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Winding device and motor

Abstract

Provided are a winding device and a motor. A nozzle that feeds out a coil has: a nozzle hole from which the coil is fed out; an inner-diameter round chamfered part formed on an opening edge of a tip of the nozzle; an outer-diameter round chamfered part formed on the outer peripheral edge of the tip of the nozzle. When the wire diameter of the coil is defined as Φc, the inner diameter of the nozzle hole is defined as Φin, the radius of curvature of the inner-diameter round chamfered part is defined as Rin, and the radius of curvature of the outer-diameter round chamfered part is defined as $Rout$, they satisfy $1.2\Phi c \leq \Phi in \leq 1.4\Phi c$, $0.5\Phi c \leq Rin \leq \Phi c$, and $0.25\Phi c \leq Rout \leq 0.5\Phi c$.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION
(1) This application is a 371 application of the International PCT application serial no. PCT/JP2021/007043, filed on Feb. 25, 2021, which claims the priority benefits of Japan Patent Application No. 2020-052779, filed on Mar. 24, 2020. The entirety of each of the above-mentioned patent applications is hereby incorporated by reference herein and made a part of this specification.
TECHNICAL FIELD
(2) The disclosure relates to a winding device and a motor.
RELATED ART
(3) Some motors include a stator having multiple teeth around which a coil is wound, and a rotor rotatably provided with respect to the stator. The winding device that winds the coil around the teeth includes a flyer having a nozzle for feeding the coil and a base for supporting the stator. Then, when winding the coil around the teeth, the base is rotated or moved up and down, and the flyer is moved. As a result, the relative position between the stator and the flyer changes. That is, a nozzle is inserted from a slot between adjacent teeth, and the nozzle moves around the teeth while feeding out a coil. As a result, the coil is wound around the teeth.
CITATION LIST
Patent Literature
(4) [Patent Literature 1] Japanese Patent Application Laid-Open No. 2007-325490
SUMMARY
Technical Problem
(5) By the way, when winding the coil around the teeth, the coil drawn out from the nozzle is greatly bent with the end of the nozzle as a fulcrum. At this time, if the pulling force of the coil is large, an unreasonable bending stress is applied to the coil, which may damage the coil.
(6) In order to suppress the bending stress, it is conceivable to increase the size of the nozzle to reduce the bending stress applied to the coil. However, if the nozzle is simply enlarged in this way, the motor may be enlarged or the motor characteristics may be deteriorated, and, for example, it is necessary to increase the slot width between the teeth.
(7) Therefore, the disclosure provides a winding device and a motor which can prevent damage on a coil during winding work and prevent an increase in size and a decrease in motor property.
Solution to Problem
(8) In view of the above problems, a winding device according to the disclosure is a winding device for winding a coil around a tooth. The winding device includes a nozzle that feeds out the coil. The nozzle includes: a nozzle hole through which the coil is fed out; an inner-diameter round chamfered part formed on an opening edge of the nozzle hole on a side where the coil is fed out; and an outer-diameter round chamfered part formed on an outer peripheral edge at an end on the side where the coil is fed out. When a wire diameter of the coil is defined as Φc, an inner diameter of the nozzle hole is defined as Φin, a radius of curvature of the inner-diameter round chamfered part is defined as Rin, and a radius of curvature of the outer-diameter round chamfered part is defined as $Rout$, each of Φc, Φin, Rin, and $Rout$ satisfies:
$1.2\Phi c \leq \Phi in \leq 1.4\Phi c,$
$0.5\Phi c \leq Rin \leq \Phi c,$ and
$0.25\Phi c \leq Rout \leq 0.5\Phi c.$
(9) A motor according to the disclosure is a motor in which a coil is wound by the winding device as described above. The motor includes: a stator having a core part in a tubular shape, and the tooth

that protrudes inward in a radial direction from an inner peripheral surface of the core part and around which the coil is wound; and a rotor provided inside the stator in the radial direction and rotating around a rotation axis. The rotor includes: a shaft that rotates around the rotation axis; a rotor core that is supported by the shaft and rotates with the rotation axis as a radial center; a magnet disposed on an outer peripheral surface of the rotor core; and a protrusion that protrudes outward in the radial direction between the magnets adjacent to each other in a circumferential direction of the outer peripheral surface of the rotor core.

(10) In the above configuration, the core part may be formed in a polygonal shape when viewed from a direction of the rotation axis, and the inner peripheral surface of the core part may be formed flat so that a wall thickness of one side of the core part is uniform.

(11) In the above configuration, the wire diameter Φc may satisfy 0.3 mm$\leq\Phi c\leq$1.5 mm.

(12) In the above configuration, the tooth may include: a tooth body that protrudes inward in the radial direction from the inner peripheral surface of the core part; and a collar that extends along a circumferential direction from a radial inner end of the tooth body. When a width in the circumferential direction at a tooth opening between the collars adjacent to each other in the circumferential direction is defined as Wt, the width Wt and the wire diameter Φc may satisfy $3.83\leq Wt/\Phi c\leq 6.73$.

Effects of Invention

(13) According to the disclosure, since the bending stress of the coil fed out from the nozzle may be reduced, damage to the coil during the winding work may be prevented. Further, since it is not necessary to unnecessarily increase the size of the nozzle, it is possible to prevent the motor from becoming large and the motor characteristics from deteriorating.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a perspective view of a brushless motor according to an embodiment of the disclosure.

(2) FIG. **2** is a cross-sectional view taken along the line A-A of FIG. **1**.

(3) FIG. **3** is a plan view of the stator and the rotor according to an embodiment of the disclosure as viewed from the axial direction.

(4) FIG. **4** is an illustration view showing a method of winding the coil around the stator core using the winding device according to an embodiment of the disclosure.

(5) FIG. **5** is a schematic view of the nozzle according to an embodiment of the disclosure.

(6) FIG. **6** is a graph showing changes in the stress ratio to the coil according to an embodiment of the disclosure.

(7) FIG. **7** is a graph showing changes in the tooth opening width and the coil wire diameter according to an embodiment of the disclosure.

DESCRIPTION OF THE EMBODIMENTS

(8) Next, an embodiment of the disclosure will be described with reference to the drawings.

(9) <Brushless Motor>

(10) FIG. **1** is a perspective view of a brushless motor **1**. FIG. **2** is a cross-sectional view taken along the line A-A of FIG. **1**.

(11) The brushless motor **1** is, for example, a drive source for a sunroof mounted on a vehicle.

(12) As shown in FIGS. **1** and **2**, the brushless motor **1** includes a motor part (motor) **2**, a deceleration part **3** that decelerates and outputs the rotation of the motor part **2**, and a controller part **4** that controls the drive of the motor part **2**.

(13) <Motor Part>

(14) The motor part **2** includes a motor case **5**, a stator **8** housed in the motor case **5**, and a rotor **9** provided inside the stator **8** in the radial direction and provided rotatably with respect to the stator

8. The motor part **2** is a so-called brushless motor that does not require a brush to supply electric power to the stator **8**.

(15) In the following description, the rotation axis C**1** direction of the rotor **9** is simply referred to as the axial direction, the rotation direction of the rotor **9** is referred to as the circumferential direction, and the radial direction orthogonal to the axial direction and the circumferential direction is simply referred to as the radial direction.

(16) <Motor Case>

(17) The motor case **5** is made of a material having good heat dissipation property such as aluminum die casting. The motor case **5** includes a first motor case **6** and a second motor case **7** which are configured to be separable in the axial direction. The outer shapes of the first motor case **6** and the second motor case **7** are each formed into a bottomed tube.

(18) The outer shape of the first motor case **6** is formed, for example, in a bottomed polygonal tubular shape with the second motor case **7** side open. The first motor case **6** is integrally molded with a gear case **40** so that the end part **10** on the deceleration part **3** side is joined to the gear case **40** of the deceleration portion **3**. A through hole **10**a through which a shaft **31** of the rotor **9** may be inserted is formed at substantially the center of the end part **10** in the radial direction. Further, an edge part **16** for joining the second motor case **7** is formed in an opening **6**a on the second motor case **7** side in the first motor case **6**.

(19) The outer shape of the second motor case **7** is formed, for example, into a regular hexagon with rounded corners when viewed from the axial direction. That is, the peripheral wall of the second motor case **7** has six corner parts **7**A and flat parts **7**B, respectively. The second motor case **7** is formed in a bottomed tubular shape with the first motor case **6** side open. An outer flange part **17** protruding outward in the radial direction is formed in the opening **7**a on the first motor case **6** side in the second motor case **7**.

(20) The motor case **5** has an internal space by abutting the edge part **16** of the first motor case **6** and the outer flange part **17** of the second motor case **7**. The stator **8** is disposed in the internal space of the motor case **5** so that a part of a coil **24** (to be described later) is housed inside the first motor case **6**, and a stator core **20** (to be described later) is fitted inside the second motor case **7**.

(21) <Stator>

(22) FIG. **3** is a plan view of the stator **8** and the rotor **9** as viewed from the axial direction.

(23) As shown in FIGS. **2** and **3**, the stator **8** has a stator core **20** in which a tubular core part **21** and multiple (for example, six in this embodiment) teeth **22** protruding radially inward from an inner peripheral surface **21**a of the core part **21** are integrally formed.

(24) The stator core **20** is formed by stacking multiple metal plates in the axial direction. The stator core **20** is not limited to the case of being formed by multiple metal plates stacked in the axial direction, and may be formed, for example, by pressure molding soft magnetic powder.

(25) The core part **21** is formed in a tubular shape of regular hexagon with rounded corners when viewed from the axial direction to be fitted inside the second motor case **7**. That is, the core part **21** has six corner parts **20**A and flat parts **20**B, respectively. The flat part **20**B is formed to have a uniform wall thickness so that the inner peripheral surface **21**a and the outer peripheral surface **21**b are parallel to each other. The flat part **20**B corresponds to one side in the claims.

(26) The multiple teeth **22** protrude from the center of each flat part **20**B of the core part **21** in the circumferential direction toward the inside in the radial direction.

(27) The tooth **22** includes an integrally molded tooth body **22**a and a pair of collars **22**b. The tooth body **22**a protrudes radially inward along the radial direction from the inner peripheral surface of the core part **21**. The collar **22**b extends along the circumferential direction from the radial inner end of the tooth body **22**a. The collar **22**b is formed to extend outward in the circumferential direction from the tooth body **22**a. Then, a slot **19** is formed between the teeth **22** adjacent to each other in the circumferential direction. In the following description, the space between the collars **22**b adjacent to each other in the circumferential direction in the slot **19** is referred to as a tooth

opening **19***a*, and the width of the tooth opening **19***a* in the circumferential direction, that is, the width between the adjacent collars **22***b* in the circumferential direction is referred to as a tooth opening width Wt.

(28) The inner peripheral surface of the core part **21** and the teeth **22** are covered with a resin insulator **23**. The coil **24** is mounted to be wound around each tooth **22** from the surface of the insulator **23**. Each coil **24** generates a magnetic field for rotating the rotor **9** by supplying power from the controller part **4**.

(29) <Rotor>

(30) The rotor **9** is rotatably provided inside the stator **8** in the radial direction via a minute gap. The rotor **9** includes a shaft **31**, a rotor core **32**, and four permanent magnets **33**. As described above, in the motor part **2**, for example, the ratio of the number of magnetic poles of the permanent magnets **33** to the number of slots **19** (teeth **22**) is 4:6.

(31) The axis of the shaft **31** coincides with the rotation axis C**1** of the rotor **9**. The shaft **31** rotates around the rotation axis C**1**. The shaft **31** is integrally molded with a worm shaft **44** (see FIG. **2**) that configures the deceleration part **3**.

(32) The rotor core **32** is fixed to be fitted to the outside of the shaft **31**. The outer shape of the rotor core **32** is formed in a columnar shape with the shaft **31** as the rotation axis C**1**.

(33) The rotor core **32** is formed by stacking multiple metal plates in the axial direction. The rotor core **32** is not limited to the case of being formed by multiple metal plates stacked in the axial direction, and may be formed, for example, by pressure molding soft magnetic powder.

(34) Further, a through hole **32***a* penetrating in the axial direction is formed at the center of the rotor core **32** in the radial direction. The shaft **31** is press-fitted into the through hole **32***a*. The shaft **31** may be relatively inserted into the through hole **32***a* so that the rotor core **32** is fitted to the outside of the shaft **31**, and the shaft **31** and the rotor core **32** may be fixed by an adhesive or the like.

(35) In the rotor core **32**, the arc center of the inner peripheral surface (that is, the inner peripheral surface of the through hole **32***a*) on the inner side in the radial direction and the arc center on the outer peripheral surface **32***b* on the outer side in the radial direction coincide with the position of the rotation axis C**1** of the shaft **31**.

(36) Further, four protrusions **35** are provided on the outer peripheral surface **32***b* of the rotor core **32** at equal intervals in the circumferential direction. The protrusion **35** is formed to protrude outward in the radial direction and extend over the entire axial direction of the rotor core **32**.

(37) Further, the protrusion **35** is formed so that two side surfaces **35***a* facing each other in the circumferential direction are parallel to the protruding direction. That is, the protrusion **35** is formed so that the width dimension in the circumferential direction is uniform in the protruding direction.

(38) Further, round chamfered parts **35***b* are formed at the corners on both sides in the circumferential direction on the outer side of the protrusion **35** in the protruding direction.

(39) On the outer peripheral surface **32***b* of the rotor core **32** formed in this way, the space between the two protrusions **35** adjacent to each other in the circumferential direction is configured as a magnet accommodating part **36**, respectively.

(40) That is, the rotor **9** is a surface permanent magnet (SPM) type rotor having field permanent magnets **33** on the outer peripheral surface **32***b* of the rotor core **32**, and is an inset-type rotor having protrusions **35** protruding radially outward from the rotor core **32** between the permanent magnets **33** arranged in the circumferential direction.

(41) The four permanent magnets **33** are disposed in the four magnet accommodating parts **36** provided on the outer peripheral surface **32***b* of the rotor core **32**. Each permanent magnet **33** is fixed to the rotor core **32** in the magnet accommodating part **36**, for example, with an adhesive or the like.

(42) The permanent magnet **33** is, for example, a ferrite magnet, a neodymium bond magnet, a

neodymium sintered magnet, or the like.

(43) The permanent magnet **33** is magnetized so that the orientation of the magnetism (magnetic field) is parallel in the thickness direction. That is, the orientation of the permanent magnet **33** is a parallel orientation in which the easy magnetization direction is parallel to the radial direction in the central part of the permanent magnet **33**.

(44) The permanent magnets **33** adjacent to each other in the circumferential direction are disposed so that their magnetization directions are opposite to each other. The four permanent magnets **33** are disposed so that the magnetic poles are alternated in the circumferential direction. That is, the permanent magnet **33** having the N pole on the outer peripheral side and the permanent magnet **33** having the S pole on the outer peripheral side are disposed to be adjacent to each other in the circumferential direction. As a result, the protrusion **35** of the rotor core **32** disposed between the permanent magnets **33** adjacent to each other in the circumferential direction is located at the boundary (pole boundary) of the magnetic poles.

(45) <Deceleration Part>

(46) With reference back to FIGS. **1** and **2**, the deceleration part **3** includes a gear case **40** to which the motor case **5** is attached, and a worm deceleration mechanism **41** housed in the gear case **40**.

(47) The gear case **40** is made of a material having good heat dissipation property such as aluminum die casting. The outer shape of the gear case **40** is formed in a box shape, for example. The gear case **40** has a gear accommodating part **42** for accommodating the worm deceleration mechanism **41** inside. Further, in an end part **40**a on the motor part **2** side of the gear case **40**, an opening **43** through which the through hole **10**a of the first motor case **6** and the gear accommodating part **42** are passed through is formed in the part where the first motor case **6** is integrally molded.

(48) Further, a guide plate **49** is provided on a side surface **40**b orthogonal to the end part **40**a of the gear case **40**. The guide plate **49** is provided to rotatably support an output shaft **48** of the worm deceleration mechanism **41**.

(49) The worm deceleration mechanism **41** housed in the gear accommodating part **42** is configured by a worm shaft **44** and a worm wheel **45** meshed with the worm shaft **44**.

(50) The worm shaft **44** is disposed coaxially with the shaft **31** of the motor part **2** (on the rotation axis C**1**). Both ends of the worm shaft **44** are rotatably supported by bearings **46** and **47** provided in the gear case **40**. The end of the worm shaft **44** on the motor part **2** side protrudes through the bearing **46** to the opening **43** of the gear case **40**. The end of the protruding worm shaft **44** and the end of the shaft **31** of the motor part **2** are joined, and the worm shaft **44** and the shaft **31** are integrated. The worm shaft **44** and the shaft **31** may be integrally formed by forming a worm shaft part and a rotation shaft part from one base material.

(51) The worm wheel **45** is provided with an output shaft **48** at the center of the worm wheel **45** in the radial direction. The output shaft **48** is disposed coaxially with the rotation axis direction of the worm wheel **45**. The output shaft **48** is connected to a gear part **50** protruding to the outside of the gear case **40** via the guide plate **49** of the gear case **40**. The gear part **50** is connected to an electrical component (not shown).

(52) Further, the worm shaft **44** is provided with a rotation position detection part **60** for detecting the rotation position of the worm shaft **44**. The rotation position detection part **60** is connected to the controller part **4**.

(53) <Controller Part>

(54) The controller part **4** that controls the drive of the motor part **2** has a controller board **62** on which a magnetic detection element or the like is mounted. The controller board **62** is disposed in the through hole **10**a of the first motor case **6**.

(55) The controller board **62** is a so-called epoxy board on which multiple conductive patterns (not shown) are formed. The end part of the coil **24** drawn from the stator core **20** of the motor part **2** is connected to the controller board **62**, and a terminal **11** provided in the gear case **40** is electrically

connected to the controller board **62**. Further, in addition to the magnetic detection element, a power module (not shown) including a switching element such as a field effect transistor (FET) that controls the current supplied to the coil **24** is mounted on the controller board **62**. Further, a capacitor (not shown) or the like that smooths the voltage applied to the controller board **62** is mounted on the controller board **62**.

(56) The terminal **11** is formed to be able to fit with a connector extending from an external power supply (not shown). Then, the controller board **62** is electrically connected to the terminal **11**. As a result, the electric power of the external power supply is supplied to the controller board **62**.

(57) <Operation of Brushless Motor>

(58) Next, the operation of the brushless motor **1** will be described.

(59) In the brushless motor **1**, the electric power supplied to the controller board **62** via the terminal **11** is selectively supplied to each coil **24** of the motor part **2** via a power module (not shown).

(60) Then, the current flowing through each coil **24** forms a predetermined interlinkage magnetic flux on the stator **8** (teeth **22**). This interlinkage magnetic flux generates a magnetic attractive force or a repulsive force (magnet torque) with the effective magnetic flux formed by the permanent magnets **33** of the rotor **9**.

(61) Further, the protrusions **35** of the rotor core **32** generate a reluctance torque that rotates the rotor core **32** so as to make the protruding direction in a direction in which the interlinkage magnetic flux from the stator **8** (teeth **22**) easily flows, and to reduce the magnetic resistance (reluctance) of the magnetic path of the interlinkage magnetic flux.

(62) These magnet torques and reluctance torques continuously rotate the rotor **9**. The rotation of the rotor **9** is transmitted to the worm shaft **44** integrated with the shaft **31**, and further transmitted to the worm wheel **45** meshed with the worm shaft **44**. Then, the rotation of the worm wheel **45** is transmitted to the output shaft **48** connected to the worm wheel **45**, and the output shaft **48** drives a desired electrical component.

(63) Further, the detection signal of the rotation position of the worm wheel **45** detected by the magnetic detection element mounted on the controller board **62** and the rotation position detection part **60** is output to an external device (not shown). The external device (not shown) is a software function part that functions by executing a predetermined program by a processor such as a central processing unit (CPU). The software function part is an electronic control unit (ECU) including a processor such as a CPU, a read only memory (ROM) for storing a program, a random access memory (RAM) for temporarily storing data, and an electronic circuit such as a timer.

(64) Further, at least a part of the external device (not shown) may be an integrated circuit such as a large scale integration (LSI). The external device (not shown) controls the switching timing of the switching element or the like of the power module (not shown) based on the rotation position detection signal of the worm wheel **45**, and controls the drive of the motor part **2**. The output of the drive signal of the power module and the drive control of the motor part **2** may be executed by the controller part **4** instead of the external device (not shown).

(65) <Winding Device>

(66) Next, a winding device **70** and a method of winding the coil **24** around the stator core **20** using the winding device **70** will be described with reference to FIGS. **4** to **7**.

(67) FIG. **4** is an illustration view showing a method of winding the coil **24** around the stator core **20** using the winding device **70**.

(68) As shown in FIG. **4**, the winding device **70** has a nozzle **71** for feeding out the coil **24**. The nozzle **71** is formed in a cylindrical shape. The tip **71***a* on the side where the coil **24** of the nozzle **71** is fed out is directed toward the slot **19**, and the nozzle **71** is inserted into the slot **19** through the tooth opening **19***a*. Then, while the nozzle **71** moves around the tooth **22**, the coil **24** is fed out from the nozzle **71**, and the coil **24** is wound around the tooth **22**.

(69) Further, the nozzle **71** repeats reciprocating movement along the radial direction, and winds the coil **24** on the tooth **22** to be disposed along the radial direction. More specifically, when the

coil **24** is wound while moving in the direction of pulling out the nozzle **71** from the slot **19** (see the arrow Y**1** in FIG. **4**), the coil **24** is sequentially wound on the outer peripheral surface of the tooth body **22***a* from the base on the core part **21** side toward the collar **22***b*. In addition, when the coil **24** is wound while moving in the direction of inserting the nozzle **71** toward the slot **19** (see the arrow Y**2** in FIG. **4**), the coil **24** is sequentially wound on the outer peripheral surface of the tooth body **22***a* from the collar **22***b* toward the base on the core part **21** side. By winding the coil **24** on the teeth **22** in this way, the coil **24** is stacked on the bundle, and the winding work of the coil **24** is completed.

(70) Here, the core part **21** of the stator core **20** is formed in a tubular shape of regular hexagon with rounded corners when viewed from the axial direction, and has six corner parts **20**A and flat parts **20**B, respectively. The flat part **20**B is formed to have a uniform wall thickness so that the inner peripheral surface **21***a* and the outer peripheral surface **21***b* are parallel to each other. Therefore, as shown in FIG. **3**, the space in the slot **19** may be increased (see the hatch part Hb in FIG. **3**) as compared with the case where the core part **21** is formed in a cylindrical shape (see reference numeral **21***e* of the two-dot chain line in FIG. **3**). The space factor of the coil **24** may be reduced by this amount, and the nozzle **71** may be easily entered into the slot **19**.

(71) Next, the details of the nozzle **71** will be described with reference to FIG. **5**.

(72) FIG. **5** is a schematic view of the nozzle **71**.

(73) As shown in FIG. **5**, the nozzle **71** has a nozzle hole **72** from which the coil **24** is fed, an inner-diameter round chamfered part **73** formed at the opening edge of the nozzle hole **72** on a tip **71***a* side, and an outer-diameter round chamfered part **74** formed on the outer peripheral edge of the nozzle hole **72** on the tip **71***a* side. Each of the round chamfered parts **73** and **74** has an arc cross-sectional shape along the axial direction of the nozzle **71**.

(74) Here, when the wire diameter of the coil **24** is defined as Φc, the inner diameter of the nozzle hole **72** is defined as Φin, the radius of curvature of the inner-diameter round chamfered part **73** is defined as Rin, and the radius of curvature of the outer-diameter round diameter part **74** is defined as Rout, each of Φc, Φin, Rin, and Rout satisfy the following:

$$1.2\Phi c \leq \Phi in \leq 1.4\Phi c \qquad (1)$$
$$0.51\Phi c \leq Rin \leq \Phi c \qquad (2)$$
$$0.25\Phi c \leq Rout \leq 0.5\Phi c \qquad (3).$$

The wire diameter Φc of the coil **24** is a value excluding the film thickness of the insulating coating of the coil **24**.

(75) This is because, regarding the equation (1), the inner diameter Φin of the nozzle hole **72** needs to be sufficiently wider than the wire diameter Φc of the coil **24**.

(76) The equation (2) will be described.

(77) First, the bending strength of the coil **24** will be described with reference to FIG. **6**.

(78) FIG. **6** is a graph showing the change in the stress ratio to the coil **24** when the vertical axis is the stress ratio to the coil **24** [1/X] and the horizontal axis is the ratio of the bending curvature/wire diameter Φc of the coil **24**.

(79) As shown in FIG. **6**, it may be confirmed that the larger the bending curvature of the coil **24** with respect to the wire diameter Φc, the smaller the stress ratio to the coil **24**. In addition, if the radius of curvature Rin of the inner-diameter round chamfered part **73** is made too large, the nozzle **71** becomes large and the tooth opening width Wt must be increased. Therefore, it is desirable that the ratio is in the vicinity of "1," and the radius of curvature Rin of the inner-diameter round chamfered part **73** satisfies the above equation (2).

(80) The equation (3) will be described.

(81) Here, the nozzle **71** repeats reciprocating movement along the radial direction, and the coils **24** are wound around the tooth **22** to be disposed along the radial direction. Therefore, as shown in FIG. **4**, the coil **24** is always in slidable contact with the inner-diameter round chamfered part **73** of the nozzle **71**, but the coil **24** is in slidable contact with the outer-diameter round chamfered part **74**

of the nozzle **71** only when the nozzle **71** is moved toward the slot **19** in the inserting direction (see the arrow Y**2** in FIG. **4**). That is, the frequency with which the coil **24** is in slidable contact with the outer-diameter round chamfered part **74** is ½ as compared with the frequency with which the coil **24** is in slidable contact with the inner-diameter round chamfered part **73**. Therefore, as shown in the equation (3), the radius of curvature Rout of the outer-diameter round chamfered part **74** is set to ½ of the radius of curvature Rin of the inner-diameter round chamfered part **73**.

(82) In addition, it is desirable that the tooth opening width Wt and the space S between the nozzle **71** and the teeth opening **19***a* satisfies the following:

$$0.1 \text{ mm} \leq S \leq 0.2 \text{ mm} \qquad (4).$$

By doing so, it is possible to avoid contact between the teeth **22** and the nozzle **71**.

(83) FIG. **7** is a graph showing the change in the tooth opening width Wt/the wire diameter Φc of the coil **24** when the vertical axis is the tooth opening width Wt/the wire diameter Φc of the coil **24** and the horizontal axis is the wire diameter Φc of the coil **24**.

(84) As shown in FIG. **7**, it is confirmed that it is desirable to set the wire diameter Φc of the coil **24** to satisfy

$$0.3 \text{ mm} \leq \Phi c \leq 1.5 \text{ mm} \qquad (5)$$

in the range from the lower limit value to the upper limit value of the above equations (1) to (4). When the wire diameter Φc of the coil **24** becomes smaller than 0.3 mm, the value of the tooth opening width Wt/the wire diameter Φc of the coil **24** increases sharply. Further, when the wire diameter Φc of the coil **24** becomes larger than 1.5 mm, it becomes difficult to actually bend the coil **24**. Therefore, the above equation (5) is used.

(85) Further, from the graph shown in FIG. **7**, it is desirable that the tooth opening width Wt/the wire diameter Φc of the coil **24** satisfies the following:

$$3.83 \leq Wt/\Phi c \leq 6.73 \qquad (6).$$

By satisfying the above equation (6), the tooth opening width Wt may be sufficiently secured, so that the coil **24** may be prevented from being scratched or damaged.

(86) As described above, the nozzle **71** in the winding device **70** is formed to satisfy the above equations (1) to (3). Therefore, the bending stress of the coil **24** fed out from the nozzle **71** may be reduced as much as possible, so that damage during the winding work of the coil **24** may be prevented. Further, since it is possible to prevent the nozzle **71** from being unnecessarily enlarged, it is possible to prevent the motor part **2** from being enlarged and the motor characteristics from being deteriorated.

(87) Further, the motor part **2** includes the rotor core **32** having the protrusions **35**. Therefore, when rotating the rotor **9**, both the reluctance torque and the magnetic force (magnet torque) of the permanent magnets **33** may be used, and the torque of the motor part **2** may be effectively increased. Since the space factor of the coil **24** may be reduced by this amount, the working hours for winding the coil **24** may be reduced, and damage to the coil **24** may be suppressed.

(88) Further, the core part **21** of the stator core **20** is formed in a tubular shape of regular hexagon with rounded corners when viewed from the axial direction, and has six corner parts **20**A and flat parts **20**B, respectively. The flat part **20**B is formed to have a uniform wall thickness so that the inner peripheral surface **21***a* and the outer peripheral surface **21***b* are parallel to each other. Therefore, as shown in FIG. **3**, the space in the slot **19** may be increased (see the hatch part in FIG. **3**) as compared with the case where the core part **21** is formed in a cylindrical shape (see the two-dot chain line in FIG. **3**). The space factor of the coil **24** may be reduced by this amount, and the nozzle **71** may be easily entered into the slot **19**. Therefore, the winding work of the coil **24** may be facilitated.

(89) Further, it is desirable that the wire diameter Φc of the coil **24** satisfies the above equation (4). With this configuration, the shape (dimensions) of the nozzle **71** and the tooth opening width Wt may be made appropriate, and the enlargement of the motor part **2** and the deterioration of the motor characteristics may be reliably prevented.

(90) Further, it is desirable that the tooth opening width Wt/the wire diameter Φc of the coil **24** satisfies the above equation (6). With this configuration, the tooth opening width Wt may be sufficiently secured, so that the coil **24** may be prevented from being scratched or damaged.

(91) The disclosure is not limited to the above-described embodiment, and includes various modifications to the above-described embodiment without departing from the spirit of the disclosure.

(92) For example, in the above-described embodiment, the brushless motor **1** is assumed to be a drive source for a sunroof mounted on a vehicle. However, the disclosure is not limited to this, and for example, the brushless motor **1** may be a drive source for various electrical components mounted on a vehicle (for example, a power window, an electric seat, a wiper, and the like) or a drive source mounted on various devices other than the vehicle.

(93) In the above-described embodiment, the case where the ratio of the number of magnetic poles of the permanent magnets **33** to the number of slots **19** (teeth **22**) in the motor part **2** is 4:6 has been described. However, the ratio is not limited to this, and the ratio between the number of magnetic poles of the permanent magnets **33** and the number of slots **19** (teeth **22**) may be set as desired.

Claims

1. A motor in which a coil is wound by a winding device, comprising: a stator having a core part in a tubular shape, and a tooth that protrudes inward in a radial direction from an inner peripheral surface of the core part and around which the coil is wound; and a rotor provided inside the stator in the radial direction and rotating around a rotation axis, wherein the rotor comprises: a shaft that rotates around the rotation axis; a rotor core that is supported by the shaft and rotates with the rotation axis as a radial center; a magnet disposed on an outer peripheral surface of the rotor core; and a protrusion that protrudes outward in the radial direction between the magnets adjacent to each other in a circumferential direction of the outer peripheral surface of the rotor core, wherein the tooth comprises: a tooth body that protrudes inward in the radial direction from the inner peripheral surface of the core part; and a collar that extends along a circumferential direction from a radial inner end of the tooth body, wherein the core part is formed in a polygonal shape when viewed from a direction of the rotation axis, and a portion of the inner peripheral surface of the core part that faces a tooth opening between the collars adjacent to each other in the circumferential direction is formed flat so that a wall thickness at a polygonal vertex portion of the core part is greater than a wall thickness of polygonal side portions of the core part.

2. The motor according to claim 1, wherein a portion of the inner peripheral surface of the core part from which the tooth protrudes inward in the radial direction is formed flat so that the wall thickness of the polygonal side portions of the core part is uniform.

3. The motor according to claim 2, wherein when a wire diameter of the coil is defined as Φc, the wire diameter Φc satisfies 0.3 mm≤Φc≤1.5 mm.

4. The motor according to claim 3, wherein the tooth comprises: a tooth body that protrudes inward in the radial direction from the inner peripheral surface of the core part; and a collar that extends along a circumferential direction from a radial inner end of the tooth body, wherein when a width in the circumferential direction at a tooth opening between the collars adjacent to each other in the circumferential direction is defined as Wt and a wire diameter of the coil is defined as Φc, the width Wt and the wire diameter Φc satisfy:

$$3.83 \leq Wt/\Phi c \leq 6.73.$$

5. The motor according to claim 2, wherein the tooth comprises: a tooth body that protrudes inward in the radial direction from the inner peripheral surface of the core part; and a collar that extends along a circumferential direction from a radial inner end of the tooth body, wherein when a width in the circumferential direction at a tooth opening between the collars adjacent to each other in the circumferential direction is defined as Wt and a wire diameter of the coil is defined as Φc, the

width Wt and the wire diameter Φc satisfy:

$3.83 \leq Wt/\Phi c \leq 6.73$.

6. The motor according to claim 1, wherein when a wire diameter of the coil is defined as Φc, the wire diameter Φc satisfies $0.3\ mm \leq \Phi c \leq 1.5\ mm$.

7. The motor according to claim 6, wherein the tooth comprises: a tooth body that protrudes inward in the radial direction from the inner peripheral surface of the core part; and a collar that extends along a circumferential direction from a radial inner end of the tooth body, wherein when a width in the circumferential direction at a tooth opening between the collars adjacent to each other in the circumferential direction is defined as Wt and a wire diameter of the coil is defined as Φc, the width Wt and the wire diameter Φc satisfy:

$3.83 \leq Wt/\Phi c \leq 6.73$.

8. The motor according to claim 1, wherein when a width in the circumferential direction at the tooth opening between the collars adjacent to each other in the circumferential direction is defined as Wt and a wire diameter of the coil is defined as Φc, the width Wt and the wire diameter Φc satisfy:

$3.83 \leq Wt/\Phi c \leq 6.73$.