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ROTARY MAGNETIC ACTUATORS

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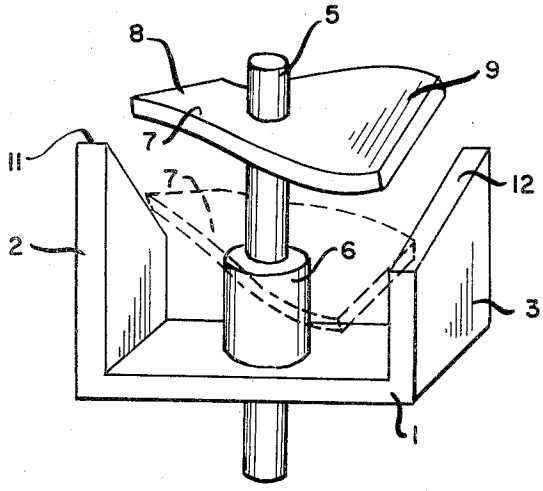


Fig. 1

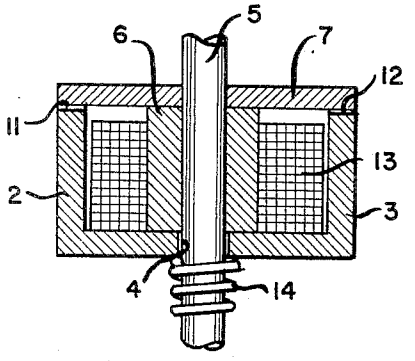


Fig. 2

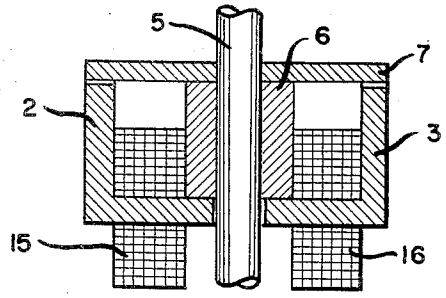


Fig. 3

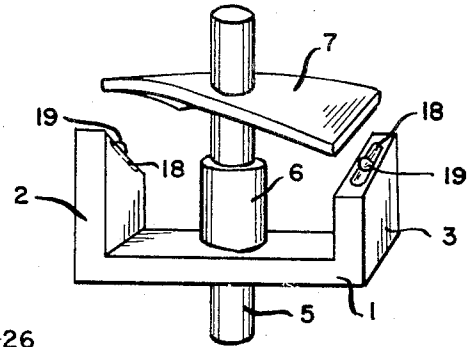


Fig. 4

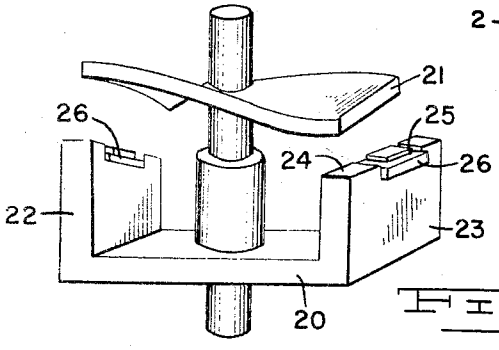


Fig. 5

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ROTARY MAGNETIC ACTUATORS

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This invention relates to a rotary magnetic actuator and more particularly, to an electromagnetic device which rotates a shaft through a limited angle with or without an applied load.

A device of this character is suitable for providing a power output which can be used for a large number of electrical and mechanical purposes, and as, for example, to operate switches, valves, clutches, latches or the like.

It is a primary object of this invention to provide a structure, inexpensive in construction, which is capable of converting a maximum amount of electrical energy into delivered torque.

In addition it is an object of my invention to provide a device wherein maximum starting torques are made available at the output shaft during any of the operations of this device.

A further object is to provide an actuator having a shaft which may both deliver a turning torque and which may be axially moved to deliver a limited axial thrust.

In order to accomplish my objectives, I provide a magnetic structure having pole pieces with inclined faces. Cooperating with these faces is an armature rigidly mounted upon a rotatable shaft. The armature is spaced from the faces by an air gap and adapted to move to reduce this air gap when the magnetic structure is energized. In addition, the pole piece faces are located on one side of the armature, so that the armature may be axially moved as the air gap is closed thereby imparting a limited axial movement to the shaft.

These and other objects and advantages will become apparent upon reading the following description of which the attached drawings form a part.

Referring to the drawings:

Figure 1 illustrates an exploded view, with parts omitted, of the basic form of my invention.

Figure 2 is a cross-sectional view of the device of Figure 1 in its operative condition.

Figure 3 is a modification of Figure 2, and illustrates a second type of coil winding, and

Figures 4 and 5 each show an exploded view of a modification.

This device is essentially a limited rotation mechanism wherein an armature fixed to an output shaft will rotate until the armature and pole pieces interfere with one another or until a mechanical stop means is operated.

In Figures 1 and 2, I illustrate a construction which shows the application of my invention. In this construction, a magnetic structure **1**, is formed with a pair of pole pieces **2** and **3**. An opening **4** is provided in the magnetic structure through which a rotatable shaft **5** is inserted. Surrounding a portion of the shaft and fixed to the magnetic structure is a bushing **6**. The bushing and the shaft, in this case, are preferably formed of a magnetic material to complete the magnetic circuit.

An armature **7**, is provided with a central opening through which shaft **5** is placed. The armature and shaft are rigidly secured together as by welding or any suitable mechanical fastening means.

The armature itself, is formed of a flat plate of magnetic material whose ends or arms **8** and **9** are twisted into a so-called "butterfly" form for reasons to be set forth hereunder.

As can be seen in the illustration of Figure 1, the pole pieces **2** and **3** which are substantially parallel to the axis of the shaft are provided with faces **11** and **12** which faces are inclined at an angle to the axis of the shaft. The twisted arms of armature **7** are so made that the portion overlapping the pole piece faces, hereinafter referred to as armature faces, are either parallel or non-parallel to the plane of the pole piece faces. The selection of parallelism or non-parallelism will depend on the application to which the device is to be put as will become apparent hereafter.

The armature is normally positioned so that a portion of its faces overlap a portion of the pole piece faces. However, these faces are preferably separated by an air gap even when they fully overlap. Thus, when a coil winding **13** is electrically energized the pole pieces become magnetized and the lines of flux pass from one pole piece through its respective armature arm and then to the second pole through its respective armature arm. In this situation the armature tends to reduce or close the air gaps and the armature thereby rotates.

Where the pole piece and armature faces are parallel rotation stops at the point of minimum air gap. When the faces are non-parallel, rotation stops when contact is made between these faces. In either case, however, a mechanical stop (not shown) may be provided to stop rotation at any predetermined point. To return the armature to its normal position when the coil is de-energized, a spring **14** or some other suitable mechanical means may be provided.

The angle of inclination of the pole piece and armature faces is chosen in accordance with the speed of rotational response desired and in accordance with the amount of rotation desired. In addition, the angle is also chosen to maximize the torque versus power input characteristic. It is to be noted that an angle which will increase the torque will decrease the time for a given rotation. However, the time constant of the actuator is unchanged.

In the modification of Figure 3, I show a construction similar in all respects to Figures 1 and 2, with the exception that the single coil winding **13** is replaced by a pair of coils **15** and **16** wound around the magnetic structure at the base of the pole pieces. It is thus apparent that the design of and the type of coils used may be varied considerably to obtain varying results from the device.

In Figure 3, the shaft **5** and bushing **6** may be made of either a magnetic or non-magnetic material. If the shaft and bushing are non-magnetic then these elements will not be included in the magnetic circuit and the two coils will oppose one another.

In Figure 4, a device similar to Figs. 1 and 2 is shown. However, here, the pole piece faces are grooved or channelled at **18** to support one or more ball bearings **19**. These ball bearings enable the rotating armature to lift the shaft upwardly (in Fig. 4) as the armature faces move over the pole piece faces. Consequently, in this type design, not only does the shaft rotate but it also moves axially to a limited degree. This feature may be utilized in various mechanical applications of this device.

Other type bearings may also be used, as for example rollers or a solid sheet of non-magnetic material secured to the faces of the pole pieces. In Fig. 4, the pole piece and armature faces are preferably non-parallel so that movement of the armature over the pole piece causes the armature to lift away from the pole piece face. By properly shaping the angular air gap, a constant axial force is obtained with armature rotation.

The device as described is a D. C. unit. Where it is

desired to use A. C. power, it is preferable to use a laminated magnetic structure and a laminated armature to reduce eddy current losses. Thus, in Figure 5, I show a laminated magnetic structure 20 and a laminated armature 21, similar otherwise to the magnetic structure and armature of Figure 1.

In addition, in order to avoid objectionable vibrations, a pole shader is used in this construction. For example, the pole pieces 22 and 23 are grooved at 24 and 25 and a solid turn of copper 26 or other suitable material encircles that portion of the pole piece located between the grooves.

In this illustration as in the illustration of Figure 4, the coil winding has been omitted to simplify the drawings.

By means of my invention, maximum desired starting torques may be obtained for any desired application, due to the flexibility of design of the various face angles. Moreover, because of the low armature inertia and because the magnetic structure produces a turning torque upon the armature, a minimum amount of energy is required to produce shaft rotation.

This invention may be developed within the scope of the following claims without departing from the essential features of said invention. Accordingly, it is desired that the foregoing description be read as showing several operative embodiments of said invention and not in a strictly limiting sense.

I claim:

1. A rotary magnetic actuator comprising a magnetic structure formed of a thin, flat, elongated plate of magnetizable material, having its opposite ends bent substantially normal to the plate to form a U-shape, with the legs of the U forming flat pole pieces which are spaced apart a considerable distance and with the planes of the legs being substantially parallel, the plate portion forming the base of the U being centrally apertured and a rotatable shaft extending through the aperture and between the pole pieces and being equidistantly spaced from and parallel to the pole pieces; the ends of each of the pole pieces being sloped, relative to the plane of the plate portion forming the base of the U, to form inclined pole faces facing away from the bottom of the U and with the slope of one pole face being opposite to that of the other pole face; and an armature consisting of a thin, flat plate centrally secured to the shaft to rotate therewith and having ends arranged to overlap the pole faces with these overlapping ends being twisted to slope at approximately the same angle as the slope of their respectively overlapped pole faces; and means to magnetize the pole pieces.

2. A rotary magnetic actuator comprising a magnetic structure formed of a thin, flat, elongated plate of magnetizable material, having its opposite ends bent substantially normal to the plate to form a U-shape, with

the legs of the U forming flat pole pieces which are spaced apart a considerable distance and with the legs being substantially parallel; a shaft rotatably mounted between the pole pieces and being equidistantly spaced from and parallel to the pole pieces; the ends of each of the pole pieces being sloped, relative to the plane of the plate portion forming the base of the U, to form inclined pole faces facing away from the bottom of the U and with the slope of one pole face being the same as, but oppositely inclined relative to the other pole face; an armature consisting of a flat, thin, plate centrally secured to the shaft for rotation therewith and having opposite portions which are arranged to extend over and overlay the pole faces, with these armature portions each being twisted to slope at approximately the same angle as the slope of their respective overlapped pole face, and a magnetic coil positioned between the two pole pieces and between the armature and the U base and with the coil surrounding the shaft.

3. A rotary magnetic actuator comprising a magnetic structure formed of two flat, thin, relatively narrow magnetizable plates arranged parallel to one another and spaced apart a considerable distance and having lower ends which are interconnected by a flat, thin bottom plate and upper ends which form pole faces facing away from the bottom plate and with the upper end pole faces being sloped in the planes of the pole pieces relative to the bottom plate; a shaft centrally located between the pole pieces and arranged parallel thereto, an armature in the form of a flat, thin narrow plate, centrally connected to the shaft and located above the pole faces and with the two ends of the armature plate radially extending from the shaft a sufficient distance to each overlap one of the pole faces, with the overlapping portions of the armature plate being twisted to slope in substantially the same direction and degree as the pole face they respectively overlap, and means for magnetizing said pole pieces.

4. A construction as defined in claim 3 and wherein the means for magnetizing said pole pieces includes an electrical coil arranged between the pole pieces, above the bottom plate and below the armature and surrounding the shaft.

5. A construction as defined in claim 3 and with the slope of the twisted overlapping portions of the armature plate being such that such overlapping portions contact their respective pole faces upon rotation of the armature and shaft relative to the pole pieces to a point where the armature overlapping portions substantially overlap their respective pole faces.

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