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Electric rotating machine

Abstract

An insulating bobbin to be mounted on a stator core has a tooth-endface facing portion that faces an endface portion, in an axial direction, of the tooth portion and a tooth-side-surface facing portion that faces a tooth side surface portion, in a circumferential direction, of the tooth portion; the tooth-side-surface facing portion has a first abutting area that abuts on the tooth side surface portion, a second abutting area that abuts on the tooth side surface portion at a more outer side in a radial direction than the first abutting area abuts thereon, and a middle inner wall surface portion that is situated between the first abutting area and the second abutting area and faces the tooth side surface portion via a space.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2004/0124733	12/2003	Yamamoto	29/596	B29C 70/72
2015/0048711	12/2014	Hino	310/215	H02K 3/522

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
2011103712	12/2010	JP	N/A
2011200060	12/2010	JP	N/A
5061788	12/2011	JP	N/A
5178935	12/2012	JP	N/A
5234899	12/2012	JP	N/A
5412880	12/2013	JP	N/A
5452177	12/2013	JP	N/A
5546373	12/2013	JP	N/A
5709461	12/2014	JP	N/A
5874418	12/2015	JP	N/A
6103559	12/2016	JP	H02K 3/345

OTHER PUBLICATIONS

English translation of JP-2011200060-A (Year: 2011). cited by examiner
English translation of JP-6103559-B1 (Year: 2017). cited by examiner
English translation of JP-2011103712-A (Year: 2011). cited by examiner
English translation of JP-5709461-B2 (Year: 2015). cited by examiner

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Background/Summary

BACKGROUND OF THE INVENTION
Field of the Invention
(1) The present disclosure relates to an electric rotating machine.

Description of the Related Art

(2) As is well known, there exists an electric rotating machine that has a rotatable rotor and a stator disposed in such a way as to be spaced a gap apart from the outer circumference portion of the rotor and in which a stator coil is mounted on a stator core through the intermediary of an insulating bobbin.

(3) To date, as the insulating bobbin in the foregoing electric rotating machine, there has been known an insulating bobbin including a first insulating bobbin and a second insulating bobbin that are fitted onto both respective axial-direction endfaces of the stator core along the axial direction (for example, refer to Patent Document 1).

PRIOR ART REFERENCE

Patent Document

(4) [Patent Document 1] Japanese Patent No. 51789325

SUMMARY OF THE INVENTION

(5) The foregoing conventional electric rotating machine is produced through a process in which after the first insulating bobbin and the second insulating bobbin are mounted on the stator core, the stator coil is wound around the stator core through the intermediary of the first insulating bobbin and the second insulating bobbin; however, there has been a problem that in the process where the stator coil is wound around the stator core, the stator coil applies excessive stress to the first insulating bobbin and the second insulating bobbin and hence cracks may be caused in the first insulating bobbin and the second insulating bobbin.

(6) The present disclosure is to disclose a technology for solving the foregoing problem; the objective thereof is to provide an electric rotating machine that realizes enhancement of the reliability by preventing breakage such as a crack from being caused in the insulating bobbin at a time when the stator coil is wound.

(7) An electric rotating machine disclosed in the present disclosure includes a rotor fixed on a pivotably supported rotor shaft and a stator containing the rotor; the electric rotating machine is characterized in that the stator has a stator core and a stator coil mounted on the stator core through the intermediary of an insulating bobbin, in that the stator core has a ring-shaped back yoke portion and a tooth portion whose front-end portion protrudes from the back yoke portion toward the rotor shaft, in that the insulating bobbin includes a first insulating bobbin and a second insulating bobbin that are fitted onto both respective endfaces of the stator core in an axial direction of the electric rotating machine, in that at least one of the first insulating bobbin and the second insulating bobbin has a coil winding portion around which a conductor wire included in the stator coil is wound and whose cross section is U-shaped, in that the coil winding portion has a tooth-endface facing portion that faces an endface portion, in the axial direction, of the tooth portion and a tooth-side-surface facing portion that faces a tooth side surface portion, in a circumferential direction of the electric rotating machine, of the tooth portion, and in that the tooth-side-surface facing portion has a first abutting area that abuts on the tooth side surface portion, a second abutting area that abuts on the tooth side surface portion at a more outer side in a radial direction of the electric rotating machine than the first abutting area abuts thereon, and a middle inner wall surface portion that is situated between the first abutting area and the second abutting area and faces the tooth side surface portion via a space.

(8) In addition, an electric rotating machine disclosed in the present disclosure includes a rotor fixed on a pivotably supported rotor shaft and a stator containing the rotor; the electric rotating machine is characterized in that the stator has a stator core and a stator coil mounted on the stator core through the intermediary of an insulating bobbin, in that the stator core has a ring-shaped back yoke portion and a tooth portion whose front-end portion protrudes from the back yoke portion toward the rotor shaft, in that at the front-end portion of the tooth portion, the stator core has a shoe portion that extends in the circumferential direction of the electric rotating machine from the tooth side surface portion in the circumferential direction of the electric rotating machine, in that the

insulating bobbin includes a first insulating bobbin and a second insulating bobbin that are fitted onto both respective endfaces of the stator core in an axial direction of the electric rotating machine, in that at least one of the first insulating bobbin and the second insulating bobbin has a coil winding portion around which a conductor wire included in the stator coil is wound and whose cross section is U-shaped, in that the coil winding portion has a tooth-endface facing portion that faces an endface portion, in the axial direction, of the tooth portion, a tooth-side-surface facing portion that faces a tooth side surface portion, and a shoe-side-surface facing inner wall surface portion that faces a shoe side-surface portion, in the circumferential direction, of the shoe portion, in that the shoe-side-surface facing inner wall surface portion has a first abutting area that abuts on the shoe side-surface portion, and in that the tooth-side-surface facing portion has a second abutting area that abuts on the tooth side surface portion and a middle inner wall surface portion that is situated between the first abutting area and the second abutting area and faces the tooth side surface portion via a space.
(9) The present disclosure makes it possible to obtain an electric rotating machine that realizes enhancement of the reliability by preventing breakage such as a crack from being caused in an insulating bobbin at a time when the stator coil is wound.
(10) The foregoing and other object, features, aspects, and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a cross-sectional view of an electric rotating machine according to Embodiment 1, taken along a plane perpendicular to the center axis;
(2) FIG. **2** is a cross-sectional view of the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow along the line X**1**-X**1** in FIG. **1**;
(3) FIG. **3** is a plan view illustrating the principal part of a stator core in the electric rotating machine according to Embodiment 1;
(4) FIG. **4** is a perspective view illustrating the stator core and a first insulating bobbin to be mounted on the stator core in the electric rotating machine according to Embodiment 1;
(5) FIG. **5** is a perspective view of the first insulating bobbin in the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow A in FIG. **4**;
(6) FIG. **6** is a front view of the first insulating bobbin in the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow A in FIG. **4**;
(7) FIG. **7** is a perspective view illustrating the first insulating bobbin and a second insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 1;
(8) FIG. **8** is a side view illustrating the first insulating bobbin and the second insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 1, when viewed from the direction of the arrow C in FIG. **7**;
(9) FIG. **9** is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow along the line X**2**-X**2** in FIG. **8**;
(10) FIG. **10** is an enlarged view of the part Y in FIG. **9**;
(11) FIG. **11** is a cross-sectional view of a first insulating bobbin mounted on a stator core in an electric rotating machine according to Comparative Example 1;
(12) FIG. **12** is a cross-sectional view of a first insulating bobbin mounted on a stator core in an electric rotating machine according to Comparative Example 2;
(13) FIG. **13** is a cross-sectional view of the first insulating bobbin mounted on the stator core in

the electric rotating machine according to Comparative Example 1, when viewed in the direction of the arrow along the line X**4**-X**4** in FIG. **11**;
(14) FIG. **14**A is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Comparative Example 2, when viewed in the direction of the arrow along the line X**5**-X**5** in FIG. **12**;
(15) FIG. **14**B is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Comparative Example 2, when viewed in the direction of the arrow along the line X**5**-X**5** in FIG. **12**;
(16) FIG. **15**A is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow along the line X**3**-X**3** in FIG. **9**;
(17) FIG. **15**B is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow along the line X**3**-X**3** in FIG. **9**;
(18) FIG. **16** is a cross-sectional view of a first insulating bobbin mounted on a stator core in an electric rotating machine according to Embodiment 2;
(19) FIG. **17** is a cross-sectional view of a first insulating bobbin mounted on a stator core in an electric rotating machine according to Embodiment 3;
(20) FIG. **18** is a cross-sectional view of a first insulating bobbin mounted on a stator core in an electric rotating machine according to Embodiment 4;
(21) FIG. **19** is a perspective view of a first insulating bobbin in an electric rotating machine according to Embodiment 5;
(22) FIG. **20** is a top view of a stator core of an electric rotating machine according to Embodiment 6;
(23) FIG. **21** is a perspective view of a first insulating bobbin in the electric rotating machine according to Embodiment 6;
(24) FIG. **22** is a plan view of the first insulating bobbin in the electric rotating machine according to Embodiment 6;
(25) FIG. **23** is a side view illustrating the first insulating bobbin and a second insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 6;
(26) FIG. **24** is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 6, when viewed in the direction of the arrow along the line X**6**-X**6** in FIG. **23**;
(27) FIG. **25** is a perspective view of a first insulating bobbin in an electric rotating machine according to Embodiment 7;
(28) FIG. **26** is a cross-sectional view of the first insulating bobbin mounted on a stator core in the electric rotating machine according to Embodiment 7; and
(29) FIG. **27** is a perspective view of a first insulating bobbin in an electric rotating machine according to Embodiment 8.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

(30) Hereinafter, two or more embodiments of the present disclosure and two of more comparative examples for the present disclosure will be explained; the same reference characters denote the same or similar portions. In addition, in the following explanations, the terms “radial direction”, “circumferential direction”, “axial direction”, “outer radial side”, and “inner radial side”, or the others similar to those are defined with reference to an electric rotating machine at a time when the members to be explained are mounted in the electric rotating machine.

Embodiment 1

(31) An electric rotating machine according to Embodiment 1 will be explained with reference to the drawings. FIG. **1** is a cross-sectional view of an electric rotating machine according to Embodiment 1, taken along a plane perpendicular to the center axis; FIG. **2** is a cross-sectional

view of the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow along the line X**1**-X**1** in FIG. **1**. In each of FIGS. **1** and **2**, an electric rotating machine **1** has a stator **2** and a rotor **3** inserted into the inner space of the stator **2**.

(32) The stator **2** includes a cylindrical tubular frame **4** having respective end wall portions **401** at the both axial-direction end portions, two or more identically shaped stator cores **5** that are fixed to the inner wall surface of the frame **4**, and two or more stator coils **6** wound around respective tooth portions **11** of the stator cores **5** through the intermediary of after-mentioned first insulating bobbin and second insulating bobbin. Each of the stator core **5** is formed of two or more magnetic steel plates stacked in the axial direction of the electric rotating machine **1**.

(33) The identically shaped stator cores **5** are aligned in a ring-shaped manner in such a way as to abut on one another at respective adjacent back-yoke side surface portions **10***c* of back yoke portions **10** in the neighboring stator cores **5** and are fixed to the inner circumference portion of the frame **4**. The two or more stator coils **6** wound around the respective tooth portions **11** of the stator cores are arranged in such a way as to be spaced evenly apart from each other in the circumferential direction of the electric rotating machine **1**. The respective stator coils **6** are connected with each other, for example, at one of or both of the axial-direction end portions of the stator **2** so as to form a concentrated-winding three-phase stator coil.

(34) The rotor **3** has two or more magnetic-field poles (unillustrated) including permanent magnets fixed to the rotor core and is fixed to a rotor shaft **7**. The rotor shaft **7** is pivotably supported by a pair of bearings (unillustrated) fixed to a pair of side wall portions **401** of the frame **4**.

(35) In the case where the electric rotating machine **1** operates as a motor, torque is produced in the rotor **3** based on the interaction between rotating magnetic flux generated by applying an electric current to the stator coil **6** and magnetic flux generated by the magnetic-field pole, so that the rotor **3** rotates along with the rotor shaft **7**. In the case where the electric rotating machine **1** operates as a power generator, the rotor **3** rotates by being driven, for example, by an internal combustion engine, and magnetic flux generated by the magnetic-field pole is interlinked with the stator coil **6**; thus, a voltage is induced in the stator coil **6** and hence electric power based on the voltage is outputted.

(36) FIG. **3** is a plan view illustrating the principal part of the stator core in the electric rotating machine according to Embodiment 1. In FIG. **3**, the stator core **5** has the back yoke portion **10** and the tooth portion **11**. The back yoke portion **10** has a back-yoke outer circumferential portion **10***a* formed in the shape of an arc, a back-yoke inner circumference portion **10***b*, and a pair of back-yoke side surface portions **10***c* that are each connected with the back-yoke outer circumferential portion **10***a* and the back-yoke inner circumference portion **10***b*. A back-yoke cutout portion **12** is provided in the back-yoke outer circumferential portion **10***a*.

(37) The tooth portion **11** extends from the back-yoke inner circumference portion **10***b* of the back yoke portion **10** toward the center axis line of the electric rotating machine **1** and has a pair of tooth side surface portions **11***a* and **11***b* and a tooth front-end portion **11***c* that faces the circumference surface portion of the rotor **3** through an air gap. The tooth portion **11** is formed in such a way that the width W**1** thereof is 1 [mm]. It may be allowed that a shoe portion is provided in the tooth front-end portion **11***c*.

(38) As described later, the stator coil **6** is wound around the tooth portion **11** of the stator core **5** through the intermediary of the first insulating bobbin disposed on one stacking-direction core endface portion of the two or more electromagnetic steel plates, which are included in the stator core **5**, and the second insulating bobbin disposed on the other stacking-direction core endface portion of the electromagnetic steel plates.

(39) FIG. **4** is a perspective view illustrating the stator core and the first insulating bobbin to be mounted on the stator core in the electric rotating machine according to Embodiment 1; FIG. **5** is a perspective view of the first insulating bobbin in the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow A in FIG. **4**; FIG. **6** is a front view of the

first insulating bobbin in the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow A in FIG. **4**.

(40) In FIG. **4**, a first insulating bobbin **9***a* is mounted on the tooth portion **11** around which a copper wire, as a conductor wire, in the stator core **5** is wound. More specifically, an insulating-bobbin opening portion **17** of the first insulating bobbin **9***a* is fitted onto the tooth portion **11** in the direction of the arrow B from the side of one stacking-direction core endface portion **51** of the electromagnetic steel plates **5***a* in the stator core **5**, so that the first insulating bobbin **9***a* is mounted on the tooth portion **11**.

(41) Although not illustrated in FIG. **4**, an after-mentioned second insulating bobbin **9***b* having a configuration the same as that of the first insulating bobbin **9***a* is mounted on the tooth portion **11** around which a copper wire in the stator core **5** is wound. More specifically, an insulating-bobbin opening portion of the second insulating bobbin **9***b* is fitted onto the tooth portion **11** in the direction opposite to the arrow B from the side of the other stacking-direction core endface portion **52** of the electromagnetic steel plates **5***a* in the stator core **5**, so that the second insulating bobbin **9***b* is mounted on the tooth portion **11**. In such a way as described above, the first insulating bobbin **9***a* is mounted on the tooth portion **11** of the stator core **5** in such a way as to cover the one core endface portion **51**; the second insulating bobbin **9***b* is mounted on the tooth portion **11** of the stator core **5** in such a way as to cover the other core endface portion **52**.

(42) In each of FIGS. **4**, **5**, and **6**, the first insulating bobbin **9***a* has a back-yoke-endface facing portion **13** that faces one stacking-direction endface portion of the back yoke portion **10** of the stator core **5**, a tooth-endface facing portion **141** that is integrally coupled with the back-yoke-endface facing portion **13** and faces one stacking-direction endface of the tooth portion **11**, a tooth-side-surface facing portion **142***a* that faces the tooth side surface portion **11***a*, and a tooth-side-surface facing portion **142***b* that faces tooth side surface portion **11***b*. The tooth-endface facing portion **141** and the tooth-side-face facing portions **142***a* and **142***b* form a coil winding portion **14** around which a copper wire included in the stator coil **6** is wound and whose cross section is U-shaped.

(43) In addition, the first insulating bobbin **9***a* has a first flange portion **15** that is formed on one end portion of the outer surface portion of the coil winding portion **14** and prevents the stator coil **6** from running off the edge of the coil winding portion **14** and a second flange portion **16** that is formed on the other end portion of the outer surface portion of the coil winding portion **14** and prevents the stator coil **6** from running off the edge of the coil winding portion **14**.

(44) As illustrated in FIG. **4**, at the anti-stator-core **5** side of the first insulating bobbin **9***a*, the first flange portion **15**, the outer surface portion of the coil winding portion **14**, the second flange portion **16**, and the surface portion, at the anti-back-yoke-portion **10** side, of the back-yoke-endface facing portion **13** are exposed. Fillet surfaces **14***a* and **14***b* are formed in the outer surface portion of the coil winding portion **14**.

(45) In addition, as illustrated in FIG. **6**, at the inside of the first insulating bobbin **9***a*, which is the stator core **5** side, a tooth-endface facing surface portion **141***a* that faces the tooth portion **11** of the stator core **5** and has an area E**1** and a back-yoke-endface facing surface portion **13***a* that faces the back yoke portion **10** of the stator core **5** are exposed. The back-yoke-endface facing portion **13** has a convex portion **131** that protrudes from the back-yoke-endface facing surface portion **13***a* facing the back yoke portion **10** of the stator core **5** toward the back yoke portion **10**.

(46) The back-yoke-endface facing portion **13**, the coil winding portion **14**, the first flange portion **15**, and the second flange portion **16** are formed by integrally molding an insulator such as a synthetic resin. When the first insulating bobbin **9***a* is mounted on the tooth portion **11**, the first flange portion **15** is situated at the radial-direction inner side of the electric rotating machine **1**, and the second flange portion **16** is situated at the radial-direction outer side of the electric rotating machine **1**.

(47) Back-yoke-inner-circumference facing portions **162***a* and **162***b* that face the back-yoke inner

circumference portion **10***b* of the stator core **5** are formed in the second flange portion **16**. The thickness dimension of each of the back-yoke-inner-circumference facing portions **162***a* and **162***b* is set to be smaller than the thickness dimension of the second flange portion **16**. Each of the back-yoke-inner-circumference facing portions **162***a* and **162***b* is formed in such a way as to vertically protrude from the back-yoke-endface facing surface portion **13***a* of the back-yoke-endface facing portion **13**.

(48) When the first insulating bobbin **9***a* is mounted on the tooth portion **11** of the stator core **5** from the one core endface portion **51** side of the stator core **5**, a side-surface portion **131***a* of the convex portion **131** in the first insulating bobbin **9***a* is pressed against a side-surface portion **12***a* of the back-yoke cutout portion **12** in the stator core **5**, and the back-yoke-inner-circumference facing portions **162***a* and **162***b* of the first insulating bobbin **9***a* are pressed against the back-yoke inner circumference portion **10***b* of the stator core **5**.

(49) The foregoing area E**1**, inside the first insulating bobbin **9***a*, that faces the tooth portion **11** of the stator core **5** includes a tooth-endface facing surface portion **141***a* that faces the one core endface portion **51** of the tooth portion **11**, a middle inner wall surface portion **142***a***1** facing the tooth side surface portion **11***a*, and a middle inner wall surface portion **142***b***1** facing the tooth side surface portion **11***b.*

(50) An inner-wall-surface convex portion **15***a***1**, as a first abutting area, and an inner-wall-surface convex portion **16***a***1**, as a second abutting area, are formed adjacent to the respective end edges of the middle inner wall surface portion **142***a***1**. Moreover, an inner-wall-surface convex portion **15***b***1**, as a first abutting area, and an inner-wall-surface convex portion **16***b***1**, as a second abutting area, are formed adjacent to the respective end edges of the middle inner wall surface portion **142***b***1**. A distance W**2***a* [mm] between the inner-wall-surface convex portions **15***a***1** and **15***b***1** that face each other and a distance W**2***b* [mm] between the inner-wall-surface convex portions **16***a***1** and **16***b***1** that face each other are set to one and the same dimension.

(51) The foregoing middle inner wall surface portion **142***a***1** is formed in an area E**2***a* between the inner-wall-surface convex portion **15***a***1** and the inner-wall-surface convex portion **16***a***1**; the foregoing middle inner wall surface portion **142***b***1** is formed in an area E**2***b* between the inner-wall-surface convex portion **15***b***1** and the inner-wall-surface convex portion **16***b***1**. These middle inner wall surface portions **142***a***1** and **142***b***1** face each other across a distance W**2***c* [mm].

(52) The distance W**2***a* [mm] between the inner-wall-surface convex portions **15***a***1** and **15***b***1** that face each other, the distance W**2***b* [mm] between the inner-wall-surface convex portions **16***a***1** and **16***b***1** that face each other, the distance W**2***c* [mm] between the middle inner wall surface portions **142***a***1** and **142***b***1** that face each other, the width W**1** [mm] of the tooth portion **11** of the stator core **5** have the following relationships among them. W**2***a*=W**2***b* W**2***c*>(W**2***a*, W**2***b*) W**1**≤(W**2***a*, W**2***b*)

(53) In addition, the second insulating bobbin **9***b* has a configuration the same as that of the first insulating bobbin **9***a*; thus, the explanation therefor will be omitted.

(54) FIG. **7** is a perspective view illustrating the first insulating bobbin and the second insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 1; FIG. **8** is a side view illustrating the first insulating bobbin and the second insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 1, when viewed from the direction of the arrow C in FIG. **7**. Each of FIGS. **7** and **8** illustrates a state where the first insulating bobbin **9***a* is mounted on the stator core **5** along the direction of the arrow B in FIG. **4** and the second insulating bobbin **9***b* is mounted on the stator core **5** in the direction opposite to the arrow B. FIG. **9** is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow along the line X**2**-X**2** in FIG. **8**; FIG. **10** is an enlarged view of the part Y in FIG. **9**.

(55) In FIGS. **7**, **8**, **9**, and **10**, the first insulating bobbin **9***a* and the second insulating bobbin **9***b* are mounted onto the stator core **5** from the respective core endface portions **51** and **52**, respectively, of the stator core **5**. In this situation, the back-yoke-inner-circumference facing portions **162***a* and

162b in each of the first insulating bobbin **9**a and the second insulating bobbin **9**b abut on the back-yoke inner circumference portion **10**b, and the side-surface portion **131**a of the convex portion **131** provided in the back-yoke-endface facing portion **13** abuts on the side-surface portion **12**a of the back-yoke cutout portion **12** provided in the back-yoke outer circumferential portion **10**a.
(56) The side-surface portion **131**a of the convex portion **131** has a slant surface; because when the first insulating bobbin **9**a and the second insulating bobbin **9**b are mounted on the stator core **5**, the side-surface portion **131**a of the convex portion **131** is pressed against the side-surface portion **12**a of the back-yoke cutout portion **12** in the back yoke portion **10**, the first insulating bobbin **9**a and the second insulating bobbin **9**b are securely fixed to the stator core **5**.
(57) In addition, as illustrated in FIG. **8**, the tooth side surface portions **11**a and **11**b and the back-yoke inner circumference portion **10**b are exposed in the range indicated by the arrow D in the stacking direction of the stator core **5**; however, it may be allowed that in order to secure the electrical insulation between the stator core **5** and the stator coil **6**, the first insulating bobbin **9**a and the second insulating bobbin **9**b are extended in the stacking direction of the tooth portion **11** in comparison with the case illustrated in FIG. **7** so that the tooth side surface portions **11**a and **11**b are completely covered. Alternatively, it may be allowed that an insulation sheet is pasted on the exposed part of the tooth side surface portions **11**a and **11**b and the back-yoke inner circumference portion **10**b.
(58) As described above, in the area E**1** in the inside of each of the first insulating bobbin **9**a and the second insulating bobbin **9**b in the electric rotating machine according to Embodiment 1, the inner-wall-surface convex portion **15**a**1** and the inner-wall-surface convex portion **16**a**1** are provided adjacent to the respective sides of the middle inner wall surface portion **142**a**1**, and the inner-wall-surface convex portion **15**b**1** and the inner-wall-surface convex portion **16**b**1** are provided adjacent to the respective sides of the middle inner wall surface portion **142**b**1**; each of the inner-wall-surface convex portions **15**a**1**, **16**a**1**, **15**b**1**, and **16**b**1** is formed in the shape of a protruding body extending in the stacking direction of the tooth portion **11**.
(59) The middle inner wall surface portion **142**a**1** inserted between the inner-wall-surface convex portions **15**a**1** and **16**a**1** is formed as a flat surface portion recessed from the respective top surface portions of the inner-wall-surface convex portions **15**a**1** and **16**a**1**. Similarly, the middle inner wall surface portion **142**b**1** inserted between the inner-wall-surface convex portions **15**b**1** and **16**b**1** is formed as a flat surface portion recessed from the respective top surface portions of the inner-wall-surface convex portions **15**b**1** and **16**b**1**.
(60) Accordingly, when the first insulating bobbin **9**a and the second insulating bobbin **9**b are mounted on the stator core, the tooth side surface portion **11**a abuts on the inner-wall-surface convex portions **15**a**1** and the **16**a**1**, and the tooth side surface portion **11**b abuts on the inner-wall-surface convex portions **15**b**1** and the **16**b**1**; in the area E**2**a indicated in FIG. **6**, a space portion is formed between the middle inner wall surface portion **142**a**1** and the tooth side surface portion **11**a, and in the area E**2**b, a space portion is formed between the middle inner wall surface portion **142**b**1** and the tooth side surface portion **11**b.
(61) Next, in order to make the features of the electric rotating machine according to Embodiment 1 clearer, respective electric rotating machines according to comparative examples will be explained.
Comparative Example 1
(62) FIG. **11** is a cross-sectional view of the first insulating bobbin mounted on a stator core in an electric rotating machine according to Comparative Example 1; the constituent elements the same as or similar to those of the electric rotating machine according to Embodiment 1 of the present disclosure are designated by reference characters the same as those therein. In FIG. **11**, the first insulating bobbin **9**a according to Comparative Example 1 does not have the foregoing inner-wall-surface convex portions and the foregoing middle inner wall surface portions provided in the first insulating bobbin **9**a in the electric rotating machine according to Embodiment 1 of the present

disclosure.

(63) The other configurations are the same as those in the electric rotating machine according to Embodiment 1. The following explanation for Comparative Example 1 will be made by use of the first insulating bobbin **9***a*; however, the same explanation can be applied also to the second insulating bobbin (unillustrated).

(64) In general, because each of materials or components to be produced definitely has dimensional tolerance, it is not made possible to make the width W**1** of the tooth portion **11** of the stator core **5** completely coincide with the distance W**2** between the tooth-side-surface facing portions **142***a* and **142***b*, of the first insulating bobbin **9***a*, that face the tooth side surface portions **11***a* and **11***b*, respectively (the equation [W**1**=W**2**] cannot be established); therefore, neither the gap between the tooth side surface portion **11***a* and the tooth-side-surface facing portion **142***a* nor the gap between the tooth side surface portion **11***b* and the tooth-side-surface facing portion **142***b* can be made "0".

(65) In the case where W**1**>W**2**, the first insulating bobbin **9***a* is mounted on the tooth portion **11** through press-fitting; in the case where W**1**<W**2**, the first insulating bobbin **9***a* is mounted on the tooth portion **11** with a gap. FIG. **11** illustrates the case where in the first insulating bobbin **9***a* according to Comparative Example 1, the inner wall surface portion of each of the tooth-side-surface facing portions **142***a* and **142***b* has neither a depression nor a protrusion and where the equation [W**1**>W**2**] is established.

(66) FIG. **13** is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Comparative Example 1, when viewed in the direction of the arrow along the line X**4**-X**4** in FIG. **11**. In FIG. **13**, it is assumed that the direction indicated by the arrow F**1** is the front end side of each of the tooth-side-surface facing portions **142***a* and **142***b* and that the direction indicated by the arrow F**2** is the root side of each of the tooth-side-surface facing portions **142***a* and **142***b*; when the first insulating bobbin **9***a* is mounted on the tooth portion **11** through press-fitting, the middle inner wall surface portions **142***a***1** and **142***b***1** of the tooth-side-surface facing portions **142***a* and **142***b*, respectively, make contact with the respective corner portions of the tooth portion **11** at respective corner portions G where the respective root sides, indicated by the arrow F**2**, of the tooth-side-surface facing portions **142***a* and **142***b* and the tooth-endface facing portion **141** intersect each other.

(67) Accordingly, when beginning from the respective corner portions G, the first insulating bobbin **9***a* is bent and deformed in the direction in which the front end sides, indicated by the arrow F**1**, of the tooth-side-surface facing portions **142***a* and **142***b* depart from the tooth side surface portions **11***a* and **11***b*, respectively; thus, at the respective corner portions G, large tensile stresses are applied to the root sides, indicated by the arrow F**2**, of the tooth-side-surface facing portions **142***a* and **142***b*.

(68) Moreover, because when the coil is wound, a circumferential-direction load is applied to the respective outer side surfaces of the fillet surfaces **14***a* and **14***b* of the coil winding portion **14** and the tooth-side-surface facing portions **142***a* and **142***b*, the amount of deformation of the first insulating bobbin **9***a* increases and hence the tensile stress on the first insulating bobbin **9***a* increases. Accordingly, because in the coil winding portion **14**, especially in the portion around the center thereof, there exists neither the first flange portion **15** nor the second flange portion **16** and hence the rigidity thereof is low, cracks may occur in the respective root portions, indicated by the arrow F**2**, of the tooth-side-surface facing portions **142***a* and **142***b*.

Comparative Example 2

(69) FIG. **12** is a cross-sectional view of a first insulating bobbin mounted on a stator core in an electric rotating machine according to Comparative Example 2. In the first insulating bobbin **9***a* according to Comparative Example 2, each of the middle inner wall surface portions **142***a***1** and **142***b***1** of the tooth-side-surface facing portions **142***a* and **142***b*, respectively, has neither a depression nor a protrusion and the equation [W**1**<W**2**] is established. The other configurations are the same as those in Comparative Example 1.

(70) Each of FIGS. **14**A and **14**B is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Comparative Example 2, when viewed in the direction of the arrow along the line X**5**-X**5** in FIG. **12**. In the case of Comparative Example 2, the first insulating bobbin **9***a* is mounted on the tooth portion **11** in such a way that there exists gaps between the tooth side surface portions **11***a* and **11***b* and the middle inner wall surface portions **142***a***1** and **142***b***1** of the tooth-side-surface facing portions **142***a* and **142***b*, respectively. Accordingly, as illustrated in FIG. **14**A, when the first insulating bobbin **9***a* is mounted on the tooth portion **11**, the root sides, indicated by the arrow F**2**, of the tooth-side-surface facing portions **142***a* and **142***b* do not make contact with the tooth side surface portions **11***a* and **11***b*, respectively; thus, no tensile stress is applied to each of the corner portions G.
(71) However, because there exists a circumferential-direction clearance H between the tooth side surface portions **11***a* and **11***b* and the middle inner wall surface portions **142***a***1** and **142***b***1** of the tooth-side-surface facing portions **142***a* and **142***b*, respectively, and neither the middle inner wall surface portion **142***al* has the foregoing inner-wall-surface convex portion **15***a***1** and **16***a***1** nor the middle inner wall surface portion **142***b***1** has the foregoing inner-wall-surface convex portion **15***b***1** and **16***b***1**, a circumferential-direction load is applied to the respective outer side surfaces of the fillet surfaces **14***a* and **14***b* of the first insulating bobbin **9***a* and the tooth-side-surface facing portions **142***a* and **142***b* at a time when the coil is wound.
(72) Accordingly, for example, as illustrated in FIG. **14**B, the coil winding portion **14** collectively shifts in the circumferential direction indicated by the arrow J and hence the inner wall surface of the coil winding portion **14** makes contact with the tooth side surface portion **11***b* at the corner portion G where the root side of the tooth-side-surface facing portion **142***b* and the tooth-endface facing portion **141** intersect each other; as a result, begins from the root portion of the tooth-side-surface facing portion **142***b*, the front-end portion of the tooth-side-surface facing portion **142***b* is bent and deformed in the direction departing from the tooth side surface portion **11***b*.
(73) Therefore, a large tensile stress is applied to the corner portion G of the coil winding portion **14**, and hence a crack may occur in the root portion of the tooth-side-surface facing portion **142***b*, because in the coil winding portion **14**, especially in the portion around the center thereof, there exists neither the first flange portion **15** nor the second flange portion **16** and hence the rigidity thereof is low.
(74) Heretofore, the respective electric rotating machines according to Comparative Examples 1 and 2 have been explained; the electric rotating machine according to Embodiment 1 can solve the foregoing problems in the respective electric rotating machines according to Comparative Examples 1 and 2. Each of FIGS. **15**A and **15**B is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 1, when viewed in the direction of the arrow along the line X**3**-X**3** in FIG. **9**.
(75) In contrast to the respective electric rotating machines according to Comparative Examples 1 and 2, in the electric rotating machine according to Embodiment 1, as illustrated in FIGS. **9**, **10**, **15**A, and **15**B, space portions, as clearances, are formed between the middle inner wall surface portions **142***a***1** and **142***b***1** of the first and second insulating bobbins **9***a* and **9***b* and the tooth side surface portions **11***a* and **11***b*, respectively; therefore, even when the stator coil **6** is wound around the tooth portion **11** through the intermediary of the first insulating bobbin **9***a* and the second insulating bobbin **9***b*, tensile stress is applied to neither the first insulating bobbin **9***a* nor the second insulating bobbin **9***b*.
(76) Moreover, even in the case where when the stator coil **6** is wound, a circumferential direction load is applied to each of the tooth-side-surface facing portions **142***a* and **142***b* of the first insulating bobbin **9***a* and the second insulating bobbin **9***b* and hence the coil winding portion **14** collectively shifts in the circumferential direction with respect to the tooth portion **11**, the inner-wall-surface convex portions **15***a***1** and **16***a***1** abut on the tooth side surface portion **11***a* and the inner-wall-surface convex portions **15***b***1** and **16***b***1** abut on the tooth side surface portion **11***b*; thus,

because the respective circumferential-direction positions of the first insulating bobbin **9***a* and the second insulating bobbin **9***b* are restricted, the space between the middle inner wall surface portion **142***a***1** and the tooth side surface portion **11***a* and the space between the middle inner wall surface portion **142***b***1** and the tooth side surface portion **11***b* are securely maintained.
(77) In general, a resin material is characterized in that the compressive strength thereof is larger than the tensile strength thereof; thus, when the insulating bobbin is configured in such a way that not tensile stress but compression stress is produced in the resin material, damage to the resin material, such as a crack, is not liable to occur. In the electric rotating machine according to Embodiment 1, when the first insulating bobbin **9***a* and the second insulating bobbin **9***b* formed of, for example, a resin material, are mounted on the stator core **5** and then the stator coil **6** is wound therearound, as described above, there is securely maintained respective spaces between the tooth side surface portions and the middle inner wall surface portions **142***a***1** and **142***b***1**, located around the center of the coil winding portion **14** between the first flange portion **15** and the second flange portion **16**, where the rigidity is low.
(78) Accordingly, even in the case where when the stator coil **6** is wound, a circumferential-direction load is applied to each of the fillet surfaces **14***a* and **14***b* and the tooth-side-surface facing portions **142***a* and **142***b* of the tooth-endface facing portion **141**, circumferential-direction displacement of the coil winding portion **14** is strongly restricted by the inner-wall-surface convex portions **15***a***1** and **15***b***1** arranged at the positions corresponding to the first flange portion **15** having a high rigidity and the inner-wall-surface convex portions **16***a***1** and **16***b***1** arranged at the positions corresponding to the second flange portion **16** having a high rigidity.
(79) Therefore, because begins from the corner portions G, the front end sides of the tooth-side-surface facing portions **142***a* and **142***b* are bent in the direction not departing from but approaching the tooth side surface portions **11***a* and **11***b*, respectively, compression stress is applied to each of the corner portions G; thus, it is made possible to prevent a crack from occurring in the corner portion G of the coil winding portion **14** and hence the reliability of the insulation between the stator coil **6** and the stator core **5** can be raised.
(80) In addition, in the electric rotating machine according to Embodiment 1, there has been explained the case where both the first insulating bobbin **9***a* and the second insulating bobbin **9***b* are configured in one and the same manner in order to prevent a crack from occurring; however, for example, in the case where there exists a difference between the probability of a crack occurring in the first insulating bobbin **9***a* and the probability of a crack occurring in the second insulating bobbin **9***b*, such as the case where the rigidities of the first insulating bobbin **9***a* and the second insulating bobbin **9***b* are different from each other or the stresses applied to the first insulating bobbin **9***a* and the second insulating bobbin **9***b* by the stator coil **6** are different from each other, or the case where one of the first insulating bobbin **9***a* and the second insulating bobbin **9***b* is configured in a manner different from that in which the other one thereof is configured so that the probability of crack occurrence is reduced, it may be allowed that the foregoing configuration is appropriately adopted only in the insulating bobbin having a relatively high probability of crack occurrence.
Embodiment 2
(81) FIG. **16** is a cross-sectional view of a first insulating bobbin mounted on a stator core in an electric rotating machine according to according to Embodiment 2; the constituent elements the same as or similar to those of the electric rotating machine according to Embodiment 1 are designated by reference characters the same as those therein. In the explanation for the electric rotating machine according to Embodiment 2, only the portions that are different from those in the electric rotating machine according to Embodiment 1 will be described. As illustrated in FIG. **16**, shoe portions **111** extending in the circumferential direction are provided at the radial-direction front end of the tooth portion **11**.
(82) In the inner surface portion of the first flange portion **15**, the first insulating bobbin **9***a* has

shoe-side-surface facing inner wall surface portions **151***a* and **151***b* facing, via a gap, shoe side-surface portions **111***a* and **111***b*, respectively, in the shoe portions **111**. In addition, the inner-wall-surface convex portions **15***a***1** and **16***a***1** are provided adjacent to the middle inner wall surface portion **142***a***1**; the inner-wall-surface convex portions **15***b***1** and **16***b***1** are provided adjacent to the middle inner wall surface portion **142***b***1**.

(83) The respective side-surface portions of the shoe portions **111** in the tooth portion **11** are apart from the shoe-side-surface facing inner wall surface portions **151***a* and **151***b* via a gap in the circumferential direction. When the first insulating bobbin **9***a* and the second insulating bobbin **9***b* are mounted on the stator core **5** and when the stator coil **6** is wound around the tooth portion **11** through the intermediary of the first insulating bobbin **9***a* and the second insulating bobbin **9***b*, the inner-wall-surface convex portions **15***a***1** and **16***a***1** abut on the tooth side surface portion **11***a* and the inner-wall-surface convex portions **15***b***1** and **16***b***1** abut on the tooth side surface portion **11***b***1**; thus, there is kept the state where the respective side-surface portions of the shoe portions **111** in the tooth portion **11** are apart from the shoe-side-surface facing inner wall surface portions **151***a* and **151***b*. The configuration of the second insulating bobbin **9***b* (unillustrated) is the same as that of the first insulating bobbin **9***a*. The other configurations are the same as those of the electric rotating machine according to Embodiment 1.

(84) The electric rotating machine according to Embodiment 2 has the shoe portions **111** in the tooth portion **11**; because circumferential-direction spaces between the middle inner wall surface portions **142***a***1** and **142***b***1** and the tooth side surface portions **11***a* and **11***b*, respectively, are securely maintained, an effect the same as that of Embodiment 1 can be obtained.

Embodiment 3

(85) FIG. **17** is a cross-sectional view of a first insulating bobbin mounted on a stator core in an electric rotating machine according to according to Embodiment 3; the constituent elements the same as or similar to those of the electric rotating machine according to Embodiment 2 are designated by reference characters the same as those therein. In the explanation for the electric rotating machine according to Embodiment 3, only the portions that are different from those in the electric rotating machine according to Embodiment 2 will be described. As illustrated in FIG. **17**, in the electric rotating machine according to Embodiment 3, the shoe portions **111** extending in the circumferential direction are provided at the radial-direction front end of the tooth portion **11**, as is the case with the electric rotating machine according to Embodiment 2.

(86) In the inner surface portion of the first flange portion **15**, the first insulating bobbin **9***a* has shoe-side-surface facing inner wall surface portions **151***a* and **151***b* facing shoe side-surface portions **111***a* and **111***b*, respectively, in the shoe portions **111**. Moreover, in the inner surface portions corresponding to the back-yoke-inner-circumference facing portions **162***a* and **162***b*, the inner-wall-surface convex portions **16***a***1** and **16***b***1** are provided adjacent to the middle inner wall surface portions **142***a***1** and **142***b***1**, respectively. The configuration of the second insulating bobbin **9***b* (unillustrated) is the same as that of the first insulating bobbin **9***a*. The other configurations are the same as those of the electric rotating machine according to Embodiment 2.

(87) The electric rotating machine according to Embodiment 3 is configured in such away that the shoe-side-surface facing inner wall surface portions **151***a* and **151***b* abut on the shoe side-surface portions **111***a* and **111***b*, respectively, and the inner-wall-surface convex portions **16***a***1** and **16***b***1** abut on the tooth side surface portions **11***a* and **11***b*, respectively, so that there are maintained spaces between the middle inner wall surface portions **142***a***1** and **142***b***1** in an area E**3** and the tooth side surface portions **11***a* and **11***b*, respectively. Because this configuration makes it possible to securely maintain the spaces between the middle inner wall surface portions **142***a***1** and **142***b***1** and the tooth side surface portions **11***a* and **11***b*, respectively, even when the shoe portions **111** are provided in the tooth portion **11**, an effect the same as that of Embodiment 1 can be obtained.

Embodiment 4

(88) FIG. **18** is a cross-sectional view of a first insulating bobbin mounted on a stator core in an

electric rotating machine according to according to Embodiment 4; the constituent elements the same as or similar to those of the electric rotating machine according to Embodiment 1 are designated by reference characters the same as those therein. In the explanation for the electric rotating machine according to Embodiment 4, only the portions that are different from those in the electric rotating machine according to Embodiment 1 will be described. In the electric rotating machine according to Embodiment 4, no inner-wall-surface convex portion is provided in each of the inner wall surfaces of the tooth-side-surface facing portions **142***a* and **142***b* of the first insulating bobbin **9***a*; tooth-side-surface convex portions **11***a***1** and **11***b***1** are provided at the inner radial sides of the tooth side surface portions **11***a* and **11***b*, respectively; tooth-side-surface convex portions **11***a***2** and **11***b***2** are provided at the outer radial sides of the tooth side surface portions **11***a* and **11***b*, respectively. The configuration of the second insulating bobbin **9***b* (unillustrated) is the same as that of the first insulating bobbin **9***a*. The other configurations are the same as those of the electric rotating machine according to Embodiment 1.
(89) In the electric rotating machine according to Embodiment 4, spaces are formed between the tooth side surface portions **11***a* and **11***b* and the middle inner wall surface portions **142***a***1** and **142***b***1**, respectively, in an area E**4** between the tooth-side-surface convex portions **11***a***1** and **11***b***1** at the inner radial side of the tooth portion **11** and the tooth-side-surface convex portions **11***a***2** and **11***b***2** at the outer radial side of the tooth portion **11**.
(90) When the first insulating bobbin **9***a* and the second insulating bobbin **9***b* are mounted on the stator core **5** and when the stator coil **6** is wound around the tooth portion **11** through the intermediary of the first insulating bobbin **9***a* and the second insulating bobbin **9***b*, the tooth-side-surface convex portions **11***a***1**, **11***b***1**, **11***a***2**, and **11***b***2** abut on the inner wall surface of the coil winding portion **14**; thus, because there are securely maintained spaces between the tooth side surface portions **11***a* and **11***b* and the middle inner wall surface portions **142***a***1** and **142***b***1**, respectively, an effect the same as that of Embodiment 1 can be obtained.
(91) In addition, in the case where although not illustrated, shoe portions are provided at the front ends of the tooth portion **11**, it may be allowed that as is the case with Embodiment 3, shoe-side-surface facing inner wall surface portions are provided in the inner wall portions of the first insulating bobbin and the second insulating bobbin so that the shoe-side-surface facing inner wall surface portions abut on the corresponding shoe side-surface portions. Moreover, it may also be allowed that instead of making the shoe-side-surface facing inner wall surface portion abut on the shoe side-surface portion, the tooth-side-surface convex portions and the inner wall surface of the coil winding portion are made to abut on each other so that spaces are maintained between the respective side surfaces of the shoe portion and the first and second insulating bobbins.
Embodiment 5
(92) FIG. **19** is a perspective view of a first insulating bobbin in an electric rotating machine according to Embodiment 5. The constituent elements the same as or similar to those of the electric rotating machine according to Embodiment 1 are designated by reference characters the same as those therein. In the explanation for the electric rotating machine according to Embodiment 5, only the portions that are different from those in the electric rotating machine according to Embodiment 1 will be described. In the electric rotating machine according to Embodiment 5, a slant surface **142***as* is provided at the front end sides, indicated by the arrow F**1**, of the inner-wall-surface convex portions **15***a***1** and **16***a***1** and the middle inner wall surface portion **142***a***1**; a slant surface **142***bs* is provided at the front end sides, indicated by the arrow F**1**, of the inner-wall-surface convex portions **15***b***1** and **16***b***1** and the middle inner wall surface portion **142***b***1**. The configuration of the second insulating bobbin **9***b* (unillustrated) is the same as that of the first insulating bobbin **9***a*. The other configurations are the same as those of the electric rotating machine according to Embodiment 1.
(93) The electric rotating machine according to Embodiment 5 make it possible to obtain an effect the same as that of the electric rotating machine according to Embodiment 1; in addition to that, the

first insulating bobbin **9**_a_ and the second insulating bobbin **9**_b_ can readily be fitted onto the tooth portion **11** of the stator core **5**; thus, the mountability of the first and second insulating bobbins on the stator core **5** can be raised.

(94) In FIG. **19**, the slant surfaces **142**_as_ and **142**_bs_ are provided only at the front end side, indicated by the arrow F**1**, of the inside of the coil winding portion **14**; however, it may be allowed that the respective slant surfaces gently change in the direction departing from the tooth side surface portions **11**_a_ and **11**_b_ from the root side indicated by the arrow F**2**.

Embodiment 6

(95) FIG. **20** is a top view of a stator core of an electric rotating machine according to Embodiment 6; FIG. **21** is a perspective view of a first insulating bobbin in the electric rotating machine according to Embodiment 6; FIG. **22** is a plan view of the first insulating bobbin in the electric rotating machine according to Embodiment 6; FIG. **23** is a side view illustrating the first insulating bobbin and a second insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 6; FIG. **24** is a cross-sectional view of the first insulating bobbin mounted on the stator core in the electric rotating machine according to Embodiment 6, when viewed in the direction of the arrow along the line X**6**-X**6** in FIG. **23**. The constituent elements the same as or similar to those of the electric rotating machine according to Embodiment 1 are designated by reference characters the same as those therein. In the explanation for the electric rotating machine according to Embodiment 6, only the portions that are different from those in the electric rotating machine according to Embodiment 1 will be described.

(96) As illustrated in FIG. **20**, unlike Embodiment 1, the stator core **5** of the electric rotating machine according to Embodiment 6 does not have any back-yoke cutout portion **12** in the back-yoke outer circumferential portion **10**_a_. In the stator core **5** according to Embodiment 6, a tooth cutout portion **115**_a_ is formed at the outer radial side of the tooth side surface portion **11**_a_ in such a way as to be adjacent to the back-yoke inner circumference portion **10**_b_, and a tooth cutout portion **115**_b_ is formed at the outer radial side of the tooth side surface portion **11**_b_ in such a way as to be adjacent to the back-yoke inner circumference portion **10**_b_. A width K**2** [mm] between the tooth cutout portion **115**_a_ and the tooth cutout portion **115**_b_ and a circumferential-direction width K**1** [mm] of the tooth portion **11** are in the relationship of [K**1**>K**2**].

(97) As illustrated in FIGS. **21** and **22**, the first insulating bobbin **9**_a_ in the electric rotating machine according to Embodiment 6 does not have the convex portion **131** that is provided in the back-yoke-endface facing portion **13** of the first insulating bobbin **9**_a_ in Embodiment 6. Inside the first insulating bobbin **9**_a_ in Embodiment 6, the inner-wall-surface convex portions **15**_a_**1** and **16**_a_**1** are provided adjacent to the middle inner wall surface portion **142**_a_**1**, and the inner-wall-surface convex portions **15**_b_**1** and **16**_b_**1** are provided adjacent to the middle inner wall surface portion **142**_b_**1**. The configuration of the second insulating bobbin **9**_b_ (unillustrated) is the same as that of the first insulating bobbin **9**_a_.

(98) A distance K**3** [mm] between the inner-wall-surface convex portions **15**_a_**1** and **15**_b_**1**, a distance K**4** [mm] between the middle inner wall surface portions **142**_a_**1** and **142**_b_**1**, and a distance K**5** [mm] between the inner-wall-surface convex portions **16**_a_**1** and **16**_b_**1** are in the relationship of [K**5**<K**3**<K**4**]. In addition, with regard to the respective widths of the tooth portion **11** of the stator core **5** and the first insulating bobbin **9**_a_, the relationships [K**1** K**3**] and [K**2**≤K**5**] are established.

(99) As illustrated in FIG. **23**, the first insulating bobbin **9**_a_ and the second insulating bobbin **9**_b_ are mounted onto the stator core **5** from the stacking-direction both sides; at a time of the mounting thereof, as illustrated in FIG. **24**, the inner-wall-surface convex portion **16**_a_**1** is press-fitted into the tooth cutout portion **115**_a_ and the inner-wall-surface convex portion **16**_b_**1** is press-fitted into the tooth cutout portion **115**_b_, so that the first insulating bobbin **9**_a_ and the second insulating bobbin **9**_b_ are fixed to the stator core **5**.

(100) In the electric rotating machine according to Embodiment 6, as is the case with the electric rotating machine according to Embodiment 1, even when at a time of coil winding, the respective

coil winding portions **14** of the first insulating bobbin **9***a* and the second insulating bobbin **9***b* are collectively shift in the circumferential direction, the inner-wall-surface convex portions **15***a***1** and **16***a***1** abut on the tooth side surface portion **11***a* and the inner-wall-surface convex portions **15***b***1** and **16***b***1** abut on the tooth side surface portion **11***b*, and hence respective circumferential-direction spaces are securely maintained; thus, an effect the same as that of Embodiment 1 can be obtained. Moreover, because the inner-wall-surface convex portion **16***a***1** is press-fitted into the tooth cutout portion **115***a* and the inner-wall-surface convex portion **16***b***1** is press-fitted into the tooth cutout portion **115***b*, the first insulating bobbin **9***a* and the second insulating bobbin **9***b* can more securely be fixed to the stator core **5**.

Embodiment 7

(101) FIG. **25** is a perspective view of a first insulating bobbin in an electric rotating machine according to Embodiment 7; FIG. **26** is a cross-sectional view of the first insulating bobbin mounted on a stator core in the electric rotating machine according to according to Embodiment 7. The constituent elements the same as or similar to those of the electric rotating machine according to Embodiment 1 are designated by reference characters the same as those therein. In the explanation for the electric rotating machine according to Embodiment 5, only the portions that are different from those in the electric rotating machine according to Embodiment 1 will be described.

(102) In FIG. **25**, in the first insulating bobbin **9***a*, there are provided the inner-wall-surface convex portions **15***a***1** and **16***a***1** and an inner-wall-surface groove portion **18***a* having a fillet surface **18***a***1** at the root portion, indicated by the arrow F**2**, of the middle inner wall surface portion **142***a***1**, and there are provided the inner-wall-surface convex portions **15***b***1** and **16***b***1** and an inner-wall-surface groove portion **18***b* having a fillet surface **18***b***1** at the root portion, indicated by the arrow F**2**, of the middle inner wall surface portion **142***b***1**.

(103) More specifically, as illustrated in FIG. **26**, the inner-wall-surface groove portion **18***a* having the fillet surface **18***a***1** is formed at a position inside the first insulating bobbin **9***a*, at which the inner wall surface of the tooth-endface facing portion **141** and the inner wall surface, of the coil winding portion **14**, that faces the tooth side surface portion **11***a*, intersect each other. In addition, the inner-wall-surface groove portion **18***b* having the fillet surface **18***b***1** is formed at a position inside the first insulating bobbin **9***a*, at which the inner wall surface, of the tooth-endface facing portion **141**, that faces the tooth endface portion, and the inner wall surface, of the coil winding portion **14**, that faces the tooth side surface portion **11***b*, intersect each other. The configuration of the second insulating bobbin **9***b* (unillustrated) is the same as that of the first insulating bobbin **9***a*.

(104) The first insulating bobbin **9***a* prevents a crack in such a way that at a time of coil winding, the radial-direction front-end portions of the middle inner wall surface portions **142***a***1** and **142***b***1** are deformed in the direction approaching the tooth side surface portions **11***a* and **11***b*, respectively, so that the stress at the corner portion of the coil winding portion **14** is changed from tensile stress to compression stress; however, in order to raise the reliability, it is desirable that the compression stress is smaller. Because the stress concentration coefficient at the corner portion of the coil winding portion **14** is high, providing the fillet surfaces **14***a* and **14***b* makes it possible that the stress concentration coefficient is decreased and hence the stress is further reduced.

(105) However, because in the case where only the fillet surfaces **14***a* and **14***b* are provided in the respective corner portions of the coil winding portion **14**, the insides of the fillet surfaces **14***a* and **14***b* may make contact with the tooth side surface portions **11***a* and **11***b*, respectively, it is required to widen the distance between the middle inner wall surface portions **142***a***1** and **142***b***1**; thus, the space between the adjacent stator coils **6** is narrowed.

(106) Accordingly, in the electric rotating machine according to Embodiment 7, there are provided the inner-wall-surface convex portions **15***a***1** and **16***a***1** and the inner-wall-surface groove portion **18***a* having the fillet surface **18***a***1** at the root portion, indicated by the arrow F**2**, of the middle inner wall surface portion **142***a***1**, and there are provided the inner-wall-surface convex portions **15***b***1** and **16***b***1** and the inner-wall-surface groove portion **18***b* having the fillet surface **18***b***1** at the root

portion, indicated by the arrow F**2**, of the middle inner wall surface portion **142***b***1**.

(107) As a result, it is made possible that without increasing the distance between the middle inner wall surface portion **142***a***1** and **142***b***1**, the inner wall surfaces of the fillet surfaces **14***a* and **14***b* are prevented from making contact with the tooth side surface portions **11***a* and **11***b*, respectively.

Embodiment 8

(108) FIG. **27** is a perspective view of a first insulating bobbin in an electric rotating machine according to Embodiment 8; the constituent elements the same as or similar to those of the electric rotating machine according to Embodiment 1 are designated by reference characters the same as those therein. In the explanation for the electric rotating machine according to Embodiment 8, only the portions that are different from those in the electric rotating machine according to Embodiment 1 will be described. As illustrated in FIG. **27**, in the electric rotating machine according to Embodiment 8, the inner-wall-surface convex portions **15***a***1** and **16***a***1** are provided only at the root side of the middle inner wall surface portion **142***a***1** of the coil winding portion **14**; the inner-wall-surface convex portions **15***b***1** and **16***b***1** are provided only at the root side of the middle inner wall surface portion **142***b***1** of the coil winding portion **14**. The configuration of the second insulating bobbin **9***b* (unillustrated) is the same as that of the first insulating bobbin **9***a*. The other configurations are the same as those of the electric rotating machine according to Embodiment 1.

(109) In the foregoing electric rotating machine according to each of the respective embodiments, when the stator coil is wound, the respective insides of the coil winding portions of the first insulating bobbin and the second insulating bobbin are made to abut on the corresponding tooth side surface portions in the abutting areas at the inner radial side and at the outer radial side, so that there is securely maintained a space between the tooth side surface portion and the middle area of the inner wall portion facing the tooth side surface portion of the coil winding portion; thus, because there is reduced tensile stress to be applied to the root portion of the middle area of the inner wall portion, facing the tooth side surface portion, of the coil winding portion, a crack in the insulating bobbin can be prevented and hence the insulation between the stator core and the stator coil can certainly be secured.

(110) Although the present application is described above in terms of various exemplary embodiments and implementations, it should be understood that the various features, aspects and functions described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described, but instead can be applied, alone or in various combinations to one or more of the embodiments. Therefore, an infinite number of unexemplified variant examples are conceivable within the range of the technology disclosed in the present application. For example, there are included the case where at least one constituent element is modified, added, or omitted and the case where at least one constituent element is extracted and then combined with constituent elements of other embodiments.

(111) Next, the respective features of the electric rotating machines disclosed in the present disclosure will be described as appendixes. (Appendix 1) An electric rotating machine comprising: a rotor fixed on a pivotably supported rotor shaft; and a stator containing the rotor, wherein the stator has a stator core and a stator coil mounted on the stator core through the intermediary of an insulating bobbin, wherein the stator core has a ring-shaped back yoke portion and a tooth portion whose front-end portion protrudes from the back yoke portion toward the rotor shaft, wherein the insulating bobbin includes a first insulating bobbin and a second insulating bobbin that are fitted onto both respective endfaces of the stator core in an axial direction of the electric rotating machine, wherein at least one of the first insulating bobbin and the second insulating bobbin has a coil winding portion around which a conductor wire included in the stator coil is wound and whose cross section is U-shaped, wherein the coil winding portion has a tooth-endface facing portion that faces an endface portion, in the axial direction, of the tooth portion and a tooth-side-surface facing portion that faces a tooth side surface portion, in a circumferential direction of the electric rotating machine, of the tooth portion, and wherein the tooth-side-surface facing portion has a first abutting

area that abuts on the tooth side surface portion, a second abutting area that abuts on the tooth side surface portion at a more outer side in a radial direction of the electric rotating machine than the first abutting area abuts thereon, and a middle inner wall surface portion that is situated between the first abutting area and the second abutting area and faces the tooth side surface portion via a space. (Appendix 2) The electric rotating machine according to Appendix 1, wherein the first abutting area is configured with a first inner-wall-surface convex portion formed adjacent to an inner side, in the radial direction, of the middle inner wall surface portion, and wherein the second abutting area is configured with a second inner-wall-surface convex portion formed adjacent to an outer side, in the radial direction, of the middle inner wall surface portion. (Appendix 3) The electric rotating machine according to Appendix 1, wherein the first abutting area abuts on a first tooth-side-surface convex portion formed in the tooth side surface portion, and wherein the second abutting area abuts on a second tooth-side-surface convex portion that is formed in the tooth side surface portion at more outer side in the radial direction than the first tooth-side-surface convex portion. (Appendix 4) The electric rotating machine according to any one of Appendix 1 and Appendix 2, wherein at the front-end portion of the tooth portion, the stator core has a shoe portion that extends in the circumferential direction of the electric rotating machine from the tooth side surface portion, and wherein the tooth-side-surface facing portion has a shoe-side-surface facing inner wall surface portion that faces, via a space, the shoe side-surface portion, in the circumferential direction, of the shoe portion. (Appendix 5) The electric rotating machine according to any one of Appendix 1 through Appendix 4, wherein at least one of the first insulating bobbin and the second insulating bobbin has a slant surface that is situated at the front-end portion, in the circumferential direction, of the tooth-side-surface facing portion and slants in a direction departing from the tooth side surface portion. (Appendix 6) The electric rotating machine according to any one of Appendix 1 through Appendix 5, wherein at least one of the first insulating bobbin and the second insulating bobbin is mounted in such a way that a gap exists between each of the first abutting area and the second abutting area and the tooth side surface portion. (Appendix 7) The electric rotating machine according to Appendix 2, wherein the tooth portion has a tooth cutout portion that is situated at an outer side, in the radial direction, of the tooth side surface portion and makes contact with an inner circumference portion of the back yoke portion, and wherein the second inner-wall-surface convex portion is press-fitted into the tooth cutout portion. (Appendix 8) The electric rotating machine according to Appendix 2, wherein each of the first inner-wall-surface convex portion and the second inner-wall-surface convex portion is formed in an area from a root side of the tooth-side-surface facing portion to a front end side thereof. (Appendix 9) The electric rotating machine according to Appendix 2, wherein each of the first inner-wall-surface convex portion and the second inner-wall-surface convex portion is formed only at a root side of the tooth-side-surface facing portion. (Appendix 10) The electric rotating machine according to any one of Appendix 1 through Appendix 9, further comprising an inner-wall-surface groove portion having a fillet surface, at a root side of the tooth-side-surface facing portion. (Appendix 11) An electric rotating machine comprising: a rotor fixed on a pivotably supported rotor shaft; and a stator containing the rotor, wherein the stator has a stator core and a stator coil mounted on the stator core through the intermediary of an insulating bobbin, wherein the stator core has a ring-shaped back yoke portion and a tooth portion whose front-end portion protrudes from the back yoke portion toward the rotor shaft, wherein at the front-end portion of the tooth portion, the stator core has a shoe portion that extends in the circumferential direction of the electric rotating machine from the tooth side surface portion in the circumferential direction of the electric rotating machine, wherein the insulating bobbin includes a first insulating bobbin and a second insulating bobbin that are fitted onto both respective endfaces of the stator core in an axial direction of the electric rotating machine, wherein at least one of the first insulating bobbin and the second insulating bobbin has a coil winding portion around which a conductor wire included in the stator coil is wound and whose cross section is U-shaped, wherein the coil winding portion has a tooth-endface facing portion that faces an endface portion, in the axial direction, of the tooth portion, a tooth-side-surface facing portion that faces a tooth side surface portion, and a shoe-side-surface facing inner wall surface portion that faces a shoe side-surface portion, in the circumferential direction, of the shoe portion, where the shoe-side-surface facing inner wall surface portion has a first abutting area that abuts on the shoe side-surface portion, and wherein the tooth-side-surface facing portion has a second abutting area that abuts on the tooth side surface portion and a middle inner wall surface portion that is situated between the first abutting area and the second abutting area and faces the tooth side surface portion via a space. (Appendix 12) The electric rotating machine according to any one of Appendix 1 through Appendix 11, wherein the back yoke portion of the stator core has a back-yoke cutout portion in a back-yoke outer circumferential portion thereof, wherein each of the first insulating bobbin and the second insulating bobbin has a back-yoke-endface facing portion that faces an endface of the back yoke portion of the stator core, wherein the back-yoke-endface facing portion has a convex portion that protrudes toward the endface of the back yoke portion, and wherein the convex portion protruding toward the endface of the back yoke portion is press-fitted into the back-yoke cutout portion in the back-yoke outer circumferential portion, so that each of the first insulating bobbin and the second insulating bobbin is fixed to the stator core.

Claims

1. An electric rotating machine comprising: a rotor fixed on a pivotably supported rotor shaft; and a stator containing the rotor, wherein the stator has a stator core and a stator coil mounted on the stator core through the intermediary of an insulating bobbin, wherein the stator core has a ring-shaped back yoke portion and a tooth portion whose front-end portion protrudes from the back yoke portion toward the rotor shaft, wherein the insulating bobbin includes a first insulating bobbin and a second insulating bobbin that are fitted onto both respective endfaces of the stator core in an axial direction of the electric rotating machine, wherein at least one of the first insulating bobbin and the second insulating bobbin has a coil winding portion around which a conductor wire included in the stator coil is wound and whose cross section is U-shaped, wherein the coil winding portion has a tooth-endface facing portion that faces an endface portion, in the axial direction, of the tooth portion and a tooth-side-surface facing portion that faces a tooth side surface portion, in a circumferential direction of the electric rotating machine, of the tooth portion, wherein the tooth-side-surface facing portion has a first abutting area that abuts on the tooth side surface portion, a second abutting area that abuts on the tooth side surface portion at a more outer side in a radial direction of the electric rotating machine than the first abutting area abuts thereon, and a middle inner wall surface portion that is situated between the first abutting area and the second abutting area and faces the tooth side surface portion via a space, and wherein the first abutting area is located at an uppermost side of the tooth side surface portion and the second abutting surface is located at a lowermost side of the tooth side surface portion in a radial direction.
2. The electric rotating machine according to claim 1, wherein the first abutting area is configured with a first inner-wall-surface convex portion formed adjacent to an inner side, in the radial direction, of the middle inner wall surface portion, and wherein the second abutting area is configured with a second inner-wall-surface convex portion formed adjacent to an outer side, in the radial direction, of the middle inner wall surface portion.
3. The electric rotating machine according to claim 2, wherein at the front-end portion of the tooth portion, the stator core has a shoe portion that extends in the circumferential direction of the electric rotating machine from the tooth side surface portion, and wherein the tooth-side-surface facing portion has a shoe-side-surface facing inner wall surface portion that faces, via a space, the shoe side-surface portion, in the circumferential direction, of the shoe portion.
4. The electric rotating machine according to claim 2, wherein at least one of the first insulating bobbin and the second insulating bobbin has a slant surface that is situated at the front-end portion,

in the circumferential direction, of the tooth-side-surface facing portion and slants in a direction departing from the tooth side surface portion.

5. The electric rotating machine according to claim 2, wherein at least one of the first insulating bobbin and the second insulating bobbin is mounted in such a way that a gap exists between each of the first abutting area and the second abutting area and the tooth side surface portion.

6. The electric rotating machine according to claim 2, wherein the tooth portion has a tooth cutout portion that is situated at an outer side, in the radial direction, of the tooth side surface portion and makes contact with an inner circumference portion of the back yoke portion, and wherein the second inner-wall-surface convex portion is press-fitted into the tooth cutout portion.

7. The electric rotating machine according to claim 2, wherein each of the first inner-wall-surface convex portion and the second inner-wall-surface convex portion is formed in an area from a root side of the tooth-side-surface facing portion to a front end side thereof.

8. The electric rotating machine according to claim 2, wherein each of the first inner-wall-surface convex portion and the second inner-wall-surface convex portion is formed only at a root side of the tooth-side-surface facing portion.

9. The electric rotating machine according to claim 2, further comprising an inner-wall-surface groove portion having a fillet surface, at a root side of the tooth-side-surface facing portion.

10. The electric rotating machine according to claim 1, wherein the first abutting area abuts on a first tooth-side-surface convex portion formed in the tooth side surface portion, and wherein the second abutting area abuts on a second tooth-side-surface convex portion that is formed in the tooth side surface portion at more outer side in the radial direction than the first tooth-side-surface convex portion.

11. The electric rotating machine according to claim 1, wherein at the front-end portion of the tooth portion, the stator core has a shoe portion that extends in the circumferential direction of the electric rotating machine from the tooth side surface portion, and wherein the tooth-side-surface facing portion has a shoe-side-surface facing inner wall surface portion that faces, via a space, the shoe side-surface portion, in the circumferential direction, of the shoe portion.

12. The electric rotating machine according to claim 1, wherein at least one of the first insulating bobbin and the second insulating bobbin has a slant surface that is situated at the front-end portion, in the circumferential direction, of the tooth-side-surface facing portion and slants in a direction departing from the tooth side surface portion.

13. The electric rotating machine according to claim 1, wherein at least one of the first insulating bobbin and the second insulating bobbin is mounted in such a way that a gap exists between each of the first abutting area and the second abutting area and the tooth side surface portion.

14. The electric rotating machine according to claim 1, further comprising an inner-wall-surface groove portion having a fillet surface, at a root side of the tooth-side-surface facing portion.

15. The electric rotating machine according to claim 1, wherein the back yoke portion of the stator core has a cutout portion in a back-yoke outer circumferential portion thereof, wherein each of the first insulating bobbin and the second insulating bobbin has a back-yoke-endface facing portion that faces an endface of the back yoke portion of the stator core, wherein the back-yoke-endface facing portion has a convex portion that protrudes toward the endface of the back yoke portion, and wherein the convex portion protruding toward the endface of the back yoke portion is press-fitted into the cutout portion in the back-yoke outer circumferential portion, so that each of the first insulating bobbin and the second insulating bobbin is fixed to the stator core.

16. An electric rotating machine comprising: a rotor fixed on a pivotably supported rotor shaft; and a stator containing the rotor, wherein the stator has a stator core and a stator coil mounted on the stator core through the intermediary of an insulating bobbin, wherein the stator core has a ring-shaped back yoke portion and a tooth portion whose front-end portion protrudes from the back yoke portion toward the rotor shaft, wherein at the front-end portion of the tooth portion, the stator core has a shoe portion that extends in the circumferential direction of the electric rotating machine

from a tooth side surface portion in the circumferential direction of the electric rotating machine, wherein the insulating bobbin includes a first insulating bobbin and a second insulating bobbin that are fitted onto both respective endfaces of the stator core in an axial direction of the electric rotating machine, wherein at least one of the first insulating bobbin and the second insulating bobbin has a coil winding portion around which a conductor wire included in the stator coil is wound and whose cross section is U-shaped, wherein the coil winding portion has a tooth-endface facing portion that faces an endface portion, in the axial direction, of the tooth portion, a tooth-side-surface facing portion that faces a tooth side surface portion, and a shoe-side-surface facing inner wall surface portion that faces a shoe side-surface portion, in the circumferential direction, of the shoe portion, where the shoe-side-surface facing inner wall surface portion has a first abutting area that abuts on the shoe side-surface portion, and wherein the tooth-side-surface facing portion has a second abutting area that abuts on the tooth side surface portion and a middle inner wall surface portion that is situated between the first abutting area and the second abutting area and faces the tooth side surface portion via a space, the middle wall surface portion extending along the tooth-side-surface portion at a midpoint of the tooth-side surface portion between the first abutting area and the second abutting area.

17. The electric rotating machine according to claim 16, wherein the back yoke portion of the stator core has a cutout portion in a back-yoke outer circumferential portion thereof, wherein each of the first insulating bobbin and the second insulating bobbin has a back-yoke-endface facing portion that faces an endface of the back yoke portion of the stator core, wherein the back-yoke-endface facing portion has a convex portion that protrudes toward the endface of the back yoke portion, and wherein the convex portion protruding toward the endface of the back yoke portion is press-fitted into the cutout portion in the back-yoke outer circumferential portion, so that each of the first insulating bobbin and the second insulating bobbin is fixed to the stator core.