

DESCRIPTION

BRUSHLESS DC MOTOR

5 TECHNICAL FIELD

[0001] The present disclosure relates to a brushless DC motor to be used for driving fans, such as ceiling fans and ventilation fans.

BACKGROUND ART

10 [0002] In recent years, ceiling fans have been required to realize more comfortable environments by air-blowing and the circulation of indoor air. In large living spaces and high-ceilinged places such as commercial and public facilities, a high airflow, in other words, blowing air strongly in a large area is needed, and accordingly a large-sized ceiling fan having a larger blade-diameter
15 has been demanded.

[0003] As this type of ceiling fan equipped with a brushless DC motor, a ceiling fan equipped with a brushless DC motor that is disclosed in Patent Literature 1 has been conventionally known.

[0004] Hereinafter, the ceiling fan equipped with the brushless DC motor will
20 be described with reference to FIG. 13.

[0005] As illustrated in FIG. 13, driving coil 102 is wound around stator core 101, and shaft 103 is fixed to the center of stator core 101. An inner ring of bearing 104a is fixed to shaft 103, and rotor yoke 105 is fixed to an outer ring of bearing 104a. A plurality of magnets 106 is attached to the inner
25 circumferential face of rotor yoke 105 at predetermined intervals. Position sensing element 107 configured to detect the magnetic flux of magnets 106 is fixed to stator core 101.

[0006] Furthermore, an inner ring of bearing 104b is fixed to shaft 103 on a side opposite to bearing 104a, and rotor cover 108 is fixed to an outer ring of bearing 104b. Rotor yoke 105 and rotor cover 108 are fixed so that rotor yoke 105 and rotor cover 108 enclose stator core 101, and thus, brushless DC motor 109 is configured.

Citation List

[0007] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2016-63678

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SUMMARY OF INVENTION

[0008] However, such conventional brushless DC motor has the following problem.

[0009] To realize a ceiling fan having a larger blade-diameter and configured to supply high airflow, a stator core and a magnet that serve as constituents of a motor need to be increased in size. In other words, such ceiling fan can be realized by, for example, making the outer diameter of a stator core larger, increasing the thickness in the direction of stacking, or making a magnet axially longer. However, to newly design each of the constituents of the motor, new equipment and molds and dies are needed, so that development investment costs increase.

[0010] The present disclosure is devised to solve the above-described problem, and an object of the present disclosure is to provide a brushless DC motor capable of reducing investment in new equipment and molds and dies and achieving higher output at low cost and with high driving torque.

[0011] In order to accomplish this object, a brushless DC motor according to an aspect of the present disclosure includes a shaft defining a rotation axis, a first

stator, a second stator, a first rotor, a second rotor, and a coupling unit. The first stator has a cylindrical shape with a top face and a bottom face, and the center of the circle of the cylindrical shape is fixed to the shaft. The second stator has a cylindrical shape with a top face and a bottom face, and, while the
5 second stator is adjacent to the first stator, the center of the circle of the cylindrical shape is fixed to the shaft. The first rotor includes a first flange in a face perpendicular to the rotation axis, and is rotatably attached to the shaft so as to face a side face of the first stator. The second rotor includes a second flange in a face perpendicular to the rotation axis, and is rotatably attached to
10 the shaft so as to face a side face of the second stator. The coupling unit is configured to axially couple the first rotor to the second rotor. The first stator and the second stator are identical components, and the first rotor and the second rotor are identical components.

[0012] According to the present disclosure, a brushless DC motor capable of
15 achieving high output at low cost can be provided.

BRIEF DESCRIPTION OF DRAWINGS

[0013] FIG. 1 is a side view of a ceiling fan equipped with a brushless DC motor according to a first embodiment of the present disclosure.

20 FIG. 2 is a perspective assembly view of an overall configuration of the brushless DC motor.

FIG. 3 is an assembly view of a configuration of a rotor of the brushless DC motor.

FIG. 4 is a cross-sectional view of the overall configuration of the
25 brushless DC motor.

FIG. 5A is a diagram illustrating a state in which holding rings of the brushless DC motor are fixed.

FIG. 5B is an enlarged view of a principal part illustrated in FIG. 5A.

FIG. 6A is a cross-sectional view illustrating the directions of magnetization of adjoining magnets between the first rotor and the second rotor of the brushless DC motor.

5 FIG. 6B is a cross-sectional view illustrating the directions of magnetization of adjoining magnets between the first rotor and the second rotor of the brushless DC motor.

FIG. 7A is a perspective view illustrating a state in which the rotors are coupled to the coupling unit in the brushless DC motor.

10 FIG. 7B is a perspective view of the coupling unit.

FIG. 7C is an enlarged view of a principal part illustrated in FIG. 7B.

FIG. 8 is a block diagram of a configuration of a ceiling fan equipped with the brushless DC motor.

FIG. 9A is a cross-sectional view of a wiring structure of a motor lead
15 wire of the brushless DC motor.

FIG. 9B is a cross-sectional view of the wiring structure of the motor lead wire of the brushless DC motor.

FIG. 10 is a plan view illustrating a wiring state of a motor lead wire.

FIG. 11 is a cross-sectional view of an overall configuration of a
20 brushless DC motor according to a second embodiment of the present disclosure.

FIG. 12 is a block diagram of a configuration of a ceiling fan equipped with the brushless DC motor.

FIG. 13 is an assembly view of a configuration of a conventional
25 brushless DC motor.

DESCRIPTION OF EMBODIMENTS

[0014] Hereinafter, embodiments of the present disclosure will be described with reference to the drawings. Note that 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 constituents are given the same reference numeral, and the repetition of the same description thereof is avoided.

[0015] (First Embodiment)

FIG. 1 is a side view of ceiling fan 1 equipped with brushless DC motor 2A according to a first embodiment of the present disclosure.

[0016] Ceiling fan 1 is an electric fan to be mounted to a ceiling and called a ceiling fan, and uses brushless DC motor 2A as a driving source. Pipe 4 is fixed to the ceiling vertically downward. Shaft 6 defining the rotation axis is connected to pipe 4. Motor drive unit 7 is attached below pipe 4. Furthermore, brushless DC motor 2A equipped with blade 3 is attached below motor drive unit 7. Brushless DC motor 2A is covered with main body cover 5.

[0017] FIG. 2 is a perspective assembly view of an overall configuration of brushless DC motor 2A.

[0018] Brushless DC motor 2A is an outer-rotor brushless DC motor. Brushless DC motor 2A includes shaft 6, first stator 11a, second stator 11b, first rotor 12a, second rotor 12b, and coupling unit 13. Note that, hereinafter, the term "stator" refers to first stator 11a and second stator 11b. Furthermore, the term "rotor" refers to first rotor 12a and second rotor 12b.

[0019] Shaft 6 defines the rotation axis of brushless DC motor 2A.

[0020] First stator 11a has a cylindrical shape with a top face and a bottom face, and the center of the circle of the cylindrical shape is fixed to shaft 6.

[0021] Second stator 11b has a cylindrical shape with a top face and a bottom face, the cylindrical shape being identical in size to that of first stator 11a, and

the center of the circle of the cylindrical shape is fixed to shaft 6.

[0022] First stator 11a and second stator 11b are fixed to shaft 6 in such a manner that the bottom face of first stator 11a and the top face of second stator 11b face and adjoin each other. Note that definitions of the bottom face and the top face will be described later.

[0023] First rotor 12a has a hollow cylindrical shape with a top face and includes an opening on the bottom. First rotor 12a further includes first flange 23a extending from the outer circumferential edge of the bottom toward the further outer circumferential side (see FIG. 3 and FIG. 4).

10 [0024] Second rotor 12b has a hollow cylindrical shape with a top face and includes an opening on the bottom. Second rotor 12b further includes second flange 23b extending from the outer circumferential edge of the bottom toward the further outer circumferential side (see FIG. 4).

[0025] With the inner circumferential side face of first rotor 12a facing the outer circumferential side face of first stator 11a, first rotor 12a is rotatably attached to shaft 6 via bearing 14a provided on the top face side of first stator 11a. With the inner circumferential side face of second rotor 12b facing the outer circumferential side face of second stator 11b, second rotor 12b is rotatably attached to shaft 6 via bearing 14b provided on the top face side of second stator 11b.

[0026] Coupling unit 13 is configured to couple first rotor 12a to second rotor 12b along the rotation axis. Note that first flange 23a of first rotor 12a and second flange 23b of second rotor 12b are connected via coupling unit 13.

[0027] Here, the stators, namely, first stator 11a and second stator 11b are identical components. The identical components mean that one component can be used as first stator 11a and also used as second stator 11b.

[0028] Here, the rotors, namely, first rotor 12a and second rotor 12b are

identical components. Similarly, the identical components mean that one component can be used as first rotor 12a and also used as second rotor 12b.

[0029] First stator 11a includes first stator core 15a, first insulator 16a, first driving coil 17a, and first circuit board 18a.

5 [0030] First stator core 15a has a cylindrical shape, and includes a plurality of electromagnetic steel sheets laminated in the direction of the rotation axis. At the center of the circle of the cylindrical shape, first stator core 15a has a center hole into which shaft 6 is press-fitted and held, and $3n$ salient poles 19 (first salient poles) are formed radially from the center (see FIG. 9A). Note that n is
10 an integer of 1 or more.

[0031] Salient poles 19 are insulated with first insulator 16a, and first driving coil 17a is wound around the side faces of salient poles 19 via first insulator 16a (see FIG. 9A).

[0032] First insulator 16a is an insulating member formed of a resin molding.
15 By covering first stator core 15a with first insulator 16a from above and below in the direction of the rotation axis, salient poles 19 are insulated from first driving coil 17a.

[0033] First driving coil 17a is a star connection coil including three windings provided in a U phase, a V phase, and a W phase, respectively, in other words,
20 three phase windings. First driving coil 17a is wound around the outer circumference of first insulator 16a covering the outer circumference of salient poles 19. Note that the wire connection of the driving coil will be described in detail later.

[0034] First circuit board 18a is held by first insulator 16a, in which lead wires
25 of first driving coil 17a are connected. When first driving coil 17a is energized, first circuit board 18a generates a magnetic field.

[0035] Note that, in the present embodiment, a face of first stator 11a to which

first circuit board 18a is fixed is defined as a top face, and a face of first stator 11a that faces the top face is defined as a bottom face. In other words, first circuit board 18a is fixed to the top face of first stator 11a, the top face being opposite to a face (the bottom face) adjacent to second stator 11b.

5 [0036] Second stator 11b includes second stator core 15b, second insulator 16b, second driving coil 17b, and second circuit board 18b.

[0037] Second stator core 15b has a cylindrical shape, and includes a plurality of electromagnetic steel sheets laminated in the direction of the rotation axis. At the center of the circle of the cylindrical shape, second stator core 15b has a
10 center hole into which shaft 6 is press-fitted and held, and $3n$ of salient poles (second salient poles) are formed radially from the center. Note that n is an integer of 1 or more.

[0038] Note that second stator 11b is a component identical to first stator 11a, and includes the same constituents as those of first stator 11a, and therefore
15 descriptions thereof will be omitted. Note that, in the present embodiment, second circuit board 18b is disposed to be adjacent to the bottom face of first stator core 15a. That is, in ceiling fan 1 in an installation state, first circuit board 18a, first stator core 15a, second circuit board 18b, and second stator core 15b are disposed in this order from vertically above.

20 [0039] There are two differences in configuration between first stator 11a and second stator 11b. Details of the differences are described below.

[0040] One of the differences is that first circuit board 18a of first stator 11a is provided with one temperature detector 30 in the vicinity of first driving coil 17a, temperature detector 30 being configured to detect ambient temperatures.
25 In other words, second circuit board 18b is not provided with temperature detector 30. Here, the term "ambient temperatures" specifically refers to both temperatures of first stator 11a and second stator 11b.

[0041] The other of the differences is that one set of position detector 31 configured to detect a rotation position of first rotor 12a is provided in the outer circumference of first circuit board 18a of first stator 11a. In other words, second stator 11b is not provided with position detector 31. Here, the term
5 "one set" means that a plurality of elements constituting position detector 31 is provided in first stator 11a, and does not mean that the elements are provided in second stator 11b. Position detector 31 detects a rotation position of first rotor 12a, thereby consequently detecting a rotation position of second rotor 12b that rotates at the same rotation speed as that of first rotor 12a.

10 [0042] The stator and the rotor are vertically double-stacked and make the same movement, and therefore it is not necessary to provide temperature detector 30 and position detector 31 in both the stator and the rotor. Thus, while accomplishing the intended purpose of rotating brushless DC motor 2A, a reduction in the number of components can be achieved, and accordingly,
15 material cost can be reduced.

[0043] First circuit board 18a and second circuit board 18b are connected by motor lead wire 29 (see FIG. 4), and details thereof will be described later.

[0044] FIG. 3 is an assembly view of a configuration of a rotor of brushless DC motor 2A.

20 [0045] First rotor 12a includes first rotor yoke 20a, first magnet 21a, first holding ring A22a, and first holding ring B22b.

[0046] First rotor yoke 20a includes first flange 23a in its bottom face perpendicular to the rotation axis. In the inner circumferential face of first rotor yoke 20a, a plurality of first magnets 21a (in the present embodiment, 10
25 first magnets 21a) is circumferentially disposed at regular intervals.

[0047] First magnets 21a are disposed so that adjoining magnets having opposite polarities are positioned in the inner circumferential side face of the

adjoining magnets. In other words, first magnets 21a are disposed in such a manner that magnets having opposite polarities are circumferentially alternately arranged.

[0048] First holding ring A22a and first holding ring B22b are identical
5 components each formed of a resin molding, and are configured to fix first magnets 21a from both sides along the rotation axis. Each of first holding ring A22a and first holding ring B22b has base 24 and protrusion 25. Base 24 has an annular shape and comes into contact with first magnets 21a from the direction of the rotation axis. Protrusion 25 comprises a plurality of
10 projections, and protrudes along first magnet 21a along the rotation axis so as to partially cover first magnets 21a. Thread rib 26 is provided in a face of base 24, the face being opposite to a face in which protrusions 25 are provided.

[0049] Thread rib 26 is a rib provided in the opposite face and protruding along the rotation axis and in the opposite direction to a direction toward first
15 magnets 21a. Thread rib 26 is a thread-shaped projection protruding more slightly than protrusions 25, and a plurality of thread ribs 26 is provided radially from the annular shape. In other words, thread ribs 26 are provided closer to the outer circumferential side than the inner circumferential edge of the center opening of the holding ring (first holding ring A22a, first holding ring
20 B22b). One or more thread ribs 26 (in the present embodiment, two thread ribs 26) are provided between protrusions 25 adjacent to each other. With this configuration, thread ribs 26 transmit a force of first rotor yoke 20a acting along the rotation axis to first magnets 21a, and thereby accelerates two sides perpendicular to the axis of first magnets 21a from above and below in the axial
25 direction.

[0050] Second rotor 12b includes second rotor yoke 20b, second magnet 21b, second holding ring A32a, and second holding ring B32b (see FIG. 5A). Second

rotor 12b is a component identical to first rotor 12a and includes the same constituents as those of first rotor 12a, and therefore descriptions thereof will be omitted.

[0051] Next, using FIG. 4 to FIG. 12, brushless DC motor 2A of the present disclosure will be described in detail.

[0052] FIG. 4 is a cross-sectional view of an overall configuration of brushless DC motor 2A.

[0053] First stator 11a and second stator 11b are press-fitted and fixed to shaft 6. First stator 11a and second stator 11b are disposed in such a manner that the bottom face of first stator 11a and the top face of second stator 11b are adjacent to each other, and a circumferential base point of first stator 11a and a circumferential base point of second stator 11b coincide with each other on the rotation axis.

[0054] The base point is a mark that indicates a circumferential (rotational) position of each of the two identical components, namely, first stator 11a and second stator 11b. When the base points coincide with each other, a circumferential position of first stator 11a and a circumferential position of second stator 11b can coincide with each other. In the present embodiment, by making the base points coincide with each other, the directions of magnetization of adjoining magnets between first stator 11a and second stator 11b can coincide with each other.

[0055] Coupling unit 13 includes base 27 and engaging unit 28.

[0056] Base 27 is formed by casting aluminum into a hollow disk shape. The inner diameter of the center opening of base 27 is larger than the outer diameter of first stator 11a and the outer diameter of second stator 11b. In FIG. 4, a face of base 27, that is, the upper face of the disk shape is in contact with first flange 23a provided on the bottom side of first rotor 12a.

Furthermore, another face of base 27, that is, the lower face of the disk shape is in contact with second flange 23b provided on the bottom side of second rotor 12b. That is, base 27 comes into contact with first rotor 12a and second rotor 12b from the direction of the rotation axis. In other words, first rotor 12a and
5 second rotor 12b come into contact with base 27 from both sides along the rotation axis.

[0057] Engaging unit 28 is a unit configured to couple blade 3 of ceiling fan 1 to the brushless DC motor 2A, and a plurality of engaging units 28 is provided in the circumference of base 27 at regular intervals.

10 [0058] First rotor 12a is rotatably attached to shaft 6 so that the inner circumferential side face of first rotor 12a faces a side face of first stator 11a. Second rotor 12b is rotatably attached to shaft 6 so that the inner circumferential side face of second rotor 12b faces a side face of second stator 11b. Coupling unit 13 is disposed so as to be coupled to first flange 23a and
15 second flange 23b along the rotation axis. In other words, the bottom face of first rotor 12a and the bottom face of second rotor 12b are brought closer to each other to house the stators in an interior space.

[0059] In the above-described configuration, the inner diameter of the center opening of base 27 is larger than the outer diameter of first stator 11a and the
20 outer diameter of second stator 11b. Therefore, after first stator 11a and second stator 11b are fixed to shaft 6, first rotor 12a, coupling unit 13, and second rotor 12b are coupled to each other so as to enclose stator constituents. In other words, the configuration is such that coupling unit 13 can be easily disposed in an axially intermediate face between first stator 11a and second
25 stator 11b, so that assembling workability is improved.

[0060] Blade 3 is fixed to coupling unit 13, and first rotor 12a and second rotor 12b are disposed above and below coupling unit 13, respectively. In other

words, since blade 3 is present in the axially intermediate face serving as the center of gravity of brushless DC motor 2A, whereby vibrations and noises of a product that are caused by the run-out of blade 3 are reduced, a good balance with high accuracy can be achieved even at the time of high speed rotation, and
5 calmness can be enhanced.

[0061] Motor lead wire 29 connects first circuit board 18a to second circuit board 18b. Furthermore, motor lead wire 29 is connected via first circuit board 18a to each of three phases (the U phase, the V phase, the W phase) in first driving coil 17a of first stator 11a. Furthermore, motor lead wire 29 is
10 connected via second circuit board 18b to each of three phases (the U phase, the V phase, the W phase) in second driving coil 17b of second stator 11b. In this connection, the three phases in first driving coil 17a are respectively connected in parallel to the three phases in second driving coil 17b so that each of three phases in first driving coil 17a coincides with a corresponding one of the three
15 phases in second driving coil 17b.

[0062] In the above-described configuration, by energizing first driving coil 17a and second driving coil 17b, rotating magnetic fields having the same rotational direction and being synchronized are respectively generated in first stator 11a and second stator 11b.

20 [0063] Note that details of wire connection of the driving coils will be described later.

[0064] FIG. 5A is a diagram illustrating a state in which holding rings of brushless DC motor 2A are fixed. FIG. 5B is an enlarged view of a principal part illustrated in FIG. 5A.

25 [0065] As illustrated in FIG. 5A, first magnets 21a are held by first holding ring A22a and first holding ring B22b. Second magnets 21b are held by second holding ring A32a and second holding ring B32b.

[0066] As illustrated in FIG. 5B, thread ribs 26 respectively provided in bases 24 of the holding rings (first holding ring A22a, first holding ring B22b) transmit, to first magnets 21a, pressures along the rotation axis from the inner wall of first rotor yoke 20a and an edge face of coupling unit 13. Similarly, thread ribs 26 respectively provided in bases 24 of second holding ring A32a and second holding ring B32b transmit, to second magnets 21b, pressures along the rotation axis from the inner wall of second rotor yoke 20b and an edge face of coupling unit 13.

[0067] With this configuration, the magnets (first magnets 21a and second magnets 21b) and the holding rings (first holding ring A22a, first holding ring B22b, second holding ring A32a, and second holding ring B32b) are prevented from rattling during motor rotation, so that calmness is enhanced.

[0068] FIG. 6A and FIG. 6B are cross-sectional views illustrating directions of magnetization of adjoining magnets (first magnets 21a and second magnets 21b) between first rotor 12a and second rotor 12b of brushless DC motor 2A.

[0069] FIG. 6A is a diagram illustrating a case in which the directions of magnetization of the adjoining magnets are the same in polarity. In this case, synchronization between rotating magnetic fields generated from first stator 11a and second stator 11b and torques obtained from first rotor 12a and second rotor 12b allows continuous and smooth rotation to be achieved. In contrast, FIG. 6B is a diagram illustrating a case in which the directions of magnetization of the adjoining magnets are not the same in polarity, in other words, opposite in polarity to each other. In this case, rotation unevenness occurs due to a difference in torque depending on a rotation position, and accordingly, continuous and smooth rotation cannot be achieved and motor output decreases. Therefore, the assembly as illustrated in FIG. 6A is needed.

[0070] In the present embodiment, in a state in which the directions of

magnetization of the adjoining magnets between first rotor 12a and second rotor 12b are identical to each other, first flange 23a and second flange 23b are axially connected to each other.

[0071] With this configuration, a rotation magnetic flux generated in first rotor 12a and a rotation magnetic flux generated in second rotor 12b are identical to each other in face perpendicular to the axial direction, so that a large driving torque is obtained, whereby high output is achieved.

[0072] FIG. 7A is a perspective view illustrating a state in which the rotor is coupled to coupling unit 13 in brushless DC motor 2A. FIG. 7B is a perspective view of coupling unit 13. FIG. 7C is an enlarged view of a principal part illustrated in FIG. 7B.

[0073] First flange 23a and second flange 23b respectively include flange-side mark 41 and flange-side mark 42, such as notches, on their flange-sides so as to identify the directions of magnetization. On the other hand, coupling unit 13 includes, on both sides of base 27, recesses respectively corresponding to flange-side mark 41 and flange-side mark 42, namely, coupling-unit-side mark 43 and coupling-unit-side mark 44.

[0074] Coupling-unit-side mark 43 provided in one face of coupling unit 13 and flange-side mark 41 in first flange 23a are disposed to coincide with each other. Furthermore, coupling-unit-side mark 44 provided in the other face of coupling unit 13 and flange-side mark 42 in second flange 23b are disposed to coincide with each other.

[0075] With this configuration, in the present embodiment, in the rotor yokes that are identical components and therefore the same in appearance and magnet polarities of which cannot be identified by visual determination, the directions of magnetization of adjoining magnets between first rotor yoke 20a and second rotor yoke 20b can be the same in polarity.

[0076] In the case where coupling unit 13 is formed by casting aluminum into a hollow disk shape, joint faces of coupling unit 13 to the flanges are sometimes subjected to machining processing in order that the joint faces are perpendicular to the rotation axis. Thus, the run-out of the blade is reduced, so that the quality of brushless DC motor 2A can be kept high. In this case, it is effective to provide recesses as coupling-unit-side mark 43 and coupling-unit-side mark 44 on the coupling unit 13 side.

[0077] Furthermore, in a case other than the case described above, as illustrated in FIG. 7B and FIG. 7C, it is effective to provide projections as coupling-unit-side mark 45 and coupling-unit-side mark 46 on the coupling unit 13 side. This allows the achievement of a configuration in which assembly can be realized only after a notch and a projection are disposed so as to coincide with each other, and thus, an assembly error is prevented and quality can be kept high.

[0078] FIG. 8 is a block diagram of a configuration of a ceiling fan equipped with brushless DC motor 2A.

[0079] Brushless DC motor 2A includes motor drive circuit 51 in motor drive unit 7 illustrated in FIG. 1.

[0080] As illustrated in FIG. 8, motor drive circuit 51 is connected to first stator 11a and second stator 11b, and is configured to output a driving signal for driving the rotor.

[0081] As described above, the stator includes salient pole 19 and driving coil 17. Driving coil 17 is star connection coil 52, as illustrated in FIG. 8. For example, first driving coil 17a includes U1 phase, V1 phase, and W1 phase as a star connection coil. Second driving coil 17b includes U2 phase, V2 phase, and W2 phase as a star connection coil.

[0082] Star connection coil 52 is configured to connect the phases in first stator

11a to the phases in second stator 11b in parallel so that each of the phases in first stator 11a coincides with a corresponding one of the phases in second stator 11b, and is drive-controlled by one motor drive circuit 51.

[0083] Motor drive circuit 51 is composed of an upper stage and a lower stage,
5 and includes inverter circuit 53 in which the stages are bridge-connected using a plurality of switching elements, drive logic controller 58, duty instruction unit 59, and motor current detector 60.

[0084] An AC voltage supplied from AC power supply 54 is rectified by rectifier diode 55 and smoothed into a DC voltage by smoothing capacitor 56, and the
10 DC voltage is applied on inverter circuit 53 via contact opening-and-closing unit 57.

[0085] Drive logic controller 58 is configured to give PWM control over the DC voltage applied on inverter circuit 53 at the upper- or lower-stage-side switching elements, and also energize the driving coils in full wave sequentially in a
15 predetermined direction and order, based on a signal from position detector 31 configured to detect a rotation position of brushless DC motor 2A.

[0086] Motor current detector 60 is configured to detect an electric current flowing through inverter circuit 53.

[0087] Duty instruction unit 59 is configured to make instructions on ON/OFF
20 duty for the PWM control over the switching elements. Based on a motor current value detected by motor current detector 60, duty instruction unit 59 controls a motor current to a predetermined electric current by increasing the duty when a value of the motor current is smaller than a value of the predetermined electric current or by decreasing the duty when a value of the
25 motor current is larger than the value of the predetermined electric current.

[0088] It is effective to dispose temperature detector 30 in the vicinity of first driving coil 17a. First driving coil 17a is disposed above second driving coil 17b

and warmed air moves upward, and, as a result, the highest temperatures of first driving coil 17a and second driving coil 17b can be detected. Temperature detector 30 is connected to contact opening-and-closing unit 57, and, for example, when a temperature of first driving coil 17a exceeds a predetermined
5 value during an abnormal operation, the operation of contact opening-and-closing unit 57 is suspended, whereby the energization of inverter circuit 53 with the DC voltage is intercepted, so that safety can be secured.

[0089] With the above-described configuration, the motor drive circuit can be realized using only some components, so that material costs can be reduced.

10 [0090] FIG. 9A and FIG. 9B are cross-sectional views of a wiring structure of motor lead wire 29 of brushless DC motor 2A. Note that FIG. 9A and FIG. 9B are cross-sectional views taken along line A-A in FIG. 4.

[0091] As illustrated in FIG. 9A, first stator 11a includes: first stator core 15a including salient poles 19 radially formed from its center; first insulator 16a;
15 and first driving coil 17a including three phase windings.

[0092] Motor lead wire 29 is passed through slot 71 that is a gap between salient poles 19, adjacent to each other, of first stator core 15a, and connects first stator 11a to second stator 11b, in other words, connects first circuit board 18a to second circuit board 18b. As a result, first driving coil 17a is connected
20 to second driving coil 17b.

[0093] Generally, a shaft of a ceiling fan is often a hollow pipe. For the connection of stators, holes for wiring are respectively provided in side faces of a shaft in the vicinity of two circuit boards. A motor lead wire is passed through the holes to connect the stators. In this case, if a space between the stators is
25 narrow like the present embodiment, it is considerably difficult to insert the motor lead wire into the inside of the shaft and connect the circuit boards.

[0094] Therefore, as is the case with the present embodiment, passing a motor

lead wire through slot 71 makes wiring work easier and improves assembling workability. Furthermore, since motor lead wire 29 is held inside slot 71, disconnection due to a contact with a magnet fixed to the inner circumferential surface of a rotor yoke during rotor rotation can be prevented, so that quality
5 can be kept high.

[0095] Slot 71 includes insulating film 72, such as a polyester film, configured to surround motor lead wire 29. Thus, motor lead wire 29 does not come into direct contact with first driving coil 17a, so that a wiring structure excellent in insulation properties and heat resistance is achieved, whereby quality can be
10 kept high.

[0096] Alternatively, as illustrated in FIG. 9B, motor lead wire 29 may be covered with insulating tube 73 in place of insulating film 72.

[0097] FIG. 10 is a plan view illustrating a wiring state of motor lead wire 29 according to the present embodiment.

15 [0098] First circuit board 18a includes movement inhibiting piece 74 configured to inhibit motor lead wire 29 from moving toward the outer circumference of first stator 11a.

[0099] Movement inhibiting piece 74 includes: recess 75 configured to allow motor lead wire 29 to pass through the inner circumference side of first stator
20 11a; and projection 76 provided on the outer circumferential side of first stator 11a in recess 75 and extending in the circumferential direction of first stator 11a.

[0100] The above-described slot 71 is opened to the outer circumferential side and is therefore advantageous in the wiring of motor lead wire 29, and thus
25 motor lead wire 29 is circumferentially fixed. However, motor lead wire 29 is not engaged in the outer circumferential direction (in the radial direction). On the other hand, projection 76 inhibits motor lead wire 29 having been passed

through recess 75 from moving along the outer circumferential direction. Thus, motor lead wire 29 can be surely held inside the slot, so that a contact with the magnet rotating outside is prevented to avoid disconnection, whereby quality can be kept high. Furthermore, there is no need to provide a new component.

5 Note that, like first circuit board 18a, second circuit board 18b may also include movement inhibiting piece 74.

[0101] Thus, according to brushless DC motor 2A in the first embodiment of the present disclosure, first stator 11a and second stator 11b are identical components and first rotor 12a and second rotor 12b are identical components,
10 and therefore investment in new equipment and molds and dies can be reduced, and as a result, high output can be achieved at low cost and with high driving torque.

[0102] (Second Embodiment)

FIG. 11 and FIG. 12 are diagrams of brushless DC motor 2B according
15 to a second embodiment of the present disclosure. In these figures, constituents identical to those in FIG. 1 to FIG. 10 are given the same reference numerals and symbols, and detailed descriptions thereof will be omitted.

[0103] FIG. 11 is a cross-sectional view of an overall configuration of brushless DC motor 2B according to the second embodiment of the present disclosure.
20 FIG. 12 is a block diagram of a configuration of a ceiling fan equipped with brushless DC motor 2B according to the present embodiment of the present disclosure.

[0104] As illustrated in FIG. 11, first stator 11a and second stator 11b are press-fitted and fixed to shaft 6.

25 [0105] The fixing of first stator 11a and second stator 11b to shaft is performed, with the bottom face of first stator 11a and the bottom face of second stator 11b being adjacent to each other. Here, the bottom face of first stator 11a is a face

of a cylindrical shape, in which first circuit board 18a is not disposed. The bottom face of second stator 11b is a face of the cylindrical shape, in which second circuit board 18b is not disposed. Under the state in which the bottom faces are adjacent to each other as described above, a circumferential base point of first stator 11a and a circumferential base point of second stator 11b coincide with each other on the rotation axis. When the base points coincide with each other, the directions of magnetization of adjoining magnets between first stator 11a and second stator 11b can coincide with each other.

[0106] That is, the present embodiment is different from the first embodiment in that, in a state in which ceiling fan 1 is mounted, first circuit board 18a, first stator core 15a, second stator core 15b, and second circuit board 18b are disposed in this order from vertically above. However, the present embodiment is the same as the first embodiment in that the directions of magnetization of adjoining magnets coincide with each other.

[0107] Under the above-described state, motor lead wire 29 connects first circuit board 18a to second circuit board 18b. As a result, motor lead wire 29 is connected to each of three phases (U1 phase, V1 phase, and W1 phase) in first driving coil 17a of first stator 11a via first circuit board 18a. Furthermore, motor lead wire 29 is connected to each of three phases (U2 phase, V2 phase, and W2 phase) in second driving coil 17b of second stator 11b via second circuit board 18b. Note that the connection of first circuit board 18a to second circuit board 18b by motor lead wire 29 is performed by passing motor lead wire 29 through two slots 71 respectively provided in first stator 11a and second stator 11b.

[0108] Here, in the present embodiment, one phase (for example, U1 phase) in first driving coil 17a and one phase (for example, U2 phase) in second driving coil 17b are connected in parallel so that the phase in first driving coil 17a

coincides with the phase in second driving coil 17b. However, other two phases (for example, V1 phase and W1 phase) in first driving coil 17a and two phases (for example, V2 phase and W2 phase) in second driving coil 17b corresponding to the other two phases in first driving coil 17a are exchanged and connected in parallel. That is, for example, a pair of U1 phase and U2 phase, a pair of V1 phase and W2 phase, and a pair of W1 phase and V2 phase are each connected in parallel.

[0109] In the above-described configuration, when first driving coil 17a and second driving coil 17b are energized, rotating magnetic fields are generated in the first stator and the second stator, the rotating magnetic fields having the same rotational direction and being synchronized.

[0110] Thus, brushless DC motor 2B in the embodiment of the present disclosure can produce the same effect and action as those in the first embodiment.

INDUSTRIAL APPLICABILITY

[0111] The brushless DC motor according to the present disclosure can achieve high output at lower cost, and is therefore useful as a motor for driving a ceiling fan and the like.

REFERENCE MARKS IN THE DRAWINGS

[0112] 1...ceiling fan

2A, 2B, 109...brushless DC motor

3...blade

4...pipe

5...main body cover

6, 103...shaft

	7...motor drive unit
	11a...first stator
	11b...second stator
	12a...first rotor
5	12b...second rotor
	13...coupling unit
	14a, 104a...bearing
	14b, 104b...bearing
	15a...first stator core
10	15b...second stator core
	16a...first insulator
	16b...second insulator
	17a...first driving coil
	17b...second driving coil
15	18a...first circuit board
	18b...second circuit board
	19...salient pole
	20a...first rotor yoke
	20b...second rotor yoke
20	21a...first magnet
	21b...second magnet
	22a...first holding ring A
	22b...first holding ring B
	23a...first flange
25	23b...second flange
	24...base
	25...protrusion

	26...thread rib
	27...base
	28...engaging unit
	29...motor lead wire
5	30...temperature detector
	31...position detector
	32a...second holding ring A
	32b...second holding ring B
	41...flange-side mark (notch)
10	42...flange-side mark (notch)
	43, 44...coupling-unit-side mark
	45, 46...coupling-unit-side mark
	51...motor drive circuit
	52...star connection coil
15	53...inverter circuit
	54...AC power supply
	55...rectifier diode
	56...smoothing capacitor
	57...contact opening-and-closing unit
20	58...drive logic control unit
	59...duty instruction unit
	60...motor current detector
	71...slot
	72...insulating film
25	73...insulating tube
	74...movement inhibiting piece
	75...recess

76...projection

CLAIMS

1. A brushless DC motor, comprising:
 - a shaft defining a rotation axis;
 - a first stator having a cylindrical shape with a top face and a bottom
 - 5 face, wherein a center of a circle of the cylindrical shape is fixed to the shaft;
 - a second stator having a cylindrical shape with a top face and a bottom
 - face and being adjacent to the first stator, wherein a center of a circle of the
 - cylindrical shape is fixed to the shaft;
 - a first rotor
 - 10 including a first flange in a face of the first rotor, the face being
 - perpendicular to the rotation axis, and
 - rotatably attached to the shaft to face a side face of the first
 - stator;
 - a second rotor
 - 15 including a second flange in a face of the second rotor, the face
 - being perpendicular to the rotation axis, and
 - rotatably attached to the shaft to face a side face of the second
 - stator; and
 - a coupling unit configured to couple the first rotor to the second rotor
 - 20 along the rotation axis,
 - wherein the first stator and the second stator are identical components,
 - and
 - wherein the first rotor and the second rotor are identical components.
- 25 2. The brushless DC motor according to claim 1, wherein
 - the bottom face of the first stator is adjacent to the top face of the
 - second stator, and

a circumferential base point of the first stator and a circumferential base point of the second stator coincide with each other on the rotation axis.

3. The brushless DC motor according to claim 1, wherein

5 the bottom face of the first stator is adjacent to the bottom face of the second stator, and

a circumferential base point of the first stator and a circumferential base point of the second stator coincide with each other on the rotation axis.

10 4. The brushless DC motor according to claim 1, wherein

the first rotor includes a first magnet,

the second rotor includes a second magnet, and,

with a first direction of magnetization of the first magnet and a direction of magnetization of the second magnet being identical to each other,
15 the coupling unit axially couples the first flange to the second flange, the first magnet and the second magnet being adjacent to each other along the rotation axis between the first rotor and the second rotor.

5. The brushless DC motor according to claim 4, wherein

20 each of the first flange and the second flange includes a flange-side mark to make the first directions and the second directions identical to each other.

6. The brushless DC motor according to claim 5, wherein

25 the coupling unit

includes coupling-unit-side marks on both sides, each of the coupling-unit-side marks being paired with a corresponding one of the

flange-side mark of the first flange and the flange-side mark of the second flange,

wherein the coupling-unit-side mark provided in one face of the coupling unit and the flange-side mark of the first flange are disposed to coincide with each other, and the coupling-unit-side mark provided in another face of the coupling unit and the flange-side mark of the second flange are disposed to coincide with each other, so that the first and second directions of magnetization of the first and second magnets adjacent to each other between the first rotor and the second rotor are identical to each other.

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7. The brushless DC motor according to claim 6, wherein the flange-side mark of the first flange and the flange-side mark of the second flange are notches, and the coupling-unit-side marks are recesses.

15

8. The brushless DC motor according to claim 6, wherein the flange-side mark of the first flange and the flange-side mark of the second flange are notches, the coupling-unit-side marks are projections, and

20

each of the notches and a corresponding one of the projections are disposed to coincide with each other.

9. The brushless DC motor according to claim 1, wherein the coupling unit has a hollow disk shape, and an inner diameter of a center opening of the hollow disk shape is larger than an outer diameter of the first stator and larger than an outer diameter of the second stator.

25

10. The brushless DC motor according to claim 1 or 2, further comprising
a motor drive circuit connected to the first stator and the second stator
and configured to output a driving signal,

wherein each of the first stator and the second stator includes:

5 a core including $3n$ salient poles radially formed from the center,
where n is integer of 1 or more; and

a star connection coil including three phase windings and
wound around each of the salient poles,

wherein the star connection coil

10 is configured to connect phases of the first stator to phases of
the second stator in parallel so that each of the phases of the first stator
coincides with a corresponding one of the phases of the second stator, and

is drive-controlled by the motor drive circuit.

15 11. The brushless DC motor according to claim 3, further comprising
a motor drive circuit connected to the first stator and the second stator
and configured to output a driving signal,

wherein each of the first stator and the second stator includes:

a core including $3n$ salient poles radially formed from the center,

20 where n is an integer of 1 or more; and

a star connection coil including three phase windings and
wound around each of the salient poles,

wherein the star connection coil

is configured to connect one of phases of the first stator to one of
25 phases of the second stator in parallel, the one of the phases of the first stator
coinciding with the one of the phases of the second stator,

is configured to exchange other two of the phases of the first

stator and other two of the phases of the second stator, the other two of the phases of the first stator coinciding with the other two of the phases of the second stator, and connect the other two of the phases of the first stator and the other two of the phases of the second stator in parallel.

5

12. The brushless DC motor according to claim 1, further comprising one temperature detector configured to detect ambient temperatures of both of the first stator and the second stator.

10 13. The brushless DC motor according to claim 1, further comprising one set of position detectors configured to detect rotation positions of both of the first rotor and the second rotor.