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ELECTRIC FAN

DESCRIPTION

5 The present invention relates to an electric fan. More specifically, the present invention relates to a novel electric fan using a DC brushless motor for driving an impeller.

10 Electric fans are disclosed in US Patent Nos. 3 446 429; and 3 481 533 which utilise an induction motor. Since an induction motor exhibits a small starting torque, difficulties can be encountered in starting i.e. from zero or low speed.

15 To overcome this difficulty, it has been proposed to utilise a starting compensating circuit, as disclosed, for example, in Japanese Utility Model Publication No. 46164/1975 but this has the disadvantage that a
20 complicated circuit is needed.

Furthermore, since the torque of an induction motor is relative low at low speed and the lower limit of the normally driveable speed is relatively high, a

so-called ultra-low speed driving of a conventional fan with an induction motor is not practical.

5 Moreover, the use of an induction motor increases the outside diameter of the motor, thereby blocking the airflow produced by the impeller and deteriorating the fan efficiency.

10 It is, therefore, an object of the present invention to provide a novel electric fan capable of overcoming the aforementioned inherent disadvantages of a conventional electric fan associated with the use of an induction motor.

15 The present invention provides a novel electric fan using a DC brushless motor for driving an impeller.

20 More particularly, the present invention provides an electric fan comprising: a rotary impeller; a DC brushless motor arranged to drive the impeller and including a plurality of coils and a magnet for rotation relative to the coils, said coils being arranged for multi-phase operation; driving means for applying a driving voltage to said coils of the motor,

said driving means including a plurality of switching elements for switching current through the motor phases respectively; a plurality of magnetic sensing elements arranged to sense rotation of the motor; phase control means responsive to said magnetic sensing elements and operative to switch said switching elements in such a manner that current is passed through the coils to energise the motor phases sequentially for periods that are overlapped in time; adjustable speed setting means for setting an operating speed condition for the fan; power control means for controlling the driving voltage applied from said driving means to the motor in dependence upon the setting of said setting means; rotational speed responsive means, responsive to said sensing elements to generate a time interval signal defining a duration corresponding to a predetermined angular rotation of the motor at its current operational speed; and period defining means for defining the duration of said overlap as a predetermined function of the duration defined by said time interval signal.

According to the present invention, since a DC brushless motor is utilised instead of the conventional induction motor, the motor size may be considerably

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reduced. Therefore, in the electric fan in accordance with the present invention, the air volume blocked by the DC brushless motor itself is minimised, so that the fan efficiency of the impeller may be improved as compared with a conventional fan using the induction motor. Furthermore, the DC brushless motor has a large starting torque at low speed, so the electric fan according to the present invention may be started directly at low speed without having any starting compensating circuit. In addition, as the DC brushless motor exhibits a large torque in its low speed area, the electric fan according to the present invention may be operated at lower speed when compared with a conventional induction motor driven fan, and thus an operation such as "breeze" or "ultra-low breeze" may be possible.

Further features and advantages of the present invention will become more apparent from the following detailed description of the embodiments of the present invention when taken in conjunction with accompanying drawings, wherein:

Figure 1 is an external view showing one embodiment in accordance with the present invention,

Figure 2 is a cross-sectional schematic view showing the embodiment in detail,

5 Figure 3 is a block diagram showing an electric circuit of the embodiment of Figures 1 and 2,

Figure 4 is a circuit diagram showing the block diagram of Figure 3 in more detail,

10 Figure 5 is a flow diagram explaining the operation for controlling a motor in the embodiment of Figures 3 and 4,

Figures 6 and 7 are timing diagrams for explaining the operation according to Figure 5,

15 Figure 8 is a graph for explaining operation of the embodiment, in which the speed is plotted along the abscissa and torques and efficiencies are plotted along the ordinate,

Figure 9 is a circuit diagram of a major part showing a different example of a constant voltage circuit,

20 Figure 10 is a block diagram showing the other example of an electric circuit in accordance with the present invention,

Figure 11 is a schematic constructional view of a major part showing a further embodiment in accordance with

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the present invention,

Figure 12 is a schematic constructional view showing a still further embodiment in accordance with the present invention, and

5 Figure 13 is a schematic constructional view of a major part of the other embodiment in accordance with the present invention.

10 Figures 1 and 2 illustrate one embodiment in accordance with the present invention. An electric fan 10 comprises a stand 12 which includes a stand base 14 and a bottom plate 16 engaged thereto. Extending upwardly from the stand base 14 is a hollow pole brace 18 into which a supporting member 20 is inserted, in such a
15 manner that the same is movable vertically. A neck-piece 22 is movably supported on the upper end of the supporting member 20.

20 On the neck-piece 22, as shown in Figure 2, there is installed a motor cover 24, in which is disposed base plate 26 having arms that define an L-shaped cross section. The base plate 26 is, in the embodiment, formed of die-cast aluminum and supported by the neck-piece 22 on one of its arms.

The substantially vertical other arm of the base plate 26 rotatably supports shaft 34 of a DC brushless motor 28. The DC brushless motor 28 is constructed as an outer rotating type motor and includes an inner stator 30 consisting of windings formed around the periphery of a cylindrical body made of a magnetic material and an outer rotor 32 provided with a magnet 38 secured to the inner wall of a cylindrical or cup-shaped yoke 36 surrounding the stator 30 serving also as a casing. The rotary shaft 34 extends through the centre of the inner stator 30, the bottom of the yoke 36 described hereinabove is secured substantially at the centre thereof, on the tip of the shaft 34. Accordingly, the outer rotor 32 will rotate during operation of the motor.

An impeller 40 is secured to the tip of the rotary shaft 34 so as to cover the peripheral surface of the yoke 36. More specifically, the tip of the rotary shaft 34 is threaded to screw a threaded member

thereon, thereby securing the impeller 40 to the rotary shaft 34.

5 The rotary shaft 34 extends through the rear end of the DC brushless motor 28 (right side in Figure 2). A Hall IC 44 for detecting a position of the rotor 32 is mounted on a circuit board 42.

10 Furthermore, as will be apparent from Figure 2, the peripheral edge of the opening of the yoke 36 is formed with a collar 36a extending radially outwardly. The peripheral edge on the opening side of the motor cover 24 is bent inwardly to form a collar 24a so as to engage to or surround the collar 36a. The collars 24a
15 and 36a, prevent the penetration of dust into the motor cover 24. More specifically, between two collars 24a and 36a, an air current flowing outwardly is produced by the rotation of the impeller 40, thereby forming a so-called air curtain and thus preventing dust from
20 entering therebetween. Moreover, there is an advantage that the DC brushless motor 28 is cooled by the air current between the collars 24a and 36a.

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Inside the motor cover 24, an oscillating device 46 is secured on the upper surface of one side portion of the L-shaped mounting base plate 26 described above. The oscillating device 46 includes an induction motor as shown in Figure 3, and oscillates the impeller 40 to both sides through a crank mechanism (not shown). The oscillating motor may be a DC motor.

In front of the motor cover 24, a guard 48 covering the impeller 40 is installed.

As shown in Figure 1, on the upper surface of the stand base 14, there is provided a switch 50 which is connected to a board 52 disposed within the stand 12 and used for setting an operating condition such as speed. The board 52 is installed within the stand 12 by means of a suitable boss, and provided with a control circuit to be explained later particularly in connection with Figures 3 and 4.

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Referring to Figure 2, the supporting member 20 extending through the pole brace 18 extending upwardly from the stand 12, includes a supporting portion 54 provided at its upper end for mounting the

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aforementioned neck-piece 22 and a telescopic guide 56 arranged at its lower end for guiding the telescopic motion thereof. The supporting member 20 consists of a tubular metal pole brace 58 and an ornamental cylinder 60 covering the metal pole brace 58, formed by moulding a synthetic resin. The cylinder 60 is mounted on the projections formed on the aforementioned supporting portion 54 and the telescopic guide 56 at its upper and lower ends. Then, the lower end of the metal pole brace 58 is inserted into an inserting hole formed in the telescopic guide 56 to engage therewith and the upper end thereof is inserted into an opening formed in the supporting portion 54 to engage therewith.

A rib 62 is formed to engage the inner surface of the lower end of the metal pole brace 58. The lower portion of the cylinder 60, the telescopic guide 56 and the lower portion of the metal pole brace 58 are secured together by a machine screw 64 screwed in from the side.

The upper end of the metal pole brace 58 is merely inserted into the above mentioned opening, and not locked together with the supporting portion 54 and the

upper portion of the cylinder 60. The metal pole brace 58 is, thus, freely slideable vertically within the opening of the supporting portion 54.

5 In the event of extension or contraction of the supporting member 20 due to changes in the ambient temperature, the degree of extension/contraction of the cylinder 60 (made of a synthetic resin) differs from that of the metal pole brace 58, the extension/
10 contraction of the metal pole brace 58 being larger than that of the cylinder 60. In the embodiment, as previously explained, the cylinder 60 and the metal pole brace 58 are secured together at their lower ends, and the metal pole brace 58 is free to extend or
15 contract within the opening of the supporting portion 54 at its upper end, thereby absorbing differences in extension/contraction caused by the changes in temperature.

20 Referring to Figures 3 and 4, for driving the DC brushless motor 28, there is provided a driving control circuit 80, which includes a microcomputer or a microprocessor 82 such as an integrated circuit "LC 6526 H" by Tokyo Sanyo. In the microcomputer 82,

although not shown, a memory such as ROM or RAM and a necessary input and/or output port is provided. In the memory area of the microcomputer 82, a timer 84 and a counter 86 are formed to be used in determining the timing for applying the voltage to the DC brushless motor 28 as will be explained later in detail.

In brief, on the basis of the signal from a position detecting circuit 88 receiving the signal from the Hall IC 44 disposed relative to the DC brushless motor 28, the microcomputer 82 feeds a control signal to a driving circuit 90, from which the necessary phase signal is given to the coils of the DC brushless motor 28 with a timing corresponding to the control signal.

Referring to Figure 4, the signals from the Hall elements H1 through H3 included in the Hall IC 44 are fed respectively to the three input terminals PA0 through PA2 of the microcomputer 82. The driving signals for the drivers D1 through D3 and D4 through D6 are outputted from the output terminals PD0 through PD2 and PE0 through PE2 of the microcomputer 82. The drivers D1 through D3 comprise NPN transistors and the drivers D4 through D6 comprise PNP transistors.

Accordingly, the drivers D1 through D3 are turned on when the high level is given to their base inputs, and are turned off when the low level is given. The drivers D4 through D6 operate in reverse. The
5 respective collectors of the drivers D1 through D3 are connected to the bases of the switching transistors Q1 through Q3 comprising PNP transistors, and the collectors of the drivers D4 through D6 are connected to the bases of the switching transistors Q4 through Q6
10 comprising NPN transistors. The emitters of the switching transistors Q1 through Q3 are commonly connected to a DC constant voltage from a smoothing circuit 122 and the emitters of the switching transistors Q4 through Q6 are commonly connected to
15 earth. The respective corresponding collectors of the switching transistors Q1 through Q3 and Q4 through Q6 are commonly connected to coils 30u, 30v and 30w of the stator 30 respectively.

20 Accordingly, with the switching transistors Q1 and Q5 ON, the current flows from the stator coils 30u to 30w. The period of current flow in this direction is indicated at ① in Figure 6. With the switching transistors Q1 and Q6 ON, the current flows from the

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stator coils 30u to 30v. The period of current flow in this direction is indicated at ② in Figure 6. With the switching transistors Q2 and Q6 ON, the current flows from the stator coils 30w to 30v. The period of current flow in this direction is indicated at ③ in Figure 6. With the switching transistors Q2 and Q4 ON, the current flows from the stator coils 30w to 30u. The period of current flow in this direction is indicated at ④ in Figure 6. With the switching transistors Q3 and Q4 ON, the current flows from the stator coils 30v to 30u. The period of current flow in this direction is indicated at ⑤ in Figure 6. With the switching transistors Q3 and Q5 ON, the current flows from the stator coils 30v to 30w. The period of current flow in this direction is indicated at ⑥ in Figure 6.

In the driving control circuit 80, a rotation error detecting circuit 92 is provided for detecting rotation errors based upon the signal from Hall IC 44. The rotation error detecting circuit 92 detects the level of current applied to the DC brushless motor 28, by means of a resistor 92c and compares this level with a reference by means of comparators 92a and 92b, to

product control signals. The detecting circuit 92 includes two circuits 92_1 and 92_2 , the former being inputted to a first voltage control circuit 118a and the latter being inputted to the driving controller 82.

5 The circuit 92_1 is designed to protect against overvoltage in such a manner that, if the rate of rotation is forcibly reduced when the impeller 40 and the rotor 32 are rotating, for example, at 40V 1500 r.p.m., by an external force (entwining of a curtain or
10 the like), the current value in the resistor 92c is increased and the output from the comparator 92a alters such that the voltage set by the first control circuit 118 reduces from 40V to 10V.

15 The circuit 92_2 operates similarly to the circuit 92_1 . However, its setting value differs from the circuit 92_1 and remains unaltered even during the aforementioned overvoltage protection. However when the rotational speed of the impeller is reduced by the external force
20 below the rate of rotation set at 10V, the comparator 92b outputs a signal which is inputted to a terminal PC1 of a microcomputer 84 in the driving controller 82 (the terminal PC1 which is normally at high level then

changes to low level), and thereby the driving controller 82 is controlled to stop the DC brushless motor 28.

5 There is also provided an operation control circuit 94, which on the basis of the signal from the switch 50 (Figure 1), controls functions such as the air flow rate. The operation control circuit 94 includes a microcomputer or a microprocessor 96 such as an
10 integrated circuit "LC 6526C" by Tokyo Sanyo. The signal from the aforementioned switch 50 is given as the input signal to the microcomputer 96, which, in accordance with the input signal, controls a first voltage control circuit 118 included in a voltage
15 controller 98 to control the voltage applied to the DC brushless motor 28, that is, its rotating speed.

Also, the operation control circuit 94 includes a sound circuit 100 generating a sound responsive to the
20 operation of the switch 50, and an indicator circuit 102 including a light emitting diode etc. indicating the operation of the switch 50. Moreover, an oscillating motor driving circuit 106 is provided for

controlling an oscillating motor 104 for in the oscillating device 46 (Figure 2).

5 The oscillating motor 104 is conveniently an induction motor that receives power from an AC power source 108. A filter circuit 110 is connected to the power source 108 and consists of coils and a capacitor as shown in Figure 4 to remove the noise produced from the DC brushless motor 28. In the filter circuit 110, a
10 circuit protective element for absorbing surge voltages, for example a varistor, is further incorporated as shown in Figure 4.

15 An AC voltage from the AC power source 108 is applied to a rectifier circuit 112 through the filter circuit 110. The rectifier circuit 112 is a full-wave diode bridge rectifier circuit and its output DC voltage is applied to a first constant voltage circuit 114 including a Zener diode as well as to a second voltage
20 control circuit 116 incorporated in the voltage controller 98. The second voltage control circuit 116 acts based upon a control signal from the first voltage control circuit 118, which chops the applied DC voltage from constant voltage circuit 114 by the signal

from an oscillation circuit 120. Thus, the chopped DC voltage is outputted by the second voltage control circuit 116, and smoothed by a smoothing circuit 122, DC voltage from which is applied to the driving circuit 90 of the motor driving control circuit 80.

The rectifier circuit 112 provides a DC voltage output having a mean value of 100V and a peak value of approximately 141V, which is chopped by the second voltage control circuit 116 (and the first voltage control circuit 118) incorporated in the voltage controller 98 and applied to the smoothing circuit 122. The smoothing circuit 122 includes a coil, which produces a saw-tooth voltage $LI^2t/2$, and a smoothing capacitor, the smoothed voltage being applied to the DC brushless motor 28 through the driving circuit 90.

The first voltage control circuit 118 is controlled by the microcomputer 96 incorporated in the driving controller 94 and changes the voltage applied to the DC brushless motor 28 by controlling the output voltage from the smoothing circuit 122 from about 5V up to 40V.



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Thereby, the rotating speed of the DC brushless motor 28 may be changed from 250 r.p.m. up to 1500 r.p.m.

5 Also, the DC voltage from the smoothing circuit 122 is fed to the second constant voltage circuit 124.

10 Since the microcomputer 82 incorporated in the driving controller 80 and the microcomputer 96 incorporated in the operation controller 94 are both arranged on the board 52 (Figure 2), a clock of e.g. 800KHz from a clock source 126 is commonly given to them and a resetting circuit 128 is connected in common. However, if the microcomputers 82 and 96 are each installed on separate boards, the clock source 126 and the resetting circuit 130 are provided separately for each board.

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A conduction angle setting circuit 130 is connected to the microcomputer 82, which includes two switches 130a and 130b as shown in Figure 4, and by switching these switches on and off selectively, different conduction angles are set. The conduction angle setting circuit 130 will be described in more detail hereinafter.

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A forward/reverse rotating mode selecting circuit 132 is connected to the microcomputer 82, which, in this embodiment, includes a resistor as shown in Figure 4, and thus only forward rotation is set. However, a
5 suitable switch may be connected to select either forward or reverse rotation.

The DC brushless motor 28 includes, as shown in Figure 4, star-connected stator coils 30u, 30v and 30w, whose
10 neutral point is not grounded. As shown in Figure 2, the rotor magnet 38 secured to the yoke 36 is formed as an anisotropic magnet magnetised in reverse polarity alternately in its circumferential direction. The Hall
IC 44 includes, as shown in Figure 4, the Hall elements
15 H1, H2, and H3 arranged at angles associated with the stator coils 30u, 30v and 30w respectively. The signals from these Hall elements H1, H2 and H3 are fed to the driving controller 80 as previously described.

20 The driving circuit 90 includes switching transistors Q1 through Q6 for applying voltage successively to the stator coils 30u, 30v and 30w previously described, with a prescribed timing, thereby providing a three-phase bipolar type driving circuit. However, the

driving circuit can be of a three-phase unipolar type or other known driving methods may be utilised.

A timer 84 incorporated in the microcomputer 82 outputs a time-up signal after a fixed time, and a counter 86 is utilised for measuring the time intervals between the position signals from the Hall elements H1 through H3.

In the embodiment, the aforementioned conduction angle setting circuit 130 is used for partly overlapping the conducting periods of the stator coils 30u, 30v and 30w, thereby permitting selection of four kinds of predetermined overlapping angles (0°, 30°, 35°, 40°) to set the overlapping ratios thereof. The conduction angles are shown in the following table.

TABLE

Setting Switch 130a 130b		Conduction Angle	Conducting Time Ton Calculation Formula	
OFF	OFF	0°	Ton = 0	
ON	OFF	30°	Ton = $\frac{30}{60}$ Td = $\frac{1}{2}$ Td	
OFF	ON	35°	Ton = $\frac{35}{60}$ Td = $\frac{7}{12}$ Td	
ON	ON	40°	Ton = $\frac{40}{60}$ Td = $\frac{2}{3}$ Td	

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Such different conduction angles are set by operating the switches 130a and 130b incorporated in the conduction angle setting circuit 130. The conduction angle is set at the value whereat vibration and noise is minimised during the operation of the electric fan, but due to the inequality of characteristics of each fan, the value is not constant for all fans so that in practice, it is advisable to determine the optimum value by experiment for each fan individually.

Referring now to Figures 5 through 7, the operation of the microcomputer 82 for controlling such conduction angle will be explained.

When a start switch incorporated in the switch 50 (Figure 1) is pressed, the microcomputer 82 first in the step S1, cuts off the signal to the drivers D1 through D6 and initialises the timer 84 and the counter 86. Next, in the step S2, the microcomputer 82 checks the condition of the signals set by the switches 130a and 130b included in the conduction angle setting circuit 130. Then, in the following step S3, the microcomputer 82 sets the setting time "0" in the timer 84 incorporated therein.

Next, the microcomputer 82 reads in the pole position signals from the Hall elements H1 through H3 as the signals U_i , V_i , and W_i . Now, as shown in Figure 6, if the pole position detecting signals at the starting time are respectively $U_i = "1"$, $V_i = "0"$ and $W_i = "0"$, this is detected in the step S4 in Figure 5. The microcomputer 82, in the following step S5, gives the high level signal to the driver D1 and the low level signal to the driver D6; thus the drivers D1 and D6 are ON and the switching transistor Q1 and Q6 are ON.

Next, the microcomputer 82, in the step S6, gives the trigger signal to the timer 84. Thus the timer 84 starts at this time. The timer 84 is designed to output a time-up signal as the set time elapses, as described above, so when the set value is 0, it gives the timer starting command and simultaneously the time-up signal is outputted.

When the microcomputer 82 detects the time-up signal from the timer 84 in the step S6, in the step S7, a high level signal is fed to the driver D5 for turning off the switching transistor Q5, which is however, OFF

in the initial state, i.e. the same as the other switching transistors; thus it remains unchanged.

5 The conducting direction of the stator coils 30u, 30v and 30w is indicated as ② as shown in Figure 6, so in the state of step S5, the current flows from the stator coils 30u to 30w. Thus in the DC brushless motor 28, based upon the pole generated in the stator coils 30u through 30w according to the current, the
10 rotor magnet 38 or the yoke 36 starts to rotate. With the rotation of the yoke 36, the impeller 40 (Figures 1 and 2) connected thereto starts to rotate.

15 The microcomputer 82, in the following step S8, reads in the time data T_d counted by the counter 86, which counts the time from the rising edge of pole position signal U_i to the falling edge of pole position signal W_i . Thus in the initial state where the pole position signals U_i and W_i are not detected yet, $T_d = 0$.

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Then the microcomputer 82, in the step S9, based upon its counted time data T_d and on the basis of the calculation formula shown in the previous table, calculates the conduction time T_{on} corresponding to the

conduction angle indicated in the table. When $T_d = 0$, $T_{on} = 0$.

5 Next, in the step S10, the microcomputer 82 sets the conduction time T_{on} thus obtained in the timer 84. However, in the initial state, since "0" has been set in the timer 84, when setting $T_{on} = 0$, the content of the timer 84 could be left unchanged.

10 As the rotor magnet 38 starts to rotate as described above, as shown in Figure 6, the respective pole position signals U_i , V_i , and W_i will change. When the microcomputer 82 detects the change in the step S11, it returns to the preceding step S4.

15 In the example shown in Figure 6, as in the step S12 of Figure 5, when the pole position signals $U_i = "1"$, $V_i = "1"$ $W_i = "0"$ are detected, the microcomputer 82, in the step S13, gives the high level signal to the driver D2 and the low level signal to the driver D6; thus the
20 switching transistors Q2 and Q6 are turned ON. When the time-up signal is detected in the step S14, the microcomputer 82, in the step S15, gives the low level signal to the driver D1. Thus the switching transistor

Q1. is turned OFF and the switching transistors Q2 and Q6 are turned ON.

5 Although the switching transistor Q6 is already turned ON at the starting time, here again the high level switching signal is given thereto. This is for effecting normal starting regardless of the state of the pole position signal.

10 When the switching transistors Q2 and Q6 are turned ON in the step S13, the current flows from the stator coils 30w to 30v in the direction ③ shown in Figure 6 and the rotor magnet 38 rotates further. Thus the pole position signals Vi through Wi change further.
15 Therefore, the process of the microcomputer 82 is returned again to the step S4.

At that time, as shown in Figure 6, the pole position signals become $U_i = "0"$, $V_i = "1"$ and $W_i = "0"$
20 respectively. Accordingly, the microcomputer 82 detects the state in the step S16 and in the succeeding steps S17 through S19, turns ON the switching transistors Q2 and Q4 and turns OFF the switching transistor Q6.

Thus the conducting directions to the stator coils 30u, 30v and 30w are successively switched over whenever the pole position signal Ui, Vi and Wi are changed, and the rotor magnet 38 is thereby rotated by half a revolution.

When the rotor magnet 38 is rotated by half, the pole position signals Ui through Wi will return to the first signal pattern after completing one period, so that such conduction control is again repeated and the rotor magnet 38 is rotated further by half. Accordingly, as a result, the rotor magnet 38 is continuously rotated and the rotary shaft 34 and the impeller 40 are rotated continuously.

During this process, when the pole position signals Ui through Wi change from "101" in the step S20 to "100" in the step S4, the counter 86 counts the time therebetween and outputs the time data Td, which is read by the microcomputer 82 in the step S8 of Figure 5 as previously described, when the pole position signal has changed to "100".

As shown in Figure 7, if the switch-on period of the switching transistor Q1 is extended, for example, by the time T_{on} , for conducting current to the stator coils 30u, 30v, and 30w, the current flowing through the stator coils 30u to 30v indicated at ② and the current flowing through the stator coils 30w to 30v indicated at ③ tend to overlap by the time T_{on} . Thus if the switch-on periods of the respective switching transistors Q1 through Q6 are extended by the time T_{on} , the respective conducting states are shifted so as to be partly overlapping.

Now, the count time data T_d produced in the counter 86 is the time corresponding to an electrical angle 60° , as shown in Figure 6. Thus as given in the previous table, the switch-on time T_{on} corresponding to the desired conduction angle may be calculated from the count time T_d .

More specifically, when the microcomputer 82 reads in the time data T_d , for example, in the step S8 of Figure 5, as shown in the table, it calculates the switch-on time T_{on} corresponding to the conduction angle selected by the switches 130a and 130b in the step S9 on the

basis of its calculation formula. Then in the following step S10, it sets the calculated switch-on time T_{on} in the timer 84.

5 As the switch-on time T_{on} is set in the timer 84, as previously described, the subsequent switch-off timing of the switching transistors Q1 through Q6 is extended by the switch-on time T_{on} . For example, in Figure 6, if the counter 86 has counted the time T_{d1} , the
10 microcomputer 82 after switching on the switching transistors Q2 and Q6 in the step S13, turns off the switching transistor Q1 after the timer 86 has detected the elapse of switch-on time T_{on} . Accordingly, as a result, the switch-on time of the switching transistor
15 Q1 is extended by the calculated time T_{on} .

In Figure 6, although the period of pole position signals U_i , V_i and W_i are illustrated as constant, in practice, the rotating speed at starting time increases
20 gradually to a constant speed, so that the period is also shortened gradually to a predetermined value. However, since the measurement of the time T_d and the setting of the time T_{on} is made every half rotation of the magnet rotor, a fixed conduction angle

corresponding to the rotating speed in that time is always set and operated at the set fixed conduction angle even after reaching the steady rate of rotation.

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As described above, the electric currents of each phase fed to the stator coils 30u, 30v and 30w flow continuously and are partly overlapped partly, so that the ripples in the stator coil or driving coil tend to reduce. Thereby, the vibration and noise of the DC brushless motor 28 is eliminated and thus the vibration and noise of the electric fan 10 (Figure 1) as a whole, may be considerably reduced.

15 As previously mentioned, the driving controller 94 is controlled by signals from the switch 50. Supposing that, for example, a "strong wind" has been set by the switch 50, then the microcomputer 96 outputs the high level signal at its output terminals PE0 through PE2
20 alike. The voltage to the (-) input of the comparator 118a (Figure 4) in the first voltage control circuit 118 incorporated in the voltage controller 98, will change according to the signals from the output terminals PE0 through PE2. When the output terminals

PE0 through PE2 are all at a high level, the voltage applied to comparator 118a increases to a maximum and a longest chopper period is attained by the second voltage control circuit 116. Thus the DC voltage from the smoothing circuit 122 becomes approximately 40V, which is conducted and controlled by the driving circuit 90 and applied to the stator coils 30u, 30v and 30w of the DC brushless motor 28. Then the DC brushless motor 28 rotates at a maximum speed, for example, at 1450 r.p.m. and a maximum air volume is outputted from the impeller 40. Alternatively, when the output terminals PE0 through PE2 are all at the low level, the voltage decreases to a minimum and a shortest chopper period is attained by the second voltage control circuit 116. Thus the DC voltage from the smoothing circuit 122 becomes approximately 5V, which is conducted and controlled by the driving circuit 90 and applied to the stator coils 30u, 30v, and 30w of the DC brushless motor 28. Then the DC brushless motor 28, therefore rotates at a minimum speed, for example at 250 r.p.m. and a minimum air volume is outputted from the impeller 40.

Thus, in the electric fan in accordance with the present invention, since the DC brushless motor is used in place of the conventional induction motor, a significant advantage may be obtained. Referring to Figure 8, there is shown a graph, in which the rate of rotation is plotted along the abscissa and the torque and efficiency are plotted along the ordinate. A line A1 in Figure 8 represents the efficiency of the embodiment of the present invention and a line B1 indicates the torque thereof. Lines A2 and B2 respectively show the characteristics of efficiency and torque of the conventional electric fan using the induction motor. As it will be apparent from Figure 8, according to the present invention, the torque in the low speed area is very large as compared with a conventional AC induction motor. Thus the start-up may be made readily at low speed and the operation of "mild wind" or "ultra-mild wind", for example, at 250 r.p.m. which was not possible by the conventional electric fan using an induction motor.

In the described electric fan in accordance with the present invention, the maximum torque was 3.80 kg.cm, as compared with the conventional electric fan using an

induction motor, whose torque was 1.20 kg.cm at 50 Hz and 1.15 kg.cm at 60 Hz. Moreover, as to the motor efficiency, the electric fan using the DC brushless motor in accordance with the present invention was improved up to 59.1% as compared with the conventional one, which was 28.5% at 50 Hz and 31.0% at 60 Hz.

Figure 9 is a circuit diagram showing a major portion of a further embodiment in accordance with the present invention. This embodiment is characterised by using one constant voltage circuit 134 as compared with the embodiment of Figures 3 and 4, forming the first and second constant voltage circuits 114 and 124 independently. The constant voltage circuit 134 couples a secondary winding to a coil disposed in the filter circuit 110, thereby obtaining the constant voltage alternating current to output the constant voltage DC voltage after rectification thereof.

Figure 10 is a block diagram showing a still further embodiment in accordance with the present invention. In the embodiment of Figure 3, it was arranged to control the magnitude of DC voltage applied to the DC brushless motor 28 on the basis of the signal from the

operation controller 94. However, in the embodiment of Figure 10 before the driving circuit 90 incorporated in the driving controller 80, there is provided a chopper circuit 136, which is controlled by the microcomputer 96 incorporated in the operation controller 94. Accordingly, in this embodiment, from the smoothing circuit 122 only the DC voltage of constant magnitude is obtained, which is chopped by the chopper control circuit 136 to control the DC voltage applied to the DC brushless motor 28.

It is operated at "strong wind" as in the previous embodiment at the 100% on-duty by the chopper control circuit 136. That is, the DC voltage of approximately 40V is outputted from the smoothing circuit 122 and if the on-duty is 100%, the voltage 40V is outputted as it is so that the DC brushless motor 28 will rotate at 1450 r.p.m.

Furthermore, in the embodiment of Figure 10, the oscillating motor 104 is constituted by a DC motor, and the DC voltage from the first constant voltage circuit 114 is applied to the oscillating motor 104. The

oscillating motor 104 may be constituted by a DC brushless motor.

Figure 11 is a schematic view of a major portion of another embodiment in accordance with the present invention. In this embodiment, the yoke 36 forming the rotor 32 and the boss casing 40' of the impeller 40 are extended further backward (right side in the drawing) from the board 42 to which the Hall IC 44 is mounted.

On the board 42, not only the Hall IC 44 but also the driving controller 80, voltage controller 98 and constant voltage circuits 114, 124 (or 134 Figure 9) are incorporated. Accordingly, in the embodiment, on the board 52 secured within the stand 12 (Figure 2), the driving controller 94, filter circuit 110 and rectifier circuit 112 etc are assembled together, and an individual, a reference clock source and resetting circuit are provided for the respective microcomputers 82 and 96.

In the embodiment, since the circuit components radiating the heat are integrally assembled on the board 42, an air current produced by the rotation of

the impeller 40 serves to cool such circuit components indirectly.

5 If still higher cooling effect is required, air vents may be formed on the other portions such as the rotor yoke 36 and the boss casing 40'.

10 In the embodiment of Figure 11, the rear edge of the rotor yoke 36 is formed to cover the board 42, so that it exhibits a shielding effect. As a result, any noise produced by the DC brushless motor 28 and the circuits on the board 42 is shielded by the yoke 36.

15 Moreover, in the embodiment of Figure 11, since the rotor yoke 36 is long, the contact surface between the boss casing 40' of the impeller 40 and the rotor yoke 36 itself may be increased, and thus the vibration of the impeller 40 may be reduced.

20 Furthermore, in the embodiment, although the driving controller 80 and the operation controller 94 are formed on the separate boards 42 and 52, since the output from the operation controller 94 is only applied to the first voltage control circuit 118, the number

of connecting lead wires between the two boards 42 and 52 is minimised.

5 Figure 12 is a schematic view of a further embodiment in accordance with the present invention. In this embodiment, on a rear guard forming the guard 48, a box 138 for containing the aforementioned board is mounted, while the board 52 is contained in the stand 12 as same as the previous embodiment. If the board 42 or the box 10 138 is mounted on the rear guard of the guard 48 as the embodiment, the board 42 may be cooled similarly to the manner described with reference to Figure 12. That is, the box 136 is cooled by the air current produced by the impeller 40, and thus the board 42 contained 15 therein is cooled indirectly. The air volume blocked by the box 138 is minimal and, in practice, gives no problem.

20 Figure 13 is a schematic view of a major portion of another embodiment in accordance with the present invention. In the embodiment, the DC brushless motor 28 is secured on a centre ornament 140 of a front guard of the guard 48, and the board 42 for mounting the Hall IC associated with the DC brushless motor 28 and the

board 52 for mounting the control circuit are installed on the portion of the ornament 140. That is, in the centre of the guard 48, a supporting body 142 is fixed, to which a cylindrical mounting member 144 is secured, thereby securing the boards 42 and 52 described above. In order to cover the boards 42 and 52, there is arranged a cylindrical cover 146, to which a heat radiating plate 148 is connected. Thus the heat produced by the circuit components mounted on the board 52 may be efficiently radiated. The cover 146 serves also as the shield against the noise produced from the boards 42 and 52.

The ornament 140 is mounted in the centre of the front guard of the guard 48 to cover the cover 146, and the outer rotor 32 of the DC brushless motor 28 includes the yoke 36 and the rotor magnet 38 mounted therein. On the guard 48, extending downwardly from its centre, is disposed a reinforcing member 150, which is formed, for example, with a pipe and supporting the lower end of the aforementioned supporting body 142 at a connector 152 mounted on the upper end thereof. Accordingly, even if the DC brushless motor 28 or circuit boards 42 and 52 and so on are mounted in the

centre of the guard 48 with the moderate strength as the embodiment, they may be steadily supported.

5 In the embodiment described above, the DC brushless motor was described as an outer rotating type. However, it may be of the inner rotating type, in which case the impeller 40 is secured to the inner rotor (rotary shaft).

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CLAIMS

1. An electric fan comprising:
 - a rotary impeller;
 - 5 a DC brushless motor arranged to drive the impeller and including a plurality of coils and a magnet for rotation relative to the coils, said coils being arranged for multi-phase operation;
 - driving means for applying a driving voltage to said
 - 10 coils of the motor, said driving means including a plurality of switching elements for switching current through the motor phases respectively;
 - a plurality of magnetic sensing elements arranged to sense rotation of the motor;
 - 15 phase control means responsive to said magnetic sensing elements and operative to switch said switching elements in such a manner that current is passed through the coils to energise the motor phases sequentially for periods that are overlapped in time;
 - 20 adjustable speed setting means for setting an operating speed condition for the fan;
 - power control means for controlling the driving voltage applied from said driving means to the motor in dependence upon the setting of said setting means;
 - 25 rotational speed responsive means, responsive to said



sensing elements to generate a time interval signal defining a duration corresponding to a predetermined angular rotation of the motor at its current operational speed; and

5 period defining means for defining the duration of said overlap as a predetermined function of the duration defined by said time interval signal.

2. An electric fan in accordance with claim 1,
10 wherein said period defining means includes means for selectively changing said function, corresponding to different conductance angles for the motor.

3. An electric fan in accordance with claim 2,
15 wherein said period defining means includes a switch for selecting said given function.

4. An electric fan in accordance with any
preceding claim, wherein said speed setting means
20 includes a manual switch.

5. An electric fan in accordance with any
preceding claim, wherein said phase control means
includes a first microcomputer, to which the signals
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from said magnetic sensing elements are inputted and from which control signals are produced for said switching means.

5 6. An electric fan in accordance with claim 5, wherein said power control means includes a second microcomputer responsive to said speed setting means to control a driving voltage applied to the switching means.

10

7. An electric fan in accordance with claim 6, wherein said driving means includes a DC voltage circuit, which is controlled by said second microcomputer.

15

8. An electric fan in accordance with any preceding claim, wherein said DC brushless motor is of an inner rotating type.

20

9. An electric fan in accordance with any one of claims 1 to 7, wherein said DC brushless motor is of an outer rotating type.





10. An electric fan in accordance with claim 9, wherein said DC brushless motor includes a stator having said coils and a rotor yoke covering said stator, said magnet being secured inside said rotor yoke.

5

11. An electric fan in accordance with claim 10, wherein said magnetic sensing elements are mounted on a first board which is arranged in the proximity of said DC brushless motor.

10

12. An electric motor in accordance with claim 11, wherein said first board is covered by said rotor yoke or other casing.

15

13. An electric fan in accordance with claim 11 or 12, which includes a stand for supporting said DC brushless motor and a second board arranged within said stand and being mounted with other circuit components.

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14. An electric fan in accordance with claim 13, wherein circuit components other than said magnetic sensing elements are installed on said first board.



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5 15. An electric fan in accordance with claim 14, wherein said other circuit components include components that produce heat and said first board is arranged in a position to be cooled by an air flow produced by said impeller.

10 16. An electric fan in accordance with claim 15, including a guard surrounding said impeller, wherein said first board is supported by said guard.

15 17. An electric fan in accordance with claim 15, which further comprises a guard surrounding said impeller and an ornament disposed on the front of said guard, wherein said DC brushless motor and said first board are mounted on said ornament.

18. An electric fan in accordance with claim 17, wherein said second board is mounted on said ornament.

20 19. An electric fan substantially as herein described with references to Figures 1 to 8 or 9 or 10 of the accompanying drawings.



* C L M S *

20. An electric fan substantially as herein described with reference to Figures 11, 12 or 13 fo the accompanying drawings.



* C L M S *