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ELECTROMAGNETIC ACTUATOR WITH TRANSLATORY ARMATURE MOVEMENT

Original Filed April 2, 1962

2 Sheets-Sheet 1

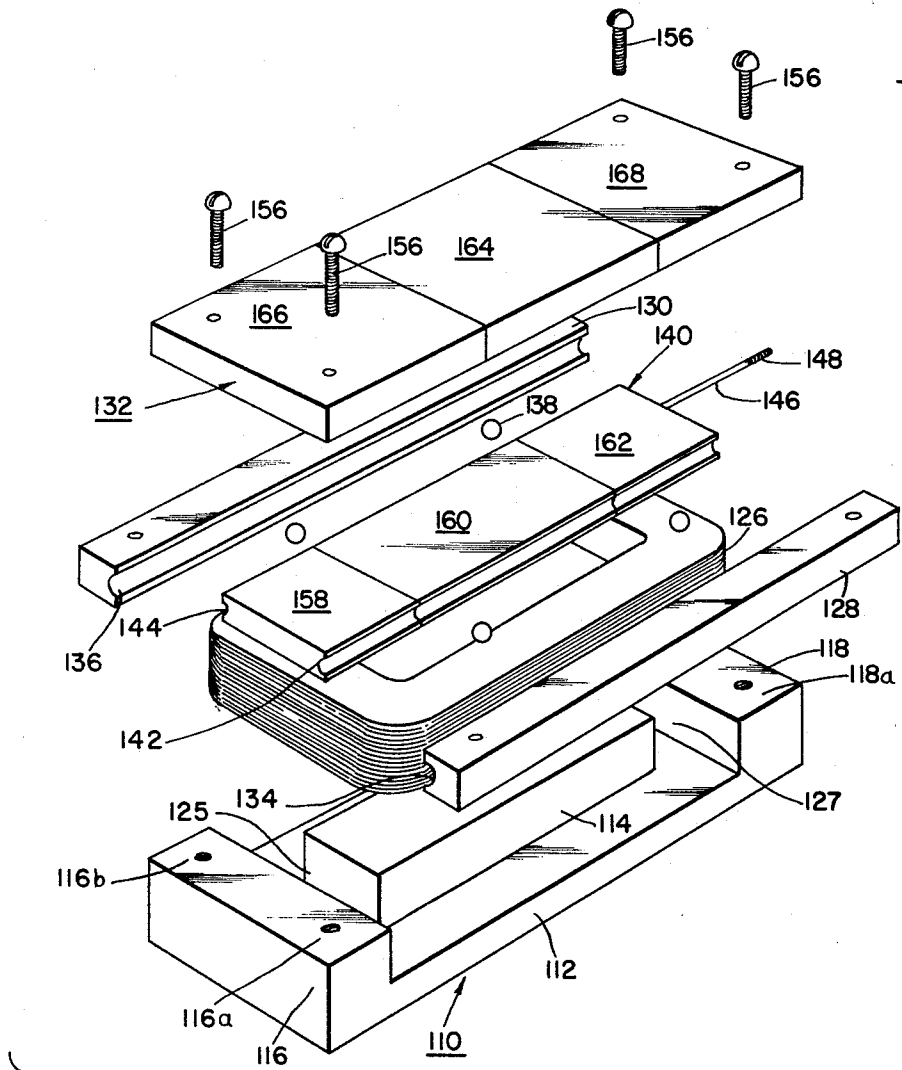
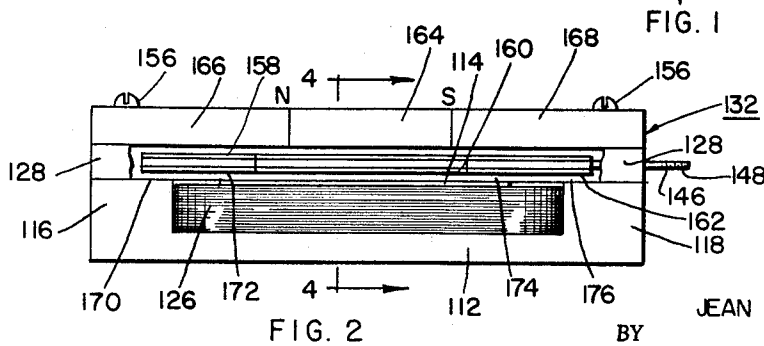


FIG. 1

FIG. 2

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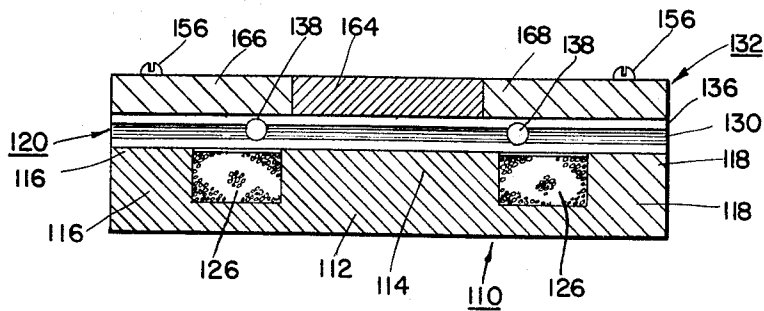


FIG. 3

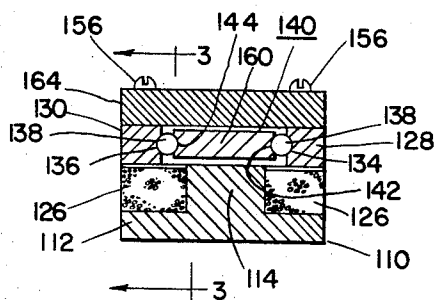


FIG. 4

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ELECTROMAGNETIC ACTUATOR WITH TRANSLATORY ARMATURE MOVEMENT**Jean I. Montagu, Boston, Mass., assignor to Mechanics for Electronics, Inc., Boston, Mass.****Continuation of application Ser. No. 184,162, Apr. 2, 1962. This application Oct. 1, 1963, Ser. No. 312,988 7 Claims. (Cl. 310-12)**

This invention relates to a novel electromechanical transducer. More particularly, it relates to a limited movement electric motor in which an armature of magnetic material undergoes translatable motion in response to the interaction between the fields of a magnet and a control winding.

Electromagnetic transducers generally provide a force which increases as the armature moves in the direction of magnetic pull. However, in many applications this characteristic is not desired.

Other problems encountered in prior translatable motors result from such factors as relatively low efficiency and relatively small force-to-mass and force-to-volume ratios, restricting high frequency capability and bucking the present day trend to miniaturization.

Accordingly, it is a principal object of my invention to provide an improved electromagnetic transducer of the type which converts an electrical input into a translatable motion.

Another object is to provide a transducer of the above type in which the force does not increase as the armature moves in response thereto.

A further object of the invention is to provide a transducer of the above type having a relatively high efficiency. A more specific object is to provide a transducer characterized by relatively low hysteresis.

Another object of the invention is to provide a transducer of the above type characterized by a relatively high force-to-mass ratio and a relatively high force-to-size ratio.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and object of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is an exploded view, in perspective, of a motor incorporating my invention,

FIG. 2 is a side view of the motor of FIG. 1,

FIG. 3 is a longitudinal section of the motor of FIGS. 1 and 2, taken along line 3-3 of FIG. 4,

FIG. 4 is a transverse section taken along line 4-4 of FIG. 2.

In general, my motor makes use of the fact that an armature of magnetic material, i.e., high permeability material, disposed simultaneously in a pair of magnetic gaps and constrained to move perpendicularly to the magnetic fields therein, will move in the direction of the gap having the stronger field. A field magnet is arranged to pass magnetic flux in the same direction through both gaps. A control coil is arranged to pass flux in a path in which the two gaps are in series, so that the flux passes through them in opposite directions. Thus, the two fields are in the same direction in one of the gaps and in opposite directions in the other. It follows that the net field is stronger in the first gap than in the second and the armature therefore moves in the direction of the first gap. If

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the current in the control winding is reversed, the fields add in the second gap and subtract in the first, thereby imparting the opposite motion to the armature.

These general principles are not new with the present invention. Rather, it is the structure in which they are embodied that is novel. This structure uses a control coil and field magnet to move two mechanically linked armatures rather than a single armature. The size of the motor is therefore reduced. Furthermore, the motor has been found to have a relatively high efficiency, and it is characterized by a good force-to-mass ratio, as evidenced by its operation with essentially undiminished output amplitude up to a frequency of 200 cycles per second.

Referring first to FIG. 1, my motor is seen to have a base generally indicated at 110 of magnetic material. The base 110 comprises a lower platform 112, a central pedestal 114 and end columns 116 and 118, all of which may be integrally cast as a single unit. A control coil 126 is shaped to fit snugly around the pedestal 114 and in the slots 125 and 127 between the pedestal and columns 116 and 118. A pair of longitudinal slide members 128 and 130, preferably of non-magnetic material, extend between the columns 116 and 118, resting on ends 116a and 118a, and 116b and 118b, thereof. The slide members support a top plate generally indicated at 132.

Referring to FIGS. 1, 3 and 4, a pair of longitudinal grooves 134 and 136 in the inwardly facing surfaces of the members 128 and 130 accommodate balls 138 (see FIGS. 3 and 4) which serve as bearings between the slide members and an armature assembly generally indicated at 140. The balls ride in grooves 142 and 144 in the armature assembly, and in this manner they support the assembly and provide for longitudinal motion thereof. The motor is completed by a drive linkage indicated at 146, pivotally connected to the assembly 140 and provided with a threaded stud 148 to facilitate connection to a member (not shown) driven by the motor. When the parts shown in FIG. 1 are assembled, the motor presents the side view shown in FIG. 2.

It will be noted that the armature assembly 140 translates to the right or left (FIG. 3) with only rolling friction, there being a substantially complete absence of the sliding friction. Furthermore, the armature supporting structure, with the balls 138 working against the grooves 134, 136, 142 and 144, maintains the armature assembly in a stable orientation with respect to the stationary parts of the motor in spite of the very substantially magnetic forces tending to skew the assembly 140, i.e., rotate it about the vertical and horizontal axes. The motor is held together by screws 156 of non-magnetic material, passing through the top plate 132 and members 128 and 130, and threaded into the end columns 116 and 118.

As seen in FIG. 2, the armature assembly 140 includes an armature 158 overlapping the column 116 and pedestal 114, a central section 160 over the pedestal 114, and an armature 162 overlapping the pedestal 114 and column 118. The armatures 158 and 162 are of soft magnetic material, and the control section 160 is of non-magnetic material, such as brass, brazed to the armatures. The top plate 132 includes a centrally disposed permanent magnet 164 and a pair of end sections 166 and 168 of magnetic material.

Operation of the motor will now be described with respect to FIG. 2. Assuming the indicated polarity of the magnet 164, a bias field from this magnet extends from the section 166 downwardly into the armature 158 and then through air gaps 170 and 172 into the column 116 and pedestal 114. The field passes to the right in the base 110 and then upwardly from the pedestal 114 and column 118 into the armature 162 by way of air gaps

174 and 176. From the armature 162 the field then returns to the magnet 164 by way of the end section 168. It will be observed that the field of the magnet 164 has equal strength at the gaps 170 and 172 and also the gaps 174 and 176, assuming equal thicknesses in the gaps of each pair. Also, the total air gap flux is independent of the position of the armature, as will be seen by the fact that the total area of the air gaps 170 and 172 is unchanged by armature movement. Therefore, this field alone imparts no longitudinal force to the armature assembly 140.

Next consider the effect of a current in the coil 126 creating a second field whose direction is up in the pedestal 114 and down in the columns 116 and 118. This field passes upwardly in the gap 172, into the armature 158 and then downwardly through the gap 170. Similarly, it passes upwardly in the gap 174 and downwardly through the gap 176. In the gaps 170 and 174 the direction of the second field, which may be termed a control field, is the same as that of the bias field from the magnet 164. Conversely, in the gaps 172 and 176, the direction of the control field is opposite to that of the bias field. Therefore, the net field in the gaps 170 and 174 is greater than in the gaps 172 and 176, and this gives rise to forces urging the armatures 158 and 162 to the left (FIG. 3). If the direction of the control field is reversed, as accomplished by a reversal of the current in the coil 126, the armature assembly 120 is urged to the right.

Neglecting secondary effects such as fringing, the force exerted on the unit comprising the armatures 158 and 162 decreases in the direction of travel in response to such force. This occurs approximately as long as they overlap both the pedestal 114 and the columns 116 and 118, respectively. In practice, secondary effects encountered as the ends of the armatures approach the ends of the air gaps may limit this range somewhat.

It will be apparent that the ball-containing grooves 134, 136, 142 and 144 need not have a circular cross section. For example, they may be parabolic, V-shaped or they may even be formed by pairs of longitudinally extending rods attached to the armature assembly 140 and slide members 128 and 130. Thus, the term "grooves" as used herein includes any ball-containing structure operating in the above manner.

It is generally preferable that the biasing magnet 164 be a permanent magnet rather than an electromagnet. In particular, it is preferably a permanent magnet having a high reluctance, such as Alnico V. Thus, the magnet isolates the end sections 166 and 168 from each other. This, in turn, provides that only a negligible portion of the control field from the coil 126 passes into the top plate 132; rather the control field passes longitudinally through the armatures 158 and 162 in going between the pedestal 114 and the columns 116 and 118.

If a low reluctance electromagnet is used as a bias source, a significant portion of the control field will pass through the plate 132 when the armature assembly 140 is displaced from its center position. This may detract from the desired operation characteristics of the actuator.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention, which, as a matter of language, might be said to fall therebetween.

This application is a continuation of my pending application Serial No. 184,162, for Linear Actuator, filed April 2, 1962.

I claim:

1. An electromagnetic transducer comprising, in combination, a base member of magnetic material having first, second and third projections defining a first slot between said first and third projections and a second slot between said second and third projections, an armature assembly comprising a first armature bridging said first slot and closely spaced from said first and third projections and a second armature bridging said second slot and closely spaced from said second and third projections, said armatures and projections forming first and second gaps between said first armature and said first and third projections and third and fourth gaps between said second armature and said second and third projections, nonmagnetic means mechanically coupling said armatures whereby they move as a single unit, means for directing a first magnetic field in one direction through said first and second gaps and in the opposite direction through said third and fourth gaps and means for directing a second magnetic field in one direction through said second and third gaps and in the direction opposite thereto in said first and fourth gaps, said means for directing said first field and said means for directing said second field being stationary with respect to said base member.

2. The combination defined in claim 1 including first and second members extending in the direction of travel of said armature assembly, said armature assembly being disposed between said members, means forming opposing grooves in said armature and said members, balls in said grooves providing bearings accommodating movement of said armature in said direction of travel.

3. The combination defined in claim 1 in which said means for directing a second field comprises a coil around said third projection and passing through said slots.

4. The combination defined in claim 3 including a cover plate bridging said third projection and said slots, the magnetic path between said cover plate and said base member that has minimum reluctance including said first, second, third, and fourth gaps, said armature assembly being disposed between said cover plate and said base members, said means for directing said first magnetic field comprising a magnet in said cover plate disposed between first and second sections thereof overlying said armatures, whereby flux from said magnet passes from said first section into said first armature and from said second armature into said second section.

5. An electromagnetic transducer comprising, in combination, a base member of magnetic material having first, second and third aligned projections defining first and second slots between said first and third and second and third projections respectively, a cover plate extending over said projections, the magnetic path between said cover plate and said projections that has minimum reluctance including said gaps, said cover plate having a first end section extending over said first and third projections, a second end section extending over said second and third projections and a magnet linking said end sections, said end sections being of low reluctance magnetic material, an armature assembly disposed between said cover plate and said projections and spaced therefrom, said armature assembly including a first armature bridging said first slot and a second armature bridging said second slot, said armatures being of magnetic material, said armature assembly also including a portion of nonmagnetic material joined to said armatures so that they move as a single unit, and a coil disposed around said third projection and passing through said slots.

6. The combination defined in claim 5 including a pair of elongated members extending along the direction of travel of said armature assembly and disposed on opposite sides of said armature assembly, said armature assembly having longitudinal grooves facing longitudinal grooves in said members, balls contained by said grooves, said balls supporting said armature assembly from said

members and providing a bearing for movement of said armature assembly.

7. The combination defined in claim 6 in which said members extend between said first and second projections, and including means securing said top plate to said members and securing said members to said first and second projections. 5

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MILTON O. HIRSHFIELD, *Primary Examiner.*