

Motor with motor parts which are movable relative to one another.

The invention relates to a motor having motor parts which are movable relative to one another, of which the first motor part forms a multi-pole excitation field in an air gap by means of a permanent magnet with $2p$ magnet poles and of which the second motor part is a yoke having a number T of pole teeth which project towards the air gap and
5 which carry exciter coils and are spaced by pole gaps.

Such motors are known as rotary motors, for example from DE 28 23 208 C2 and from DE 31 22 049 C2. In such motors a detent torque is produced as a result of the
10 interaction between the magnetized poles of the permanent magnet and the pole teeth of the yoke. This detent torque is usually undesirable because it may give rise to unwanted oscillations. The order of the fundamental frequency of the torque follows from the least common multiple of the number of magnet poles $2p$ and the number of teeth T and should be as large as possible because the amplitude of this undesirable torque decreases as the order
15 increases. Accordingly, there are motors having large detent torques and motors having small detent torques on account of the number of magnet poles $2p$ of the permanent magnet and the number of pole teeth T . A motor having a pole-pair number $2p = 2$ and a tooth number $T = 3$ will have a detent torque with a fundamental frequency of the order 6. The amplitude of the detent torque is consequently comparatively high. DE 28 23 208 C2 describes how such
20 detent torques can be reduced by indentations in the pole teeth.

However, there are also motors which on account of their magnet pole number $2p$ and tooth number T already have a small detent torque without such additional measures. For example, the detent torque of a motor having a magnet pole number $2p = 8$ and a tooth number $T = 9$ has a fundamental frequency of the order 72. Therefore, the
25 amplitude of the detent torque of such a motor is very low. However, a problem associated with such a motor is that it is not symmetrical, i.e. the magnetic field in the air gap is not symmetrical. As a result, radial forces are exerted on the rotating motor part of the motor. For example, if a magnet pole of such a motor directly faces a pole tooth across the air gap, the magnet pole which is 180° shifted in the circumferential direction faces a pole gap, as a

result of which the radial forces between the two motor parts no longer cancel one another.

It is an object of the invention to construct a motor of the type defined in
5 the opening paragraph so as to reduce or eliminate radial forces produced as a result of
asymmetrical magnet fields in the air gap.

According to the invention this object is achieved in that, in the case of
motors in which the number $2p$ of magnet poles and the number T of pole teeth do not have
a common submultiple greater than 1, the pole teeth each have an auxiliary slot in their
10 centers at the side facing the air gap.

Radial forces always occur if the magnetic field in the air gap has no
symmetry. The magnetic field in the air gap is asymmetrical if, viewed in the circumferential
direction, the magnetic field recurs periodically only after 360° . This is the case if the
number of magnet poles and the number of pole teeth do not have a common submultiple
15 greater than 1 because the periodicity is exactly 360° divided by the greatest common
divisor.

Practical examples of motors of this type include motors having three pole
teeth and two magnet poles, three pole teeth and four magnet poles and nine pole teeth and
eight magnet poles.

20 Since the number of magnet poles $2p$ is always even radial forces can
occur only in the case of an odd number T of pole teeth in the above arrangements. If each
tooth is provided with an auxiliary slot in its center at the side facing the air gap, this will
cause the number of openings of the yoke directed towards the air gap to be doubled, i.e. T
pole gaps and T auxiliary slots. This results in symmetrization of the magnetic field in the air
25 gap. If a magnet pole faces a pole gap, the magnet pole which is 180° shifted in the circum-
ferential direction faces an auxiliary slot, thereby reducing the radial forces between the two
motor parts.

An advantageous embodiment of the invention is characterized in that the
auxiliary slots have been formed in such a manner that each of them has the same magnetic
30 effect as the pole gaps between the pole teeth.

If each pole tooth is provided with an auxiliary slot, whose effect as
regards the formation of the magnetic field corresponds to that of a pole gap, complete
symmetry of the magnetic field in the air gap is achieved and the radial forces are eliminated
completely.

The compensation effect of the auxiliary slots can be also explained on the basis of the following considerations. If each pole tooth is provided with an auxiliary slot, whose effect as regards the formation of the magnetic field corresponds to that of a pole gap, this doubles the effective number of teeth. Since, as a result of this, the effective number of
5 teeth has become even, the number of teeth and the number of magnet poles now have a common divisor and the radial forces are eliminated.

As already stated hereinbefore, the order of the fundamental wave of the detent torque is equal to the least common multiple of the number of teeth and the number of magnet poles. The measure described above has no influence on this because in the case of
10 an even number of magnet poles the multiplication of the odd number of teeth by a factor of 2, as a result of which the effective number of teeth is doubled, does not affect the least common multiple.

15 The invention will now be described in more detail with reference to the single Figure of the drawing.

The single Figure of the drawing is a diagrammatical sectional view showing a motor with motor parts which are movable relative to one another. The motor comprises a first motor part 10 with a multi-pole permanent magnet 11 mounted in a soft-
20 iron yoke 12, which surrounds this permanent magnet. The permanent magnet 11 has eight magnet poles 13, which are equi-spaced along the circumference and whose polarity alternates in the circumferential direction. The first motor part 10 and a second motor part 20 are supported so as to be rotatable relative to one another. An air gap 1 exists between the first motor part 10 and the second motor part 20. The second motor part 20 comprises a soft-iron
25 yoke 21 having nine pole teeth 22, which project towards the air gap 1 and which carry exciter coils 23. Viewed in the circumferential direction nine pole gaps 24 are present between the nine pole teeth 22 of the second motor part 20. In their centers the teeth 22 of the second motor part 20 each have an auxiliary slot 25 at the side facing the air gap 1, which slots have approximately the same size as the pole gaps 24.

30 The order of the fundamental frequency of the detent torque of the motor in the embodiment described here is equal to the least common multiple of the number of teeth $T = 9$ and the number of magnet poles $2p = 8$, i.e. 72. Therefore, the amplitude of the detent torque, which decreases as the order increases, is very small so that this motor is preferably utilized for a variety of uses. As this motor has an odd number of teeth $T = 9$, an

asymmetrical magnetic field is obtained in the air gap if no additional measures are taken, as a result of which radial forces occur between the first motor part 10 and the second motor part 20. The auxiliary slots 25 ensure that the air-gap field becomes symmetrical and thereby preclude the occurrence of radial forces.

5 In order to clarify the function of these auxiliary slots 25, the pole tooth 31 with the auxiliary slot 32, the magnet pole 33 as well as the pole gap 35 and the magnet pole 34 at the opposite side will now be considered more closely. These elements are exactly similar to the other magnet poles 13, pole gaps 24, pole teeth 22 and auxiliary slots 25 and have only been given other reference numerals in order to explain the role of the auxiliary
10 slots 25. In the position of the motor parts 10 and 20 shown in the single Figure of the drawing the pole tooth 31 with the auxiliary slot 32 is centered, viewed in the circumferential direction, relative to the magnet pole 33 of the permanent magnet 11. The magnet pole 34, which is 180° shifted relative to the magnet pole 33 in the circumferential direction, is centered relative to the pole gap 35. Since the pole gap 35 and the auxiliary slot 32 are
15 substantially equal in size they also have the same magnetic influence on the formation of the magnetic field in the air gap 1. The magnetic resistance of the second motor part 20 relative to the magnet pole 34 of the first motor part 10 is equal to the magnetic resistance of the second motor part 20 relative to the magnet pole 33 of the first motor part 10. As a result of this, the radial forces between the motor parts 10 and 20 in the direction of the magnet poles
20 33 and 34 cancel one another. Similar considerations apply to the other magnet poles 13 of the permanent magnet 11. Hence, it follows that no radial forces occur between the motor parts 10 and 20 as a result of the magnetic interaction between these parts.

The embodiment of the motor with a pole pair number $2p = 8$ and a tooth number $T = 9$ is an example of a motor having an asymmetrical magnetic field in its air gap
25 without auxiliary slots 25. The symmetrization of the air-gap field and hence the elimination of radial forces by means of the auxiliary slots 25 is possible for all motors with asymmetrical air-gap fields. Crucial for the symmetrizing effect of the auxiliary slots 25 is that these slots are disposed in the centers of the pole teeth 22. These auxiliary slots 25 situated in the centers of the pole teeth 22 do not change the order of the fundamental frequency of the
30 detent torque.

Claims:

1. A motor having motor parts (10, 20) which are movable relative to one another, of which the first motor part (10) forms a multi-pole excitation field in an air gap (1) by means of a permanent magnet (11) with $2p$ magnet poles (13) and of which the second motor part (20) is a yoke (21) having a number T of pole teeth (22) which project towards the air gap (1) and which carry exciter coils (23) and are spaced by pole gaps (24), characterized in that,
- in the case of motors in which the number $2p$ of magnet poles (13) and the number T of pole teeth (22) do not have a common submultiple greater than 1, the pole teeth (22) each have an auxiliary slot (25) in their centers at the side facing the air gap.
2. A motor as claimed in Claim 1, characterized in that the auxiliary slots (25) have been formed in such a manner that each of them has the same magnetic effect as the pole gaps (24) between the pole teeth (22).
3. A motor as claimed in Claim 1 or 2, characterized in that the auxiliary slots (25) are similar or identical in shape to the pole gaps (24).

