

TITLE OF THE INVENTION

MAGNETIC-GEARED MOTOR WITH IRONLESS WINDING

BACKGROUND OF THE INVENTION

Field Of The Invention

- 5 The present invention relates to magnetic-geared motor, and in particular to a magnetic-geared motor with ironless winding.

Description Of The Related Art

10 Magnetic-geared motors have a structure in which a magnetic gear is integrated with a brushless motor. The magnetic gear has advantages such as no mechanical losses and maintenance-free operation that are not observed in conventional mechanical gears. When a load torque is more than the maximum transmission torque being applied to the low-speed rotor, the high-speed rotor will slip. Therefore, the magnetic-geared motor can totally replace conventional systems which consist of a motor, mechanical gear, and torque limiter.

15 Most of the geared-motors available in the market are the combination of an electric motor with a mechanical gear, wherein the electric motor outputs the high speed, low torque which is transferred to low speed and high torque via a mechanical gearbox.

20 The shortcomings associated with traditional mechanical gearboxes includes: acoustic noise and mechanical vibration, the need of lubrication to the components of the gearbox, less reliable and require constant maintenance, and require a big space to install. Other minor shortcomings include: no overload protection and the gear teeth break when the load applied becomes larger than the maximum transmission torque, and low efficiency, generally electrical motor rated efficiency around 80% and 90% around one stage gearbox and 80% two stage gearboxes, the efficiency of the combination of the two is around 50%-70%.

25 Magnetic gear is similar to the planetary gear which can convert the high speed low torque to low speed high torque, for the magnetic gear, generally there are three components, inner rotor (high speed low torque rotor), stationary pole pieces and outer rotor (low speed high torque rotor) there is no contact between each component, the gear ratio and the torque ripple are decided by the combination of outer and inner pole number.

30 The gear ratio is equal to the low speed rotor pole pair number/high speed rotor pole pair number. The stationary pole pieces number is equal to the sum of the inner pole pair number

and the outer pole pair number. The max transmission torque capability is related to the gear size and magnet type and quantity.

US Patent Publication No. 20110037333 discloses a magnetic gear comprising: a first movable member having a first set of magnetic poles, a second movable member having a second set of magnetic poles, and a third movable member having a set of pole pieces; wherein the first and second members have magnetic poles at different spacing and the pole pieces are arranged to modulate the magnetic field acting between the magnetic poles, and control means arranged to control rotation of one of the members so as to vary the gear ratio between the other two members.

The product from this patent publication is a combination of electrical motor together with the magnetic gear. The stator current drives the inner high-speed rotor which is far away from the stator coils, then the pole pieces serve as output low speed rotor which convert the high speed low torque to low speed high torque, so the inner rotor needs large quantity of magnet and the torque per ampere is small because the coils is far away from the inner high-speed rotor (one layer of magnets stuck in stator, one layer of pole pieces and two air-gaps). The pole pieces function as high torque output rotor which needs high torsional stiffness, meanwhile to reduce the iron loss produced by magnet, the pole-piece is made with SiFe laminations, it is hard to make and assemble, to increase its strength, the stainless-steel rods and epoxy are added, but also the eddy current loss in the stainless steel will be added. After the pole pieces manufacturing process, the fact that pole pieces rotate within two air-gaps increases the assembling difficulty, the pole pieces and inner high-speed rotor both need high degree of manufacturing precision and tolerance to avoid the eccentricity. Another issue, the inner high-speed rotor and low speed rotor (pole-piece) are very close to each other, the vibration and the deformation will be increased as the rotor speed increased, the two rotors may contact each other. Low speed high torque poles pieces are put inside the stator which has small diameter that decreases the max torque density, the torque is proportional to the radius squared.

US Patent Publication No. 20110127869 discloses a magnetic gear comprising input and output moveable members arranged to interact in a magnetically geared manner and transmit torque therebetween via a first electrical winding arrangement arranged to generate, at least in part, a first magnetic flux having a first number of pole-pairs, and one or more pole-pieces arranged to modulate the first magnetic flux to interact with a second magnetic flux having a second number of pole-pairs, such that asynchronous harmonics of the magnetic field that is produced by each flux-producing member are created which have the same number of poles

as the other flux-producing member and so interact, wherein the first number of pole-pairs is less than the second number of pole-pairs.

SUMMARY OF THE PRESENT INVENTION

It is an object of the present invention to provide a magnetic-gear motor with ironless winding, wherein with ironless winding, the winding supports itself with high strength such that the pole pieces can be stuck with the winding with epoxy. As there is no stainless steel needed in the geared motor, the geared motor can be made easily, and no eddy current is loss in the stainless steel.

It is an object of the present invention to provide a magnetic-gear motor, wherein the high torque low speed rotor is positioned at the external of the pole pieces which has a large diameter for a given size motor, so the maximum torque density is generated.

Still yet another object of the present invention is to provide a magnetic-gear motor with ironless winding, wherein the winding is close to the high-speed rotor, the torque per current will be higher. This is due to the fact that the ironless winding has lower inductance, thus the current changes is a lot quicker. As compared to the slotted motor, the present magnetic-gear motor has no cogging torque, low acoustic noise and vibration, no saturation in the stator teeth, and high efficiency results in desired quiet operation and smooth performance. As for the slotted motor, the uneven magnetic pull causes the cogging, which ultimately contributes to torque ripple, efficiency loss, motor vibration and noise, as well as prevents smooth motor operation at slow speed.

Yet another object of the present invention is to provide a magnetic-gear motor, wherein for both the rotors, there are only one air-gap which facilitates the manufacturing process of the present invention. Other conventional products generally have three or four air-gaps which increase the manufacturing difficulty and decrease the service life time.

Yet another object of the present invention is to provide a magnetic-gear motor which has low acoustic noise and low vibration and need no lubrication.

A main object of the present invention is to provide a magnetic-gear motor with ironless winding comprising: a plurality of bearing; an inner array consisting of a flange, an inner core, a coil and an inner rotor lamination, wherein the inner core, the coil and the inner rotor lamination are cylindrical in shape, and the inner core contains the coil and the coil surrounds the inner rotor; and an outer array consisting of an outer rotor lamination, an outer core and bar magnet, wherein the outer rotor lamination, the outer core and the bar magnet are in cylindrical shape and the outer rotor lamination holds the outer core and the outer core holds

the bar magnet, thereby the outer array contains the inner array, and thereby forming a magnetic-gear motor.

Still a further object of the present invention is to provide a magnetic-gear motor, wherein the bearings are rotatably mounted at both the ends of the shaft of the geared motor, and are
5 used for keeping the shaft in a straight position.

Still yet another object of the present invention is to provide a magnetic-gear motor, wherein the winding coil is a 3-phase knitted winding coil, and the pole pieces laminations is a laminated SiFe steel with a plurality of teeth thereon. The plurality of teeth is for the adjustment of magnetic gear ratio of the motor.

10 Another object of the present invention is to provide a magnetic-gear motor, wherein the outer rotor lamination is generally cylindrical shape for the insertion of the bar magnet, and is made from a laminated silicon steel.

Still a further object of the present invention is to provide a magnetic-gear motor, wherein the outer rotor lamination is provided with a plurality of teeth, or if no teeth, where the outer
15 rotor magnets replace the teeth part with the combination of N and S poles to adjust magnetic gear ratio of the magnetic-gear motor.

Yet another object of the present invention is to provide a magnetic-gear motor, wherein the inner rotor magnet is made from NdFe rare earth material magnet and is served as a high speed rotor in the magnetic-gear motor.

20 Still yet a further object of the present invention is to provide a magnetic-gear motor, further comprising a hall sensor printed circuit board (PCB) or encoder which enables the positioning of the inner rotor.

Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

25 **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 is a perspective view of a magnetic geared-motor (MGM) (100) with ironless winding in accordance with a preferred embodiment of the present invention;

Figure 2 shows an exploded, sectional view of the magnetic geared-motor (100) in accordance with the present invention;

30 Figure 3 is a sectional view of the magnetic geared-motor (100) in accordance with the present invention;

Figure 4 is a perspective view of a coreless winding coil (34) in accordance with the present invention;

Figure 5 is a perspective view of a pole piece lamination (321) in accordance with the present invention;

5 Figure 6 is a perspective view of an outer rotor lamination (12) having a slot for insertion of a bar magnet in accordance with the present invention;

Figure 7 is a perspective view of an inner rotor magnet (36) in accordance with the present invention;

10 Figure 8 is a perspective view of an outer rotor housing (10) in accordance with the present invention;

Figure 9 is a perspective view of the inner array consisting of a flange (30), an inner core (32) and an inner rotor magnet (36) of the present invention;

15 Figure 10 is a perspective view of the outer array component consisting of an outer core (12), a bar magnet (14) and an outer rotor housing (10) in accordance with the present invention; and

Figure 11 is an axial sectional view of the magnetic geared-motor (100) in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

20 With reference to FIG. 1, there is shown a preferred embodiment of a magnetic geared-motor (100) in accordance with the present invention. The magnetic geared-motor (100) has an outer rotor housing (10) that rotates under the influence of rotating magnetic fields produced by a rotor as an inner motor (36), and is then modulated by a plurality of stationary pole pieces (321) (shown in FIG.2). The outer rotor housing (10) is cylindrical shape and encloses an outer core (12). FIG. 2 is an exploded, sectional view of the magnetic-geared motor (100) in
 25 accordance with the preferred embodiment of the present invention. As shown in the figure, the outer core (12) is hollow and cylindrical shape, and a plurality of bar magnets 14 are being arranged axially in a cylindrical shape. Again, referring to Figure 1, the magnetic-geared motor (100) has a flange (30) having a boss (not shown) to hold the inner core (32) (shown in FIG. 2). Referring to FIG. 2, a back cover (91) is located at the end of the magnetic-geared motor (100), following by bearings (40). A coil or motor winding (34) is in the shape of a hollow cylindrical containing an inner rotor (36) including the inner rotor magnet (14) and the pole
 30 pieces (321) of the inner core (32). The inner rotor magnet (14) encloses the shaft (361) of

the magnetic-gear motor (100). The ends of the shaft (361) are rotatably mounted by bearings (40). However, one end of the magnetic-gear motor (100) is an output shaft (461) which is then mounted to the bearing (40).

In accordance with a preferred embodiment of the present invention, the magnetic-gear motor (100) with ironless winding comprises: (a) a pair of bearings (40) rotatably mounted to support the geared motor (100); (b) an inner array consisting of a flange (30), an inner core (32) which is made from a plurality of pole piece (321), a coil or motor windings (34) and an inner rotor magnet (36), wherein the inner core (32) as well as the pole pieces (321), the coil (34) and the inner rotor magnet (36) are cylindrical in shape, and the inner core (32) including the pole pieces (321) contains the coil (34), and the coil (34) surrounds the inner rotor magnet (36); and (c) an outer array consisting of an outer rotor housing (10), an outer core laminations (12) and a plurality of bar magnets (14), wherein the outer rotor housing (10), the outer core laminations (12) and the bar magnets (14) are in a cylindrical shape, and the outer rotor housing (10) holds the outer core lamination (12) and the outer core lamination (12) holds the bar magnet (14), thereby the outer array encloses the inner array, and an inner shaft (361) which is formed as an extension of the inner rotor magnet (36), an output shaft (461) is mounted to one end of the shaft (361), thereby forming a magnetic-gear motor (100).

FIG. 2 is an exploded, sectional view of the magnetic geared-motor (100) in accordance with the preferred embodiment of the present invention. As shown in the figure the order of the components of the magnetic geared-motor (100) from the external to the internal is: an outer housing (110), the outer rotor housing (10) encompasses the outer core lamination (12), then the bar magnets (14), the coil (34), and the inner rotor magnet (36), which is the center of the geared motor (100). The flange (30) is at one lateral end of the geared motor (100) and is then mounted by the back cover (91).

The inner rotor magnet (36) rotates under the influence of rotating magnetic fields produced by the coil (34). The motion of the bar magnet (14), carried by the inner rotor magnet (36) and is then modulated by pole pieces (321), acts in a gearing effect to decrease the speed and increase the torque of the geared motor (100).

Figure 3 is a sectional view of the magnetic geared-motor (100) in accordance with the present invention. As shown in the figure, the centre of the magnetic-gear motor (100) is the shaft (361). The shaft (361) is surrounded by the inner rotor magnet (36). A plurality of motor windings or coils (34) are provided next to the bar magnet (14). A plurality of pole pieces (321) are disposed immediately after the motor windings or coils (34), An outer rotor magnet (120) is next to the pole pieces (321), and then in turn surrounded by the outer core lamination (12)

and the outer rotor housing (10). The outer housing (110) is the final layer of the magnetic-geared motor (100) in accordance with the present invention.

FIGS.4-10 show the perspective view of the components of the magnetic geared-motor (100) in accordance with the present invention. The output speed of the geared motor (100) in accordance with the present invention is low and the shaft (361) of the inner rotor magnet (36) rotatably mounted within a casing (not shown) by means of bearings (40).

Figure 4 is a perspective view of a magnetic winding or coil (34) in accordance with the present invention. In accordance with the preferred embodiment, the coil (34) is a 3-phase knitted winding coil.

Figure 5 is a perspective view of pole pieces (321) in accordance with the present invention. The pole piece (321) is the inner core (32) and is made from laminated SiFe steel. A plurality of teeth is formed on the inner core (32) so as to modulate the inner rotor magnetic flux and allow adjustment of the magnetic gear ratio.

Figure 6 is a perspective view of an outer core lamination (12) having a slotted center for insertion of the bar magnets (14) in accordance with the present invention. In another preferred embodiment, the outer rotor lamination can be without slot and put combination of NS magnets inside the inner surface instead. Figure 7 is a perspective view of an inner rotor magnet (36) in accordance with the present invention. The inner rotor magnet (36) is made from NdFe rare earth material and the rotor magnet (36) is served as a high speed rotor. The inner rotor magnet (36) surrounds the shaft (361).

Figure 8 is a perspective view of an outer rotor housing (10) in accordance with the present invention. The outer rotor housing (10) is cylindrical shape which is used to hold the outer core lamination (12). The outer rotor housing (10) is served as a magnetic gear output. Two bearings (40) (FIG. 2) are used to hold the outer rotor housing (10) onto the same axis of the shaft (361) of the magnetic-geared motor (100).

Figure 9 is a perspective view of the inner array consisting of a flange (30), an inner core (32) and an inner rotor magnet (36) of the present invention. In the figure, the flange (30) has the inner rotor magnet (36) as the center of the inner array, following by the coil (34), then the pole piece (321) of the inner core (32). The pole piece (321) is a component of the inner core (32) in accordance with the present invention.

Figure 10 is a perspective view of outer array consisting of an outer core (12), a plurality of bar magnets (14) and an outer rotor housing (10) in accordance with the present invention. Also, referring to FIG.2, it is shown that the outer rotor housing (10) encompasses the outer

core (12), and in turn, the plurality of bar magnets (14). The inner core (32) is at the center of the magnetic- geared motor (100).

Figure 11 is an axial sectional view of the magnetic geared-motor in accordance with the present invention. As shown in the figure, the one end of shaft 361 is coupled to a first bearing (40), and another end of the shaft (361) is connected to an output shaft (461) which is couple
5 to a second bearing (41). The central region of the shaft (361) is surrounded by the inner rotor magnet (36). Motor windings or coil (34) surround the inner rotor magnet (36). A plurality of pole pieces (321) are adjacent to the motor windings or coil (34). The next layer to the pole pieces (321) is the outer rotor magnets (120). The final layer of the magnetic geared-motor is
10 the outer rotor housing (10), which encompasses the entire magnetic geared-motor (100). As mentioned, the output shaft (461) is mounted onto one end of the shaft (361) and the output shaft (461) is coupled to a second bearings (41). In another words, the second bearings (40) is mounted to the output shaft (461) which is disposed onto one end of the shaft (361), and the other end of the shaft (361) is coupled to the first bearings (40). Both the output shaft
15 (461) and the shaft (361) are connected respectively to the second bearings (41) and the first bearings (40).

In operation, the current from the winding coil (34) triggers the inner rotor magnet (36) to drive at a high speed but at low torque, then the torque is transferred to the outer rotor magnet (120) via a plurality of pole pieces (321). The outer rotor magnet (120) provides a high torque and
20 low speed, and the gear ratio is proportional to the number of pole pieces (321) in the outer rotor magnet (120) divided by the pole pair number in the inner rotor magnet (36). The current of the winding coil (34) produces mechanical power to the outer rotor magnet (120), and the torque in the inner rotor magnet (36) is zero.

In accordance with the present invention, the winding coil (34) is designed and manufactured together with sensor PCB (not shown) mounted thereto. Other components such as the inner
25 rotor magnet (36) and a housing (not shown) and the winding coil (34) are being assembled. The outer rotor magnet (120), the inner rotor magnet (36) and a plurality of bar magnets (14) and the shaft (361) are assembled, and then the inner rotor magnet (36) and the outer rotor magnet (120) are mounted. A magnetic geared-motor 100 is obtained after the back cover
30 (91) is mounted thereto. The bearings (40) are rotatably mounted at both the ends of the shaft (361) of the geared motor (100), and are used for keeping the shaft (361) in a straight position.

The flange (30) of the magnetic-geared motor (100) is provided with a boss (not shown) at one end of the shaft for attaching a plurality of pole pieces lamination (321) and the winding coil (34), wherein the winding coil (34) is a 3-phase knitted winding coil. In accordance to the
35 present invention the pole pieces laminations (321) is a laminated SIFe steel with a plurality

of teeth thereon. The plurality of teeth is for the adjustment of magnetic gear ratio of the motor. The outer rotor lamination (32) is served as a magnetic gear output of the magnetic-gear motor (100).

5 To make the magnetic- geared motor functions correctly, the relation of outer rotor pole pair number and the inner rotor pole number should be equal to the pole pieces (321) number, then the gear ratio is equal to the outer rotor pole pair/inner rotor pole pair.

10 The outer rotor housing (10) is generally cylindrical shape for the insertion of the bar magnets (14). The outer rotor housing (10) is a laminated silica steel, and the outer rotor magnet (120) is provided with a plurality of teeth to adjust magnetic gear ratio of the magnetic-gear motor (100). The inner rotor magnet (36) is made from NdFe rare earth material magnet and is served as a high speed rotor in the magnetic-gear motor (100). The outer rotor housing (10) is substantially cylindrical and is used to hold the outer core lamination (12) of the outer array of the geared motor (100), wherein the outer rotor magnet (120) is served as a magnetic gear output of the geared motor (100). The outer rotor housing (10) is provided internally with
15 two slots for bearing (40) to keep the outer rotor magnet (120) on the same axis of the shaft (361) of the inner rotor magnet (36).

A hall sensor printed circuit board (PCB) or encoder which enables the positioning of the inner rotor magnet (36) is provided to the motor (100). The bar magnet (14) is made from a neodymium material, or other magnetic material.

20 It will be apparent that within the scope of the invention various other changes can be made to the disclosed embodiments. Still other modifications will occur to those of ordinary skill in the art. All such modifications and variations are within the scope of the invention. The embodiments chosen and described here have the purpose of explaining the principles of the invention and its practical application, thereby enabling those skilled in the art to utilize the
25 invention in various embodiments and with various modifications as suitable for the particular use contemplated. It is therefore the intention that the following claims not be given a restrictive interpretation but should be viewed to encompass variations and modifications that are derived from the subject matter disclosed.

CLAIMS

1. A magnetic-gear motor with ironless winding comprising:

(a) a pair of bearings, which is a first bearings (40) and a second bearings (41) rotatably mounted respectively to a shaft (361) and an output shaft (461) of the geared motor (100);

(b) an inner array consisting of a flange (30) , an inner core (32) which is made from a plurality of pole pieces (321), a coil or motor winding (34) ; and an inner rotor magnet (36), wherein the inner core (32) as well as the pole pieces (321), the coil (34) and the inner rotor magnet (36) are cylindrical in shape, and the inner core (32) including the pole pieces (321) contains the coil (34), and the coil (34) surrounds the inner rotor magnet (36); and

(c) an outer array consisting of an outer rotor housing (10), an outer core laminations (12) and a plurality of bar magnets (14), wherein the outer rotor housing (10), the outer core laminations (12) and the bar magnets (14) are in a cylindrical shape, and the outer rotor housing (10) holds the outer core lamination (12) and the outer core lamination (12) holds the bar magnet (14), thereby the outer array encloses the inner array, and an inner shaft (361) which is formed as an extension of the inner rotor magnet (36), an output shaft (461) is mounted to one end of the shaft (361),

thereby forming a magnetic-gear motor (100).

2. The magnetic-gear motor of Claim 1, wherein the second bearings (41) are rotatably coupled to the output shaft (461) of the magnetic-gear motor.

3. The magnetic-gear motor of Claim 3, wherein the winding coil (34) is a 3-phase knitted winding coil.

4. The magnetic-gear motor of Claim 1, wherein the pole pieces laminations (321) is a laminated SiFe steel with a plurality of teeth thereon for the adjustment of magnetic gear ratio of the motor.

5. The magnetic-gear motor of Claim 1, wherein the outer rotor housing (10) is generally cylindrical shape for the insertion of the bar magnet (14).

6. The magnetic-gear motor of Claim 5, wherein the outer rotor housing (10) is a laminated silica steel.

7. The magnetic-geared motor of Claim 5, wherein the outer rotor lamination (10) is provided with a plurality of teeth to adjust magnetic gear ratio of the magnetic-geared motor.
- 5 8. The magnetic-geared motor of Claim 1, wherein the inner rotor magnet (36) is made from NdFe rare earth material magnet and is served as a high speed rotor in the magnetic-geared motor.
9. The magnetic-geared motor of Claim 1, further comprising a hall sensor printed circuit board (PCB) or encoder which enables the positioning of the inner rotor magnet (36).
- 10 10. The magnetic-geared motor of Claim 1, wherein the bar magnet (14) is made of neodymium.
11. The magnetic-geared motor of Claim 1, wherein the outer rotor housing (10) is substantially cylindrical and is used to hold the outer core lamination (32) of the outer array of the magnetic-geared motor.
- 15 12. The magnetic-geared motor of Claim 11, wherein the outer rotor lamination (32) is served as a magnetic gear output of the magnetic-geared motor.
13. The magnetic-geared motor of Claim 1, wherein the outer rotor housing (10) is provided internally with slots for bearings to keep the outer rotor housing (10) on the same axis of the shaft (361).
- 20 14. The magnetic-geared motor of Claim 1, wherein the first and second bearings (40, 41), the inner array, the outer array, the output shaft (461) and the shaft (361) are in alignment.
15. The magnetic-geared motor of Claim 1, wherein the bar magnet (14) is of a high flux density.
- 25 16. The magnetic-geared motor of Claim 1, wherein the gear ratio of the magnetic-geared motor depends on the outer pole number and the inner pole number.