

TITLE

FLUX MACHINE

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TECHNICAL FIELD

[0001] This disclosure relates to rotating electromagnetic motors and generators.

BACKGROUND ART

10 [0002] Magnet transverse flux machines conduct magnetic flux perpendicular (transverse) to the current in the coil and can produce higher torque density than standard brushless machines with longitudinal flux. Such machines have high power density and can be used both as motors and generators. Torque increases with the number of poles at a constant stator current. Due to the high number of poles in a transverse flux machines, the frequency of electric current in stator windings is high while shaft speed is low. Such machines have a
15 three dimensional magnetic circuit which has traditionally made fabrication and assembly of stator and rotor components difficult. Prior art methods of manufacturing the magnetic circuits require the formation of individual U-shaped magnetic circuits. For example, a U-shaped magnetic circuit may be comprised of a plurality of individual U-shaped laminations stacked together. Assembly of such machines then requires the correct placement, alignment and spacing of each U-shaped magnetic circuit. Another method known in the
20 prior art is to construct two 3D stacks, each having one half of every magnetic circuit as a series of L-shaped protrusions. When joined together around the coil, the magnetic circuits are completed in the U-shape. This method requires the construction of a stack with a complex three-dimensional shape and requires precise rotational alignment of the stacks to properly form the magnetic circuit. The present flux machine described herein is simple to manufacture and assemble, is compact and has other novel and highly beneficial aspects.
25 The prior art relevant to the present disclosure is included in the following table and incorporated herein by reference:

Cited Patent	Filing date	Publication date	Applicant	Title
US4973868	Jul 28, 1989	Nov 27, 1990	J. M. Voith Gmbh	Electrical machine with permanent magnet excitation
US5051641	Feb 5, 1988	Sep 24, 1991	J. M. Voith Gmbh	Transversal flow machine in

Cited Patent	Filing date	Publication date	Applicant	Title
				accumulator arrangement
US5117142	Jan 30, 1991	May 26, 1992	501 Ibk Ab	Permanent magnetized synchronous machine designed according to the transverse flux principle
US5289072	Oct 15, 1991	Feb 22, 1994	J. M. Voith Gmbh	Electrical machine
US5543674	Jun 28, 1991	Aug 6, 1996	Radio Energie	Dynamolectric machine composed of sectors having transverse fluxes
US5777418	Jun 17, 1996	Jul 7, 1998	Voith Turbo Gmbh	Transverse flux motor with magnetic floor gap
US5942828	Jun 23, 1997	Aug 24, 1999	Hill; Wolfgang	Transverse flux machine
US5973436	Jul 30, 1997	Oct 26, 1999	Rolls-Royce Power Engineering Plc	Electrical machine
US6043579	Jan 6, 1998	Mar 28, 2000	Hill; Wolfgang	Permanently excited transverse flux machine
US6492758	Nov 1, 2000	Dec 10, 2002	Fisher & Paykel Limited	Polyphase transverse flux motor
US6700267	Jan 25, 2002	Mar 2, 2004	Deere & Company	Transverse flux drive
US6729140	Jan 30, 2002	May 4, 2004	Rolls-Royce Plc	Electrical machine
US6741010	Jan 8, 2001	May 25, 2004	Rolls Royce Plc	Rotor disc assembly having rotor rim with alternate magnets and laminated pole pieces
US6847135	Dec 11, 2001	Jan 25, 2005	Robert Bosch Gmbh	Unipolar transverse flux machine
US6888272	Aug 1, 2002	May 3, 2005	Robert Bosch Gmbh	Unipolar transverse magnetic flux machine

Cited Patent	Filing date	Publication date	Applicant	Title
US6952068 *	Dec 18, 2000	Oct 4, 2005	Otis Elevator Company	Fabricated components of transverse flux electric motors
US7030529	Jan 29, 2003	Apr 18, 2006	Robert Bosch Gmbh	Electrical machines, especially engines excited by permanent magnets
US7124495	May 31, 2005	Oct 24, 2006	Otis Elevator Company	Method for making an electric motor
US7164220 *	May 12, 2005	Jan 16, 2007	Rolls-Royce Plc	Stator pole structure for an electrical machine
US7312549	May 8, 2002	Dec 25, 2007	Aalborg Universitet	Transverse flux machine with stator made of e-shaped laminates
US7466058	Jun 28, 2006	Dec 16, 2008	Eocycle Technologies, Inc.	Transverse flux electrical machine with segmented core stator
US7492074	Mar 30, 2007	Feb 17, 2009	Norman Rittenhouse	High-efficiency wheel-motor utilizing molded magnetic flux channels with transverse-flux stator
US7579742	Jan 17, 2008	Aug 25, 2009	Norman Rittenhouse	High-efficiency parallel-pole molded-magnetic flux channels transverse wound motor-dynamo
US20010008356	Jan 8, 2001	Jul 19, 2001	Wilkin Geoffrey A	Rotor disc
US20040155548	May 8, 2002	Aug 12, 2004	Rasmussen Peter Omand	Transverse flux machine with stator made of e-shaped laminates
US20040251759	Jun 9, 2004	Dec 16, 2004	Hirzel Andrew D.	Radial airgap, transverse flux motor
US20060192453	May 27, 2003	Aug 31, 2006	Gieras Jacek F	Modular transverse flux motor with integrated brake
US20070216249	Apr 28, 2006	Sep 20, 2007	Mtu Aero Engines Gmbh	Transverse flux machine and turbine-

Cited Patent	Filing date	Publication date	Applicant	Title
				type machine having such a transverse flux machine
US20070267929	May 11, 2007	Nov 22, 2007	Minebea Co., Ltd.	Stator arrangement and rotor arrangement for a transverse flux machine
US20080136272	Dec 5, 2007	Jun 12, 2008	Toshio Ishikawa	Rotating electrical machine
US20080211326	Dec 28, 2007	Sep 4, 2008	Korea Electro Technology Research Institute	Inner rotor type permanent magnet excited transverse flux motor
US20080246362	May 21, 2008	Oct 9, 2008	Hirzel Andrew D	Radial airgap, transverse flux machine
US20090026869	Jul 16, 2008	Jan 29, 2009	Christian Kachler	Transverse flux reluctance machine and method for manufacturing same
US20090108712	Jul 25, 2008	Apr 30, 2009	Holtzapfel Mark T	Short-flux path motors / generators
DE10037787A1	Aug 3, 2000	Mar 14, 2002	Landert Motoren Ag	Permanent magnet excited synchronous machine e.g. general purpose drive motors, has external rotor design with external rotor joined rotationally-rigidly to rotatable shaft, around common axis
WO2006117210A1	May 4, 2006	Nov 9, 2006	Bosch Rexroth Ag	Phase module for a transverse flux motor
WO2007000054A1	Jun 26, 2006	Jan 4, 2007	Maxime R Dubois	Transverse flux electrical machine with segmented core stator
WO2009070333A1	Nov 28, 2008	Jun 4, 2009	Norman P Rittenhouse	Wind turbine generator

DISCLOSURE OF INVENTION

[0003] The drawings illustrate a novel electromagnetic rotating flux machine **10** having manufacturing and operational advantages with respect to the prior art. For example, flux density is relatively high, and the pole number may be increased without reducing magnetomotive force per pole, enabling higher power densities. Further advantages include a large number of poles with relatively short current pathways enabling efficiency gains due to a high torque/weight ratio, a high power/weight ratio and relatively low copper losses.

[0004] An arrangement of coils and magnets has been developed with magnetic flux directed from four or more directions coupled into coil assemblies. For instance, there may be two magnets that are oriented with poles facing for directing magnetic flux in a radial direction from opposite sides of the coils, and two additional magnets that are oriented with poles facing axially, to direct flux axially from opposite sides of the coils. Additionally, the coils may be oriented so that the windings and current within those windings flows in a plane that is perpendicular to a vector pointing in an established circumferential direction of motion of a rotor of the flux machine.

[0005] Thus, the magnets may be adjacent to different sides of the coils but and all magnetic flux circuits combine additively.

[0006] With the magnets (electromagnets or permanent magnets, or a combination of the two) mounted on independent rotors and axels as described herein, they may be operated independently at different frequencies and/or as a motor and generator independently and simultaneously. These innovations are possible given the orientation of the coils that sit in a plane that is perpendicular to the rotational axis of the machine. Rotation causes a relative motion between magnets and coils with the magnets and coils close coupled with a minimum air gap therebetween.

BRIEF DESCRIPTION OF DRAWINGS

[0007] Embodiments of the described machine are illustrated by way of example in the figures of the accompanying drawing sheets, in which like references indicate similar elements and in which:

[0008] Figure 1 is a perspective view of a flux machine according to the following detailed description;

[0009] Figure 2 is a perspective expanded view thereof;

[0010] Figure 3 is a perspective view of an outer rotor-magnet assembly of an embodiment thereof;

[0011] Figure 4 is an elevation view of a stator plate of an embodiment thereof;

[0012] Figure 5 is a perspective view of an exemplary coil assembly and magnets thereof;

[0013] Figures 6-8 are exemplary conceptual diagrams of arrangements of said coil assemblies, magnets, supporting frames with axles; and

[0014] Figure 9 is an exemplary mechanical schematic diagram of a further arrangement as in Figs. 6-8.

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BEST MODES FOR CARRYING OUT THE INVENTION

[0015] Fig. 1 shows that machine 10 may be generally circular in shape and relatively short axially between shroud 30 and flywheel housing 170 providing space and weight savings. Electrical connections to machine 10 may be made via a standard connection box 20 and mechanical engagement may be made via one or more coaxial shafts aligned with central axis 5 as shown in the Figs. 6-9.

10 [0016] Fig. 2 illustrates several components and sub-assemblies of machine 10 according to embodiments, showing their relative axial positions. Moving from left to right in Fig. 2, shown are: shroud 30, outer rotor-magnet assembly 40, fan 60, inner rotor-magnet assembly 70, stator assembly 100 with coil assemblies 120, rotor hub 150, flywheel 160, and flywheel housing 170. These components are aligned about common axis 5 which is also the center of rotation of machine 10. In embodiments, outer rotor-magnet assembly 40, fan 60, inner rotor-magnet assembly 70, rotor hub 150, and flywheel 160 may be mutually joined
15 mechanically and therefore may rotate together. In other embodiments some of these elements and other elements may be adapted for independent rotation about coaxial shafts as will be discussed and shown. In embodiments shroud 30, stator assembly 100 and flywheel housing 170 may not rotate, may be mutually mechanically joined, and may be fixed in place as a stator. In other embodiments stator assembly 100 may be
20 mounted for rotation about a central axle with each of the winding phases connected via a standard rotary electrical interface, such as those commonly found in slip ring motors. Assembly 100 would therefore function as the rotor of machine 10 while outer rotor-magnet assembly 40 and inner rotor-magnet assembly 70 may function as the stator of machine 10. Those of skill would understand how to make this simple adaptation.

[0017] As exemplified in Fig. 3 the sets of axially aligned magnets 46 and radially aligned magnets 47
25 may be held in circular fixed positions as part of an outer rotor assembly 40 attached to a single axle. Alternately, magnets 46, 47 may be secured to one or more axially aligned axles by distinct mechanical frames as shown in Figs. 6-9.

[0018] Fig. 4 illustrates circular plate 110 of stator assembly 100 which may have central circular opening 112 large enough in diameter to accept outer flange 74 of assembly 70 (Fig. 2). As shown in Figs. 6-8, mounting standoffs 114 or similar hardware may be used to secure coil assemblies 120 to plate 110. In Figs.
30 6-8, fasteners, shown as hidden lines 115 may be used to secure coil assembly 120 to standoffs 114.

[0019] Fig. 5 shows that coil assembly 120 may be rectangular, near rectangular, curvilinear, ovular, or other shapes. Electrical coil 121 may be made of wound flat, round or other shaped electrical conductors such as

electrical copper or aluminum strip, and may be placed within core stack 122. Core stack 122 may be of soft iron, laminated silicon steel, insulated iron sheets, carbonyl iron, iron powder, ferrite, vitreous metal or other materials and structures. In embodiments, coil assembly 120 may be ovular, rectangular, circular or other suitable shapes. A full complement of mounted coil assemblies 120 are shown in Fig. 2 secured to standoffs 114. In Fig. 5, magnets 46, 47, and 76 are shown as close coupled to core stack 122. The direction of lines of magnetic flux Φ (the primary or largest component of the magnet flux for each magnet) are shown by arrows. It is noted that in Fig. 5 no magnet is positioned along the right edge of coil assembly 120. It should be realized that magnets 46, 47, 76, (and 77 as shown in Fig. 6) are positioned immediately adjacent to the sides of coil assembly 120 for maximizing magnetic flux linkage and assuring low reluctance. Any or all of magnets 46, 47, 76 or 77 may be permanent magnets or electromagnets, with all magnets directly attached to axles utilizing slip ring or other rotary electrical interfaces as are known in the electromechanical arts. Although the side edges of coil assemblies 120 are shown linear in Figs. 5-9 these edges may be non-linear and the adjacent surfaces of magnets 46, 47, 76, and 77 may conform so that air gaps between magnets and coil assemblies are minimized. Therefore, coil assemblies 120 may be other than rectangular as those of skill in the electrical arts will appreciate. As shown in referenced applications US 62028220, and US 62028235 more than three magnets may be arranged so as to be close coupled with coil assemblies 120 during machine rotation.

[0020] Fig. 6 shows that a structural frame 44 may extend around four sides of coil assemblies 120 and may secure magnets 46, 47, 76 and 77 in close coupled positions. Structural frame 44 may extend as a continuous circular assembly, or may be arranged as a series of radial spokes arranged over 360 degrees and may comprise one (or more or less) said spoke 44 for each coil assembly 120. Frame 44 may be fixed to axle 80 which is aligned with central axis 5. As axle 80 is rotated, by an external motor for instance, all of the sets of magnets 46, 47, 76, and 77 pass coil assemblies 120 producing a Faraday current. Fig. 6 illustrates a single axle machine 10.

[0021] Fig. 7 shows that structural frame 44 may extend around two sides of any one of coil assemblies 120 and may secure magnets 46 and 47 in preferred positions, close coupled to two sides, in turn, of each one of coil assemblies 120 during rotation. As with the arrangement shown in Fig. 6, frames 44 may be secured to axle 80 as shown. A further structural frame 74 may extend around the remaining two sides of coil assemblies 120 and may secure magnets 76 and 77 in place close coupled to coil assemblies 120 and may be secured to axle 82 as shown. Axles 80 and 82 may be coaxially aligned and may be mutually free in rotation. In both motor and generator operation, depending on magnet polarity the axles may rotate in the same or opposite senses. In motor operation the axles will both rotate at the same rpm, while in generator mode the axle may rotate at different rpms as long as electrical phase synchrony is maintained. It is possible for one driven axle to function in generator mode adding a supplementary current to inlet current at input lines 130,

while the second axle functions in motor mode driven by the total of input and supplementary currents. **Fig. 7** illustrates a dual axle machine **10**.

[0022] **Fig. 8** shows that three structural frames **44**, **72**, and **74** may secure magnets **46**, **47**, **72**, **77A** and **77B**. In this arrangement magnet **77** is replaced by two magnets **77A** and **77B** as shown. Frames **44**, **72**, and **74** may be secured to coaxial axles **80**, **82** and **84** as shown. In both motor and generator operation, depending on magnet polarity the axles may rotate in the same or sense or not. In motor operation the axles will all rotate at the same rpm, while in generator mode the axle may rotate at different rpms as long as electrical phase synchrony is maintained. It is possible for a driven axle to function in generator mode adding a supplementary current to inlet current at input lines **130**, while another axle functions in motor mode driven by the total of input and supplementary currents. Of course all axles may be driven by different rotational drivers and may deliver rotational forces to different loads. It should be clear that each magnet **46**, **47**, and **76** may be replaced by multiple magnets in the manner of magnet **77** being replaced by magnets **77A** and **77B**. **Fig. 8** illustrates a triple axle machine **10**.

[0023] **Fig. 9** illustrates a four axle machine, axles **82**, **84**, **86**, and **88**, wherein four magnets **46**, **47**, **76**, and **77** may be mounted by frames **44**, **72**, **74**, and **78** to one of the four axles. In like manner if each one of magnets **46**, **47**, **76**, and **77** were to be replaced by two magnets as shown in **Fig. 8**, all eight magnets can be supported by eight coaxial axles and machine **10** can be used to drive eight separate rotational loads. **Fig. 9** illustrates a quad-axle machine **10**.

[0024] For coaxial integration and operation all said axles except the inner most axle, can be tubular as shown in **Figs. 6-9** and may include toroidal bearings to maintain their mutual coaxial positions and spacing while preserving rotational independents as is known in the mechanical arts. The outermost of the coaxial axles, for instance axle **88** in **Fig. 9**, may be supported by exterior bearing sets so as to secure all of the axles in their position centered on axis **5** as is also well known.

[0025] As shown in **Figs. 6** and **7** the direction of flux, or the primary component (the largest component for each magnet) may be axial or radial. The direction of rotation of machine **10** may be orthogonal to the orientation of flux circuits. Therefore, machine **10** is considered to be a transverse flux machine. It is noted that a normal vector to coil assemblies **120** mounted on the stator of machine **10** defines rotor rotation direction and the magnitude of rpm.

[0026] In the foregoing description, embodiments are described as a plurality of individual parts, and this is solely for the sake of illustration. Accordingly, it is contemplated that some additional parts may be added, some parts may be changed or omitted, and the order of the parts may be re-arranged, without leaving the sense and understanding of the apparatus as claimed.

INDUSTRIAL APPLICABILITY

5 [0027] The several embodiments described make such machines desirable in a variety of applications including: propulsion motors for land and sea vehicles, electric and hybrid electric vehicles, underwater vehicles, torpedoes, propulsion motors for electric helicopters and aircraft, elevator propulsion motors, tidal wave generators, wind generators, integrated starter/generators, diesel and natural gas gen-sets, and high frequency low speed machines.