

DESCRIPTION

CEILING FAN

5 TECHNICAL FIELD

[0001]

The present invention relates to a ceiling fan equipped with a sensorless brushless DC motor.

10 BACKGROUND ART

[0002]

Recently, a ceiling fan is often used as a means for enhancing cooling efficiency or heating efficiency by generating cool air in summer and by circulating warm air accumulating around a ceiling in winter. In addition, a
15 brushless DC motor is often used as a motor used for a ceiling fan in view of controllability, energy-saving performance, reduction in size, and reduction in weight.

[0003]

When a plurality of ceiling fans of this type using a brushless DC
20 motor is installed in a wide space such as schools, public facilities, or commercial facilities as well as in conventional homes, with the state in which each fan has a different rotating speed, a user may feel a sense of strangeness. For this reason, a ceiling fan that is controlled to have a constant rotating speed has been known (see Patent Literature 1, for example).

25 [0004]

This ceiling fan will be described below with reference to FIG. 7. FIG. 7 is a view illustrating a configuration of a conventional ceiling fan.

[0005]

As illustrated in FIG. 7, ceiling fan 101 includes blade 102, brushless DC motor 103 that rotates blade 102, control circuit 104 that controls brushless DC motor 103, and illuminator 105 mounted on the lower part of ceiling fan 101. In addition, control circuit 104 controls to keep the rotating speed of blade 102 mounted to the brushless DC motor 103 constant.

[0006]

Further, there has been proposed a method using current and a rotating speed as a method for calculating an air volume (see Patent Literature 2, for example).

[0007]

In Patent Literature 2, a current detector is connected between a circuit ground and a position at which negative-potential-side terminals of switching elements composing a lower stage of an inverter circuit are combined into one.

Citation List

Patent Literature

[0008]

PTL 1: Japanese Patent No. 4649934

PTL 2: Unexamined Japanese Patent Publication No. 2002-165477

SUMMARY OF THE INVENTION

[0009]

A problem in a conventional ceiling fan using a brushless DC motor as disclosed in Patent Literature 1 will be described.

[0010]

It has been known that, from the similarity rule of general fluid, air

volume Q and rotating speed N have the proportional relation described below, when a diameter of a blade is defined as D .

[0011]

$$Q \propto N \times D$$

5 If the diameter of the blade is constant, the air volume is proportional to the rotating speed. However, even if rotating speeds are the same, air volumes are different depending on increase/decrease in work load of the blade, between the case in which the ceiling fan is installed to be close to the ceiling and the case in which the ceiling fan is installed to be separated from the
10 ceiling to some extent, by changing the length of a mounting pole.

[0012]

 When the distance from the blade to the ceiling is short, a space for circulating air into an inner peripheral part of the blade is narrowed, so that the ceiling fan creates stream of air only by an outer peripheral part of the
15 blade. Therefore, the closer to the ceiling the blade is, the lower the air volume is. On the other hand, when the distance from the blade to the ceiling is increased, a space for circulating air into the inner peripheral part of the blade is widened, so that the ceiling fan creates stream of air also by the inner peripheral part of the blade. Therefore, the more apart from the ceiling the
20 blade is, the more the air volume is increased.

[0013]

 When the blade is separated from the ceiling by a distance larger than the distance by which the sufficient space for circulating air into the inner peripheral part of the blade can be ensured, no change is observed in the air
25 volume.

[0014]

 For example, a ceiling fan which includes a blade with relatively a

large diameter and is installed to have a distance of 200 mm from the blade to the ceiling through a mounting pole will be described. FIG. 8 is a diagram illustrating a relationship among distance from the blade to the ceiling of the conventional ceiling fan, and air volume and rotating speed of the ceiling fan, with respect to a target air volume. FIG. 9 is a diagram illustrating a relationship among distance from the blade to the ceiling of the conventional ceiling fan, and rotating speed and power consumption of the ceiling fan, with respect to a target air volume. As illustrated in FIGS. 8 and 9, when the ceiling fan is operated in this state, and operated so that the rotating speed of the blade becomes constant at 230 r/min, the air volume is 284 m³/min and the power consumption is 39 W. This state is defined as high air volume setting, and the air volume of 284 m³/min at that time is defined as “high air volume” in the high setting.

[0015]

When the distance from the blade to the ceiling is changed to 300 mm, and the ceiling fan is operated at the rotating speed of 230 r/min, the air volume becomes 307 m³/min which is higher than the high air volume, and the power consumption becomes 32 W. Therefore, the rotating speed needs to be changed to 220 r/min to operate the ceiling fan to blow air in the high air volume in the high setting. That is, the air volume is higher than the target high air volume, and extra power is consumed.

[0016]

In addition, when the distance from the blade to the ceiling is changed to 150 mm, and the ceiling fan is operated at the rotating speed of 230 r/min, the air volume becomes 273 m³/min which is lower than the high air volume, and the power consumption becomes 44 W. Therefore, the rotating speed needs to be changed to 245 r/min to operate the ceiling fan to blow air in the

high air volume.

[0017]

As described above, there is a problem in which, when the rotating speed is controlled to be constant, an air volume is changed depending on the distance from the blade to the ceiling.

[0018]

In addition, in the configuration disclosed in Patent Literature 2, current of a motor is measured by the current detector. However, the current detector is connected to the circuit ground, so that the motor current can be detected only with three-phase synthesis current. Further, when a driver is composed of the switching elements, the current detector may detect current necessary for the driver. Accordingly, this configuration entails a problem of being unable to detect precise motor phase current.

[0019]

In view of this, the present invention solves the foregoing conventional problem. The present invention precisely detects current flowing through a motor, and performs air volume control with respect to a target air volume with high precision. The present invention aims to provide a ceiling fan that can provide substantially constant air volume regardless of a distance from a blade to a ceiling, and when a plurality of ceiling fans is installed, enables operation of each ceiling fan at substantially the same rotating speed.

[0020]

In order to attain the foregoing object, the ceiling fan according to the present invention includes a blade, a motor that drives the blade, and a control circuit that controls the motor, and the ceiling fan is installed on a ceiling through a mounting pole for circulating air in a room. In addition, the control circuit includes an AC/DC conversion circuit that converts AC voltage to DC

voltage; and an inverter circuit which is composed of an upper stage and a lower stage and configured such that three arms, each of which includes two switching elements that perform opposing ON/OFF operation and are connected in series with DC voltage, are connected in three-phase bridge, the
5 inverter circuit driving the motor when fed with A/D converted voltage by a three-phase PWM (pulse width modulation) method. In addition, the control circuit includes: a shunt resistor inserted for each of phases of the inverter circuit, between the lower stage and a negative potential side of the phase; an amplifier that amplifies inter-terminal voltage of the shunt resistors; and a
10 current detector that detects, from an output of the amplifier, a current value of each phase flowing in the motor. Further, the control circuit includes: a rotation detector that calculates a rotating speed and a position of the motor based on current detected by the current detector; and an air volume calculator that calculates a distance from the blade to the ceiling and compares a target
15 air volume with a current output air volume. Still further, the control circuit includes a speed controller that, based on a comparison result of the air volume calculator, controls the rotating speed of the motor by outputting a duty to the inverter circuit so that air volumes are substantially uniform. Still further, the air volume calculator inputs the current value of one phase in
20 current values of the respective phases detected by the current detector and the rotating speed calculated by the rotation detector, calculates a distance from the blade to the ceiling from the current value and the rotating speed which have been input, and sets the current value and the rotating speed, which have been input, to a current value and a rotating speed corresponding
25 to the target air volume determined based on the calculated distance from the blade to the ceiling, thereby setting the current output air volume to the target air volume determined based on the calculated distance from the blade to the

ceiling. Thus, the original object can be achieved.

[0021]

In addition, in the ceiling fan according to the present invention, the control circuit further includes an amplification factor changing unit that changes an amplification factor of the amplifier, and the amplification factor changing unit switches, based on the target air volume, an amplification factor of the amplifier for detecting a current value input to the air volume calculator. Thus, the original object can be achieved.

[0022]

In addition, in the ceiling fan according to the present invention, the control circuit further includes an amplification factor changing unit that changes an amplification factor of the amplifier, and the amplification factor changing unit switches, based on the current detected by the current detector, an amplification factor of the amplifier for detecting a current value input to the air volume calculator. Thus, the original object can be achieved.

[0023]

As described above, the present invention enables precise detection of current flowing through the windings of the motor. Therefore, the present invention provides an effect of keeping an air volume substantially constant regardless of the distance from the blade to the ceiling and suppressing an increase in power consumption.

BRIEF DESCRIPTION OF DRAWINGS

[0024]

FIG. 1 is a view illustrating a configuration of a ceiling fan according to an exemplary embodiment of the present invention.

FIG. 2 is a block diagram illustrating a configuration of a control

circuit in the ceiling fan according to the exemplary embodiment of the present invention.

FIG. 3 is a flowchart illustrating an operation of the ceiling fan according to the exemplary embodiment of the present invention.

5 FIG. 4 is a diagram storing a relationship among distance from a blade of the ceiling fan to a ceiling, and current and rotating speed of the ceiling fan according to the exemplary embodiment of the present invention.

FIG. 5A is a table storing set air volumes, target air volumes, and initial rotating speeds of the ceiling fan according to the exemplary
10 embodiment of the present invention.

FIG. 5B is a table for calculating a distance from the blade of the ceiling fan according to the exemplary embodiment of the present invention to the ceiling.

FIG. 5C is a table of a threshold of current for calculating a distance
15 from the blade of the ceiling fan according to the exemplary embodiment of the present invention to the ceiling.

FIG. 6A is a diagram illustrating a relationship among distance from the blade to the ceiling, and current and rotating speed of the ceiling fan according to the present exemplary embodiment, with respect to a target air
20 volume.

FIG. 6B is a diagram illustrating a control operation of the ceiling fan according to the present exemplary embodiment with respect to a target air volume, the diagram illustrating a relationship among distance from the blade to the ceiling, current, and rotating speed.

25 FIG. 7 is a view illustrating a configuration of a conventional ceiling fan.

FIG. 8 is a diagram illustrating a relationship among distance from a

blade of the conventional ceiling fan to a ceiling, and air volume and rotating speed of the conventional ceiling fan, with respect to a target air volume.

FIG. 9 is a diagram illustrating a relationship among distance from the blade of the conventional ceiling fan to the ceiling, and rotating speed and power consumption of the conventional ceiling fan, with respect to a target air volume.

DESCRIPTION OF EMBODIMENTS

[0025]

One exemplary embodiment of the present invention will be described below with reference to the drawings.

[0026]

Ceiling fan 1 according to the present exemplary embodiment is installed on a ceiling of a building. Ceiling fan 1 is controlled to be operated at any rotating speed ranging from low speed to high speed by making use of the characteristics of a DC (Direct Current) motor, thereby blowing air in an air volume ranging from a low air volume to a high air volume.

[0027]

FIG. 1 is a view illustrating the configuration of ceiling fan 1 according to the exemplary embodiment of the present invention. As illustrated in FIG. 1, ceiling fan 1 includes blade 2, sensorless brushless DC motor 3, control circuit 4, remote controller 5, and remote controller light-receiving unit 6. Sensorless brushless DC motor 3 rotates blade 2. Remote controller 5 sets the operation of ceiling fan 1. Remote controller light-receiving unit 6 receives a signal from remote controller 5. Remote controller 5 is operated by a user, and has start/stop button 5a for turning on/off ceiling fan 1 and air volume setting button 5b for switching an air volume. Ceiling fan 1 is suspended

from the ceiling by mounting pole 7.

[0028]

Control circuit 4 drives sensorless brushless DC motor 3 to rotate blade 2 mounted to sensorless brushless DC motor 3.

5 [0029]

FIG. 2 is a block diagram illustrating the configuration of control circuit 4 in ceiling fan 1 according to the exemplary embodiment of the present invention. In FIG. 2, AC voltage supplied from commercial power supply 8 is converted into DC by AC/DC conversion circuit 9. Then, the DC voltage which has been subjected to A/D conversion is smoothed by smoothing capacitor 10, and the smoothed DC voltage is applied to inverter circuit 11. Inverter circuit 11 is composed of an upper stage and a lower stage and configured such that three arms, each of which includes two switching elements that perform opposing ON/OFF operation and are connected in series with DC voltage, are connected in three-phase bridge, inverter circuit 11 driving sensorless brushless DC motor 3 when fed with A/D converted voltage by a three-phase PWM (pulse width modulation) method. Sensorless brushless DC motor 3 includes stator 12 around which windings are wound and rotor 13 provided with a permanent magnet.

20 [0030]

In addition, a shunt resistor 14 inserted for each of phases of the inverter circuit 11, between lower stage and a negative potential side of phase. Voltages at both ends of shunt resistors 14 generated by current flowing through shunt resistors 14 are amplified by amplifier 15. From the output of amplifier 15, current detector 16 detects current of each phase flowing in sensorless brushless DC motor 3. Rotation detector 17 calculates the rotating speed and position of sensorless brushless DC motor 3 on the basis of the

current detected by current detector 16.

[0031]

Air volume calculator 18 compares the current value of one phase in current values of the respective phases detected by current detector 16 and the
5 rotating speed calculated by rotation detector 17 to a current value and a rotating speed corresponding to later-described target air volume Q_s . This will be described in detail later. Air volume calculator 18 determines whether the air volume currently output is higher or lower than target air volume Q_s on the basis of the comparison result.

10 [0032]

Remote controller signal determination unit 19 receives a signal transmitted from the remote controller by remote controller light-receiving unit 6 by the operation on start/stop button 5a and air volume setting button 5b on remote controller 5. Remote controller signal determination unit 19
15 analyzes the signal from remote controller 5. Remote controller signal determination unit 19 obtains a set air volume from the analysis result, and outputs target air volume Q_s to target air volume calculator 20.

[0033]

Target air volume calculator 20 calculates the distance from blade 2 to
20 the ceiling from the current value of one phase in current values of the respective phases detected by current detector 16 and the rotating speed calculated by rotation detector 17. This will be described in detail later. Target air volume calculator 20 calculates target air volume Q_s on the basis of the calculated distance from blade 2 to the ceiling, and indicates target air
25 volume Q_s to air volume calculator 18.

[0034]

Amplification factor changing unit 21 inputs target air volume Q_s

calculated by target air volume calculator 20, and changes an amplification factor of amplifier 15 for a predetermined phase according to the magnitude of target air volume Q_s .

[0035]

5 Speed controller 22 outputs a duty to inverter circuit 11 to vary the rotating speed of sensorless brushless DC motor 3.

[0036]

 The rotating speed of blade 2 mounted on sensorless brushless DC motor 3 is varied by varying the rotating speed of sensorless brushless DC motor 3. Thus, a necessary air volume is output from ceiling fan 1.

[0037]

 The operation of ceiling fan 1 according to the present exemplary embodiment will be described below with reference to FIG. 3. FIG. 3 is a flowchart illustrating an operation of ceiling fan 1 according to the exemplary embodiment of the present invention.

[0038]

 To start the operation of ceiling fan 1, a user operates start/stop button 5a on remote controller 5 for starting the operation of ceiling fan 1. Then, the user operates air volume setting button 5b to set the air volume setting to a high notch, for example. Then, remote controller signal determination unit 19 analyzes the signal from remote controller 5 and obtains the set air volume from the analysis result to obtain target air volume Q_s . Target air volume Q_s may be determined by referring to a table stored in a memory or determined based on a calculation equation set in advance, for example.

25 [0039]

 After target air volume Q_s is determined, target air volume calculator 20 determines whether or not the distance from blade 2 to the ceiling has

already been determined (step S101). The case in which the distance from blade 2 to the ceiling has not yet been determined (NO in step S101) will be described. When the distance from blade 2 to the ceiling has not yet been determined, an initial rotating speed corresponding to target air volume Q_s is
5 determined from a table stored in the memory as illustrated in FIG. 5A to be described later (step S102). Speed controller 22 outputs a duty to inverter circuit 11.

[0040]

When the duty is output to inverter circuit 11, inverter circuit 11
10 sequentially energizes six switching elements to drive sensorless brushless DC motor 3. When sensorless brushless DC motor 3 is driven, current flows through shunt resistors 14. Amplifier 15 amplifies voltage at both ends of each shunt resistor 14. Current detector 16 detects the amplified voltage at both ends of each shunt resistor 14, and detects, for each phase, current
15 (winding current) flowing through the windings of sensorless brushless DC motor 3 based on this potential (step S103). The winding current of two phases in the detected winding current is input to rotation detector 17.

[0041]

The winding current of the remaining one phase is input to air volume
20 calculator 18. This will be described later in detail. Rotation detector 17 detects the rotating speed and position of sensorless brushless DC motor 3 on the basis of the winding current of two phases (step S104).

[0042]

Next, air volume calculator 18 compares the initial rotating speed
25 determined by target air volume calculator 20 with the rotating speed detected by rotation detector 17, that is, the current rotating speed (step S105). When the current rotating speed is different from the initial rotating speed (NO in

step S105), that is, when the current rotating speed is lower than the initial rotating speed, air volume calculator 18 issues an instruction to output increased duty to speed controller 22 (step S106).

[0043]

5 On the other hand, when the current rotating speed is higher than the initial rotating speed, air volume calculator 18 issues an instruction to output decreased duty to speed controller 22 (step S106).

[0044]

 According to this process, the rotating speed of sensorless brushless DC
10 motor 3 gradually approaches the initial rotating speed.

[0045]

 When the current rotating speed is equal to the initial rotating speed (YES in step S105), air volume calculator 18 calculates the distance from blade 2 to the ceiling from the current value of one phase detected by current
15 detector 16 and the rotating speed detected by rotation detector 17. The distance from blade 2 to the ceiling may be calculated by referring to a table stored in the memory or determined based on a calculation equation set in advance, for example.

[0046]

20 A method for calculating the distance from blade 2 to the ceiling will be described as one example with reference to FIGS. 4, 5A, 5B, and 5C, which store the relationship among distance from blade 2 to the ceiling, current, and rotating speed. FIG. 4 is a diagram storing a relationship among distance from blade 2 of the ceiling fan to the ceiling, and current and rotating speed of
25 the ceiling fan according to the exemplary embodiment of the present invention. FIG. 5A is a table storing set air volumes, target air volumes Q_s , and initial rotating speeds of the ceiling fan. FIG. 5B is a table for calculating

a distance from blade 2 of the ceiling fan to the ceiling. FIG. 5C is a current threshold table for calculating a distance from blade 2 of the ceiling fan to the ceiling.

[0047]

5 Firstly, the relationship of target air volume Q_s to a set air volume (that is, air volume notch) and the relationship of an initial rotating speed to target air volume Q_s are indicated in FIG. 5A in which the distance from blade 2 to the ceiling is set as 200 mm. These relationships are stored in a form of a table. Hereinafter, the case in which the air volume setting is set to a high
10 notch will be described.

[0048]

When the air volume setting is set to a high notch, target air volume Q_s is 284 m³/min, and the initial rotating speed is 230 r/min.

[0049]

15 Ceiling fan 1 is constantly operated at the initial rotating speed of 230 r/min by varying the distance from blade 2 to the ceiling, and the distance from blade 2 to the ceiling, the rotating speed of the blade, and the current value of one phase detected by current detector 16 in each case are measured. The measurement result is shown in FIG. 4.

20 [0050]

This measurement result, that is, the relationship between the distance from blade 2 to the ceiling and the current value at the initial rotating speed of 230 r/min is stored in the memory in a form of a table (FIGS. 5B and 5C).

25 [0051]

Then, the distance from blade 2 of ceiling fan 1 mounted on the ceiling to the ceiling is calculated using the stored table. Firstly, ceiling fan 1 which

is mounted is operated at initial rotating speed of 230 r/min. Then, a current value of one phase flowing through sensorless brushless DC motor 3 at that time is detected by current detector 16. From the current value of one phase, the distance from blade 2 to the ceiling is calculated on the basis of the table shown in FIG. 5B. For example, when the detected current value of one phase is 260 mA, the range from current marks I2 to I3 is selected from FIG. 5C, and from the table shown in FIG. 5B, the distance from blade 2 to the ceiling is 250 mm (step S107).

[0052]

10 Since the distance from blade 2 to the ceiling can be calculated here, distance determination completion is set, and the completion of the calculation of the distance from blade 2 to the ceiling is stored (step S108).

[0053]

Next, the case in which the distance from blade 2 to the ceiling has been determined will be described.

[0054]

Target air volume Q_s with respect to the high notch is determined, and indicated to air volume calculator 18 on the basis of the set air volume corresponding to the air volume notch set by the air volume setting button (S109). Target air volume Q_s may be determined by referring to a table stored in a memory or determined based on a calculation equation set in advance.

[0055]

After target air volume Q_s is determined, the amplification factor of any one of three phases is changed by amplification factor changing unit 21 according to target air volume Q_s (step S110).

[0056]

When output air volume Q_n becomes lower than target air volume Q_s , current flowing through shunt resistors 14 is decreased. Therefore, current detector 16 is difficult to precisely detect current flowing through the windings. In view of this, when target air volume Q_s is lower than predetermined air volume Q_a , amplification factor changing unit 21 performs a process for increasing the amplification factor of amplifier 15 to detect the current value input to air volume calculator 18. Predetermined air volume Q_a is a value of an air volume stored in advance. Predetermined air volume Q_a is set to have a value which is sufficiently smaller than target air volume Q_s and by which precise winding current cannot be detected by current detector 16 unless the amplification factor is switched for the detection.

[0057]

Speed controller 22 outputs a duty to inverter circuit 11 on the basis of the value determined based on target air volume Q_s .

[0058]

When the duty is output to inverter circuit 11, inverter circuit 11 sequentially energizes six switching elements to drive sensorless brushless DC motor 3. When sensorless brushless DC motor 3 is driven, current flows through shunt resistors 14. Amplifier 15 amplifies voltage at both ends of each shunt resistor 14. Current detector 16 detects the amplified voltage at both ends of each shunt resistor 14, and detects, for each phase, current (winding current) flowing through the windings of the sensorless brushless DC motor based on this voltage (step S111).

[0059]

Current detector 16 inputs the winding current of two phases in the detected winding current to rotation detector 17. The winding current of the remaining one phase is input to air volume calculator 18 as described later.

Rotation detector 17 calculates the rotating speed and position of sensorless brushless DC motor 3 on the basis of the winding current of two phases (step S112).

[0060]

5 Next, air volume calculator 18 calculates current output air volume Q_n from the current value of one phase detected by current detector 16 and the rotating speed detected by rotation detector 17 (step S113).

[0061]

10 In this case, even if the rotating speeds are the same, air volumes are different depending on the distance from blade 2 to the ceiling. The relationship between current and rotating speed for each of different distances between blade 2 and the ceiling is measured in advance and created in a form of a table. That is, ceiling fan 1 is operated to constantly blow air in target air volume Q_s , and the rotating speed of blade 2 and the current value of one
15 phase detected by current detector 16 are measured by changing the distance from blade 2 to the ceiling. From the measurement result, the relationship between rotating speed and current value is formed in a form of a table (FIG. 6A). FIG. 6A is a diagram illustrating a relationship among distance from blade 2 of the ceiling fan 1 to the ceiling, and current and rotating speed of
20 ceiling fan 1, according to the exemplary embodiment of the present invention, with respect to target air volume Q_s . From FIG. 6A, values of rotating speed and current are obtained on the basis of target air volume Q_s and distance from blade 2 to the ceiling.

[0062]

25 This will be specifically described. The distance from blade 2 to the ceiling obtained in step S107 is 250 mm. The relationship between rotating speed and current with the distance from blade 2 to the ceiling being 250 mm

in target air volume Q_s is as indicated in FIG. 6B. FIG. 6B is a diagram illustrating a control operation of ceiling fan 1 according to the exemplary embodiment of the present invention, with respect to a target air volume, the diagram illustrating a relationship among distance from blade 2 to the ceiling, current, and rotating speed.

[0063]

From FIG. 6B, when the distance from blade 2 to the ceiling is 250 mm, the operating state satisfying target air volume Q_s is such that the rotating speed is N_1 and current is I_1 . When the current value of one phase detected by current detector 16 is I_2 and the rotating speed detected by the rotation detector is N_2 (point A), current output air volume Q_n is smaller than target air volume Q_s . In addition, when the current value of one phase is I_3 and the rotating speed detected by the rotation detector is N_3 (point B), current output air volume Q_n is larger than target air volume Q_s . When the current value of one phase is I_1 and the rotating speed detected by the rotation detector is N_1 , current output air volume Q_n is equal to target air volume Q_s . Air volume calculator 18 compares calculated output air volume Q_n with target air volume Q_s (step S114).

[0064]

When output air volume Q_n is smaller than target air volume Q_s , air volume calculator 18 instructs speed controller 22 to output increased duty to increase the rotating speed. When output air volume Q_n is larger than target air volume Q_s , air volume calculator 18 instructs speed controller 22 to output decreased duty. With this control, the rotating speed of blade 2 is lowered to decrease the deviation between output air volume Q_n and target air volume Q_s .

[0065]

Ceiling fan 1 thus configured can detect winding current flowing through sensorless brushless DC motor 3 with high precision by the configuration in which a shunt resistor 14 inserted for each of phases of the inverter circuit 11, between the lower stage and a negative potential side of the phase. and current flowing through shunt resistors 14 is detected. In addition, winding current can precisely be detected by changing the amplification factor of one of the respective phases by amplification factor changing unit 21. Therefore, the operation with an air volume ranging from a low air volume to a high air volume by making use of the characteristic of the DC motor is enabled. Accordingly, an air volume can substantially be kept constant regardless of the distance from blade 2 to the ceiling, and an increase in power consumption due to excess air volume can be suppressed.

[0066]

The present exemplary embodiment describes the case in which the air volume setting is set to a high notch. However, an air volume can be substantially kept constant in every air volume setting, so long as the control is performed for each air volume which is similarly set. In this case, the similar effect can be obtained.

[0067]

In addition, while amplification factor changing unit 21 is configured to switch an amplification factor based on target air volume Q_s in the present exemplary embodiment, the amplification factor may be switched on the basis of a current value detected by current detector 16.

[0068]

As described above, ceiling fan 1 according to the present exemplary embodiment includes blade 2, sensorless brushless DC motor 3 that drives blade 2, and control circuit 4 that controls the motor, ceiling fan 1 being

installed on a ceiling through a mounting pole for circulating air in a room. In addition, control circuit 4 includes AC/DC conversion circuit 9 that converts AC voltage to DC voltage; and inverter circuit 11 which is composed of an upper stage and a lower stage and configured such that three arms, each of which includes two switching elements that perform opposing ON/OFF operation and are connected in series with DC voltage, are connected in three-phase bridge, inverter circuit 11 driving the motor when fed with A/D converted voltage by a three-phase PWM method. In addition, control circuit 4 includes: a shunt resistor 14 inserted for each phases of the inverter circuit 11, between the lower stage and a negative potential side of the phase; amplifier 15 that amplifies inter-terminal voltage of shunt resistors 14; and current detector 16 that detects, from the output of amplifier 15, a current value of each phase flowing in the motor. In addition, control circuit 4 includes: rotation detector 17 that calculates a rotating speed and a position of the motor based on the current detected by current detector 16; and air volume calculator 18 that calculates a distance from the blade to the ceiling and compares a target air volume with a current output air volume. Still further, control circuit 4 includes speed controller 22 that, based on the comparison result of air volume calculator 18, controls the rotating speed of the motor by outputting a duty to inverter circuit 11 so that air volumes are substantially uniform. Still further, air volume calculator 18 inputs the current value of one phase in current values of the respective phases detected by current detector 16 and the rotating speed calculated by rotation detector 17, calculates a distance from the blade to the ceiling from the current value and the rotating speed which have been input, and sets the current value and the rotating speed which have been input to a current value and a rotating speed corresponding to the target air volume determined based on the calculated

distance from the blade to the ceiling, thereby setting the current output air volume to the target air volume determined based on the calculated distance from the blade to the ceiling.

[0069]

5 Thus, current flowing through the windings of the motor can precisely be detected, whereby an air volume can be kept substantially constant regardless of the distance from the blade to the ceiling and an increase in power consumption can be suppressed.

[0070]

10 In addition, control circuit 4 may include amplification factor changing unit 21 that changes an amplification factor of amplifier 15. Amplification factor changing unit 21 may switch an amplification factor of amplifier 15 for detecting a current value input to air volume calculator 18 based on the target air volume.

15 [0071]

 According to this configuration, current flowing through the windings of the motor can precisely be detected by changing the magnitude in amplification factor changing unit 21 according to the target air volume, whereby a ventilation air volume can be always kept constant even if the
20 target air volume is low.

[0072]

 In addition, control circuit 4 may include amplification factor changing unit 21 that changes an amplification factor of amplifier 15. Amplification factor changing unit 21 may switch an amplification factor of amplifier 15 for
25 detecting a current value input to air volume calculator 18 based on current detected by current detector 16.

[0073]

According to this configuration, current flowing through the windings of the motor can precisely be detected by changing the magnitude in amplification changing unit 21 according to current detected by current detector 16, whereby an air volume can be kept almost constant even if the
5 target air volume is low.

INDUSTRIAL APPLICABILITY

[0074]

The ceiling fan according to the present invention is installed on a
10 ceiling through a mounting pole for circulating air in a room. The present invention is widely useful for a product that can blow air in a predetermined air volume, regardless of the distance from a blade to the ceiling, even if it has a large blade diameter.

15 REFERENCE MARKS IN THE DRAWINGS

[0075]

- | | | |
|----|----|--|
| | 1 | ceiling fan |
| | 2 | blade |
| | 3 | sensorless brushless DC motor |
| 20 | 4 | control circuit |
| | 5 | remote controller |
| | 5a | start/stop button |
| | 5b | air volume setting button |
| | 6 | remote controller light-receiving unit |
| 25 | 7 | mounting pole |
| | 8 | commercial power supply |
| | 9 | AC/DC conversion circuit |

	10	smoothing capacitor
	11	inverter circuit
	12	stator
	13	rotor
5	14	shunt resistor
	15	amplifier
	16	current detector
	17	rotation detector
	18	air volume calculator
10	19	remote controller signal determination unit
	20	target air volume calculator
	21	amplification factor changing unit
	22	speed controller

15

CLAIMS

1. A ceiling fan comprising:
 - a blade;
 - 5 a motor that drives the blade; and
 - a control circuit that controls the motor,
 - the ceiling fan being installed on a ceiling through a mounting pole for circulating air in a room,
 - wherein
 - 10 the control circuit includes:
 - an alternating current-to-direct current conversion circuit that converts alternating current voltage to direct current voltage;
 - an inverter circuit which is composed of an upper stage and a lower stage and configured such that three arms, each of which comprises two
 - 15 switching elements that perform opposing ON and OFF operations and are connected in series with direct current voltage, are connected in three-phase bridge, the inverter circuit driving the motor when fed with voltage subjected to alternating current-to-direct current conversion by a three-phase pulse width modulation method;
 - 20 a shunt resistor inserted for each of phases of the inverter circuit, between the lower stage and a negative potential side of the phase;
 - an amplifier that amplifies inter-terminal voltage of the shunt resistors;
 - a current detector that detects, from an output of the amplifier, a
 - 25 current value of each phase flowing in the motor;
 - a rotation detector that calculates a rotating speed and a position of the motor based on current detected by the current detector;

an air volume calculator that calculates a distance from the blade to the ceiling and compares a target air volume with a current output air volume; and

5 a speed controller that, based on a comparison result of the air volume calculator, controls the rotating speed of the motor by outputting a duty to the inverter circuit so that air volumes are substantially uniform,

the air volume calculator inputs the current value of one phase in current values of the respective phases detected by the current detector and the rotating speed calculated by the rotation detector,

10 the air volume calculator calculates the distance from the blade to the ceiling from the current value and the rotating speed which have been input, and

the air volume calculator sets the current value and the rotating speed, which have been input, to a current value and a rotating speed corresponding to the target air volume determined based on the calculated distance from the blade to the ceiling, thereby setting the current output air volume to the target air volume determined based on the calculated distance from the blade to the ceiling.

20 2. The ceiling fan according to claim 1, wherein

the control circuit includes an amplification factor changing unit that changes an amplification factor of the amplifier, and

the amplification factor changing unit switches, based on the target air volume, an amplification factor of the amplifier for detecting a current value input to the air volume calculator.

3. The ceiling fan according to claim 1, wherein

the control circuit includes an amplification factor changing unit that changes an amplification factor of the amplifier, and

the amplification factor changing unit switches, based on current detected by the current detector, an amplification factor of the amplifier for
5 detecting a current value input to the air volume calculator.