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# ROTOR/STATOR COMBINATION

## BACKGROUND OF THE INVENTION

This invention relates to improvements to electro-magnetic-mechanical machines, that is machines with two portions moving with respect to each other and with a magnetic field between the two portions.

In the past, electro-magnetic-mechanical machines would typically have a rotor and a stator as the two pieces. However, the two pieces could be non-rotating oscillating pieces as in the so-called linear apparatus.

Although the "rotor" is usually a rotary part and the "stator" is usually a stationary part, this does not have to be so. Throughout this disclosure and claims, it will be understood that either the rotor or the stator may rotate or move, and in fact both may rotate or move, provided there is relative movement between the two portions.

In the prior art, a magnetic flux **B** would be created in or around the stator. The magnetic path of the field **B** would pass through a pole of the stator, through an air gap, and into the rotor through a pole. The magnetic path would then be completed through the rotor and would pass through at least a second pole of the rotor, through an air gap and back into the stator to be complete.

Thus, with the exception of homopolar machines in which there are no windings, there were always at least two poles associated with the rotor face which meant that there was always a magnetic field entering into one portion of the rotor and always a magnetic field exiting from another portion of the rotor. Effectively, associated with one portion of the rotor was a field in one direction and associated with another portion of the rotor was a field in the opposite direction.

Therefore, there was never a single field that was always in the same direction, either into or out from, the rotor face. Therefore, as the rotor rotated within the stator, armature coils on the rotor would pass through magnetic fields of opposite directions either **B** or **-B**. As a result, in order to derive useful current or useful force through the entire 360° of rotation of the rotor, it was necessary to reverse the flow of current in the armature coils when the coils moved into or out of a magnetic field of opposite direction.

In order to reverse the flow of current, various commutating means have been developed. However, these various commutating means all share the same drawback in that they complicate the practical implementation of the machine and they add to the expense of production and maintenance.

It is also advantageous to improve the efficiency of an electro-magnetic-mechanical machine in general. It is well-known that the force Lorentz force **F** acting on an electron with charge Q moving with velocity **v** in a magnetic flux **B** is defined as:

$$\mathbf{F} = Q(\mathbf{v} \times \mathbf{B}) \qquad \text{(Equation 1)}$$

Bold face is used to represent vectors and "x" is used to represent vector multiplication.

It is also well-known that if an external power source is used to maintain electron flow in a conductor moving in a magnetic field, a counter electro motor force, or counter potential, will be created in the conductor which acts against the external power source and thereby reducing the efficiency of operation.

SUMMARY OF THE INVENTION

Accordingly, it is an object of this invention to provide an alternative structural geometry for a rotor/stator combination.

It is another object of this invention to provide a rotor/stator combination in an electro-magnetic-mechanical machine that does not require any commutating means.

It is another object of this invention to provide a rotor/stator combination in an electro-magentic-mechanical machine that provides increased efficiency of energy conversation.

It is another object of this invention to provide in a general electro-magnetic-mechanical machine an electrical circuit which provides improved efficiency.

Accordingly, in one broad aspect, the invention resides in providing a geometrical construction for a rotor/stator combination whereby the magnetic field is either entering or leaving the entire face of the rotor.

In another aspect, the invention resides in using the unique geometrical construction of the rotor/stator combination in combination with a rectified, multi-phase a.c. current to the armature windings in series with a d.c.-component filter to filter from the a.c. power source any d.c.-component of counter potential.

In another of its broad aspects, the invention resides in improving the efficiency of general electro-magnetic-mechanical machines. This is accomplished by reducing the effect of Lenz law and still providing a useful Lorentz force capable of doing useful work.

A counter electro-motor-force will have little effect in an alternating current circuit if the counter potential is a direct current potential. If the a.c. circuit contains a filtering means such as a capacitor, which blocks the passage of direct current but allows alternating current to pass, the effect of the counter electro-motor-force is reduced or minimized.

Current flowing in an a.c. circuit which contains little or no ohmic resistance, but contains only reactive reactance, such as inductance or capacitance, requires little or no real power imput to maintain the current flow.

However, any current, even reactive current, flowing through a magnetic field will create a Lorentz force which can be computed in accordance with Equation 1 above.

The Lorentz force created by pure or nearly pure reactive current in a magnetic field can be utilized in a rotating or in a non-rotating oscillating electro-magnetic-mechanical machine.

## BRIEF DESCRIPTION OF THE DRAWINGS

These aspects of the invention and other aspects will become apparent after reading the following disclosure and reviewing the drawings, in which:

Figure 1A is a longitudinal cross-sectional view of an embodiment of the invention;

Figure 1B is a simplified longitudinal cross-sectionalview of an embodiment of the invention;

Figure 2 is a transverse, cross-sectional view of an embodiment of the invention;

Figure 3 is a perspective view of a rotor of a preferred embodiment of the invention;

Figure 4 is a schematic diagram showing an electrical circuit of an embodiment of the invention; and

Figure 5 is a diagrammatic representation of currents and potentials associated with an embodiment of the invention.

## DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS

Figure 1A is a cross-sectional view of an embodiment of the unique geometrical construction of this invention. An electro-magnetic-mechanical machine with which the invention may be used is shown generally as

10. The machine 10 as illustrated includes most of the elements required to properly make the machine work. If some of the details have been omitted, it is merely for ease of illustration, and it will be understood that all of the necessary elements are included when the phrase "machine" is used.

A housing 11 surrounds the machine 10. Within the machine 10 is a magnetic flux path 12 along which is located a magnetic flux **B**. Preferably, the magnetic flux **B** is uniform throughout.

As more readily seen in simplified Figure 1B, a preferred embodiment of the rotor/stator combination comprises a twin rotor 14 and a twin stator 16. Magnetic flux path 12 passes around through the stator/rotor combination.

The dimensions on Figure 1B have been exaggerated to assist in explanation. It will be understood that actual dimensions, in some instances, will be different than shown.

The twin rotor 14 has a first rotor means 14A and second rotor means 14B. The twin rotor 14 rotates around the axis Ax.

Each of the first rotor means 14A and the second rotor means 14B is substantially toroidal-shaped (as seen in Figure 2), has an inner side 15A and 15B, respectively, and has a face 17A and 17B extending around the periphery of the respective rotor means 14A and 14B which faces radially outwardly.

The first and second rotor means 14A and 14B are spaced longitudinally from each other along the axis Ax but are spaced concentrically with respect to each other.

The first and second rotor means 14A, 14B are connected together by at least one member made from a magnetic material such that a magnetic path is created between the two rotor means 14A, 14B. The rotor-magnetic-path-connecting means 24 extends longitudinally from the inner side 15A of the first rotor means 14A to the inner side 15B of the second rotor means 14B.

The surface of the rotor-magnetic-path-connecting means 24 may be flush with the faces 17A, 17B of the rotor means 14A, 14B as shown in Figure 3. Also, the surface of the rotor-magnetic-path-connecting means 24 may be depressed with respect to the faces 17A, 17B such that the faces 17A, 17B are more distinctly separated from the rotor-magnetic-path-connecting means 24.

The purpose of the rotor-magnetic-path-connecting means 24 is to provide a ready magnetic path between the rotor means 14A and 14B for the magnetic flux **B**. Thus, only one rotor-magnetic-path-connecting means is required for this purpose. However, for structural purposes, a plurality of rotor-magnetic-path-connecting means can be used and are preferred. There can be two rotor-magnetic-path-connecting means 22, 24 as shown in Figure 3 or there can be more. Preferably, the rotor-magnetic-path-connecting means should be symmetrically spaced around the twin rotor 14.

Also, the rotor-magnetic-path-connecting means can be a single cylinder which would, in effect, be an extension of the toroidal-shaped first rotor means 14A and extend to the second rotor means 14B.

Referring once again to Figure 1B, there is a twin stator 16 which has a first stator means 16A and a second stator means 16B. Each of the stator means 16A, 16B is substantially toroidal in shape, has an inner side 19A, 19B, and has a face 21A, 21B facing radially inwardly towards the first rotor face 17A and the second rotor face 17B, respectively.

There is a first air gap 39A between the first rotor face 17A and the first stator face 19A.

There is a second air gap 39B between the second rotor face 17B and the second stator face 19B.

Preferably, the distance between the first rotor face 17A and the first stator face 21A is uniform, or at least approximately the same, at all points on the first rotor face 17A such that the first air gap 39A is substantially uniform in distance along the first rotor face 17A.

Similarly, preferably the distance between the second rotor face 17B and the first stator face 21B is uniform, or at least approximately the same, at all points on the second rotor face 17B such that the second air gap 39B is substantially uniform in distance along the second rotor face 17B.

The first and second stator means 16A, 16B are connected together by at least one member made from a magnetic material such that a magnetic path is created between the two stator means 16A, 16B. The stator-magnetic-path-connecting means 25 extends longitudinally from the inner side 19A of the first stator means 16A to the inner side 19B of the second stator means 16B.

The surface of the stator-magnetic-path-connecting means 25 may be flush with the faces 21A, 21B of the stator means 16A, 16B. Also, the surface of the stator-magnetic-path-connecting means 25 may be depressed with respect to the faces 21A, 21B such that the faces 21A, 21B are more distinctly separated from the stator-magnetic-path-connecting means 25.

The purpose of the stator-magnetic-path-connecting means 25 is to provide a magnetic path between the stator means 16A and 16B for the magnetic flux B.

Thus, only one stator-magnetic-path-connecting means is required. However, for structural purposes a plurality of stator-magnetic-path-connecting means may be used and are preferred. There can be two or three or any number of stator-magnetic-path-connecting means but, preferably, they should be symmetrically spaced around the twin stator 16.

Also, the stator-magnetic-path-connecting means could be a single cylinder which would, in effect, be an extension of the toroidal-shaped first stator means 16A and extend to the second stator means 16B.

In a further embodiment of the invention, a magnetic field excitation means, such as the coils 36 with excitation current 38 as seen in Figure 1A, provides a substantially constant or uniform magnetic flux **B** along the magnetic path 12.

The magnetic path is along the first stator-magnetic-path-connecting means 25, through the first stator face 21A, through the first air gap 39A and, because the first stator face 21A faces the first rotor face 17A, the magnetic path 12 exits from the first stator face 21A and enters into the first rotor face 17A substantially perpendicularly to the faces 21A and 17A.

The magnetic path 12 continues through the first rotor-magnetic-path-connecting means 24 to the second rotor means 14B. Once again, because the second stator face 21B faces the second rotor face 17B, the magnetic path exits the second rotor face 17B and enters the second stator face 21B substantially perpendicularly to the faces 21B and 17B.

The magnetic path 12 completes a loop by passing through the second stator means 16B and back into the stator-magnetic-path-connecting means 25. Thus, the magnetic path 12 is a complete loop. Also, the direction of the magnetic flux **B** is arbitrary in that, depending on the configuration of the magnetic field excitation means, the direction of the magnetic flux **B** may be selected to be in either one direction or the other along the magnetic path 12.

Once a direction of the magnetic flux **B** is selected and determined, for example going from the first stator face 21A to the first rotor face 17A, the magnetic flux **B** at the first rotor face 17A will be entering the rotor face 17A at all points on the rotor face 17A. Similarly, at the second rotor face 17B the magnetic flux **B** will be exiting the second rotor face 17B at all points on the second rotor face 17B. Thus, if the magnetic field going into the twin rotor 14 is considered to be positive, the magnetic flux **B** will be positive at the first rotor face 17A and negative at the second rotor face 17B.

There are many ways of implementing a magnetic flux excitation device. For example, the excitation means could be around the rotor-magnetic-path connecting means 24 or the stator-magnetic-path-connecting means 25. Also, there could be extensions of the rotor faces 17A and 17B extending radially and the excitation means could surround those extensions. A similar configuration could be used on the stator faces 21A and 21B. A practical embodiment of the invention in a practical electro-magnetic-mechanical machine is shown in Figure 1A. As shown in Figure 1A, the role of the twin rotor 14 and the twin stator 16 is interchangeable. If one of the twin rotor 14 and the twin stator 16 is stopped, the other may rotate, or both can be counter rotated relative to each other.

In Figure 1A, twin stator 16 is rotatably mounted on hollow shaft 30 by bearing means 26. When twin rotor 14 is used as a rotating rotor, twin stator is stopped by breaking pulley 28. Rotating twin rotor 14 is fastened to member 18 and rotated by non-magnetic end pieces 18 which are keyed to shaft 30. Shaft 30 is rotatably mounted on stands 36 and base 38 by bearing means 32. Pulley 34 is used to rotate shaft 30 together with twin rotor 14, or pulley 34 may be used to transmit usable mechanical torque.

In a further embodiment of the invention, a first set of electrical coils 42 crosses the first rotor face 17A. The coils cross the face 17A in a substantially longitudinal fashion as shown in Figure 3.

Although the word "coil" includes a conductor that is actually coiled around a rotor means, it also must be understood to include conductors that merely cross a rotor face without actually being coiled around the rotor means.

In a further embodiment, a second set of electrical coils 44 crosses the second rotor face 17B. The coils cross the face 17B in a substantially longitudinal fashion as shown in Figure 3.

The coils 42 and 44 cross the faces 17A and 17B in substantially longitudinal fashion in order that current passing in the coils 42 and 44 will be moving perpendicularly to the magnetic flux **B**.

When current 76 flows in the first set of coils 42, current 76 flows in those portions of the coils 42 that are on the face 17A. Because the magnetic flux **B** is substantially perpendicular to the face 17A, the magnetic flux **B** is also substantially perpendicular to the flow of current 76 in the portions of the coils 42 on the face 17A. Therefore, there will be a Lorentz force F1 acting on the coils 42 in the region of face 17A. The individual

Lorentz forces acting on the individual coils 42 will all act in the same direction. Therefore, the total Lorentz force is cumulative in one direction. The total Lorentz force thereby causes the twin rotor means 14A to rotate.

For improved efficiency, in order to take advantage of the second half of the twin rotor 14, a second set of coils 44 may be used on rotor means 14B. In this embodiment, a current 80 is made to flow in the coils 44 in a direction such that the Lorentz force F2 created in the coils 44 will compliment or add to the Lorentz force F1 developed in coils 42. Thus, the Lorentz force F2 developed in coils 44 rotates the rotor means 14B in the same direction as the rotor means 14A is rotated.

In a further embodiment of the invention, the coils 42 are not actually "coiled" all the way around the rotor means 14A or 14B. Rather, the "coils" take the form of conductors configured together in parallel such that the coils 42 cross the rotor face 17A substantially longitudinally. It will be understood that the word "coil" includes this type of configuration.

In a further embodiment of the invention, as shown in the "left side" of Figure 4, an a.c. electrical power source 84 supplies a.c. multi-phase current to the first set of coils 42. However, in this embodiment, the first set of coils 42 includes multi-phase coils.

Preferably, the coils and the power supplied thereto are 3, 6 or 12 phase.

For clarity of illustration, the set of coils 42 is illustrated in Figure 3 as being only a single conductor. However, it will be understood that when the set of coils 42 is multi-phase, there will be as many conductors 42a, 42b, 42c .... 42n as there are "n" phases.

Power source 84 can be a synchronous generator, or any other suitable a.c. source or supply.

Referring to Figure 4, for illustration, the synchronous reactance of the power supply 84 is indicated as both 86 and Xa. Similarly, the "scatter" or leakage reactance associated with the power source 84 is indicated by both 90 and Xs. The reactance of coils 42 and 44 is shown as both 92 and X3.

Also shown in Figure 4 is rectifying means 69. Rectifying means 69 rectifies the multi-phase electrical current supplied from the power source 84 and provides to the first set of coils 42 a rectified a.c. multi-phase current 78.

In a preferred embodiment, the rectifier 69 is a switching means 69. When switch 70 is closed and the switch 68 is open during one half cycle, only current of, for example, positive polarity is allowed to pass to the first set of coils 42.

During the other half of the cycle, the negative half, the switch 70 is open and the switch 69 is closed such that the current of negative polarity is passed to the second set of coils 44. It is possible to have switch 69 always open, but that mode of operation is less efficient than to have current being supplied to both sets of coils 42 and 44.

As shown by example in Figure 5, the "bumpiness" or uneveness of the effective total current supplied is reduced when multi-phase a.c. current is used. In Figure 5, 3-phase a.c. current is used. The "bumpiness" decreases as the number of phases increases.

Thus, as the number of phases increases, the total effective current approaches a constant value which is the equivalent of a d.c. current.

In a further embodiment, there is an additional power source 84' that is out of phase with the power source 84 by 180°. The current supplied by the power source 84' is supplied to the first and second sets of coils 42 and 44 in the same fashion as current is supplied by power source 84. Thus, a switching means 69' is configured such that the positive polarity current from power source 84' is being supplied to the first set of coils 42 when the negative polarity current from power source 84 is being supplied to the second set of coils

44. Similarly, negative polarity current from power source 84' is being supplied to the second set of coils 44 when positive polarity current from power source 84 is being supplied to the first set of coils 42.

In this fashion, the "bumpiness" or uneveness of the rectified a.c. current to coils 42 and 44 is reduced.

As discussed previously, the interaction of the current 78 in the first set of coils 42 and the magnetic flux **B** results in a Lorentz force **F**1 that rotates the rotor means 14A.

However, as pointed out previously, a counter potential or counter electro-motor-force is developed in the first set of coils 42 as a result of the rotation of rotor means 14A. Because the effective total current in the coils 42 is the equivalent of a d.c. current, the counter electro-motor-force is a d.c. equivalent.

In order to minimize the effect of this counter electro-motor-force to the a.c. circuit, especially to the power source 84, the d.c. component created by the counter electro-motor-force can be effectively removed or filtered by a suitable filtering means 88 that does not allow the d.c. component to pass. One suitable filtering means is a capacitance C with a reactance Xc.

It should be noted that because there is only negligible ohmic resistance in the circuit as described, the multi-phase currents 78 passing through the first set of coils 42 are virtually reactive currents requiring little real power input from the power source 84 to supply the current 78. However, even reactive current results in useful Lorentz force being created. Therefore, although little real power is required by the power supply 84, useful work can be obtained from the developed Lorentz force.

It is recognized by the inventor that an actual d.c. power source supplying d.c. current to the first set of coils 42 will also result in useful work from the operation of the rotor/stator combination. Moreover, because the direction of the magnetic flux **B** does not change with respect to the rotor face 17A, commutation is not required.

Therefore, a further embodiment of the invention includes a d.c. electrical power source supplying d.c. current to the first set of coils 42 without any commutating means.

Also, the same or another d.c. electrical power supply can supply d.c. current to the second set of coils 44 without commutating means, in order to take advantage of the second half of the twin rotor 14.

A further embodiment of the invention provides an apparatus for supplying useful d.c. power to an electrical load without any commutating means. The devices as described thus far may be used. However, the first and second set of coils 42 and 44 will, for this embodiment, be referred to as motor coils 42 and 44 to distinguish them from sets of generator coils 40 and 46 as shown in Figure 3 on the "right side" of Figure 4.

The first set of generator coils 40 is configured much the same as the first set of motor coils 42. The generator coils 40 substantially longitudinally cross the first rotor face 17A. However, the first set of generator coils 40 is connectable to an electrical load R. In Figure 4, the first set of generator coils 40 is shown connectable to the electrical load R1 through switch 66.

As the first set of generator coils 40 moves perpendicularly through the magnetic flux B, a d.c. current IDC1 is developed in the coils 40. However, because the direction of the magnetic flux B does not change around the periphery of the rotor face 17A, the generated current IDC1 is always in the same direction and no commutating means is required to supply the current to the electrical load R1.

Similarly, to take advantage of the other half of the twin rotor 14, a second set of generator coils 46 can similarly be configured across the rotor face 17B.

Thus, as the rotor means 14B rotates, a d.c. current IDC2 is generated and is connectable through switch 64 to electrical load R2.

As will be understood, this embodiment of the invention has more practical applications when rectified a.c. multi-phase current is supplied to the first and second sets of motor coils 42 and 44. But, the embodiment of the invention also has application when a d.c. current is applied.

In a further aspect of the invention, the method and circuit for more efficiently operating an electro-magnetic-mechanical machine having the rotor/stator combination of this invention is expanded to other more general types of electro-magnetic-mechanical machines.

In particular, the invention has application with any general electro-magnetic-mechanical machine having a first member having a first face, and also having a second member having a second face, wherein the first and second members are spaced such that the first face faces the second face and wherein the first and second members are relatively movable with respect to each other in a first transverse direction across the first face or the second face.

In the electro-magnetic-mechanical machine as shown in Figures 1, the rotor 14 would the first member and the stator 16 would be the second member.

Between the first face and the second face of the general machine, there is a magnetic field capable of creating a Lorentz force on moving electrons.

In this aspect of the invention, there is an electrical circuit which has an a.c. electrical power source supplying a.c. multi-phase current and a d.c.-component filtering means in series with the power source. Also, there is a first set of multi-phase electrical coils crossing the first face or second face in a direction substantially transverse to the first transverse direction. Also, there is a rectifying means for rectifying the a.c. multi-phase electrical current from the power source and supplying rectified a.c. multi-phase current to the first set of coils.

Further embodiments of this aspect of the invention will be the same as or similar to the preferred described above with respect to the embodiments utilizing the stator/rotor combination of the invention.

Although specific preferred embodiments have been described herein, it will be understood by those skilled in the art that now that the aspects of the invention have been described there are many equivalent embodiments which will function the same as the invention described herein and it will further be understood that those embodiments fall within the scope of the present invention.