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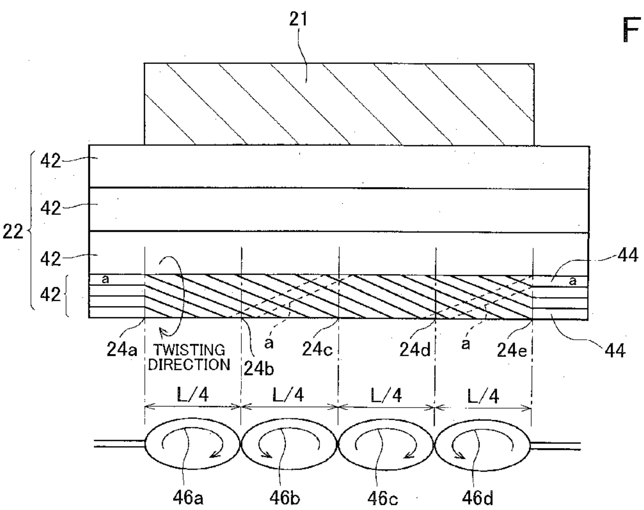
(54) **Title**: STATOR OF ROTARY ELECTRIC MACHINE

FIG.4



(57) **Abstract**: A stator of a rotary electric machine includes a stator core and a coil. The stator core is such that a plurality of teeth that protrude out toward a rotor are arranged spaced apart from one another, and a slot is arranged between the teeth. The coil passes through the slot and is wound around the teeth. The coil includes an assembly or assemblies of conductors, each of which is formed by an assembly of a plurality of wires. The assembly or assemblies of conductors are arranged in the slot, stacked in the slot in a direction in which the teeth protrude, and wound around the teeth. Each of the assemblies of conductors is twisted in the slot, and an arrangement of the plurality of wires in the slot is reversed an odd number of times.

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STATOR OF ROTARY ELECTRIC MACHINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to stator of a rotary electric machine, that includes a stator core in which a plurality of teeth that protrude toward a rotor are arranged spaced apart from each other, and in which a slot is formed between the teeth, and a coil that passes through the slot and is wound around the teeth.

[0002] Japanese Patent Application Publication No. 2012-110114 (JP 2012-110114 A) describes a rotary electric machine that attempts to reduce an eddy current generated by a fluctuation in magnetic flux that is interlinked with a coil, by making a tip end portion of the coil that is close to a rotor be a split cross-section type winding portion.

[0003] When magnetic flux that flows through the teeth of the stator becomes saturated when applying magnetic flux between the stator and the rotor, the magnetic flux leaks out from the teeth and flows out through the coil positioned between adjacent teeth (i.e., in the slot). When leakage flux that flows through the coil between the teeth fluctuates, an eddy current is generated in the coil.

[0004] The technology in JP 2012-110114 A attempts to reduce an eddy current by making a coil serve as a split cross-section type winding in which the coil is divided into a plurality of regions. However, when leakage flux that flows through the coil between teeth fluctuates, a circulating current that circulates through the coil is generated by the eddy current that is generated in the divided regions, and loss due to this circulating current occurs.

SUMMARY OF THE INVENTION

[0005] The invention thus provides a stator of a rotary electric machine, that inhibits a circulating current from being generated in a coil due to a fluctuation in leakage current that flows through the coil between teeth, and thus inhibits loss resulting from this circulating current.

[0006] The stator of a rotary electric machine according to the invention employs the means described below.

[0007] One aspect of the invention relates to a stator of a rotary electric machine, that includes a stator core and a coil. The stator core including a plurality of teeth and a plurality of slots, the teeth protruding out toward a rotor and being arranged spaced apart from one another, and the slot being arranged between the teeth. The coil passes through the slot and is wound around the teeth. The coil includes an assembly or assemblies of conductors, each of which is formed by an assembly of a plurality of wires. The assembly or assemblies of conductors are arranged in the slot, stacked in the slot in a direction in which the teeth protrude, and wound around the teeth. Also, each of the assembly or assemblies of conductors is twisted in the slot, and an arrangement of the plurality of wires in the slot is reversed an odd number of times. [0008] According to the invention, even if eddy currents are generated in the assembly or assemblies of conductors due to a fluctuation in leakage flux between the teeth, the eddy currents that flow through the wires will cancel each other out over the entire inside of the slot. As a result, it is possible to inhibit a circulating current from being generated in the assembly collectors, and thus inhibit loss from the circulating current.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a sectional view schematically showing the structure of a stator and a rotor viewed from a rotor rotation axis direction;

FIG. 2 is a sectional view schematically showing the structure of the stator and the rotor viewed from a direction orthogonal to the rotor rotation axis;

FIG. 3 is a sectional view of the structure of a coil inserted into a slot, in the stator according to an example embodiment of the invention; and

FIG. 4 is a view showing a dislocation state of a plurality of wires inserted into the slot, in the stator according to the example embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0010] Hereinafter, modes for carrying out the invention (hereinafter simply referred to as "example embodiments") will be described with reference to the accompanying drawings.

[0011] FIGS. 1 to 4 are views schematically showing the structure of a rotary electric machine provided with a stator according to one example embodiment of the invention. FIG. 1 is a schematic diagram of the structure of a stator 12 and a rotor 14 viewed from a stator axis or rotor rotation axis (hereinafter simply referred to as "rotation axis") direction. FIG. 2 is a schematic diagram of the stator 12 and the rotor 14 viewed from a direction orthogonal to the rotation axis. FIG. 3 is a schematic diagram of the stator 12 viewed from the rotation axis direction. Also, FIG. 4 is a schematic diagram of the stator 12 viewed from a direction orthogonal to the rotation axis. The rotary electric machine according to this example embodiment includes the stator 12 that is stationary (i.e., fixed so that it will not rotate), and the rotor 14 that is able to rotate relative to the stator 12. In the example shown in FIGS. 1 and 2, the stator 12 and the rotor 14 are arranged face-to-face across a predetermined small gap, in a radial direction orthogonal to the rotation axis. The rotor 14 is arranged on an inner peripheral side of the stator 12.

[0012] The rotor 14 includes a rotor core 31 and a plurality of permanent magnets 32 that are arranged in the rotor core 31 in the circumferential direction thereof. The stator 12 includes a stator core 21, and a coil 22 of a plurality of phases (such as three phases) arranged on the stator core 21. A plurality of teeth 23 that protrude radially inward toward the rotor 14 are arranged on the stator core 21 at intervals (i.e., equidistant intervals) in the circumferential direction around the rotation axis. Slots 24 are formed extending in the rotation axis direction between the teeth 23 that are adjacent in the circumferential direction. In the example shown in FIGS. 1 and 2, the direction in which the plurality of teeth 23 are arranged matches the circumferential direction, and the direction in which the slots 24 extend matches the rotation axis direction. Magnetic poles are formed on the stator 12 by the coil 22 being wound around the teeth 23 through the slots 24 between the teeth 23. The winding method is a distributed winding for example.

[0013] As shown in FIGS. 3 and 4, the coil 22 has an assembly of conductors 42, which is formed by an assembly of a plurality of wires (thin wires) 44 that are joined together, inside the slot 24. A plurality of these assemblies of conductors 42 that extend through the slot 24 in the rotation axis direction are stacked together in the radial direction (i.e., the direction in which the teeth protrude) and wound around the teeth 23. In FIG. 3, the teeth 23 and the coil 22 are only partially shown in the circumferential direction, but the structure of the portion that is not shown may be realized by the same structure as that of the portion that is shown. Each of the wires 44 is formed by a conductor wire and an insulator layer that covers an outer periphery of the conductor wire. The wires 44 are electrically insulated from each other by the insulator layer inside the slot 24, and are electrically connected outside the slot 24. In this way, a coil turn that is arranged in each slot 24 is formed with the assembly of conductors 42 that are an assembly of the wires 44 as the unit. In FIG. 3, the assemblies of conductors 42 are the regions divided by the bold section lines. Also, one assembly of conductors 42 is formed as the component for each coil turn, and the coil turns are joined together by welding or the like, for example. In the example shown in FIGS. 3 and 4, the assemblies of conductors 42 are arranged lined up in four layers in a line in the radial direction. In the example shown in FIG. 3 and 4, four layers of coil bodies 42 are lined up in the radial direction, but the number of coil bodies 42 that are lined up in the radial direction may be set as appropriate. Also, in the example shown in FIGS. 3 and 4, each assembly of conductors 42 is formed with four wires 44 in the circumferential direction and four wires 44 in the radial direction, for a total of 16 wires, but the number of the wires 44 that form each assembly conductor 42 may also be set as appropriate. Also, the coil 22 does not necessarily have to be formed by the assembly of conductors 42 outside of the slot 24.

[0014] In this example embodiment, the assemblies of conductors 42 are such that the arrangement of the wires 44 is dislocated by the assemblies of conductors 42 being twisted about a central axis thereof from one end 24a to the other end 24e of the slot 24, as shown in FIG. 4. Furthermore, with each of the assemblies of conductors 42 that extend between the one end 24a and the other end 24e of the slot 24 in the rotation axis direction, the arrangement of the plurality of wires 44 is phase inverted an odd number of times in the slot 24. Phase inversion of the wires 44 in this case refers to a state in which the wires 44 are moved to a position of 180° point symmetry with respect to the central axis of the assembly conductor 42. As shown in FIG. 4, each assembly of conductors 42 is such that the arrangement of the wires 44 is equal (in-phase) at the one end 24a of the slot 24 and at the other end 24e of the slot 24. Also, when the distance in the rotation axis direction between the one end 24a and the other end 24e of the slot 24 is designated L, at a slot position 24b of a distance L / 4 in the rotation axis direction from the one end 24a of the slot 24, the arrangement of the plurality of wires 44 is phase-inverted 180° by the assembly of conductors 42 being twisted 180° compared with the one end 24a of the slot 24. Also, at a slot position (a center position) 24c of a distance L / 2 in the rotation axis direction from the one end 24a of the slot 24, the arrangement of the plurality of wires 44 is phase-inverted 180° by the assembly of conductors 42 being twisted 180° compared with the slot position 24b. Moreover, at the slot position 24d of a distance 3 × L / 4 in the rotation axis direction from the one end 24a of the slot 24, the arrangement of the plurality of wires 44 is phase-inverted 180° by the assembly of conductors 42 being twisted 180° compared with the slot position 24c. Furthermore, the assemblies of conductors 42 are twisted 180° from the slot position 24d to the other end 24e of the slot 24. In FIG. 4, the structure of the wires 44 is shown for only the assembly conductor 42 on the innermost radial side (i.e., nearest the rotor 14), but the configuration of the wires 44 of the other assembly of conductors 42 that are not shown may be realized by a configuration similar to that of the portion that is shown.

[0015] In this way, the assemblies of conductors 42 are twisted in the slot 24, such that the arrangement of the wires 44 are dislocated in different positions in the slot 24. Further, the assemblies of conductors 42 each have phase inversion locations of the plurality of wires 44 at odd locations in the slot 24. In the example shown in FIG. 4, there are three phase inversion locations, i.e., slot positions 24b, 24c, and 24d. However, the arrangement of the wires 44 is dislocated (i.e., phase-inverted) within the same coil turn, but the arrangement of the wires 44 is not dislocated between different coil turns. Also, the arrangement of the wires 44 is dislocated only within the slot 24, but the arrangement of the wires 44 is not dislocated outside of the slot 24. Furthermore, in the assembly of conductors 42, the distance between phase inversion locations of the plurality of wires 44 is preferably equal. The distance between the phase-inversion locations is the distance between the slot positions 24b, 24c, and 24d. Also, in the example shown in FIG. 4, there are three phase inversions in the slot 24 where the wires 44 that form the assembly of conductors 42 are arranged, but the number of phase inversions in the slot 24 where the wires 44 that form the assembly of conductors 42 are arranged may be set as appropriate as long as it is an odd number. For example, the number of phase inversions of the slot 24 where the wires 44 that form the assembly of conductors 42 are arranged may be one or five or the like.

[0016] In the rotary electric machine, the teeth 23 are magnetized in order by flowing alternating current through the coil 22 of a plurality of phases (three phases), such that a rotating magnetic field that rotates in the circumferential direction is formed in the stator 12. Also, electromagnetic interaction between the rotating magnetic field generated in the stator 12 and a field flux generated by the permanent magnets 32 of the rotor 14 applies torque (magnetic torque) to the rotor 14, which enables the rotor 14 to be rotatably driven. This electromagnetic interaction is attraction and repulsion. In this way, the rotary electric machine is able to be made to function as an electric motor that has the rotor 14 generate power using electric power supplied to the coil 22. On the other hand, the rotary electric machine is also able to be made to function as a generator that has the coil 22 generate electric power using the power of the rotor 14. Also, the rotor 14 is not limited to a structure provided with the permanent magnets 32. For example, the rotor 14 may also have a structure provided with a coil, or a structure that uses reluctance torque from a change in magnetic resistance.

[0017] When applying torque between the stator 12 and the rotor 14, magnetic flux acts between the stator 12 and the rotor 14, and this magnetic flux flows through the teeth 23 in the radial direction. However, when the magnetic flux that flows through the teeth 23 becomes saturated, magnetic flux leaks out from the teeth 23 and flows out between adjacent teeth 23 (i.e., through the slot 24) in the circumferential direction. In particular, when the torque of the rotor 14 is large, magnetic flux that flows through the teeth 23 tends to become saturated, so magnetic flux tends to flow between the teeth 23 in the circumferential direction. This leakage flux between the teeth 23 flows through the assembly of conductors 42 (i.e., the wires 44) in the circumferential direction. Also, when the leakage flux that flows through the assembly of conductors 42 between the teeth 23 fluctuates, an eddy current is generated in each of the wires 44. As a result, a circulating current is generated in the assembly of conductors 42, and consequently, loss from this circulating current occurs.

[0018] In contrast, in this example embodiment, the assemblies of conductors 42 are twisted in the slot 24, and the arrangements of the wires 44 are dislocated in different positions within the slot 24. As a result, the direction of the eddy currents that are generated in the wires 44 also changes due to a fluctuation in the leakage flux between the teeth 23, and the eddy currents will cancel themselves out considering the entire inside of the slot 24. The entire inside of the slot 24 refers to the space between the one end 24a and the other end 24e of the slot 24. For example, as shown in FIG. 4, the direction of an eddy current 46a that flows through a wire a between the one end 24a of the slot 24 and the slot position 24b, and the direction of an eddy current 46b that flows through the wire a between the slot position 24b and the slot position 24c are reversed, so they cancel each other out. Also, the direction of an eddy current 46c that flows through the wire a between the slot position 24c and the slot position 24d, and the direction of an eddy current 46d that flows through the wire a between the slot position 24d and the other end 24e of the slot 24 are reversed, so they cancel each other out. In this way, the directions of the eddy currents that flow through the wires before and after the slot positions 24b, 24c, and 24d (i.e., the phase inversion locations) are reversed, so the eddy currents that flow through the wire a cancel each other out over the entire inside of the slot 24. Also, for the other wires as well, the eddy currents will also cancel each other out considering the entire inside of the slot 24, the eddy currents will cancel themselves out considering the entire inside of the slot 24. As a result, it is possible to inhibit a circulating current from being generated in the assembly of conductors 42, and thus inhibit loss from a circulating current. Furthermore, a closed loop of current that circulates through the wires 44 will become smaller, so even if the distance between the phase inversion locations of the plurality of wires 44 is not equal, loss from a circulating current is able to be reduced.

[0019] In the foregoing example embodiment, the arrangement of the wires 44 does not necessarily have to be phase inverted in the slot 24 for all of the assemblies of conductors 42 that are lined up in the radial direction. For example, the arrangement of the wires 44 may be phase inverted an odd number of times in the slot 24 only for the assembly conductor 42 on the radially inner side (i.e., on the tip end side of the teeth) where the distance to the rotor 14 is close, and the arrangement of the wires 44 may not be phase inverted in the slot 24 for the assembly of conductors 42 on the radially outer side (i.e., the root side of the teeth) that is farther away from the rotor 14.

[0020] In the example embodiment described above, a case is described in which the coil 22 is wound around the teeth 23 in a distributed winding, but the coil 22 may also be wound around the teeth 23 by a winding method other than a distributed winding. For example, the coil 22 may also be wound around the teeth 23 in a concentrated winding.

[0021] In the example embodiment described above, a case in which the invention is applied to a radial type rotary electric machine is described, but the invention may also be applied to an axial type rotary electric machine.

[0022] While the invention has been described with reference to example embodiments thereof, it should be understood that the invention is not limited in any way to these example embodiments. That is, the invention may of course be carried out in modes that have been modified in any of a variety of ways without departing from the scope thereof.

CLAIM:

1. A stator of a rotary electric machine, comprising:

a stator core including a plurality of teeth and a plurality of slots, the teeth protruding out toward a rotor and being arranged spaced apart from one another, and the slots being arranged between the teeth; and

a coil that passes through the slots and is wound around the teeth,

wherein the coil includes an assembly or assemblies of conductors, each of which is formed by an assembly of a plurality of wires;

the assembly or assemblies of conductors are arranged in the slot, stacked in the slot in a direction in which the teeth protrude, and wound around the teeth; and

each of the assembly or assemblies of conductors is twisted in the slot, and an arrangement of the plurality of wires in the slot is reversed an odd number of times.

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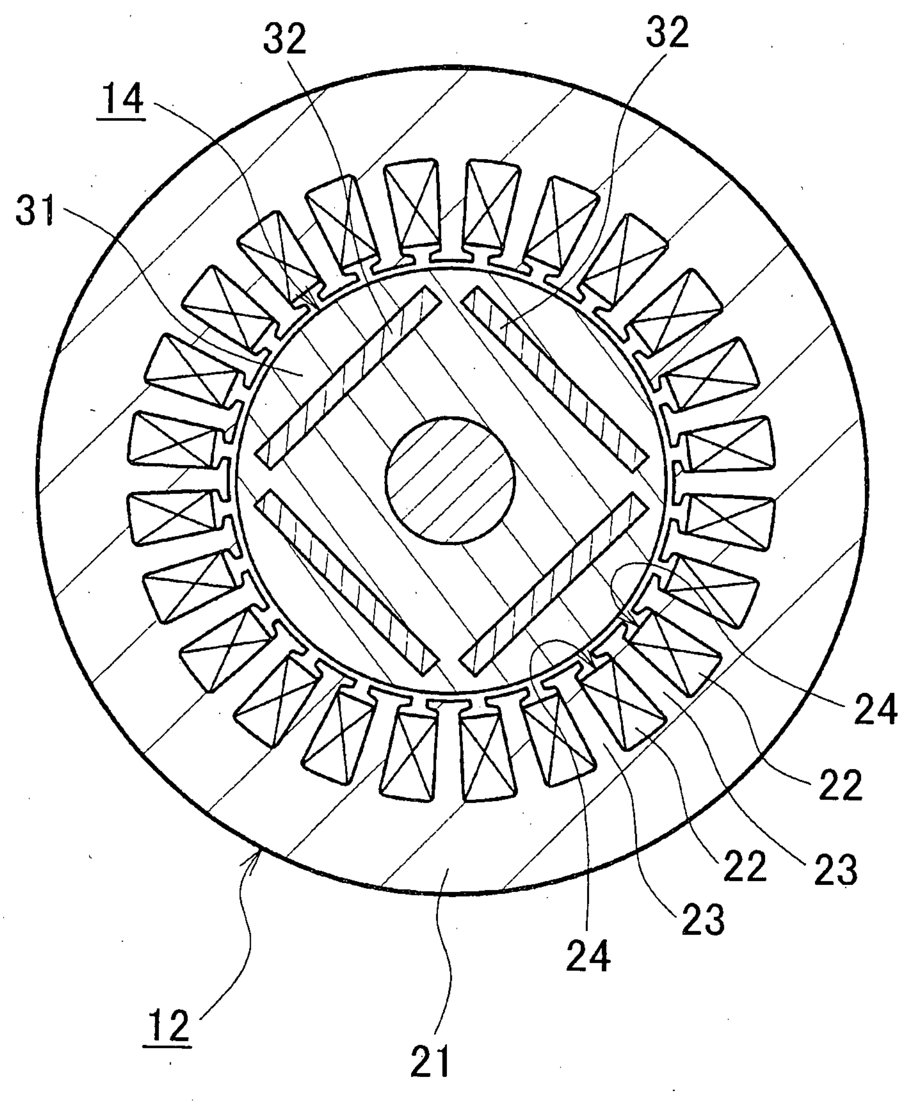


FIG. 2

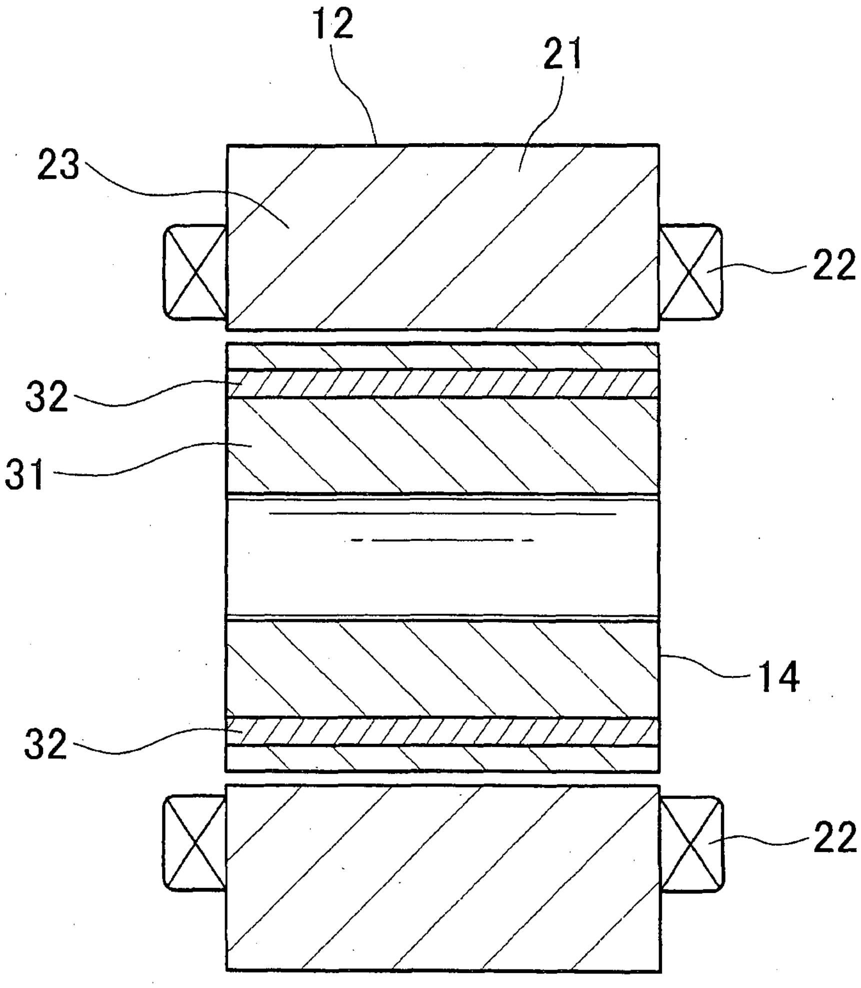


FIG. 3

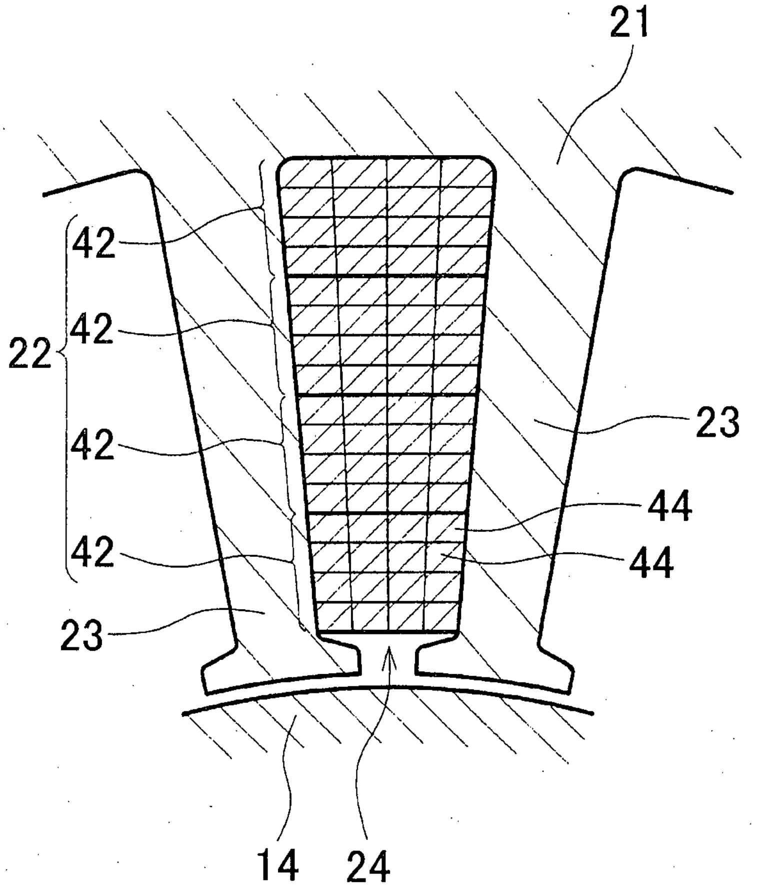
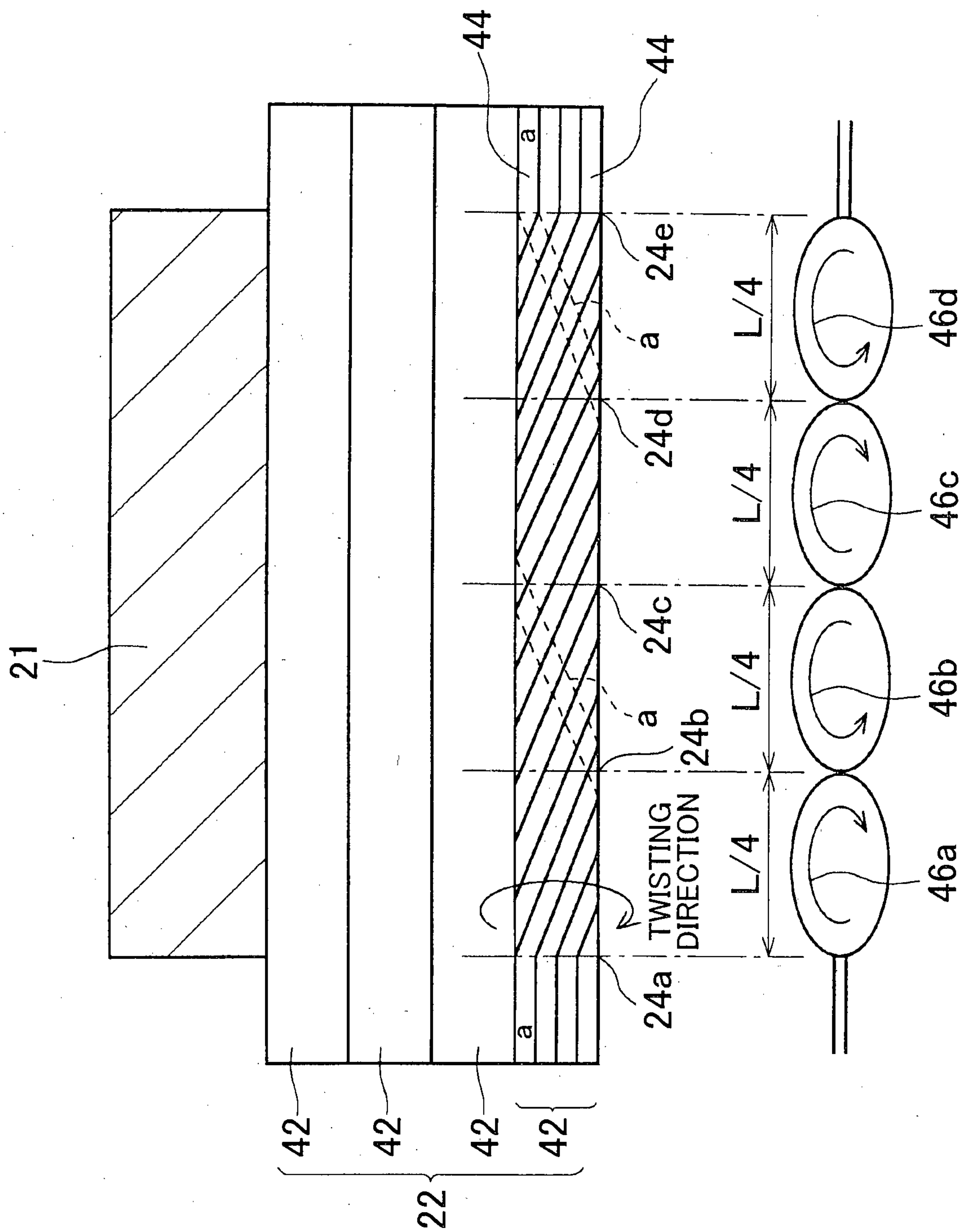


FIG. 4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