[0018] In FIG. 3, the rotor core 111 includes holes 301a to 301c in which the permanent magnets 112 (112a to 112c) are installed and holes 301d to 301g in which the permanent magnets 112 are not installed.

[0019] The holes 301a to 301b in which the permanent magnets 112a to 112b are installed are disposed at such a way that the pole faces 201a to 201d (see FIG. 2) of the permanent magnets 112a to 112b installed in the holes 301a to 301b are inclined relative to the outer peripheral surface of the rotor core 111, which is the end surface of the rotor core 111 that opposes the stator 120. In other words, the pole faces 201a to 201d of the permanent magnets 112a to 112b are disposed so as to be inclined relative to the radial direction of the rotor core 111. FIG. 3 shows as an example a case where the holes 301a to 301b are manufactured in such a way that the circumferential direction spacing between the holes 301a to 301b in which the permanent magnets 112a to 112b are installed (the permanent magnets 112a to 112b installed in the holes 301a to 301b) becomes wider closer to the outer peripheral surface of the rotor core 111. In this way, FIG. 2 shows as an example a case where the permanent magnets 112a to 112b are arranged in what is called a V-shape (an inverted truncated chevron shape). By contrast, the hole 301c in which the permanent magnet 112c is installed is manufactured in such a way that the pole faces 201e to 201f (see FIG. 2) of the permanent magnet 112c installed in the hole 301c oppose the outer peripheral surface of the rotor core 111 via a high permeability portion 311 (in such a way as to have what is called a flat arrangement).

[0020] FIG. 1 shows as an example an inner rotor type of IPMSM 100. Consequently, as shown in FIG. 1, the outer peripheral surface of the rotor 110 (the rotor core 111) is the end surface that opposes the stator 120 across a gap.

Furthermore, in FIG. 2, side surfaces 202 (202a to 202c), 203 (203a to 203c) of the permanent magnets 112 (112a to 112c) are end surfaces positioned on end portion sides in a direction (hereinafter called the lengthwise direction) parallel to the pole faces 201 (201a to 201f) of the permanent magnets 112 (112a to 112c) (in the example shown in FIG. 2, end surfaces positioned on lengthwise direction end portions of the pole faces 201 (201a to 201f) of the permanent magnets 112 (112a to 112c)).

[0021] As described above, in the present embodiment, a case where three holes per pole are manufactured in the rotor core 111 as the holes 301a to 301c in which the permanent magnets 112a to 112c are installed is described as an example. However, the number of holes per pole in which the permanent magnets are installed may be more than three or two or less. For example, a permanent magnet may be installed in the hole 301d, and the permanent magnet 112c need not be installed in the hole 301c.

[0022] In FIG. 4, of the regions of the holes 301a to 301c in which the permanent magnets

example 3, the value, expressed as a percentage, of the ratio of the area of the low permeability portions 821a to 821f in the inner peripheral bridge portions 501a to 501b to the area of the inner peripheral bridge portions 501a to 501b in the rotor core cross-section is 60%.

[0045] The high permeability portion 311 in example 1, comparative example 1, comparative example 2, and comparative example 3 has the same magnetization characteristics. Furthermore, the low permeability portions 321a to 321b, 721a to 721b, 821a to 821f in example 1, comparative example 2, and comparative example 3 differ only in the ratios of the areas they occupy in the inner peripheral bridge portions 501a to 501b, and have the same magnetization characteristics. Here, when evaluating the torques of the IPMSMs using an electromagnetic field analysis, samples obtained by pressing electromagnetic steel sheets of the same type as the high permeability portion 311 to a plate thickness half the plate thickness of those electromagnetic steel sheets were manufactured, the magnetization characteristics of the samples were measured, and the measured magnetization characteristics were taken as the magnetization characteristics of the low permeability portions 321a to 321b, 721a to 721b, 821a to 821f. It will be noted that the magnetization characteristics of the high permeability portion 311 are the magnetization characteristics of the electromagnetic steel sheets configuring the high permeability portion 311.

[0046] An electromagnetic field analysis of the IPMSMs when the IPMSMs equipped with the rotor cores of example 1, comparative example 1, comparative example 2, and comparative example 3 were operated under the operating conditions of a 3,000 rpm rotational speed, an excitation current (excitation current effective value) of 20 A, and an advance angle of 30 deg was executed by the finite element method using the magnetization characteristics of the high permeability portion 311 and the magnetization characteristics of the low permeability portions 321a to 321b, 721a to 721b, 821a to 821f. Here, a two-dimensional electromagnetic field analysis on the x-y plane was performed. Then, the Maxwell stress tensors were calculated based on the magnetic flux density vectors obtained as a result of the electromagnetic field analysis, and the torques of the IPMSMs were calculated from the Maxwell stress tensors.

[0047] As a result, in comparative example 1 shown in FIG. 6 the torque T of the IPMSM was 15.00 Nm; in comparative example 2 shown in FIG 7 the torque of the IPMSM was 15.08 Nm; in comparative example 3 shown in FIG. 8 the torque T of the IPMSM was 15.10 Nm; and in example 1 shown in FIG. 4 the torque T of the IPMSM was 15.14 Nm. Consequently, the greater the ratio of the area of the low permeability portions to the area of the inner peripheral bridge portions 501a to 501b is in the order of 321a to 321b, 721a to 721b, 821a to

rotating electrical machine.

[0050] (Second Embodiment)

Next, a second embodiment will be described. In the first embodiment, a case where the entireties of the inner peripheral bridge portions 501a to 501b were configured to serve as the low permeability portions 321a to 321b was described as an example. In the present embodiment, a case where bridge portions apart from the inner peripheral bridge portions 501a to 501b are also configured to serve as low permeability portions will be described. In this way, the present embodiment is one where the number of portions configured to serve as low permeability portions is increased over that of the first embodiment. Consequently, in the description of the present embodiment, parts that are identical to those in the first embodiment are assigned reference signs that are identical to the reference signs in FIG. 1 to FIG. 8, and detailed description thereof will be omitted.

[0051] In the present embodiment, the rotor 110 shown in FIG. 2 is changed as follows. FIG. 9 is a view showing an example of the configuration of a rotor 910. FIG. 9 is a sectional view of the rotor 910 (a view showing a rotor cross-section) as cut perpendicular to a centerline 0 of the rotor 910 and corresponds to FIG. 2. In the present embodiment also, as in the first embodiment, a case where the rotor 910 rotates in the direction of the arrowed line shown in FIG. 9 (the counterclockwise direction as one faces the page) and where the rotor 910 does not rotate in the opposite direction (the clockwise direction as one faces the page) of the direction of the arrowed line shown in FIG. 9 is described as an example.

[0052] The rotor 910 includes a rotor core 911 and plural permanent magnets 112 (three permanent magnets 112a to 112c per pole). The rotor core 911 is, for example, configured by stacking plural electromagnetic steel sheets along the centerline 0 of the rotor 910. However, it is not always necessary for the rotor core 911 to be configured by stacking plural electromagnetic steel sheets. As described as an example in the first embodiment, the rotor core 911 may also be configured by other soft magnetic materials.

[0053] The holes manufactured in the rotor core 911 are the same as the holes manufactured in the rotor core 111 of the first embodiment. Furthermore, the plural permanent magnets 112 are also the same as the plural permanent magnets 112 of the first embodiment. Consequently, in the rotor 910 of the present embodiment also, the same flux barriers 113 (113a to 113j) and hole 114 as those in the rotor 110 of the first embodiment are manufactured.

[0054] Furthermore, in the present embodiment also, as in the first embodiment, a case where the shape of the rotor cross-section has the shape shown in FIG. 9 in any position in the z-axis direction of the rotor 910 is described as an example. Furthermore, FIG. 9 shows as an

one pole of the rotor core 911 and at the leading side in the rotational direction of the rotor core 911 relative to a circumferential direction center of the region. By contrast, the second outer peripheral bridge portions are disposed at a region configuring one pole of the rotor core 911 and at the trailing side in the rotational direction of the rotor core 911 relative to a circumferential direction center of the region.

[0059] In the example shown in FIG. 10 and FIG. 11, the low permeability portions 1021a to 1021c are manufactured in parts of the first outer peripheral bridge portions. By contrast, the low permeability portions 1022a to 1022c are manufactured in the entireties of the second outer peripheral bridge portions. FIG. 12 is a view showing an example of first outer peripheral bridge portions 1211a to 1211c and second outer peripheral bridge portions 1221a to 1221c. It will be noted that in FIG. 12 illustration of the low permeability portions 1021a to 1021c, 1022a to 1022c is omitted because otherwise the notation would become complicated.

[0060] In FIG. 10 to FIG. 12, the first outer peripheral bridge portions 1211a to 1211c and the second outer peripheral bridge portions 1221a to 1221c are bridge portions where at least parts of the plural holes 301a to 301g manufactured in the rotor core 911 are disposed at the outer peripheral surface side of the rotor core 911 relative to the inner peripheral bridge portions 501a to 501b. The first outer peripheral bridge portions and the second outer peripheral bridge portions include bridge portions that are sandwiched between two holes to thereby be disposed between the two holes or bridge portions that are sandwiched between one hole and the outer peripheral surface of the rotor core to thereby be disposed between the hole and the outer peripheral surface of the rotor core.

[0061] Specifically, the first outer peripheral bridge portion 1211a is a bridge portion disposed between the hole 301a manufactured in the rotor core 911 and the outer peripheral surface of the rotor core 911. Furthermore, the second outer peripheral bridge portion 1221a is a bridge portion disposed between the hole 301b manufactured in the rotor core 911 and the outer peripheral surface of the rotor core 911.

[0062] As mentioned above, in FIG. 12, the first outer peripheral bridge portion 1211a (the entire region of the first outer peripheral bridge portion 1211a) is disposed at a region configuring one pole of the rotor core 911 and at the leading side in the rotational direction of the rotor core 911 relative to the circumferential direction center of the region. The second outer peripheral bridge portion 1221a (the entire region of the second outer peripheral bridge portion 1221a) is disposed at a region configuring one pole of the rotor core 911 and at the trailing side in the rotational direction of the rotor core 911 relative to the circumferential direction center of the region. The leading side in the rotational direction of the rotor core 911

Nm. Consequently, the torque T of the IPMSM increases more when parts of the first outer peripheral bridge portions 1211a to 1211c are configured to serve as the low permeability portions 1021a to 1021c than in a case where the entireties of the first outer peripheral bridge portions 1211a to 1211c are configured to serve as the low permeability portions 1321a to 1321c. In this example, the torque T of the IPMSM increases 0.1% in example 2 shown in FIG. 11 compared to comparative example 4 shown in FIG. 13.

[0088] As described above, in the present embodiment, parts of the first outer peripheral bridge portions 1211a to 1211c, at least parts of which are disposed at the outer peripheral surface side of the rotor core 911 relative to at least one of the regions 401a to 401c where the permanent magnets 112a to 112c are installed and which are disposed at a region configuring one pole of the rotor core 911 and at the leading side in the rotational direction relative to the circumferential direction center of the region, are configured to serve as the low permeability portions 1021a to 1021c. Consequently, the torque of the IPMSM 100 can be increased more.

[0089] Furthermore, in the present embodiment, the entireties of the second outer peripheral bridge portions 1221a to 1221c, at least parts of which are disposed at the outer peripheral surface side of the rotor core 911 relative to at least one of the regions 401a to 401c where the permanent magnets 112a to 112c are installed and which are disposed at a region configuring one pole of the rotor core 911 and at the trailing side in the rotational direction relative to the circumferential direction center of the region, are configured to serve as the low permeability portions 1022a to 1022c. Consequently, the torque of the IPMSM 100 can be increased even more.

[0090] In the present embodiment, as in the first embodiment, a case where the entireties of the inner peripheral bridge portions 501a to 501b are configured to serve as the low permeability portions 321a to 321b is described as an example. However, a configuration where the entireties of the inner peripheral bridge portions 501a to 501b are not configured to serve as the low permeability portions 321a to 321b may also be employed. That is, a rotor core that includes the low permeability portions 1021a to 1021c, 1022a to 1022c but does not include the low permeability portions 321a to 321b may also be employed.

[0091] Furthermore, it is preferred that parts of the first outer peripheral bridge portions 1211a to 1211c be configured to serve as the low permeability portions 1021a to 1021c, but the entireties of the first outer peripheral bridge portions 1211a to 1211c may also be configured to serve as low permeability portions. In a case where this is done, the entireties of all the bridge portions of the rotor core become low permeability portions. Furthermore, parts of the second outer peripheral bridge portions 1221a to 1221c may be configured to serve as low permeability portions.