

Aug. 17, 1965

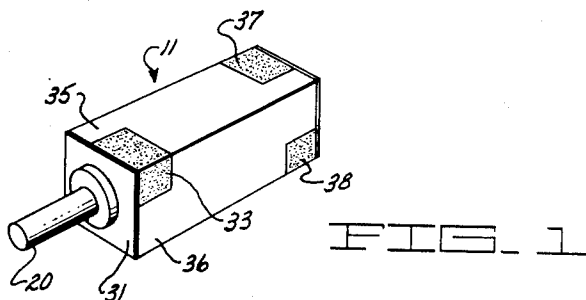
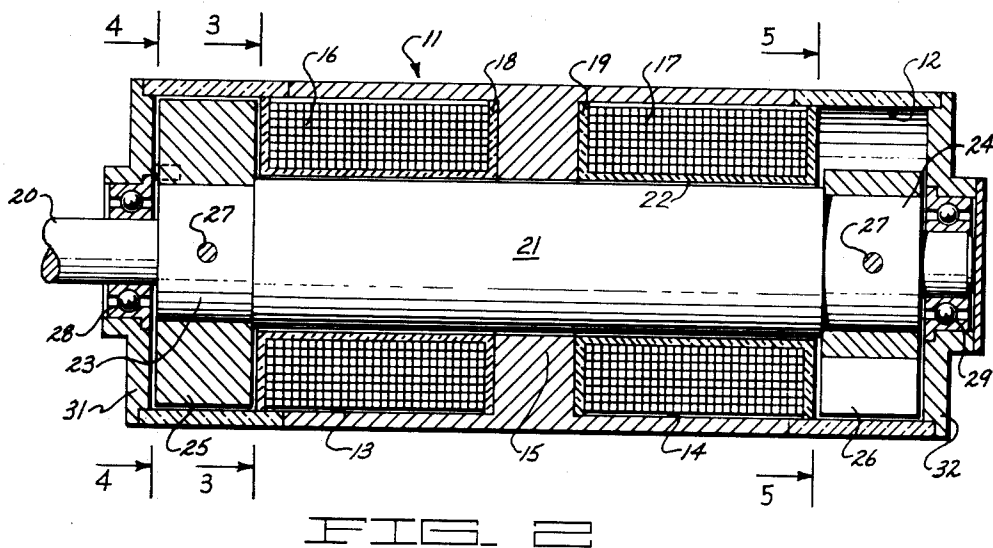
R. J. KOUTNIK

3,201,661

ROTARY SOLENOID HAVING A RECTANGULAR STATOR MEMBER

Filed Jan. 11, 1963

2 Sheets-Sheet 1



INVENTOR.
RODRICK J. KOUTNIK

BY

Paul E. Schumacher
ATTORNEY

3,201,661

ROTARY SOLENOID HAVING A RECTANGULAR STATOR MEMBER

Rodrick J. Keutnik, Vista, Calif., assignor to Clary Corporation, San Gabriel, Calif., a corporation of California

Filed Jan. 11, 1963, Ser. No. 250,372

5 Claims. (Cl. 317-189)

The present invention relates to electromagnetic rotary actuators and in particular to the type wherein the output shaft provides bi-directional angular movement.

Previous attempts to construct rotary solenoids in small, compact or miniaturized packages have resulted in complicated or costly constructions which often failed to meet the high standards of reliability required in today's space age.

Therefore, a principal object of the invention is to provide an electromagnetic rotary actuator which can be incorporated in a small, compact package and which provides a maximum torque output.

Another object is to provide a rotary actuator whose body construction is utilized to control its output torque characteristics.

Another object is to provide a bi-directional rotary actuator whose output torque requires less input energy than that provided by previous actuators.

Another object is to provide a bi-directional rotary actuator whose output torque approaches a straight line graph characteristic.

Still another object is to provide a rotary actuator of the above type which is simple and inexpensive to manufacture.

The manner in which the above and other objects of the invention are accomplished will be readily understood on reference to the following specification when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is a perspective view of a rotary actuator embodying a preferred form of the present invention.

FIG. 2 is an enlarged longitudinal sectional view through the actuator.

FIG. 3 is a sectional elevation view showing an energizing coil in relationship with the shaft and is taken along the line 3-3 of FIG. 2.

FIG. 4 is a sectional elevation view showing one of the armatures in its rest position and is taken along the line 4-4 of FIG. 2.

FIG. 5 is a sectional elevation view showing the second armature in its activated position and is taken along the line 5-5 of FIG. 2.

FIG. 6 is a graphic illustration of the torque output per angle of rotation.

Referring to the drawings, an elongate body or stator section 11, FIG. 2, is provided with a cylindrical bore 12 which is divided into two sections 13 and 14 by an inwardly projecting annular ring 15 integral with the section 11. The body is formed of magnetizable material, such as iron, having a relatively high magnetic permeability.

A pair of coils 16 and 17, wound on spools 18 and 19 of electrical insulating material are suitably attached in respective bore sections 13 and 14 adjacent the annular ring 15.

A shaft 21 formed of magnet material similar to that of the body is rotatably positioned in a bore 22 which is formed concentric with the bore 12 by the inside diameters of the spools 18, 19 and annular ring 15.

The shaft 21 has, adjacent opposite ends thereof, reduced sections 23 and 24 which have armatures 25 and 26, respectively, secured thereto by pins 27. The arma-

tures are formed of a magnetic material similar to that of the body and shaft and are positioned within the bore 12 adjacent coils 16 and 17, respectively.

The shaft 21 is rotatably supported at the opposite ends of the body 11 in ball bearings 28 and 29 fitted in end caps 31 and 32, respectively. The end caps, formed of a non-magnetic material such as aluminum, are glued to the body 11.

The portion of the shaft 21 supported by the bearing 28 projects out beyond the cap 31 to form a drive section 20.

The body 11 is square in cross section and has at its end adjacent the armature 25 two diametrically opposite corners 33 and 34 removed and replaced with a non-magnetic material such as brass or plastic, FIGS. 1, 4 and 5, thereby forming two magnetic pole pieces in the two remaining corners 35 and 36. Such corners extend lengthwise over the entire outer faces of the armature 25.

The end of the body adjacent the armature 26, FIG. 5, has the alternate two diametrically opposite corners 37 and 38 removed and replaced with a non-magnetic material, such as aluminum, thereby forming magnetic pole pieces in the two remaining corners 39 and 41.

The removal of the magnetic material in the corners 33, 34, 37 and 38 is, in the present embodiment, shown being formed at 30° to the base of the actuator for reasons to be described later.

The armatures, as shown in FIGS. 4 and 5, are angularly displaced from one another and have leading tips 42 and 43 thereon which, when an armature is in its rest position, as shown in FIG. 4, slightly overlap the adjacent pole pieces.

It will be noted that when one armature, i.e. 25, is in its rest position, as shown in FIG. 4, the other armature, i.e. 26, is in its activated position, as shown in FIG. 5, and vice versa.

The arrangement is such that upon energization of the coil 16 (considering the shaft and armatures to be in their positions shown in FIGS. 4 and 5) a magnetic flux path will be set up in the shaft 21, annular ring 15, pole pieces 35 and 36 and the armature 25 to thereby rotate the armature 25 and shaft in a counterclockwise direction to stop against a pin 62. Through the shaft 21, the armature 26 will also be rotated counterclockwise into its position of rest intermediate the non-magnetic corners 37 and 38.

Upon energization of the coil 17, the armature 26, which would be in its position of rest with its tips 43 barely overlying respective pole pieces, will rotate in a clockwise direction to stop against a pin 63.

The pins 62 and 63 are glued to end caps 31 and 32, respectively, and are so positioned as to limit the amount of rotation of the shaft 21.

The direction of rotation of the armatures is determined by the fact that the leading tips 42 and 43 of respective armatures slightly overlie their respective pole pieces during their alternate positions of rest, and since the trailing edges 44, during such period of rest, is approximately midway across the adjacent non-magnetic corners, a stronger field of magnetic flux is developed through the leading tips.

It will be noted, that even though the square cross sectional configuration of the stator section results in a package of minimum size and weight and the thickness of the wall defining the cylindrical bore 12 (as seen in FIG. 2) is relatively small, adequate cross sectional area is provided in the corners of the stator section to properly convey the magnetic flux. Also, since the pole pieces form continuations of such corners, they likewise have sufficient cross sectional area to convey the magnetic flux.

The angle of cut to form the pole pieces is an im-

3

portant feature of the invention where the mass of the parts is to be held to a minimum in that the body 11, being square, can be cut at many different angles to form different pole piece shapes, resulting in different output characteristics.

Shown graphically in FIG. 6 are curves illustrating the torque output of the shaft 21 in inch-ounces plotted against angular rotation. The curve 51 represents the characteristics of a 30° cut such as that illustrated in FIGS. 4 and 5 while the curve 52 represents the characteristics of a 45° cut which is not shown.

It can be seen that a 30° cut produces a relatively high torque at the start of rotation and thereafter a constant decrease through angular rotation which graphically approaches a straight line. The 45° cut produces less starting torque but at approximately 10° the torque output increases disproportionately to approximately 25° whereupon it decreases at a substantially constant rate. It will be noted that a higher torque output results during the latter part of the armature rotation than that obtained from the 30° cut.

From the foregoing it will be noted that the present actuator can be incorporated into a small, compact package having a square cross-section with a maximum and substantially straight line output torque characteristic, in that all parts are arranged to produce a maximum size magnetic flux path within the confines of such package.

Although the invention has been described in detail and certain specific terms and languages have been used, it is to be understood that the present disclosure is illustrative rather than restrictive and that changes and modifications may be made without departing from the spirit or scope of the invention as set forth in the claims appended hereto.

Having thus described the invention, what is desired to be secured by United States Letters Patent is:

1. An electromagnetic actuator comprising an elongate stator of magnetic material, said stator having a substantially square cross section, a first longitudinally extending cylindrical bore in said stator adjacent one end of said stator, a second longitudinally extending cylindrical bore in said stator adjacent the opposite end of said stator, a shaft of magnetic material rotatably mounted in said stator concentrically of said bores, a first armature of magnetic material on said shaft, said first armature extending within said first bore and adjacent the outer end thereof, a second armature of magnetic material on said shaft and angularly displaced from said first armature, said second armature extending within said second bore and adjacent the outer end thereof, a first coil in said first bore intermediate said first armature and the inner end of said first bore, a second coil in said second bore intermediate said second armature and the inner end of said second bore, two diametrically opposite corners of said stator adjacent each of said armatures being removed whereby to form two diametrically opposite magnetic pole pieces adjacent each of said armatures in the remaining two corners of said stator, said pole pieces cooperating with said armatures whereby magnetic flux induced in said stator, said shaft and said first armature by said first coil will tend to rotate said first armature into alignment with the adjacent said pole pieces, and whereby magnetic flux induced in said stator, said shaft and said second armature by said second coil will tend to rotate said second armature into alignment with the adjacent said pole pieces.

2. An electromagnetic actuator comprising an elongate stator of magnetic material, said stator having a substantially square cross section, a longitudinally extending cylindrical bore in said stator, a shaft of magnetic material rotatably mounted in said stator concentrically of said bore, a first armature of magnetic material on said shaft adjacent one end of said stator, a first coil in said bore adjacent said first armature, a second armature of magnetic material on said shaft adjacent the opposite end of

4

said stator, a second coil in said bore adjacent said second armature, two diametrically opposite corners of said stator adjacent said first armature being removed whereby to form two diametrically opposite magnetic pole pieces adjacent said first armature in the remaining two corners of said stator, and said corners forming pole pieces for said first armature being removed from the opposite end of said stator adjacent said second armature whereby to form two diametrically opposite magnetic pole pieces adjacent said second armature in the remaining two corners, said pole pieces cooperating with said armatures whereby magnetic flux induced in said stator, said shaft and said first armature by said first coil will tend to rotate said first armature into alignment with the adjacent said pole pieces, and whereby magnetic flux induced in said stator, said shaft and said second armature by said second coil will tend to move said second armature into alignment with the adjacent said pole pieces.

3. An electromagnetic actuator comprising an elongate stator of magnetic material, said stator having a substantially square cross section, a longitudinally extending cylindrical bore in said stator, a shaft of magnetic material rotatably mounted in said stator concentrically of said bore, an armature of magnetic material on said shaft, said armature extending within said bore and adjacent one end of said stator, a coil in said bore intermediate said armature and the opposite end of said stator, two diametrically opposite corners of said stator adjacent said armature being removed whereby to form two diametrically opposite magnetic pole pieces adjacent said armature in the remaining two corners of said stator, said pole pieces cooperating with said armature whereby magnetic flux induced in said stator, said shaft and said armature by said coil will tend to rotate said armature from a position generally out of alignment with said pole pieces to a position generally in alignment with said pole pieces, the corners of each said pole piece and said armature which are adjacent each other when said armature is in said first mentioned position, diverging from each other at approximately 45 degrees.

4. An electromagnetic actuator comprising an elongate stator of magnetic material, said stator having a substantially square cross section, a first longitudinally extending cylindrical bore in said stator adjacent one end of said stator, a second longitudinally extending cylindrical bore in said stator adjacent the opposite end of said stator, a shaft of magnetic material rotatably mounted in said stator concentrically of said bores, a first armature of magnetic material on said shaft, said first armature extending within said first bore and adjacent the outer end thereof, a second armature of magnetic material on said shaft, said second armature extending within said second bore and adjacent the outer end thereof, a first coil in said first bore intermediate said armature and the inner end of said first bore, a second coil in said second bore intermediate said second armature and the inner end of said second bore, two diametrically opposite corners of said stator adjacent each of said armatures being non-magnetic whereby to form two diametrically opposite magnetic pole pieces adjacent each of said armatures in the remaining two corners of said stator, said pole pieces cooperating with said armatures whereby magnetic flux induced in said stator, said shaft and said first armature by said first coil will tend to rotate said first armature into alignment with the adjacent said pole pieces while said second armature tends to rotate into alignment with the adjacent said non-magnetic corners, and whereby magnet flux induced in said stator, said shaft and said second armature by said second coil will tend to rotate said second armature into alignment with the adjacent said pole pieces while said first armature tends to rotate into alignment with the adjacent said non-magnetic corners.

5. An electromagnetic actuator comprising an elongate stator of magnetic material, said stator having a substantially square cross section, a longitudinally extend-

5

ing cylindrical bore in said stator, a shaft of magnetic material rotatably mounted in said stator concentrically of said bore, a first armature of magnetic material on said shaft adjacent one end of said stator, a first coil in said bore adjacent said first armature, a second armature of magnetic material on said shaft adjacent the opposite end of said stator, a second coil in said bore adjacent said second armature, two diametrically opposite corners of said stator adjacent each of said armatures being removed whereby to form two diametrically opposite magnetic pole pieces adjacent each of said armatures in the remaining two corners of said stator, said pole pieces cooperating with said armatures whereby magnetic flux induced in said stator, said shaft and said first armature by said first coil will tend to rotate said first armature from a substantially misaligned position to a position of substantial alignment with the adjacent said pole pieces, and

6

whereby magnetic flux induced in said stator, said shaft and said second armature by said second coil will tend to rotate said second armature into substantial alignment with the adjacent said pole piece and to return said first armature to its said substantially misaligned position.

References Cited by the Examiner

UNITED STATES PATENTS

10	1,764,658	6/30	Stoecklin.	
	2,872,627	2/59	Buchtenkirch	317—197
	3,039,027	6/62	Cuches	317—192

FOREIGN PATENTS

15	1,126,994	4/62	Germany.
----	-----------	------	----------

JOHN F. BURNS, *Primary Examiner.*