

ELECTRIC MOTOR WITH IMPROVED MAGNETIC BALANCE

This invention relates generally to electric motors, particularly to miniature motors of the type in which a rotor is mounted for rotation in a magnetic field created by permanent magnets, the rotor having rotor windings wound on a plurality of poles of a rotor core. Typically, the permanent magnets constitute a two-pole field, and the rotor has rotor windings wound on a rotor core of a three-pole construction.

In known miniature motors of the above type, the gap between the permanent magnet and the outer periphery of the rotor core facing the permanent magnet is substantially constant. This can result in the generation of asymmetric magnetic forces, and as a consequence cause the rotor to wobble as it rotates.

As a means for solving the aforementioned problem, various measures have been conceived, such as selection and adjustment of the type and amount of addition of bearing lubricant, and adjustment of clearance between the motor shaft and the bearings. The great degree of wobbling of the motor shaft during revolution, however, tends to accelerate the wear of the bearings, increasing the clearance between the motor shaft and the bearings. This can result in various unwanted problems, including rolling noise, or burn-out and sticking between the motor shaft and the bearings.

The present invention also addresses the above problem, and provides an electric motor having a rotor mounted for rotation about an axis in a magnetic field created by a stator comprising a pair of permanent magnets disposed symmetrically on either side of said axis, each magnet having a "C" section perpendicular to said axis, and the rotor having rotor windings wound on a plurality

of poles of a rotor core, wherein the cross-section of each pole of the rotor core in a plane normal to the axis of rotation of the rotor is symmetrical with respect to the radial centre line thereof, and wherein the radial distance from said axis to a first portion of the outer surface of each pole including said centre line is reduced relative to the radial distance from said axis to second portions of said outer surface circumferentially spaced from said centre line on either side thereof whereby the total surface area of the second portions in juxtaposition with each magnet is substantially the same at all times.

The first portion of the outer surface of each pole in a motor embodying the invention may be planar, convex or concave. When convex or concave, it will normally be cylindrical.

In a motor according to the invention, the rotor core is formed in such a manner that the cross-section of the rotor core normal to the motor shaft is made symmetrical with respect to the radial centre line of each pole thereof and the gap between the permanent magnets and a predetermined range from the centre line of the arc-shaped outer periphery of the rotor core facing the permanent magnet is made larger than the gap between the permanent magnet and at least part of the other range of the outer periphery of the rotor core.

Further features and advantages of the invention will be apparent from the following description of the prior art and of some embodiments of the invention given by way of example only. Reference will be made to the schematic drawings wherein:

Figure 1A is a cross-section of a miniature motor according to one embodiment of the invention;

Figure 1B is a front view of the rotor core the motor shown in Figure 1;

Figure 2A through 2L are diagrams illustrating magnetic flux distribution in the motor of Figure 1;

Figures 3 and 4 are front views of rotor cores used in alternative embodiments of the invention;

Figure 5 is a cross-sectional view, similar to that of Figure 1, of a miniature motor of the prior art; and

Figure 6A through 6L are diagrams showing magnetic flux distributions in a motor of the type shown in Figure 5.

The known motor illustrated with reference to Figures 5 and 6 will first be described.

The miniature motor shown in Figure 5 comprises a stator having a pair of permanent magnets 2 mounted in a case 1 between stoppers 3 and a retaining spring 4. A rotor having rotor windings (not shown) wound on a rotor core 5 of a three-pole construction, is mounted on a motor shaft 6 supported by bearings (also not shown).

In the conventional type of miniature motor shown, the outer periphery 5-2 of each pole 5-1 of the rotor core 5 is formed into a substantially arc shape, and adapted so that the gap between the outer periphery 5-2 and the permanent magnet 2 is substantially uniform over the entire circumference of the rotor core 5. Whereas a

magnetic attraction force is produced between the permanent magnet 2 and the rotor core 5, the magnetic attraction force, when produced unwantedly in a point-asymmetrical fashion with respect to the motor shaft 6, tends to cause the motor shaft 6 to wobble in the bearings as the rotor core 5 revolves, generating a rolling noise.

Figures 6A to 6L are diagrams illustrating magnetic flux distributions in the motor at 30-degree angular positions in a revolution of the miniature motor shown in Figure 5. In other words, Figures 6A to 6L illustrate magnetic flux distributions in the motor at 30-degree angular positions in a clockwise revolution of the motor, starting from the state where the rotor core 5 is in an angular position shown in Figure 6A to the state where the rotor core 5 returns to the position shown in Figure 6A.

As is evident from Figure 6A, the conventional type of miniature motor shown in Figure 5 has point-asymmetrical magnetic flux distributions with respect to the motor shaft 6, particularly at angular positions at which the radial centre of each pole 5-1 of the rotor core 5 agrees with the centre of the permanent magnet 2 (as shown in Figures 6A, 6C, 6E, 6G 6I, and 6K).

In the type of miniature motor shown in Figure 5, therefore, the magnetic attraction force generated by the permanent magnet 2 and the rotor core 5 tends to be out of balance, causing the revolving motor shaft 6 to wobble seriously in the bearings, leading to an unwanted rolling noise, as noted earlier.

The miniature motor embodying this invention and

shown in Figure 1 has such a construction that the outer periphery of the pole 5-1 of the rotor core 5 consists of two arc-shaped portions 5-21 forming a uniform gap facing the permanent magnet 2 and a wide-gap portion 5-22 having a gap wider than the gap between the arc-shaped portion 5-21 and the permanent magnet 2, as shown. By providing the wide-gap portion 5-22 on part of the outer periphery of the rotor core 5, a magnetic flux distribution that is point-symmetrical with respect to the motor shaft 6 can be obtained, as will be described later with reference to Figure 2. That is, the magnetic attraction force generated between the permanent magnet 2 and the rotor core 5 is balanced over the entire circumference of the revolving rotor core 5 by making the magnetic flux distribution in the motor point-symmetrical with respect to the motor shaft 6. Thus, the motor shaft 6 shows less tendency to wobble during motor rotation.

In the embodiment shown in Figure 1, the wide-gap portion 5-22 constituting part of the outer periphery of the rotor core 5 is formed into a flat surface. That is, the wide-gap portion 5-22 is formed by cutting a part of the arc-shaped outer periphery (as shown by a dotted line in Figure 1B) of the rotor core 5. The rotor core 5 of a laminated-core type can also be formed by laminating core sheets cut in advance into a shape shown by solid lines in Figure 1B.

In forming the wide-gap portion 5-22, it is desirable to set the ratio of the distance (shown at "b" in Figure 1B) of the arc-shaped portion 5-21 to the distance (shown

by at "a") between the tips of the opposing poles 5-1 to a range of 0.8 - 2.2. This is because a b-to-a ratio less than 0.8 would reduce the counter-electromotive force E_c generated by the rotor windings (not shown), increasing the input current to the rotor windings. This would increase heat loss in the rotor windings, reducing the life of the motor. A b-to-a ratio more than 2.2, on the other hand, would destroy the balance of magnetic attraction force between the permanent magnet 2 and the rotor core 5.

Figures 2A through 2L are diagrams showing magnetic flux distributions in the motor at 30-degree angular positions in one revolution of the miniature motor shown in Figure 1. In other words, Figures 2A through 2L illustrate magnetic flux distributions in the motor at 30-degree angular positions in a clockwise revolution of the motor, starting from the state where the rotor core 5 is in an angular position shown in Figure 2A to the state where the rotor core 5 returns to the position shown in Figure 2A. As is apparent from Figure 2, the miniature motor shown in Figure 1 has magnetic flux distributions that are substantially point-symmetrical with respect to the motor shaft 6 at any angular positions. Consequently, the magnetic attraction force generated between the permanent magnet 2 and the rotor core 5 is balanced over the entire circumference of the rotor core 5, preventing the motor shaft 6 from unwanted wobbling during motor revolution. This helps prevent the generation of a rolling noise in the bearings (not shown) and abnormal

wear of the bearings.

Although the foregoing description has been mainly of the embodiment shown in Figure 1, similar benefits can be obtained with the alternative embodiments shown in Figures 3 and 4.

The embodiment shown in Figure 3 has a rotor core 5 with a wide-gap portion 5-22 having a radius of curvature R_1 as shown in the figure, with the centre thereof located on the opposite side of the motor shaft 6.

The embodiment shown in Figure 4, on the other hand, has a rotor core 5 with a wide-gap portion 5-22 having a radius of curvature R_2 as shown in the figure, with the centre thereof located on the same side of the motor shaft 6.

3.

CLAIMS:

1. A direct current electric motor having a rotor mounted for rotation about an axis in a magnetic field created by a stator comprising a pair of permanent magnets disposed symmetrically on either side of said axis, each magnet having a "C" section perpendicular to said axis, and the rotor having rotor windings wound on three poles of a rotor core, wherein the cross-section of each pole of the rotor core in a plane normal to the axis of rotation of the rotor is symmetrical with respect to the radial centre line thereof, and wherein the radial distance from said axis to a first portion of the outer surface of each pole including said centre line is reduced relative to the radial distance from said axis to second portions of said outer surface circumferentially spaced from said centre line on either side thereof, whereby the total surface area of the second portions in juxtaposition with each magnet is substantially the same at all times.
2. A motor according to Claim 1 wherein said first portion of said outer surface is planar.
3. A motor according to Claim 1 wherein said first portion of said outer surface is convex.
4. A motor according to Claim 3 wherein said first portion of said outer surface is substantially cylindrical, and has an axis of curvature parallel to said rotational axis and disposed on the opposite side thereof relative to the respective pole.
5. A motor according to Claim 1 wherein said first portion of said outer surface is concave.
6. A motor according to Claim 5 wherein said first portion of said outer surface is substantially cylindrical and has an axis of curvature parallel to said rotational axis and disposed on the same side thereof as the respective pole.
7. An electric motor substantially as described herein with reference to any of Figures 1 and 2, Figure 3, and Figure 4 of the accompanying drawings.

