

[54] **PERMANENT MAGNET
ELECTROMAGNETIC ACTUATOR**

[72] Inventor: **Brandt M. Griffing**, Delray Beach, Fla.
[73] Assignee: **International Business Machines Corporation**, Armonk, N.Y.
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[51] Int. Cl. **H01f 7/08**
[58] Field of Search **101/93 C; 335/229, 230, 236, 335/179, 84, 227, 296**

[56] **References Cited**

UNITED STATES PATENTS

2,888,290	5/1959	Pierce	335/229 X
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3,449,639	6/1969	Brown et al.	101/93 C UX

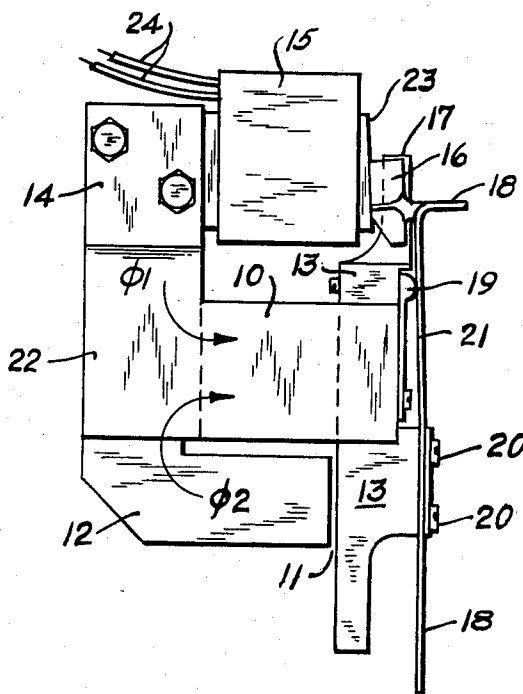
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Primary Examiner—George Harris
Attorney—Hanifin and Jancin and Earl C. Hancock

[57] **ABSTRACT**

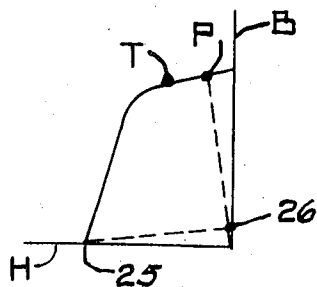
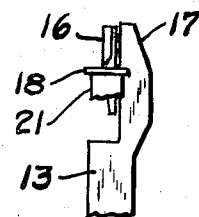
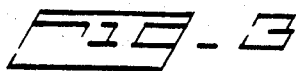
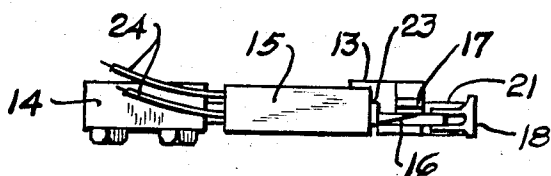
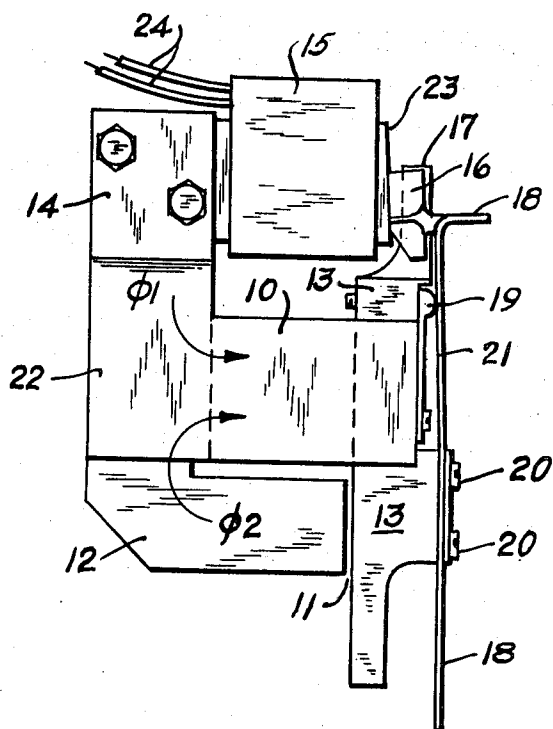
Two essentially parallel magnetic flux paths are arranged so as to share a permanent magnet. A movable armature in one flux path functions as a mechanical actuator by means of a selectively actuated magnetic opposing coil for effectively cancelling the flux in that path. The other of the parallel magnetic flux paths is constructed and arranged for providing a shunt for sufficient additional magnetic flux during actuation of the opposing coil so as to prevent the shifting of the magnetic properties of the permanent magnet beyond the point of recovery to the original operating point upon deactuation of the coil. The mechanical arrangement is such that the movable armature is retrieved by the magnetic circuit when the coil is deenergized.

4 Claims, 4 Drawing Figures



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INVENTOR
BRANDT M. GRIFFING

BY
Earl C. Hancock

ATTORNEY

PERMANENT MAGNET ELECTROMAGNETIC ACTUATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to electromechanical actuators. More particularly, this invention relates to devices for imparting mechanical motion to movable components by means of introducing and removing energizing pulses to control coils which operate in conjunction with magnetic flux circuits.

A particular utility for the present invention resides in its application to print hammer actuators, especially wherever high reliability, maintainability and minimum space arrangement of multiple actuators are involved.

2. Cross-Reference of Related Patent

U.S. Pat. No. 3,460,469 "Print Hammer Actuator" by Brown et al. which is assigned to the same assignee as the present invention shows an electromechanical actuator that is particularly useful for print hammer operations.

3. Description of the Prior Art

Electromechanical actuators in the past wherein AC magnetic flux operations are involved have not employed permanent magnets for providing the static holding force since this static holding force must be reduced substantially to zero upon actuation of the device. Typically, this is effected by a so-called bucking coil which reduces the magnetic flux to substantially zero by an appropriate design of ampere turns. The Brown et al. U.S. Pat. No. 3,460,469 shows such an arrangement and, in apparatus such as is there shown, the use of a permanent magnet for normal or static biasing is not possible since the reduction of the magnetic flux to zero would result in sufficient demagnetization of the permanent magnet so that it would not return to its normal static operating point with sufficient strength to effect retrieval of the movable armature. Therefore, the prior art devices have relied upon the use of additional holding coils for recreating the magnetic flux that provides the static holding force.

Other attempts in the prior art to obtain the advantages of permanent magnets and avoid the requirement for remagnetizing holding coils have been generally unsatisfactory. For instance, U.S. Pat. No. 3,217,640 by Bradshaw shows a somewhat involved apparatus for providing such a function. In devices such as that shown by Bradshaw, the electromechanical actuator requires that the bucking coil actually reverse the magnetic flux in the movable shunt path which accordingly requires that the coil be appropriately mounted and movable with the armature. Further, such arrangements require complete flux reversal in the armature in order to operate at all.

SUMMARY OF THE INVENTION

This invention is an electromechanical actuator particularly well suited for operations such as a print hammer actuator or a punch control or the like. The apparatus includes a pair of magnetic flux paths which are arranged so that a permanent magnet provides a common magnetomotive force. One flux path includes a movable magnetic portion or armature which is normally biased so as to provide a force in the direction that the desired mechanical motion is to occur. The strength of the magnetic field in that flux path is sufficient to retrieve the actuator portion at its maximum movement position notwithstanding this biasing force. This actuator magnetic flux path also includes means for introducing an opposing magnetic flux to the flux generated by the permanent magnet, this typically being effected by a so-called bucking coil.

Additionally, the invention includes a shunt magnetic path which is separate from the actuator path except for a common leg including the aforementioned permanent magnet. This shunt path is constructed and arranged so as to absorb a sufficient amount of the magnetic flux from the permanent magnet when the bucking coil is actuated so as to permit the permanent magnet to operate within a range of its B-H curve in such a manner that removal of the opposing magnetic field

will result in the permanent magnet substantially returning to its original or static point on the B-H curve. This shunt path would normally include an arrangement of magnetic reluctance such as an air gap.

It is an object of this invention to provide an electromechanical actuator which is capable of AC magnetic operation while employing a permanent magnet.

Another object of this invention is to provide an electromechanical actuator which requires only the input for the bucking coil to cause operation.

Still another object of the present invention is to provide an electromechanical actuator which can be combined with a multiplicity of other actuators in a compact arrangement such that reliability and serviceability are markedly enhanced.

Yet another object of this invention is to provide an electromechanical actuator which utilizes a permanent magnet shared by an actuator magnetic flux path and a shunt magnetic flux path.

A still further object of the present invention is to provide an electromechanical actuator capable of AC magnetic operation while using a permanent magnet in such a manner that energization and deenergization of an actuating operation will not result in demagnetization of the permanent magnet.

The foregoing and other objects, features, and advantages of the present invention can be more fully understood from the following detailed description of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a preferred embodiment of the present invention particularly adapted for print hammer actuation.

FIG. 2 presents a view of the part of the actuator components as would be seen from the right side of the FIG. 1 embodiment.

FIG. 3 is an upper view of the FIG. 1 embodiment.

FIG. 4 shows a typical B-H curve portion that might be applicable to one type of material useful for the permanent magnet employed in the FIG. 1 apparatus.

DETAILED DESCRIPTION

The preferred embodiment for the present invention will be shown and described relative to its utility as a print hammer actuator. However, it will be readily apparent that the present invention is easily adapted to a multiplicity of other operations such as punches, etc. Many of the details applicable to the present invention have been set forth in U.S. Pat. No. 3,460,469 by Brown et al. and accordingly will be omitted from this specification.

In the past, permanent magnets have not been generally favored for use in electromechanical actuators since they have generally been considered not to be adaptable to AC magnetic operations. They have been predominately employed for DC magnetic functioning. Devices which have attempted to utilize the permanent magnet for electromechanical actuators have involved acceptance of certain undesirable features such as movable coils, the requirement for flux reversal instead of merely reducing the flux to zero and the like. The major objection to the use of a permanent magnet in an AC magnetic operation of an electromechanical device is that the normal physical state of a permanent magnet tends to be reduced to one of less energy content when the magnetic field is reduced to zero.

The FIG. 1 apparatus illustrates one form of the present invention which maintains a nearly constant flux level in the permanent magnet while allowing the flux level in the movable portion or armature to be reduced to zero to fire a print hammer. The present invention reduces the ampere turns required to fire the hammer to a minimum.

Excluding leakage, the apparatus illustrated in FIG. 1 includes two flux paths which have a common leg that includes a permanent magnet 10. The first flux path shown generally as 01 provides the necessary flux to retrieve and retain movable armature element 16 into the energized position against the

upper magnetic core portion 14. The other magnetic flux path is shown generally as 02 with this path providing the shunt with magnetic flux which, when passing through the gap 11, generates the necessary magnetomotive force in the lower portion 12 to drive 01. It can be seen from the following description that, the larger the ratio of 02 to 01, the smaller the flux change will be in the magnet and the lower the ampere turns required in the buck coil 15 to fire the hammer 18.

A C-shaped magnetic path portion composed of lower portion or arm 12 and upper portion or arm 14 (including the extension through bucking coil 15 ending in face 23) are held in place by cover plate 22. Magnet 10 and column 13 are bonded together and to plate 22. However, various fabrication techniques other than that shown can be used. For instance, the C-shaped path could be cast in one piece from magnetic material (typically iron) which could include upper and lower arms 14 and 12 as well as the upper extension ending in face 23. The portion of upper arm 14 ending in face 23 could be bolt mounted as shown to permit some movement to accommodate adjustment of the interfacing between 23 and armature 16. The flux density in the upper path loop is low everywhere except in the vicinity of the armature 16 so that the potential difference HL of permanent magnet 10 drives flux in two parallel paths, armature path 01 and gap path 02. HL refers to the coercive force H and the magnet length L.

Initially the magnet is driven to positive saturation and returns to the quiescent operating point P in FIG. 4. When the bucking coil 15 is energized by introducing an appropriate pulse to leads 24, the flux 01 is driven to zero. This is accompanied by a shift in the operating point of magnet 10 to point T on FIG. 4 as it attempts to drive 01 through the gap 11 in addition to the static 02. Since all permanent magnets have some degree of slope on their B-H curves as is shown in FIG. 4, not all of 01 can appear across the shunt. However, as long as the apparatus is arranged to operate along the substantially horizontal portion of the B-H curve as is shown between P and T in FIG. 4, the greater magnetizing force required can be provided while the return of the device to static condition wherein the bucking coil 15 is deenergized will cause the permanent magnet to return to point P from T.

The ampere turns (NI) required for bucking coil 15 can be determined from the following equation:

$$NI = H_p L_M \left[1 + \frac{01}{02 + K A H_p} \right]$$

where K is the slope of the B-H curve at P, A is the area of the magnet, H_p is the coercive force generated by the magnet as shown in the FIG. 4 curve and L is the magnet length. Also, K and H are taken as positive quantities and 0 is a measure of the induced flux.

Although it has been mentioned that elements 12, 13, 14 and 23 can be fabricated from magnetic material using any desired technique, it should be understood that these elements actually provide portions of both flux paths. Thus, the actuator path includes a permanent magnet 10, the upper portion of column 13 including post 17, magnetic actuator or armature portion 16 which is movable relative to both the face 23 and the post 17, the upper arm ending in face 23, and arm 14. The shunt path includes lower portion 12, gap 11 which might typically be an air gap, the lower portion of column 13 and permanent magnet 10. The print hammer is mechanically actuated by the face 18 of lever arm 21 which is attached to the apparatus by bolts 20. Fulcrum 19 might be included for mechanical leverage purposes substantially for the same reasons as is shown and described in the Brown et al. patent.

If the shunt path were not included, the reduction of the magnetic flux in the armature path using permanent magnet 10 would result in driving the permanent magnet to point 25 shown in FIG. 4. Consequently, permanent magnet 10 would return to point 26 instead of point P when the bucking coil was deactivated. The magnetic strength available from that point obviously would be insufficient to retrieve armature element 16 and retain it in the ready position. The FIG. 4 B-H curve is

illustrated as might be typically encountered for a permanent magnet composed of the Alnico 5 materials with a magnetic flux density of nearly 13,000 gauss at point P and only slightly less at point T. From the above-mentioned equation, it can be seen that the flatter the slope of the upper portion of the B-H curve, the smaller will be the slope K and thus the less significant that factor might be in the equation. Therefore, the major factors in determining the magnetic size and ampere turns can be obtained from the equation and are primarily a function of the 01 to 02 ratio.

The present invention is particularly well adapted for arrangements of multiple electromechanical actuating devices similar to those shown in FIG. 2 of Brown et al. U.S. Pat. No. 3,460,469. The use of the present invention clearly makes it possible to place many devices side by side in a relatively compact environment wherein there is little or no air space to permit flux leakage around the actuator. At the same time, electromechanical actuators such as the present invention can be replaced with relative ease from that compact environment since no intervening holding coil is required.

It should be noted that the armature 16 does not need to be fixed to the flux path in the manner shown. It need only be biased sufficiently to move it away from the flux path so as to perform the particular mechanical function desired but not be biased enough so that it cannot be retrieved by the magnetomotive force when the buck coil is not energized. If desired, the length of mechanical thrust available for armature 16 could be extended by utilizing some additional means for returning armature 16 to sufficient proximity with face 23 so that the magnetic flux in the armature path will retrieve and/or hold armature 16 in the ready position.

The advantages of using Alnico material primarily is that it has been available for a considerable length of time such that it is now consistently manufactured within acceptable tolerances such as 5 percent and is readily available in the commercial market.

It should be noted that, if a flexible magnetic path were used for spring arm 21 and armature 16, the upper part of column 13 including post 17 and movable armature 16 could all be made as one member of that flexible magnetic material. If adequate, the spring qualities of this flexible material might actually provide the biasing force in conjunction with appropriate mounting for performing operations similar to that provided by elements 21, 16 and 19, as well as the upper portion of column 13 and post 17.

While the novel features of the present invention have been shown and described with reference to a preferred embodiment, thereof, it will be understood by those skilled in the art that many changes of form and detail other than those mentioned herein may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. An electromechanical actuator comprising a permanent magnet, first and second flux paths coupled for common magnetic energization by said magnet, a movable means held so as to form a portion in magnetic circuit in said first flux path by the magnetic holding force in said first path, means for applying a biasing force to said movable means in a direction tending to move said movable means out of said first path, means for restricting said movable means in responding to the force from said biasing means from moving beyond recovery by the static magnetic force in said first path, said movable means being arranged for introducing a gap in said first flux path when responding to the force from said biasing means, and means for selectively reducing the magnetic flux in said first path sufficiently to permit the force applied by said biasing means to overcome the said holding magnetic force in said first path,

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said second path being constructed and arranged for absorbing sufficient magnetic flux when said flux reducing means is actuated so that said permanent magnet can substantially recover its magnetic strength when said flux reducing means is deactivated and said movable means is returned in magnetic circuit with said first flux path.

2. An electromechanical actuator in accordance with claim 1 wherein said first flux path generates a sufficient magnetic force for overcoming the force from said biasing means and for retrieving said movable means back in magnetic circuit with said first flux path upon deactuation of said flux reducing means.

3. An electromechanical actuator in accordance with claim

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1 wherein said second flux path includes a magnetic reluctance portion for maintaining the magnetomotive force demands upon said magnet when said flux reducing means is actuated within the range of the B-H curve of said magnets which will permit substantial recovery of said magnet to its magnetic strength prior to actuation of said flux reducing means after deactuation thereof.

4. Apparatus in accordance with claim 3 wherein said magnetic reluctance portion is an air gap, and said first and second flux paths including said movable means being constructed of material having inconsequential magnetic reluctance.

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