

US Patent & Trademark Office

Patent Public Search | Text View

| | |
|----------------------|---------------------|
| United States Patent | 12388324 |
| Kind Code | B2 |
| Date of Patent | August 12, 2025 |
| Inventor(s) | Tanaka; Koki et al. |

Rotating electrical machine

Abstract

A rotating electrical machine includes: a rotor; a stator including a stator core and a coil and including a radial protrusion for fastening located above a rotation center of the rotor; a housing member that houses the rotor and the stator and to which the radial protrusion is fastened; and an oil passage portion located above the rotation center of the rotor and extending in an axial direction within a range in which the stator core extends in the axial direction, the oil passage portion having a discharge hole that discharges oil in a direction toward a position radially outward of the radial protrusion as viewed in the axial direction.

| | |
|------------------------------|---|
| Inventors: | Tanaka; Koki (Kariya, JP), Yoneda; Takahiro (Kariya, JP) |
| Applicant: | AISIN CORPORATION (Aichi, JP) |
| Family ID: | 1000008751257 |
| Assignee: | AISIN CORPORATION (Kariya, JP) |
| Appl. No.: | 18/039748 |
| Filed (or PCT Filed): | February 15, 2022 |
| PCT No.: | PCT/JP2022/005892 |
| PCT Pub. No.: | WO2022/185902 |
| PCT Pub. Date: | September 09, 2022 |

Prior Publication Data

| | |
|----------------------------|-------------------------|
| Document Identifier | Publication Date |
| US 20240022135 A1 | Jan. 18, 2024 |

Foreign Application Priority Data

| | | |
|----|-------------|---------------|
| JP | 2021-034657 | Mar. 04, 2021 |
|----|-------------|---------------|

Publication Classification

Int. Cl.: H02K9/19 (20060101); H02K5/18 (20060101); H02K5/20 (20060101)

U.S. Cl.:

CPC H02K9/19 (20130101); H02K5/18 (20130101); H02K5/203 (20210101);

Field of Classification Search

CPC: H02K (5/203); H02K (1/185)

References Cited

U.S. PATENT DOCUMENTS

| Patent No. | Issued Date | Patentee Name | U.S. Cl. | CPC |
|--------------|-------------|---------------|----------|--------------|
| 11114921 | 12/2020 | Ito | N/A | F16H 57/045 |
| 11318834 | 12/2021 | Suyama | N/A | F16H 57/0409 |
| 2022/0123628 | 12/2021 | Nakamatsu | N/A | H02K 5/20 |
| 2023/0327518 | 12/2022 | Horio | 310/52 | H02K 5/203 |
| 2024/0051378 | 12/2023 | Inoue | N/A | H02K 5/203 |

FOREIGN PATENT DOCUMENTS

| Patent No. | Application Date | Country | CPC |
|-------------|------------------|---------|-----|
| 2019-170030 | 12/2018 | JP | N/A |

OTHER PUBLICATIONS

Apr. 26, 2022 International Search Report issued in International Patent Application No. PCT/JP2022/005892. cited by applicant

Primary Examiner: Iwarere; Oluseye

Assistant Examiner: Vaziri; Masoud

Attorney, Agent or Firm: Oliff PLC

Background/Summary

TECHNICAL FIELD

(1) The present disclosure relates to rotating electrical machines.

BACKGROUND ART

(2) There is known a technique in which a stator having radial protrusions (also referred to as “bolting portions”) for fastening to a case is provided, and the stator is cooled by discharging oil to the outer peripheral surface of a stator core by using an oil passage portion in a pipe located above the rotation center of a rotor and extending in the axial direction. In this technique, in order to cause the oil to properly spread to a portion below the bolting portion, the pipe itself is rotated by a rotation mechanism to change the discharge direction in which the oil is discharged from discharge ports of the pipe.

Patent Documents

(3) Patent Document 1: Japanese Unexamined Patent Application Publication No. 2019-170030 (JP 2019-170030 A)

SUMMARY OF THE DISCLOSURE

Problem to be Solved by the Disclosure

(4) However, the related art as described above has a complicated configuration because, for example, the rotation mechanism is provided. It is therefore difficult to properly cool the stator by using a simple configuration.

(5) Accordingly, in one aspect, it is an object of the present disclosure to properly cool a stator having a radial protrusion by using a simple configuration.

Means for Solving the Problem

(6) In one aspect, a rotating electrical machine is provided that includes a rotor, a stator including a stator core and a coil and including a radial protrusion for fastening located above a rotation center of the rotor, a housing member that houses the rotor and the stator and to which the radial protrusion is fastened, and an oil passage portion located above the rotation center of the rotor and extending in an axial direction within a range in which the stator core extends in the axial direction, the oil passage portion having a discharge hole that discharges oil in a direction toward a position radially outward of the radial protrusion as viewed in the axial direction.

(7) The rotating electrical machine further includes a rib portion that is provided above the rotation center of the rotor in the housing member, that protrudes radially inward from an inner peripheral surface of the housing member, and that overlaps the stator core as viewed in an up-down direction.

(8) The discharge hole is provided within a range in which the rib portion extends in the axial direction.

(9) The oil passage portion, the radial protrusion, and the rib portion are located in this order as viewed in the axial direction.

Effects of the Disclosure

(10) In one aspect, according to the present disclosure, a stator having a radial protrusion can be properly cooled by using a simple configuration.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 is a plan view schematically showing a rotating electrical machine according to an embodiment.

(2) FIG. 2 is a perspective view showing an example of a stator.

(3) FIG. 3 is a schematic sectional view taken along line A-A in FIG. 1.

(4) FIG. 4 is a schematic sectional view taken along line B-B in FIG. 1.

(5) FIG. 5 is a schematic sectional view taken along line C-C in FIG. 1.

(6) FIG. 6 is a schematic sectional view taken along line D-D in FIG. 1.

(7) FIG. 7A is a diagram schematically showing an oil passage structure.

(8) FIG. 7B is a sectional view taken along line E-E in FIG. 4.

(9) FIG. 8 is an illustration of an oil passage structure according to a first comparative example.

(10) FIG. 9 is an illustration of an oil passage structure according to a second comparative example.

(11) FIG. 10 is a schematic sectional view of a main part of a rotating electrical machine according to a modification.

MODES FOR CARRYING OUT THE DISCLOSURE

(12) Embodiments will be described in detail below with reference to the accompanying drawings. The dimensional ratios in the drawings are merely illustrative, and are not limited to these. The

shapes etc. in the drawings may be partially exaggerated for convenience of explanation. For simplicity, reference signs may be given only to part of a plurality of portions having the same attribute throughout the drawings.

(13) FIG. 1 is a plan view schematically showing a rotating electrical machine 1 according to an embodiment. In FIG. 1, X, Y, and Z axes are defined in a right-handed coordinate system, and a Y direction is parallel to the direction in which a central axis I0 (design central axis I0) of the rotating electrical machine 1 extends. A Z direction corresponds to an up-down direction, and the positive side in the Z direction corresponds to an upper side. The Z direction need not necessarily be parallel to the direction of gravity. FIG. 1 is a plan view as viewed in the Y direction, and only a peripheral wall portion 2a of a case 2 is shown in section (planar section taken along an XZ plane). An axial direction, a radial direction, and a circumferential direction hereinafter represent directions based on a rotating body about the central axis I0. FIG. 2 is a perspective view showing an example of a stator 3. FIG. 3 is a schematic sectional view taken along line A-A in FIG. 1. FIG. 4 is a schematic sectional view taken along line B-B in FIG. 1. FIG. 5 is a schematic sectional view taken along line C-C in FIG. 1. FIG. 6 is a schematic sectional view taken along line D-D in FIG. 1. In FIGS. 3 to 6, a Y1 side (positive side in the Y direction) and a Y2 side (negative side in the Y direction) in the Y direction are defined.

(14) The rotating electrical machine 1 includes the case 2, the stator 3, a rotor 4, and a tubular member 8.

(15) The case 2 forms a chamber that houses the stator 3. The case 2 supports the stator 3. The case 2 may be formed by, for example, casting aluminum. The case 2 may be implemented by two or more case members. The case 2 may form part of a chamber that houses elements other than the rotating electrical machine 1 (e.g., an inverter and a power transmission mechanism, both not shown).

(16) The case 2 includes a fastening portion 20, a stator holding portion 22, a side wall portion 26, and a rib portion 28.

(17) The fastening portion 20 is a portion for fastening the stator 3 to the case 2. A plurality of the fastening portions 20 may be provided around the central axis I0 as viewed in the axial direction. In the present embodiment, for example, the fastening portions 20 are provided at three positions at intervals of 120° corresponding to radial protrusions 34 of the stator 3 described later. Each fastening portion 20 forms a seating portion (seating portion for the radial protrusion 34) parallel to the XZ plane, and has a fastening hole 202 (see FIG. 3). A fastener 90 such as a bolt may be screwed into each fastening hole 202. Of the three fastening portions 20, the upper fastening portion 20 is hereinafter also referred to as “fastening portion 20-1.”

(18) The stator holding portion 22 has a function to maintain the attitude of the stator 3 (e.g., a function to prevent tilting of the stator 3, which is also referred to as “stator holding function”). The stator holding portion 22 forms a curved holding surface 221 in order to implement such a stator holding function. The curved holding surface 221 extends in the axial direction and faces the outer peripheral surface of a stator core 31 in the radial direction. A radial clearance $\Delta 0$ (see FIG. 5) between the curved holding surface 221 and the outer peripheral surface of the stator core 31 may have a very small value such as approximately zero, and may correspond to, for example, the maximum value in a possible deviation range (variable range due to allowable tolerance etc.) with respect to a design value (nominal value) of the outside diameter of the stator core 31. In this case, the curved holding surface 221 may contact the outer peripheral surface of the stator core 31 in the radial direction depending on the individual stator core 31. Alternatively, the radial clearance $\Delta 0$ (see FIG. 5) between the curved holding surface 221 and the outer peripheral surface of the stator core 31 may have a value slightly larger than the maximum value in the possible deviation range with respect to the design value of the outside diameter of the stator core 31. In either case, the outer peripheral surface of the stator core 31 comes into contact with the curved holding surface 221 when the attitude of the stator 3 changes in such a manner that the axis of the stator 3 is tilted

with respect to the normal central axis **10**. The stator holding function thus reduces the change in attitude of the stator **3**. In the following description, it is assumed that the clearance $\Delta 0$ is approximately zero.

(19) The curved holding surface **221** is preferably part of the outer peripheral surface of a cylindrical body about the central axis **10**. That is, the curved holding surface **221** is preferably a surface formed by offsetting the outer peripheral surface of the stator core **31** in a normal form radially outward. In this case, the radial clearance $\Delta 0$ (see FIG. 5) between the curved holding surface **221** and the outer peripheral surface of the stator core **31** is constant along the entire circumferential length of the curved holding surface **221** when the outside diameter of the stator core **31** is the design value (nominal value).

(20) A plurality of the stator holding portions **22** may be provided. In the present embodiment, the stator holding portions **22** are provided on both sides of the fastening portion **20-1** in the circumferential direction so as to sandwich the fastening portion **20-1** therebetween in the circumferential direction. The two stator holding portions **22** provided on both sides of the fastening portion **20-1** in the circumferential direction are hereinafter also referred to as “pair of stator holding portions **22**.” The stator holding portion **22** may be provided at a position other than on both sides of the fastening portion **20-1** in the circumferential direction. In the example shown in FIG. 1, a total of three stator holding portions **22** are provided so as to form a pair on both sides of each fastening portion **20**.

(21) The set range of the stator holding portion **22** (curved holding surface **221**) in the circumferential direction (circumferential range facing the stator holding portion **22** in the radial direction out of the entire circumference of the stator core **31**) is adapted so as to properly implement the stator holding function of the stator holding portion **22**. The larger the set range of the stator holding portion **22** in the circumferential direction, the more the material cost tends to increase. Therefore, the set range of the stator holding portion **22** in the circumferential direction may be kept to the minimum required. In the present embodiment, the stator holding portions **22** are distributed in the circumferential direction so as to form a pair on both sides of each fastening portion **20**. Efficient arrangement can thus be implemented.

(22) Similarly, the set range of the stator holding portion **22** (curved holding surface **221**) in the axial direction (axial range facing the stator holding portion **22** in the radial direction out of the entire axial length of the stator core **31**) is adapted so as to properly implement the stator holding function of the stator holding portion **22**. The larger the set range of the stator holding portion **22** in the axial direction, the more the material cost tends to increase. Therefore, the set range of the stator holding portion **22** in the axial direction may be kept to the minimum required.

(23) The side wall portion **26** is located on the Y2 side in the Y direction with respect to the pair of stator holding portions **22** and extends in the circumferential direction concentrically with the central axis **10**. The side wall portion **26** is provided so as to adjoin each of the pair of stator holding portions **22** in the axial direction on the Y2 side in the Y direction. That is, the side wall portion **26** is provided so as to be continuous from the ends on the Y2 side of the pair of stator holding portions **22** toward the Y2 side. Separate side wall portions **26** may be provided for the pair of stator holding portions **22**, or a single side wall portion **26** that is continuous in the circumferential direction may be provided for the pair of stator holding portions **22**. The side wall portion **26** may extend to the Y2 side with respect to the fastening portion **20**.

(24) The side wall portion **26** is located farther away from the central axis **10** in the radial direction than the curved holding surface **221**. In the example shown in FIG. 5, the side wall portion **26** does not face the stator core **31** in the radial direction, but faces a coil end **322** on the Y2 side in the radial direction. In a modification, the side wall portion **26** may face the end on the Y2 side of the stator core **31** in the radial direction and face the coil end **322** on the Y2 side in the radial direction.

(25) The rib portion **28** is provided on the case **2**. In the present embodiment, the rib portion **28** is integral with the case **2**. However, the rib portion **28** may be a separate member from the case **2** and

may be attached to the case **2**. The rib portion **28** protrudes radially inward from an inner peripheral surface **20a** of the peripheral wall portion **2a** of the case **2**.

(26) The rib portion **28** extends in the axial direction and the radial direction in an annular space between the inner peripheral surface **20a** of the peripheral wall portion **2a** of the case **2** and the stator **3**. That is, the rib portion **28** extends in the axial direction and the radial direction at a position radially outward of a rotor core **40** and radially inward of the peripheral wall portion **2a** of the case **2**. The rib portion **28** extends within a range overlapping the stator core **31** as viewed in the radial direction. That is, the rib portion **28** extends in the axial direction in the range in which the stator core **31** extends in the axial direction. The rib portion **28** extends in the radial direction such that its radially inner end is separated from the outer peripheral surface of the stator core **31** in the radial direction.

(27) In the present embodiment, as shown in FIG. 5, the rib portion **28** is continuous on its Y2 side with the stator holding portion **22**, and extends from the stator holding portion **22** toward the Y1 side in the Y direction. As shown in FIG. 5, the rib portion **28** extends, on its Y1 side, to substantially the same axial position as the end on the Y1 side of the stator core **31**. In a modification, the rib portion **28** may extend, on its Y1 side, to such an axial position that the rib portion **28** overlaps a coil end **321** as viewed in the radial direction, or may extend, on its Y1 side, only to a position located on the Y2 side with respect to the axial position shown in FIG. 5.

(28) The rib portion **28** is provided at such a circumferential position that the rib portion **28** and the tubular member **8** sandwich the fastening portion **20-1** (and therefore the radial protrusion **34** for fastening that is fastened to the fastening portion **20-1**) therebetween in the circumferential direction. That is, the rib portion **28** is provided at such a circumferential position that the fastening portion **20-1** is located between the rib portion **28** and the tubular member **8** as viewed in the axial direction.

(29) As will be described later with reference to FIG. 7B, the rib portion **28** has a function to drop oil flowing along the inner peripheral surface **20a** of the peripheral wall portion **2a** of the case **2** onto the outer peripheral surface of the stator core **31** (hereinafter referred to as “oil dropping function”). In order to implement this oil dropping function, the rib portion **28** overlaps the stator core **31** as viewed in the up-down direction (Z direction).

(30) A plurality of the rib portions **28** may be provided so as to be separated from each other. For example, the plurality of rib portions **28** may be provided so as to be separated from each other in the axial direction, or the plurality of rib portions **28** may be provided at different positions in the circumferential direction.

(31) Moreover, the rib portion **28** may be in any form as long the oil dropping function can be implemented. For example, the rib portion **28** may have a curved portion or a bent portion. In the present embodiment, for example, the rib portion **28** has a rectangular shape as viewed in the axial direction. In this case, the rib portion **28** may have a tapered shape whose circumferential width gradually decreases toward the radially inner side.

(32) The stator **3** is provided concentrically with the central axis **I0**. That is, the central axis (axial center) of the stator **3** coincides with the central axis **I0**. The stator **3** includes the stator core **31** and a coil **32**.

(33) The stator core **31** may be formed by, for example, stacking electrical steel sheets. The coil **32** is in the form of, for example, a coil wire having a rectangular cross section, and is wound in slots **311** of the stator core **31**. The coil **32** forms the coil ends **321**, **322** on both sides in the axial direction of the stator core **31**.

(34) In the present embodiment, the stator **3** includes the radial protrusions **34** for fastening. The radial protrusions **34** for fastening are in such a form that they protrude in the radial direction, and are also referred to as “bolting portions.” The radial protrusions **34** for fastening are provided in order to fix the stator **3** to the case **2** by fastening. The radial protrusions **34** may be integral with the stator core **31**, or may be separate members from the stator core **31** and may be connected to the

stator core **31**. As shown in FIG. 2, the radial protrusions **34** for fastening may extend along the entire axial length of the stator core **31**. The radial protrusions **34** for fastening may be provided at regular intervals in the circumferential direction. In the example shown in FIG. 2, the radial protrusions **34** are provided at three positions at intervals of 120°.

(35) Each radial protrusion **34** for fastening has a fastening hole **341**. For example, the fastening hole **341** is formed so as to extend through the radial protrusion **34** in the axial direction. The fastener **90** is inserted through each fastening hole **341**. As shown in FIGS. 2 and 3, the stator **3** is fastened and fixed to the case **2** by screwing the fasteners **90** into the fastening portions **20** of the case **2** through the fastening holes **341**.

(36) The rotor **4** is provided radially inward of the stator **3**. As schematically shown in FIG. 4, the rotor **4** includes the rotor core **40** and a rotor shaft **42**.

(37) The rotor core **40** may be formed by, for example, stacking electrical steel sheets. Permanent magnets (not shown) may be embedded in the rotor core **40**.

(38) The rotor shaft **42** is preferably a hollow member as shown in FIG. 4. In this case, oil can be supplied to an axial oil passage **86** that is the hollow interior of the rotor shaft **42**, so that the rotor core **40** and/or the permanent magnets can be cooled from the radially inner side by the oil. The rotor shaft **42** may have oil holes (not shown) that can discharge the oil in the axial oil passage **86** toward the coil ends **321**, **322** by using a centrifugal force.

(39) The tubular member **8** extends in the axial direction in the annular space between the inner peripheral surface **20a** of the peripheral wall portion **2a** of the case **2** and the stator **3**. That is, the tubular member **8** extends in the axial direction at a position radially outward of the rotor core **40** and radially inward of the peripheral wall portion **2a** of the case **2**. Hereinafter, the tubular member **8** refers to a portion of a generally tubular member that extends within a range overlapping the stator **3** in the radial direction, unless otherwise specified. The tubular member **8** may be bent etc. in the radial direction at a position outside the range overlapping the stator **3** in the radial direction. For example, the tubular member **8** may be inserted from the Y1 side into the case **2** and may have a free end on the Y2 side. In this case, the end on the Y2 side of the tubular member **8** may be a closed end. For example, the end on the Y2 side (free end) of the tubular member **8** may be closed by a separate plug member. In a modification, for example, the tubular member **8** may be inserted from the Y2 side into the case **2** and may have a free end on the Y1 side, or the tubular member **8** may be configured so that the tubular member **8** does not have a free end and the internal space (oil passage **80**) of the tubular member **8** communicates with an oil passage inside the case (not shown).

(40) The tubular member **8** is disposed above the central axis **I0**. The tubular member **8** is preferably provided at a position higher than the highest position of the stator core **31** (highest position of the stator core **31** excluding the radial protrusions **34**). The stator **3** can thus be efficiently cooled from above by the oil discharged from the tubular member **8**. For example, as shown in FIG. 1, the tubular member **8** may be provided near the top part of the annular space between the inner peripheral surface **20a** of the peripheral wall portion **2a** of the case **2** and the stator **3**. In the example shown in FIG. 1, the tubular member **8** is set at the uppermost position (top position) about the central axis **I0**. However, the tubular member **8** may be set at a position that slightly deviates from the top position (e.g., a position within 45°).

(41) The tubular member **8** has the oil passage **80** inside. The tubular member **8** is preferably in the form of a hollow pipe. In this case, the tubular member **8** can be easily formed from an existing pipe material.

(42) The sectional shape of the tubular member **8** (sectional shape taken along the XZ plane) is, for example, a circle, but may be other shape (e.g., a rectangle). The tubular member **8** may have the same sectional shape along its entire axial length. A central axis **I1** of the tubular member **8** may be located at the same distance (same diameter) from the central axis **I0**. That is, the central axis **I1** of the tubular member **8** may be parallel to the central axis **I0**.

(43) The tubular member **8** is preferably provided at such a radial position that the tubular member

8 is less likely to cause an increase in overall radial size of the rotating electrical machine **1** including the case **2**. For example, the radially innermost part of the tubular member **8** is located closer to the central axis **I0** in the radial direction than the radially outermost part of the radial protrusion **34**. In this case, the radially outermost part of the tubular member **8** is not separated too much from the central axis **I0** in the radial direction. This can reduce the possibility that the overall radial size of the rotating electrical machine **1** may increase due to the tubular member **8**.

(44) In the present embodiment, as shown in FIG. **4**, the tubular member **8** is provided near the outer peripheral surface of the stator core **31** so as to be separated away from the outer peripheral surface of the stator core **31** by a relatively small clearance $\Delta 1$. In the example shown in FIG. **4**, the radial clearance $\Delta 1$ (see FIG. **4**) between the tubular member **8** and the outer peripheral surface of the stator core **31** may be slightly larger than $\Delta 0$ (see FIG. **5**) described above. That is, the tubular member **8** is separated from the central axis **I0** slightly more than the pair of stator holding portions **22** (curved holding surfaces **221**). Such a clearance $\Delta 1$ may be a minimum value at which oil can be discharged from an oil hole **81** described later.

(45) As shown in FIG. **4**, the tubular member **8** has the oil hole **81** communicating with the oil passage **80**. The oil hole **81** is formed so that it can discharge oil toward the coil end **321** on one side in the axial direction (Y1 side). A plurality of the oil holes **81** may be provided along the circumferential direction and/or along the axial direction. In this case, the oil holes **81** can discharge oil in various directions toward the coil end **321**, so that the coil end **321** can be more uniformly cooled along its entire circumference. For example, the oil hole **81** may be formed so as to discharge oil in a tangential direction to the outer peripheral portion of the coil end **321** as viewed in the axial direction. The coil end **321** may extend on the opposite side from leads.

(46) As shown in FIG. **4**, the tubular member **8** further has an oil hole **82** communicating with the oil passage **80**. The oil hole **82** is formed so that it can discharge oil in the oil passage **80** toward the coil end **322** on the other side in the axial direction (Y2 side). A plurality of the oil holes **82** may be provided along the circumferential direction and/or along the axial direction. In this case, the oil holes **82** can discharge oil in various directions toward the coil end **322**, so that the coil end **322** can be more uniformly cooled along its entire circumference. For example, the oil hole **82** may be formed so as to discharge oil in a tangential direction to the outer peripheral portion of the coil end **322** as viewed in the axial direction. The coil end **322** may extend on the lead side.

(47) The tubular member **8** has similar oil holes **83**, **84** facing the outer peripheral surface of the stator core **31** in the radial direction, in addition to the oil hole **81** facing the coil end **321** on the Y1 side in the radial direction.

(48) The oil hole **83** is provided on the Y1 side with respect to the middle position in the axial direction of the stator core **31** within the range in which the stator core **31** extends in the axial direction. In the present embodiment, as shown in FIGS. **4** and **5**, the oil hole **83** is located within the range in which the rib portion **28** extends in the axial direction (see also FIG. **7B**). A plurality of the oil holes **83** may be provided along the circumferential direction and/or along the axial direction. In this case, the oil holes **83** can discharge oil in various directions toward the stator core **31**, so that the stator core **31** can be more uniformly cooled along its entire circumference.

(49) In the present embodiment, referring to FIG. **7B**, the oil holes **83** include an oil hole **830** (see FIG. **7B**) for discharging oil toward the side in the circumferential direction on which the radial protrusion **34** is not located, and an oil hole **831** (see FIG. **7B**) for discharging oil toward the side in the circumferential direction on which the radial protrusion **34** is located, as will be described in detail later. For example, the oil hole **830** may be formed so as to discharge oil in a tangential direction to the outer peripheral surface of the stator core **31** as viewed in the axial direction. The oil holes **83** may include a hole for discharging oil directly downward (e.g., substantially in the same direction as the direction toward the central axis **I0**), in addition to the oil hole **830** and the oil hole **831**.

(50) The oil hole **84** is provided on the Y2 side with respect to the middle position in the axial

direction of the stator core **31**. A plurality of the oil holes **84** may be provided along the circumferential direction and/or along the axial direction. In this case, the oil holes **84** can discharge oil in various directions toward the stator core **31**, so that the stator core **31** can be more uniformly cooled along its entire circumference. For example, the oil hole **84** may be formed so as to discharge oil in a tangential direction to the outer peripheral surface of the stator core **31** as viewed in the axial direction.

(51) In the present embodiment, there is the radial clearance $\Delta 1$ between the tubular member **8** and the outer peripheral surface of the stator core **31** as described above. Therefore, oil can be discharged from such oil holes **83**, **84** (oil holes **83**, **84** facing the stator core **31** in the radial direction) to the outer peripheral surface of the stator core **31**. The coil **32** in the slots **311** can thus be cooled via the stator core **31**.

(52) Although only one tubular member **8** is provided in the present embodiment, two or more tubular members **8** may be provided.

(53) Next, the flow of oil discharged from the tubular member **8** according to the present embodiment will be described with reference to FIG. 7A.

(54) FIG. 7A is a diagram schematically showing an oil passage structure including the tubular member **8** according to the present embodiment. In FIG. 7A, oil flows are schematically shown by arrows **R1** to **R7**.

(55) The oil passage structure according to the present embodiment includes a first supply oil passage **8a**, a second supply oil passage **8b**, the oil passage **80** (tubular member **8**) described above, and the axial oil passage **86** described above.

(56) The first supply oil passage **8a** communicates with the oil passage **80**. The second supply oil passage **8b** communicates with the axial oil passage **86**. The first supply oil passage **8a** and the second supply oil passage **8b** are connected to each other and are supplied with oil from an oil supply position **P0**. The oil may be supplied via an oil pump **89** and an oil cooler **88**.

(57) The oil supplied to the first supply oil passage **8a** (see arrow **R2**) flows into the oil passage **80** (see arrow **R3**). The oil having flowed into the oil passage **80** is discharged toward the coil end **321** through the oil hole **81** (see arrow **R4**), and is also discharged toward the coil end **322** through the oil hole **82** (see arrow **R7**). The oil is also discharged toward the stator core **31** through the oil holes **83**, **84** (see arrows **R5**, **R6**).

(58) The oil supplied to the second supply oil passage **8b** (see arrow **R1**) is supplied to the axial oil passage **86**, and is used to cool the rotor core **40** and/or the permanent magnets as described above.

(59) In the present embodiment, as described above, the oil passage **80** (tubular member **8**) has the oil holes **82**, **84** on the Y2 side in addition to the oil holes **81**, **83** on the Y1 side. However, the oil passage **80** may have only the oil holes **81**, **83**, or may have only the oil holes **81**, **83**, and **84**. In this case, an oil passage for cooling the coil end **322** may be formed on the second supply oil passage **8b** side. In addition to the oil passage **80**, the axial oil passage **86** may also be connected to the first supply oil passage **8a**. The oil passage **80** may have only the oil hole **83**, or may have only the oil holes **83**, **84**.

(60) Next, the flow of oil discharged from the oil hole **83** and the oil dropping function of the rib portion **28** will be described with reference to FIG. 7B. In the following description, the radial protrusion **34** refers to the upper radial protrusion **34** out of the three radial protrusions **34**.

(61) FIG. 7B is a sectional view in the range of a portion **Q1** shown in FIG. 1, and is a sectional view taken along line E-E (see FIG. 4) passing through the oil hole **831**. In FIG. 7B, oil flows are schematically shown by arrows **R60** to **R65**. In FIG. 7B, oil flows for comparison are also schematically shown by dashed arrows **R71**, **R72**.

(62) As shown in FIG. 7B, oil flowing through the oil passage **80** of the tubular member **8** is discharged into the space between the stator core **31** and the inner peripheral surface **20a** of the case **2** through the oil holes **83** (oil holes **830**, **831**). In the present embodiment, as described above, the oil holes **83** include the oil hole **830** for discharging oil toward the side in the circumferential

direction on which the radial protrusion **34** is not located, and the oil hole **831** for discharging oil toward the side in the circumferential direction on which the radial protrusion **34** is located.

(63) As shown by arrow **R60**, the oil hole **830** discharges oil radially inward in such a manner that the oil hits the outer peripheral surface of the stator core **31**. For example, the direction in which oil is discharged from the oil hole **830** may be adapted to a direction along the outer peripheral surface of the stator core **31** (tangential direction as viewed in the axial direction). The oil discharged from the oil hole **830** thus flows downward due to gravity along the outer peripheral surface of the stator core **31** on the side in the circumferential direction on which the radial protrusion **34** is not located. Accordingly, the stator core **31** (stator core **31** and coil **32** in the slots **311**) can be properly cooled.

(64) On the other hand, as shown by arrow **R61**, the oil hole **831** discharges oil in a direction toward a position radially outward of the radial protrusion **34** as viewed in the axial direction. For example, as shown in FIG. 7B, the direction in which oil is discharged from the oil hole **831** may be a direction toward any position between an outermost radial position **P1** of the radial protrusion **34** and a position **P2** on the inner peripheral surface **20a** of the case **2** along a line **L7**. In this case, the line **L7** may be a straight line passing through the central axis **I0** and through the center of the radial protrusion **34** (e.g., the center of the fastener **90**) as viewed in the axial direction.

(65) In order to achieve such an oil discharge direction, the oil hole **831** may open more upward than the oil hole **830** and may be located above the oil hole **830**, as shown in FIG. 7B.

(66) The position and orientation of the oil hole **831** may be such that the discharged oil stably hits the inner peripheral surface **20a** of the case **2**. In this case, the oil may hit the inner peripheral surface **20a** of the case **2** at a position closer to the rib portion **28** than the position **P2**. An oil flow along the inner peripheral surface **20a** of the case **2** toward the rib portion **28** (see arrow **R62**) can thus be stably formed. In a modification, the position and orientation of the oil hole **831** may be such that the oil stably hits a side surface **281** of the rib portion **28** (side surface **281** on the radial protrusion **34** side).

(67) In the present embodiment, the radial protrusion **34** is located on the side to which oil is discharged from the oil hole **831**, unlike the oil hole **830**. Therefore, if the direction in which oil is discharged from the oil hole **831** is such a direction that the oil directly hits the outer peripheral surface of the stator core **31** like the oil hole **830**, the oil flow will be blocked by the radial protrusion **34** (arrow **R71**). In such a case, the stator core **31** may not be able to be properly cooled on the side in the circumferential direction on which the radial protrusion **34** is located (which will be described later with reference to FIG. 8).

(68) In this regard, in the present embodiment, the radial protrusion **34** is located on the side to which oil is discharged from the oil hole **831**, but the direction in which oil is discharged from the oil hole **831** is the direction toward the position radially outward of the radial protrusion **34** as viewed in the axial direction, as described above. This can reduce the possibility that the oil flow may be blocked by the radial protrusion **34** (see arrow **R71**).

(69) In the present embodiment, as described above, the direction in which oil is discharged from the oil hole **831** is the direction toward the position radially outward of the radial protrusion **34** as viewed in the axial direction. Therefore, the oil flow that will not be blocked by the radial protrusion **34** can be implemented, but some oil flows along the inner peripheral surface **20a** of the case **2**. The oil that flows along the inner peripheral surface **20a** of the case **2** tends to continue to flow along the inner peripheral surface **20a** of the case **2** toward the lower side of the rotating electrical machine **1** due to gravity (see arrow **R72**). Since such an oil flow does not significantly contribute to cooling of the stator core **31**, the stator core **31** may still not be able to be properly cooled on the side in the circumferential direction on which the radial protrusion **34** is located.

(70) In this regard, in the present embodiment, the rib portion **28** is provided as described above. Therefore, the oil that flows along the inner peripheral surface **20a** of the case **2** toward the lower side of the rotating electrical machine **1** due to gravity (see arrow **R72**) can be reduced or eliminated by the oil dropping function of the rib portion **28**.

(71) Specifically, when the oil flowing along the inner peripheral surface **20a** of the case **2** reaches the base on the side surface **281** side (end on the inner peripheral surface **20a** side) of the rib portion **28**, the oil flow is blocked by the rib portion **28**, so that the oil flows radially inward along the side surface **281** of the rib portion **28** (see arrow **R63**). The oil flowing radially inward along the side surface **281** of the rib portion **28** drops downward from the radially inner end of the rib portion **28** due to gravity (see arrow **R64**). The oil having dropped downward hits the outer peripheral surface of the stator core **31**. That is, in the present embodiment, the rib portion **28** overlaps the stator core **31** as viewed in the up-down direction, as described above. Therefore, the oil that drops from the rib portion **28** will be received by the outer peripheral surface of the stator core **31**. As a result, the oil that drops from the rib portion **28** can subsequently flow downward along the outer peripheral surface of the stator core **31** due to gravity (see arrow **R65**). The stator core **31** (stator core **31** and coil **32** in the slots **311**) can be properly cooled by such oil.

(72) As described above, according to the present embodiment, by appropriately setting the direction in which oil is discharged from the oil hole **831** and implementing the oil dropping function of the rib portion **28**, the stator core **31** (stator core **31** and coil **32** in the slots **311**) can be properly cooled even on the side in the circumferential direction on which the radial protrusion **34** is located.

(73) Next, effects of the present embodiment regarding cooling of the stator **3** (stator core **31** and coil **32** in the slots **311**) using the oil holes **83** described above will be described in comparison with comparative examples with reference to FIGS. **8** and **9**.

(74) FIG. **8** is an illustration of an oil passage structure **6A** according to a first comparative example, schematically showing the oil passage structure **6A** and the stator **3** as viewed in the axial direction. In FIG. **8**, arrows **R70**, **R71** schematically indicate the directions in which oil is discharged, and a hatched area **51** schematically indicates the range covered by the discharged oil (coolable area).

(75) In the oil passage structure **6A** according to the first comparative example, a tubular member **600** is provided in a manner similar to that in the present embodiment. However, oil is discharged from the tubular member **600** toward the outer peripheral surface of the stator **3** on both sides in the circumferential direction.

(76) In such a first comparative example, when the tubular member **600** is located at a radial position similar to that of the radial protrusion **34** as shown in FIG. **8**, the oil distribution is likely to be blocked by the radial protrusion **34** (see arrow **R71** in comparison with arrow **R70**). As a result, as shown by the hatched area **51**, the range covered by the oil discharged from the tubular member **600** toward the stator core (coolable area of the stator core) will not become uniform in the circumferential direction, which tends to cause unsatisfactory cooling.

(77) On the other hand, in the present embodiment, as described above, uniform cooling of the stator core **31** and the coil **32** in the slots **311** can be implemented on both sides of the tubular member **8** (or the radial protrusion **34**) in the circumferential direction, based on the oil discharged from each oil hole **83** of the tubular member **8**.

(78) FIG. **9** is an illustration of an oil passage structure **6B** according to a second comparative example, schematically showing the oil passage structure **6B** and the stator **3** as viewed in the axial direction.

(79) The oil passage structure **6B** according to the second comparative example is configured so that the tubular member **600** that is a separate member from the case extends in the Y direction. In the second comparative example, unlike in the first comparative example described above, the tubular member **600** is disposed at a radial position farther away from the stator **3** than the radial protrusion **34**. In this case, the oil distribution will not be blocked by the radial protrusion **34** (see arrow **R81** in comparison with arrow **R80**). Therefore, the disadvantage of the first comparative example can be partially eliminated.

(80) In the second comparative example, however, the overall radial size of the rotating electrical

machine tends to increase because the tubular member **600** is disposed at the radial position away from the stator **3**. That is, the overall radial size of the rotating electrical machine tends to increase by an amount corresponding to the space for mounting the tubular member **600**.

(81) In this regard, in the present embodiment, the tubular member **8** is located at a radial position similar to that of the radial protrusion **34**, as described above. This can prevent an increase in overall radial size of the rotating electrical machine **1** due to the tubular member **8**. As described above, according to the present embodiment, the oil passage **80** that can implement uniform cooling in the circumferential direction can be achieved while reducing the overall radial size and cost of the rotating electrical machine **1** including the case **2**.

(82) Next, a modification of the embodiment described above will be described with reference to FIG. **10**.

(83) FIG. **10** is a schematic sectional view of a main part of a rotating electrical machine **1A** according to the modification, showing a section corresponding to FIG. **4** described above (section taken along line B-B in FIG. **1**).

(84) The rotating electrical machine **1A** according to the modification is different from the rotating electrical machine **1** according to the embodiment described above in that the case **2** is replaced with a case **2A**. The tubular member **8** is provided in the embodiment described above. In the modification, however, a similar function is implemented by an oil passage **80A** formed in the case **2A** instead of the tubular member **8**. Specifically, an oil passage forming portion **24** extending toward the Y1 side in the axial direction is provided in the stator holding portion **22** of the case **2A**. The oil passage forming portion **24** is integral with the stator holding portion **22**. The oil passage **80A** is formed in the oil passage forming portion **24** and the stator holding portion **22**. The oil passage **80A** itself may have the same configuration as the oil passage **80** described above. That is, the oil passage **80A** has the oil holes **830**, **831** etc. described above. In FIG. **10**, the end on the Y1 side of the oil passage **80A** is closed, and oil may be supplied to the oil passage **80A** from the Y2 side. According to this modification, the effects of the embodiment described above can be obtained while reducing the number of parts. When the oil passage forming portion **24** has a tubular shape different from that of the stator holding portion **22**, the oil passage **80A** for cooling the stator core **31** (stator core **31** and coil **32** in the slots **311**) and the coil end **321** on the Y1 side can be formed while minimizing the set range of the stator holding portion **22** in the circumferential direction (and reducing the material cost).

(85) Although the embodiments are described in detail above, the present disclosure is not limited to specific embodiments, and various modifications and changes can be made within the scope of the claims. It is also possible to combine all or part of the constituent elements of the embodiments described above. Of the effects of each embodiment, those related to dependent claims are additional effects distinct from generic concepts (independent claim).

(86) For example, in the embodiment described above, the rib portion **28** is integral with the case **2**. However, the rib portion **28** may be a separate member from the case **2**. In this case, the rib portion **28** may be fixed to the case **2** by welding, a fixing tool, etc.

DESCRIPTION OF THE REFERENCE NUMERALS

(87) **1** . . . rotating electrical machine, **3** . . . stator, **4** . . . rotor, **8** . . . tubular member (oil passage portion), **31** . . . stator core, **32** . . . coil, **34** . . . radial protrusion, **2** . . . case (housing member), **20a** . . . inner peripheral surface, **24** . . . oil passage forming portion (member in tubular shape), **28** . . . rib portion, **80** . . . oil passage, **83** (**831**) . . . oil hole (discharge hole), **I0** . . . central axis (rotation center)

Claims

1. A rotating electrical machine including a rotor, a stator including a stator core and a coil, and including a radial protrusion for fastening located above a rotation center of the rotor, a housing

member that houses the rotor and the stator and to which the radial protrusion is fastened, and an oil passage portion located above the rotation center of the rotor and extending in an axial direction within a range in which the stator core extends in the axial direction, the oil passage portion having a discharge hole that discharges oil in a direction toward a position radially outward of the radial protrusion as viewed in the axial direction, the rotating electrical machine further comprising a rib portion that is provided above the rotation center of the rotor in the housing member, that protrudes radially inward from an inner peripheral surface of the housing member, and that overlaps the stator core as viewed in an up-down direction, wherein the discharge hole is provided within a range in which the rib portion extends in the axial direction, and the oil passage portion, the radial protrusion, and the rib portion are located in this order as viewed in the axial direction.

2. The rotating electrical machine according to claim 1, further comprising a member in a tubular shape that is housed in the housing member, wherein the oil passage portion is located in the member in the tubular shape.

3. The rotating electrical machine according to claim 1, wherein the oil passage portion is located in the housing member.

4. The rotating electrical machine according to claim 1, wherein at least part of the oil passage portion is located at a position radially inward of the radial protrusion as viewed in the axial direction.

5. The rotating electrical machine according to claim 1, wherein the rib portion has a function to drop, toward the stator core, oil flowing along the inner peripheral surface of the housing member out of the oil discharged from the discharge hole in the direction toward the position radially outward of the radial protrusion as viewed in the axial direction.

6. The rotating electrical machine according to claim 2, wherein at least part of the oil passage portion is located at a position radially inward of the radial protrusion as viewed in the axial direction.

7. The rotating electrical machine according to claim 3, wherein at least part of the oil passage portion is located at a position radially inward of the radial protrusion as viewed in the axial direction.

8. The rotating electrical machine according to claim 2, wherein the rib portion has a function to drop, toward the stator core, oil flowing along the inner peripheral surface of the housing member out of the oil discharged from the discharge hole in the direction toward the position radially outward of the radial protrusion as viewed in the axial direction.

9. The rotating electrical machine according to claim 3, wherein the rib portion has a function to drop, toward the stator core, oil flowing along the inner peripheral surface of the housing member out of the oil discharged from the discharge hole in the direction toward the position radially outward of the radial protrusion as viewed in the axial direction.

10. The rotating electrical machine according to claim 4, wherein the rib portion has a function to drop, toward the stator core, oil flowing along the inner peripheral surface of the housing member out of the oil discharged from the discharge hole in the direction toward the position radially outward of the radial protrusion as viewed in the axial direction.

11. The rotating electrical machine according to claim 6, wherein the rib portion has a function to drop, toward the stator core, oil flowing along the inner peripheral surface of the housing member out of the oil discharged from the discharge hole in the direction toward the position radially outward of the radial protrusion as viewed in the axial direction.

12. The rotating electrical machine according to claim 7, wherein the rib portion has a function to drop, toward the stator core, oil flowing along the inner peripheral surface of the housing member out of the oil discharged from the discharge hole in the direction toward the position radially outward of the radial protrusion as viewed in the axial direction.
