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(54) Title: PERMANENT MAGNET ROTOR FOR ELECTRIC SUBMERSIBLE PUMPS

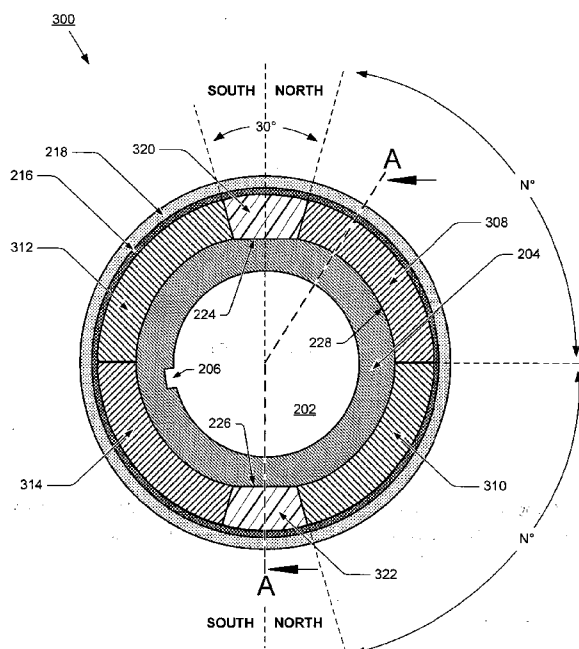


FIG. 3

(57) Abstract: A permanent magnet rotor for electric submersible pumps is provided. An example 2-pole rotor pack for an ESP has curved north and south pole magnets each spanning, for example, 150 degrees of a circumference of the rotor. A high-temperature glue containing a damping agent protects the magnets from cracking during thermal cycling. A magnetically transparent, high-strength amorphous or fiber-reinforced wrap is applied around the rotor to bind the magnets to the rotor and protect brittle magnets from high centrifugal forces. A layer of tough, high-temperature nylon or polyphenylene sulfide (PPS) may encase the outside of the 2-pole rotor pack to protect from corrosives, abrasives, and aggressive chemicals in a well. The 2-pole rotor can rotate twice as fast as a 4-pole rotor at the same AC frequency, or can use one-half the AC frequency as a 4-pole rotor to rotate the same speed as a 4-pole rotor.



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PERMANENT MAGNET ROTOR FOR ELECTRIC SUBMERSIBLE PUMPS

BACKGROUND

[0001] In oil and gas wells, production tubing brings fluid hydrocarbon resources to the surface. When the wells lack enough pressure, then motorized pumps apply artificial lift to recover the hydrocarbon resources. A permanent magnet motor (PMM) provides advantages over conventional three-phase motors that use wound rotors in that the PMM can be made more compact, may use less electricity, and can eliminate the problem of commutator brushes wearing out.

[0002] A conventional PMM rotor for use in an electric submersible pump (ESP) has a package of steel laminations mounted on a shaft with holes for permanent magnets. Jumpers are placed between the holes to solve leakage flux, but reduced magnetic flux and reduced motor performance still results. This conventional design also requires a high volume of metal, which in turn requires time-consuming balancing in high-speed engines.

[0003] Another conventional PMM rotor has a metal hub with permanent magnets affixed, but the magnets are covered with a thin metal sleeve on the outside and covered with metal caps welded to the sides to protect the magnets from breakage by centrifugal forces and aggressive chemicals. This requires complex manufacturing, including accurate grinding of magnets and metal surfaces. The presence of metal clips covering the magnets increases the electrical losses in the rotor.

[0004] Another design has a hub with permanent magnets fixed inside by pouring high-strength polymeric material, such as polyphenylene sulfide, PPS. The PPS, however, does not reinforce well in this configuration because of compressive brittleness at high RPMs.

[0005] An apparatus comprises a permanent magnet motor for driving an electric submersible pump in an oil well, a rotor attached to a hub in the permanent magnet motor for applying torque to a rotatable shaft of the permanent magnet motor, a first arcuate magnet of the rotor that includes an outer convex surface of north magnetic polarity, a second arcuate magnet of the rotor that includes an outer convex surface of south magnetic polarity, a high-temperature glue containing a damping agent, and a magnetically transparent high-strength matrix around the outer circumference of the rotor to bind the first and second arcuate magnets to the hub. An electric submersible pump comprises a pump for artificial lift of fluid from a well, a permanent magnet motor to drive the pump, a 2-pole rotor in the permanent magnet motor including a north pole magnet and a south pole magnet, and a layer of glass fiber-reinforced plastic around the outer surface of the 2-pole rotor to bind the north and south pole magnets to the 2-pole rotor. A rotor pack for an electric submersible pump comprises a shaft to provide power in a permanent magnet motor of the electric submersible pump, a hub attached to the shaft to hold permanent magnets, a curved north pole magnet spanning 150 degrees of a circumference of the rotor, a curved south pole magnet spanning 150 degrees of a circumference of the rotor, a magnetically transparent wrap binding the curved north pole magnet and the curved south pole magnet to the hub, and a glass fiber reinforcement within the magnetically transparent wrap.

[0006] This summary section is not intended to give a full description of permanent magnet rotors for ESPs. A detailed description with example embodiments follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Fig. 1 is a diagram of an example electric submersible pump (ESP) including a permanent magnet motor, in a well.

[0008] Fig. 2 is a diagram showing a transverse cross-sectional view of an example rotor for the permanent magnet motor of an ESP.

[0009] Fig. 3 is a diagram showing a transverse cross-sectional view of an example implementation of a 2-pole rotor in which each pole covers 150 degrees of a rotor circumference.

[0010] Fig. 4 is a diagram showing a longitudinal cutaway view of the example rotor of Fig. 3 along the A-A lines.

[0011] Fig. 5 is a flow diagram showing an example method of constructing a permanent magnet rotor for an electrical submersible pump.

DETAILED DESCRIPTION

[0012] This disclosure describes permanent magnet rotors for electric submersible pumps. In the description below, each element or component of a permanent magnet rotor may be replaced by numerous equivalent alternatives, some of which are disclosed in the specification. An example permanent magnet rotor described herein is included in a motor, which drives an electric submersible pump (ESP) for recovering oil or other hydrocarbon fluids from an underground reservoir.

[0013] The example permanent magnet rotor for ESP applications consists of permanent magnet sectors (also called “segments”) connected to a metal hub that is fixed to a shaft for driving a submersible pump. High-speed and high-torque electric submersible pumps demand that the magnet segments are secured to the hub in a robust and reliable manner that is not so rigid as to break brittle magnets, and that is also easy to assemble during manufacture, since ultra-powerful magnet segments tend to repel or attract each other during the manufacture. In an implementation, a magnetically transparent layer of amorphous tape or fiber-reinforced material is used as an outside wrap to hold the magnet segments against the hub and prevent the magnet segments from drifting or disintegrating even when generating high torque and in thermally and chemically harsh and abrasive environments. An adhesive layer providing a small degree of adaptive cushioning or damping may be used between the magnets and the hub to absorb differences in coefficients of thermal expansion between the magnet material and the hub material. This prevents the magnets from fracturing under stress. A system of nonmagnetic inserts placed as keys against flattened areas on the hub facilitates manufacture and stabilizes the magnet segments during motor operation. To protect the permanent magnet segments from aggressive

fluids, the exterior of the entire rotor pack system can be bound, filled, and encapsulated with a high temperature and high-toughness nylon or PPS thermoplastic.

[0014] In an implementation, the example rotor construction eliminates PPS as a conventional fixing agent between the hub and components to be attached to the hub. A layer of adaptive glue, formulated with a damping filler, such silicon resin, a hardening agent, and finely-dispersed boron nitride powder, can be used between the magnets and the hub to provide damping and absorb differences in expansion and contraction between the magnets and the hub material during thermal extremes or thermal cycling. In addition, an amorphous or fiber-reinforced tape or other magnetically transparent amorphous or fiber-reinforced layer is used as an outer wrap to fix the magnet segments to the hub. The strong outer wrap also prevents damage to the magnet segments from powerful centrifugal forces at high rotational speed. Yet another exterior layer, such as a high temperature nylon or PPS may be used as an outermost encapsulating layer to protect the magnet segments and the wrap too, from chemically aggressive environments.

Example System

[0015] **Fig. 1** shows an example submersible pumping system 100 that includes an example permanent magnet motor 102 in a motor section of the pumping system 100. The submersible pumping system 100 may include a variety of sections and components depending on the particular application or environment in which it is used. Examples of components utilized in submersible pumping system 100 include at least one submersible pump 104, the example permanent magnet motor 102, and one or more motor protectors 106 that are coupled together to form

stages, sections, or segments of the submersible pumping system 100, also referred to as an electric submersible pump (ESP) string 100.

[0016] In the example system shown, submersible pumping system 100 is designed for deployment in a well 108 within a geological formation 110 containing desirable production fluids, such as petroleum. A wellbore 112 is drilled into formation 110, and, in at least some applications, is lined with a wellbore casing 114. Perforations 116 are formed through wellbore casing 114 to enable flow of fluids between the surrounding formation 110 and the wellbore 112.

[0017] The example submersible pumping system 100 is deployed in wellbore 112 by a deployment system 118 that may have a variety of configurations. For example, deployment system 118 may comprise tubing 120, such as coiled tubing or production tubing, connected to submersible pump 104 by a connector 122. Power is provided to the at least one submersible motor 102 via a power cable 124. The submersible motor 102, in turn, powers submersible pump 104, which can be used to draw in production fluid through a pump intake 126. Within submersible pump 104, multiple impellers are rotated to pump or produce the production fluid through, for example, tubing 120 to a desired collection location which may be at a surface 128 of the Earth.

[0018] The illustrated example submersible pumping system 100 is only one example of many types of submersible pumping systems that can benefit from the features described herein. For example, multiple pump stages with multiple permanent magnet motors 102 and other components can be added to the pumping system 100, and other deployment systems may be used. Additionally, the production fluids may be pumped to the collection location through tubing 120 or through an annulus around the deployment system 118. The submersible pump or pumps 104 can also utilize different types of stages, such as centrifugal, mixed flow, or radial flow stages.

[0019] Fig. 2 shows a transverse cross-sectional view of an example rotor 200 or “rotor pack” for the permanent magnet motor 102. Fig. 2 is only one example of rotor construction provided to show example components and placement. The example rotor 200 attaches to a metal shaft 202, represented as a shaft opening 202 (hole) in the rotor 200. The rotor 200 attaches to the shaft 202 via the inside diameter of a magnetically conductive metal hub 204 (or sleeve) surrounding the shaft 202 and connected to the shaft 202, for example, by a keyway 206 in the hub 204.

[0020] Curved magnet segments 208 and 210, with a north magnetic polarity on the outer convex surface, for example, and curved magnet segments 212 and 214, with a south magnetic polarity on the outer convex surface, for example, are mounted on the hub 204 and held in place by a wrap or a layer of amorphous or fiber-reinforced tape 216 or other strong matrix. The matrix may be a plastic that is reinforced, for example, by fibers of glass, or layers of such fibers. The matrix may be a high-strength amorphous tape for binding that has high resistance to tensions. “Fiberglass tape 216” is used herein to represent such reinforced matrices. Besides holding the magnets 208, 210, 212 & 214 in place, the fiberglass tape 216 maintains the integrity of the magnet segments 208, 210, 212 & 214 against the disintegrating tendency caused by the centrifugal energy of fast rotation and high torque being applied from the magnets 208, 210, 212 & 214 to the hub 204.

[0021] An outermost layer or coating 218 of nylon, PPS, or other thermoplastic sheath may bind the entire example rotor 200 together and protect the magnet segments 208, 210, 212 & 214 and strength matrix from chemically aggressive, corrosive, and abrasive environments which can occur inside ESP motors 102 in some wells. Nonmagnetic inserts 220 & 222 can be used to stabilize the magnet segments 208, 210, 212 & 214, and in an implementation to also facilitate the assembly process.

The hub metal 204 may be machined with flat areas 224 & 226 to seat the nonmagnetic inserts 220 & 222 and to discourage the nonmagnetic inserts 220 & 222 from rotating when the magnet segments 208, 210, 212 & 214 are applying torque to the hub 204 and shaft 202.

[0022] The coefficient of thermal expansion of the magnetic material used for magnet manufacture is significantly different from the coefficient of thermal expansion of the magnetically conductive material of the hub 204 (e.g., steel) to which the magnets 208, 210, 212 & 214 are being fixed. Because of the difference in coefficients of thermal expansion, the magnets 208, 210, 212 & 214 are vulnerable to being cracked when the assembled rotor pack 200 is subjected to operation under high temperature or temperature cycling. Damaged magnets 208, 210, 212 & 214 lead to a loosening of magnetic parameters and eventually to damage and total destruction of the rotor pack 200.

[0023] In an implementation, a damping material 228 between the magnet segments 208, 210, 212 & 214 and the hub 204 is used to prevent damage. A high-temperature adhesive or glue formulated with a filling compound can be used in an example rotor pack design, as the damping material 228. For example, the damping material 228 may be part of a high-temperature adhesive formulation, such as VT-25-200 (Russian Cyrillic name is BT-25-200), silicon resin, hardening agent, with a filling compound included into the composition, such as fine-dispersed boron nitride powder. This filling compound compensates difference in coefficients of thermal expansion between hub material and magnet material. (Chemproduct Ltd., Moscow, Russia). The filling compound can consist of a finely dispersed powder of boron nitride, for example.

[0024] Because the example rotor 200 has no exterior metal sleeve covering the magnets as in conventional rotors, there is a reduction in electrical losses within the rotor 200, as compared with conventional permanent magnet rotors.

[0025] In an implementation, the magnet segments 208, 210, 212 & 214 are samarium-cobalt (SmCo) or other magnetic material with high temperature ratings and high maximum energy products. Preferred magnet segments 208, 210, 212 & 214 are resistant to thermal, mechanical, and chemical decomposition, even though samarium-cobalt magnets tend to be brittle and prone to cracking and chipping. The hub 204 may be keyed to a cam on the motor shaft 202 via the keyway 206. In addition to this keyed slot 206 on the inside surface of the hub 204, the periphery of the hub also has the two flattened areas 224 & 226 providing planar surfaces machined onto the outside surface of the hub 204 at 180 degrees apart from each other. The two flat areas 224 & 226 provide two locations on the exterior of the hub 204 to which the flat-bottomed, nonmagnetic separators or inserts 220 & 222 can be glued, for example with adhesive glue VT-25-200. Because flat areas 224 & 226 are machined from the curved surface (of the hub 204) to be flat, the flat areas 224 & 226 provide non-slip keys on the outside of the hub 204 to which the nonmagnetic inserts 220 & 222 can be glued.

[0026] The nonmagnetic inserts 220 & 222 are spacers that separate the north pole magnet segments 208 & 210 from the south pole magnet segments 212 & 214 on the rotor 200, and also help keep the magnet segments 208, 210, 212 & 214 from physically slipping around the hub 204 during rotation (especially when producing torque).

[0027] In an example construction process, the four magnet segments (the two north segments 208 & 210 and the two south segments 212 & 214) are first glued onto the outside of the hub 204 before the nonmagnetic inserts 220 & 222 are glued onto the hub 204 between the north magnet segments 208 & 210 and the south magnet segments 212 & 214. The glue may be formulated for high-temperature and as a damping material 228, and with a filling compound to compensate differences in expansion and contraction between the

magnet segments 208, 210, 212 & 214 and the hub 204. The glue may be VT-25-200, with a filler of finely dispersed boron nitride, for example. In another example construction process, nonmagnetic inserts 220 & 222 are installed on the hub 204 before or simultaneous with the magnet segments 208 & 210, and 212 & 214.

[0028] **Fig. 3** shows a transverse cross-sectional view of another example implementation of an example rotor 300. Each magnet segment 308, 310, 312 & 314 is an arcuate magnetic element (C-shaped) that occupies a "N" degree sector of the exterior surface of the hub 204 and defines a "N" degree arc of the rotor's 360 degree outside circumference. In the example implementation, N may be equal to 75 degrees, for example. The entire outer convex side of each magnet segment defines a single operative magnetic pole, that is, a north pole or a south pole, for that magnet segment, and the inner concave side of each segment is the opposite magnetic pole of the outer convex side. Thus, the segments are magnetized radially with the north-south or the south-north poles for a given segment occurring across the thickness of each magnet segment, proceeding radially outward from the hub 204 to the outside circumference of the rotor 300.

[0029] In an implementation, the two north magnet segments 308 & 310, with north pole on the outer convex side, are glued adjacent to each other on the hub 204 with the high-temperature glue containing a damping agent 228, such as one containing boron nitride, to form a 150 degree north pole segment on the hub 204, and the two south magnet segments 212 & 214, with south pole on the outer convex side, are likewise glued adjacent to each other on the opposite side of the hub 204 to form a corresponding opposite 150 degree south pole segment. Between the two 150 degree segments occur the flat areas 224 & 226 on the hub 204. The nonmagnetic inserts 320 & 322 are glued to the flat areas 224 & 226, each with an arc of approximately, for example, 30

degrees to complete the 360 degree outer circumference of the rotor 300. In this implementation, each nonmagnetic insert 320 & 322 is tapered to help hold adjacent magnet segments onto the hub 204 when the nonmagnetic inserts 320 & 322 are bound to the hub 204 by the fiberglass tape 216 or other glass fibered layer.

[0030] The outer circumference of rotor 300, composed of the magnet segments 308, 310, 312 & 314 and the nonmagnetic inserts 320 & 324, is then wrapped or otherwise enveloped with a layer of amorphous or fiber-reinforced plastic matrix, for example, reinforced with woven or mesh glass fibers, such as the fiberglass tape 216 or other glass mesh reinforced layer. The amorphous or fiberglass tape 216 preferably has high tensile strength and is refractory or tolerant to high temperatures. The fiberglass tape 216 may have one or more layers of glass fibers, woven glass fibers, or glass mesh, immersed in a plastic, such as epoxy, a thermosetting plastic such as polyester or vinyl ester, or a thermoplastic. Such a fiberglass tape 216 may have an operating temperature of at least 180°C (350°F). In an implementation, a high temperature, heat-resistant and thermal insulating PTFE (TEFLON) coated fiberglass tape 216 offers a higher temperature range with excellent resistance to almost all solvents, caustics, and acids. The base fiberglass fabric is rated to 537°C (1000°F) while the PTFE melting point is 327°C (620°F).

[0031] The layer of fiberglass tape 216 may then be covered with a tough thermoplastic that also fills any cracks and spaces between the magnet segments 308, 310, 312 & 314 and the inserts 320 & 322. The thermoplastic may be, for example, a high-temperature, high-strength plastic PPS (polyphenylene sulfide "Z-230"). Polyphenylene sulfide (PPS) is a high-performance thermoplastic made of an organic polymer consisting of aromatic rings linked with sulfides. Synthetic fiber and textiles derived from this high-performance polymer are known to resist

chemical and thermal attack. The PPS can be molded and machined, if necessary, to high tolerances for the dimensions of the example rotor 200. The PPS coating 218 has a maximum service temperature of approximately 218°C (424°F), and the PPS coating 218 does not dissolve in any solvent at temperatures below approximately 200°C (392°F).

[0032] In an implementation, the nonmagnetic inserts 220 & 222, or 320 and 322, are also made of the polyphenylene sulfide (PPS).

[0033] Fig. 4 shows a longitudinal cutaway view of the example rotor 300 of Fig. 3 along the A-A lines. The hub 204 includes a keyway 206 for positive engagement with a key or cam on the shaft to be inserted in shaft space 202. Magnet segment 308, with a north pole polarity directed radially toward the outer circumference of the rotor 300, is bound to the hub 204 with the fiberglass tape 216. The magnet segment 308 may initially be glued directly to the hub 204 with the glue containing a damping filler 228, including boron nitride for example, during manufacture. A nonmagnetic insert 322 near the bottom of the rotor 300 provides mechanical support between north and south magnet segments, and also provides a 30 degree nonmagnetic transition between north and south poles when the rotor 300 is rotating. The nonmagnetic insert 322 is also bound to the hub 204 with the same amorphous or fiberglass tape 216 as binds the magnet segments 308, 310, 312 & 314 to the hub 204. The entire outer surface of the rotor 300 may then be encased in tough, magnetically transparent thermoplastic, such as the polyphenylene sulfide, PPS. The encasement or envelopment of the exterior of the rotor 300 may also proceed around the ends of the magnet segments 308, 310, 312 & 314 and the ends of the nonmagnetic inserts 320 & 322 to at least partially include the sides of the rotor pack 300 in PPS or other thermoplastic encasement.

[0034] The completed rotor pack 200 or 300 has two poles, a north pole defining, in one example implementation, approximately 150 degrees of the rotor's outer circumference, and a corresponding south pole occupying 150 degrees on the other side of the rotor 300. The intervening 30 degree segment occupied by the nonmagnetic insert 320 between the north and south poles at the top of the rotor 300, and a corresponding 30 degree segment occupied by the other nonmagnetic insert 322 between south and north poles at the bottom of the rotor 300, provide a total 60 degrees of nonmagnetic periphery around the outside circumference of the rotor 300 (or 200).

[0035] A conventional permanent magnet motor for electric submersible pumps uses a 4-pole rotor. Since conventionally there are four poles, each pole must travel, for example, 90 degrees ($1/4$ of 360 degrees) to stay in synch with a rotating magnetic field generated by the stator of the motor. For the example 2-pole rotor 200 being described herein, each pole must travel, for example, 180 degrees ($1/2$ of 360 degrees) to stay in synch with a rotating magnetic field of the same frequency. This means that for a given frequency of alternating current (AC) power being supplied, the example 2-pole rotor 200 will rotate twice as fast as a conventional 4-pole rotor. Or stated in another manner, to rotate at the same speed as the conventional 4-pole rotor, the example 2-pole rotor 200 only needs one-half of the AC frequency that the conventional 4-pole motor requires to rotate at the same speed. Thus, if the conventional 4-pole rotor requires 100 Hz for a given RPM, the example 2-pole rotor 200 may only need 50 Hz to rotate at the same RPM.

Example Methods

[0036] Fig. 5 shows an example method 500 of constructing a permanent magnet rotor for an electrical submersible pump.

[0037] In the flow diagram, the operations are summarized in individual blocks.

[0038] At block 502, a first curved magnet of north magnetic polarity and a second curved magnet of south magnetic polarity are combined on a rotor with a damping layer to provide a 2-pole motor for the electric submersible pump.

[0039] At block 504, the rotor, including the first and second curved magnets, are wrapped in a magnetically transparent layer that has glass-fiber or glass-mesh reinforcement.

[0040] Although only a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from the subject matter of low profile valves. Accordingly, all such modifications are intended to be included within the scope of this disclosure as defined in the following claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. For example, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. § 112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words 'means for' together with an associated function.

CLAIMS

1. An apparatus, comprising:
 - a permanent magnet motor for driving an electric submersible pump in a well;
 - a rotor attached to a hub in the permanent magnet motor for applying a torque to a rotatable shaft of the permanent magnet motor;
 - a first arcuate magnet of the rotor including an outer convex surface of north magnetic polarity;
 - a second arcuate magnet of the rotor including an outer convex surface of south magnetic polarity; and
 - a magnetically transparent high-strength matrix around an outer surface of the rotor to bind the first and second arcuate magnets to the hub and to prevent drifting and disintegration of the first and second arcuate magnets when generating high torque and in thermally, chemically, and abrasively harsh environments.
2. The apparatus of claim 1, wherein the magnetically transparent high-strength matrix comprises one of a plastic reinforced with a glass fiber or a high tensile-strength amorphous tape.
3. The apparatus of claim 2, wherein the magnetically transparent high-strength matrix binds the first and second arcuate magnets with a contractive tension to prevent disintegration of a brittle magnet composition of the first and second arcuate magnets at a high rotational speed.
4. The apparatus of claim 1, further comprising a high-temperature adhesive to bind the first arcuate magnet and the second arcuate magnet to the hub, wherein the high-temperature adhesive is

formulated with a high-temperature glue, a silicon resin, a hardening agent, and a damping agent to compensate for difference in coefficients of thermal expansion between the arcuate magnets and the hub.

5. The apparatus of claim 4, wherein the damping agent comprises at least one of a silicon resin and a finely-dispersed boron nitride powder.

6. The apparatus of claim 1, further comprising nonmagnetic inserts between each set of ends of the first and second arcuate magnet segments; and

wherein the magnetically transparent high-strength matrix binds each nonmagnetic insert to a respective flat area on the hub.

7. The apparatus of claim 1, wherein the first and second arcuate magnets each occupy 150 degrees of a circumference of the rotor to provide a 2-pole rotor with a single north pole and a single south pole.

8. The apparatus of claim 6, wherein two nonmagnetic inserts each occupy 30 degrees of a circumference of the rotor, to provide magnetically inert transitions between the single north pole and the single south pole during a single rotation of the rotor.

9. The apparatus of claim 8, wherein each nonmagnetic insert is tapered to hold two ends of the first and second arcuate magnets against the hub when the nonmagnetic inserts are bound by the magnetically transparent glass fiber matrix.

10. The apparatus of claim 1, further comprising a high-temperature and high-toughness nylon or polyphenylene sulfide (PPS) thermoplastic over the magnetically transparent high-strength matrix to encapsulate an outside of the rotor against corrosive, abrasive, and high temperature environments.

11. The apparatus of claim 1, wherein the first and second arcuate magnets each occupy 150 degrees of a circumference of the rotor to provide a 2-pole rotor with a single north pole and a single south pole;

wherein each magnetic pole of the 2-pole rotor travels 180 degrees to remain in synchronization with a rotating magnetic field.

12. The apparatus of claim 11, wherein for a given frequency of alternating current (AC) supplied power, the 2-pole rotor rotates twice as fast as a 4-pole rotor at the given frequency.

13. The apparatus of claim 11, wherein the 2-pole rotor uses one-half a given frequency of alternating current (AC) supplied power to rotate at a same speed as a 4-pole rotor at the given frequency.

14. An electric submersible pump, comprising:
a pump for artificial lift of fluid from a well;
a permanent magnet motor to drive the pump;
a 2-pole rotor in the permanent magnet motor including a north pole magnet and a south pole magnet;

an adhesive containing a damping agent to bind the north and south pole magnets to the 2-pole rotor and protect the north and south magnets from damage due to differences in coefficients of thermal expansion in the 2-pole rotor;

a layer of high-strength plastic around an outer surface of the 2-pole rotor to bind the north and south pole magnets to the 2-pole rotor and to prevent drifting of the north and south pole magnets during high torque duty of the 2-pole rotor.

15. The electric submersible pump of claim 14, wherein the layer of high-strength plastic comprises one of an amorphous tape or a fiberglass tape.

16. The electric submersible pump of claim 14, wherein the 2-pole rotor comprises:

- a first curved magnet including a convex side with a north magnetic pole and a concave side with a south magnetic pole;

- a second curved magnet including a convex side with a south magnetic pole and a concave side with a north magnetic pole;

- each curved magnet spanning approximately 150 continuous degrees of a circumference of the 2-pole rotor.

17. A rotor pack for an electric submersible pump, comprising:

- a shaft to provide power in a permanent magnet motor of the electric submersible pump;

- a hub attached to the shaft to hold permanent magnets;

- a curved north pole magnet spanning 150 degrees of a circumference of the rotor;

- a curved south pole magnet spanning 150 degrees of a circumference of the rotor;

- a magnetically transparent wrap binding the curved north pole magnet and the curved south pole magnet to the hub; and

- a glass fiber reinforcement within the magnetically transparent wrap.

18. The rotor pack of claim 17, wherein the magnetically transparent wrap comprises a fiberglass tape.

19. The rotor pack of claim 17, further comprising a high-temperature adhesive between the hub and the curved magnets, wherein the adhesive includes a damping agent; and

a nylon or polyphenylene sulfide (PPS) thermoplastic encapsulation around the magnetically transparent wrap to protect the rotor from corrosives, abrasives, and high temperature environments.

20. The rotor pack of claim 17, wherein the curved north pole magnet and the curved south pole magnet provide a 2-pole rotor; and

wherein each curved magnet comprises multiple contiguous curved magnet segments of like magnetic polarity.

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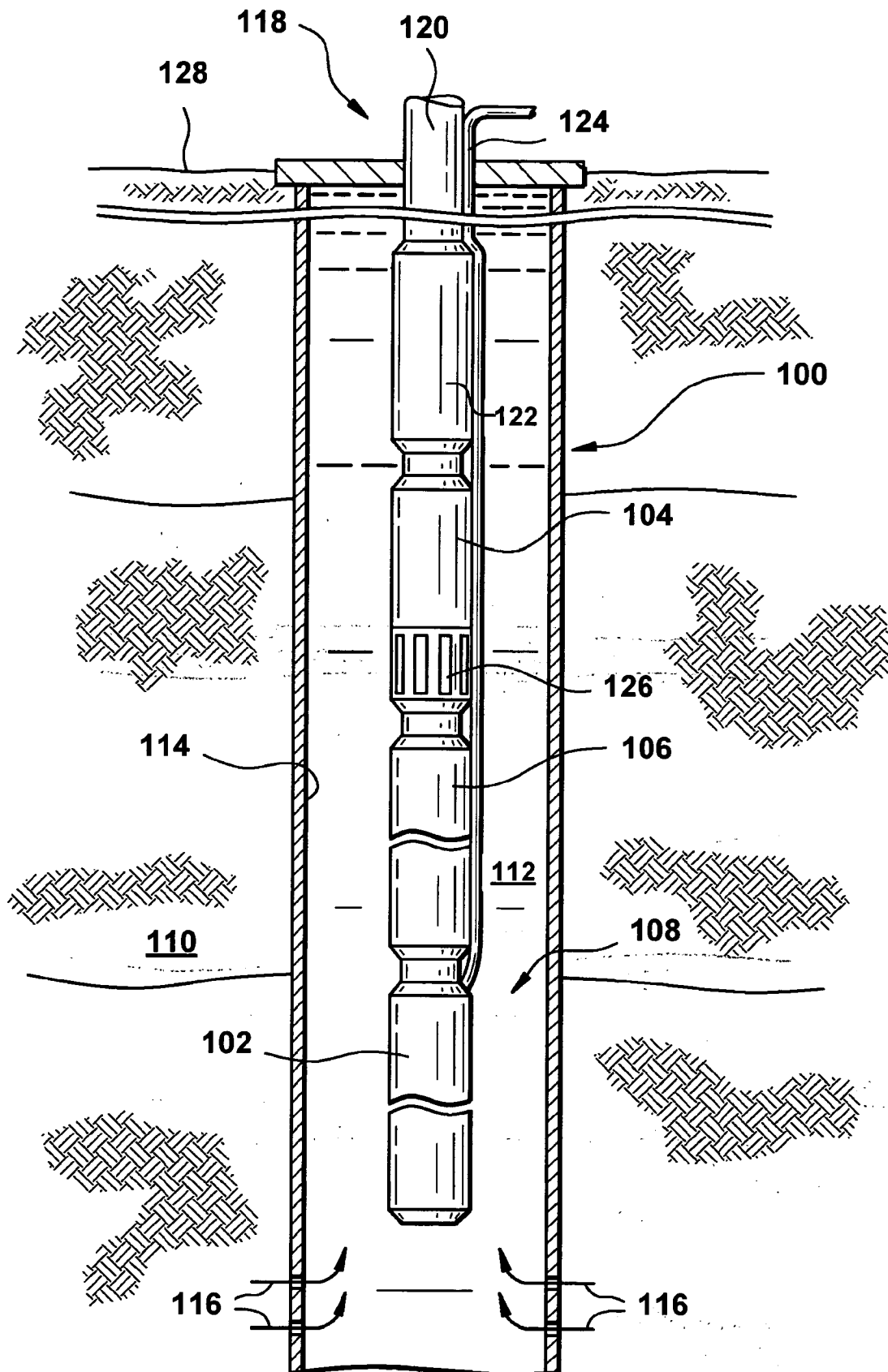


FIG. 1

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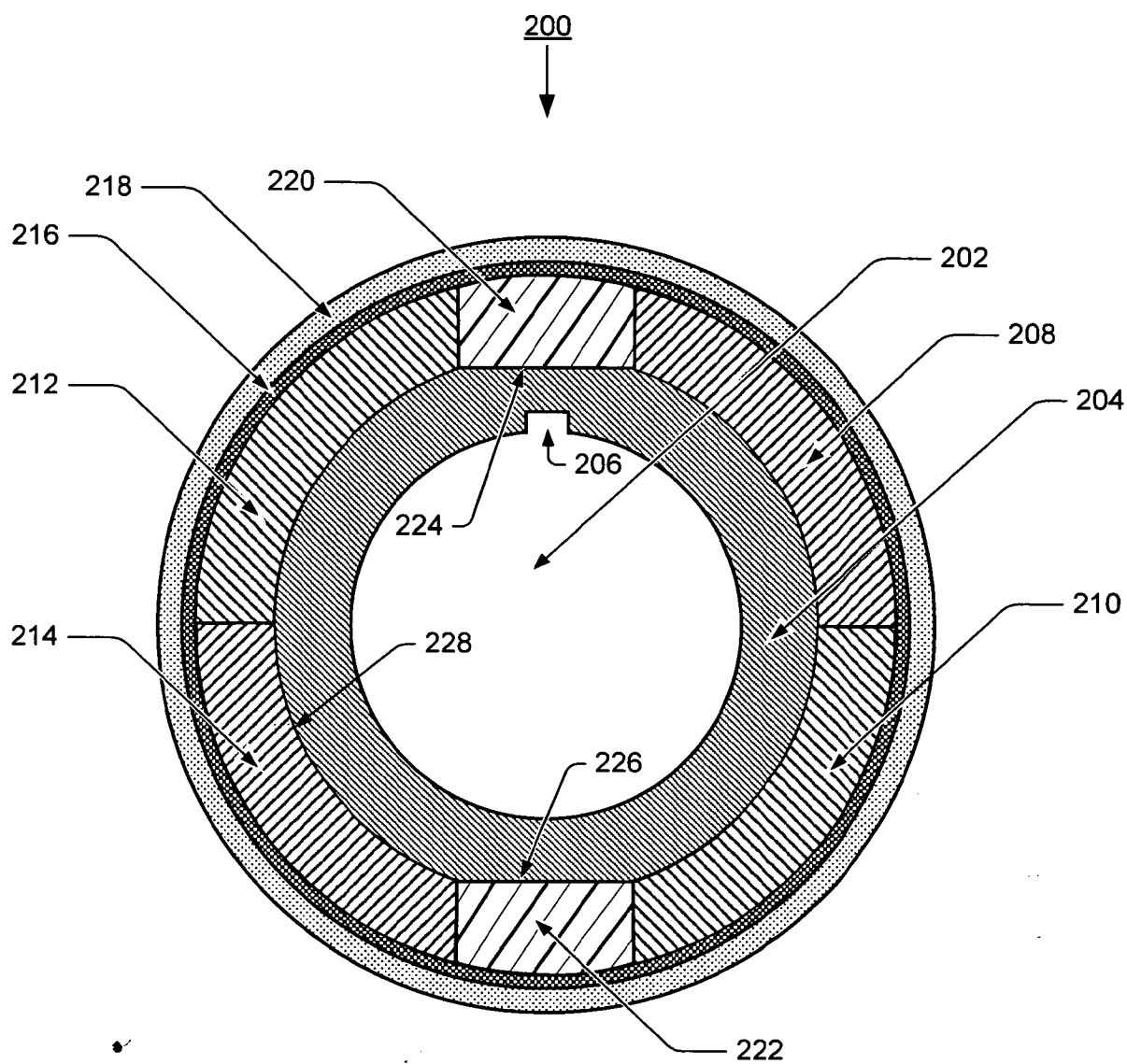


FIG. 2

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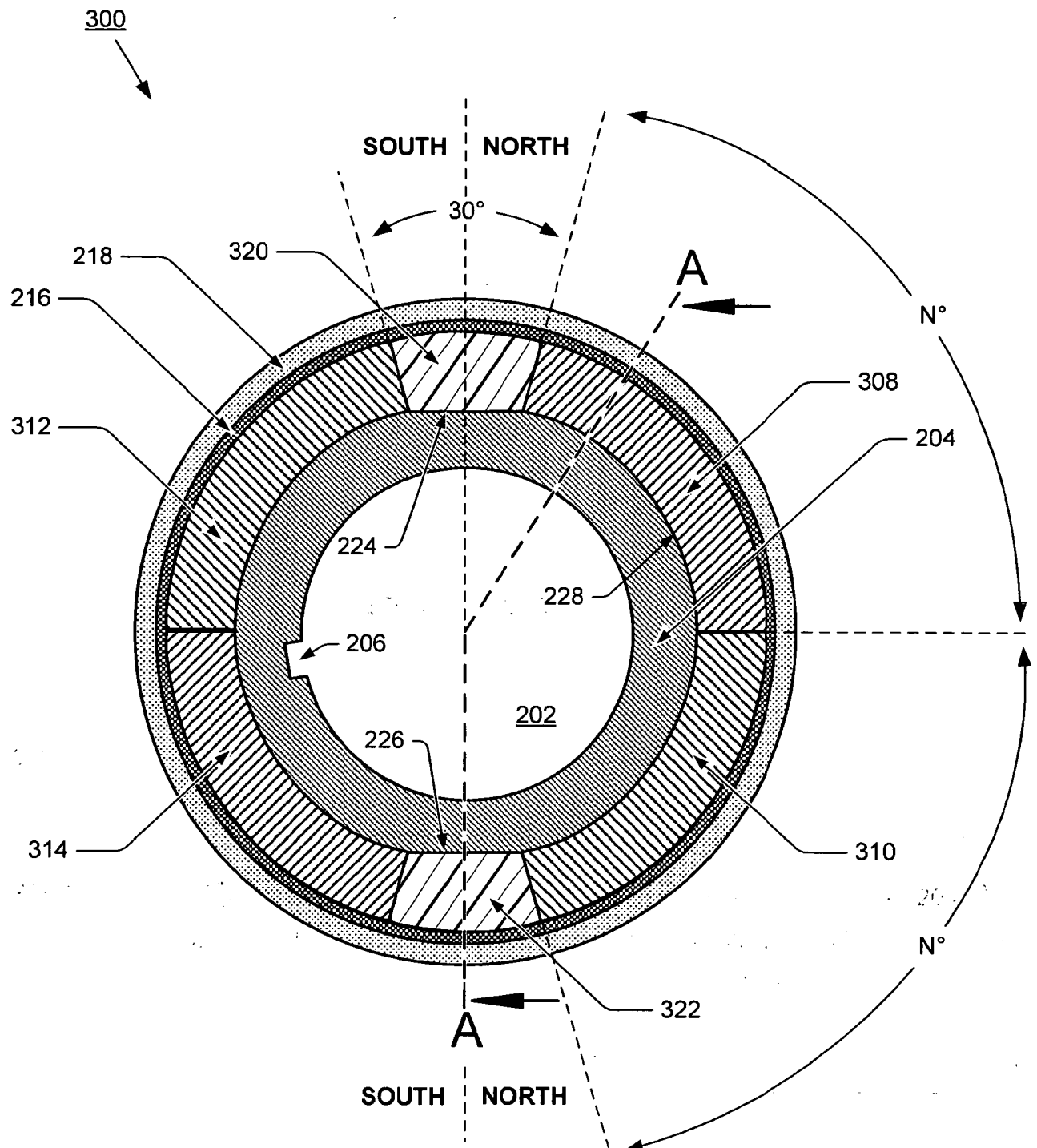


FIG. 3

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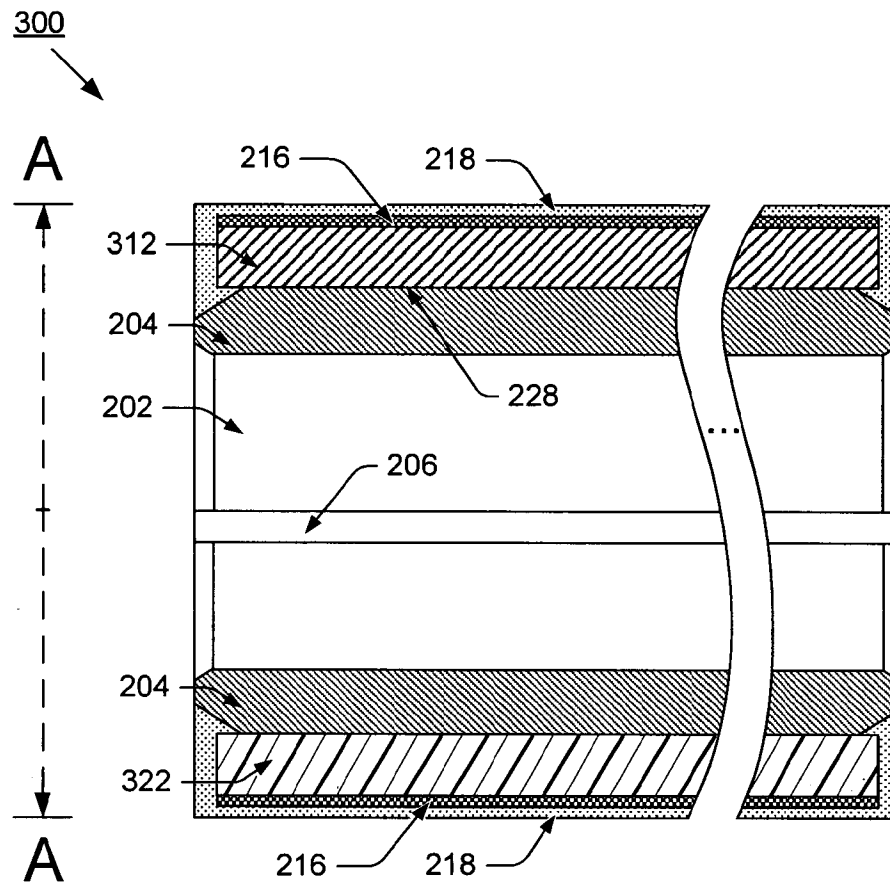


FIG. 4

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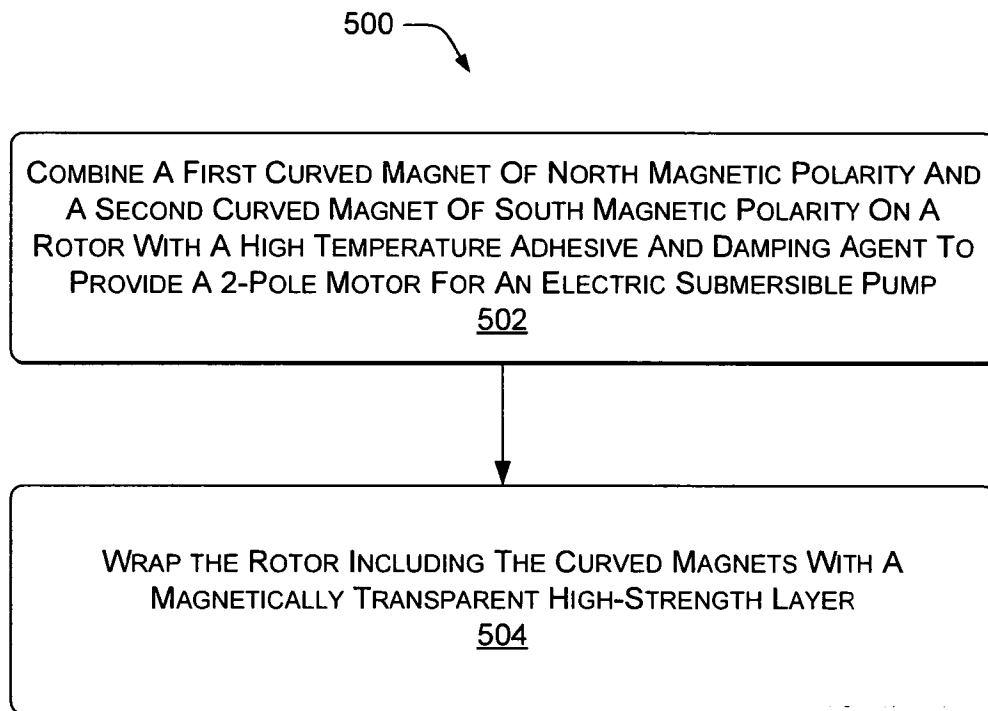


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/RU 2014/000490

A. CLASSIFICATION OF SUBJECT MATTER		
H02K 1/27 (2006.01) H02K 1/28 (2006.01) H02K 21/14 (2006.01) F04B 17/03 (2006.01) According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
H02K 1/00, 1/06, 1/22, 1/27, 1/28, 21/00, 21/12, 21/14, F04B 17/00, 17/03		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE, Information Retrieval System of FIPS		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/0028119 A1 (VLADIMIR IOSIFOVICH SAGALOVSKIY et al.) 30.01.2014 [0002]-[0004], [0015]-[0024], fig.3A	1
Y		2-3,6, 14-15
A		4-5, 7-13, 16-20
Y	US 2004/0108781 A1 (ANTHONY G.RAZELL) 10.06.2004, [0012] [0044]	2, 15
Y	RU 2505908 C1 (OTKRYTOE AKTSIONERNOE OBSHESTVO "AGREGATNOE KONSTRUCTORSKOE BURO "YAKOR" et al.) 27.01.2014, p.4, lines 40-54, p.5, lines 37-49	3
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
"A" document defining the general state of the art which is not considered to be of particular relevance		
"E" earlier document but published on or after the international filing date		
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)		
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search	Date of mailing of the international search report	
05 March 2015 (05.03.2015)	02 April 2015 (02.04.2015)	
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Authorized officer E.Chuhlantseva Telephone No. (299) 240-25-91	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/RU 2014/000490

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0204289 B1 (HITACHI, LTD) 24.10.1990, col.2, lines 32-65, col.3, lines 1-13	6
Y	US 7375451 B2 (FABER S.P.A.) 20.05.2008, col.3, lines 20-23	14-15
Y	US 2008/0204539 A1 (YUKIO ITAMI et al) 28.08.2008, [0071]	14-15