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ELECTROMAGNETIC MOTOR WITH TWO ROTATION SENSES
PARTICULARLY INTENDED FOR A TIMEPIECE

This invention concerns a low power electromagnetic motor having two rotation senses, adapted to function with an n-phased energization mode, wherein n is greater than 1.

More specifically, the invention concerns such an electromagnetic motor of small dimensions comprising a stator in an essentially flattened form having n magnetic circuits arranged in a manner to define an opening in which a rotor provided for instance with a permanent magnet may pivot. The magnetic circuits are generally magnetically decoupled from one another and each cooperates with the rotor through two magnetic stator poles placed in positions approximately diametrically opposed relative to the rotation axis of the rotor, such axis extending perpendicularly to the general plane of the stator. Motors of this type may be advantageously used as stepping motors in analog display watches.

There is known from the Japanese patent application JP-61-10958 a two-phase symmetric stepping motor having two rotation senses which is formed of two single-phase stator parts superposed onto one another and with an angular shift of 90° relative to one another.

The two single phase stator parts are fastened to one another, but are located in different planes. They are magnetically insulated from one another while being each provided with an excitation winding. Furthermore, each stator part defines an opening for a permanent magnet rotor common to both of them, the openings being aligned on the axis of rotation of the latter.

In order to define a stable position of the rotor, the edge of each opening of such stator parts is provided

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with two positioning notches which are diametrically aligned along a direction separated by 45° relative to the principal direction of the magnetic flux passing through the rotor and generated by excitation of the corresponding winding. In the absence of excitation, the stable position of the rotor is attained when the North-South axis of the permanent magnet of the rotor is perpendicular to the alignment axis of the notches.

Thanks to this construction, the two stator parts work under exactly the same conditions with the rotor, however, because of their 90° shift each assures the rotation of the rotor in a sense which is individual to it. If one admits that the volume of the permanent magnet of the rotor traversed by each of the two magnetic fluxes is the same, the resulting motor couple is identical for both senses of rotation.

This known motor exhibits several disadvantages. Initially, the volume occupied by the permanent magnet of the rotor is only partially used since each magnetic circuit surrounds less than the half of this volume. This disadvantage is further aggravated by the fact that the magnetic circuits are necessarily spread apart from one another along the rotor axis in order to assure the magnetic insulation thereof. There results therefrom a comparatively substantial height which is above all inconvenient when the motor is employed in horological applications.

Another disadvantage resides in the fact that the openings of the magnetic circuits must be aligned with precision along the rotor axis which causes manufacturing difficulties so as to increase in an exaggerated manner the cost of the motor.

The invention has as its purpose to provide an electric

motor of the type indicated hereinabove which does not exhibit these disadvantages.

It has thus as object an n-phased, electromagnetic motor, n being greater than 1, with two rotation senses, such motor including:

- a stator defining on the one hand a stator cavity and on the other hand at least four magnetic poles, each such pole comprising a polar expansion partially defining said stator cavity, a polar arm and a polar attachment lug serving as magnetic contact at the other end of said polar arm, said polar expansions being separated from one another by high magnetic reluctance zones forming necks;
- a rotor mounted in the stator cavity to rotate relative to said stator around an axis;
- at least two magnetic shunts which couple two non-adjacent magnetic poles to one another;
- means mounted on each magnetic shunt for generating a magnetic flux in the poles with which they are associated, each of said shunts forming, with said magnetic poles and the permanent magnet of the rotor, a magnetic circuit which is magnetically decoupled from the other magnetic circuits of the motor, this latter being characterized in that said magnetic poles are formed by the branches of a single star-shaped piece in the center of which said stator cavity is provided, said polar expansions being situated in a single and common plane perpendicular to the rotation axis of said rotor.

Thanks to these characteristics, the motor of this invention exhibits no particular difficulty in manufacture or assembly. In addition, all the magnetic circuits of the motor take in the same volume of the rotor permanent magnet since all the polar expansions are substantially located in a single and common plane. It will be noted

that this latter characteristic is obtained together with a magnetic decoupling of each magnetic circuit relative to the other magnetic circuits.

The invention will be better understood with the help of the description to follow and drawings which illustrate it solely by way of example. In the drawings :

- Figure 1 shows schematically a two-phased stepping motor having two rotation senses according to the invention;

- figure 2 is a cross-section on an enlarged scale according to line II-II of figure 1 showing schematically a first variant of the motor in order to obtain a magnetic insulation gap;

- figures 3 to 5 are cross-section views respectively of second, third and fourth possible variants of the motor according to the invention, in particular in view of obtaining a gap;

- figure 6 shows a partial view of another embodiment of a two-phased motor with two rotation senses according to the invention;

- figure 7 shows another embodiment of a two-phased stepping motor with two rotation senses according to the invention;

- figures 8 to 11 and 13 to 16 represent according to a first and respectively second method of operation, schematic views of the bipolar permanent magnet of the rotor in a rest position and the sense of rotation resulting from the interaction of said magnet with the magnetic flux generated in the stator which traverses such permanent magnet;

- figures 12 and 17 show schematically a manner according to which the windings must be energized in order to control the motor according to said first and respectively said second mode of operation;

- figure 18 represents schematically on the same scale as that of figure 1 a three-phase motor having two rotation senses according to a further embodiment of the invention.

In referring to figure 1, there will be hereinafter described a first embodiment of a two-phased symmetric stepping motor having two rotation senses in accordance with the invention.

Such motor comprises a stator 1 and a rotor 2 rotatively mounted within said stator in a stator cavity 3 having an essentially circular form provided in such stator. The rotation axis X-X of rotor 2 is perpendicular to the general plane of stator 1. It is to be noted that in conformity with a construction known to specialists, the rotor may be mounted for rotation in bearings fixed in a mounting which is fastened to the stator, such elements not being shown.

Stator 1 comprises four magnetic poles 4a to 4d and two magnetic shunts 5a, 5b. Each of such magnetic poles ends up in a polar expansion 6a and respectively 6b, 6c and 6d which determine a portion of the edge of the stator cavity 3. These magnetic poles 4a to 4d are extended towards the exterior by polar arms 7a to 7d, each of which ends up with a polar lug 8a to 8d serving as a fastening means and magnetic contact applied to a corresponding lug 9a to 9d belonging respectively to the magnetic shunts 5a and 5b. Each of these shunts bears a winding 10a, 10b of which it forms the core and beyond which it extends by arms 11a to 11d respectively ending up by lugs 9a to 9d.

The lugs 8a to 8d and 9a to 9d are respectively coupled

to one another by pins 12; other known means of attachment can be provided.

In order to magnetically insulate each stator pole from the neighbouring poles, the polar expansions 6a to 6d are coupled among themselves by means of necks 13a to 13d which form zones having high magnetic reluctance while maintaining the poles rigidly relative to one another.

It is thus established that the central part of the stator 1 defining the stator cavity 3 and including the polar arms 7a to 7d, the expansions 6a to 6d and the necks 13a to 13d forms a star-shaped piece in a single plane designated by the general reference 14. Such piece thus exhibits here four arms, each arm extending at 90° from its two neighbouring arms starting from the stator cavity 3, two of such arms, namely arm 7a and 7b, being elbowed at a right angle.

This configuration associates two magnetic stator poles diametrically opposed relative to the rotation axis X-X of said rotor 2 with each of the two magnetic circuits.

In order to insulate magnetically such magnetic circuits from one another, there is provided an insulating gap 15 in the region 15R where said arms 7a and 11d intersect one another in superposition owing to the fact that the two magnetic circuits are located at least partially in two neighbouring parallel planes. In the embodiment of figure 1, such gap is obtained by providing a recess 16 in the elbowed arm 11d of shunt 5b and, in order to facilitate the construction of such motor, also in the elbowed arm 11c of shunt 5a. Such recess may be obtained by simple grinding. In this case the gap 15 is filled up by a surrounding non-magnetic fluid (see also figure 2).

Figures 3 to 5 show three other variants in the formation of the gap arranged between the arm 7a of the star-shaped piece 14 and, the arm 11d of the shunt 5b.

On figure 3, shunt 5b also includes a recess 16. However, in this case such recess is filled with a non-magnetic material 17, plastic material for example, acting as a spacer. Such arrangement enables one to obtain increased rigidity of the stator assembly, the shunt 5b no longer being cantilevered relative to its fastening onto pole 4d.

As shown on figure 4, gap 15 may also be provided between arm 7a and shunt 5b by deforming arm 11d of such shunt 5b by a swaging operation. The deformed part 18 of such arm gives rise to a recess 16b.

According to another variant represented on figure 5, shunt 5b exhibits in its connection zone to lug 9b a deformation 16c which transports the major portion of such shunt over into another plane. An analogous deformation (not visible on the drawing) must then be provided in arm 11b of such same shunt 5b in order to bring its fastening lug 9b into the appropriate level. A spacer 19 of non-magnetic material may be provided in this case between arm 7a and shunt 5b.

It is to be noted that other similar variants are not excluded, in particular variants in which the recesses 16 and 16b are provided, not in arm 11d of shunt 5b, but in a similar manner in arm 7a of the star-shaped piece 14.

As may be determined from figure 1, magnetic shunts 5a and 5b are advantageously identical from whence results a reduction in the cost of manufacture and a greater flexibility for assembly, each shunt bearing its winding being

adapted to be employed equally for one or the other of the magnetic circuits.

If the application of the motor does not require a thickness as small as possible, as may be the case in horology, one may envisage a stator on three parallel planes. This embodiment of the motor according to the invention is partially shown on figure 6. In this case a single star 14a is situated in the median plane, while shunts 5a-A and 5b-A are situated on either side of such median plane in corresponding parallel and adjacent planes. As is well understood, one of the shunts 5a-A then exhibits the general form of a U one of the arms 11a-A of which intersects in superposition the arm 11d-A of the other shunt 5b-A. Arm 11a-A is terminated by a lug 8a-A which is fixed to the corresponding lug 9a-A.

The gap 15A then has a thickness substantially equal to the thickness of the star-shaped piece 14A.

Figure 7 represents another embodiment of the invention enabling one to obtain a more compact assembly than that of figure 1 and in which there is provided a star-shaped piece 14B the arms 7b-B and 7c-B of which are bent back in a manner to extend parallel to one another starting from their respective polar expansions. The parts of shunts 5a-B and 5b-B forming the cores of the windings of the motor, are then inwardly curved in a manner to connect the attachment points formed by the corresponding lugs 9a-B to 9d-B of such shunts.

The motor according to the invention which has been previously described may function principally in two different manners, namely in a continuous mode or in a stepping mode.

There will now be examined the stepping mode of

operation in referring to figures 8 to 17, figures 8 to 11 concerning the embodiment of figure 1 while figures 13 to 16 bear on that of figure 7.

In order to be able to operate in a stepping mode, it is necessary to provide the rotor with stable rest positions relative to the stator. This may be accomplished by providing two notches respectively 20 and 20b in diametrically opposite positions in the edge of the stator cavity 3. Under these conditions since the permanent magnet rotor exhibits a given direction of magnetization it will come to locate itself in a manner such that in the absence of excitation of windings 10a and 10b, such direction DR (rest direction) orients itself perpendicularly to the direction DE (notch direction) defined by notches 20 (see figures 8 and 13).

It will be noted that in the case of figures 1 and 8 to 11, notches 20 are aligned with the polar expansions 6b and 6d, while in the case of figures 7 and 13 to 16, notches 20 coincide with two necks 13b-B and 13d-B which are diametrically opposed.

Figure 12 shows schematically a method according to which windings 10a and 10b may be energized in order to control the motor of figure 1. One step of the motor corresponds to an angular displacement of 180° of the rotor around its axis X-X.

It is seen that this displacement takes place according to the counter clockwise (negative) sense (as seen on figures 8 and 9) when the windings receive current pulses of the same polarity per step, the sense of the corresponding flux being indicated on figures 8 and 9 by references $\pm F1$ and $\pm F2$ and the resulting magnetic fields in the permanent magnet of the rotor by references $\pm B1$.

The displacement takes place in the clockwise positive sense when the pulses applied to windings 10a and 10b are respectively of opposite polarities (see figures 10 and 11), the resulting magnetic fields being then $\pm B2$.

On the other hand, the motor windings of figure 7 must be controlled in conformity with the schematic shown on figure 17, the sense of the fluxes being here also shown by references $\pm F1$ and $\pm F2$ and the resulting magnetic fields in the permanent magnet of the rotor by $\pm B3$ and $\pm B4$ on figures 13 to 16.

For the motor of figure 7, it is seen that in order to effect two steps in the same counter-clockwise sense, one applies successive control pulses of opposite polarities to winding 10a only; then, in order to make two steps in the clockwise sense, it is winding 10b which receives two successive pulses of opposite polarities.

The motors of figure 1 as well as of figure 7 have central parts 14 and 14b for which each high reluctance neck is oriented at 90° to the two neighbouring necks.

Furthermore, the relative position of the positioning notches 20 relative to the polar expansions such as is shown on figures 1 and 7 respectively, permit an operation of the motor which is rigorously identical whatever may be the rotation sense by means of a control with the help of current pulses, likewise identical disregarding their polarity. This leads also to identical performances for both senses of rotation. It is thus possible to control and to slave such motors in an optimum manner for both rotation senses in employing a single voltage level, this being very advantageous.

Figure 18 represents another embodiment of the invention which constitutes a three-phase motor.

Such motor comprises a stator 31 defining a stator cavity 33 in which is rotatively mounted a rotor 32 having a bipolar permanent magnet.

The stator comprises a single central star-shaped piece 34 in the center of which is provided the stator cavity 33.

For each phase of the motor, the stator comprises a magnetic circuit 35 magnetically decoupled from the other magnetic circuits by necks 36.

Each magnetic circuit comprises:

- a long branch 37 belonging to a pole of the star-shaped piece;
- a short branch 38 belonging to another pole of the latter situated in a diametrically opposite position;
- a C-shaped magnetic shunt 39 fastened by lugs 40 to corresponding lugs (not visible on the drawing) provided at the free ends of the branches 37 and 38 of the star-shaped piece 34;
- a winding 41 mounted on the magnetic shunt 39.

In this motor, there are three regions of intersection in superposition 42 in which there is provided a gap 43 in order to magnetically insulate the magnetic circuits concerned. This gap may be obtained in a manner analogous to those shown respectively by figures 2 to 4.

It will be noted that the magnetic circuits of this motor belonging respectively to its three phases are of identical construction, each circuit being shifted by 120° relative to the two adjacent circuits.

This three-phase motor is represented on figure 18 without a positioning notch; however, it is entirely

possible to provide positioning notches appropriate to a stepping mode of operation. Just as for the two-phase motor considered previously, this motor may operate according to a continuous mode or according to a stepping mode.

CLAIMS

1. Electromagnetic motor of n phases, n being greater than 1, having two senses of rotation, such motor including :

- A stator (1; 31) defining on the one hand a stator cavity (3; 33) and on the other hand at least four magnetic poles (4a to 4d; 37, 38), each such pole comprising a polar expansion (6a to 6d respectively) partially defining said stator cavity, a polar arm (7a to 7d respectively) which extends said expansion and a polar attachment lug (8a to 8d respectively) serving as magnetic contact at the end of said polar arm, said polar expansions being separated from one another by high magnetic reluctance zones forming necks (13a to 13d; 13b-B, 13d-B; 36);

- a permanent magnet rotor (2; 32) mounted in the stator cavity to rotate relative to said stator around an axis;

- at least two magnetic shunts (5a, 5b; 5a-A, 5b-A; 5a-B, 5b-B; 39) which couple two non-adjacent magnetic poles (4a, 4c, respectively 4b, 4d; 37, 38) to one another;

- means (10a, 10b; 41) mounted on each magnetic shunt for generating a magnetic flux ($\pm F_1$, $\pm F_2$ respectively) in the poles with which they are associated; each of said shunts forming, with said magnetic poles and the permanent magnet of the rotor (2, 32), a magnetic circuit which is magnetically decoupled from the other magnetic circuits of the motor, characterized in that said magnetic poles of the motor being formed by the branches of a single star-shaped piece (14; respectively 14A; 14B; 34) in the center of which said stator cavity (3, 33) is provided, said polar expansions (6a to 6d) being situated in a single and common plane perpendicular to the rotation axis (X-X) of said rotor.



2. Motor as set forth in claim 1, characterized in that the totality of said single star-shaped piece (14; respectively 14A; 14B; 34) for the stator extends in a single and common place.

3. Motor as set forth in claim 1 or in claim 2, characterized in that said stator is situated essentially on two adjacent parallel planes perpendicular to the rotor axis, each magnetic circuit of the motor having at least one intersection in superposition respectively with at least one other of said magnetic circuits, each superposed intersection occurring between the arm (11d) of the shunt (5b) of a first magnetic circuit and a polar arm (7a) of the single star-shaped piece (14), such latter arm belonging to a second affected magnetic circuit, the magnetic insulation of the region (15R, 42) of said superposed intersection being assured by a gap (15, 43).

4. Motor as set forth in claim 3, characterized in that a recess (16) machined in said arm (11d) of said shunt (5b) of said first magnetic circuit or in said polar arm (7a) of said second magnetic circuit defines said gap (15, 43) in said region of said superposed intersection.

5. Motor as set forth in claim 3, characterized in that a swaged portion (18) in said arm (11d) of said shunt (5b) of said first magnetic circuit or in said polar arm (7a) of said second magnetic circuit forms a recess (16B) in said region of superposed intersection, such recess defining said gap (15, 43).

6. Motor as set forth in claim 3, characterized in that it is a two-phase motor in which the lugs (9b, 9d) of said shunt (5b) of said first magnetic circuit are swaged in a manner to offset the remainder of such shunt into a neighbouring plane which defines said gap (15).



7. Motor as set forth in claim 1 or in claim 2, characterized in that it is a two-phase motor and in that said stator is situated essentially on three neighbouring parallel planes which are perpendicular to the rotor axis (X-X), the single star-shaped piece (14A) being situated in the median plane while said shunts (5a-A, 5b-A) are situated on either side of such median plane, said magnetic circuits being magnetically insulated from one another by means of a gap (15A) situated between an arm (11a-A) of one of the two shunts (5a-A) and an arm (11d-A) of the other (5b-A) of the two shunts, the gap depth being the thickness of said single star-shaped piece.

8. Motor as set forth in any one of the claim 1 to 7, characterized in that it is a two-phase motor and in that the stator cavity (3) is essentially circular, each of said magnetic insulating necks forming with the two adjacent necks a central angle of substantially 90°.

9. Motor as set forth in claim 8, characterized in that two rotor (2) positioning notches (20, 20B) are provided on the edge of said stator cavity (3) in positions which are diametrically opposite relative to the center of said stator cavity.

10. Motor as set forth in claim 9, characterized in that the positioning notches (20) are aligned along a direction defined by two non-adjacent polar expansions (6b, 6d).

11. Motor as set forth in claim 9, characterized in that the positioning notches (20B) are aligned along a direction defined by two non-adjacent necks (13b-B, 13d-B).

12. Motor as set forth in any one of the claims 1 to 5, characterized in that it is three-phase motor and in



that said single star-shaped piece (34) exhibits six branches, each of such branches being roughly angularly offset by 60° relative to the two branches adjacent thereto, each magnetic circuit (35) having a single region of superposed intersection (42) in which the magnetic insulation between the circuits is assured by a gap (43).

13. Motor as set forth in any one of the claims 3 to 7, 12, characterized in that the gap is filled in with a solid non-magnetic material (17, 19).

14. Motor as set forth in claim 12, characterized in that rotor positioning notches (32) are provided on the edge of said stator cavity (33).

15. Motor as set forth in any one of the claims 1 to 14, characterized in that said magnetic shunts (5a, 5b; 39) are identical to one another.

