

Electric motor with permanent magnet excitation.

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The invention relates to an electric motor with permanent-magnet excitation, having motor parts which are movable relative to one another, of which one motor part forms a multi-pole excitation field in an air gap by means of permanent magnets and the other motor part comprises a coil configuration situated in this air gap, the
5 permanent-magnetically excited motor part comprising a cylindrical yoke having substantially radial slots, which are uniformly spaced about the circumference and in which permanent magnets are mounted, which permanent magnets are magnetised in a circumferential direction with directions of magnetisation which change from magnet to magnet.

The generation of multi-pole magnet fields is one of the most important
10 technical uses of permanent magnets, most of these components being used in permanent-magnet motors. These components may have different shapes. The most important shapes include rotationally symmetrical disks, which produce a multi-pole magnetic field in an axial direction, rectangular blocks, which generate a multi-pole field directed perpendicularly to one of the block surfaces, and cylinders or hollow cylinders, which generate a multi-pole
15 magnetic field in a radial direction.

DE 36 07 648 C2 discloses a motor in which permanent-magnet annular segments are arranged on an iron sleeve, thus forming a cylindrical permanent-magnet rotor. The permanent magnets are magnetised in such a manner that in the direction of the air gap each north pole is followed by a south pole. The rotor is surrounded by a cylindrical stator
20 without winding slots. The winding is arranged in the air gap between the permanent-magnet rotor and a soft-magnetic stator sleeve.

If only those materials which are currently used in large quantities are considered, these segments can be made either of ferrites, which are cheap but which generate comparatively weak magnetic fields, or rare-earth materials, which are expensive
25 but which produce strong magnetic fields.

For both groups of materials a distinction is made between sintered and resin-bonded materials. The sintered materials are anisotropic, as a result of which the magnetic fields produced by them are stronger than those produced by the isotropic resin-bonded materials. The disadvantage of sintered materials is that they can be manufactured



only in simple shapes and these shapes are anisotropic only in a few directions which are dictated by physical properties. Therefore, only simple magnetisation patterns can be produced. Moreover, it is very difficult to manufacture sintered magnets with narrow tolerances of their mechanical dimensions. Conversely, resin-bonded materials have the advantage that components with complicated geometries and narrow mechanical tolerances can be manufactured at low cost and that by means of a suitable magnetisation process it is also possible to obtain intricate magnetisation patterns in the material.

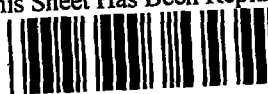
A problem when generating multi-pole radial magnetic fields is that to date cylinders or hollow cylinders with radial anisotropy cannot be manufactured in an industrial process. It is possible to manufacture cylinders or hollow cylinders with diametral anisotropy but these are only capable of generating two-pole magnetic fields and are therefore not suitable for uses requiring magnetic fields with a larger number of poles.

The manufacture of the rotors described in DE 36 07 648 C2 is intricate because the permanent-magnetic annular segments each have to be glued onto the rotor sleeve. To guarantee a reliable operation rotor binding is necessary. Large magnetic fields can be obtained when the magnet segments are made of an anisotropic material. However, even the production of annular segments from an anisotropic material is already very intricate.

From DE 42 16 938 (PHD 92.057) a permanent-magnet rotor is known which consists of an iron yoke having radial slots in which block-shaped permanent magnets are mounted. These permanent magnets are magnetised circumferentially and have a direction of magnetisation which changes from magnet to magnet in the circumferential direction. These rotors can be manufactured more simply than the rotors known from DE 36 07 648 C2. Gluing the blocks into the slots is not a problem. No additional fastening is required. Their simple geometry allows the block-shaped magnets to be simply made of an anisotropic material and to be subsequently magnetised so that large magnetic fields can be produced.

It is an object of the invention to provide a rotor for an electric motor of the type defined in the opening paragraph, which in comparison with the known constructions generates a substantially larger magnetic field in the air gap, so as to produce a larger torque for a given current in the coil configuration.

According to the invention this object is achieved in that the cylindrical yoke consists of an isotropic permanent-magnet material which in yoke portions between the permanent magnets in the slots is predominantly radially magnetised with such apolarity that



the polarity of the resulting magnetic field in the air gap corresponds to the polarity of the magnetic field produced by the permanent magnets in the slots, and in that the permanent magnets in the slots consist of an anisotropic permanent-magnet material.

5 In this way it is achieved that the yoke actively contributes to the generation of the multi-pole magnetic field.

In a further embodiment of the invention the slots have an inclination between -30° and $+30^\circ$ relative to the radial direction. By varying this inclination it is possible to adapt the shape of the magnetic field in the air gap and, consequently, the voltage induced in the coil configuration to specific requirements.

10 In a further embodiment of the invention the coil configuration consists of curved foil windings. This provides a higher copper factor in the case of a flat construction.

In a further embodiment of the invention the coil configuration consists of curved preformed wound coils. Such a coil configuration can be manufactured economically.

15 In a further embodiment of the invention a cylindrical yoke of a soft-magnetic material is disposed at the side of the air gap which faces the permanent magnet, behind the coil configuration, which yoke is fixedly connected to the coil configuration.

In a further embodiment of the invention a cylindrical yoke of a soft-magnetic material is disposed at the side of the air gap which faces the permanent magnet, behind the coil configuration, which yoke is fixedly connected to the permanent magnet. This
20 has the advantage that the rotor no longer induces any alternating fields in the cylindrical yoke, so that no more iron losses occur.

The invention will now be described in more detail with reference to the drawings. In the drawings:

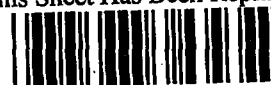
25 Fig. 1 shows an example relating to a spindle motor having a cylindrical rotor,

Fig. 2 is a sectional view of the rotor with permanent magnets mounted in radial slots, and

Fig. 3 is a sectional view of the rotor with permanent magnets mounted in slots which are inclined relative to the radial direction.

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Fig. 1 is a sectional view of a spindle motor 1a, intended particularly as a drive motor for hard disk drives in data processing equipment. A motor shaft 2 of this spindle motor 1a is fixedly connected to a disk 3 of a hard disk housing, not shown. Bearings 4, 5a and 5b support a rotatable hub 6 on the motor shaft 2. The hub 6 has an inner



hub portion 6a surrounding the motor shaft 2 and carrying a permanent-magnet cylindrical rotor 7 on its outer circumference 6b. The field generated by the rotor magnet 7 at its outer circumference 7a extends perpendicularly to the axis of rotation 16. The motor shaft 2 carries a mounting plate 8. This mounting plate carries externally a coil configuration 9, which belongs to the motor, and a yoke 10. The hub 6 further has an outer hub portion 6c, which surrounds the yoke 10.

The coil configuration 9 may consist of a curved foil winding or of curved preformed wound coils. With the present motor construction the mounting plate 8 carries the sleeve-shaped soft-magnetic yoke 10 at the outer circumference 9a of the coil configuration 9. With this construction two air gaps 11 and 12 are formed, one air gap 11 separating the yoke 10 from the hub 6 and the other air gap 12 separating the rotor magnet 7 from the coil configuration 9.

Fig. 2 is a sectional view of the permanent-magnet rotor 7. This rotor consists of a cylindrical yoke 17 of an isotropic magnet material, which has radial slots 18 in which the block-shaped permanent magnets 19 of an anisotropic material are mounted. These permanent magnets 19 are circumferentially magnetised and have directions of magnetisation 20, 21 which change from magnet to magnet in the circumferential direction. In its portions 22 between the permanent magnets 19 mounted in the slots 18 the yoke 17 is predominantly radially magnetised in such a manner that the resulting magnetic field in the air gap 11 has the same polarity as the magnetic field produced by the permanent magnets 19 mounted in the slots 18.

Fig. 3 is a modification of the embodiment shown in Fig. 2, in which the slots 18a have an inclination of approximately 20° relative to the radial direction.

In another embodiment of the invention which is not shown herein, it is also possible that the cylindrical yoke 10 of a soft-magnetic material is disposed at the side of the air gap which faces the permanent magnet 7, behind the coil configuration 9, which yoke is fixedly connected to the permanent magnet 7. This has the advantage that the rotor 7 no longer induces any alternating fields in the cylindrical yoke, so that no more iron losses occur.

CLAIMS:

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1. An electric motor with permanent-magnet excitation, having motor parts (7, 9) which are movable relative to one another, of which one motor part forms a multi-pole excitation field in an air gap (11) by means of permanent magnets (7) and the other motor part comprises a coil configuration (9) situated in this air gap, the permanent-magnetically
5 excited motor part comprising a cylindrical yoke (17) having substantially radial slots (18, 18a), which are uniformly spaced about the circumference and in which permanent magnets (19) are mounted, which permanent magnets are magnetised in a circumferential direction with directions of magnetisation which change from magnet to magnet, characterised in that the cylindrical yoke (17) consists of an isotropic permanent-magnet material which in yoke
10 portions (22) between the permanent magnets (19) in the slots (18, 18a) is predominantly radially magnetised with such apolarity that the polarity of the resulting magnetic field in the air gap (11) corresponds to the polarity of the magnetic field produced by the permanent magnets (19) in the slots (18, 18a), and in that the permanent magnets (19) in the slots (18, 18a) consist of an anisotropic permanent-magnet material.
- 15 2. An electric motor as claimed in Claim 1, characterised in that the slots (18, 18a) have an inclination between -30° and $+30^{\circ}$ relative to the radial direction.
3. An electric motor as claimed in Claim 1 or 2, characterised in that the coil configuration (9) consists of curved foil windings.
4. An electric motor as claimed in Claim 1 or 2, characterised in that the
20 coil configuration (9) consists of curved preformed wound coils.
5. An electric motor as claimed in Claim 3 or 4, characterised in that a cylindrical yoke (10) of a soft-magnetic material is disposed at the side of the air gap which faces the permanent magnet, behind the coil configuration (9), which yoke is fixedly connected to the coil configuration (9).
- 25 6. An electric motor as claimed in Claim 3 or 4, characterised in that a cylindrical yoke (10) of a soft-magnetic material is disposed at the side of the air gap which faces the permanent magnet, behind the coil configuration (9), which yoke is fixedly connected to the permanent magnet (7).