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Stator for suppressing peeling of insulating coating

Abstract

A stator includes a stator core and a stator winding installed in the stator core. The stator winding has multiple conductor segments in which a conductor is coated with an insulating film **35**. The conductor segment includes an exposed portion in which the conductor is exposed at its leading end, and a covered portion in which the conductor remains coated with the insulating film. At a coil end section of the stator winding, the exposed portions of different conductor segments are engaged with each other. A depression as a plastic deformation formed by crushing at least a part of the insulating film is provided at an edge of the covered portion of the conductor segment, located closer to the leading end of the conducting wire, thereby Providing a stator capable of suppressing peeling off of the insulating film and ensuring insulation reliability of the stator winding.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION
(1) This patent application is based on and claims priority to Japanese Patent Application No. 2021-127815, filed on Aug. 3, 2021 in the Japan Patent office, the entire disclosure of which is hereby incorporated by reference herein.
BACKGROUND
Technical Field
(2) The present disclosure relates to a stator employed in a rotation electric machine.
Related Art
(3) In a stator employed in a rotation electric machine, a stator winding is installed in a stator core. The stator winding is generally configured by connecting multiple conductor segments to each other. Such a conductor segment is constituted by a conducting wire configured by including a

conductor coated with an insulating film. The conductor segment has both an exposed portion at a leading end thereof in which the conductor is exposed and a covered portion in which the conductor remains coated with an insulating film. Then, the conductor segment is connected to another conductor segment at the exposed portion thereof. In a known insulating film coated on a conductor segment, to increase a creepage distance between adjacent joints, an insulating film peeling off portion peels off from a conductor while inclining to a given direction.
(4) In general, an insulating film possibly peels off at an edge of the covered portion closer to the exposed portion in the conductor segment. For example, when conductor segments are mutually joined together in a manufacturing process, an insulating film can peel off due to contact of other parts or the like at an edge of the insulating film. In the known technology, since an insulating film peeled off portion inclines to the conductor, the insulating film can increasingly peel off starting from the insulating film peeling off portion. When the insulating film peels off from the covered portion, insulation reliability may possibly decrease.
(5) The present disclosure has been made to address and resolve such a problem, and it is a main object of the present disclosure to provide a stator capable of suppressing peeling off of an insulating film while ensuring insulation reliability of a stator winding.
SUMMARY
(6) Accordingly, one aspect of the present disclosure provides a novel stator that includes: a stator core; and a stator winding installed in the stator core. The stator winding is configured by including multiple conducting wires constituted by conductors respectively coated with insulating films. Each of the conducting wires has; an exposed portion at a leading end, where the conductor is exposed, and a covered portion in which the conductor remains coated with the insulating film. A pair of exposed portions of different conductor wires are joined together at a coil end section of the stator winding. The covered portion of the conducting wire of each of different conductor wires has a depression as a plastic deformation at an edge thereof closer to the leading end of the conducting wire, the depression being formed by crushing a part of the insulating film at the edge of the covered portion.
(7) Hence, according to a first aspect of the present disclosure, the depression as a plastic deformation is formed at the edge of the covered portion of the conducting wire closer to the leading end thereof by crushing at least a part of the insulating film. Accordingly, in this configuration, the edge of the insulating film adheres to the conductor, thereby inhibiting the insulating film from easily peeling accidentally. Hence, occurrence of the peeling off of the insulating film in the covered portion can be suppressed, thereby ensuring insulation reliability of the stator winding.
(8) Accordingly, in another aspect of the present disclosure, the depression has a given depth measured from the insulating film of the covered portion to a part of the conductor directly under the insulating film.
(9) Hence, according to the second aspect of the present disclosure, the depression is formed with the depth measured from the insulating film of the covered portion to a part of the conductor directly under the covered portion. In this configuration, since the depression is formed in the conductor as a plastic deformation and the edge of the insulating film enters the depression of the conductor, adhesion of the insulating film to the conductor is improved. With this, it is possible to further reduce peeling off of the insulating film.
(10) According to a third aspect of the present disclosure, the conductor wire is a rectangular conductor wire having a rectangular cross-section. The coil end section is configured by connecting a leading end of the conductor wire extended in a first circumferential direction and a leading end of the other conductor wire extended in a second circumferential direction opposite to the first circumferential direction at an axially outside of the stator core. The exposed portions of the different conductor wires are engaged side by side with each other in a radial direction of the stator core and are joined together by welding. The depression is formed on surfaces of the covered

portion facing to the axial and radial directions, respectively, at the edge of the covered portion closer to the leading end of the conducting wire in each of the different conductor wires. That is, in a configuration in which the exposed portion is formed at the leading end of each of the conducting wires oppositely extended in the circumferential direction and these exposed portions are joined together, respective edges of the insulating films closer to leading ends of the conducting wires can peel off due to a contact between these conducting wires or the like. However, according to this aspect of the present disclosure, since the depressions are formed on the respective surfaces of the covered portions of the conducting wires, which face perpendicular to both axial and radial directions, respectively, at the edges of the covered portions closer to the leading ends of the conducting wires, peeling off of the insulating film caused by the contact between the conducting wires and the like can be favorably reduced or suppressed.
(11) According to a fourth aspect of the present disclosure, the depression serves as a positioning member for positioning the exposed portions when the exposed portions of different conducting wires are joined together.
(12) Hence, according to the fourth aspect of the present disclosure, the depression serves as the positioning member for positioning the exposed portion of the different conducting wire when the exposed portions are mutually engaged with each other. Here, when the edge of the covered portion closer to the leading end of the conducting wire is used in alignment of the exposed portion of the different conducting wire, the exposed portion comes into contact with the edge of the covered portion closer to the leading end of the different conducting wire, so that the insulating film is likely to peel off. However, according to the fourth aspect of the present disclosure, since the depression is formed at the edge of the covered portion closer to the conducting wire leading end, peeling off of the insulating film can be reduced or suppressed even if the exposed portion comes into contact with the edge of the covered portion of the different conducting wire.
(13) According to a fifth aspect of the present disclosure, the conducting wires are extended in the first and second circumferential directions and are also extended outwardly in the axial direction obliquely to an axial end face of the stator core at a given angle. Then, the exposed portions of the leading ends of the different conducting wires are joined together. Further, among two depressions formed on two opposite surfaces perpendicular to the axial direction at the edge of the covered portion located closer to the leading side of the conducting wire, the depression formed on the axial inner surface is located closer to the leading end of the conducting wire in the longitudinal direction of the conducting wire than the depression formed on the axial outer surface.
(14) That is, in a configuration in which conducting wires are extended oppositely in the circumferential direction and axially outward in the axial direction obliquely to an axial end face of the stator core at a given angle, and the exposed portions of the leading ends thereof are joined together, the closer to the leading ends of the conductor wires, the more the conducting wires are located outside in the axial direction. Hence, in such a situation, the further outward in the axial direction, the higher the risk of coming into contact with other components than the stator, and ultimately, the insulating film is increasingly likely to peel off due to the contact. In view of this, according to a fifth aspect of the present disclosure, among multiple depressions formed on the two axial surfaces (i.e., surfaces perpendicular to the axial direction) at the edge of the covered portion closer to the leading end of the conducting wire, the depression formed on the axial inner surface of the conducting wire is closer to the leading end of the conducting wire in a longitudinal direction thereof than the depression formed on the axial outer surface of the conducting wire. With this, the risk of parts other than the stator coming into contact with the edge of the covered portion closer to the leading end of the conductor wire (i.e., the depression) on the axial outer surface of the conductive wire can be decreased. Hence, peeling off of the insulating film can be more appropriately suppressed.
(15) According to a sixth aspect of the present disclosure, the exposed portion is configured to include a recess formed at a boundary with the covered portion partially to constitute the

depression, and a protrusion formed closer to the leading end of the conducting wire than the recess is.
(16) Hence, according to the sixth aspect of the present disclosure, in the exposed portion, a recess as a depression is formed at the boundary with the covered portion, and a protrusion is successively formed at a position closer to the leading end of the conducting wire than the recess, so that other conductor wires and the like are prevented from coming into contact with the edge of the insulating film. With this, peeling off of the insulating coating from the conducting wire can be readily reduced or suppressed.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) A more complete appreciation of the present disclosure and many of the attendant advantages of the present disclosure will be more readily obtained as substantially the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:
(2) FIG. **1** is a perspective view illustrating an exemplary stator according to one embodiment of the present disclosure;
(3) FIG. **2** is a front view illustrating the stator of FIG. **1**;
(4) FIG. **3** is a plan view illustrating an exemplary stator core according to one embodiment of the present disclosure;
(5) FIG. **4** is a perspective view illustrating conductor segments and a part of the stator core according to one embodiment of the present disclosure;
(6) FIG. **5** is a diagram illustrating some conductor segments accommodated in a slot according to one embodiment of the present disclosure;
(7) FIGS. **6**A and **6**B are diagrams collectively illustrating a basic connection mechanism connecting the conductor segments according to one embodiment of the present disclosure;
(8) FIGS. **7**A to **7**C are diagrams collectively illustrating a configuration of a leading end of the conductor segment according to one embodiment of the present disclosure;
(9) FIGS. **8**A to **8**D are diagrams illustrating an exemplary process of forming a leading end of the conductor segment according to one embodiment of the present disclosure;
(10) FIGS. **9**A and **9**B are diagrams collectively illustrating a raised portion formed in the exposed portion of the conductor segment according to one embodiment of the present disclosure; and
(11) FIG. **10** is a diagram illustrating a configuration of a leading end of a conductor segment according to another example of the present disclosure.
DETAILED DESCRIPTION
(12) Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views thereof and to FIGS. **1** to **9**B, a rotating electric machine according to one embodiment of the present invention will be described. Hereinbelow, in various embodiments and modifications, the same or equivalent portions are given the same reference numerals. Then, a portion having the same reference numeral is not described repeatedly while making a reference thereto. In this embodiment, a motor acting as a rotating electric machine is used, for example, as an electric motor for either a vehicle or an aerial vehicle.
(13) The rotating electric machine has a three-phase winding and can be applied to a permanent magnet synchronous motor, a winding field type motor, and an induction machine. The rotating electric machine includes a cylindrical stator **10** shown in FIG. **1** and a rotor (not shown) disposed in a radial inner part of the stator **10** or the like. The rotor is opposed to the stator **10** and is rotatable around a rotation axis. Hereinafter, an axial direction refers to an axial direction of the stator **10**, that is, an axial direction of the rotation axis of the rotor. A radial direction refers to a

radial direction of the stator **10**, that is, a direction passing through a center of the rotation axis of the rotor and orthogonal to the rotation axis. A circumferential direction indicates a circumferential direction of the stator **10**, that is, a rotational direction of the rotor around the rotation axis.

(14) As shown in FIGS. **1** and **2**, the stator **10** includes a stator core **11** having an annular shape and a stator winding **12** wrapped around the stator core **11**. The rotating electric machine of the present disclosure is an inner-rotor type rotary electric machine, in which the rotor is rotatably arranged radially inside of the stator **10**. The stator winding **12** is a type of a three-phase winding configured by including a U-phase winding, a V-phase winding, and a W-phase winding as respective phase windings. A power line busbar **13** is connected to one end of the phase winding of each phase. A neutral point busbar **14** is also connected to the other end of the phase winding of each phase. Among a total extent of the stator winding **12**, a range overlapping with the stator core **11** in the axial direction serves as a slot inside coil section CS. Among the total extent of the stator winding **12**, portions located outside of the stator core **11** in the axial direction serve as coil end sections CE**1** and CE**2**, respectively.

(15) As shown in FIG. **3**, the stator core **11** includes an annular back yoke **21** and multiple teeth **22** radially protruding inwardly from the back yoke **21** and arranged apart from each other at a given distance in the circumferential direction. Hence, the stator core **11** includes multiple slots **23** formed between respective adjacent teeth **22**. Each of the slots **23** has an opening with a longitudinal side extending in the radial direction, and is arranged at substantially the same intervals in the circumferential direction in the stator core **11**. Then, the stator winding **12** is wrapped around each of the slots **23**. The stator core **11** is configured as a core sheet laminate, formed by laminating core sheets in the axial direction to act as a magnetic body constituted by electromagnetic steel sheets, for example.

(16) The stator winding **12** is configured by connecting three-phase windings by a method of Y-letter wire connection (i.e., star-shaped connection). The stator winding **12** generates magnetic fluxes when power (i.e., AC power) is supplied from a power supply via an inverter (not shown). The stator winding **12** is configured by using multiple conductor segments **30** configured by including substantially U-shaped split conductors. Hereinafter, a segment structure of the stator winding **12** will be described in detail.

(17) FIG. **4** is a perspective view illustrating the conductor segments **30** (**30**) and a part of the stator core **11**. As shown in FIG. **4**, the conductor segment **30** has a pair of linear portions **31** and a turn portion **32** bent to connect the pair of linear portions **31** each other, thereby substantially forming a U-shape. Each of the pair of linear portions **31** has an overall length longer than an axial thickness of the stator core **11**. The conductor segment **30** is configured by using a rectangular conductor produced by coating a conductor having a rectangular cross section (i.e., a conductor having a pair of opposing planar portions) with an insulating film. A leading end of each of linear portions **31** serves as an exposed portion **33** where the conductor is exposed by removing the insulating film from the linear portion **31**.

(18) Then, multiple conductor segments **30** are inserted into given slots **23** of the stator core **11**, and are radially aligned therein in a row. In this embodiment, six layers of linear portions **31** of the conductor segments **30** are accommodated in the slots **23** as a laminate. The pair of linear portions **31** of the conductor segment **30** is housed in given two slots **23** separated by a given coil pitch, respectively. Among the entire portion of the linear portion **31**, a portion accommodated in the slot **23** corresponds to a slot inside coil section CS of the stator winding **12**. Here, in the slot **23**, an insulating sheet **24** is disposed to electrically insulate the stator core **11** from the stator winding **12** (i.e., the conductor segments **30**). Specifically, the insulating sheet **24** is disposed in the slot **23** between an inner peripheral surface (i.e., an inner wall surface) of the stator core **11** and the conductor segment **30** and is folded completely to surround multiple conductor segments **30** inserted into the slot **23**.

(19) Further, the pair of linear portions **31** of the conductor segment **30** are positioned in the two

respective slots **23** by relatively shifting a radial position by an amount of one coil. For example, when one of the linear portions **31** is accommodated at an n-th position counted from a radial back side (i.e., a side of the back yoke), the other one of the linear portions **31** is accommodated at a n+1-th position counted from the radial back side.

(20) Further, each conductor segment **30** is inserted into given slots **23** of the stator core **11** as described below. That is, the linear portion **31** of each conductor segment **30** is inserted from a first end of the stator core **11** out of first and second ends respectively located at both ends of the stator core **11** in the axial direction. Then, a leading end of each of the linear portions **31** protrudes from the second end of the stator core **11** in the axial direction. With this, facing the first end of the stator core **11**, one of coil ends CE**1** is formed by the turn portion **32** of the conductor segment **30**. By contrast, axially outside of the second end of the stator core **11**, the other one of coil end sections CE**2** is formed. That is, at the coil end section CE**2**, an opposite end (hereinafter simply referred to as a non-turn portion) of each linear portion **31** opposite to the turn portion **32** is bent in the circumferential direction and connected to a linear portion **31** of another conductor segment **30** as also bent. An outline of each of the coil ends CE**1** and CE**2** is illustrated in FIG. **2**.

(21) Next, an exemplary connection process of connecting conductor segments **30** at the coil end section CE**2** will be hereinbelow described in more detail. Initially, the exemplary connection process performed between conductor segments **30** will be briefly described.

(22) FIG. **5** is a diagram illustrating some conductor segments **30** housed in given slots **23**. In the drawing, the stator core **11** is shown by virtual lines, for convenience. As shown, non-turn portions of a pair of linear portions **31** of the conductor segment **30** protrude from the axial end face (i.e., an upper end face in the drawing) of the stator core **11**. The non-turn portions of the pair of linear portions **31** are then obliquely bent in the circumferential direction at a given angle formed from the core end face. Then, conductor exposed portions **33** located at leading ends of different conductor segments **30** respectively are joined together by welding, thereby causing the multiple conductor segments **30** to connect to each other.

(23) Further, as shown, at the coil end section CE**2**, a leading end of the conductor segment **30** extended in a first circumferential direction at an outside of the stator core **11** in the axial direction and a leading end of the other conductor segment **30** extended in a second circumferential direction opposite to the first circumferential direction are joined together. With this, at the coil end section CE**2**, a leading end of the linear portion **31** of the conductor segment **30** of the stator winding **12** is bent and extends obliquely to the axial direction and is folded back (i.e., turned) at a given top position. Hence, each of the linear portions **31** of the conductor segment **30** is bent differently as described below. That is, a leading end of a linear portion **31** closer to the non-turn portion is bent to the same side in the circumferential direction as the turn portion **32**. By contrast, a leading end of another linear portion **31** closer to the non-turn portion is oppositely bent in the circumferential direction in which the turn portion **32** is bent.

(24) Next, an exemplary configuration of a leading end of the conductor segment **30** will be described more in detail.

(25) FIGS. **6**A and **6**B are diagrams collectively illustrating a basic configuration of conductor segments **30** connected to each other. As shown in FIG. **6**A, the conductor segment **30** is configured by including a linear conductor **34** and an insulating film **35** covering the conductor **34**. The conductor **34** is exposed at a leading end of the conductor segment **30** to provide an exposed portion **33** of the conductor segment **30**. In the conductor segment **30**, a portion other than the exposed portion **33** serves as a covered portion **36** in which the conductor **34** is coated with the insulating film **35**. In the exposed portion **33**, an axial outer surface **33***a* providing an axially outer surface (i.e., an upper surface in the drawing) has an arc shape with a convex protruding outside in the axial direction. Further, each of surfaces of the exposed portion **33** other than the axial outer side **33***a*, that is, an axial inner side, a radial outer side, and a radial inner side of the conductor exposed portion **33** provide flat surfaces.

(26) Then, as shown in FIG. **6**B, the exposed portions **33** of the respective conductor segments **30** are superimposed and engaged with each other in the radial direction. Then, these the exposed portions **33** are joined together by laser welding maintaining the engaging state. In such a situation, the exposed portions **33** are joined to each other with the axial outer surfaces **33***a* substantially coinciding with each other. Then, laser welding is performed on the axial outer surfaces **33***a* (i.e., upper surfaces in the drawing) as the laser irradiation surface. Here, each of portions among the exposed portions **33** of the respective conductor segments **30** opposed to each other has a horizontally long shape longer in the circumferential direction than in the axial direction. Hence, at a time of laser welding, laser scanning is applied within a given range in the circumferential direction along an arc-shaped axial outer surface **33***a*.
(27) In such a situation, however, with the configuration shown in FIGS. **6**A and **6**B, there is a risk that an insulating film **35** of the covered portion **36** may unintentionally peel off at a boundary between the covered portion **36** and the exposed portion **33**. For example, when the exposed portion **33** is formed at a leading end of the conductor segment **30** by peeling off the insulating film **35**, a burr-like surplus portion can remain in the insulating film **35**. In such a situation, the insulating film **35** is likely to be accidentally peeled off when the surplus portion is caught by something. Also, the insulating film **35** may probably peel off when an exposed portion **33** of another conductor segment **30** comes into contact with an edge of the covered portion **36** closer to the leading end of the conductor. Here, in FIG. **6**, the edge of the insulating film **35** closer to the exposed portion **33** is chamfered, so that it is expected that the insulating film **35** can hardly peel off due to the chamfer.
(28) However, another configuration capable of more reliably suppressing peeling off of the insulating film **35** is demanded.
(29) Hence, according to one embodiment of the present disclosure, a plastic deformation depression **37** is formed at the edge of the covered portion **36** of the conductor segment **30** closer to the exposed portion **33**. The plastic deformation depression **37** has a depth measured from the insulating film **35** of the covered portion **36** to a part of the conductor **34** directly under the insulating film **35**. Hence, unintended peeling off of the insulating film **35** can be reduced or suppressed as described hereinbelow more in detail.
(30) FIGS. **7**A to **7**C are diagrams collectively illustrating a configuration of a leading end of the conductor segment **30** of the present disclosure obtained by partially modifying the configuration shown in FIGS. **6**A and **6**B. That is, FIG. **7**A is a diagram illustrating the leading end of the conductor segment **30** when viewed in the radial direction (i.e., viewed from a front side in FIG. **2**). FIG. **7**B is a diagram illustrating the leading end of the conductor segment **30** when viewed from an outside thereof in the axial direction (i.e., viewed from above the stator **10** in FIG. **2**). FIG. **7**C is a diagram illustrating a connected condition in which leading ends of the conductor segments **30** are engaged with each other.
(31) As shown in FIGS. **7**A and **7**B, each of the conductor segments **30** has the exposed portion **33** and the covered portion **36** as described earlier. Further, a depression **37** is formed as plastic deformation having a concaved shape at the boundary between the exposed portion **33** and the covered portion **36**. The depression **37** is an indentation (or impression) formed on both sides of the exposed portion **33** and the covered portion **36** across the boundary therebetween by pressing the conductor segment **30** from an outside thereof.
(32) To form the depressions **37** on the covered portion **36**, the conductor **34** and the insulating film **35** were crushed all together in the above configuration. By contrast, in the following configuration, only the conductor **34** of the exposed portion **33** is crushed. In such a situation, the depression **37** formed on the covered portion **36** has a given depth measured from the insulating film **35** to a part of the conductor **34** directly under the insulating film **35**. Hence, the edge of the insulating film **35** tightly adheres to the conductor **34**, and accordingly, the insulating film **35** rarely unintentionally peels off therefrom. In addition, since the edge of the insulating film **35** enters the

recess of the conductor **34**, the insulating film **35** rarely unintentionally peels off therefrom as well.
(33) The depression **37** is formed on each of sides of the cross section of the conductor segment **30** (i.e., around the cross section thereof). Here, the conductor segment **30** has two faces in the axial direction and two faces in the radial direction as an outer peripheral surface. Then, depressions **37** formed on the two faces in the axial direction are referred to as "depressions **37**A". By contrast, depressions **37** formed on the two sides in the radial direction are referred to as "depressions **37**B". When compared, each of depressions **37**A and **37**B has a different form from the other. However, in any of the faces, the depression **37** is commonly formed to have a given depth measured from the insulating film **35** to a part of the conductor **34** directly under the insulating film **35**. Further, these two sides of the conductor segment **30** in the axial direction correspond to a laser irradiation incidence face receiving an incidence of laser irradiation and a laser irradiation absent face located opposite to the laser irradiation incidence face. The pair of radial faces include an engaging surface at which exposed portions **33** of different conductor segments **30** are engaged and ultimately joined together.
(34) More specifically, as shown in FIG. **7**B, the depressions **37**A are formed on two opposite faces of the conductor segment **30** in the axial direction and are extended linearly in a direction orthogonal to a longitudinal direction of the conductor segment **30**. Further, among the plastic deformation depressions **37**A formed on the two axial faces, the depression **37**A formed on the axial outer surface (i.e., upper face in the drawing) is located farther from the leading end of the conductor segment **30** in the longitudinal direction (i.e., left and right directions in FIG. **7**A) thereof than the depression **37**A formed on the axial inner face (i.e., lower face the conductor segment **30** in the drawing).
(35) By contrast, as shown in FIG. **7**A, on each of two faces of the conductor segment **30** in the radial direction, a depression **37**B with a curvature forming a convex directed toward an opposite side to the leading end of the conductor segment **30** are formed between the depressions **37**A formed on the faces facing to the axial direction. Hence, the depressions **37**A and **37**B are continuously formed surrounding four faces of the conductor segment **30** as plastic deformations.
(36) Further, as shown in FIG. **7**C, in a situation where the exposed portions **33** of the two conductor segments **30** are superimposed radially, a leading end of the exposed portion **33** of one of the conductor segments **30** and the plastic deformation depression **37**B of the other one of the conductor segments **30** are opposed to each other in the longitudinal direction of the conductor segment **30**. With this configuration, the exposed portions **33** of the two conductor segments **30** as superimposed can be positioned in the circumferential direction.
(37) In particular, according to the present disclosure, since the plastic deformation depression **37**B has a convex curvature convex toward the opposite side to the leading end of the conductor segment **30**, the plastic deformation depression **37**B functions appropriately as a positioning portion positioning the exposed portion **33**. In such a situation, it is preferable if the plastic deformation depression **37**B has a circular groove formed around the conductor segment **30**, and a curved portion of the circular groove has substantially the same shape as a leading end of the exposed portion **33** of the conductor segment **30**.
(38) Further, as shown in FIG. **7**C, the conductor segments **30** are extended in the circumferential direction from opposite sides to each other and axially outward oblique to an axial end surface of the stator core **11**. Then, the exposed portions **33** of the leading ends of the conductor segments **30** are engaged and ultimately joined together. Hence, in such a situation, since a portion of the conductor segment **30** extends to the leading end, the portion thereof is increasingly located outside in the axial direction (i.e., upper side of the drawing), there is a risk that an edge of the covered portion **36** closer to the leading end of the conducting wire is highly likely to contact other parts than the stator **10** or the like after a stator winding **12** is attached to the stator core **11**. In view of this, according to this embodiment, as described earlier, the depression **37**A formed as the plastic deformation on the axial outer surface of the conductor segment **30** is positioned closer to the

opposite side to the leading end of the conductor segment **30** than the depression **37**A formed as the plastic deformation on the axial inner surface. Hence, the edge of the covered portion **36** (i.e., the depression **37**A) closer to the leading end of the conductor wire is unlikely to come into contact with other components than the stator **10** on the axial outer surface of the conductor segment **30**.
(39) Next, a process of producing the leading end of the conductor segment **30** will be described with reference to FIGS. **8**A and **8**B. A step of producing the leading end of the conductor segment **30** includes a first sub-step of forming a plastic deformation depression **37** and a second sub-step of producing an exposed portion **33**. Specifically, FIGS. **8**A to **8**C collectively illustrate a process of forming depressions **37** as plastic deformations. FIG. **8**D illustrates a step of producing the exposed portion **33**.
(40) Hereinbelow, a process of forming the depression **37** as the plastic deformation will be described with reference to FIG. **8**A. As shown in FIG. **8**A, a leading end (i.e., a left end in the drawing) of the conductor segment **30** is coated with an insulating film **35** before the depression **37** is formed thereon. Then, by pressing the insulating film **35** with a given cutting tool having a given shape from above the insulating film **35**, a depression **37** is formed as a plastic deformation. Here, among plastic deformation depressions **37** formed around the entire periphery of the conductor segment **30**, depressions **37**A are initially formed on two faces of the conductor segment **30** in the axial direction. Then, remaining depressions **37**B are formed on two radial faces of the conductor segment **30**.
(41) More specifically, as shown in FIG. **8**A, cutting tools T**1** and T**2** are pressed against two faces of the conductor segment **30** in the axial direction, respectively. At this moment, the cutting tools T**1** and T**2** are pressed against these sides to penetrate the insulating films **35** and bite into the conductor **34** of the conductor segment **30**. With this, as shown in FIG. **8**B, depressions **37**A are formed on the two faces in the axial direction at a depth measured from the insulating film **35** to a part of the conductor **34** directly under the insulating film **35**.
(42) Subsequently, as shown in FIG. **8**C, other depressions **37**B are formed on two radial faces in the radial direction. At this moment, although cutting tools pressed against these radial faces in the radial direction are not shown, each of the cutting tools has a curved cutting edge. Thus, the cutting tools penetrate the insulating films **35** and bite into the conductor **34** when pressed against the radial faces of the conductor segment **30**. With this, each of the depressions **37**B is formed on the radial surface at a depth measured from the insulating film **35** to a part of the conductor **34** directly under the insulating film **35**. As described heretofore, the depressions **37** are formed around a periphery of a cross section of the conductor segment **30** at the leading end thereof.
(43) Next, a process of producing the exposed portion **33** performed after forming the depressions **37** as the plastic deformation will be herein below described with reference to FIG. **8**D. This process includes a sub process of obtaining a given shape by punching the leading end of the conductor segment **30** and a sub process of peeling off the insulating film **35** from the conductor segment **30**. In FIG. **8**D, a hatched portion of the leading end of the conductor segment **30** is removed by punching. Hence, each of faces facing to the axial direction are formed into a given shape by the punching. At this moment, an upper face in the drawing is shaped into a convex arc state. Simultaneously, insulating films **35** extended from the depression **37**A to the leading end on the two faces of the conductor segment **30** in the axial direction are removed.
(44) Further, as shown by dots In FIG. **8**D, insulating films **35** partially remain on two radial faces, respectively, at the leading end of the segment after the punching process. Then, these portions of the insulating films **35** are removed by using a laser peeling process. That is, the insulating films **35** extended to the leading end from the depression **37**B are removed by using the laser peeling process from two radial faces facing to the radial direction. In this way, the exposed portion **33** is produced at the leading end of the conductor segment **30**.
(45) According to the above-described embodiment, the below described advantages can be obtained.

(46) First, as described earlier, the depression **37** as the plastic deformation is formed at the edge of the covered portion **36** of the conductor segment **30** closer to the leading end of the conducting wire, with at least a part of the insulating film **35** being crushed. Hence, with this configuration, since the edge of the insulating film **35** tightly adheres to the conductor **34**, the insulating film **35** is unlikely to peel off therefrom unintentionally. With this, the insulating film **35** on the covered portion **36** can be inhibited from peeling off from the conductor **34**, so that insulation reliability of the stator winding **12** can be ensured.
(47) Further, in particular, the depression **37** is formed at a depth measured from the insulating film **35** of the covered portion **36** to a part of the conductor **34** directly under the insulating film **35**. Hence, it is possible to reduce the risk of the insulating film **35** peeling.
(48) Further, in a configuration in which exposed portions **33** at leading ends of the respective conductor segments **30** extended from opposite sides in a circumferential direction, and are engaged and joined together, an edge of the insulating film **35** closer to a leading end of the conducting wire is likely to peel off due to contact between the conductor segments **30** or the like. However, since the depressions **37** are formed on the respective faces of the covered portion **36** in both the axial and radial directions at the edge thereof closer to the leading end of the conductor segment **30**, the insulating film **35** rarely peels off therefrom even if the conductor segments **30** mutually contact to each other, for example.
(49) Further, since the depression **37** formed at the edge of the covered portion **36** closer to the leading end of the conducting wire serves as a positioning portion for an exposed portion **33** when these exposed portions **33** are engaged with each other, the exposed portions **33** can be mutually precisely positioned. Further, if the edge of the covered portion **36** closer to the leading end of the conducting wire is used as a positioning tool in this way, another exposed portion **33** comes into contact with the edge of the covered portion **36** closer to the leading end of the conducting wires, thereby causing a risk that the insulating film **35** peels off due to contact. However, according to this embodiment of the present disclosure, since the depression **37** is formed at the edge of the covered portion **36** closer to the leading end of the conducting wire, the insulating film **35** can be inhibited from peeling off therefrom, even if another exposed portion **33** comes into contact with the edge of the covered portion **36** closer to the leading end of the conducting wires.
(50) Further, since a shape of the depression **37** (**37**B) formed at the edge of the covered portion **36** closer to the leading end of the conducting wire is substantially the same as that of the leading end of the exposed portion **33**, the exposed portion **33** can be precisely positioned. Further, it is also possible that the exposed portion **33** is inhibited from locally impacting against the depression **37**. Hence, a configuration capable of inhibiting an insulating film from peeling off can be advantageously obtained.
(51) Further, among the depressions **37**A formed on the two axial faces at the edge of the covered portions **36** closer to the leading end of the conducting wire (i.e., which is shown as the conductor **34**), the depression **37**A on the axial outer face is located closer to a position opposite to the leading end of the conducting wire in the longitudinal direction of the conductor segment **30** than the depression **37**A on the axial inner surface. With this, the edge (i.e., plastic deformation depressions **37**) of the covered portion **36** closer to the leading end of the conducting wire become less likely to contact the other components than the stator **10** or the like on the axial outer face of the conductor segment **30**. Accordingly, the insulating film **35** can be more appropriately inhibited from peeling off.
(52) The configuration of the above-described embodiment may be modified as will be hereinbelow described.
(53) First, as shown in FIG. **9**A, a recess **41** is essentially formed at a boundary between a covered portion **36** and an exposed portion **33** as a plastic deformation depression **37**. In addition, a protrusion **42** can be formed at a position on the exposed portion **33** closer to a leading end of the conducting wire than the recess **41**. FIG. **9**B is a cross-sectional view illustrating a conductor

segment **30** illustrated in FIG. **9**A, along a **9***b*-**9***b* line drawn in FIG. **9**A. With this, the protrusion **42** inhibits another conductor segment **30** or the like from coming into contact with the edge of the insulating film **35**. Hence, the insulating film **35** can be inhibited from peeling off.

(54) Here, the protrusion **42** may be formed successively after forming the depression **37**B as the plastic deformation in the process of forming the depression **37**B. That is, after pressing the cutting tool for use of forming a plastic deformation depression **37**B against a conductor segment **30** and forming the depression **37**A thereon, thereby partially generating a thicker portion in the exposed portion **33**, the cutting tool is shifted toward the leading end of the conducting wire while continuously pressing the cutting tool thereagainst, thereby forming a raised portion on the exposed portion **33**. Then, the raised portion is used as the protrusion **42**.

(55) A second modification is herein below described. In the above-described embodiment, the depression **37** is formed on the covered portion **36** and the exposed portion **33** at the boundary therebetween. However, such a configuration may be modified. For example, a depression **37** as a plastic deformation is formed only on the covered portion **36** near the boundary between the covered portion **36** and the exposed portion **33**. That is, the depression **37** is not formed on the exposed portion **33** even near the boundary.

(56) A third modification is herein below described. In the above-described embodiment, the depression **37** is formed at the edge of the covered portion **36** of the conductor segment **30** closer to the exposed portion **33** to have a given depth measured from the insulating film **35** of the covered portion **36** to a part of the conductor **34** directly under the insulating film **35**. However, such a configuration can be modified. For example, as shown in FIG. **10**, a depression **37** as a plastic deformation can be formed only on the insulating film **35** at the edge of the covered portion **36** closer to the exposed portion **33**. That is, the depression **37** as the plastic deformation may be formed at the edge of the covered portion **36** closer to the exposed portion **33**, but is not formed directly under the insulating film **35**.

(57) Fourthly, In the above-described embodiment, the plastic deformation depressions **37** are formed over (i.e., around) the entire circumference of the cross section at the covered portion **36**. However, such a configuration may be modified. For example, one or more plastic deformation depressions **37** can be formed on one, two, or three sides of a cross-sectional surface in the covering portion **36**. That is, it is sufficient if the plastic deformation depression **37** is formed on one or more sides of the cross section of the end.

(58) Further, in a situation in which the plastic deformation depression **37** is formed on one or more sides of the cross section of the end, it is preferable if the plastic deformation depression **37** is formed over the entire side, that is, from one edge to the other edge in the side.

(59) In the above-described embodiment, in the stator winding **12**, the exposed portions **33** are formed at the leading ends of each conductor segment **30** extended in the circumferential directions, and the exposed portions **33** of the leading ends **33** extended in the circumferential directions respectively are joined together by welding. However, this can be modified. For example, the leading end of each of conductor segments **30** is bent and extended outwardly in the axial direction, and exposed portions included in the leading ends respectively may be joined together by welding.

(60) Fifthly, the stator winding **12** may not have a structure of the segment. Then, depressions as plastic deformations may be formed at an edge of the covered portion closer to the exposed portion, other than the exposed portion and the weld portion. Then, a conductor directly under an insulation film of the covered portion. Further, a round wire conductor made of conductor having a round cross section coated with an insulating film may be used. That is, multiple conductor wires are connected by welding to obtain each of phase windings for each phase of the stator winding **12**.

(61) Numerous additional modifications and variations of the present disclosure are possible in light of the above teachings. It is hence to be understood that within the scope of the appended claims, the present disclosure may be performed otherwise than as specifically described herein.

For example, the present disclosure is not limited to the above-described stator and may be altered as appropriate.

Claims

1. A stator comprising: a stator core; and a stator winding installed in the stator core, the stator winding being configured by including multiple conducting wires constituted by conductors respectively coated with insulating films, each of the conducting wires comprising: an exposed portion at a leading end, where the conductor is exposed; and a covered portion in which the conductor remains coated with an insulating film, wherein a pair of exposed portions of different conducting wires are joined together at a coil end section of the stator winding, wherein the covered portion of each conducting wire of the different conducting wires has a depression as a plastic deformation at an edge thereof corresponding to the leading end of the conducting wire, wherein the depression of the covered portion is formed by crushing the conductor and the insulating film all together on the covered portion, and has a given depth measured from the insulating film of the covered portion to a part of the conductor directly under the insulating film, wherein an edge of the insulating film enters a depressed part of the conductor at which the depression of the covered portion is formed, wherein the exposed portion has a depression, wherein the depression of the covered portion and the depression of the exposed portion are formed across a boundary of the depression of the covered portion and the depression of the exposed portion, and wherein a depth of the depression of the covered portion at the boundary is deeper than an adjacent part that is not depressed to the boundary of the exposed portion.
2. The stator as claimed in claim 1, wherein the conducting wire is a rectangular conducting wire having a rectangular cross-section, wherein the coil end section is configured by connecting a leading end of the conducting wire extended in a first circumferential direction and a leading end of the other conducting wire extended in a second circumferential direction opposite to the first circumferential direction at an outside of the stator core in an axial direction of the stator core, wherein the exposed portions of the different conducting wires are engaged side by side with each other in a radial direction of the stator core and are joined together by welding, and wherein the depression of the covered portion is formed on surfaces of the covered portion, facing to the axial direction and the radial direction, respectively, at the edge of the covered portion corresponding to the leading end of the conducting wire in each of the different conducting wires.
3. The stator as claimed in claim 2, wherein the depression of the covered portion formed on a radial face at the edge of the covered portion of each of the different conducting wires serves as a positioning member for positioning the exposed portion when the exposed portions of different conducting wires are joined together.
4. A stator comprising: a stator core; and a stator winding installed in the stator core, the stator winding being configured by including multiple conducting wires constituted by conductors respectively coated with insulating films, each of the conducting wires having; an exposed portion at a leading end, where the conductor is exposed, and a covered portion in which the conductor remains coated with the insulating film, wherein a pair of exposed portions of different conductor wires are joined together at a coil end section of the stator winding, wherein the covered portion of each of the different conducting wires has a depression as a plastic deformation at an edge thereof closer to the leading end of the conducting wire, the depression being formed by crushing a part of the insulating film at the edge of the covered portion, wherein the conducting wire is a rectangular conducting wire having a rectangular cross-section, wherein the coil end section is configured by connecting a leading end of the conducting wire extended in a first circumferential direction and a leading end of the other conducting wire extended in a second circumferential direction opposite to the first circumferential direction at an outside of the stator core in an axial direction of the stator core, wherein the exposed portions of the different conducting wires are engaged side by side with

each other in a radial direction of the stator core and are joined together by welding, wherein the depression is formed on surfaces of the covered portion, facing to the axial direction and the radial direction, respectively, at the edge of the covered portion corresponding to the leading end of the conducting wire in each of the different conducting wires, wherein the conducting wires extended in the first and second circumferential directions are extended outwardly in the axial direction obliquely to an axial end face of the stator core at a given angle, wherein among the two depressions formed on two opposite surfaces perpendicular to the axial direction at the edge of the covered portion closer to the leading end of the conducting wire, the depression formed on an axial inner surface is located closer to the leading end of the conducting wire in a longitudinal direction of the conducting wire than the depression formed on an axial outer surface is.

5. The stator as claimed in claim 1, wherein the exposed portion is configured to include: a recess as the depression of the exposed portion; and a protrusion formed closer to the leading end of the conducting wire than the recess is.