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(54) SYNCHRONOUS ELECTRIC MOTOR

(71) We, KABUSHIKI KAISHA SEIKOSHA, a Japanese Company of 5, 2-chome Kyobashi, Chuo-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to synchronous electric motors.

In a conventional type motor, a stator has the same number of polepieces as there are magnetic poles on a rotor. Moreover, magnetic poles formed at the polepieces are concentrated therein. Thus the coupling between the rotor and the stator is relatively strong and the motor cannot be made to self-start. Pull-in is therefore effected by initially rotating the rotor using a separate starter. Since any cut-away portion or indentation in the stator cannot be made of large size, the motion of the rotor lacks smoothness and pull-out is prone to occur.

According to the present invention there is provided a synchronous electric motor comprising a stator having two arms at the free end of each of which is formed a polepiece, the polepieces being spaced apart and opposed to one another, and a rotor, which has a single pair of N- and S-poles, disposed between said polepieces, each polepiece having two magnetic pole faces equidistant from the axis of the rotor and an indent portion formed between the magnetic pole faces at a greater distance from the axis of the rotor than the magnetic poles so that the stator is quadripolar statically and bipolar dynamically.

The terms "static" and "dynamic" used herein refer to the states in which a coil of the electric motor is not energised and is energised, respectively.

Preferably each arm has a further indent portion adjacent to the respective first-mentioned indent portion.

In one embodiment the polepieces are symmetric with respect to a plane passing through the rotor and bisecting the space between the free ends of the arms.

In another embodiment the first-mentioned indent portions are asymmetric with respect to a plane passing through the rotor and bisecting the space between the free ends of the arms and symmetric with respect to the axis of rotation of the rotor.

A coil may be formed on one of the arms. Preferably, the pole faces on the stator are disposed substantially equi-angularly relative to the axis of the rotor.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:

Figure 1 is a plan view of an embodiment of a motor according to the present invention;

Figure 2 is a sectional view taken on the line II—II in Figure 1;

Figure 3 is a diagram of an input wave form to the motor of Figure 1; and

Figure 4 is a plan view of another embodiment of a motor according to the present invention.

Referring to Figures 1 and 2, a motor according to the present invention has a substantially U-shaped stator 1 with two arms 2, 3. A bobbin 4a on which a coil 4 is wound is fitted on the arms 3. Symmetric stator polepieces 5, 6 are formed at the free ends of the arms 2, 3 respectively. The stator polepiece 5 includes pole faces 5a, 5b arcuate indent portion 5c formed between the pole faces 5a, 5b and an indent portion 5d formed below the pole face 5b. The stator polepiece 6 is symmetric with the stator polepiece 5 and includes pole faces 6a, 6b, and indent portions 6c, 6d. A rotor 8 is mounted for rotation on the shaft 7 between the pole faces 5a, 5b, 6a, 6b the shaft 7 being rotatably supported in bearings 9, 10. The rotor 8 is bipolar i.e. is formed with diametrically opposed N-S poles. A rotor pinion 11 is formed integrally with the shaft 7. The pole faces 6a, 6b, 5a, 5b, 6d are equidistant from the axis of the rotor and are closer to the axis of the rotor than the indent portions 5c, 6c.

The pole faces 5a, 6a subtend an angle α at the axis of the shaft 7 as also do the

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pole faces 5b, 6b. Similarly, the pole faces 5a, 5b subtend an angle β at the axis of the shaft 7 as also do the pole faces 6a, 6b. A magnetic centreline A couples the pole faces 5a, 6b and a magnetic centreline B couples the pole faces 5b, 6a. When the coil 4 has no input signal applied thereto, the rotor 8 is in rest position in which its N- and S-poles are magnetically coupled with the stator polepieces 5, 6 at the shortest distance therefrom. That is, the N- and S-poles of the rotor 8 are at rest at either the centreline A or the centreline B. This is because there is a relatively feeble magnetic coupling between the indent portions 5c, 6a and the rotor 8. When the coil 4 has an input signal applied thereto, the dynamic magnetic centre of the stator polepieces 5, 6 lies on a line C which couples the centre between the pole faces 5a, 5b and the centre between the pole faces 6a, 6b: in other words, the line C bisects the angle β .

The operation of the motor will now be described. Initially let it be assumed that when the coil has no input signal applied thereto, the rotor 8 is in the rest position with N-pole adjacent to pole face 6a of the stator and with the S-pole adjacent to pole face 5b, as shown in Figure 1. When the coil 4 receives an input signal of a wave form as shown in Figure 3, the stator polepieces 5, 6 become S- N-poles and N- S-poles alternately in time. In the case where, when the rotor 8 is in the rest position as shown in Figure 1, the coil 4 receives an initial positive pulse of the input signal and the stator polepiece 5 is magnetised to become a S-pole and stator polepiece 6 becomes a N-pole, the S-pole of the rotor repels the S-pole of the stator polepiece 5 and the N-pole of the rotor repels the N-pole of the stator polepiece 6, so that the rotor is swung or oscillates in the anticlockwise direction. Note, however, that the rotor 8 is not yet rotating continuously but is merely oscillated. Subsequently, when the magnetic polepiece 5 becomes a N-pole, and the magnetic polepiece 6 becomes a S-pole, by virtue of the subsequent negative pulse of the input signal which is inverted with respect to the initial positive pulse, the S-pole of the rotor is attracted by the magnetic polepiece 5 and the N-pole of the rotor by the magnetic polepiece 6, so that the rotor oscillates in the clockwise direction. When this operation is repeated several times, the rotor 8 oscillates through more than one-half β so that the N- S-poles of the rotor pass over the line C of the stator and rotate clockwise to the next centreline A, so that the S-pole of the rotor is adjacent to the pole face 5a and the N-pole is adjacent to the magnetic pole face 6b. Then the next negative pulse of the input signal is received. When the stator polepiece 5 be-

comes a S pole and the stator polepiece 6 becomes a N pole the N- and S-poles of the rotor are respectively repelled and the rotor further rotates clockwise to the line B. Thereafter, the rotation of the rotor is in the same direction and is smoothly continued each time a negative pulse of the input signal is applied to the coil 4. That is to say, when the rotor 8 oscillates through more than one-half the angle β the rotor begins to rotate continuously in one direction. The magnetic couplings between the stator and the rotor in the rest position is thus made small, whereby the rotor can be easily oscillated by relatively small input signal supplied to the coil. By making the angular frequency of the rotor and the input frequency substantially equal, a resonance state is established. When the amplitude of oscillation of the rotor gradually increases and the N- and S-poles of the rotor go beyond the line C of the stator, the motor begins to rotate as a synchronous motor.

In driving the rotor 8, the indents 5d, 6d act effectively. Without the indents, the rotor 8 is affected by magnetic forces from the parts of the arms 2, 3 below static pole faces 5b, 6b and it is difficult to shift from the oscillating motion to the continuous rotation. This is because a control force, i.e. a force continuing to oscillate the rotor, which is proportional to the speed of the rotor, acts and impedes the change to continuous rotation. By forming the indents 5d, 6d the magnetic influences of the arms 2, 3 of the rotor are reduced, whereby the rotor can smoothly shift from the oscillating motion to the continuous rotation using a relatively small input signal.

In the foregoing embodiment, the magnetic centrelines of the stator 1 are indicated by lines AB. It can occur, however, that the N- and S-poles of the rotor 8 do not become stationary exactly along the centreline A or the centreline B but that they come to rest along a line D or a line E being respectively neutral lines. In such a case, if the N- and S-poles come to rest along the line D no problem is posed. However, if they come to rest along the line E, no torque is generated in the rotor 8 even though the input signal is applied to the coil 4 because, in the embodiment shown in Figure 1, the line E is coincident with the line C of the stator 1.

A motor according to the present invention show in Figure 4 is constructed so as to reduce the occurrence of such a neutral line. The difference between the embodiment of Figure 4 and that of Figure 1 resides in the shape of incidents 55c, 56c. The incident 55c consists of an arcuate part 55c₁ with its centre at the point P₁ and an arcuate part 55c₂ with its centre at the point P₂. The incident 56c is formed sym-

metrically with the indent 55c with respect to an axis 57. It has been found experimentally that, even with such a form of the indents 55c, 56c, the line C is not influenced to any appreciable extent. As in the case illustrated in Figure 1, accordingly, the magnetic centreline is on the line C. In contrast, however, the line E is moved clockwise relative to the line C under the influence of the indents 55c, 56c. Therefore, even when the N- and S-poles of the rotor 8 come to rest along the line E, self-starting is reliably effective since the line E slightly deviates from the line C. The shape of the indents 55c, 56c is not restricted to that shown in Figure 4: the indents may be any construction which is such as to cause the line E to deviate from the line C. In this arrangement the magnetic poles and pole faces on the stator are disposed substantially equi-angularly relative to the axis of the rotor.

It will be appreciated from the above that the above synchronous motors are quadrupolar statically and bipolar dynamically.

WHAT WE CLAIM IS:—

1. A synchronous electric motor comprising a stator having two arms at the free end of each of which is formed a polepiece, the polepieces being spaced apart and opposed to one another, and a rotor, which has a single pair of N- and S-poles, disposed between said polepieces, each polepiece having two pole face equi-distant from the axis of the rotor and an indent portion formed between the pole faces at

greater distance from the axis of the rotor than the magnetic poles so that the stator is quadripolar statically and bipolar dynamically.

2. A motor as claimed in claim 1 in which each arm has a further indent portion adjacent to the respective first-mentioned indent portion.

3. A motor as claimed in claim 1 or 2 in which the polepieces are symmetric with respect to a plane passing through the rotor and bisecting the space between the free ends of the arms.

4. A rotor as claimed in claim 1 in which the first-mentioned indent portions are asymmetric with respect to a plane passing through the rotor and bisecting the space between the free ends of the arms and symmetric with respect to the axis of rotation of the rotor.

5. A motor as claimed in any preceding claim in which a coil is formed on one of the arms.

6. A motor as claimed in any preceding claim in which the pole faces on the stator are disposed substantially equiangularly relative to the axis of the rotor.

7. A synchronous electric motor as substantially as herein described with reference to and as shown in the accompanying drawings.

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4. A rotor as claimed in claim 1 in which the first-mentioned indent portions are asymmetric with respect to a plane passing through the rotor and bisecting the space between the free ends of the arms and symmetric with respect to the axis of rotation of the rotor.

5. A motor as claimed in any preceding claim in which a coil is formed on one of the arms.

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