Description

A rotor for an electrical machine

Technical Field

This invention relates to a rotor for an electrical machine and, in particular, a rotor having permanent embedded magnets, that is, magnets that are seated in slots made in the rotor itself.

Background Art

Embedded magnet rotors of known type, used especially in brushless motors, usually consist of a laminated core, that is to say, a core made up of a plurality of thin metal laminations and having a principal axis that coincides with the axis of rotation of the motor.

The rotor normally has a plurality of longitudinal slots, parallel to the principal axis, and a central hole or opening, also parallel to the principal axis, for accommodating the magnets and a drive shaft, respectively.

The rotor is mounted in a stator equipped with magnetic poles which, when powered, generate a magnetic field that interacts with the magnets and causes the rotor to turn.

One disadvantage of motors that use rotors of this kind is due to the magnetic attraction between the magnets in the rotor and the poles on the stator giving rise to what is commonly referred to as "cogging torque" or "detent torque"

Cogging torque causes non-uniformity in the angular speed of the rotor, which tends to rotate in a series of small "jerky" movements instead of smoothly and continuously.

Embedded magnet rotors are also difficult to balance and assemble, especially when the magnets are inserted into the longitudinal slots.

The inside dimensions of the slots are slightly larger than the outside dimensions of the magnets so that the latter can be inserted into the slots.

The result is that in prior art rotors, however small these dimensional differences between slots and magnets may be, the magnets are not held firmly in place and the centrifugal force

created by the rotational motion pushes them against the radially outermost wall of the slot.

That means the weight distribution and air gap shape when the rotor is at rest differ from the weight distribution and air gap shape when it is rotating.

In other words, the position of the magnets relative to the rotor core changes when the motor is started, making it very difficult to optimise flows and geometry in the motor design.

Optimisation of geometry is also made more difficult by concentricity errors in the different sheets making up the rotor due to the fact that the sheets are cut at different times. These errors cause rotor unbalance.

Disclosure of the Invention

In this context, the main purpose of the present invention is to propose an embedded magnet rotor which is easy to assemble and in which the position of the magnets when the rotor is at rest does not change when the motor is switched on and the rotor starts turning.

Another aim of the invention is to provide a rotor with a balanced weight distribution under both static and rotating conditions.

Yet another aim of the invention is to provide a rotor, especially for brushless motors, that reduces cogging torque during motor operation.

The above mentioned purpose and aims are substantially achieved by a rotor for an electrical machine having the characteristics defined in the independent claims 1 and 14 and in one or more of the dependent claims herein.

Description of the Drawings

Further features and advantages of the present invention are more apparent in the detailed description below, with reference to a preferred, non-limiting, embodiment of a rotor for an electrical machine, as illustrated in the accompanying drawings, in which:

Figure 1 is a schematic perspective view of a four-pole rotor according to the present invention;

Figure 2 illustrates the rotor of Figure 1 in a schematic front

view with some parts cut away in order to better illustrate others;

Figure 3 illustrates the detail A from Figure 2 in a schematic scaled-up front view with some parts cut away in order to better illustrate others;

Figure 3a illustrates the detail B from Figure 3 in a schematic scaled-up front view;

Figure 3b is a schematic side view of an elastic element forming part of the rotor according to the invention;

Figure 4 is a schematic front view, with some parts cut away to better illustrate others, of the rotor shown in the drawings listed above;

Figure 5 illustrates a part of the rotor of Figure 2 in a schematic scaled-up front view;

Figure 6 is a schematic front view, with some parts cut away in order to better illustrate others, of an eight-pole motor equipped with a rotor according to the invention;

Figure 7 illustrates the magnetic flux pattern in a preferred embodiment of an electric motor equipped with the rotor according to the invention;

Figure 8 shows the curve representing the cogging torque in the motor of Figure 7;

Figure 9 illustrates a second embodiment of a four-pole rotor according to the invention in a schematic perspective view;

Figure 10 shows a detail of another embodiment of a rotor according to the invention.

Description of the preferred embodiments of the invention

With reference to the accompanying drawings, the numeral 1 denotes a rotor, according to the present invention, for an electric motor M.

As shown in Figures 4 and 6, the motor M comprises a stator 200 which accommodates the rotor 1.

The rotor 1 has a principal axis of rotation D, normally coinciding with the axis of the motor M, and comprises a laminated core 2, that is to say, consisting of a plurality of thin laminations 3 firmly joined to each other by bonding elements 3a (assembled according to what is known as "stacking technology")

delimited by a first and a second end wall 4, 5 and by a lateral surface 6.

The core 2 has a longitudinal hole 7, whose axis substantially coincides with the principal axis D, for coupling with a motor shaft 8.

The first and second end walls 4, 5 are preferably parallel with each other. To guarantee this parallelism, the laminations 3 are grouped together in stacks which are bonded to form the laminated core 2.

Advantageously, each stack is rotated relative to the adjacent stack, not only to maintain the parallelism of the end walls 4, 5 but also to correct the stacking factor which is altered when the laminations 3 are cut.

The purpose of stacking factor correction is to keep resistance constant along the entire laminated core 2.

As shown in Figures 1 and 2, illustrating a four-pole rotor 1, the core 2 also has four longitudinal slots 9, each housing a respective magnet 10.

Preferably, each magnet 10 has a predetermined weight so as to make it easier to balance the rotor 1.

Advantageously, in alternative embodiments that are not illustrated, the magnets 10 are longer or shorter than the respective slots 9 so as to optimise or maximise the magnetic field.

As shown in Figure 3, each slot 9 has a central zone 14 for accommodating the respective magnet 10 and a pair of shaped end portions 15 which are suitably angled with respect to the central zone 14.

As is known, these end portions 15 are empty and are used, in particular, to prevent closure of the leakage flux created by the magnet 10 housed in the slot 9.

At the end portions 15, each slot 9 has ribs 16 for guiding each magnet 10 in the respective slot 9.

The magnet 10 abuts against the ribs 16 in such a way as to prevent the magnet 10 itself from moving sideways in the slot 9.

As illustrated in Figures 3a and 10, the ribs 16 are made respectively in a radially inside wall 9a of the slot 9 and in a radially outside wall 9b.

It should be noticed that, in the preferred embodiment illustrated, the ribs 16 have a circular profile of radius R.

The lateral surface 6 of the core 2 is defined by a plurality of circular arcs 11 connected to each other and, more specifically, in the case of a four-pole rotor 1, the lateral surface of each lamination 3 is defined by four arcs 11 of radius R3.

Looking in more detail at a single lamination 3 for simplicity of description, the tops 12 of the arcs 11 are located at an equal distance R1 from the axis D and each is positioned along an axis D1 that is substantially perpendicular to the principal axis D and passes through the centre line of a respective longitudinal slot 9.

Basically, each arc 11 is positioned at a respective slot 9 and adjacent arcs 11 are joined by a straight segment 13.

The single lamination 3 (and, consequently, the core 2) has the shape of a polygon with rounded corners.

The centres of the arcs 11 are at an equal distance R2 from the axis D.

As illustrated in particular in Figure 2, the centres of the arcs 11 are positioned substantially at an internal edge 24 of the longitudinal hole 7 so as to optimise the magnetic flux distribution through the air gap, as described in more detail below.

By way of example and without restricting the scope of the invention, each arc 11 in the 4-pole rotor preferred embodiment subtends an angle H of between approximately 55° and approximately 65°, measured with reference to the principal axis D. More specifically, the angle H subtended by the arcs 11 in the preferred embodiment is approximately 60°.

As illustrated in Figure 5, the core 2 of the rotor 1 has a series of substantially T-shaped portions or zones 25.

The zones 25 are delimited by the above mentioned connecting segments 13 and by the profile of the end portions 15 of the contiguous slots 9.

Each zone 25 has a leg 26 of width S extending in a substantially radial direction along the axis D1 and a bridge 27, of width S1, joining two consecutive arcs 11 and extending in a direction substantially perpendicular to the leg 26.

As illustrated in particular in Figures 3 and 3b, the rotor 1

comprises elastic retaining means 17 for keeping the magnet 10 in the slot 9 and preventing it from moving radially during operation of the motor M.

The means 17 comprise an elastic element 18 positioned between the magnet 10 and the core 2.

The elastic element 18 consists preferably of a flexural spring (leaf spring). The spring 18 has a substantially straight portion 100 on which the respective magnet 10 rests.

Preferably, the portion 100 extends for the full length of the respective slot 9 and the corresponding magnet 10 is supported along its full length by the portion 100.

The spring 18 also has a pair of suitably curved side portions 101 abutting against the core 2.

Each spring 18 is inserted lengthways into the rotor 1, in particular in a groove 19 extending in a direction parallel to the axis D and located half way along the respective slot 9.

Each spring 18 pushes the respective magnet 10 in the aforementioned radial direction D1 towards the edge of the rotor 1.

It should be noticed that the springs 18 oppose the magnetic forces of attraction and repulsion acting on the magnets 10 and due to the operation of the motor M and thus prevent the magnets 10 from moving inside the respective slots 9.

Thus, there are no changes in either magnetic or weight distribution in the rotor 1 when it changes from a static to an operating configuration. The magnets remain positioned against the radially outermost wall of the slot when the rotor is stopped and when it rotates.

The elastic retaining means 17 and the guide ribs 16 thus constitute means 20 for positioning the magnets 10 in the slots 9 and are designed not only to facilitate insertion of the magnets into the slots but also to keep them in the same radial position during the operation of the motor.

Notice that in the preferred embodiment illustrated in Figure 9, the magnets 10 consist of a plurality of portions 10a, 10b, 10c, 10d housed side by side in the respective slot 9.

This solution advantageously reduces losses due to eddy currents in the rotor. In this case, the spring 18, not illustrated,

is suitably shaped to push all the portions 10a, 10b, 10c, 10d in a substantially radial direction and to keep them in the right position.

Advantageously, in other embodiments which are not illustrated each magnet 10 consists of any number of portions, according to need.

The rotor 1 also has a series of longitudinal balancing holes 21.

The holes 21 are preferably filled with suitable balancing weights 22 used to compensate for imbalances caused by differences in the magnets 10 in the same rotor.

The weights 22 for balancing the rotor are also useful in cases where the individual laminations 3 are not precisely concentric.

In the preferred embodiment of the rotor with 4 poles described by way of example, the arcs 11 of the rotor 1 have a radius R3 measuring between approximately 12 mm and approximately 15 mm, and specifically, measuring approximately 13.1 mm.

The magnets 10 are between approximately 30 mm and approximately 50 mm in length L1, between approximately 14 mm and approximately 16 mm in width L2 and between approximately 2.5 mm and approximately 3.5 mm in height L3.

Specifically, the magnets 10 are approximately 40 mm in length L1, approximately 15.4 mm in width L2 and approximately 3 mm in height L3.

The radius R of the ribs 16 measures between approximately 0.1 mm and approximately 0.5 mm in length, and specifically, the radius R measures approximately 0.2 mm.

Thus, the ribs 16 are low compared to the magnet 10 so as to prevent short circuiting the latter.

The thickness S of the leg 26 is between approximately 0.8 mm and approximately 2.2 mm, and specifically, is approximately 2 mm, whilst the thickness S1 of the bridge 27 is between approximately 0.5 mm and approximately 0.8 mm, and is preferably approximately 0.6 mm.

As shown in Figures 7 and 8, the motor M equipped with the rotor 1 described herein has practically no flux leakage and its cogging torque curve is substantially sinusoidal and has relatively

low maximum values.

In the case of a motor M with an 8-pole rotor, as shown in Figure 6, the preferred distance R2, that is, the common distance between the principal axis D and the centres of the arcs 11 defining the lateral surface 6 is equal to approximately one third of the distance R1 between the tops of the arcs 11 and the principal axis D.

Each arc 11 subtends an angle H of approximately 30 degrees and the rotor 1 has ventilation holes 28.

Preferably, in alternative embodiments, the distance R2, that is, the common distance between the principal axis D and the centres of the arcs 11 defining the lateral surface 6 is equal to approximately one half of the distance R1 between the tops of the arcs 11 and the principal axis D.

The invention brings important advantages.

The positioning means 20 guarantee optimum rotor balance since the weight distribution does not change significantly when the rotor changes from a static to a dynamic configuration.

The stable position of the magnets enables rotor geometry to be optimised to achieve good flux distribution through the air gap and a significant reduction of the cogging torque.

The invention described has evident industrial applications and can be modified and adapted in several ways without thereby departing from the scope of the inventive concept. Moreover, all the details of the invention may be substituted by technically equivalent elements.

Claims

1. A rotor for an electric motor with permanent magnets (10), said rotor having a principal axis (D), comprising a laminated core (2) delimited by a first and a second end wall (4, 5) and by a lateral surface (6) and having a hole (7) for coupling to a motor shaft (8) and a plurality of longitudinal slots (9) for housing the magnets (10); the rotor being characterised in that it also comprises positioning devices (20) for stabilizing the magnets (10) in the slots (9).

2. The rotor according to claim 1, characterised in that the positioning means (20) comprise elastic retaining means (17) operating between the core (2) and the magnets (10).

3. The rotor according to claim 2, characterised in that the elastic retaining means (17) comprises at least one elastic element (18) positioned between each magnet (10) and the respective slot (9).

4. The rotor according to claim 3, characterised in that the elastic element (18) operates in a direction (D1) that is substantially radial to the principal axis (D).

5. The rotor according to claim 3 or 4, characterised in that the core (2) has a groove (19) for each elastic element (18).

6. The rotor according to claim 5, characterised in that the groove (19) extends between the first and second end surfaces (4, 5) and is, in particular, substantially parallel to the principal axis (D).

7. The rotor according to any of the claims from 3 to 6, characterised in that the elastic element (18) consists of a flexural spring.

8. The rotor according to any of the foregoing claims, characterised in that the positioning means (20) comprise guide ribs

(16) in each of the slots (9) for guiding the magnets (10) in the slots (9).

9. The rotor according to claim 8, characterised in that the ribs (16) have a circular profile of radius (R) measuring between approximately 0.1 mm and approximately 0.5 mm.

10. The rotor according to claim 9, characterised in that the radius (R) measures approximately 0.2 mm.

11. The rotor according to any of the foregoing claims, characterised in that it comprises balancing holes (21) that extend between the first and second end surfaces (4, 5) and are, in particular, substantially parallel to the principal axis (D).

12. The rotor according to claim 11, characterised in that it comprises balancing holes (22) placed inside the holes (21).

13. The rotor according to any of the foregoing claims from 1 to 12, characterised in that the lateral surface (6) is defined by a plurality of connected arcs (11) each positioned at one of the longitudinal slots (9), the arcs (11) having tops (12) located at an equal distance (R1) from the axis (D) and centres positioned substantially at an internal edge (24) of the longitudinal hole (7), the rotor being, in particular a 4-pole rotor.

14. A rotor for an electric motor with permanent magnets (10), said rotor having a principal axis (D), comprising a laminated core (2) delimited by a first and a second end wall (4, 5) and by a lateral surface (6) and having a hole (7) for coupling to a motor shaft (8) and a plurality of longitudinal slots (9) for housing the magnets (10), the lateral surface (6) being defined by a plurality of connected arcs (11) whose respective tops are equidistant from the axis (D) and each of which is located at a respective slot (9); the rotor being characterised in that the centres of the arcs (11) are positioned substantially at an internal edge (24) of the hole (7), the rotor being, in particular a 4-pole rotor.

15. The rotor according to claim 13 or 14, characterised in that the arcs (11) subtend an angle (H) of between approximately 55° and approximately 65°.

16. The rotor according to claim 15, characterised in that the arcs (11) subtend an angle (H) of approximately 60°.

17. The rotor according to any of the foregoing claims from 13 to 16, characterised in that the arcs (11) have a radius (R3) measuring between approximately 12 mm and approximately 15 mm, the magnets (10) being between approximately 30 mm and approximately 50 mm in length (L1), between approximately 14 mm and approximately 16 mm in width (L2) and between approximately 2.5 mm and approximately 3.5 mm in height (L3).

18. The rotor according to claim 17, characterised in that the arcs (11) have a radius (R3) measuring approximately 13.1 mm, the magnets (10) being, specifically, approximately 40 mm in length (L1), approximately 15.4 mm in width (L2) and approximately 3 mm in height (L3).

19. The rotor according to any of the foregoing claims from 13 to 18, characterised in that the arcs (11) subtend an angle (H) of between approximately 55° and approximately 65°.

20. The rotor according to claim 19, characterised in that the arcs (11) subtend an angle (H) of approximately 60°.

21. The rotor according to any of the foregoing claims from 1 to 12, characterised in that the lateral surface (6) is defined by a plurality of connected arcs (11) having respective tops (12) located at an equal distance (R1) from the axis (D) and centres at an equal distance (R2) from the principal axis (D), the distance (R2) being approximately one third of the distance (R1), the rotor being, in particular an 8-pole rotor and the magnets (10) being positioned at the arcs (11).

22. The rotor according to claim 21, characterised in that the arcs (11) subtend an angle (H) of between approximately 25° and approximately 35°.

23. The rotor according to claim 22, characterised in that the arcs (11) subtend an angle (H) of approximately 30°.

24. The rotor according to any of the foregoing claims from 1 to 12, characterised in that the lateral surface (6) is defined by a plurality of connected arcs (11) having respective tops (12) located at an equal distance (R1) from the principal axis (D) and centres at an equal distance (R2) from the principal axis (D), the distance (R2) being approximately one half of the distance (R1), the rotor being, in particular an 8-pole rotor and the magnets (10) being positioned at the arcs (11).

25. The rotor according to any of the foregoing claims from 1 to 24, characterised in that the magnets (10) consist of a plurality of portions (10a, 10b, 10c, 10d) housed side by side in the respective slot (9).

26. The rotor according to any of the foregoing claims from 1 to 25, characterised in that each of the magnets (10) has a predetermined weight.

27. The rotor according to any of the foregoing claims from 1 to 26, characterised in that the first and second end walls (4, 5) are substantially parallel with each other, the laminated core (2) comprising a plurality of laminations (3) that are at least partially rotated relative to each other about the principal axis (D).