14b. Magnet 6 is attached to inner circumferential surface 54 of insert ring 5b. Magnet 6 is
10 attached so that the top surface of magnet 6 comes into contact with stepped portion 14b. Insert ring 5b is produced in such a way that a flat plate made of a ferromagnetic metal is transformed into a cylinder to be fitted to the inner circumferential surface of holder outer frame 5a, and mounted onto holder outer frame 5a. Examples of the ferromagnetic metal of which insert ring 5b is
15 made include iron.

[0048] Holder outer frame 5a is produced by die-casting using aluminum. With die-casting, the external shape of holder outer frame 5a can be designed highly flexibly. After the mounting of insert ring 5b, inner circumferential surface 54 of insert ring 5b is subjected to machining using an engine lathe, for
20 example, whereby a high-precision cylindrical shape is achieved. In other words, inner circumferential surface 54 of insert ring 5b forms a cylinder shape exhibiting an approximately true circular cross section. Magnet 6 is bonded and fixed to inner circumferential surface 54 of insert ring 5b. Thus, magnet 6 mounted onto the inner circumferential surface of the cylinder having an
25 approximately true circular cross section is highly accurately arranged with respect to shaft 3. That is, the distance between the outer circumferential surface of stator core 1 and magnet 6 is more accurately provided, and as a

result, brushless DC motor 9 rotates efficiently.

[0049] With the machining, the flatness (surface smoothness) of a surface to which magnet 6 is bonded is increased, whereby the adhesion of the magnet can be enhanced. Furthermore, with such machining, solid metal comes only to the surface to which magnet 6 is bonded, whereby the adhesion of the magnet can be enhanced, and rust can be prevented without machining any surface other than the surface to which magnet 6 is bonded.

[0050] Insert ring 5b is preferably be produced by rolling up a rectangular metal plate by a triple roller. When a cylinder is thus formed, a portion at which both edges of the plate are joined to each other, that is, a joint, is made. A magnetic flux is hard to pass through this joint. Therefore, an edge of magnet 6 at which a line of magnetic force is generated is preferably not in agreement with the joint of insert ring 5b. Magnet 6 is more preferably disposed so that the center of magnet 6 is in agreement with the joint of insert ring 5b. Note that, since there is a plurality of magnets 6, it is only required that the circumferential center of at least one of magnets 6 is in agreement with the joint of insert ring 5b. Note that the joint is a portion formed of circumferential edges of the rolled metal plate.

[0051] Since the top surface of magnet 6 comes into contact with stepped portion 14b, positioning of magnet 6 can be easily performed.

[0052] The thickness of insert ring 5b, in other words, the radial thickness of insert ring 5b is preferably larger. In other words, since insert ring 5b functions as a rotor yoke, a larger thickness of insert ring 5b allows the saturation of a magnetic flux to be reduced. In other words, a larger thickness of insert ring 5b allows an induction voltage generated in a winding to be increased, whereby magnet 6 functions sufficiently, and thus, brushless DC motor 9 with high efficiency is achieved. Note that, although insert ring 5b

having a larger thickness leads to a higher induction voltage to be generated, the generated induction voltage is saturated in a region having a thickness larger than a predetermined thickness. Therefore, an appropriate thickness of insert ring 5b is preferably employed in accordance with a magnetic force of magnet 6 to be used.

[0053] The length of insert ring 5b along the rotational axis is preferably longer than the length of magnet 6 along the rotational axis. Insert ring 5b having a length longer than the length of magnet 6 allows a magnetic flux to efficiently pass through, whereby brushless DC motor 9 with high efficiency is achieved.

[0054] Next, position sensing element 7 will be described.

[0055] As illustrated in FIG. 1, stator core 1 is provided with an opening, namely, slot 1b, for arranging a winding after the installation of a slot insulator. A plurality of slots 1b is circumferentially provided. On the other hand, as described above, control circuit board 10 configured to drive brushless DC motor 9 is disposed below stator core 1 along the rotational axis. Position sensing element 7 is provided so as to connect control circuit board 10 to outer circumferential edge 1c of stator core 1.

[0056] More specifically, as illustrated in FIG. 5 and FIG. 6, position sensing element 7 includes Hall element 7a configured to actually detect a position, and element holder 7b configured to hold Hall element 7a.

[0057] Hall element 7a is fixed to control circuit board 10, and also connected to a circuit formed on control circuit board 10. Thus, Hall element 7a is configured to transmit a detected position to the control circuit. Element holder 7b configured to hold Hall element 7a includes protrusion 7c protruding toward stator core 1. Protrusion 7c is inserted into slot 1b of stator core 1 from below along the rotational axis. Hence, Hall element 7a is positioned with

respect to stator core 1.

[0058] More specifically, Hall element 7a stands on control circuit board 10. Hall element 7a stands at a position approximately facing outer circumferential edge 1c of stator core 1. In other words, Hall element 7a is positioned in the radial vicinity of outer circumferential edge 1c of stator core 1. Hall element 7a is positioned below stator core 1 along the rotational axis. More specifically, Hall element 7a is positioned between stator core 1 and substrate 10b along the rotational axis. The vicinity of outer circumferential edge 1c in which Hall element 7a stands may be a position on the radially outer or inner side of outer circumferential edge 1c of stator core 1, the position allowing a magnetic force of magnet 6 to be detected and not hindering a rotor from rotating.

[0059] Then, element holder 7b covers three Hall elements 7a from the stator-core 1 side to integrally hold three Hall elements 7a. Under this state, protrusion 7c is inserted into slot 1b so as to be united to stator core 1 together with control circuit board 10. A plurality of protrusions 7c is provided, and each of protruding sections 7c is inserted into a corresponding one of slots 1b, whereby positioning and fixing is surely performed.

[0060] The length of magnet 6 along the rotational axis is larger than the thickness of stator core 1 along the rotational axis. A certain portion in the lower part of magnet 6 does not face stator core 1. In particular, magnet 6 protrudes from stator core 1 toward control circuit board 10 along the rotational axis. Hall element 7a is configured to detect a magnetic force coming out of the above-mentioned portion.

[0061] With this configuration, the positional relationship between driving coil 2 and Hall element 7a is fixed regardless of a manufacturing process or variations between components. Therefore, positional information on a rotor (magnet 6) outputted from Hall element 7a can be highly accurate, and as a

result, efficient motor characteristics can be achieved.

[0062] As illustrated in FIG. 7 and FIG. 8, brushless DC motor 9 of the present embodiment includes three phase windings, namely, winding U15, winding V16, and winding W17. Brushless DC motor 9 of the present embodiment further
5 includes 12 teeth 1a. As illustrated in FIG. 7, 12 teeth 1a are disposed radially around shaft 3. Winding U15 includes coil U15-1, coil U15-2, coil U15-3, and coil U15-4, each being wound around a corresponding one of four teeth 1a in phase U. As illustrated in FIG. 7, coil U15-1 and coil U15-3 face each other across the rotational axis (shaft 3), and similarly, coil U15-2 and coil U15-4 face
10 each other across the rotational axis. The same applies to winding V16 in phase V and winding W17 in phase W.

[0063] As illustrated in FIG. 8, winding U15, winding V16, and winding W17 are connected by star connection. Coil U15-4, coil V16-4, and coil W17-4 are commonly connected.

15 [0064] For example, winding U15 is configured with coil U15-1, coil U15-2, coil U15-3, and coil U15-4 arranged in series in this order. In other words, winding U15 is formed of an electric wire having first end 15-8 and second end 15-9. This electric wire forms coil U15-1, coil U15-2, coil U15-3, and coil U15-4. The electric wire further forms crossover-wire 24-1 for connecting coil U15-1 to coil
20 U15-2, crossover-wire 24-2 for connecting coil U15-2 to coil U15-3, and crossover-wire 24-3 for connecting coil U15-3 to coil U15-4. Similarly, winding V16 is formed of an electric wire having first end 16-8 and second end 16-9. This electric wire forms coil V16-1, coil V16-2, coil V16-3, coil V16-4, crossover-wire 22-1, crossover-wire 22-2, and crossover-wire 22-3. Similarly,
25 winding W17 is formed of an electric wire having first end 17-8 and second end 17-9. This electric wire forms coil W17-1, coil W17-2, coil W17-3, coil W17-4, crossover-wire 23-1, crossover-wire 23-2, and crossover-wire 23-3.

[0065] In the present embodiment, crossover-wires 24-2, 22-2, and 23-2 of respective windings U15, V16, and W17 are treated by making use of substrate holder support 18.

[0066] As described above, substrate holder support 18 includes a plurality of
5 cylindrical walls standing between shaft 3 and windings U15, V16 and W17. As illustrated in FIG. 9, in the present embodiment, substrate holder support 18 includes three cylindrical walls coaxially arranged, namely, first support wall 18a, second support wall 18b, and third support wall 18c when viewed from the inner circumference side. First support wall 18a and second support wall 18b
10 are of the same height, and the tops of first support wall 18a and second support wall 18b are in contact with substrate holder 10a. The height of third support wall 18c is lower than the height of first support wall 18a and the height of second support wall 18b. First support wall 18a and second support wall 18b are provided with recesses (portions having a lower wall-height)
15 through which a later-mentioned terminal wire, namely, a common wire passes. Third support wall 18c has three height stages to allow the crossover-wires to pass.

[0067] Between first support wall 18a and second support wall 18b, there is formed inner circumferential groove 19 through which first end 15-8 and second
20 end 15-9 of winding U15, first end 16-8 and second end 16-9 of winding V16, and first end 17-8 and second end 17-9 of winding W17 pass. Outer circumferential groove 20 is formed between second support wall 18b and third support wall 18c so as to allow crossover-wire 24-2 of winding U15, crossover-wire 22-2 of winding V16, and crossover-wire 23-2 of winding W17.
25 In other words, substrate holder support 18 acts as a member that forms inner circumferential groove 19 and outer circumferential groove 20.

[0068] Windings (terminal wires) drawn from coil U15-1, coil V16-1, and coil

W17-1 pass through the recesses provided in second support wall 18b, and are drawn into inner circumferential groove 19. Then, connection between these terminal wires and lead wires is executed inside inner circumferential groove 19 and connection hole 21. In other words, first end 15-8 of winding U15, first
5 end 16-8 of winding V16, and first end 17-8 of winding W17 are accommodated in inner circumferential groove 19. The lead wires are pulled out to the outside.

[0069] Connection hole 21 is provided on the inner circumference side of first support wall 18a, and protrudes inward. The lead wires and the terminal
10 wires are connected by soldering to form a connection portion. The connection portion is inserted into connection hole 21, thereby being held.

[0070] On the other hand, windings (common wires for star connection) drawn from coil U15-4, coil V16-4, and coil W17-4 also pass through the recesses provided in second support wall 18b, and are drawn into inner circumferential
15 groove 19. Then, soldered connection is applied to the windings in inner circumferential groove 19. In other words, second end 15-9 of winding U15, second end 16-9 of winding V16, and second end 17-9 of winding W17 are accommodated in inner circumferential groove 19. Note that recesses through which the common wires pass are separately provided from the recesses
20 through which the terminal wires pass.

[0071] Crossover-wire 24-1 between coil U15-1 and coil U15-2 adjacent to each other is laid in a winding space. Crossover-wire 24-3 between coil U15-3 and coil U15-4 adjacent to each other is also laid in the winding space. As described above, coil U15-1 and coil U15-3 face each other across the rotational
25 axis, while coil U15-2 and coil U15-4 face each other across the rotational axis. Crossover-wire 24-2 between coil U15-2 and coil U15-3 approximately facing each other is laid in outer circumferential groove 20 of substrate holder support

18 so as not to come into contact with other windings. In other words, crossover-wire 24-2 connected to coil U15-2 passes through outer circumferential groove 20 and is connected to coil U15-3 positioned to approximately face coil U15-2. Similarly, crossover-wire 22-2 between coil
5 V16-2 and coil V16-3 and crossover-wire 23-2 between coil W17-2 and coil W17-3 pass through outer circumferential groove 20. As described above, third support wall 18c has three height stages. Such walls having different heights are wall 18c-1, wall 18c-2, and wall 18c-3 in descending order of height. The terminal wires and the common wires are introduced into inner circumferential
10 groove 19 via the top of wall 18c-1. Then, crossover-wires 22-2, 23-2, and 24-2 are introduced into outer circumferential groove 20 via the tops of wall 18c-2 and wall 18c-3. At this time, each of crossover-wires 22-2, 23-2, and 24-2 is introduced into outer circumferential groove 20 via the top of a corresponding one of third support walls 18c having different heights so that winding U15,
15 winding V16, and winding W17 do not come into contact with each other.

[0072] As described above, crossover-wires 22-2, 23-2, and 24-2 are treated (organized) by using outer circumferential groove 20 provided in substrate holder support 18. This allows work for windings to be continuously performed and thereby simpler wiring to be achieved. That is, work for
20 windings can be more easily performed.

[0073] Wiring for the terminal wires and the common wires is performed in inner circumferential groove 19. Wiring for the crossover-wires is performed in outer circumferential groove 20. The position of inner circumferential groove 19 is different radially from the position of outer circumferential groove 20.
25 This allows a radial space to be effectively used without making use of a space along the rotational axis, and thereby can reduce the size of brushless DC motor 9. Furthermore, through the use of inner circumferential groove 19 and outer

circumferential groove 20, higher insulation reliability can be achieved.

[0074] The connection portion between the terminal wires of winding U15, winding V16, winding W17 and the lead wires to be pulled out to the outside is inserted into connection hole 21. With this configuration, the connection
5 portion between the terminal wires and the lead wires is protected, and insulation treatment using an insulation tube can be made unnecessary.

[0075] The tops of first support wall 18a and second support wall 18b come into contact with substrate holder 10a, so that control circuit board 10 can be stably held. First support wall 18a and second support wall 18b are disposed
10 in the vicinity of winding U15, winding V16, and winding W17, and are in the shape of a cylinder having a predetermined diameter. Thus, substrate holder 10a can be more stably held.

[0076] As illustrated in FIG. 4, earth section 31 is printed on substrate 10b. One end 31a of earth section 31 is disposed so as to be distant by the size of
15 discharge gap 33 from a predetermined portion (referred to as proximal portion 32a) of power source line 32. Power source line 32 is an input section to which a power source is connected. In the present embodiment, AC power source is connected to power source line 32. In the present embodiment, a description is given in which a motor connected to a single-phase alternative current power
20 source is taken as an example, and accordingly, two power source lines 32 are provided. Earth section 31 is provided in the vicinity of proximal portion 32a of each of power source lines 32. In other words, each of power source lines 32 has proximal section 32a positioned closest to earth section 31. The shortest distance between proximal section 32a of power source line 32 and earth section
25 31 corresponds to the size of discharge gap 33. Another end 31b of earth section 31 is disposed at the edge of center opening 37 (the circumference of center opening 37) of substrate 10b, in particular, at a portion of the edge in

contact with shaft 3. Thus, shaft 3 is arranged to be in contact with the edge of center opening 37 of substrate 10b. Here, shaft 3 is not always in contact with the edge of center opening 37 of substrate 10b, but, there is a narrow gap between shaft 3 and the edge of center opening 37. In other words, the inner
5 diameter of center opening 37 provided in substrate 10b is larger than the outer diameter of shaft 3.

[0077] In this configuration, when a high voltage such as a lightning surge is impressed to power source line 32, first, electric discharge occurs across discharge gap 33, and a large current flows into earth section 31. The current
10 having flowed into earth section 31 is discharged at other end 31b of earth section 31, that is, the edge of center opening 37 of substrate 10b, and flows into shaft 3. Then, the current escapes to a ground (GND) through shaft 3, and, as a result, substrate 10b is protected.

[0078] Thus, without connecting substrate 10b to shaft 3 by using a lead wire,
15 a countermeasure against, for example, a lightning surge can be taken with a simple configuration.

[0079] The size of discharge gap 33 is preferably 0.5 mm or larger.

[0080] Earth section 31 is preferably printed so as to come around from the edge of center opening 37 of substrate 10b into the inner circumferential surface
20 of center opening 37. In other words, other end 31b of earth section 31 is preferably printed on the inner circumferential edge surface of center opening 37 of substrate 10b.

[0081] Outer-rotor brushless DC motor 9 with the above-described configuration is suitably used for a ceiling fan having a large blade-diameter.
25 The ceiling fan is an air blower arranged to be hung from a ceiling. In such ceiling fan, it is necessary to correct poor balance caused due to a large blade-diameter. Specifically, a balance is struck by putting a balance weight

on a certain portion of a housing so that, when a blade is attached, the horizontal center of gravity is on the rotational axis (shaft 3).

[0082] As illustrated in FIG. 3, in the present embodiment, a plurality of balance-weight insertion holes 41 for the insertion of balance weight 40 is provided on the bottom of holder outer frame 5a. As illustrated in FIG. 2 and FIG. 3, balance-weight insertion hole 41 is a hole that allows a balance weight to be inserted therein from the bottom side of holder outer frame 5a. Two or more balance-weight insertion holes 41 are circumferentially arranged at the bottom of holder outer frame 5a. In the present embodiment, balance-weight insertion holes 41 are arrayed without a gap therebetween at the bottom of holder outer frame 5a. For striking a balance, one or more balance weights 40 are inserted into balance-weight insertion holes 41 so that the horizontal center of gravity is put on shaft 3.

[0083] Furthermore, balance weight 40 is preferably smaller in order to make fine adjustment of balance. However, too small balance weight 40 cannot sufficiently offer targeted performance on balance adjustment. In contrast, too large balance weight 40 makes balance adjustment more difficult.

[0084] In the present embodiment, balance weight 40 is in the shape of an approximately rectangle. Balance-weight insertion hole 41 is configured to hold two facing sides of balance weight 40 by sandwiching the two sides with two rails of the hole. Balance-weight insertion hole 41 has a tapered shape, that is, tapers down from its entry toward the back. In other words, the two rails forming balance-weight insertion hole 41 are not parallel, but the clearance therebetween is narrowed from the entry toward the back.

[0085] The shape of balance-weight insertion hole 41 is not limited to the above-described shape formed by the two rails, but may be a conical or pyramid shape.

[0086] In ceiling fan 50 including outer-rotor brushless DC motor 9, the upper part of brushless DC motor 9 may be covered with canopy 42, as illustrated in FIG. 10. Through the use of canopy 42, connection of power source wiring and connection of control wiring, each being provided in shaft 3, can be made inside
5 canopy 42. In other words, a connection portion in power source wiring and a connection portion in control wiring can be covered up.

[0087] In brushless DC motor 9 of the present embodiment, control circuit board 10 is disposed below stator core 1. As illustrated in FIG. 1, due to direct-current drive, control circuit board 10 of brushless DC motor 9 is
10 equipped with many controller components, and thereby is large in size. Therefore, by covering a portion of brushless DC motor 9 on the stator-core 1 side with canopy 42, canopy 42 and ceiling fan 50 can be reduced in size.

INDUSTRIAL APPLICABILITY

15 [0088] An air blower equipped with the brushless DC motor according to the present disclosure is useful as an air blower equipped with a brushless DC motor for driving fans that is used for a ceiling fan with a large blade-diameter or other fans.

20 REFERENCE MARKS IN THE DRAWINGS

[0089] 1...stator core

1a...teeth

1b...slot

1c...outer circumferential edge

25 2...driving coil

3...shaft

3a...stepped portion

	3b...stepped portion
	4a...bearing (first bearing)
	4b...bearing (second bearing)
	5...rotor holder
5	5a...holder outer frame
	5b...insert ring
	6...magnet
	7...position sensing element
	7a...hall element
10	7b...element holder
	7c...protrusion
	8...rotor cover
	8a...shaft opening
	8b...bearing mount
15	9...motor
	10...control circuit board
	10a...substrate holder
	10b...substrate
	10c...cylindrical section
20	10d...holder
	10e...arm
	10f...hook
	10g...upper edge (third edge)
	10h...lower edge (fourth edge)
25	11...elastic member
	11a...upper edge (first edge)
	11b...lower edge (second edge)

	12...fixing section
	13...bearing holder
	14a...stepped portion
	14b...stepped portion
5	15...winding U
	15-1, 15-2, 15-3, 15-4...coil U
	16...winding V
	16-1, 16-2, 16-3, 16-4...coil V
	17...winding W
10	17-1, 17-2, 17-3, 17-4...coil W
	18...substrate holder support
	18a...support wall
	18b...support wall
	18c...support wall
15	19...inner circumferential groove
	20...outer circumferential groove
	21...connection hole
	22-1, 22-2, 22-3...crossover-wire
	23-1, 23-2, 23-3...crossover-wire
20	24-1, 24-2, 24-3...crossover-wire
	31...earth section
	32...power source line
	33...discharge gap
	34...small-diameter section (first section)
25	35...small-diameter section (second section)
	36...large-diameter section (third section)
	41...balance-weight insertion hole

	42...canopy
	43...inner ring
	44...outer ring
	45...inner ring
5	46...outer ring
	50...ceiling fan
	51...top surface
	52...inner circumferential surface
	53...shaft opening
10	54...inner circumferential surface
	101...bracket
	101a...opening
	102...stator core
	103...bobbin
15	104...coil
	106...rotor
	106a...rotor magnet
	113...sensor
	114...Hall IC
20	115...printed circuit board

CLAIMS

1. A brushless direct-current (DC) motor, comprising:
 - a shaft;
 - a stator core including a plurality of slots, and fixed to the shaft, the
 - 5 plurality of slots being arranged along a periphery of the stator core;
 - a rotor holder having an inner peripheral surface facing the stator core;
 - a plurality of magnets arranged on the inner peripheral surface of the
 - rotor holder along a peripheral of the rotor holder; and
 - a control circuit board allowing the shaft to pass therethrough, and
 - 10 being adjacent, along a rotational axis of the shaft, to the stator core,
 - wherein the control circuit board includes at least one Hall element
 - configured to detect magnetic forces of the plurality of magnets, and
 - wherein the at least one Hall element is held by an element holder
 - inserted into at least one of the slots of the stator core, the Hall element
 - 15 standing on the control circuit board, and
 - wherein the element holder includes protrusions protruding toward the stator
 - core, the protrusions being inserted into the slots of the stator core to position
 - the at least one Hall element with respect to the stator core.
2. The brushless DC motor according to claim 1,
 - 20 wherein the control circuit board further includes a substrate to which
 - the at least one Hall element is connected, and
 - wherein the at least one Hall element is positioned in a radial vicinity of
 - an outer peripheral edge of the stator core, and positioned between the stator
 - core and the substrate along the rotational axis.
- 25 3. The brushless DC motor according to claim 1, wherein at least one of
- the magnets protrudes from the stator core toward the control circuit board
- along the rotational axis.
4. The brushless DC motor according to claim 1,

wherein the element holder includes two or more protrusions, each of the two or more protrusions being configured to be inserted into a corresponding one of two or more of the plurality of slots.

- 5 5. The brushless DC motor according to claim 1,
 wherein the at least one Hall element comprises a plurality of Hall elements, and

 wherein the element holder is configured to integrally hold the plurality of Hall elements.

- 10 6. A ceiling fan, including the brushless DC motor according to claim 1.

7. The brushless DC motor according to claim 2,
 wherein the radial vicinity of the outer peripheral edge is a position on a radially outer side of the outer circumferential edge of the stator core.

8. The brushless DC motor according to claim 1,

- 15 wherein the at least one Hall element is positioned below the stator core along the rotational axis, and

 a length of the magnet along a rotational axis is larger than a thickness of the stator core along the rotational axis, and a portion of the lower part of magnet does not face the stator core.