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[73] Assignee **Bell Aerospace Corporation**

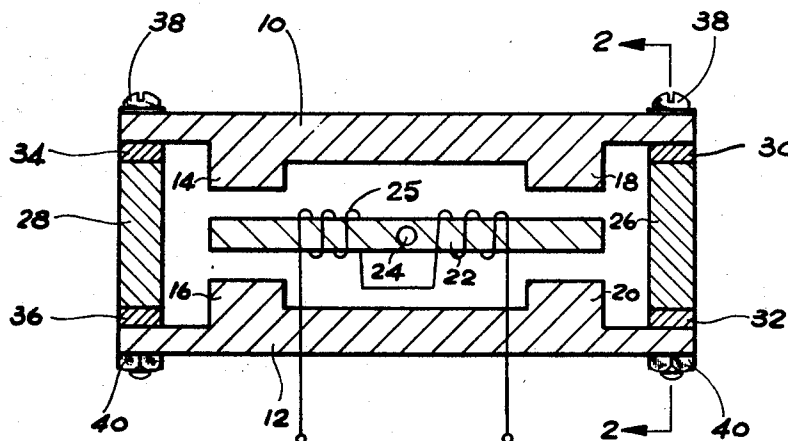
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UNITED STATES PATENTS
362,135 5/1887 Wilson 335/230
2,941,130 6/1960 Fischer et al. 335/236 X
3,154,728 10/1964 Bordehet 335/227 X
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RE. 26,749 1/1970 Montagu 335/229

Primary Examiner—G. Harris
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[54] **ELECTROMAGNETIC FORCE MOTORS HAVING
EXTENDED LINEARITY**
5 Claims, 2 Drawing Figs.

[52] U.S. Cl. 335/227,
335/230, 335/236
[51] Int. Cl. H01f 7/13
[50] Field of Search 335/227,
229, 230, 236, 237

ABSTRACT: An improvement in electromagnetic force motors in which linearity of the force versus input signal characteristic is extended. Discrete sections of magnetically saturable material are inserted in the flux path between the frames and permanent magnets and have induction/magnetic force characteristics different from the characteristic of the frame material to obtain magnetic saturation paths thereat.



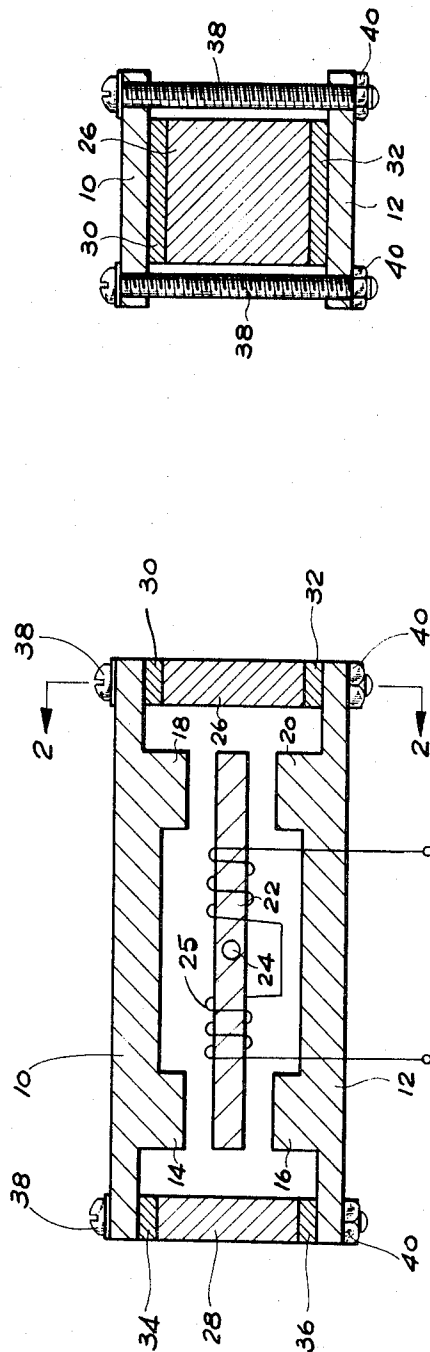


Fig. 2

Fig. 1

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ELECTROMAGNETIC FORCE MOTORS HAVING EXTENDED LINEARITY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The field of art to which the invention pertains includes the field of torque motors.

2. Description of the Prior Art

The use of force motors in the prior art has long been known. One example of the utility of force motors is in the positioning of the pilot valve such as a flapper or spool of an hydraulic servo valve. The force motor in such applications is used as an element of a control system and is adapted by its operating characteristics to convert an electrical input signal into a desired mechanical position of the spool valve. Force motors also have a wide variety of other uses, for example, in automatic control systems for industrial machinery.

Such force motors which utilize a large percentage of the airgap for armature motion are typically faced with non-linearity over all but a small part of the airgap. In various of the prior art applications it has long been desirable to provide force motors which bear a linear relationship to the applied input signal and wherein the force exerted upon the armature remains substantially linear as it approaches the pole faces. This would permit displacement of the armature over the entire gap.

A variety of schemes have been proposed to accomplish such linearization, for example, reducing the effective length of the cross-sectional area of a part of the armature and keeping that portion always saturated magnetically, as illustrated in the U.S. Pat. No. 3,071,174. Another linearization scheme provides recesses on the face of the armature and a plurality of mating teeth on the face of the pole pieces, for example, as shown in U.S. Pat. No. 2,930,945.

Each of the foregoing devices attempts to utilize magnetic saturation to obtain linearization by carefully formulating the configuration of the magnetically permeable material that defines the flux path. Although each of these devices operate for the purpose intended, problems sometimes arise in manufacturing to the close tolerances required to obtain acceptable devices. There is a need, therefore, for a simple means for attaining magnetic saturation appropriate to the linearization of the force versus input signal characteristic of the force motor.

SUMMARY OF THE INVENTION

The present invention provides an improvement in electromagnetic force motors in which linearity of the force versus input signal characteristic is extended. A motor is provided of the electromagnetic force type, that is, having a pair of pole pieces spaced apart by frame members to provide an airgap therebetween, an armature within the airgap and permanent magnet means defining a magnetic circuit. The improvement of this invention comprises providing at least one discrete member of magnetically saturable material between the frame member and permanent magnet means and having an induction/magnetic force characteristic different from the induction/magnetic force characteristic of the frame member. Polarizing flux from the permanent magnet, is sufficient to magnetically saturate the discrete member, but would be insufficient to magnetically saturate that member if constituted of the frame material. In particular embodiments, a plurality of magnetically saturable discrete members is provided to completely separate the frame members from the permanent magnets. The present invention is an improvement over the invention disclosed in U.S. Pat. No. 3,517,360.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic, cross-sectional view of an electromagnetic force motor utilizing the present invention; and

FIG. 2 is a cross-sectional view of the apparatus illustrated in FIG. 1, taken on line 2-2 of FIG. 1, in the direction of the arrows.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the FIGS. there is illustrated in schematic manner an electromagnetic force motor constructed in accordance with the present invention. The force motor includes frame members 10 and 12 which are formed to define oppositely disposed pairs of pole pieces 14, 16 and 18, 20. An armature 22 is supported about a pivot point 24 between the pole pieces. Although not shown in the schematic drawing herein, the armature can support a flapper so as to serve as the first stage of a control valve, all as well known to the art. Further, a coil 25 is positioned about the armature 22 and is adapted to receive an electrical input signal which thereby causes the armature to take a physical position, displaced from the Null position (illustrated), depending upon the strength of the applied input signal and the polarity thereof.

In prior art torque motors, a pair of permanent magnets would be secured between the frame members, directly contacting the frame members. In the present invention, permanent magnets 26 and 28 are also affixed to the frame members 10 and 12, so as to bridge the frame members and provide magnetic flux for the torque motor. However, in the present invention the permanent magnets 26 and 28 are separated from the frame members 10 and 12 by means of inserts 30, 32, 34 and 36, as hereinafter described. The inserts and permanent magnets are secured between the edges of the frame members 10 and 12 by means of machine screws 38 and nuts 40 therefor extending through the edges of the frame members, as shown in the drawings.

The inserts 30, 32, 34 and 36 are of magnetically permeable material having a predetermined induction/magnetic force characteristic which is different from the induction/magnetic force characteristic of the material of which the frame members 10 and 12 are constituted. The induction/magnetic force characteristic of each of the inserts 30, 32, 34 and 36 is such that the magnetic flux from the permanent magnet 10 and 12 is sufficient to magnetically saturate the inserts at a preselected armature 22 position within the airgap between the poles 14, 16 and 18, 20, but is insufficient at that armature position for magnetic saturation if the inserts were constructed of the same material as the frame members 10 and 12. In other words, the inserts 30, 32, 34 and 36 are constructed of material which passes its maximum magnetic induction at a particular position of the armature 22 in the airgap displaced from its Null position.

With prior art torque motors, as the armature approaches one of the pole faces, the reluctance due to the gap decreases, resulting in an increase in flux from the permanent magnet, which increase is proportional to the square of the armature displacement. At the same time, a linearly increased amount of such nonlinear flux passes through the gap. The total result is a flux increase that is nonlinear with respect to armature displacement. However, when the present invention is utilized, as a result of saturation of the inserts 30, 32, 34 and 36, a decrease in reluctance does not effect an increase in flux. Since the gap is decreasing in length the number of flux lines passing therethrough does increase; however, this increase is in linear proportion to such decreasing gap length, i.e., in linear proportion to armature displacement.

What we claim is:

1. In an electromagnetic force motor having a pair of pole pieces spaced apart to provide an airgap therebetween;
 - an armature positioned with a portion thereof in said airgap,
 - said armature being adapted to move in said airgap from a null position thereof thereby more closely approaching one of said pole pieces;
 - a magnetic circuit in said motor including said pole pieces and said armature and including permanent magnetic means for providing polarizing flux and a frame member securing said pole pieces to said permanent magnet means;
 - electrical signal receiving means disposed on said magnetic circuit to establish magnetic flux therein of a strength proportional to a received electrical signal;

the improvement of apparatus for extending the linearity of the force versus input signal characteristic of said force motor, comprising:

at least one discrete member of magnetically saturable material disposed between said frame member and said permanent magnetic means and having an induction/magnetic force characteristic different from the induction/magnetic force characteristic of said frame member so as to define a magnetic saturation path thereat;

said permanent magnet polarizing flux being sufficient to magnetically saturate said discrete member at a preselected armature position other than its null position within said airgap but being insufficient, at said preselected armature position to magnetically saturate

frame member material of the same configuration as said discrete member.

2. The invention as defined in claim 1 in which said frame member is formed integral with said pole pieces.

3. The invention as defined in claim 1 wherein a plurality of said discrete members are disposed between said frame member and said permanent magnetic means.

4. The invention as defined in claim 3 wherein each of said discrete members has the same induction/magnetic force characteristic.

5. The invention as defined in claim 3 wherein said discrete members completely separate said frame member from said permanent magnetic means.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,585,547 Dated June 15, 1971

Inventor(s) Oded E. Sturman et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 33, "3,071,174" should read -- 3,071,714 --.

Signed and sealed this 11th day of April 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents