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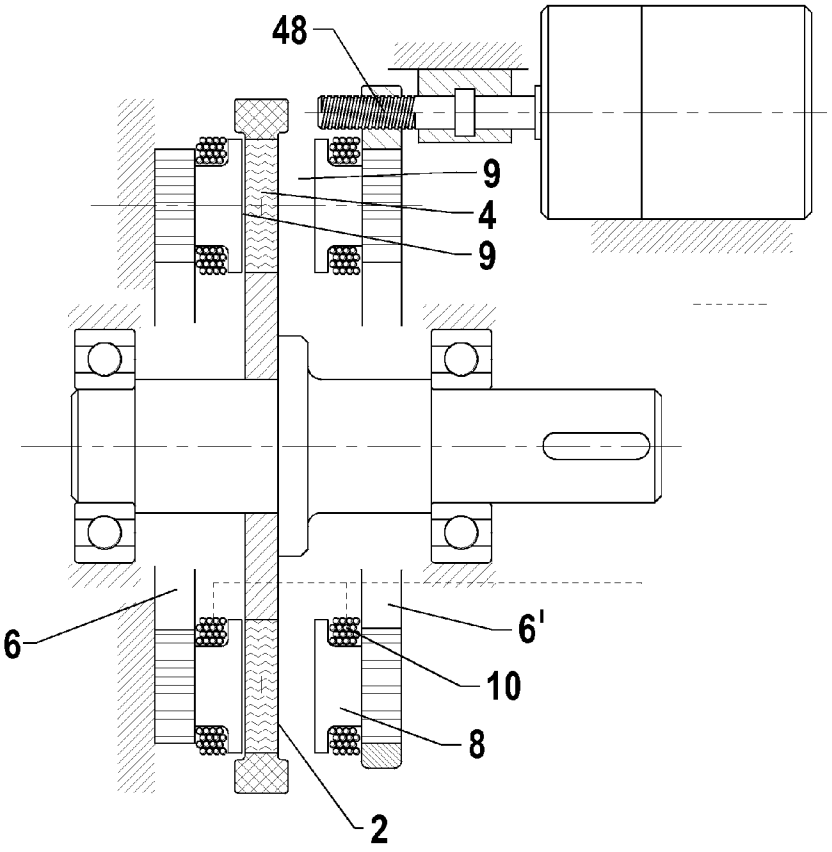
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[Continued on next page]

(54) Title: PERMANENT MAGNET ROTATING ELECTRIC MACHINE



(57) Abstract: A permanent magnet rotating electric machine has a rotor and a stator, one of the rotor and stator having thereon a plurality of permanent magnets, and the other having thereon a plurality of electromagnetic poles arranged to receive electrical windings. In addition to typical rotation of the rotor, the stator and rotor are movable relative to one another in an axial direction to cause a variation in the airgap between the permanent magnets and the electromagnetic poles. A phased current is applied to the electrical windings of at least one of the electromagnetic poles by way of electrical means. This phased current results in a variation of the magnetic field produced by the electromagnetic poles such that relative movement of the stator towards or away from the rotor can be magnetically controlled.

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Permanent Magnet Rotating Electric Machine

The present invention relates to a permanent magnet rotating electric machine.

Three types of brushless electric motor used for driving vehicles at present are known, namely induction, switched reluctance (SR) and permanent magnet (PM) motors. For performance per weight and volume and for efficiency at a given speed, permanent magnet motors are superior to the other two, as they can be considerably smaller and lighter for a certain power and torque requirement. Furthermore, if designed correctly, they can be virtually silent.

By contrast, it is difficult to design reasonably quiet switched reluctance motors and induction motors suffer from low efficiency at low speed and high torque.

However, when using permanent magnet electric machines for wide speed and torque ranges, their mean efficiency can drop drastically, because the permanent magnets create a constant generally high strength field, no matter how much torque is required.

Various methods of weakening this field have been proposed, one of which is to widen the airgap between the permanent magnets and the electromagnetic poles. This weakens the field approximately proportionally to the airgap dimension. By using a changeable airgap to control the strength of the field of the permanent magnets, it is also possible to control the speed of rotation of the rotor.

It has also been found to be desirable in many applications, especially in, for example, vehicles and winches, to use the electric motor as an electrically actuated clutch or brake, especially when the motor is at or close to zero speed.

The above ideas, i.e. field weakening and use of the electric motor as an electrically activated motor have been used in motors other than permanent

magnet motors. For example, there is a Demag induction motor having conical shaped rotors and stators that are in spring loaded contact to provide the braking and locking action desired.

However, in permanent magnet motors, the force of attraction between the permanent magnets and the soft iron core of electro-magnetic poles is typically so strong that a considerable amount of mechanical energy would be required to break a magnetic connection once formed, or it would be necessary to prevent the permanent magnets and electro-magnets from making such magnetic contact. Accordingly, where field weakening has previously been used in permanent magnet motors, mechanical means are provided to prevent such contact being made.

The present invention seeks to overcome some of the above-identified problems that have prevented this form of locking from being applied to the permanent magnet rotating electrical machines.

According to the present invention, there is provided a permanent magnet rotating electric machine comprising:

a rotor and a stator, one of said rotor and stator having a plurality of permanent magnets thereon and the other having a plurality of electromagnetic poles thereon arranged to receive electrical windings, wherein in addition to the rotation of the rotor, the stator and the rotor are movable relative to one another in an axial direction to vary the airgap between the permanent magnets and the electromagnetic poles; and

electrical means arranged to apply a phased current to the electrical windings of at least one of the electromagnetic poles to control relative movement of the stator towards or away from the rotor.

By applying a phased current to the electrical winding of at least one electromagnetic pole, it is possible to vary the magnetic field of the electro-magnetic pole and accordingly the magnetic attraction between the electro-magnetic poles and the permanent magnets.

Controlling the magnetic attraction between the stator and rotor enables the stator to be brought into contact with the rotor to provide a built-in braking

system. Without control of the magnetic attraction, the magnetic force between the permanent magnets and soft iron cores of the poles could be so strong that a significant mechanical force would be required to detach the rotor and stator. When the power supply to the motor is stopped, this magnetic attraction between the permanent magnets and the soft iron cores is sufficient to keep the stator and rotor in contact and thus can be used as a brake or lock that does not require any additional electrical energy.

Such a brake or lock could be used, for example, as an automatic parking brake for electric driven vehicles, or for holding stationary members of a vehicle transmission to provide certain modes of operation, including ratio changes.

The invention may be applied to any arrangement of electromagnetic poles and permanent magnets used in known motors. For example, the electromagnetic poles may be provide on the rotor and the permanent magnets on the stator.

In a preferred embodiment, the permanent magnets are located on the rotor and the electromagnetic poles are located on the stator such that the permanent magnets face the electromagnetic poles with the airgap therebetween.

It will be appreciated that either the rotor or the stator may be movable in an axial direction to enable relative movement of the rotor to the stator. In this respect the relative movement should result in a variation in the size or dimensions of the airgap between the electromagnetic poles and the permanent magnets.

Preferably, the rotor rotates about a fixed shaft and the stator is movable towards or away from the rotor.

In an embodiment mechanical means for moving the stator towards or away from the rotor are provided. These mechanical means can be any form of activator, for example, a screw that is twisted to effect motion or hydraulic means.

Preferably, application of the phased current to the electrical windings of at least one of the electromagnetic poles located on the stator enables said mechanical means to move the stator towards or away from the rotor, and together with the mechanical means provides precise control over said movement.

The electromagnetic poles are selectively energised to permit or prevent the stator from making contact with the rotor based on whether the electromagnetic poles remain neutral or attract or repel the permanent magnets located on the rotor.

By controlling the electric pulses delivered to the respective poles of the stator, it is possible to select which pole(s) should be energised to achieve the desired motion. This motion can range from axial motion of the stator relative to the rotor, i.e. towards or away from the rotor, or rotation of the rotor.

Any known method for selectively energising the electromagnetic poles or applying a phased current may be used to control the magnetic field. In a preferred embodiment a 3-phased current is used to cause a variation in magnetic field of each of the electromagnetic poles.

Based on the resultant axial and radial magnetic forces, the mechanical means can be used to effect movement. In this respect, the mechanical means, in conjunction with the axial magnetic force, are used to move the stator in an axial direction.

In one embodiment, the application of the phased current to one or more selectable electromagnetic poles enables the stator to be brought into contact with the rotor by the mechanical means.

Preferably, application of the phased current to one of more selectable electromagnetic poles enables the stator to be moved away from the rotor.

Any electromagnetic pole that is so aligned with the permanent magnets to result in repulsion when energised, may have a current applied to enable

the stator to be moved away from the rotor.

In an alternative embodiment, the application of the phased current to one of more selectable electromagnetic poles obstructs movement of the stator towards the rotor.

Prevention or obstruction of the stator from making content with the rotor enables the stator to be brought into close proximity to the rotor without the permanent magnets becoming fixed to the electromagnetic poles. Thus the motor can be slowed down, or brought to a standstill without becoming locked.

In this respect, and in embodiments, engagement of the stator to the rotor prevents further movement of the rotor.

Separate electrical means can be provided for energising appropriate pulses and controlling the magnetic attraction between the rotor and stator. However, in a preferred embodiment, the electrical means provided for controlling rotation of the rotor are the same as those for controlling relative movement of the stator and rotor in an axial direction.

These can be any electrical means typically found in electrical motors.

It will be appreciated that relative movement of the stator and rotor can be independent of any variation in the speed of the rotor. However, in a preferred embodiment, variation of the airgap between the permanent magnets and the electromagnetic poles further controls the speed of rotation of the rotor.

In this respect, as the airgap is increased, the strength of the magnetic field as realised by the poles of the stator, weakens approximately proportional to the airgap dimension. Weakening of the magnetic field causes an increase in the speed of the motor as the back EMF generated in the circuit increases. By contrast, as the stator is moved closer to the rotor, and the airgap is reduced, the back EMF and the magnetic field realised by the poles of the stator increases, and the speed of the motor decreases. Thus, this effect may also be used to reduce the speed of the motor to zero as the stator is brought

into contact with the rotor.

In addition to this, movement of the stator relative to the rotor can be used to improve efficiency of the motor. If field weakening is not used to govern the speed of the motor, it can still be used to increase efficiency of the motor. For example, to increase the speed of the motor, typically, the supply voltage to the motor is increased. If, in addition to increasing the supply voltage, the airgap between the rotor and stator is increased, then less additional supply voltage will be required to achieve the same effect. Furthermore the magnetic flux losses are also reduced this way. Thus, to increase efficiency of a motor, the stator can be adjusted such that at low speed and high torque, a small airgap is provided, and at high speed and high torque, a large airgap is provided.

It will be appreciated that the invention may be applied to various configurations of motors. Specifically, the invention may be used in any motor where the stator is movable relative to the rotor causing a variation in the size and dimension of the airgap. In addition, it should be possible for the stator to be brought into contact with the rotor in such a way that further rotation of the rotor can be prevented by the magnetic attraction between the permanent magnets and soft iron core of the electromagnetic poles.

In one embodiment, the rotating electric machine is a radial flux machine having a conical rotor located within a corresponding conical stator, and one of the rotor or stator are movable relative to the other in an axial direction to vary the dimensions of the airgap between the permanent magnets and the electromagnetic poles.

In an alternative embodiment, the rotating electric machine is an axial flux machine having a disc-shaped rotor in parallel to a disc-shaped stator, and one of the rotor or stator are movable in a direction perpendicular to the face of the rotor and stator to vary the size of the airgap between the permanent magnets and the electromagnetic poles.

It will be appreciated that axial flux machines may be used, for example, a double rotor axial flux machine.

In a preferred embodiment the axial flux machine has a first fixed stator and a second movable stator, one on either side of the disc-shaped rotor, and the second stator is movable to vary the size of the airgap between the second stator and the disc-shaped rotor.

The present invention also extends to a method of controlling the magnetic attraction between a rotor and a stator of a permanent magnet rotating electric machine, one of said rotor and stator having a plurality of permanent magnets thereon and the other having a plurality of electromagnetic poles thereon arranged to receive electrical windings, wherein in addition to the rotation of the rotor, the stator and rotor are movable relative to one another in an axial direction to vary the airgap between the permanent magnets and the electromagnetic poles, the method comprising applying a phased current to the electrical windings of at least one of the electromagnetic poles to control relative movement of the stator towards or away from the rotor.

Embodiments of the present invention will hereinafter be described, by way of example, with reference to the accompanying diagrams, in which:

Figure 1 shows a schematic of a double stator type axial flux permanent magnet electric machine of the present invention having one screw adjustable stator;

Figure 2 shows a schematic of a double stator axial flux permanent magnet electric machine of the present invention with one hydraulically adjustable stator;

Figure 3 shows a schematic of a radial flux permanent magnet electric machine of the present invention with a conical rotor and stator; and

Figures 4a and 4b show schematically the change in phase polarity for torque unlocking; and

Figure 5 is a table showing the change in magnetic force every 5° of rotation of the rotor relative to the stator.

The present invention is applicable in general to permanent magnet rotating electric machines, including permanent magnet motors and generators. However, for simplicity, the remainder of the invention will be

described with reference to its use in a motor. A motor as described in the present invention may be used in all electrical driven vehicles and machinery where brakes may be applied and where motion is preferably prevented when not in use, for example, cars, cranes, winches, capstans, windlasses and machine tools etc. or transmission systems where the locking of one or several shafts can change mode and ratio.

Figures 1, 2 and 3 show embodiments of different arrangements of motors where the invention may be applied. Figures 1 and 2 show double stator axial flux motors and Figure 3 shows a radial flux motor having a conical rotor. The invention may be applied in any permanent magnet motor having a rotor and at least one stator.

Shown in Figures 1 and 2 are embodiments of the invention as applied in a double stator axial flux motor, having a disc-shaped rotor 2 located in parallel with and between two disc-shaped stators 6, 6'. The rotor has a plurality of permanent magnets 4 on both faces, and both stators have a plurality of electromagnetic poles 8 located thereon facing the permanent magnets of the rotor. The electromagnetic poles 8 have a soft iron core and are arranged to receive electrical windings 10 to complete the electromagnetic circuit. The respective faces of the permanent magnets and the electromagnetic poles define airgaps 9 between the rotor and the respective stators.

As a controlled and timed voltage is supplied to the electrical windings located around the electromagnetic poles, the rotor rotates about its central axis.

The first stator 6 is in a fixed position a fixed distance away from the rotor. The second stator 6' is movable relative to the rotor in a direction perpendicular to the face of the rotor. Movement of the stator towards or away from the rotor causes a variation in the size and dimensions of the airgap formed between the stator 6' and the rotor.

In the embodiment shown in Figure 1, movement of the stator is effected by a mechanical screw 48. As the screw is turned, the stator 6' can be moved

away from the rotor, or it can be moved towards the rotor and brought into contact with the rotor. In the embodiment shown in Figure 2, movement of the stator in Figure 2 is effected by a hydraulically actuated arm 50.

It will be appreciated that while double stator type axial flux machines have been shown, the invention may also be applied to single stator axial flux machines, or other known arrangements.

Figure 3 shows an example of a radial flux machine having a conical rotor 40 located within a conical stator 42. The rotor is provided with a plurality of permanent magnets 44 around its circumference that face the inner wall 46 of the stator. The inner wall of the stator is provided with a plurality of electromagnetic poles 48, around which electrical windings are provided to complete the magnetic circuit. Upon activation of the electrical windings, the rotor rotates about its central axis.

The stator shown in figure 3 is movable away from or towards the rotor in an axial direction. It will be appreciated that alternatively, the rotor could be moved in an axial direction away from the stator. Movement of the stator away from the rotor results in a variation in dimensions of the airgap between the permanent magnets 44 and the electromagnetic poles 48.

Movement of the stator is effected by a screw, although it will be appreciated that any other known method may be used. Again, the stator can be moved away from or towards and into contact with the rotor.

In each of the embodiments described, the permanent magnets are located on the rotor while the electromagnetic poles are located on the stator. It will, of course, be appreciated that these could be reversed.

In each of the embodiments shown in Figures 1, 2 and 3, the stator can be brought into contact with the rotor such that the permanent magnets can become magnetically linked to the soft iron cores of the electromagnetic poles. To prevent frictional damage, the stator is preferably only brought into contact with the rotor when the rotor is stationary, or very nearly stationary. Thus, it is required to reduce the speed of the rotor prior to contact. When the stator

makes contact with the rotor, the magnetic force between the permanent magnets located on the rotor and the soft iron core of the electromagnetic poles located on the stator is so strong that the mechanical energy provided by either the screws shown in Figures 1 and 3, or the hydraulic system shown in Figure 2, would not be sufficient to distance the stator from the rotor. Thus, when the stator is brought into contact with the rotor, the stator engages with the rotor, preventing motion of the rotor, and can be used as a brake or lock and to prevent motion when the motor is not in use.

Accordingly, if a brake is required, the power supply to the electrical windings of the stator can be switched off, and the stator will remain in contact with the rotor without requiring any additional electrical or mechanical energy.

Thus, for example, if this were to be applied in a car, no handbrake or parking brake would be required.

To disengage the stator and the rotor, it is therefore necessary to manipulate and vary the magnetic force between the permanent magnet of the rotor and the electromagnetic poles of the stator. The present inventors have found that the electrical current that is supplied to the electrical windings of the stator to cause rotation of the rotor, may also be used to control the polarity of the electromagnetic poles to enable movement of the stator away from the rotor.

Specifically, depending on the alignment of the electromagnetic poles with the permanent magnets, if a certain phased current is applied to the electromagnetic poles, the polarity of the face of the electromagnetic poles facing the permanent magnets can be adapted to enable or prevent or at least obstruct movement of the stator relative to the rotor.

For example, if adjacent faces of an aligned electromagnetic pole and permanent magnet are of opposing polarity, there will be magnetic attraction between the electromagnetic pole and the permanent magnet. Thus, without excessive force, it would not be possible using mechanical means to move the stator away from the rotor. Similarly, if the polarity of the adjacent faces is the same, then magnetically, they will repel each other. At this point, it would be

possible, using the available mechanical means, to move the stator away from the rotor. By contrast, if at all possible, it would not be easy to move the stator towards the rotor at this time. If, however, a north pole of the electromagnetic pole is faced with both north and south poles of respective permanent magnets, then the magnetic force will be neutral, and this will have no effect on the mechanical movement of the stator.

This is illustrated in Figures 4a and 4b which show schematically the alignment between permanent magnets 20 located on a rotor of an axial flux motor, and electromagnetic poles 22 located on a stator. The rotor shown in Figures 4a or 4b has 12 permanent magnets of alternating polarity 20 located around the outer edge of the disc-shaped rotor, of which 5 are shown. The disc-shaped stator shown in Figure 4 has 9 electromagnetic poles 22, also located around the outer edge of the stator, of which 4 are shown. The polarity of the stator facing sides of the respective permanent magnet poles are shown as positive or negative.

The three electromagnetic poles 24, 26, 28 shown in Figure 4a illustrate the effect of three phases of current being applied to the windings. The alignment of these respective electromagnetic poles 24, 26, 28 with the permanent magnets 20 will determine which electromagnetic pole should be energised by applying a phased current to achieve the desired effect. If one electromagnetic pole is considered in isolation, it can be seen if, when energised, the force produced would cause movement in an axial direction and/or if it would produce torque, and if torque, in which direction. Accordingly, by looking at the polarity and alignment of these poles with the permanent magnets it is possible to determine what, if any, rotational movement will occur and what, if any, motion of the stator relative to the rotor will be possible.

For example, as shown in Figure 4a, if energised, the first electromagnetic pole 24 would repel the positive permanent magnet of the rotor and would result in the rotor rotating in a clockwise direction. If the second electromagnetic pole 26 were to be energised, this would result in repulsion of the positive permanent magnet and cause movement of the rotor in an anticlockwise direction. If the third electromagnetic pole 28 were to be

energised, there would be no resulting torque. However, there would be movement in an axial direction as the resulting polarity of the electromagnetic pole is the same as that of the electromagnetic pole and would therefore cause it to repel.

Thus, if the stator and rotor were in a locked position, and the third electromagnetic pole 28 were to be energised, the magnetic repulsion would enable the stator to be moved away from the rotor using mechanical means. By contrast, if the stator and rotor were not in engagement, as a result of this repulsion, it would be difficult to move the stator towards the rotor.

Fig 4b shows the PM poles rotated by 5 degrees, relatively to the stator poles and the table in figure 4 shows how the phased energisation of the poles changes every 5 degrees, in order to achieve either axial repulsion, clockwise torque, axial attraction or anticlockwise torque.

The table shown in Figure 5 shows the different results for both axial and radial motion as the permanent magnets are rotated by 5 degrees relative to the electromagnetic poles. The table is divided into two sections, a first showing the overall axial force (shown as “unlock”) and the second showing the resulting radial motion (shown as “run clockwise”).

In the unlock section, “+” indicates overall attraction between the electromagnetic poles and the corresponding permanent magnets. “0” indicates overall neutrality – neither attraction nor repulsion. Finally, “-“ indicates overall repulsion.

In the clockwise rotation section, “+” indicates relative rotation of the rotor in a clockwise direction. “0” represents no movement in a radial direction. This occurs when the centres of both the electromagnetic poles and permanent magnets are in line with one another. Finally, “-“ indicates movement of the rotor in an anticlockwise direction.

Thus, both torque and force in an axial direction can be controlled. This can be used while the motor is in motion, for example to prevent or obstruct the rotor and stator from becoming engaged, or as a means of disengaging the

rotor and stator when in a locked position.

As described above, in embodiments of the present invention, the speed of the rotor is electrically reduced as the stator is brought into close proximity to the rotor. However, as a result of the effect of field weakening, the speed of the rotor may also decrease as a consequence of reducing the air gap between the stator and the rotor.

In this respect, in embodiments, movement of the stator relative to the rotor causes a change in speed of rotation of the rotor 2. As the airgap is increased, the strength of the magnetic field as realised by the poles of the stator, weakens approximately proportional to the airgap dimension. Weakening of the magnetic field causes an increase in the speed of the motor as the back EMF generated in the circuit increases. By contrast, as the stator is moved closer to the rotor, and the airgap is reduced, the back EMF and the magnetic field realised by the poles of the stator increases, and the speed of the motor decreases. Thus, this effect may also be used to reduce the speed of the motor to zero as the stator is brought into contact with the rotor.

In addition to this, movement of the stator relative to the rotor can be used to improve efficiency of the motor. If field weakening is not used to govern the speed of the motor, it can still be used to increase efficiency of the motor. For example, to increase the speed of the motor, typically, the supply voltage to the motor is increased. If, in addition to increasing the supply voltage, the airgap between the rotor and stator is increased, then less additional supply voltage will be required to achieve the same effect. Furthermore the magnetic flux losses are also reduced this way. Thus, to increase efficiency of a motor, the stator can be adjusted such that at low speed and high torque, a small airgap is provided, and at high speed and high torque, a large airgap is provided.

Once in contact, a significant amount of mechanical force would be required to separate the stator and the rotor. Thus, the power supply to the motor can be removed with the magnetic force between the stator and rotor acting as a brake for the motor without the need for additional electrical energy.

It will be appreciated that modifications to and amendments of the embodiments as described and claimed may be made within the scope of this application.

CLAIMS

1. A permanent magnet rotating electric machine comprising:

a rotor and a stator, one of said rotor and stator having a plurality of permanent magnets thereon and the other having a plurality of electromagnetic poles thereon arranged to receive electrical windings, wherein in addition to the rotation of the rotor, the stator and the rotor are movable relative to one another in an axial direction to vary the airgap between the permanent magnets and the electromagnetic poles; and

electrical means arranged to apply a phased current to the electrical windings of at least one of the electromagnetic poles to control relative movement of the stator towards or away from the rotor.

2. A rotating electric machine as claimed in claim 1, wherein the permanent magnets are located on the rotor and the electromagnetic poles are located on the stator such that the permanent magnets face the electromagnetic poles with the airgap therebetween.

3. A rotating electric machine as claimed in claim 1 or claim 2, wherein the rotor rotates about a fixed shaft and the stator is movable towards or away from the rotor.

4. A rotating electric machine as claimed in any preceding claim, further comprising mechanical means for moving the stator towards or away from the rotor.

5. A rotating electric machine as claimed in claim 4, wherein in use, application of the phased current to the electrical windings of at least one of the electromagnetic poles located on the stator enables said mechanical means to move the stator towards or away from the rotor, and together with the mechanical means provides precise control over said movement.

6. A rotating electric machine as claimed in claim 5, wherein the application of the phased current to one or more selectable electromagnetic poles enables the stator to be brought into contact with the rotor by the mechanical means.

7. A rotating electric machine as claimed in claim 6, wherein upon contact of the stator and rotor, application of the phased current to one of more selectable electromagnetic poles enables the stator to be moved away from the rotor.

8. A rotating electric machine as claimed in claim 7, wherein the application of the phased current to one of more selectable electromagnetic poles obstructs movement of the stator towards the rotor.

9. A rotating electric machine as claimed in any preceding claim, wherein engagement of the stator to the rotor prevents further movement of the rotor.

10. A rotating electric machine as claimed in any preceding claim, wherein the electrical means further control rotation of the rotor.

11. A rotating electric machine as claimed in any preceding claim, wherein variation of the airgap between the permanent magnets and the electromagnetic poles further controls the speed of rotation of the rotor.

12. A rotating electric machine as claimed in any preceding claim, wherein the rotating electric machine is a radial flux machine having a conical rotor located within a corresponding conical stator, and one of the rotor or stator are movable relative to the other in an axial direction to vary the dimensions of the airgap between the permanent magnets and the electromagnetic poles.

13. A rotating electric machine as claimed in any of claims 1 to 11, wherein the rotating electric machine is an axial flux machine having a disc-shaped rotor in parallel to a disc-shaped stator, and one of the rotor or stator are movable in a direction perpendicular to the face of the rotor and stator to vary the size of the airgap between the permanent magnets and the electromagnetic poles.

14. A rotating electric machine as claimed in claim 13, wherein the axial flux machine has a first fixed stator and a second movable stator, one on either

side of the disc-shaped rotor, and the second stator is movable to vary the size of the airgap between the second stator and the disc-shaped rotor.

15. A method of controlling the magnetic attraction between a rotor and a stator of a permanent magnet rotating electric machine, one of said rotor and stator having a plurality of permanent magnets thereon and the other having a plurality of electromagnetic poles thereon arranged to receive electrical windings, wherein in addition to the rotation of the rotor, the stator and rotor are movable relative to one another in an axial direction to vary the airgap between the permanent magnets and the electromagnetic poles, the method comprising applying a phased current to the electrical windings of at least one of the electromagnetic poles to control relative movement of the stator towards or away from the rotor.

16. A method as claimed in claim 15, further comprising applying the phased current to one or more selectable electromagnetic poles to enable movement of the stator into engagement with the rotor.

17. A method as claimed in claim 15, further comprising applying the phased current to one or more selectable electromagnetic poles to enable movement of the stator away from the rotor.

18. A method as claimed in claim 17, further comprising applying the phased current to one or more selectable electromagnetic poles to obstruct movement of the stator towards the rotor.

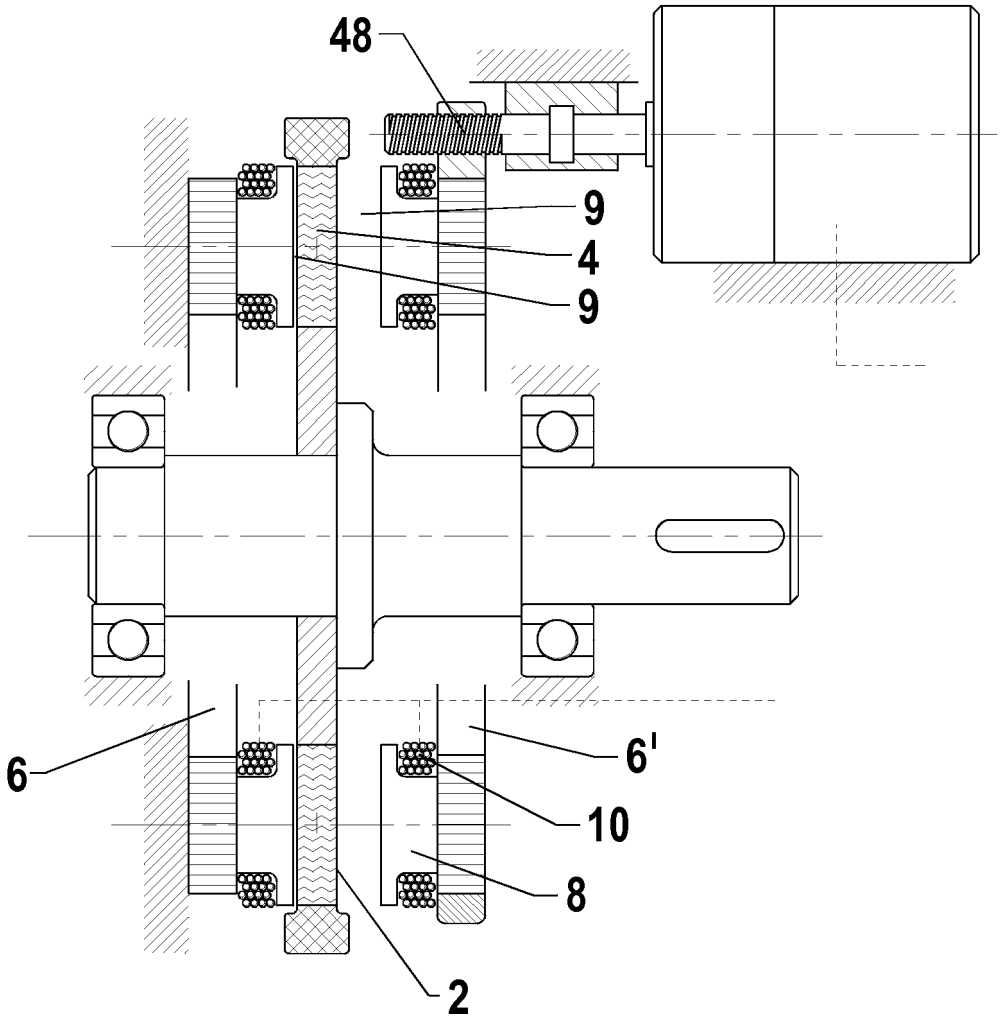


Fig 1

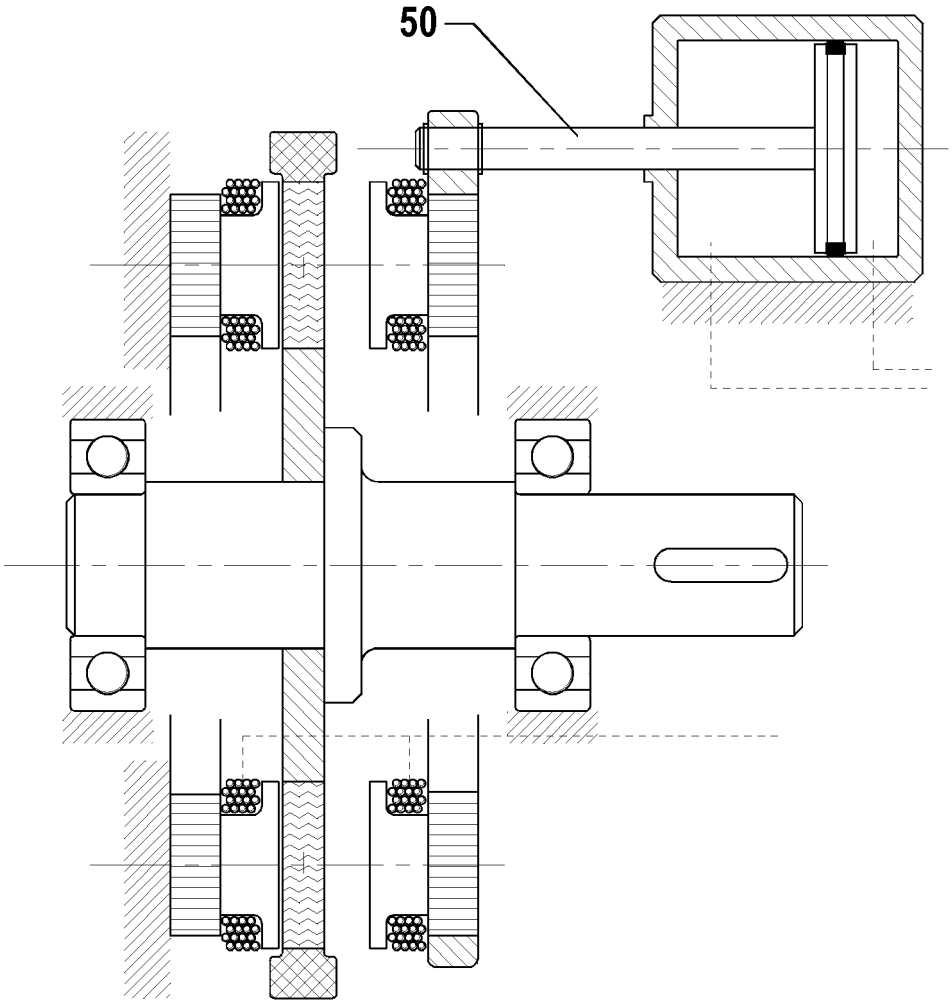


Fig 2

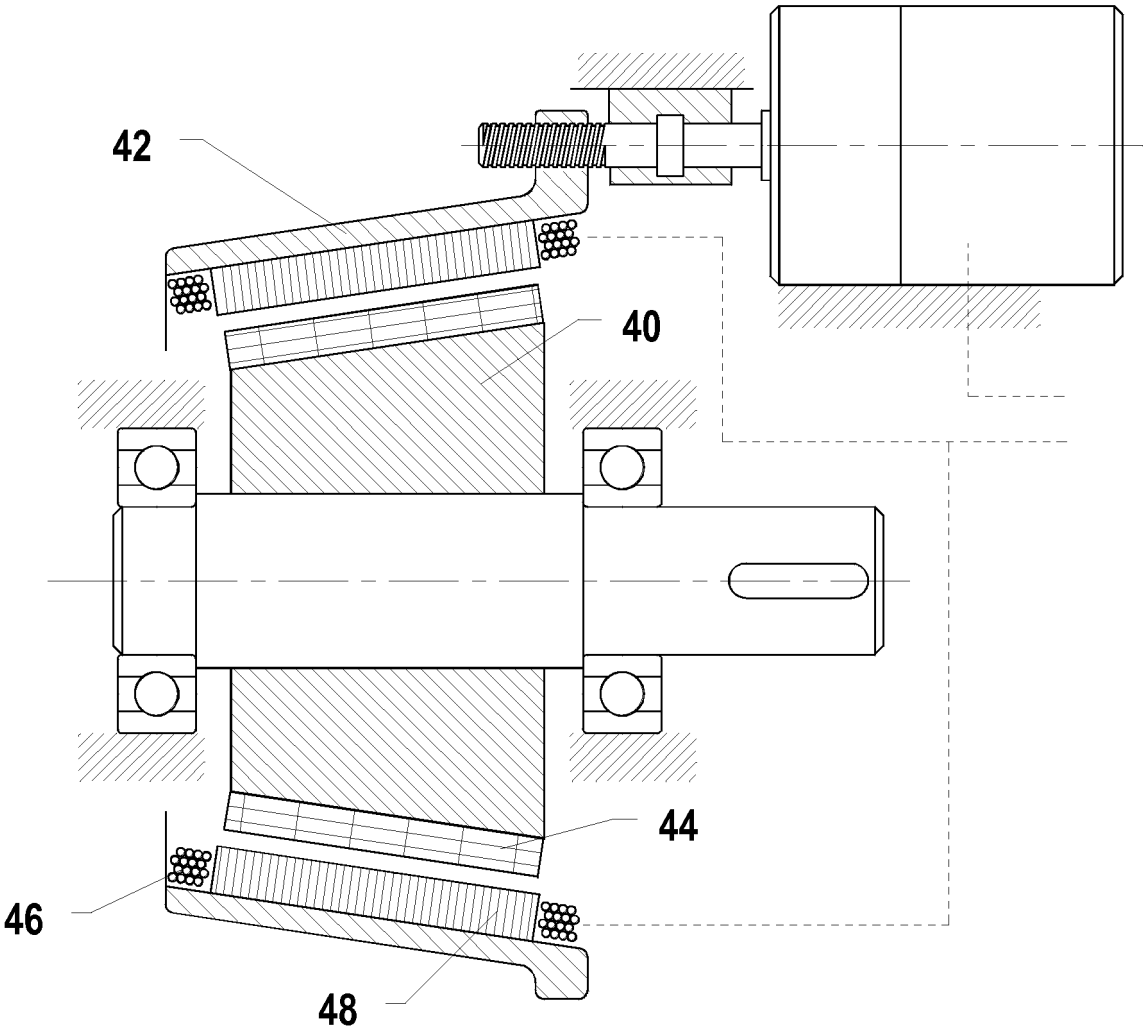


Fig 3

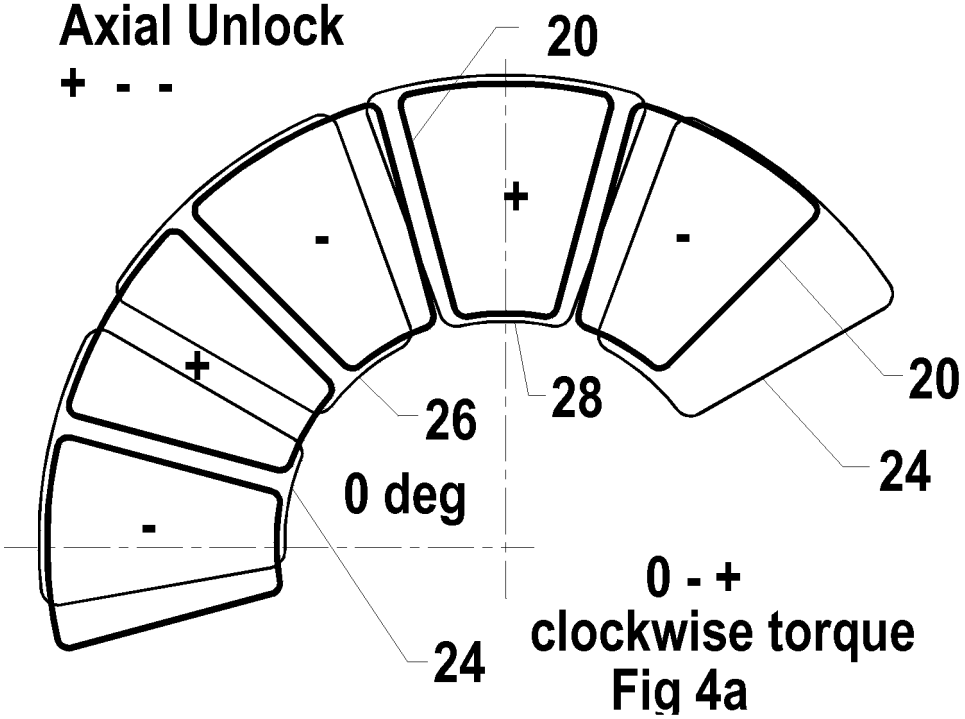

Axial Unlock
+ - -
20
+
-
-
+
-
20
26
28
24
0 deg
0 - +
clockwise torque
24

Fig 4a

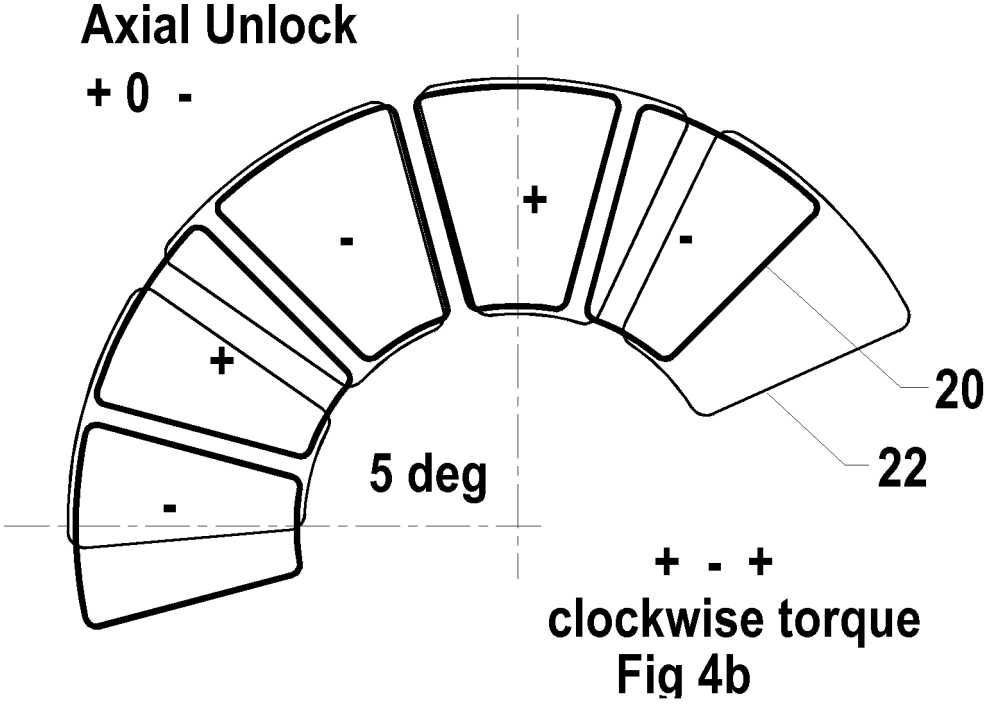

Axial Unlock
+ 0 -
+
-
-
+
-
20
22
5 deg
+ - +
clockwise torque

Fig 4b

energise	deg	0	5	10	15	20	25	30	35	40	45	50	5
unlock													
Phase 1	___2	+	+	+	0	-	-	-	-	-	0	+	+
Phase 2	_‗_	-	0	+	+	+	+	+	0	-	-	-	-
Phase 3	._‗._2	-	-	-	-	-	0	+	+	+	+	+	0
run clockwise													
Phase 1	___2	0	+	+	+	+	+	0	-	-	-	-	-
Phase 2	_‗_	-	-	-	-	0	+	+	+	+	+	0	-
Phase 3	._‗._2	+	+	0	-	-	-	-	-	0	+	+	+

Fig 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2007/057270

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02K7/102 H02K21/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 05 336700 A (FUJI ELECTRIC CO LTD) 17 December 1993 (1993-12-17) abstract figures 1-4	1-18
X	EP 0 208 467 A (RINEFAS LTD [AU]) 14 January 1987 (1987-01-14) figures 3,4	1-18
X	US 2004/086083 A1 (BIER PETER [DE] ET AL) 6 May 2004 (2004-05-06) figure 1 pages 7,12	1-18

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
29 October 2007	07/11/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Le Chenadec, Hervé

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2007/057270

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97/09770 A (MORRIS MECH HANDLING [GB]; SHORT MICHAEL [GB]; PICKERING KEVIN [GB]; O) 13 March 1997 (1997-03-13) figure 2 paragraphs [0029], [0030]	1-18
X	US 6 455 975 B1 (RAAD BERNARD [US] ET AL) 24 September 2002 (2002-09-24) figure 1 columns 2,4,6-8	1-18
A	WO 03/077403 A (ZEPP LAWRENCE P [US]; MEDLIN JERRY W [US]) 18 September 2003 (2003-09-18) figure 2	4,5
A	EP 1 670 124 A (YAMAHA MOTOR CO LTD [JP]) 14 June 2006 (2006-06-14) figure 2 paragraphs [0001], [0002], [0013], [0060], [0068], [0106] paragraphs [0117] - [0124] paragraphs [0133], [0137], [0144], [0145], [0149]	1-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2007/057270

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 5336700 A	17-12-1993	NONE	
EP 0208467 A	14-01-1987	NONE	
US 2004086083 A1	06-05-2004	DE 10143749 A1	18-06-2003
WO 9709770 A	13-03-1997	NONE	
US 6455975 B1	24-09-2002	NONE	
WO 03077403 A	18-09-2003	AU 2003217963 A1	22-09-2003
		CN 1639947 A	13-07-2005
		EP 1483821 A1	08-12-2004
		JP 2005520471 T	07-07-2005
EP 1670124 A	14-06-2006	JP 2006191782 A	20-07-2006
		KR 20060065479 A	14-06-2006
		US 2006152104 A1	13-07-2006