

Sept. 15, 1964

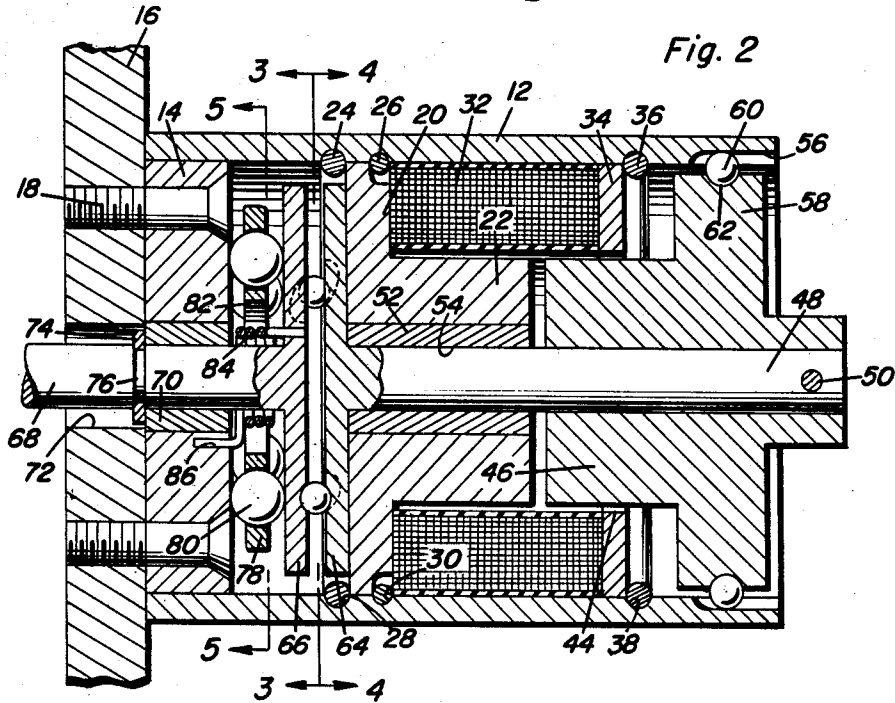
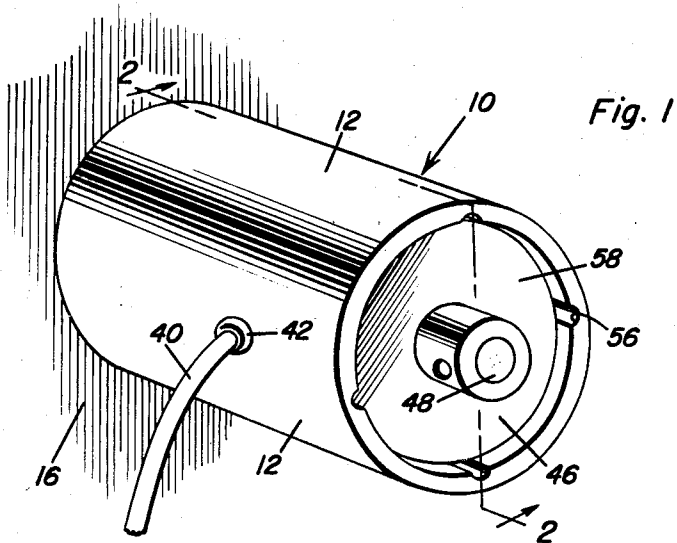
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3,148,552

SOLENOID OPERATED ROTARY ACTUATOR

Filed March 30, 1959

2 Sheets-Sheet 1



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Fig. 3

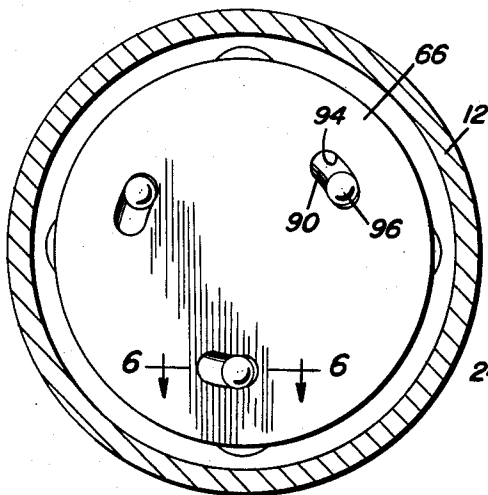


Fig. 4

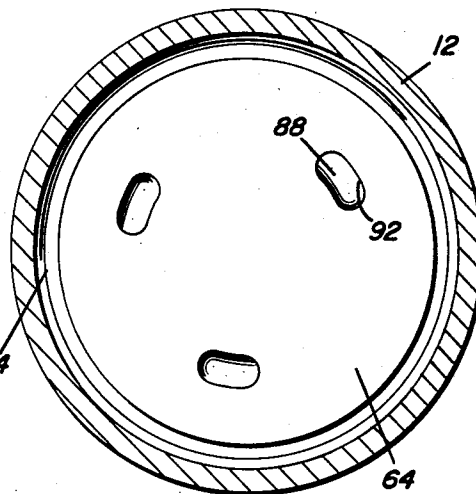


Fig. 5

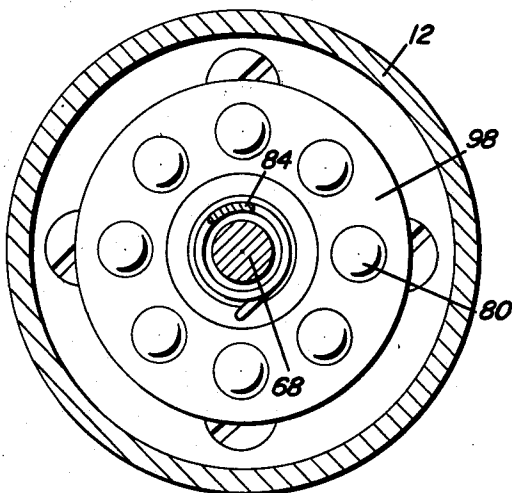
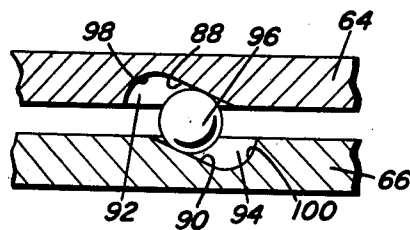


Fig. 6



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SOLENOID OPERATED ROTARY ACTUATOR

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13 Claims. (Cl. 74-99)

The present invention generally relates to a rotary actuator and more particularly to such an actuator that is operated by a solenoid or electromagnetically.

Specifically, the present invention pertains to actuators in which the axial movement of an armature toward an energized solenoid or electromagnet is utilized to produce a rotary output movement.

In prior devices of this nature, fixation of the rotary output member with the armature has resulted in both axial and rotary movement of both the armature and the output member. Also, the inertia of both the output member and the armature must necessarily be overcome with respect to both the axial movement and the rotary movement of the components. While such devices are satisfactory under some requirements, where it is essential that the actuated device receive only rotary movement, the coupling necessary for removing the axial component of the output movement of the actuator is rather complex and requires considerable space as well as being more expensive. This objection has been overcome in the present invention by providing an arrangement in which the armature is restrained against rotary movement and the axial movement of the armature is utilized to impart rotary movement only to an output member through a cam means interposed between the output member and the armature with the actuator thus having an output of rotary movement only.

It is a further object of the present invention to eliminate the combination of both rotary and linear or axial movement to a driven mechanism but which will provide for rotary drive of an output shaft on one end of the device with this one end having only rotary output movement with the other end of the device being capable of transmitting direct axial movement to an output member.

It is another important object of the present invention to provide an actuator in which movement is imparted to the components having a small moment of inertia thus utilizing a smaller portion of the total energy to overcome the inertia of the parts thus leaving a greater portion of the energy as useful output.

It is yet another object of the present invention to provide a solenoid operated rotary actuator in which the magnetic circuit is axially isolated from the rotary components thereby affording a wide flexibility in the location and size of the rotary components.

Still another feature of the present invention is to provide a solenoid operated rotary actuator or drive mechanism in which there is a source of instantaneous and powerful rotary only output or axial only output movement, either or both of which can be directly coupled to a driven mechanism by simple coupling methods.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout, and in which:

FIGURE 1 is a perspective view of the rotary actuator of the present invention;

FIGURE 2 is a longitudinal, vertical sectional view taken substantially upon a plane passing along section line 2-2 of FIGURE 1 illustrating the structural components of the actuator;

FIGURE 3 is a transverse, sectional view taken substantially upon a plane passing along section line 3-3 of

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FIGURE 2 and looking in the direction of the arrows for illustrating the structure of a portion of the cam groove plate which forms part of a camming means;

FIGURE 4 is a sectional view taken substantially upon a plane passing along section line 4-4 of FIGURE 2 illustrating the face of the other camming plate;

FIGURE 5 is a transverse, sectional view taken substantially upon a plane passing along section line 5-5 of FIGURE 2 illustrating the thrust bearing construction for the output member and the spring associated with the output member; and

FIGURE 6 is a detailed sectional view taken substantially upon a plane passing along section line 6-6 of FIGURE 3 but with both cam plates disposed in assembled facing relation and illustrating the construction of the cam grooves formed in the facing surfaces of the cam plates.

Referring now specifically to the drawings, the numeral 10 generally designates the rotary actuator of the present invention which includes an exterior casing or housing 12 which may be of any shape and construction but which is illustrated as being cylindrical. The Paramagnetic casing 12 may be of one piece construction or of screw threaded detachable elements with the casing 12 having an end plate 14 in one end thereof which is secured to a supporting plate 16 by screw threaded fasteners 18. The end plate 14 may be screw threaded into the casing 12 with the casing 12 defining an enclosed substantially cylindrical volume in which the operating components of the actuator are disposed.

Mounted within the casing 12 is a circular magnetically permeable core 20 having a central axial protruding portion 22. The peripheral edge of the core 20 is held in position by a pair of spring rings 24 and 26 respectively which are received in peripheral grooves 28 and 30 in the interior of the casing 12 thus rigidly holding the core 20 in position within the casing 12.

Disposed against the core is an electromagnetic coil 32 that is held in position by Paramagnetic end plate 34 abutting the coil 32 in opposition to the core 20. A spring ring 36 engaged in a groove 38 in the interior of the casing 12 also retains the end plate 34 in position. Electrical energy is supplied to the coil 32 by virtue of electrical conductors 40 extending through a grommet 42 received in the casing 12.

The end wall or plate 34 is provided with an enlarged opening 44 which receives a magnetically permeable armature 46 located in spaced relation to the core 20 and the protrusion 22 thereon. The armature 46 is closely spaced to the end of the protruding portion 22 of core 20 for axial movement towards the core upon energization of the magnetizing coil 32. The armature 46 is supported for axial movement by a non-magnetic shaft which may be of stainless steel and which is designated by the numeral 48 which is secured to the armature 46 by a pin 50 extending transversely thereof with the shaft 48 being disposed for longitudinal movement in the core 20 by virtue of a bearing 52 having a cylindrical bore 54 therethrough slidably receiving the shaft 48.

While the armature 46 is free to move longitudinally or axially towards and away from the core 20, the armature 46 is restrained from rotary movement by a plurality of axially extending semi-cylindrical grooves 56 in the inner surface of the casing 12. Also, the armature 46 is provided with a radially extending flange or radially extending means 58 carrying balls 60 to reduce friction between the radially extending flange means 58 and the grooves 56. Since the balls 60 are received in semi-spherical sockets 62 in the flange means 58, the flange means 58 and the armature 46 cannot rotate but can only move axially for causing reciprocation of the shaft 48.

A circular non-magnetic cam plate 64 is disposed to the

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opposite side of core 20 from armature 46 and is rigidly secured to or affixed to shaft 48. In normal deenergized condition of the actuator, plate 64 is substantially in abutting relation with the end plate of the core 20 as seen in FIGURE 2. Inasmuch as the plate 64 is rigid with the shaft 48 which in turn is rigid with armature 46, the plate 64 and armature 46 are movable axially as a unit and are both restrained against rotary movement by the ball member 96 engaging the recesses 92 and the sockets 62 provided therefor. Therefore, when coil 32 is energized, armature 46 will be attracted to core 20 and will move plate 64 to the left as seen in FIGURE 2.

Arranged in opposing relationship to cam plate 64 is a second non-magnetic cam plate 66 having a rigid integral central shaft extending outwardly of the casing by virtue of being rotatably received within a bearing 70 in the end plate or wall 14 with the shaft 68 also being received in an aperture 72 in the wall member 16. The plate 66 is restrained from axial movement by the provision of a retaining ring 74 disposed in a groove 76 with the retaining ring or washer 74 engaging the end of the bearing 70. This prevents axial movement of the plate 66 in one direction. For preventing axial movement of the plate 66 in the other direction, a ball bearing retainer plate or cage 78 is provided with a plurality of ball bearings 80 having the opposite surfaces thereof engaging the plate 66 and the inner surface of the end plate 14 thus forming a thrust bearing for the plate 66 and preventing axial movement thereof towards the end plate 14. The bearing retainer or cage 78 is provided with an enlarged central opening 82 for receiving an axial coil spring 84 having one end thereof connected with the plate 66 and the other end thereof extending into a socket 86 in the end plate 14. The shaft 68 serves as the output member and may be coupled in any suitable fashion to any device for imparting rotary motion only thereto.

The means whereby axial movement of armature 46 is utilized to impart rotary movement to plate 66 and shaft 68 includes at least one pair and preferably a plurality of pairs of opposed oppositely inclined surfaces 88 and 90 each of which forms the base or bottom of an arcuate groove or recess 92 and 94 respectively. Rotatable anti-friction elements such as spherical ball members 96 which may be in the form of hardened steel balls are disposed between the plates 64 and 66 with each ball bearing seated at its diametrically opposed side portions in said respective recesses and in rolling engagement with said inclined surfaces.

In normal deenergized condition of the actuator, plate 66 is maintained in such a rotational or angular position relative to plate 64 that the high portion of each pair of opposed inclined surfaces 88, 90 are in overlapping relation as shown in FIGURE 6 with the ball 96 disposed between the surfaces. When the coil 32 is energized, armature 46 will move axially towards the core 20 causing plate 64 to move towards plate 66. The force exerted by plate 64 on each ball 96 will be transmitted by the ball to the plate 66 and since the plate 64 is restrained against rotation in the same manner as the armature 26 is restrained against rotation, the force exerted on the plate 64 and the spherical balls 96 will result in rotational movement of the plate 66 and of course the output shaft 68. In the course of the movement of the ball 96, the ball 96 will rotate clockwise as seen in FIGURE 6 and roll from the shallow to the deep ends of recesses 92 and 94 and the engagement of the balls 96 with the deep end walls 98 and 100, such deep walls will act as stops for the ball members 96 to prevent further rotation of the plate 66.

As the armature 46 approaches the core 20, the length of the air gap between these parts is thus diminished and, therefore, the axial force exerted by the electromagnet on armature 46 will continuously increase.

The means for restoring the parts to normal relative position includes the spring 84 which returns the com-

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ponents to a deenergized position when the solenoid is deenergized. During the operating stroke of the plate 64 the spring 84 will be placed under torsional compression. When the electromagnet or solenoid is deenergized, the spring will rock the plate 66 and shaft 68 in the reverse direction whereby plate 64 and shaft 48 along with the armature 46 attached thereto will be shifted axially to their normal unoperated condition. Thus, when the electromagnet is energized, the shaft 68 is rotated through a limited angle in one direction and when the electromagnet is deenergized, the shaft is returned through said limited angle to its original position, with the result that the motion of the shaft 68 is an oscillatory motion.

Also of significance in the present invention is the arrangement whereby magnetic armature 46 is disposed to one side of magnetic core 20, and non-magnetic plates 64 and 66 are both disposed to the opposite side of the core. This disposition of the parts makes possible considerable flexibility in the choice of radial location of the inclined surfaces. While in the present embodiment the inclined surfaces are shown at some radial distance from the axis of rotation of plate 66, in certain applications it may be desirable to have the inclined surfaces in closely spaced relation to the longitudinal axis of the actuator. It will be apparent that by the present construction, the inclined surfaces may be disposed as closely as desired to the axis of rotation regardless of the diameter of the armature.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention as claimed.

What is claimed as new is as follows:

1. An electromagnetically operated rotary actuator comprising an electromagnet, an armature mounted for axial movement toward said electromagnet and restrained against rotary movement relative thereto, a first member fast with said armature for axial movement therewith, a second member arranged for rotary movement relative to said armature, said members being provided with at least one pair of opposed inclined surfaces, and rotatable means disposed between said members in rolling engagement with said inclined surfaces to impart rotary movement through a limited angle to said second member upon axial movement of said armature and first member.

2. The invention set forth in claim 1, said members including opposed recesses, said inclined surfaces defining the bases of said recesses whereby each recess includes a shallow portion and a deeper portion.

3. The invention set forth in claim 2 further including spring means urging said members to and normally maintaining said members in a relative rotational position wherein the shallow portions of said recesses overlap.

4. An electromagnetically operated rotary actuator comprising an electromagnet, an armature mounted for axial movement toward said electromagnet and restrained against rotary movement relative thereto, a first member fast with said armature for axial movement therewith, a second member arranged for rotary movement relative to said armature and restrained against axial movement, said members being provided with at least one pair of opposed inclined surfaces, and rotatable means disposed between said members in rolling engagement with said inclined surfaces to impart rotary movement through a limited angle to said second member upon axial movement of said armature and first member.

5. The invention set forth in claim 4, said armature, second member, and rotatable means each being moved from an unoperated to an operated position upon operation of the device, and restoring means for urging said

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armature, second member, and rotatable means from operated to unoperated position.

6. The invention as set forth in claim 5, said first and second members including opposed recesses, said inclined surfaces defining the bases of said recesses.

7. The invention set forth in claim 6, further including a wall portion fixed relative to the electromagnet, and anti-friction means between said second member and wall portion supporting said second member for rotary movement relative to said wall portion.

8. An electromagnetically operated rotary actuator comprising: an electromagnet including a core; an armature disposed to one side of the core and mounted for axial movement toward the core; first and second members disposed to the opposite side of said core, the first member being restrained against rotary movement relative to the electromagnet, the second member being free for rotary movement relative to the electromagnet, one of said members being coupled to the armature for axial movement therewith; an inclined surface provided on one of said members, and rotatable means operatively associated with the other member and disposed in rolling engagement with said inclined surface to impart rotary movement through a limited angle to said second member upon axial movement of the armature and member coupled thereto.

9. An electromagnetically operated rotary actuator comprising: an electromagnet including a core; an armature disposed to one side of said core, said armature being mounted for axial movement toward the core and restrained against rotary movement relative to said electromagnet; a first member disposed to the opposite side of said core and mounted fast with said armature for axial movement therewith; a second member disposed to said opposite side of the core and mounted for rotary movement relative to the electromagnet; an inclined surface provided on one of said members, and rotatable means operatively associated with the other member and in rolling engagement with said inclined surface to impart rotary movement through a limited angle to said second member upon axial movement of said first member with said armature.

10. An electromagnetically operated rotary actuator comprising: an electromagnet including a core; an armature disposed to one side of the core, said armature being mounted for axial movement toward the core; first and second opposed members disposed to the opposite side of the core, the first member being restrained against rotary movement relative to the electromagnet, the second member being mounted for rotary movement relative to the electromagnet, one of said members being

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coupled to said armature for axial movement therewith towards the other member; opposed oppositely inclined surfaces provided on said members; rotatable means disposed between and in rolling engagement with said inclined surfaces to impart rotary movement through a limited angle to said second member upon axial movement of the one member coupled to the armature toward the other member.

11. An electromagnetically operated rotary actuator comprising: an electromagnet including a core; an armature disposed to one side of the core, said armature being mounted for axial movement toward the core and restrained against rotary movement relative thereto; first and second opposed members disposed to the opposite side of said core, the first member being mounted fast with the armature for axial movement therewith, the second member being free for rotary movement relative to the electromagnet and restrained against axial movement; said members being provided with at least one pair of opposed inclined surfaces; and a ball disposed between and in rolling engagement with said inclined surfaces to impart rotary movement through a limited angle to said second member upon axial movement of said armature and first member.

12. An electromagnetically operated rotary actuator comprising an electromagnet, an armature mounted for axial movement toward said electromagnet, a first member fast with said armature for axial movement therewith, a wall member fixed relative to said electromagnet, an element interposed between said first and second members and arranged for rotary movement relative to said wall member, force transmitting spacer means between said element and one of said members, said element and the other of said members being provided with a pair of opposed inclined surfaces, a rotatable element disposed between and in rolling engagement with said inclined surfaces to impart rotary movement through a limited angle to said element upon axial movement of the armature and first member.

13. The invention set forth in claim 12, said opposed inclined surfaces being provided on said element and first member.

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