

Fractional horsepower a.c. motor having an oscillating permanent magnet armature

The invention refers to a fractional horsepower a.c. motor having an oscillating permanent magnet armature, in particular for the oscillating drive of a toothbrush fastened to the armature shaft, with an armature which
5 is a cylindrical, diametrically magnetised permanent magnet and having a stationary coil.

Known a.c. motors of this kind (/ French Patent No. 1 470 893) have rather complicated stator structures with several stator parts in double - T or Z form, where the bars on the
10 inside form bent poles and surround the radially orientated middle parts of the stator coils.

In the case of a known electric toothbrush (West German Patent No. 1 119 819) the motor is supported in a caselike handle and exhibits an armature which oscillates
15 at the frequency of the supply voltage and is fastened to a shaft onto which an interchangeable plug-on toothbrush can be mounted. Upon connection of the a.c. motor to the a.c. network the plug-on toothbrush oscillates at the network frequency about the axis of the brush.

20 The oscillating armature of this known a.c. motor is made in the form of a salient-pole rotor which exhibits a permanent magnet having soft iron pole shoes and is held by a return spring in its rest position. The stator exhibits two pole shanks forming poles and without windings,
25 which are orientated in the direction longitudinal to the case and lie diametrically opposite one another; the pole

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shanks have arms prolonged beyond the region of the oscillating armature in the direction towards the rear end of the case, which are connected by a cross-yoke which carries the stator winding.

5 The object of the invention is to improve the motor efficiency as compared with known a.c. motors having oscillating armatures, in such a way that either approximately the same torque can be achieved at reduced power consumption or else a higher torque at approximately the
10 same power consumption, and furthermore to design the construction of the motor in a particularly compact and simple way. The higher efficiency in particular allows the motor to operate at low voltage, that is, for example, at 20V, which in the very case of electric toothbrushes or
15 else massage appliances is particularly advantageous for reasons of safety. Such a hand appliance can then preferably be fed from the network via a transformer and as regards its electrical insulation does not need to fulfil any strict regulations.

20 According to the invention there is provided a fractional horsepower a.c. motor giving an oscillating drive output, said motor comprising an oscillating permanent magnet armature in the form of a cylindrical diametrically magnetized permanent magnet for the oscillat-
25 ing drive of a device attached to the armature shaft, a relatively stationary coil orientated with its axis perpendicular to the longitudinal axis of the armature and surrounding the permanent magnet, the winding turns of the coil defining rectangular shapes, a stator comprising
30 a magnetisable tubular portion of a case which encloses the

coil and which is arranged coaxial with the axis of the armature, said stator having a polygonal or oval cross-section in which a pair of opposed sidefaces are larger than any other side face of the stator and form poles, the axis of the coil being orientated perpendicular to said larger sidefaces, a rest position of the armature being determined by return means, and in said rest position the diametrical magnetic field of the armature lying substantially perpendicular to the axis of the coil.

10 This produces a simple, space-saving structure and an optimal degree of efficiency because the armature consists of a simple cylindrical permanent magnet which can be surrounded over its whole length by the stationary coil which in turn lies inside the tubular case of the stator.

15 With this compact arrangement having an armature coaxial with the stator case and a coil lying between them, which preferably can take up almost all the vacant space inside the stator - of course with the exception of the clearance required for the armature, the stray losses are restricted

20 to a minimum. In addition this makes optimal use of the space taken by the coil and the stator.

The coil may preferably be composed of two essentially equal part-coils the plane of contact of which passes at least approximately through the axis of the armature and

25 which may be connected in series or in parallel, depending upon the supply voltage employed.

In a preferred embodiment the tubular case of the stator has a rectangular cross-section having a long and a short pair of sidefaces, where the long sidefaces preferably

form poles and thereby a geometry having variable reluctance dependent upon the position of the armature, without special pole shoes or projecting poles of some other shape being provided. In this way it can be achieved that the torque exerted upon the armature by the magnetic field of the coils is strengthened by the static torque originating from the rectangular stator geometry, which tries to turn the armature so that the direction of magnetization of the permanent magnet is lying in parallel with the short sidefaces of the stator. In order to make optimum use of this favourable effect, the axis of the coils must be orientated in parallel with the short sidefaces of the stator. The armature in its rest position is held by the return means, for example, by a return spring, in a position in which the direction of the diametrical magnetic field of the armature is lying perpendicular to the axis of the coil and thereby in parallel with the long sidefaces of the stator.

A similar effect is obtained by a stator with octagonal cross-section with a pair of opposite sidefaces which are larger than the other sidefaces.

The present invention will now be described by way of example with reference to the accompanying diagrammatic drawings in which only electrical components necessary for an understanding of the invention are shown and in which :-
Fig. 1 - is an exploded perspective view of a first embodiment of a motor according to the present invention;
Fig. 2 - is a perspective view of the motor shown in Figure 1 in an assembled state but with the stator shown

cut away;

Fig. 3 - is a perspective view of one of the part-coils of the motor shown in Figures 1 and 2;

Fig. 4 - is a perspective view of the other part-coil in partial cross-section;

Fig. 5 is a perspective view of the motor when assembled, and

Fig. 6 is a cross-section through an octagonal two-part stator of a second embodiment of motor according to the invention.

With reference to Figure 1, the stator 1 of the a.c. motor shown therein consists of a tubular part of the case having a rectangular cross-section, which case is made of magnetizable material and has long or respectively larger sidefaces 1a and the short of respectively smaller sidefaces 1b. The armature fastened to the armature shaft 5 consists of a cylindrical permanent magnet 4 having diametrical magnetization. The poles are indicated in Figure 1 by the letters N and S. The armature shaft 5 may consist of magnetic material.

The permanent magnet 4 is surrounded over its whole length by a coil consisting of two part-coils 2 and 3, the axis of which runs perpendicular to the armature shaft 5 and perpendicular to the long sidefaces 1a of the stator 1 and the direction of winding of which is indicated in Figure 2 by arrows. The turns run essentially rectangularly and are adapted to the cross-section of the cylindrical permanent magnet 4, passing through the axis. The part-coils 2 and 3 are constructed the same and rest against one another with their faces which point inwards and are orientated in parallel with their plane of winding, in a plane passing through the axis of the armature; the edges of

the part-coil bodies, running diametrically to the armature, have in the centre approximately semi-circular recesses 2a, 2b and 3a, 3b respectively, which in the assembled state complete openings for the armature shaft 5 to pass through.

5 The outer periphery of the two part-coils 2 and 3 is adapted to the inner periphery of the rectangular stator 1, which in this way holds the coils essentially positively, so that the rectangular coil openings 2c and 3c respectively lie in front of the long sidefaces 1a of the stator. The inner periphery
10 of the part-coils 2 and 3 is adapted to the cylindrical shape of the permanent magnet 4. In this way the permanent magnet 4 is surrounded by the part-coils 2 and 3 like a box and with only slight clearance, whereby the vacant space between armature and stator is in practice completely filled by
15 the coil-turns. If necessary the coil arrangement can also be made in such a way that they only partially fill the vacant space within the stator.

Instead of two part-coils which facilitate the assembly of the motor, in principle only a one-part coil may also be
20 provided.

The end faces of the stator 1 are closed by two rectangular flanges 6 and 7 adapted to the cross-section of the stator opening, and exhibiting in the centre bearing openings 8 and 9 respectively for the armature shaft 5 to pass through, and
25 may likewise consist of magnetic material.

The motor described may typically have an axial length of about 55mm, a height of about 20mm and a width of about 15mm. The power consumption in operation at 50 Hz or at 60 Hz may typically lie between 1.3 and 1.6 W.

For reduction of eddy current losses it may be advantageous to provide in the walls of the stator 1 as shown in broken lines in Figure 1, slits 10 which run in parallel with a plane orientated perpendicularly to the axis of the armature.

5 The motor described works as follows: the permanent magnet armature 4 in the rest position is forced by return means, for example, a return spring 20 surrounding the armature shaft 5 as indicated in Figure 2, into a position which is shown in Figure 2 and in which the direction of the diametrical magnetic field of the armature is lying perpendicular to the axis of the coil. If the part-coils 2 and 3, which may be connected in series or in parallel, depending upon the level of the supply voltage, are now energized by an alternating current, the alternating magnetic field H generated cooperates with the magnetic moment $\underline{m}$ of the armature magnet 4 in such a way that an alternating torque is exerted upon the armature of the value $M = m H \sin \alpha$, where α is the angle between the direction of the magnetic field H and that of the armature magnetization and in the position of rest of the armature illustrated in Figures 2 amounts to 90° . The armature thereby experiences an oscillating deflection out of its rest position, so that it oscillates at the frequency of the supply voltage.

The rectangular shape of the case 1 of the stator now confers two additional advantageous effects. Firstly this stator geometry for a given amount of copper in the wire of the coil allows the generation of a relatively high field in the direction axial to the coil. Secondly the magnetic circuit exhibits a reluctance which depends relatively strongly upon the angle between the axis of magnetization of the

armature magnet 4 and the major axis of symmetry of the rectangular cross-section of the stator, since the two long or respectively large sidefaces 1a of the stator 1 have the function of preferred poles. The action of this variable reluctance consists in the following: When the armature is deflected a little out of its rest position shown in Figure 2, which forms an unstable balance, in the absence of a coil field a static torque acts upon it, which tries to turn the armature into that position in which the reluctance of the magnetic circuit is least; in this position which differs from the rest position by an angle of 90° , the direction of magnetization of the armature magnet 4 is aligned with the minor axis of symmetry of the cross-section of the stator. This static torque advantageously strengthens the normal torque generated by the coil field and thereby favours the oscillating motion of the armature.

This effect of strengthening the useful torque may also be described by the statement that in the expression specified above for the torque M the value m , that is, the magnetic moment of the armature magnet, depends upon the aforesaid angle α .

Under given electrical and magnetic conditions the value of the angle of oscillation of the armature depends upon the external loading and upon the tuning of the mechanical oscillating system, that is, upon the mass of the armature and the object fastened to it, upon the characteristic of the return means and upon the damping or friction respectively.

Under certain circumstances this angle may amount to 180° and possibly even exceed this value. That is, if no measures were provided for limiting the angle of the armature and therefore the armature were free, the motor would behave as a rotating singlephase synchronous motor. Measures are provided to ensure the motor gives an oscillating drive output, and for the special application of the motor to the drive of a toothbrush the angle of oscillation of the armature and hence the oscillatory motion of the toothbrush about the axis of the brush is limited to an angle of about 60° or less.

Figure 6 shows the stator 21 with octagonal cross-section of a further embodiment of a motor in accordance with the invention, in the case of which, analogous to the example given in Figure 1, the outer peripheries of the two halves of the coil (not shown) are adapted to the octagonal internal periphery of the stator and advantageously take up practically all the vacant space between stator and armature. In order to facilitate production and assembly of the motor, in the example given in Figure 11 two equal box-like halves of the stator 21' and 21" are provided, which are joined in a plane which at least approximately passes through the longitudinal axis of the stator 21 and are fixed together in any manner at all, which can be, for example, with the aid of flanges adapted to the octagonal cross-section, which, like the flanges as in Figure 1, form the end faces of the stator. The two opposite side faces 21a of the stator 21 are larger than the other sidefaces and the axis of the coil is orientated perpendicular to these large sidefaces, so that

equal advantageous effects are produced, as explained for the rectangular stator 1 shown in Figure 1 with its pair of long sidefaces 1a and its pair of short sidefaces 1b. The distance between sidefaces orientated perpendicular to the large sidefaces 21a may generally be between 10 and 50%, preferably about 30% greater than the distance between the large sidefaces 21a. This applies also to the measurement of the rectangular stator shown in Figure 1.

An octagonal form of stator as in Figure 6 brings with it the additional advantages that the motor can be particularly well accommodated in a space-saving manner in a grip-type casing with oval cross-section, such as used typically for electric toothbrushes, and that the maximum radial distance between armature and stator-sleeve is reduced by comparison with the diagonal dimensions in the case of a rectangular stator; in this way the volume of air or copper within the magnetic circuit is reduced and thus the field is enlarged. In addition, by amplifying the static torque a more favourable characteristic curve of the torque as a function of the armature angle is obtained.

Of course, also in the example as shown in Figure 1 the stator 1 can be composed of two halves, analogous to the stator 21 in Figure 6.

The preferred application of the a.c. motor in accordance with the invention is the building into the handlelike case of an electric toothbrush having interchangeable plug-on toothbrushes; because of the relatively low power consumption such an electric toothbrush can then be supplied at low voltage via a transformer from the network, so that in practice no problems arise of electrical

insulation. But the motor in accordance with the invention is also suitable for other purposes, for example, for massage appliances and for any application in the technical fields which rapid periodic motion plays a part such, for example, as in small pumps.

The invention is not restricted to the embodiments described with reference to the drawings but as regards the construction and assembly of the individual parts, especially as regards the cross-section of the stator, which may also be oval, or generally polygonal, and as regards the coils, allows of manifold variants.

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CLAIMS:

1. A fractional horsepower a.c. motor giving an oscillating drive output, said motor comprising an oscillating permanent magnet armature in the form of a cylindrical diametrically magnetized permanent magnet
5 for the oscillating drive of a device attached to the armature shaft, a relatively stationary coil orientated with its axis perpendicular to the longitudinal axis of the armature and surrounding the permanent magnet, the winding turns of the coil defining rectangular shapes,
10 a stator comprising a magnetisable tubular portion of a case which encloses the coil and which is arranged coaxial with the axis of the armature, said stator having a polygonal or oval cross-section in which a pair of opposed sidefaces are larger than any other sideface of the stator and form
15 poles. the axis of the coil being orientated perpendicular to said larger sidefaces, a rest position of the armature being determined by return means, and in said rest position the diametrical magnetic field of the armature lying substantially perpendicular to the axis of the coil.

20 2. A motor as claimed in claim 1, in which the stator has a substantially rectangular or octagonal cross-section.

25 3. A motor as claimed in claim 1 or claim 2, in which the coil comprises two at least approximately equal part-coils which rest against one another at faces orientated substantially parallel with their plane of wind in a plane passing at least approximately through the axis of the armature, the edges of the part-coil bodies running,



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approximately diametrically to the armature defining at their centre semicircular recesses through which the armature shaft can pass.

4. A motor as claimed in claim 3, in which the part-coils are connected in series or in parallel depending upon the level of the supply voltage.

5. A motor as claimed in claim 2, in which the axis of the coil is orientated in parallel with one pair of opposite sidefaces of the stator which are smaller than said larger sidefaces.

6. A motor as claimed in claim 5, in which the distance between the sidefaces of the stator orientated perpendicular to the larger sidefaces is between 10% and 50% larger than the distance between the larger sidefaces.

7. A motor as claimed in any one of claims 1 to 6, in which the outer periphery of the coil or respectively part-coils is adapted to the shape of the inner periphery of the stator and the winding turns take up approximately all the vacant space between armature and stator.

8. A motor as claimed in any one of claims 1 to 6, in which the endfaces of the tubular stator are closed by flanges the shape of which is adapted to the cross-sectional shape of the stator and which define bearing openings for the armature shaft.

9. A motor as claimed in claim 1, in which the tubular part of the case of the stator is provided with slits for the reduction of eddy currents, and the slits

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are arranged to run in parallel with a plane orientated perpendicular to the axis of the armature.

10. A motor as claimed in any one of claims 1 to 9,
in which the tubular stator is composed of two box-like
5 halves which rest against each other in a plane which
passes at least approximately through the longitudinal
axis of the stator.

11. A fractional horsepower a.c. motor substantially
as hereinbefore described with reference to Figs. 1 to
10 5 or Fig. 6 of the accompanying drawings.