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Motor and control method thereof

Abstract

A motor is provided and driven by two phase. The first and second control signals have a phase difference of 90 degrees and are configured to control the first and second driving units, respectively, and the first and second control signals drive the first and second coil sets, respectively. Each of the first and second poles of the permanent magnet occupies a mechanical angle of $360/2n$ degrees of the permanent magnet, respectively, and n is 1 or 3. The four sets of the coils of the stator are equally located on the stator, each set of the coil occupies a mechanical angle of $360/2m$ degrees of the stator, any two sets of the coils adjacent to each other are separated by a mechanical angle of $90-(360/2m)$ degrees, and m is 3 or 2, wherein m corresponds to 2 when n is 1, m corresponds to 3 when n is 3.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION (1) This application is a Divisional Application of U.S. patent application Ser. No. 17/733,483 filed on Apr. 29, 2022 and entitled “MOTOR AND CONTROL METHOD THEREOF”, which claims the priority to Chinese Patent Application No. 202220060143.1 filed on Jan. 11, 2022. The entire contents of the above-mentioned patent applications are incorporated herein by reference for all purposes.

FIELD OF THE INVENTION

(1) The present disclosure relates to a motor and a control method thereof capable of improving the space utilization rate of coils.

BACKGROUND OF THE INVENTION

(2) The motor structure includes a stator and a rotor, wherein the stator includes coils, and the rotor includes a magnetic element. Through the interaction between the coils and the magnetic element, a magnetic field is generated between the stator and the rotor, thereby making the rotor to rotate.

(3) The conventional motor utilizes a 4-slot coil stator with an 8-pole rotor in structure, that is, the stator is formed by 4 independent coils. Each coil occupies a mechanical angle of 45 degrees of the circumference of the stator, which will form a mechanical angle of 22.5 degrees or 67.5 degrees between the adjacent coils. The rotor is a permanent magnet with eight uniform pole faces, and each pole occupies a mechanical angle of 45 degrees. In terms of control, the conventional motor connects the 4 independent coils in series and performs two-phase driving.

(4) Regarding to the structure design of the conventional motor including the 4-slot coil stator and the 8-pole rotor, the space utilization rate of the stator coil is only 50%. Since the space utilization rate of the coil is positively related to the efficiency of the motor, the efficiency of the conventional motor has room for improvement.

(5) Therefore, there is a need of providing a motor and a control method thereof to obviate the drawbacks encountered from the prior arts.

SUMMARY OF THE INVENTION

(6) It is an object of the present disclosure to provide a motor and a control method thereof. The motor and the control method thereof are capable of reducing the ripple of the torque to reduce the vibration of the motor during operation. The space utilization rate of the stator coil is improved, thereby optimizing the efficiency of the motor.

(7) In accordance with an aspect of the present disclosure, there is provided a motor. The motor includes a rotor, a stator and a driving element. The rotor includes a permanent magnet. The permanent magnet includes n first poles and m second poles. The first pole and the second pole have different polarities and are staggered with each other. Each of the first and second poles occupies a mechanical angle of $360/2n$ degrees of the permanent magnet, respectively, and n is 1 or 3. The stator has four sets of coils. The four sets of coils are equally located on the stator, and each set of the coils occupies a mechanical angle of $360/2m$ degrees of the stator. Any two sets of coils adjacent to each other are separated by a mechanical angle of $90-(360/2m)$ degrees, and m is 3 or 2, wherein m corresponds to 2 when n is 1, and m corresponds to 3 when n is 3. The four sets of the coils of the present disclosure are wound in an axial winding shaft, wherein two of the four sets of coils are disposed relative to a center of the stator to form a first coil set. The other two of the four sets of coils are disposed relative to the center of the stator to form a second coil set. A first extension line is formed by passing through a midpoint of any coil of the first coil set and the center of the stator, and a second extension line is formed by passing through the midpoint of any coil of the second coil set and the center of the stator. The angle between the first and second extension lines is a mechanical angle of 90 degrees. In the present disclosure, the midpoint of the coil can be regarded as the winding shaft of the coil axis. The driving element of the motor includes two Hall elements, a first driving unit and a second driving unit. Two Hall elements are configured to sense the change of the magnetic field generated by the passage of the permanent magnet. The first driving unit drives the first coil set according to a first control signal, and the second driving unit drives the second coil set according to a second control signal. The first and second control signals are generated according to the sensing results of the two Hall elements, respectively, and the phase difference between the first and second control signals is 90 degrees in electrical angle.

(8) In an embodiment of the present disclosure, the amount of the Hall element is one, and the Hall element is electrically connected to a logic unit. The logic unit generates a first control signal and a

second control signal with a phase difference of 90 degrees in electrical angle after receiving the sensing result of the Hall element. The first and second driving units drive the first coil set and the second coil set according to the first and second control signals, respectively.

(9) In accordance with another aspect of the present disclosure, there is provided a control method of a motor. The motor includes a rotor, a stator and a driving element. The rotor includes a permanent magnet. The permanent magnet includes n first poles and n second poles. The first pole and the second pole have different polarities and are staggered with each other. Each of the first and second poles occupies a mechanical angle of $360/2n$ degrees of the permanent magnet, respectively, and n is 1 or 3. The stator has four sets of coils equally located on the stator, and each set of the coils occupies a mechanical angle of $360/2m$ degrees of the stator. Any two sets of the coils adjacent to each other are separated by a mechanical angle of $90-(360/2m)$ degrees, and m is 3 or 2, wherein m corresponds to 2 when n is 3, and m corresponds to 3 when n is 3. The four sets of coils of the present disclosure are wound in an axial winding shaft, wherein two of the four sets of the coils are disposed relative to a center of the stator to form a first coil set. The other two of the four sets of coils are disposed relative to the center of the stator to form a second coil set. A first extension line is formed by passing through a midpoint of any coil of the first coil set and the center of the stator, a second extension line is formed by passing through the midpoint of any coil of the second coil set and the center of the stator. The angle between the first and second extension lines is a mechanical angle of 90 degrees. The control method includes steps of: (a) providing a first Hall element and a second Hall element, wherein the first Hall element and the second Hall element are disposed by a mechanical angle of 90 degrees Circumferential angle; (b) utilizing the first Hall element and the second Hall element to sense the change of the magnetic field generated by the permanent magnet and generating a first control signal and a second control signal with a phase difference of 90 degrees by the first and second Hall elements, respectively; and (c) driving the first coil set and the second coil set according to the first control signal and the second control signal, respectively.

(10) In accordance with another aspect of the present disclosure, there is provided a control method of a motor. By utilizing a Hall element and a logic unit, the same effect by two Hall elements mentioned above is achieved. The logic unit generates a first control signal and a second control signal with a phase difference of 90 degrees in electrical angle according to the sensing result of the Hall element, and the first driving unit and the second driving unit drive the first coil set and the second coil set according to the first control signal and the second control signal, respectively.

(11) The above contents of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, in which:

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 is a schematic cross-sectional view illustrating a motor according to a first embodiment of the present disclosure;

(2) FIG. 2A schematically shows a top view of the rotor of the motor of FIG. 1;

(3) FIG. 2B schematically shows a top view of a stator corresponding to the rotor of the motor of FIG. 2A;

(4) FIG. 3A schematically shows a top view of the rotor of the motor of FIG. 1 according to another embodiment of the present disclosure;

(5) FIG. 3B schematically shows a top view of the stator of the motor of FIG. 1 according to another embodiment of the present disclosure;

(6) FIG. 4 is a schematic circuit diagram of the motor of FIG. 1;

- (7) FIG. 5 is a schematic oscillogram of the signals of the motor in FIG. 4;
- (8) FIGS. 6A to 6D are the structural diagrams of the integrated driving units and Hall elements according to other embodiments of the present disclosure;
- (9) FIG. 7 is a schematic cross-sectional view illustrating a motor according to a second embodiment of the present disclosure;
- (10) FIG. 8 is a schematic cross-sectional view illustrating a motor according to a third embodiment of the present disclosure;
- (11) FIG. 9 is a schematic cross-sectional view illustrating a motor according to a fourth embodiment of the present disclosure;
- (12) FIG. 10 is a flow chart illustrating a control method of a motor according to a first embodiment of the present disclosure; and
- (13) FIG. 11 is a flow chart illustrating a control method of a motor according to a second embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

(14) The present disclosure will now be described more specifically with reference to the following embodiments. It is to be noted that the following descriptions of preferred embodiments of this disclosure are presented herein for purpose of illustration and description only. It is not intended to be exhaustive or to be limited to the precise form disclosed.

(15) FIG. 1 is a schematic cross-sectional view illustrating a motor according to a first embodiment of the present disclosure. FIG. 2A schematically shows a top view of the rotor of the motor of FIG. 1. FIG. 2B schematically shows a top view of a stator corresponding to the rotor of the motor of FIG. 2A. FIG. 3A schematically shows a top view of the rotor of the motor of FIG. 1 according to another embodiment of the present disclosure. FIG. 3B schematically shows a top view of the stator of the motor of FIG. 1 according to another embodiment of the present disclosure. FIG. 4 is a schematic circuit diagram of the motor of FIG. 1. As shown in FIGS. 1, 2A, 2B, 3A, 3B and 4, the motor 1 of the present disclosure includes a rotor 2, a stator 3 and a driving element. The rotor 2 includes a permanent magnet 20 having n first poles 201 and n second poles 202. The first poles 201 and the second poles 202 have different polarities and are staggered with each other. Each of the first poles 201 and each of the second poles 202 occupy a mechanical angle of $360/2n$ degrees of the permanent magnet 20 respectively, where n is 1 or 3. As shown in FIG. 2A, when n is 3, the rotor 2 has three first magnetic poles (S poles) 201 and three second magnetic poles (N poles) 202, and each of the first and second magnetic poles 201, 202 has a mechanical angle of 60 degrees. As shown in FIG. 3A, when n is 1, the rotor 2 has one first magnetic pole (S pole) 201 and one second magnetic pole (N pole) 202, and each of the first and second magnetic poles 201, 202 has a mechanical angle of 180 degrees.

(16) Please refer to FIGS. 1, 2B and 3B again. The stator 3 has four sets of the coils 31, 32, 33 and 34 equally located on the stator 3. In the present disclosure, the coils of the present disclosure are wound around an axial winding shaft. Each set of the coils occupies a mechanical angle of $360/2m$ degrees of the stator 3. Any two sets of the coils adjacent to each other are separated by a mechanical angle of $90-(360/2m)$ degrees, and m is 3 or 2, wherein m corresponds to 3 when n is 3, and m corresponds to 2 when n is 1. In FIGS. 2A and 2B, the motor 1 is a 6-pole and 4-slot motor when n is 3, and m is 3. Each set of the coils 31, 32, 33 and 34 occupies a mechanical angle of 60 degrees of the stator 3, and any two sets of the coils adjacent to each other are separated by a mechanical angle of 30 degrees. In FIGS. 3A and 3B, the motor 1 is a 2-pole and 4-slot motor when n is 1, and m is 2. Each set of the coils 31, 32, 33 and 34 occupies a mechanical angle of 90 degrees of the stator 3, and any two sets of the coils adjacent to each other are separated by a mechanical angle of 0 degrees.

(17) Please refer to FIGS. 2B, 3B and 4. In the four sets of the coils 31, 32, 33 and 34, two sets of the coils 31 and 33 opposite to each other are disposed relative to a center O (i.e., the center of circle) of the stator 3 to form a first coil set T1. The coils 31 and 33 are in the same phase. The

other two sets of the coils **32** and **34** opposite to each other are disposed relative to a center **O** of the stator **3** to form a second coil set **T2**. The coils **32** and **34** are in the same phase. A first extension line **L1** is formed by passing through a midpoint of any coil of the first coil set **T1** and the center **O** of the stator **3**. FIG. 2B exemplifies the first extension line **L1** passing through the midpoint of the coil **31** of the first coil set **T1** and the center **O** of the stator **3**. FIG. 3B exemplifies the first extension line **L1** passing through the midpoint of the coil **31** of the first coil set **T1** and the center **O** of the stator **3**. A second extension line **L2** is formed by passing through a midpoint of any coil of the second coil set **T2** and the center **O** of the stator **3**. FIG. 2B exemplifies the second extension line **L2** passing through the midpoint of the coil **32** of the second coil set **T2** and the center **O** of the stator **3**. FIG. 3B exemplifies the second extension line **L2** passing through the midpoint of the coil **31** of the second coil set **T2** and the center **O** of the stator **3**. According to the definitions of the first extension line **L1** and the second extension line **L2** defined above, the angle between the first and second extension lines **L1**, **L2** is a mechanical angle of 90 degrees.

(18) Please refer to FIGS. 1, 2B, 3B and 4. The driving element includes Hall elements **41a** and **41b**, a first driving unit **42** and a second driving unit **43**. As shown in FIG. 4, each of the illustrated first driving unit **42** and the second driving unit **43** includes a full-bridge switching circuit, respectively. When the motor **1** of the present disclosure is operating, the Hall elements **41a** and **41b** are configured to sense the change of the magnetic field generated by the permanent magnet **20** driven by the rotor **2**, and generate two sensing signals with a phase difference of 90 degrees in electrical angle sequentially. The controller (not shown) of the driving element generates a first control signal and a second control signal according to the two sensing signals, and controls the first driving unit **42** and the second driving unit **43** to drive the first coil set **T1** and the second coil set **T2** according to the first control signal and the second control signal, respectively. The first and second control signals have a phase difference of 90 degrees in electrical angle.

(19) Accordingly, the motor **1** of the present disclosure controls the first driving unit **42** and the second driving unit **43** according to the first control signal and the second control signal, respectively, so as to drive the first and second coil sets **T1** and **T2** of the stator **3**, respectively. The first and second control signals have a phase difference of 90 degrees in electrical angle. Each of the first and second poles **201**, **202** of the permanent magnet **20** of the rotor **2** occupies a mechanical angle of $360/2n$ degrees of the permanent magnet **20**. The four sets of the coils **31**, **32**, **33** and **34** occupy a mechanical angle of $360/2m$ degrees of the stator **3**, and any two sets of the coils adjacent to each other are separated by a mechanical angle of $90-(360/2m)$ degrees.

Therefore, when n is 3 and m is 3, the motor **1** of the present disclosure is a 6-pole and 4-slot motor as shown in FIGS. 2A and 2B. When the winding shaft of the coils is in the axial direction and the rotor magnet and the coil are in the axial direction, the space utilization rate of coils is 66.67%.

Therefore, compared with the conventional 8-pole and 4-slot motor, the space utilization rate of the motor **1** is increased by 16.67%, and the efficiency of the motor **1** with 6 poles and 4 slots in the present disclosure is also improved correspondingly. When n is 1 and m is 2, the motor **1** of the present disclosure is a 2-pole and 4-slot motor as shown in FIGS. 3A and 3B, and the space utilization rate of coils is close to 100%. Therefore, compared with the conventional 8-pole and 4-slot motor, the space utilization rate is increased by 50%, which can further improve the efficiency.

(20) In the embodiment of the present disclosure, the first and second control signals are generated by two sensing signals with a phase difference of 90 degrees in electrical angle. The first driving unit **42** and the second driving unit **43** drive the first coil set **T1** and the second coil set **T2** according to the first control signal and the second control signal, respectively. Accordingly, other implementation with the third coil set is excluded.

(21) In the embodiment of present disclosure, the amount of the Hall elements can be two. As shown in FIGS. 2B, 3B and 4, one Hall element **41a** is disposed on the first coil set **T1** (e.g., on the coil **33** of the first coil set **T1** as shown in FIGS. 2B and 3B), and the other Hall element **41b** is disposed on the second coil set **T2** (e.g., on the coil **34** of the second coil set **T2** as shown in FIGS.

2B and 3B). The two Hall elements **41a** and **41b** are disposed by a mechanical angle of 90 degrees Circumferential angle.

(22) Please refer to FIGS. 4 and 5. FIG. 5 is a schematic oscillogram of the signals of the motor in FIG. 4. As shown in FIGS. 4 and 5, the Hall element **41a** is electrically connected to the first driving unit **42**, and the other Hall element **41b** is electrically connected to the second driving unit **43**. The first driving unit **42** and the Hall element **41a**, which are electrically connected to each other, can be integrated into a first integrated circuit **100**. The second driving unit **43** and the Hall element **41b**, which are electrically connected to each other, can be integrated into a second integrated circuit **200**. The first driving unit **42** drives the first coil set T1 according to the first control signal generated by the sensing result of the corresponding Hall element **41a**. The second driving unit **43** drives the second coil set T2 according to the second control signal generated by the sensing result of the corresponding Hall element **41b**. The first control signal has the same phase as the continuous induction electromotive force BEMF1 generated by the first coil set T1. The second control signal has the same phase as the continuous induction electromotive force BEMF2 generated by the second coil set T2. The driving voltage continuously outputted by the first driving unit **42** is V1, the driving voltage continuously outputted by the second driving unit **43** is V2, and the phase difference between the driving voltage V1 and the driving voltage V2 is 90 degrees in electrical angle. In addition, the current flowing through the first coil set T1 is I1, the current flowing through the second coil set T2 is I2, and the phase difference between the current I1 and the current I2 is 90 degrees in electrical angle. The first control signal can also be regarded as being generated by the first integrated circuit **100**, and the second control signal can be regarded as being generated by the second integrated circuit **200**.

(23) The method of integrating the driving unit and the Hall element in the driving element and the amount of the Hall element are not limited to the above. The following examples illustrate the different types of integration methods of the driving unit and the Hall elements and different amounts of the Hall elements. FIGS. 6A to 6D are the structural diagrams of the integrated driving units and Hall elements according to other embodiments of the present disclosure. As shown in FIG. 6A, the first integrated circuit **100** only includes a first driving unit **42**, the second integrated circuit **200** only includes a second driving unit **43**, and the driving element of the motor **1** includes two Hall elements **41a** and **41b**. The Hall elements **41a** and **41b** are electrically connected to the first integrated circuit **100** and the second integrated circuit **200** respectively, that is, the Hall elements **41a** and **41b** are disposed independently and are not integrated into the first integrated circuit **100** and the second integrated circuit **200**, respectively.

(24) As shown in FIG. 6B, the first driving unit **42** and the second driving unit **43** are integrated into one integrated circuit **300**, and the motor **1** includes two Hall elements **41a** and **41b**. The two Hall elements **41a** and **41b** are independently disposed outside the integrated circuit **300** and are not integrated into the integrated circuit **300**. The two Hall elements **41a** and **41b** are electrically connected to the integrated circuit **300**, and provide the sensing results to the first driving unit **42** and the second driving unit **43** of the integrated circuit **300**, respectively.

(25) As shown in FIG. 6C, the driving element further includes a logic unit **44**. The first driving unit **42**, the second driving unit **43** and the logic unit **44** are integrated into the integrated circuit **300**. The logic unit **44** is electrically connected to the first driving unit **42** and the second driving unit **43**. The motor **1** includes only a Hall element **41a**, and the Hall element **41a** is independently disposed outside the integrated circuit **300** and is not integrated into the integrated circuit **300**. The Hall element **41a** is electrically connected to the logic unit **44** of the integrated circuit **300**. After the Hall element **41a** senses the change of the magnetic pole on the rotor, the logic unit **44** calculates according to the sensing result of the Hall element **41a** to generate the first control signal and the second control signal with a phase difference of 90 degrees in electrical angle. The first driving unit **42** and the second driving unit **43** drive the first coil set T1 and the second coil set T2 according to the first control signal and the second control signal, respectively.

(26) As shown in FIG. 6D, the motor **1** includes a Hall element **41a**, and the Hall element **41a**, the first driving unit **42**, the second driving unit **43** and the logic unit **44** are integrated into the integrated circuit **300**. The Hall element **41a** is electrically connected to the logic unit **44**. After the Hall element **41a** senses the change of the magnetic pole on the rotor, the logic unit **44** calculates according to the sensing result of the Hall element **41a** to generate the first control signal and the second control signal with a phase difference of 90 degrees in electrical angle. The first driving unit **42** and the second driving unit **43** drive the first coil set T1 and the second coil set T2 according to the first control signal and the second control signal, respectively.

(27) Please refer to FIG. 1. The rotor **2** of the motor **1** is assembled with a fan blade **9** to form a fan, and the motor **1** drives the fan blade **9** to rotate. In addition, the motor **1** includes a shaft **5**, a hub **6**, a circuit board **7**, an annular magnetic conductive element **8**, a rotor **2**, a stator **3**, a base **10** and a driving element. The structures and operations of the rotor **2**, the stator **3** and the driving element are as described above, and the detailed descriptions thereof are omitted herein. The base **10** is disposed on the bottom of the motor **1** to carry the structure of the motor **1**. The circuit board **7** is disposed on the inner wall surface of the base **10**, and the shaft **5** is connected to the hub **6** of the rotor **2** and is connected to the shaft tube of the base **10** through a bearing. The hub **6** is connected to the permanent magnet **20** so that the permanent magnet **20** and the stator coils **31**, **32**, **33** and **34** are axially opposite to each other. One end of the shaft **5** protrudes from the hub **6** to form a protrusion part **5a**, and the protrusion part **5a** can increase the stability of the shaft **5** and the hub **6**. The shaft **5** penetrates through the through holes **21** of the rotor **2** and the through holes **35** of the stator **3**. The rotor **2** and the stator **3** are disposed in an axial direction relative to the shaft **5**. When a magnetic field is generated between the stator **3** and the rotor **2**, the rotor **2** drives the hub **6** to rotate, and the shaft **5** and the fan blades **9** connected to the hub **6** also rotate synchronously. The driving element is formed on the circuit board **7**. The circuit board **7** has a first side and a second side opposite to each other, wherein the first side is closer and faced to the rotor **2** than the second side. The stator **3** is disposed on the first side of the circuit board **7**, and the windings of the coils **31**, **32**, **33** and **34** of the stator **3** are axial winding shaft. A first magnetic circuit F1 is generated between the coils **31**, **32**, **33** and **34** and the permanent magnet **20** of the rotor **2** in the axial direction, and the rotor **2** rotates through the first magnetic circuit F1.

(28) In FIG. 1, the annular magnetic conductive element **8** is disposed on the second side of the circuit board **7**. That is, the annular magnetic conductive element **8** is disposed between the circuit board **7** and the base **10**. The annular magnetic conductive element **8** corresponds to the position of the permanent magnet **20** of the rotor **2** in the axial direction. An axial second magnetic circuit F2 is generated between the annular magnetic conductive element **8** and the permanent magnet **20**. The second magnetic circuit F2 is located between the shaft **5** and the coils **31**, **32**, **33**, and **34** in the axial direction. That is, with respect to the stator coil, the second magnetic circuit F2 shown in FIG. 1 is located on the inside. Due to the formation of the second magnetic circuit F2 between the annular magnetic conductive element **8** and the permanent magnet **20**, a fixed magnetic attraction force can be further generated to the rotor **2** so as to prevent the rotor **2** from disengaging when it rotates, and the stability of the rotor **2** is improved.

(29) In addition, taking the shaft **5** as a reference point, the position of the annular magnetic conductive element **8** on the circuit board **7** is closer to the shaft **5** than the position of the stator **3** on the circuit board **7**. The second magnetic circuit F2 generated by the annular magnetic conductive element **8** and the permanent magnet **20** is axially projected on the permanent magnet **20**.

(30) FIG. 7 is a schematic cross-sectional view illustrating a motor according to a second embodiment of the present disclosure. The annular magnetic conductive element **8a** shown in FIG. 7 is disposed between the circuit board **7** and the base **10**. As shown in the FIG. 7, taking the shaft **5** as a reference point, the position of the annular magnetic conductive element **8a** on the circuit board **7** is farther from the shaft **5** than the position of the stator **3** on the circuit board **7**. The coils

31, 32, 33, and **34** are located between the shaft **5** and the second magnetic circuit **F2** in the axial direction. That is, with respect to the stator coil, the second magnetic circuit **F2** shown in FIG. 7 is located outside the stator coil. The second magnetic circuit **F2** generated by the annular magnetic conductive element **8a** and the permanent magnet **20** is axially projected on the permanent magnet **20**. The second magnetic circuit **F2** generates a fixed magnetic attraction force to the rotor **2**.

Therefore, the disengagement of rotor **2** when rotating is avoided, and the stability is improved.

(31) FIG. 8 is a schematic cross-sectional view illustrating a motor according to a third embodiment of the present disclosure. The motor **1** shown in FIG. 8 is similar to that shown in FIG. 1, except that the base **10** of the motor **1** in FIG. 8 includes a magnetic conductive portion **10a** and a non-magnetic conductive portion **10b**. The magnetic conductive portion **10a** is disposed on the bottom of the non-magnetic conductive portion **10b**. That is, the magnetic conductive portion **10a** and the non-magnetic conductive portion **10b** are disposed on different planes. At least part of the magnetic conductive portion **10a** overlaps with the permanent magnet **20** in the axial direction. Therefore, an axial second magnetic circuit **F2** generated between the magnetic conductive portion **10a** and the permanent magnet **20** generates a fixed magnetic attraction force to the rotor and improves the stability of the rotor during rotation.

(32) In the present disclosure, the positions of the magnetic conductive elements **8** and **8a** are not limited to being disposed on the second side of the circuit board **7**, the positions of the magnetic conductive elements **8** and **8a** can also be disposed close and faced to the first side of the rotor **2**. In other words, the magnetic conductive portion is adjacent to the circuit board **7**, and an axial second magnetic circuit **F2** is generated between the magnetic conductive portion and the permanent magnet **20**.

(33) FIG. 9 is a schematic cross-sectional view illustrating a motor according to a fourth embodiment of the present disclosure. As shown in FIG. 9, the base **10** of the motor **1** includes a magnetic conductive portion **10c** and a non-magnetic conductive portion **10d**. The magnetic conductive portion **10c** and the non-magnetic conductive portion **10d** are disposed on the same plane. The magnetic conductive portion **10c** is disposed on the outside with respect to the non-magnetic conductive portion **10d** in the axial direction. That is, the magnetic conductive portion **10c** is far away from the shaft **5**. At least part of the magnetic conductive portion **10c** overlaps with the permanent magnet **20** in the axial direction so as to achieve the effect of the annular magnetic conductive element **8a** shown in FIG. 7. That is, an axial second magnetic circuit **F2** is generated between the magnetic conductive portion **10c** and the permanent magnet **20**, which generates a fixed magnetic attraction force to the rotor **2** and improves the stability of the rotor **2** during rotation.

(34) FIG. 10 is a flow chart illustrating a control method of a motor according to a first embodiment of the present disclosure. The control method of the motor of this embodiment is applicable to the motor **1** in the above embodiments. The control method of the motor includes following steps.

(35) In step **S1**, a first Hall element **41a** and a second Hall element **41b** are provided. The first Hall element **41a** and the second Hall element **41b** are disposed by a mechanical angle of 90 degrees Circumferential angle.

(36) In step **S2**, the first Hall element **41a** and the second Hall element **41b** sense the change of the magnetic field generated by the permanent magnet **20** and generate a first control signal and a second control signal with a phase difference of 90 degrees, respectively.

(37) In step **S3**, the first coil set **T1** is driven according to the first control signal, and the second coil set **T2** is driven according to the second control signal.

(38) FIG. 11 is a flow chart illustrating a control method of a motor according to a second embodiment of the present disclosure. The control method of the motor of this embodiment is applicable to the motor **1** in the above embodiments. The control method of the motor includes following steps.

(39) In step S1a, a first Hall element **41a** and a logic unit **44** are provided.

(40) In step S2a, the first Hall element **41a** senses the change of the magnetic field generated by the permanent magnet **20**, and the logic unit **44** calculates according to the sensing result of the Hall element **41a** to generate the first control signal and the second control signal with a phase difference of 90 degrees in electrical angle.

(41) In step S3a, the first coil set **T1** is driven according to the first control signal, the second coil set **T2** is driven according to the second control signal.

(42) From the above description, the present disclosure provides a motor. The motor is driven by two phase. That is, the motor **1** of the present disclosure controls the first driving unit and the second driving unit according to the first control signal and the second control signal respectively, so as to drive the first and second coil sets of the stator, respectively. The first control signal and the second control signal have a phase difference of 90 degrees in electrical angle. In addition, since each of the first and second poles of the permanent magnet of the rotor of the motor of the present disclosure occupies a mechanical angle of $360/2n$ degrees of the permanent magnet, and the four sets of the coils of the stator occupy a mechanical angle of $360/2m$ degrees of the stator, and any two sets of the coils adjacent to each other are separated by a mechanical angle of $90-(360/2m)$ degrees, and wherein n is 3 and m is 3, or n is 1 and m is 2. Compared with the conventional 8-pole and 4-slot motor, the space utilization rate of the motor **1** is increased, and the efficiency is improved correspondingly.

(43) While the disclosure has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the disclosure needs not be limited to the disclosed embodiment. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

Claims

1. A motor comprising: a rotor comprising a permanent magnet, wherein the permanent magnet comprises n first poles and m second poles, the first and second poles have different polarities and are staggered with each other, each of the first and second poles occupies a mechanical angle of $360/2n$ degrees of the permanent magnet, respectively, and n is 1 or 3; a stator having four sets of coils, wherein a winding shaft of the four sets of the coils is axial relative to a shaft of the rotor, each set of the coils occupies a mechanical angle of $360/2m$ degrees of the stator, any two sets of the coils adjacent to each other are separated by a mechanical angle of $90-(360/2m)$ degrees, and m is 3 or 2, wherein m corresponds to 2 when n is 1, and m corresponds to 3 when n is 3, wherein two of the four sets of the coils are disposed relative to a center of the stator to form a first coil set, the other two of the four sets of the coils are disposed relative to the center of the stator to form a second coil set; and a driving element comprising a first Hall element, a second Hall element, a first driving unit and a second driving unit, wherein the first and second Hall elements are configured to sense the change of the magnetic field generated by the passage of the permanent magnet, the first driving unit drives the first coil set according to a first control signal, the second driving unit drives the second coil set according to a second control signal, and the first and second control signals are generated according to the sensing results of the first and second Hall elements, respectively, and the phase difference between the first and second control signals is 90 degrees in electrical angle; wherein the first Hall element is electrically connected to the first driving unit, and the second Hall element is electrically connected to the second driving unit, the first driving unit and the first Hall element are integrated into a first integrated circuit, and the second driving unit and the second Hall element are integrated into a second integrated circuit.

2. The motor according to claim 1, wherein a first extension line is formed by passing through a

midpoint of any coil of the first coil set and the center of the stator, a second extension line is formed by passing through a midpoint of any coil of the second coil set and the center of the stator, and the angle between the first and second extension lines is a mechanical angle of 90 degrees.

3. The motor according to claim 1, wherein the first and second Hall elements are disposed by a mechanical angle of 90 degrees Circumferential angle.

4. A motor comprising: a rotor comprising a permanent magnet, wherein the permanent magnet comprises n first poles and m second poles, the first and second poles have different polarities and are staggered with each other, each of the first and second poles occupies a mechanical angle of $360/2n$ degrees of the permanent magnet, respectively, and n is 1 or 3; a stator having four sets of coils, wherein a winding shaft of the four sets of the coils is axial relative to a shaft of the rotor, each set of the coils occupies a mechanical angle of $360/2m$ degrees of the stator, any two sets of the coils adjacent to each other are separated by a mechanical angle of $90-(360/2m)$ degrees, and m is 3 or 2, wherein m corresponds to 2 when n is 1, and m corresponds to 3 when n is 3, wherein two of the four sets of the coils are disposed relative to a center of the stator to form a first coil set, the other two of the four sets of the coils are disposed relative to the center of the stator to form a second coil set; and a driving element comprising a Hall element, a logic unit, a first driving unit and a second driving unit, wherein the Hall element is disposed on any one of the four sets of the coils, the Hall element is configured to sense the change of the magnetic field generated by the passage of the permanent magnet, the logic unit calculates according to the sensing result of the Hall element to generate a first control signal and a second control signal with a phase difference of 90 degrees in electrical angle, and the first and second driving units drive the first and second coil sets according to the first and second control signals, respectively; wherein the driving element further comprises an integrated circuit, wherein the Hall element, the logic unit, the first driving unit and the second driving unit are integrated into the integrated circuit.
