Oct. 26, 1965 B. E. DUFF 3,214,646

TORQUE MOTOR

Filed Nov. 13, 1962

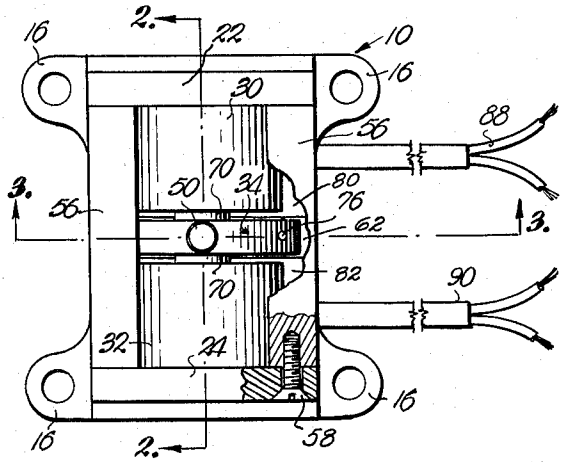


Fig. 1.

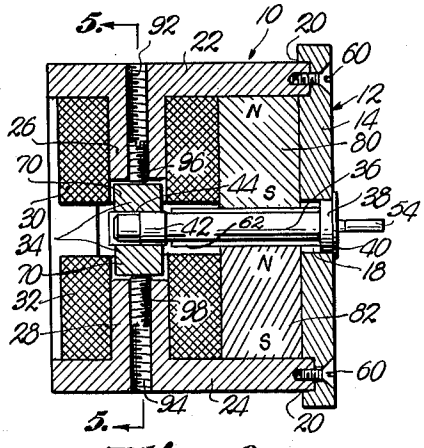


Fig. 2.

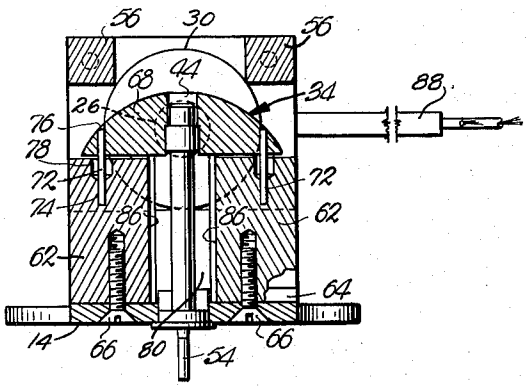


Fig. 3.

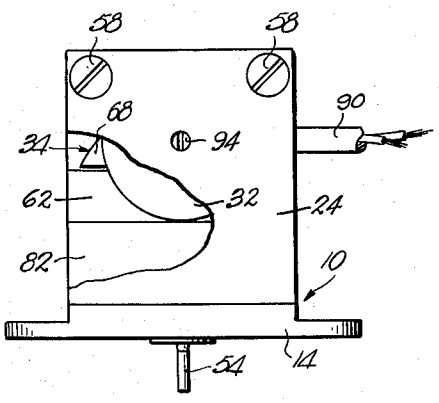


Fig. 4.

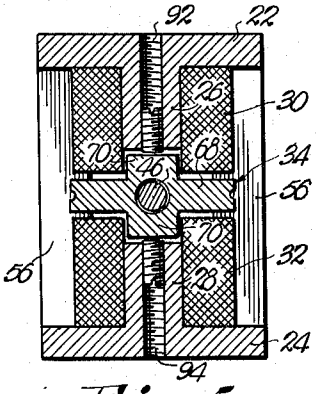


Fig. 5.

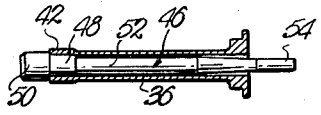


Fig. 6.

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United States Patent Office

3,214,646
Patented Oct. 26, 1965

3,214,646

TORQUE MOTOR

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Filed Nov. 13, 1962, Ser. No. 237,205
8 Claims. (Cl. 317—171)

This invention relates to electro-mechanical actuating means, and more particularly, to actuator mechanism for displacing linkage structure in response to relatively low-power electrical signals.

It is the primary object of the present invention to provide actuator mechanism having armature means shiftable through small displacements in predetermined directions under the influence of magnetic fields created by the flow of an electrical current through suitable conducting means whereby the displacement of the armature means may be utilized for shifting linkage structure.

Another object of the present invention is the provision of actuator means of the type described wherein elongated, resilient means is utilized for mounting the armature between a pair of current-carrying coils, whereby the attraction of the armature to one of the coils under the magnetic field created thereby is sufficient to displace the resilient means to in turn shift the linkage structure coupled therewith at a location remote from the armature.

Still another object of the present invention is the provision of an elongated tube of resilient material for mounting the armature between the coils, and wherein is included a shaft extending through the tube away from the armature and projecting outwardly from the tube, whereby the shaft is sealed off from the armature and the remainder of the mechanism while allowing the linkage structure to be coupled with the shaft for movement in a predetermined direction as the armature is attracted to one of the coils and the shaft is deflected thereby.

Yet another object of the present invention is the provision of magnetic structure on opposed sides of the tube for creating equal and opposite magnetic forces between a pair of spaced, opposed pole pieces and the armature, whereby the centering force of the tube mounting the armature between the coils may be controlled and the restoring force of the tube may be augmented by the presence of the magnetic structure when the tube is deflected under the influence of the movement of the armature toward one of the coils.

Other objects of the present invention will become apparent as the following specification progresses, reference being had to the accompanying drawing, wherein:

FIGURE 1 is an elevational view of the rear of the actuator mechanism forming the subject of the present invention, parts being broken away and in section to illustrate details of construction;

FIG. 2 is a cross-sectional view of the actuator mechanism taken along line 2—2 of FIG. 1;

FIG. 3 is a cross-sectional view taken along line 3—3 in FIG. 1 illustrating the interior of the actuator mechanism and the relative positions of the armature, the support, and one of the coils therefor;

FIG. 4 is a bottom plan view of the actuator mechanism showing the magnetic structure for controlling the centering force of the resilient tube for mounting the armature between a pair of electrical current-carrying coils;

FIG. 5 is a cross-sectional view of the actuator mechanism taken along line 5—5 of FIG. 2; and

FIG. 6 is a cross-sectional view of the resilient means for mounting the armature between the coils and illustrating the shaft therewithin intercoupling the armature with linkage structure to be displaced when current flows through one of the coils.

The present invention provides actuator mechanism

comprising a support, a pair of spaced, electrical current-carrying coils mounted on spaced pole pieces carried by the support, and an armature disposed between the pole pieces and coils by a tubular, resilient member mounted adjacent one end thereof on the support. The coils are adapted to be operably coupled with sources of electrical control signals so that magnetic fields may be created about the armature to attract the same to one or the other of the coils when current flows therethrough. Movements of the armature result in the deformation of the tubular member, such deformation being transmitted by means of the deflection of a shaft or stem extending through and outwardly from the tube to linkage structure to be displaced. Permanent magnets are disposed on opposed sides of the tubular member and coupled with the pole pieces for controlling the centering force on the armature by creating equal, opposed magnetic forces on the armature between the pole pieces.

The actuator mechanism which forms the subject of the present invention is broadly denoted by the numeral **10** and includes a support **12** in the nature of a base plate **14** having perforated ears **16** thereon facilitating the mounting of mechanism **10** on suitable structure.

Plate **14** is provided with a central opening **18** therein, and a pair of parallel grooves **20** on opposed sides of opening **18**. A pair of pole pieces **22** and **24** are received adjacent corresponding longitudinal edges thereof within respective grooves **20** as is clear in FIG. 2. Pole pieces **22** and **24** thus extend outwardly from plate **14**. Pole pieces **22** and **24** are provided with cylindrical bosses **26** and **28** for mounting a pair of electrical current-carrying coils **30** and **32** in spaced relationship.

An armature **34** is carried by a resilient, thin walled tube or tubular member **36** on plate **14** and disposed between and spaced from bosses **26** and **28** as is clear in FIG. 2. The terminal ends of bosses **26** and **28** adjacent armature **34** form pole faces for directing magnetic flux through the armature. Member **36** is provided with a collar **38** which is preferably press-fitted within opening **18**. A flange **40** integral with collar **38**, bears against the corresponding face of plate **14** to limit the inward travel of collar **38**.

Member **36** is provided with an enlargement **42** thereon which is preferably press-fitted within an opening **44** through armature **34** so that the latter is rigid to member **36**. An elongated shaft or stem **46** extends through member **36** in the manner shown in FIG. 6. Stem **46** is provided with an enlargement **48** thereon adjacent one end thereof which is preferably press-fitted within the end of member **36** corresponding to enlargement **42**. One end **50** of stem **46** is larger in diameter than enlargement **48** and bears against the end edge of enlargement **42** to limit the inward travel of stem **46**. The shank **52** of stem **46** is of lesser diameter than the inside diameter of member **36** so that limited movement of stem **46** relative to member **36** is permitted. The opposite end **54** of stem **46** projects outwardly from member **36** and, when member **36** is received within opening **18**, is adapted to be operably coupled with linkage structure to be displaced.

It is to be noted that spacers **56** extend between, and are secured to pole pieces **22** and **24** by screw means **58**. Thus, pole pieces **22** and **24** are maintained in predetermined, spaced relationship at all times. In addition, screw means **60** intercouple plate **14** with pole pieces **22** and **24** as is clear in FIG. 2.

A pair of blocks **62** is carried within grooves **64** in plate **14** in the manner shown in FIG. 3 by screw means **66**. Blocks **62** extend outwardly from plate **14** in the same direction as member **36** and terminate in spaced relationship to armature **34**, the latter being comprised of a substantially semi-circular section **68** and a pair of bosses **70** integral with section **68**. Blocks **62** provide means for

mounting a resilient pin or spring 72 at each end of section 68 in the manner show in FIG. 3 to dampen any armature vibrations caused by external sources or otherwise. Also, the pins 72 limit the lateral acceleration of armature 34. Each pin is formed from a length of resilient material such as copper wire or the like, and is press-fitted within a bore 74 drilled in the corresponding block 62 and a bore 76 formed in the corresponding end of section 68. Bore 74 is countersunk at 78 to permit deflection of pin 72, notwithstanding the close proximity of armature 34 with the corresponding block 62.

Magnetic structure in the nature of a pair of permanent magnets 80 and 82 is secured to the inner surface of plate 14 as is clear in FIG. 2. Magnets 80 and 82 substantially span the distance between the opposing longitudinal edges of pole pieces 22 and 24 and are disposed on opposed sides of member 36. Blocks 62 are disposed between magnets 80 and 82 and provide additional support therefor, it being noted that each block 62 is provided with a substantially concave surface 86 facing member 36 as is clear in FIG. 3.

Magnets 80 and 82 are magnetically coupled with pole pieces 22 and 24 so that equal, opposing magnetic forces are exerted on armature 34 at all times, thus providing a centering force for armature 34 in addition to tubular member 36. This centering force may be controlled by varying the residual magnetism of the permanent magnets. Magnets 80 and 82 also augment the restoring force of member 36.

As is clear in FIGS. 1, 3 and 4, suitable electrical conductor means 88 and 90 are coupled with coils 30 and 32 respectively. These conductors would, of course, be coupled with electrical control signals when the mechanism is operated so that the desired magnetic fields may be created by coils 30 and 32.

Pole pieces 22 and 24 are provided with threaded bores 92 and 94 through the bosses 26 and 28 thereof for receiving setscrews 96 and 98 which move toward and away from armature 34. Thus, setscrews 96 and 98 provide stop means for limiting the movement of armature 34 toward and away from the pole faces of the corresponding bosses 26 and 28. Thus, the deflection of stem 46 is thereby limited.

In use, mechanism 10 is adapted to be secured by suitable screw means received within the perforations of ears 16 to rigid support structure. The outermost end of stem 46 is then coupled with linkage structure to be displaced, and conductor means 88 and 90 are coupled with the control signal sources.

By directing an electric current through one of the coils 30 and 32, a magnetic field is created adjacent armature 34 which attracts the latter toward the corresponding coil to in turn cause the deformation of member 36 and the deflection of stem 46. When armature 34 is attracted to boss 26 under the influence of the magnetic field created by coil 30, end 54 of stem 46 moves toward pole piece 24 when viewing FIG. 2. Conversely, when armature 34 is attracted to boss 28, end 54 moves toward pole piece 22. It should be understood that the end 54 moves in a arcuate path, since enlargement 42 is rigid with armature 34, the latter thus flexing member 36, and hence swinging stem 46, about fulcrum point formed by collar 38. The displacements involved are small, however, so the movement of end 54 may be considered linear for all practical purposes. End 54 will move to a position where the magnetic force on the armature is equalled by the restoring force of tubular member 36.

Electrical signals may well be directed simultaneously through both coils 30 and 32 and, if the magnitudes of the signals are equal, no deflection of armature 34 will result. However, if the magnitude of one of the signals is greater than that of the other signal, an unbalanced common magnetic force will result and armature 34 will be attracted to the coil creating the larger force. It is to be noted that the magnetic force vectors created by magnets 80 and 82 are added vectorially to the magnetic forces created by coils 30 and 32.

Mechanism 10 is especially suitable for use with low-power input signals since relatively large forces will be exerted on armature 34 by the magnetic fields created as a result of the presence of such signals in coils 30 and 32. It should be appreciated that suitable design of the magnetic circuit will enable the displacement of the actuating shaft (stem 46) to be directly proportional to the magnitude of the current in one of the coils 30 or 32 until maximum displacement is reached. Mechanism 10 also has the advantage of a magnetic circuit completely shielded from contamination, since member 36 is disposed in position to seal the magnetic circuit from such contamination. Furthermore, the mechanism may be of relatively small size and lightweight in character, thus making the same readily adapted for confined spaced wherein a high work output is required and where low-power inputs only are available. Member 36 has the advantage of a high natural frequency, and the magnetic circuit exhibits low hystersis characteristics.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. An electro-mechanical actuator comprising:
   - a pair of electromagnetic devices each provided with a pole piece and adapted to receive an electrical signal;
   - a movable armature between the pole pieces and normally spaced therefrom, said armature being of magnetic material rendering the same responsive to energization of said devices;
   - an elongated tube of resilient material having one end thereof rigid to the armature;
   - means rigidly supporting the opposite end of the tube;
   - an actuator shaft in said tube; and
   - means rigidly interconnecting the shaft and the tube adjacent said one end of the latter.

2. The invention of claim 1, said means supporting the tube being disposed to hold the armature in a null position between the pole pieces.

3. The invention of claim 2, and means separate from said devices for augmenting the action of the tube and its supporting means in holding the armature in said null position comprising permanent magnet means having said pole pieces in the magnetic field thereof.

4. The invention of claim 1, said means rigidly interconnecting the shaft and the tube comprising an enlargement on the shaft tightly fitted in and closing the tube.

5. An electro-mechanical actuator comprising:
   - a movable armature of magnetic material;
   - a pair of electromagnetic devices disposed on opposite sides of the armature and each provided with a pole piece extending toward the armature in substantial alignment with the opposing pole piece, each of said pole pieces defining a pole face at the terminal end thereof nearest said armature, the latter being normally spaced between the pole faces, the devices being adapted to receive an electrical signal and thereby actuate said armature toward and away from the pole faces;
   - an elongated tube of resilient material having one end thereof rigid with the armature and extending away from said armature in a plane orthogonal to the line of alignment of said pole pieces;
   - means rigidly supporting the opposite end of the tube;
   - an actuator shaft in said tube; and
   - means rigidly interconnecting the shaft and the tube adjacent said one end of the latter.

6. The invention of claim 5, a setscrew for each pole piece, the latter having a threaded bore therethrough from said terminal end to the opposite end thereof for receiving its setscrew, whereby to provide means for limiting the deflection of the armature, tube and shaft when the setscrews are advanced toward the armature clear of the pole faces.

7. The invention of claim 5, said means supporting the tube being disposed to hold the armature in a null position between the pole faces, the support means including a member adjacent said armature, and a pair of resilient pins engaging the armature and the member for flexing in directions orthogonal to said tube.

8. The invention of claim 7, said pins comprising a length of wire-like material, the member and the armature being bored to receive and anchor the ends of the pins, the member being counterbored to permit deflection of the pins.

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