DESCRIPTION

TITLE OF INVENTION: ROTOR CORE, ROTOR, ROTARY ELECTRIC MACHINE, AND PRESSURIZING JIG

TECHNICAL FIELD

[0001]

The present invention relates to a rotor core, a rotor, a rotary electric machine, and a pressurizing jig.

The present application claims priority based on Japanese Patent Application No. 2024 063432 filed in Japan on April 10, 2024, the contents of which are incorporated herein by reference.

BACKGROUND ART

[0002]

With the progress of electrification of automobiles, a motor is desired to be small and have high output. In order to increase the output of the motor, for example, an increase in rotation speed is considered. With the increase in rotation speed, a larger centrifugal force is generated in the rotor core of the motor, and thus, it is necessary to enhance centrifugal force resistance by applying a high-strength electrical steel sheet or the like. For example, Patent Document 1 discloses a technique in which slits formed at both end portions of a permanent magnet are filled with resin to improve centrifugal force resistance strength by relaxing stress concentration due to contact between the permanent magnet and the slits. In addition, Patent Document 2 discloses a technique for bonding a magnet and a rotor core by an adhesive directly coated on the magnet. Patent Document 3 discloses a technique in which a stress concentration portion is strengthened by work hardening, and a thinned portion is filled with an adhesive to enhance work strengthening and heat removal

properties.

Citation List

Patent Documents

[0003]

Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2002-359942

Patent Document 2: Japanese Unexamined Patent Application, First Publication No. 2003-199303

Patent Document 3: Japanese Unexamined Patent Application, First Publication No. 2005-94940

SUMMARY OF INVENTION

Technical Problem

[0004]

The strength and magnetic characteristics of the electrical steel sheet forming the rotor core are in a trade-off relationship. Therefore, when high-strengthening of the electrical steel sheet itself is performed in order to improve the centrifugal force resistance of a bridge portion supporting the magnet, portions other than the bridge portion also have unnecessarily high strength, and the magnetic characteristics are deteriorated. For this reason, it is conceivable to improve centrifugal force resistance by increasing only the width of the bridge portion, but an increase in the amount of magnetic flux flowing back through the bridge portion is allowed. Therefore, the amount of magnetic flux between the rotor and the stator that contributes to the improvement in torque decreases, and as a result, the performance of the motor deteriorates.

[0005]

The present disclosure has been made in view of the above-described problems,

and an object of the present disclosure is to provide a rotor core, a rotor, and a rotary electric machine capable of improving centrifugal force resistance and characteristics.

Solution to Problem

[0006]

<1> A rotor core according to an embodiment of the present disclosure includes: a plurality of laminated electrical steel sheets; a fixing portion that fixes the electrical steel sheets adjacent to each other in a lamination direction together; and a first adhesive portion that is partially provided in a region different from the fixing portion between the electrical steel sheets and has a fixing strength different from a fixing strength of the fixing portion, in which the electrical steel sheet includes a first portion that is required to have a higher strength than that of other portions, the first portion includes a bridge portion, and the first adhesive portion is provided so as to cover the first portion of the electrical steel sheet.

<2> In the rotor core according to <1>, each of the electrical steel sheets may have one or more through-holes for installing a permanent magnet constituting each of a plurality of magnetic poles, and the first portion may include a first bridge portion formed between an outer circumferential edge of the electrical steel sheet and the through-hole.

<3> In the rotor core according to <1> or <2>, each of the electrical steel sheets may have a plurality of through-holes for installing a plurality of permanent magnets constituting each of a plurality of magnetic poles, and the first portion may include a second bridge portion formed between two adjacent through-holes in each of the magnetic poles.

<4> In the rotor core according to any one of <1> to <3>, the fixing portion may be a second adhesive portion that is provided between the electrical steel sheets adjacent to each other in the lamination direction and bonds the electrical steel sheets together, and compressive stress remaining in the first portion where the first adhesive portion is

provided may be greater than compressive stress remaining in the second adhesive portion.

<5> In the rotor core according to <4>, the second adhesive portion may be provided to cover a remaining region without the first adhesive portion between the electrical steel sheets adjacent to each other.

<6> In the rotor core according to <5>, the fixing portion may be a second adhesive portion in which a second adhesive different from a first adhesive that becomes the first adhesive portion when solidified is solidified, and may be partially provided between the electrical steel sheets.

<7> In the rotor core according to any one of <1> to <4>, the fixing portion may be a crimping portion.

<8> A rotor according to an embodiment of the present disclosure includes: the rotor core according to any one of <1> to <7>; a permanent magnet that is installed in the rotor core; and a rotary shaft that is fixed to the rotor core.

<9> A rotary electric machine according to an embodiment of the present disclosure includes: the rotor according to <8>; and a stator.

<10> A pressurizing jig according to an embodiment of the present disclosure is a pressurizing jig that is used for manufacturing a laminated core having a first adhesive portion and a second adhesive portion, the pressurizing jig including: a pressing surface that presses the first adhesive portion and the second adhesive portion, in which in the pressing surface, a first pressing portion corresponding to the first adhesive portion protrudes more than a second pressing portion corresponding to the second adhesive portion.

Advantageous Effects of Invention

[0007]

The present disclosure provides a rotor core, a rotor, and a rotary electric machine

capable of improving centrifugal force resistance and characteristics.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

[FIG. 1] A cross-sectional view illustrating a rotor core according to an embodiment of the present disclosure.

[FIG. 2] An enlarged cross-sectional view of the rotor core illustrated in FIG. 1.

[FIG. 3] A diagram illustrating a calculation result of generated stress of a second bridge portion.

[FIG. 4] A graph showing calculation results of the rotation speed and the maximum principal stress.

[FIG. 5] A diagram illustrating a relationship between the width of the second bridge portion and the average torque in one period.

[FIG. 6] A graph showing calculation results of the rotation speed and the maximum principal stress.

[FIG. 7] A diagram illustrating a relationship between the width of a first bridge portion and the maximum principal stress.

[FIG. 8] A diagram illustrating a relationship between the width of the first bridge portion and average torque in one period.

[FIG. 9] A cross-sectional view illustrating a pressurizing jig according to an embodiment of the present disclosure.

DESCRIPTION OF EMBODIMENTS

[0009]

Hereinafter, a rotor core, a rotor, and a rotary electric machine according to an embodiment of the present disclosure will be described with reference to the drawings. A rotary electric machine 100 according to the present disclosure is, for example, an electric

motor (motor) or a generator. Specifically, examples of the electric motor include an AC electric motor, more specifically a synchronous electric motor, and still more specifically a permanent magnet field type electric motor such as an interior magnet type. Such a type of electric motor is adopted appropriately in, for example, an electric vehicle.

[0010]

FIG. 1 is a cross-sectional view illustrating the rotary electric machine 100 according to the present embodiment.

As illustrated in FIG. 1, the rotary electric machine 100 includes a stator 20 and a rotor 30. The rotor 30 includes a rotor core 31, a permanent magnet 32, and a rotary shaft 60. The stator 20 includes a stator core 21 and a winding (not illustrated). The rotor 30 is disposed coaxially with the stator 20 (stator core 21), for example, on the inside in a radial direction. The rotary electric machine 100 of the embodiment illustrated in FIG. 1 is an inner rotor type in which the rotor 30 is disposed inside the stator 20, but may be an outer rotor type in which the rotor 30 is disposed outside the stator 20.

[0011]

Hereinafter, a direction in which a central axis O of the rotary shaft 60 extends (a lamination direction of a laminated core 1 described later) is referred to as an axial direction, a direction orthogonal to the central axis O (a radial direction of the laminated core 1) is referred to as a radial direction, and a direction around the central axis O (a circumferential direction of the laminated core 1) is referred to as a circumferential direction.

[0012]

More specifically, the stator core 21 includes an annular shape (ring-shaped) core back portion 22 and a plurality of tooth portions 23.

The core back portion 22 is formed in a ring shape in a plane view (FIG. 1) in which the stator core 21 is viewed from the axial direction.

The plurality of tooth portions 23 protrude toward the inside in the radial direction from the core back portion 22 (toward the central axis O of the core back portion 22 along the radial direction). The plurality of tooth portions 23 are disposed at equal intervals in the circumferential direction. In the present embodiment, 48 tooth portions 23 are provided every 7.5 degrees of the central angle about the central axis O. The plurality of tooth portions 23 are formed in an equal shape and an equal size.

A winding (not illustrated) is wound around each tooth portion 23 to constitute the stator 20. The winding may be concentratedly wound or may be distributedly wound.

[0013]

On the other hand, the rotor 30 includes the rotor core 31, a plurality of permanent magnets 32 installed in the rotor core 31, and the rotary shaft 60 fixed to the rotor core 31.

The rotor core 31 is formed in an annular shape (ring shape), and the rotary shaft 60 is fixed to the center of the ring shape. In addition, in the rotor core 31, for example, one permanent magnet 32 or a set of a plurality of permanent magnets 32, such as a set of two permanent magnets 32, forms one magnetic pole, and a plurality of magnetic poles are disposed at equal intervals in the circumferential direction. The number of poles, the number of slots, the number of phases, and the like of the motor core can be appropriately changed. In the embodiment illustrated in FIG. 1, two permanent magnets 32 forming each magnetic pole are disposed in a V shape protruding toward the inside in the radial direction in the plane view.

[0014]

Further, a plurality of permanent magnets 32 are installed in a plurality of through-holes 33 formed in the rotor core 31 and penetrating the rotor core 31 in the axial direction. Each permanent magnet 32 is fixed to the rotor core 31 in a state of being disposed in the corresponding through-hole 33. Each permanent magnet 32 can be fixed to the rotor core

31, for example, by bonding an outer surface of the permanent magnet 32 to an inner surface of the through-hole 33 with an adhesive.

[0015]

Describing the through-hole 33 in detail, as illustrated in FIG. 1, each through-hole 33 may include an installation region of the permanent magnet 32 and a flux barrier 34. The flux barrier 34 is a magnetic gap portion penetrating the rotor core 31 in the axial direction, and reduces a magnet magnetic flux (hereinafter, also referred to as a reflux magnetic flux) from the permanent magnet 32 returning in the rotor 30 or changes an inflow path of the magnet magnetic flux from the permanent magnet 32 to the stator 20. In FIG. 1, the flux barriers 34 are provided on both sides of the installation region of the permanent magnet 32 in the through-hole 33. Accordingly, the magnet magnetic flux of the permanent magnet 32 (hereinafter simply referred to as a magnet magnetic flux) is effectively transmitted to the stator 20, which causes high torque to be output. It can also be said that the flux barrier 34 guides the magnet magnetic flux to the stator 20.

[0016]

In addition, at least one of the rotor core 31 or the stator core 21 described above is the laminated core 1 constituted by a plurality of laminated electrical steel sheets 10. Various holes are formed in each of the electrical steel sheets 10 forming the laminated core 1, and the above-described through-holes 33 and the like are formed by laminating the plurality of electrical steel sheets 10 to connect the various holes in the axial direction.

[0017]

The thickness of each electrical steel sheet 10 forming the laminated core 1 is appropriately determined in consideration of an iron loss improving effect, a manufacturing cost, press punching workability, and the like. In addition, each of the electrical steel sheets 10 forming the laminated core 1 is formed by, for example, punching

an electrical steel sheet serving as a base metal. As the electrical steel sheets 10, a known electrical steel sheet can be used. The chemical composition of the electrical steel sheet 10 is not particularly limited. In the present embodiment, as the electrical steel sheet 10, a non-oriented electrical steel sheet (for example, JIS C 2552:2014 or the like) is adopted, but a grain-oriented electrical steel sheet (for example, JIS C 2553:2019 or the like) may be adopted. In order to improve the workability of the electrical steel sheet and iron loss of the laminated core, insulating coatings are provided on both surfaces of the electrical steel sheet 10. A substance and a thickness (a thickness per one surface of the electrical steel sheet 10) constituting the insulating coating are appropriately determined in consideration of insulation performance, a space factor, and the like in the electrical steel sheets 10 laminated to each other.

[0018]

Next, the present invention will be described in detail with an example in which the laminated core 1 is the rotor core 31.

As illustrated in FIG. 1, the rotor core 31 includes a fixing portion 11 and a first adhesive portion 12A.

[0019]

The fixing portion 11 fixes the electrical steel sheets 10 adjacent to each other in the lamination direction together. For example, the fixing portion 11 may be a crimping, or may be an adhesive portion in which an adhesive is solidified (cured). The adhesive portion bonds and fixes the electrical steel sheets 10 together. Alternatively, other objects may be used. When the fixing portion 11 is a crimping, a plurality of crimpings may be provided at intervals along the circumferential direction of the laminated core 1. When the fixing portion 11 is an adhesive portion, examples of the type of adhesive to be used include a thermosetting adhesive by polymerization bonding, an acrylic-based adhesive, a room-

temperature curing adhesive, an anaerobic adhesive, an instantaneous adhesive, and an elastomer-containing acrylic-based adhesive.

[0020]

The first adhesive portion 12A is formed by solidifying (curing) the adhesive, and is partially provided in a region different from the fixing portion 11 between the electrical steel sheets 10. The type of the adhesive forming the first adhesive portion 12A may be a type different from the adhesive used when the fixing portion 11 is an adhesive portion. That is, a first adhesive 12Ag forming the first adhesive portion 12A and a second adhesive 12Bg forming the fixing portion 11 may be different adhesives. In addition, the same type of adhesive may be used by using an adhesive of a type that exhibits bonding strength corresponding to the magnitude of pressure applied during bonding. That is, the first adhesive 12Ag forming the first adhesive portion 12A and the second adhesive 12Bg forming the fixing portion 11 may be the same adhesive.

[0021]

Furthermore, the first adhesive portion 12A and the fixing portion 11 have different fixing strengths. The fixing strength here is strength (fixing force) for fixing the electrical steel sheets 10 together, and differs depending on the type of a fixing method. For example, the fixing strength by crimping is different from the fixing strength (bonding strength) by an adhesive. If the bonding strength varies depending on the type of adhesive, a difference in pressure during bonding, or the like, it is considered that the compressive stress (described later) applied to the electrical steel sheet 10 also varies, and thus the fixing strength varies. On the other hand, when the bonding strength is the same, the fixing strength is the same. In addition, although the first adhesive portion 12A is formed by solidifying (curing) the adhesive, the adjacent electrical steel sheets 10 may be bonded and fixed together. Alternatively, the first adhesive portion 12A may be solidified without

bonding the adjacent electrical steel sheets 10 together, and the fixing strength in this case may be 0.

[0022]

Here, the electrical steel sheet 10 constituting the rotor core 31 has a portion (hereinafter, a first portion 13) requiring relatively higher strength than other portions. The portion requiring a higher strength than the other portions is, for example, a portion that supports the permanent magnet 32 from a large stress generated in the bridge portion 14 supporting the permanent magnet 32 when a centrifugal force having a magnitude corresponding to the rotation speed acts on the permanent magnet 32 at the time of rotation of the laminated core 1. Examples of such a portion include a bridge portion 14. Therefore, the first portion 13 may include the bridge portion 14. Note that the thickness (sheet thickness) of the electrical steel sheet 10 forming the bridge portion 14 is the same as that of the other portions of the electrical steel sheet 10, and it is not necessary to perform work hardening in a sheet thickness direction.

[0023]

Furthermore, the first adhesive portion 12A is provided so as to cover the first portion 13 of the electrical steel sheet 10. The first adhesive portion 12A may be provided so as to cover the first portion 13 by being continuously provided over the entire first portion without being divided in the first portion 13. Alternatively, the first adhesive portion 12A may be divided into a plurality of parts in the first portion 13. That is, the first adhesive portion 12A is only required to be provided over the entire first portion 13. In other words, the first adhesive portion 12A is only required to be provided so as to cover most of the first portion 13. Alternatively, the first adhesive portion 12A is only required to be provided so as to cover the entire first portion 13.

As long as the first adhesive portion 12A is provided over the entire first portion

13, the first adhesive portion 12A may be divided into a plurality of solidified portions that are separated from each other and in which the adhesive is solidified. The plurality of solidified portions may be regularly provided, for example, in a dotted shape, a staggered shape, a broken line shape, an inclined shape, or the like, or may be irregularly provided.

[0024]

When the laminated core 1 rotates, a centrifugal force having a magnitude corresponding to the rotation speed acts on the permanent magnet, so that a large stress is generated in the bridge portion 14 supporting the permanent magnet 32. The first adhesive portion 12A provided on the first portion 13 of the electrical steel sheet 10 improves the strength of the first portion 13 by applying the compressive stress to the first portion 13 when the applied adhesive is solidified. Therefore, since the bridge portion 14 can be high-strengthened, a necessary strength can be secured even if the width of the bridge portion 14 is narrowed. Therefore, if the width of the bridge portion 14 is made narrower, the reflux magnetic flux through the bridge portion 14 can be reduced by that amount, so that the characteristics of the rotary electric machine 100 including the rotor core 31 can be improved.

[0025]

In the embodiment illustrated in FIG. 1, the fixing portion 11 is formed of an adhesive portion (hereinafter, the adhesive portion serving as the fixing portion 11 is referred to as a second adhesive portion 12B), and is provided on the entire portion (region) of the electrical steel sheet 10 other than the first portion 13 in the plane view. In addition, the first adhesive portion 12A is the bridge portion 14. The thickness (sheet thickness) of the electrical steel sheet 10 forming the bridge portion 14 is the same as that of the other portions of the electrical steel sheet 10.

[0026]

At this time, the bonding strength of the first adhesive portion 12A is greater than the bonding strength of the second adhesive portion 12B. In other words, the compressive stress remaining in the first portion 13 where the first adhesive portion 12A is provided is greater than the compressive stress remaining in the second adhesive portion 12B.

The compressive stress can be measured by, for example, an X-ray diffraction method (such as an XRD method). The X-ray diffraction method is described in detail in the following document. Document [Standard for X-ray Stress Measurement Method (2002 version), Iron and Steel ed. (JSMS SD-5-02:2002), published by The Society of Materials Science, Japan]

In the laminated core 1, when the compressive residual stress is a predetermined threshold (for example, 3 MPa, 5 MPa, or the like) or more as compared with other regions, it can be recognized as a region (first adhesive portion 12A) having a large bonding force. The threshold may be set to a value larger than a variation range of the measurement value such as a measurement error.

[0027]

The region (first adhesive portion 12A) having a large bonding force is pressed by a protrusion of a pressurizing jig 200 described later. Therefore, there is a possibility that a dimple is generated as compared with other regions. That is, there is a possibility that, in the region where the bonding force is large, the first adhesive portion 12A becomes thinner than the second adhesive portion 12B by being strongly pressurized. Therefore, a method is considered which confirms and recognizes the region (first adhesive portion 12A) having a large bonding force, for example, by observing the surface or cross section of the laminated core 1. Furthermore, in this method, it is also possible to confirm and recognize the region (first adhesive portion 12A) in which the bonding strength is changed by partial pressurization.

[0028]

For example, a method is also considered which confirms that the bonding strength of the first adhesive portion 12A is greater than the bonding strength of the second adhesive portion 12B in a test (JIS) of the bonding strength such as a peel bonding strength test of an adhesive.

In addition, the bonding strength of the first adhesive portion 12A or the second adhesive portion 12B may be measured by a shear strength measurement method. In the shear strength measurement method, for example, Autograph AGS-10kNX (Shimadzu Corporation) is used as a tensile tester. Test conditions are as follows. That is, the tensile form is a shear tensile test, the tensile temperature is 25°C, and the tensile speed is 50 mm/min. In the measurement of the shear strength, a tensile test is performed until fracture of a test piece (the first adhesive portion 12A or the second adhesive portion 12B), and when a plurality of test pieces can be taken, the average value of maximum strengths until fracture of each test piece is taken as a shear bonding strength. Furthermore, a value obtained by dividing the obtained value of the shear bonding strength by a bonding area is determined as room-temperature bonding strength. Accordingly, it is also possible to confirm that the bonding strength of the first adhesive portion 12A is greater than the bonding strength of the second adhesive portion 12B.

[0029]

Such distribution of the compressive stress on the electrical steel sheet 10 in the plane view can be formed, for example, when, in a state where one type of adhesive that exhibits bonding strength corresponding to the magnitude of the pressure applied at the time of bonding is applied to at least a part between two electrical steel sheets 10 at the time of manufacturing the laminated core 1, the adhesive is solidified (cured) in a state where the pressure applied in the lamination direction is varied between the first portion

13 of the electrical steel sheet 10 and the other region. For example, the distribution of the compressive stress on the electrical steel sheet 10 (the pressure distribution on the surface of the electrical steel sheet 10 applied at the time of manufacturing) may be formed by using the pressurizing jig 200 or the like described later. Accordingly, while the laminated core 1 is appropriately bonded and fixed by the second adhesive portion 12B (fixing portion 11), a compressive stress is applied by the first adhesive portion 12A, thereby realizing high-strengthening of the bridge portion 14.

[0030]

However, the present invention is not limited to the above-described embodiment. The second adhesive portion 12B constituting the fixing portion 11 may bond and fix at least a part of a region other than the first adhesive portion 12A. At this time, the bonding strength (the compressive stress applied to the first portion 13) between the first adhesive portion 12A and the second adhesive portion 12B may be the same or different. In addition, the adhesives used for both may be the same or different. That is, the fixing portion 11 may be constituted by the second adhesive portion 12B in which the same adhesive as the first adhesive 12Ag that becomes the first adhesive portion 12A when solidified is solidified. Alternatively, the fixing portion 11 may be constituted by the second adhesive portion 12B in which the second adhesive 12Bg different from the first adhesive 12Ag that becomes the first adhesive portion 12A when solidified is solidified.

[0031]

In addition, in the present embodiment, the first adhesive portion 12A bonds the adjacent electrical steel sheets 10 together, but the first adhesive portion 12A is intended for partial high-strengthening of the bridge portion 14, and the adjacent electrical steel sheets 10 may not be bonded together.

[0032]

According to the above-described constitution, the first adhesive portion 12A is provided so as to cover the bridge portion 14 (first portion 13) which is a part requiring relatively higher strength than other portions of the rotor core 31. The first adhesive portion 12A provided on the first portion 13 of the electrical steel sheet 10 can improve the strength of the first portion 13 by applying the compressive stress to the first portion 13 when the applied adhesive is solidified. Accordingly, since the bridge portion 14 can be high-strengthened, the width of the bridge portion 14 can be further narrowed within a range in which the centrifugal force resistance required at the time of rotation can be secured, and the reflux magnetic flux through the bridge portion 14 can be more effectively reduced. Therefore, by using such a rotor core 31, the centrifugal force resistance and characteristics of the rotary electric machine 100 can be improved.

[0033]

Hereinafter, a specific example of the bridge portion 14 in the first portion 13 will be described.

(First bridge portion 14A)

The first portion 13 may include a first bridge portion 14A formed between an outer circumferential edge 16 of the electrical steel sheet 10 and the through-hole 33 (see FIGS. 1 and 2). The first bridge portion 14A includes a portion of the electrical steel sheet 10 sandwiched between the outer circumferential edge 16 of the electrical steel sheet 10 and the through-hole 33, and portions of the electrical steel sheet 10 on both sides thereof are connected via the first bridge portion 14A on the outer circumferential edge 16 side of the electrical steel sheet 10. Furthermore, the above-described first adhesive portion 12A is provided so as to cover the first bridge portion 14A.

[0034]

When the laminated core 1 rotates, a large centrifugal force is generated in the

permanent magnet 32, but the strength of the first bridge portion 14A is improved by providing the first adhesive portion 12A. Furthermore, the width (the length in the radial direction) of the first bridge portion 14A is determined on the premise of the strength of the first bridge portion 14A improved by the first bridge portion 14A. That is, as compared with a case where the first adhesive portion 12A is not provided in the first bridge portion 14A, the first bridge portion 14A can withstand strong centrifugal force due to high-strengthening, and thus the width of the first bridge portion 14A provided with the first adhesive portion 12A is made narrower than that in a case where the first adhesive portion 12A is not provided. Therefore, the reflux magnetic flux through the first bridge portion 14A can be more effectively reduced.

[0035]

According to the above constitution, the first adhesive portion 12A is provided in the first bridge portion 14A. Accordingly, the centrifugal force resistance of the rotor core 31 can be improved. In addition, in the first bridge portion 14A provided with the first adhesive portion 12A, the width of the first bridge portion 14A is made smaller than that in a case where the first adhesive portion 12A is not provided, so that characteristics of the rotary electric machine 100 and the like can be improved.

[0036]

(Second bridge portion 14B)

The first portion 13 may include a second bridge portion 14B formed between two adjacent through-holes 33 in each of the magnetic poles (see FIGS. 1 to 3). As illustrated in FIGS. 1 to 3, in each magnetic pole, a plurality of through-holes 33 are disposed adjacent to each other so as to have a portion closest to each other. The second bridge portion 14B includes a portion of the electrical steel sheet 10 that is narrowed by being sandwiched between a pair of most adjacent through-holes 33, and portions of the electrical steel sheet

10 in the radial direction of the through-holes 33 are connected to each other via the second bridge portion 14B. In FIGS. 1 to 3, the second bridge portion 14B is formed along the radial direction on a V-shaped distal end side of a pair of through-holes 33. Furthermore, the first adhesive portion 12A described above is provided on the second bridge portion 14B so as to cover the second bridge portion 14B.

[0037]

According to the above constitution, the first adhesive portion 12A is provided in the second bridge portion 14B. Accordingly, similarly to the case already described in the first bridge portion 14A, the second bridge portion 14B can be high-strengthened as compared with a case where the first adhesive portion 12A is not provided in the second bridge portion 14B. Therefore, the width of the second bridge portion 14B provided with the first adhesive portion 12A can be narrowed as compared with a case where the first adhesive portion 12A is not provided, and the characteristics of the rotary electric machine 100 can be improved.

[0038]

Note that in the embodiment illustrated in FIGS. 1 to 3, the first adhesive portion 12A is provided in both the first bridge portion 14A and the second bridge portion 14B, but the present invention is not limited to the present embodiment, and the first adhesive portion 12A may be provided only in the first bridge portion 14A or only in the second bridge portion 14B.

[0039]

[Examples]

The generated stress of the second bridge portion 14B was calculated. FIG. 3 illustrates a calculation result of generated stress around the second bridge portion 14B. In FIG. 3, a dark color portion is a portion having small generated stress, and a light color

portion is a portion having large generated stress. The maximum value was obtained on both ends 33a of the second bridge portion 14B in the radial direction.

[0040]

FIG. 4 illustrates calculation results of a rotation speed and a maximum principal stress when the width w of the second bridge portion 14B is changed. In FIG. 4, the horizontal axis represents the rotation speed (rpm), and the vertical axis represents the maximum principal stress (MPa). In FIG. 4, with respect to the width w of the second bridge portion 14B, a reference value of the width w is "1", and a case where the width w is 1 times the reference value "1" is expressed as "w1", a case where the width w is 0.57 times the reference value "1" is expressed as "w0.57", and a case where the width w is 0.35 times the reference value "1" is expressed as "w0.35". For example, from the comparison of the results of w1 and w0.57, when the width w of the second bridge portion 14B decreases by 43% at a predetermined maximum rotation speed (a rotation speed at which yield stress is generated as the maximum principal stress at w1) of the motor, the generated stress increases by about 50%.

[0041]

FIG. 5 illustrates a relationship between the width w of the second bridge portion 14B and average torque (N·m) in one period. In FIG. 5, the horizontal axis represents a "bridge width", which is the width w of the second bridge portion 14B, and the vertical axis represents the average torque (N·m) in one period.

For example, from the comparison of the results of w1 and w0.83, it has been found that a torque increase of about 1% can be expected by narrowing the width w of the second bridge portion 14B by 17%.

[0042]

FIG. 6 illustrates calculation results of the rotation speed and the maximum

principal stress when the width w (see FIGS. 2 and 3) of the second bridge portion 14B is fixed and a width b of the first bridge portion 14A in the radial direction is changed. In FIG. 7, the horizontal axis represents the rotation speed (rpm), and the vertical axis represents the maximum principal stress (MPa). In FIG. 6, with respect to the width b of the first bridge portion 14A, a reference value of the width b (see FIG. 2) is set to "1", and cases where the width b is 1 time, 0.5 times, and 1.5 times the reference value are denoted as "b1", "b0.5", and "b1.5", respectively.

[0043]

FIG. 7 illustrates a relationship between the width b of the first bridge portion and the maximum principal stress. In FIG. 7, the horizontal axis represents a "bridge width", which is the width of the first bridge portion 14A, and the vertical axis represents the maximum principal stress (MPa). FIG. 8 illustrates a relationship between the width b of the first bridge portion 14A and average torque in one period. In FIG. 8, the horizontal axis represents the "bridge width", which is the width b of the first bridge portion 14A, and the vertical axis represents the average torque (N·m) in one period.

For example, from the comparison of the results of b1 and b0.3 illustrated in FIG. 7, it has been found that the width can be narrowed by about 70% when the strength is improved by about 20% by bonding. At this time, from the comparison of the results of b1 and b0.3 illustrated in FIG. 8, it has been found that the torque increases from a reference condition, and an improvement effect of about 5% is obtained.

[0044]

Note that the width of the bridge portion (the width b of the first bridge portion 14A and the width w of the second bridge portion 14B) is determined based on the strength of the bridge portion 14 provided with the first adhesive portion 12A. The strength of the bridge portion 14 can be obtained through calculation or experiments in consideration of,

for example, a pressurization condition of the adhesive. The required necessary strength of the bridge portion 14 is determined on the basis of the rotation speed specification of the rotary electric machine or the like. Furthermore, the width of the bridge portion 14 is determined by selecting, for example, the narrowest one within a range satisfying the required strength while changing the width of the bridge portion 14.

[0045]

In the present example, first, an upper limit of the generated stress of the bridge portion 14 is determined with reference to the rotation specification such as the maximum rotation speed of the rotary electric machine 100 to be designed, and the strength improvement amount of the electrical steel sheet 10 by providing the first adhesive portion 12A such as bonded fixation is obtained through experiments or the like. Next, the generated stress (maximum rotation speed condition) was calculated for each of a plurality of candidates for the width W of the bridge portion 14. Furthermore, the width of the bridge portion was determined such that a sum of an upper value of the generated stress and a value of the strength improvement amount obtained through experiments or the like was equal to or less than an upper limit value of the generated stress. That is, a manufacturing method of the rotor core 31 (laminated core 1) includes a step of obtaining, on the basis of the specification of the rotary electric machine 100 to be designed, the maximum generated stress applied to the bridge portion 14 (first portion 13) of the laminated core 1 of the rotary electric machine 100 by the centrifugal force and setting the maximum generated stress as the upper limit value, and a step of determining the width W of the bridge portion 14 to which the strength improvement amount of the electrical steel sheet 10 (bridge portion 14) by the first adhesive portion 12A is added, on the basis of the upper limit such that the upper limit is not exceeded. The manufacturing method may further include a step of subsequently manufacturing the laminated core 1 provided with

the first adhesive portion 12A having the bridge portion 14 having the determined width W.

[0046]

Hereinafter, the pressurizing jig 200 that can be used for manufacturing the laminated core 1 according to the above-described embodiment will be described. FIG. 9 is a schematic view illustrating a usage example of the pressurizing jig 200. The pressurizing jig 200 is used in a case where pressure application is required for bonding, for example, mainly in a case where an adhesive coating is provided on the electrical steel sheet 10.

[0047]

The pressurizing jig 200 is a jig for pressing, for bonding and fixing, a laminate of at least a part of a plurality of electrical steel sheets 10 constituting the laminated core 1, with an adhesive interposed therebetween (hereinafter, a core portion P) at the time of manufacturing the laminated core 1. As illustrated in FIG. 9, the pressurizing jig 200 includes a first member 210 having unevenness on a pressing surface 211 that presses the core portion P, for example, while contacting it. Furthermore, the core portion P is bonded by applying pressure to the core portion P through the first member 210 by a pressing portion 201 of a pressing device. The pressure may be applied after the core portion P is heated to a predetermined temperature.

[0048]

More specifically, in the pressing surface 211 of the first member 210, a surface (region) corresponding to a region where the first adhesive portion 12A is formed in the first portion 13 of the electrical steel sheet 10 protrudes more than a surface (region) corresponding to a region where the second adhesive portion 12B is formed in the lamination direction of the laminated core 1. That is, the surface (region) corresponding

to the first adhesive portion 12A has a convex shape in the lamination direction of the laminated core 1, and the surface (region) corresponding to the second adhesive portion 12B has a concave shape in the lamination direction of the laminated core 1. As described above, the pressing surface 211 includes a first pressing portion 211A (protrusion) configured to relatively strongly press the region corresponding to the first adhesive portion 12A and a second pressing portion 211B (recessed portion) configured to relatively weakly press the region corresponding to the second adhesive portion 12B.

[0049]

In short, in the pressurizing jig 200, the pressing surface 211 has unevenness such that a pressurizing force in a desired region in the core portion P becomes higher than that in other regions at the time of bonding. The shape of the unevenness of the pressing surface 211 in a plane view in which the laminated core 1 is viewed from the lamination direction is designed according to the shape and position of the region of the first portion 13 of the electrical steel sheet 10. Accordingly, in the region corresponding to the protrusion (first pressing portion 211A), the pressure at the time of pressing becomes higher than in the region corresponding to the recessed portion (second pressing portion 211B). Therefore, when the adhesive used for bonding and fixing the laminated core 1 is of a type that exhibits bonding strength corresponding to the magnitude of the pressure applied at the time of bonding, the first adhesive portion 12A and the second adhesive portion 12B can be formed by applying pressure to the core portion P once.

[0050]

In the embodiment illustrated in FIG. 9, the pressurizing jig 200 (first member 210) is a member in which unevenness is formed on a plate-shaped member such as a die in which unevenness is formed in a thickness direction on a metal sheet having a predetermined thickness. In addition, by being pressed by the pressing portion 201, the

first pressing portion 211A of the first member 210 presses the first portion 13 (first adhesive portion 12A) of the electrical steel sheet 10, and the second pressing portion 211B presses a region (second adhesive portion 12B) other than the first portion 13.

[0051]

In addition, the pressing surface 211 includes a taper portion 212 that connects the first pressing portion 211A and the second pressing portion 211B. That is, the first pressing portion 211A and the second pressing portion 211B are smoothly connected to each other, and are formed such that the pressurizing force gradually changes. As a constitution in which the pressurizing force gradually changes, for example, the taper portion 212 may be gradually inclined at a constant rate or may change in a quadratic curve manner.

[0052]

In addition, in the embodiment illustrated in FIG. 9, the first member 210 is disposed above the core portion P with the pressing surface 211 facing downward. In addition, in a state where the core portion P is supported from below by disposing the core portion P on the upper surface of a second member 220 fixedly disposed below the core portion P, the pressing portion 201 of the pressing device presses the first member 210 in an arrow F direction (downward in the lamination direction), thereby applying pressure to the core portion P to perform bonding and fixing.

[0053]

However, the present invention is not limited to the above-described embodiments. For example, the first member 210 may be disposed below and the second member 220 may be disposed above. Furthermore, in addition to the first member 210, unevenness may also be formed on the support surface of the core portion P in the second member 220 in accordance with the unevenness of the pressing surface 211 of the first member 210. In addition, the first pressing portion 211A and the second pressing portion 211B of the first

member 210 may not include the taper portion 212, and may be connected by, for example, a stepped part having a single step shape.

[0054]

Note that FIG. 9 schematically illustrates the shape of the pressurizing jig 200 for easy understanding, and the actual dimensions and the like of the pressurizing jig 200 are different. For example, in the arrow view of FIG. 9 (viewing from the side of the laminated core 1), a difference H (μm) of the unevenness of the pressing surface 211 is provided. The difference H may be determined on the basis of a relationship between the pressurization condition of the adhesive obtained in advance through experiments, calculation, or the like and the strength improvement amount of the electrical steel sheet 10 by providing the first adhesive portion 12A.

[0055]

According to the pressurizing jig 200 described above, the unevenness formed on the pressing surface 211 enables provision of the pressure distribution on the surface of the electrical steel sheet 10 in one pressurization. Therefore, at the time of bonding and fixing, by one application of pressure, a higher pressure can be applied to a region of the electrical steel sheet 10 where the first adhesive portion 12A is to be formed than to a region where the second adhesive portion 12B is to be formed. Therefore, since the first adhesive portion 12A and the second adhesive portion 12B can be efficiently formed, the manufacturing cost of the laminated core 1 can be reduced.

[0056]

Although the preferred embodiments of the present invention have been described in detail with reference to the accompanying drawings, the present invention is not limited to such examples. It is obvious that a person having ordinary knowledge in the technical field to which the present invention belongs can conceive various changes or modifications

within the scope of the technical idea described in the claims, and it is naturally understood that these also belong to the technical scope of the present invention.

[0057]

The shape of the laminated core 1 is not limited only to the forms described in the above-described embodiment. The dimensions of the outer diameter and the inner diameter of the laminated core 1, the lamination thickness, and the like can be arbitrarily designed according to desired characteristics of the laminated core 1. In addition, the number of slots of the stator core, a dimensional proportion between the circumferential direction and the radial direction of the tooth portion 23, a dimensional proportion between the tooth portion 23 and the core back portion 22 in the radial direction, and the like can be arbitrarily designed according to desired characteristics of the laminated core 1. In addition, in the above description, the bridge portion 14 of the rotor core 31 has been described as an example. However, if necessary, other portions of the rotor core 31 other than the bridge portion 14 and the stator core 21 may perform partial high-strengthening by an adhesive.

INDUSTRIAL APPLICABILITY

[0058]

According to the laminated core of the present disclosure, it is possible to provide a rotor core, a rotor, and a rotary electric machine capable of improving centrifugal force resistance and characteristics. Therefore, the industrial applicability is large.

REFERENCE SIGNS LIST

[0059]

1 Laminated core

10 Electrical steel sheet

11 Fixing portion

12 Adhesive portion

12A First adhesive portion

12Ag First adhesive

12B Second adhesive portion

12Bg Second adhesive

13 First portion

14 Bridge portion

14A First bridge portion

14B Second bridge portion

16 Outer circumferential edge

20 Stator

21 Stator core

22 Core back portion

23 Tooth portion

30 Rotor

31 Rotor core

32 Permanent magnet

33 Through-hole

34 Flux barrier

100 Rotary electric machine

200 Pressurizing jig

201 Pressing portion

210 First member

220 Second member

211 Pressing surface

211A First pressing portion

211B Second pressing portion

212 Taper portion

CLAIMS

[Claim 1] A rotor core comprising:

a plurality of laminated electrical steel sheets;

a fixing portion that fixes the electrical steel sheets adjacent to each other in a lamination direction together; and

a first adhesive portion that is partially provided in a region different from the fixing portion between the electrical steel sheets and has a fixing strength different from a fixing strength of the fixing portion,

wherein

the electrical steel sheet includes a first portion that is required to have a higher strength than that of other portions,

the first portion includes a bridge portion, and

the first adhesive portion is provided so as to cover the first portion of the electrical steel sheet.

[Claim 2] The rotor core according to claim 1, wherein

each of the electrical steel sheets has one or more through-holes for installing a permanent magnet constituting each of a plurality of magnetic poles, and

the first portion includes a first bridge portion formed between an outer circumferential edge of the electrical steel sheet and the through-hole.

[Claim 3] The rotor core according to claim 1, wherein

each of the electrical steel sheets has a plurality of through-holes for installing a plurality of permanent magnets constituting each of a plurality of magnetic poles, and

the first portion includes a second bridge portion formed between two adjacent through-holes in each of the magnetic poles.

[Claim 4] The rotor core according to claim 1, wherein

the fixing portion is a second adhesive portion that is provided between the electrical steel sheets adjacent to each other in the lamination direction and bonds the electrical steel sheets together, and

compressive stress remaining in the first portion where the first adhesive portion is provided is greater than compressive stress remaining in the second adhesive portion.

[Claim 5] The rotor core according to claim 4, wherein the second adhesive portion is provided to cover a remaining region without the first adhesive portion between the electrical steel sheets adjacent to each other.

[Claim 6] The rotor core according to claim 5, wherein the fixing portion is a second adhesive portion in which a second adhesive different from a first adhesive that becomes the first adhesive portion when solidified is solidified, and is partially provided between the electrical steel sheets.

[Claim 7] The rotor core according to claim 1, wherein the fixing portion is a crimping portion.

[Claim 8] A rotor comprising:

the rotor core according to any one of claims 1 to 7;

a permanent magnet that is installed in the rotor core; and

a rotary shaft that is fixed to the rotor core.

[Claim 9] A rotary electric machine comprising:

the rotor according to claim 8; and

a stator.

[Claim 10] A pressurizing jig that is used for manufacturing a laminated core having a first adhesive portion and a second adhesive portion, the pressurizing jig comprising:

a pressing surface that presses the first adhesive portion and the second adhesive portion, wherein

in the pressing surface, a first pressing portion corresponding to the first adhesive portion protrudes more than a second pressing portion corresponding to the second adhesive portion.