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Hoshina et al.

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[45] **Dec. 11, 1973**

[54] **SCREW DRIVING APPARATUS HAVING MAGNET NUT**

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[21] Appl. No.: **225,196**

[30] **Foreign Application Priority Data**

Feb. 18, 1971 Japan 46/5376

[52] **U.S. Cl.** .... **74/424.8 R,** 310/80
[51] **Int. Cl.** **H02k 7/06**
[58] **Field of Search** .... 74/424.8 R, 210, 74/409; 310/80, 103, 15, 84; 318/135

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Assistant Examiner—Allan Russell Burke
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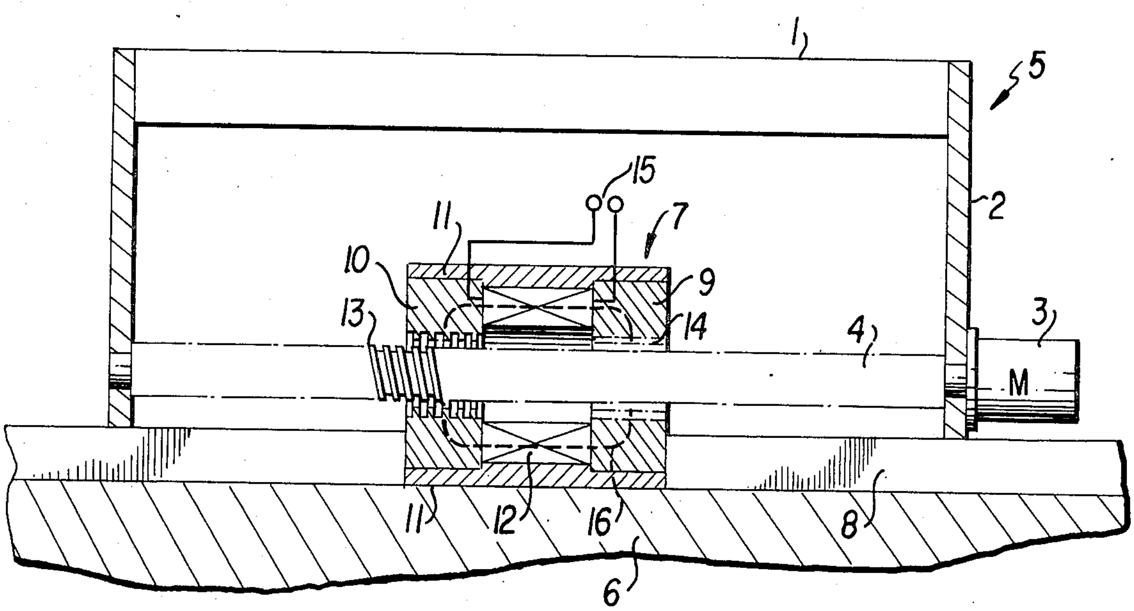
[57] **ABSTRACT**

A continuously threading drive screw made of a paramagnetic material is magnetically surrounded in a nut being radially spaced to operate a determinate reciprocable non-engaging movement of one with respect to the other by rotation of the drive screw, said nut being threaded the same as the drive screw and having at least to magnetic pole pieces, and being provided with means for energizing the pole pieces.

12 Claims, 10 Drawing Figures



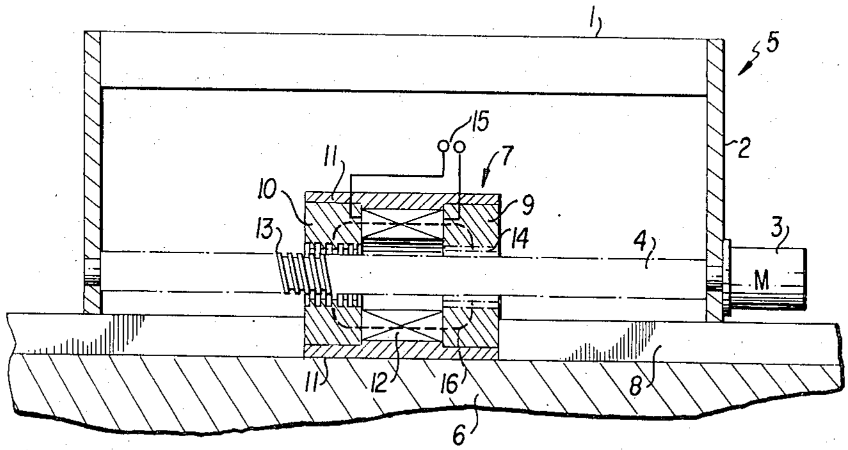


FIG.1

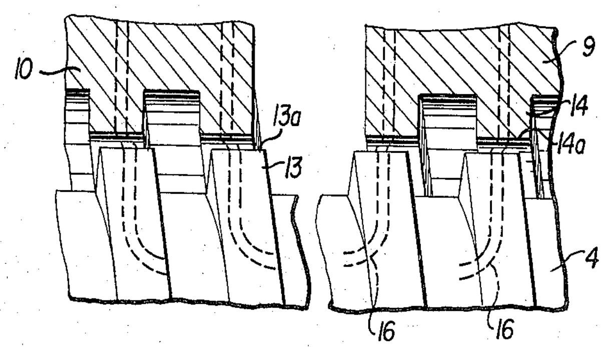


FIG.2

FIG.4

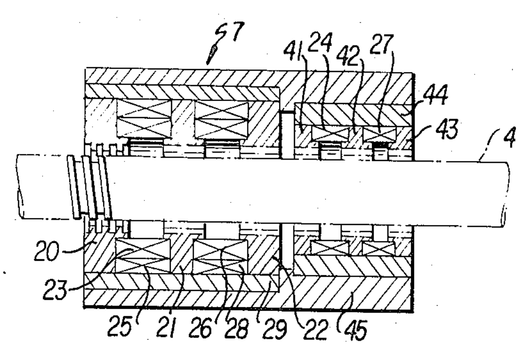
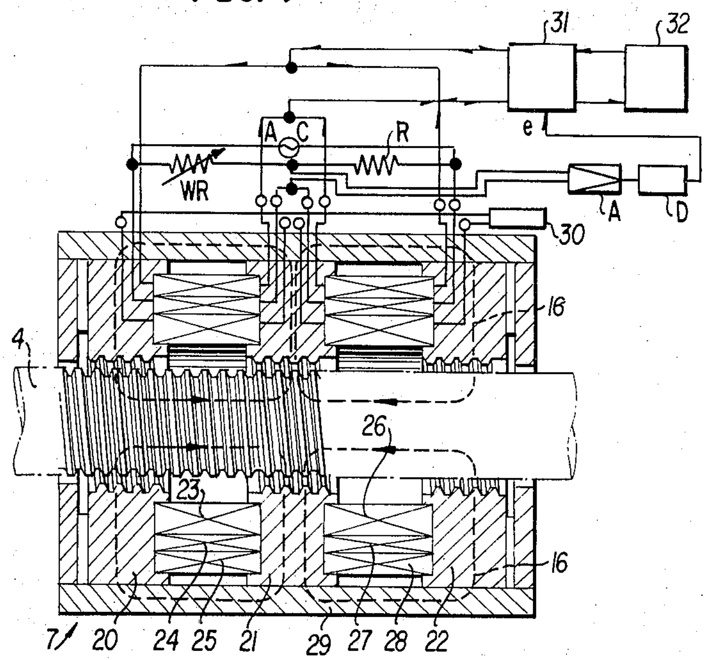


FIG. 3



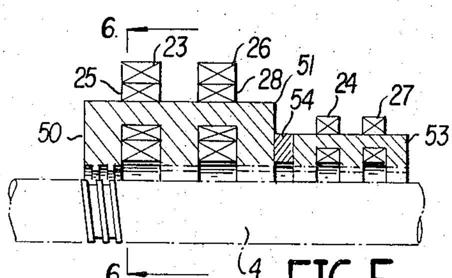


FIG. 5

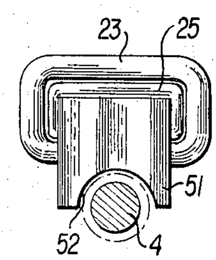


FIG. 6

FIG. 9

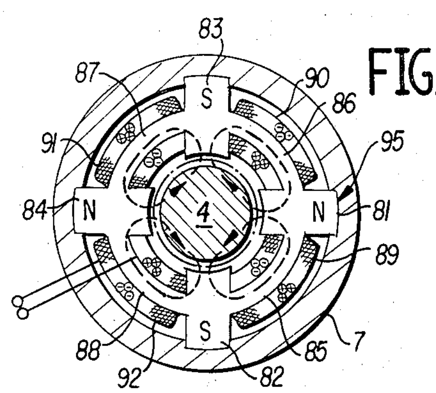


FIG. 10

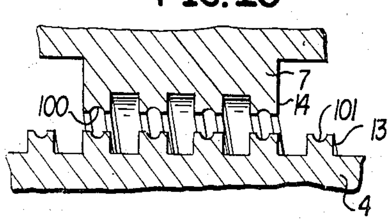


FIG. 7

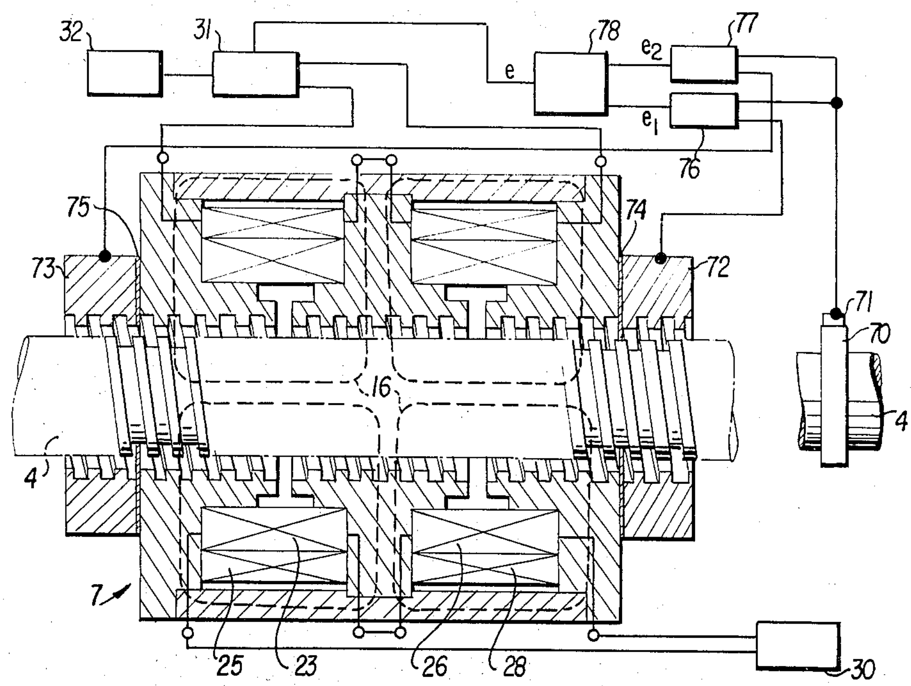

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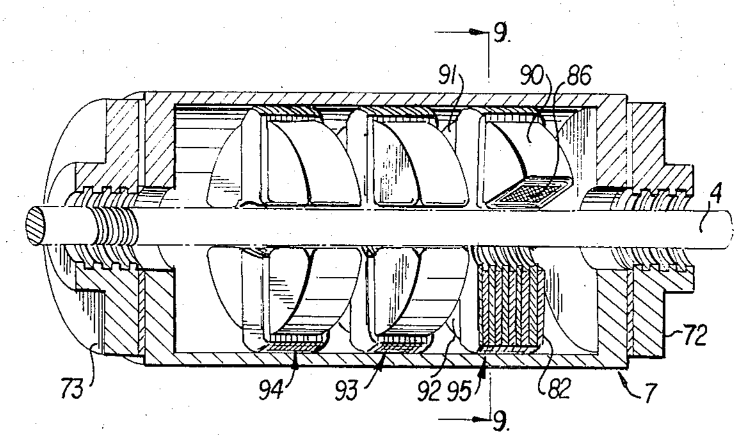
FIG. 8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SCREW DRIVING APPARATUS HAVING MAGNET NUT

BACKGROUND OF THE INVENTION

1. Field Of The Invention

This invention relates generally to screw driving mechanisms, and more particularly to a continuously threaded screw driving apparatus having a magnetic nut.

2. Description Of The Prior Art

Conventionally, in driving apparatus of the character described which have been used to automatically drive a work table or cutter table of a manufacturing machine, the driving screw and nut being employed have been operated by a mechanical thread engagement with friction. In these driving mechanisms, however, the threads of the drive screw and nuts are susceptible to becoming worn, and additionally they have required too much power in the form of sliding frictional engagement being generated in the axial direction on the thread faces. Therefore, to insure precise movements, even expensive screws and nuts must often be changed because of the wearing of their threads. For these reasons, conventional threaded screw driving mechanisms have proven to be very uneconomical and to possess too many defects, and although attempts to avoid such shortcomings have been made, such as, for example, using a driving screw of the ball type which has little friction, the same problems have continued to occur.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved threaded screw driving apparatus being less susceptible to wear and therefore having longer life while providing precise operation.

Another object of the present invention is to provide a threaded screw driving apparatus in which friction between the screw and the nut is substantially eliminated for increasing the resistance of the device to wear.

Still another object of this invention is to provide a threaded screw driving mechanism which is extremely precise in operating characteristics, durable in use and relatively economical to manufacture.

The foregoing and other objects are attained according to one aspect of the present invention through the provision of a continuously threaded driving screw which is made of a paramagnetic material journalled in a linearly movable member and being magnetically surrounded within a stator nut which is threaded the same as the driving screw and is provided with at least two magnetic pole pieces. The threads of the screw and the nut do not mechanically engage, but are radially spaced, so that upon the generation of a magnetic flux therethrough, rotation of the driving screw by a drive motor will result in linear movement of the movable member with the driving screw moving axially through the nut without frictional engagement.

BRIEF DESCRIPTION OF THE DRAWING

Various other objects, features and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood from the following detailed description, when considered in connection with the accompanying drawings, wherein like reference numerals designate like or corresponding parts, and in which:

FIG. 1 is a schematic front view of a standard automatically positioning manufacturing machine embodying a driving mechanism according to this invention;

FIG. 2 is an enlarged view of the screw and nut portion of the mechanism shown in FIG. 1;

FIG. 3 illustrates another embodiment of the invention having a control circuit consonant therewith;

FIG. 4 shows still another embodiment of the present invention;

FIG. 5 illustrates yet another embodiment of the invention;

FIG. 6 is a cross-sectional view taken along the section line 6—6 in FIG. 5;

FIG. 7 illustrates the invention with a different control circuit;

FIG. 8 is another embodiment of the invention featuring modified pole piece structure;

FIG. 9 is a cross-sectional view taken along the line B—B in FIG. 8; and

FIG. 10 is a cross-sectional view of a modified thread construction being used in the driving mechanism of the present invention.

DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Referring now to the Drawings, and more particularly to FIG. 1, an automatic positioning machine is illustrated as having a work table 1 mounted on a frame 2 to which is secured a driving motor 3 for rotating a continuously threaded drive screw 4 journalled at both ends in the frame 2. A nut 7, or stator means, which can be magnetically excited by an electric power source, loosely receives the drive screw 4 and is fixed onto a base 6. In carrying out the present invention, the driving apparatus thus is composed of a drive screw 4 and an actuated part generally designated by the reference numeral 5 mounted for linear movement with respect to a guide rail 8 slidably engaged by the frame 2. Upon rotation of the drive screw 4 by the driving motor 3, which may be a pulse motor controlled by an electric pulse signal obtained from a numerical control system, therefore, the actuated part being composed, in addition to the drive screw 4, of the motor 3, the frame 2 and the work table 1 is reciprocably moved by the control signal data.

The drive screw 4 preferably has the square type thread 13, shown in FIG. 2, at regularly spaced intervals, although the thread is not limited to the shape illustrated. The nut 7 is threaded with the same constant thread pitch and shape as the thread of the drive screw, but has a thread of a larger inner diameter than the outer diameter of the drive screw. It is further provided with two magnetic pole pieces 9 and 10 which form the threaded portion thereof being supported and spaced by a substantially tubular spacer 11 which is made of a paramagnetic material, and a co-axial exciting coil 12 wound between the poles 9 and 10 within the spacer 11 and connected to terminals 15.

An enlarged view of the threaded portion of this invention is shown in FIG. 2. The threads of each of the poles 9 and 10 are spaced a distance being a noninteger multiple against the threads of the drive screw.

When the coil 12 is electrically excited or energized by a power source applied to the terminals 15, a magnetic flux is produced, being passed through the pole 9, the spacer 11, the pole 10, and the drive screw 4, as shown by the reference numeral 16.

The thread face 14*a* of each of the pole pieces 9 and 10 is not directly opposed against the thread face 13*a* of the drive screw 4. Instead, as shown in FIG. 2, the thread of the pole piece 9 is slightly shifted in a rightward direction as seen in this Figure, and the pole piece 10 is shifted slightly in a leftward direction, as viewed in the Figure, of the threads of the screw 4. Therefore, the magnetic flux lines in the gaps between the threads 13 and 14 are inclined toward the direction of the nut center. This causes the threads 13 and 14 to become almost balanced to provide a minimum reluctance path through the drive screw 4. Thus, the magnetic nut 4 is restrained and balanced on the drive screw 4 at a steady position which can be controlled, whereby the work table 1 may be linearly moved in the axial direction of the screw by the driving motor 3 affixed thereto.

As described, the driving apparatus may suffer from one slight deficiency, namely, that when an external force, for example, the inertial force generated by an acceleration or a deceleration, is inflicted on the actuated part 5, the positioning control may become inaccurate and cause some error.

In FIGS. 3 to 9, therefore, other embodiments yet more improved over the embodiment of this invention just described are shown in detail.

FIG. 3 shows a nut 7 which is composed of three pole pieces 20, 21 and 22 being made of paramagnetic material in a ring-shaped configuration, a pair of sets of three coils each designated as 23, 24 and 25, and as 26, 27 and 28, respectively, being wound between the side pole piece 20 and the center pole piece 21 and between the side pole piece 22 and the center pole piece 21, respectively, and a tubular shaped spacer 29 supporting the three pole pieces 20, 21 and 22 and being made of a paramagnetic material. The thread faces of the pole pieces 20 and 22 are not directly opposed against the thread face of the screw 4, but the thread face of the pole piece 21 is directly opposed to the thread face of the screw 4, as shown in FIG. 3.

The pole pieces 20 and 22 are magnetized N and the pole piece 21 is magnetized S by the inside coils 23 and 26 of the sets of coils being energized by a power source 30. The middle coils 24 and 27 of the coil sets are one part of the detector for detecting the change of inductance being generated by any displacement of the actuated part. The outside coils 25 and 28 of the coil sets are used for controlling the position of the actuated construction part 5 through a control circuit 31.

The middle coils or detector coils 24 and 27, which are connected to a variable resistor WR and a resistor R in series, constitute a bridge circuit of which the input signal is an alternating current signal from source AC and the output signal is fed to a displacement detector circuit D through an amplifier A. If the bridge circuit becomes unbalanced, the displacement detector circuit D generates an output signal *e*, which is fed to the control circuit 31. Therefore, since the power of control circuit 31 is applied to the controlling coils 25 and 28, a direct current power source 32 can be controlled by the output signal *e* of the detector circuit D.

In the operation of the driving apparatus shown in FIG. 3, for considering the case where the actuated construction part 5 receives an external force, such as a force produced by inertia, if the coils 24 and 27 are energized in equal currents respectively, the thread face of the center pole 21 will directly oppose the drive screw thread face and the thread faces of both side poles 20 and 22 will provide balanced different pitch positions for the drive screw thread face. In such a condition, the bridge circuit is adjusted by the variable resistor WR so that the output signal becomes zero. If the actuating construction part 5 is slightly moved by an external force or the like, the displacement of the one side pole thread against the screw thread is decreased, while the other side is increased. Namely, the inductance of the one side coil 24 will increase and the other side coil's inductance, namely, that of coil 27, will decrease. Then the bridge circuit will generate the AC signal, which is amplified by the amplifier A and is converted to the output signal e of negative or positive direct current by the displacement detector D. The displacement of the actuated construction part 5 is compensated by the control coils 25 and 28 being energized by the DC power source 32 through the control circuit 31, which is controlled by the signal *e*.

Thus, the actuated construction part 5, that is, the work table 1 and the other related elements, can be linearly precisely moved by the rotation of the drive screw.

FIG. 4 shows another embodiment of this invention, being different from the embodiment shown in FIG. 3 in that the middle detector coil means is separated from the combination of the inside and outside coils for restricting and controlling position through a magnetic insulator 45. The displacement detector coils 24 and 27 are wound between pole pieces 41 and 42 and between pole pieces 42 and 43, respectively, which are supported by a tubular spacer 44 made of a paramagnetic material and being of desired length. Thus, a nut portion supported by the sleeve 29 which is for restricting and controlling and a second nut portion supported by the sleeve 44 which is for detecting are both supported by an outer insulating sleeve 45 providing a desired separation.

A driving apparatus using such a magnetic nut can be accurately operated, since the magnetic flux lines generated by the restricting coils and/or the controlling coils are not distributed to influence the detector coils.

Still another embodiment of this invention is shown in FIGS. 5 and 6. In this case, a magnetic nut generally designated by the reference numeral 50 is provided with two cores 51 and 53, being E-shaped in cross-section as shown in FIG. 5, made of silicon steel plates. The threads 52 of the pole pieces are formed in a shape corresponding to a half-cylindrical portion of a conventional nut, or being sliced through along a diametrical plane. Each of the sets of coils 25, 28 and 24, 27 are wound, respectively, in the narrow portions of the cores 51 and 53. Between the cores 51 and 53 and spacing the same is a spacer 54 made of a non-magnetic material for magnetically insulating the cores, such as, for example, aluminum. The magnetic nut 50 can be used in the form of a pair of nuts, as shown, being disposed so that the thread faces of the pole pieces oppose the threads around the drive screw 4.

The embodiment illustrated in FIG. 7 modifies the detecting system of this invention. The displacement detection of this embodiment uses a capacitance type displacement detector which is provided with a ring or flange 70 disposed on the end of the drive screw 4, a brush 71 electrically engaging the flange 70, a pair of nuts 72 and 73 which are used for detecting capacitance being secured respectively to the opposite sides of the primary paramagnetic nut 7 and spaced therefrom by insulators 74 and 75 which are made of non-conductive materials. The threads of the detector nuts 72 and 73 have the same spacing and thread pitch as the threads of the side pole pieces.

Between the pair of nuts 72 and 73 and the drive screw 4 there is a capacitance which is electrically led by lead wires to displacement detector circuits 76 and 77 that can be used to produce the signals e_1 and e_2, respectively, in proportion to a change of the capacitance or the displacement of the actuated means. The direction and quantity of the displacement of the actuator are calculated through a calculator 78 to which the signals e_1 and e_2 are applied. Thus, the calculator 78 produces an output of control signals e which is supplied to the control circuit 31 for controlling the current being passed through the controlling coils 25 and 28.

FIGS. 8 and 9 shown an embodiment in which each of the pole pieces are formed of four poles 81, 82, 83 and 84 and four arms 85, 86, 87 and 88 in each sheet being comprised of side-by-side silicon steel plates. The magnetic nut 7 is composed of a combination of three such pole pieces. On the arms 85 through 88, coils 89, 90, 91 and 92 are wound for causing the poles 81 and 84 to be magnetized N and the poles 82 and 83 to be magnetized S, as shown in FIG. 9 by dotted lines. The center pole piece 93 in the nut 7 is used for restriction on the drive screw 4 and both side pole pieces 94 and 95 are used for restriction and controlling. On the ends of the pole pieces, threaded nuts 72 and 73 are provided, the same as in the embodiment described above in FIG. 7.

A modified thread portion of the nut 7 and drive screw 4 is shown in FIG. 10. Here, the threads 13 and 14 have ditches or grooves 100 and 101 formed on the thread surfaces 13*a* and 14*a*, respectively. According to this construction, a magnetic force occurs on both threads 13 and 14 in order to concentrate the magnetic flux flow.

Obviously many modifications and variations of the present invention are possible in light of these teachings. It is to be understood, therefore, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A driving apparatus for producing a linear movement between an actuated means and a stator means comprising:
- a stator means;
- an actuated means;
- a drive screw mounted on one of said actuated means and stator means being continuously formed with equally spaced threads;
- at least one nut means mounted on the other of said actuated means and stator means being formed to provide at least two pole pieces;
- winding means magnetically associated with said pole pieces;
- each of said pole pieces having an inner diameter pole surface formed with equally spaced threads the same as the threads of said screw;
- restricting means comprising at least two of said pole pieces for effecting a stationary restriction of said actuated means, said restricting means includes a fraction of the thread pitch of said actuated means; and
- drive means for rotating said drive screw.

2. A driving apparatus as defined in claim 1, comprising;
- detector means generating a control signal proportional to the displacement of said actuated means and mounted on said nut; and
- control means electrically connected to said detector means for compensating the displacement of said actuated means and being controlled by said control signal.

3. A threaded driving mechanism for producing linear movement of one threaded part with respect to another threaded part, comprising:
- a linearly moveable support;
- a continuously threaded drive screw suitably journaled for rotation in said linearly moveable support, said drive screw being formed of a magnetic material;
- a stator nut having at least two pole pieces axially spaced along said drive screw and being threaded for non-engagingly receiving said drive screw;
- at least one exciting coil disposed between said at least two pole pieces;
- means for energizing said at least one exciting coil; and
- means for rotating said drive screw to cause said linearly movable support to move linearly with respect to said stator nut.

4. A threaded driving mechanism according to claim 3, further comprising spacer means for supportingly spacing said at least two pole pieces, said spacer means being formed of a magnetic material.

5. A threaded driving mechanism according to claim 3, wherein said at least two pole pieces are substantially tubular in configuration the threaded inside diameter of which is larger than the threaded outside diameter of said drive screw.

6. A threaded driving mechanism according to claim 3, wherein said threads of said drive screw and said at least two pole pieces are square-type threads, and said threads of said drive screw are so displaced axially of said threads of said pole pieces that the magnetic flux lines produced in the gaps therebetween are inclined toward the center of said stator nut.

7. A threaded driving mechanism according to claim 3, wherein said stator nut is composed of three pole pieces axially spaced along said drive screw, and each adjacent pair of said three pole pieces has a set of three coils radially arranged between about said drive screw.

8. A threaded driving mechanism according to claim 7, further comprising:
- power means for energizing the radially inside coils of each set of three radially arranged coils for magnetizing the outside pole pieces of said three pole pieces N and the inside pole pieces of said three pole pieces S;
- detector means for detecting inductance changes being connected to the middle exciting coil of each set of three radially arranged coils; and
- control means connected to the radially outside coils of each set of three radially arranged exciting coils and to said detector means for controlling the position of said linearly movable support.

9. A threaded driving mechanism according to claim 3, wherein said stator nut is composed of two nut portions, one of said two nut portions having three axially spaced pole pieces with each adjacent pair of said three

pole pieces having a set of two coils radially arranged therebetween about said drive screw, the other of said two nut portions having three axially spaced pole pieces with each adjacent pair of said three pole pieces having an exciting coil disposed therebetween and about said drive screw;

magnetic insulative means for supporting said nut portions in fixed axially spaced relation;

detector means connected to the coils in the other of said nut portions for detecting inductance changes caused by inertial displacement; and

control means connected to the coils of said one of said nut portions and to said detector means for controlling the position of said linearly movable support.

10. A threaded driving mechanism according to claim **9**, wherein said nut portions are substantially semi-cylindrical in configuration.

11. A threaded driving mechanism according to claim **7**, wherein the threads of the outer pole pieces of

said three axially spaced pole pieces are displaced axially of the threads of said drive screw such that the magnetic flux lines produced in the gaps therebetween are inclined toward the center of said stator nut, and the threads of the central pole piece of said three axially spaced pole pieces directly oppose the threads of said drive screw.

12. A threaded driving mechanism according to claim **3**, wherein said stator nut is composed of three pole pieces axially spaced along said drive screw with each adjacent pair of said three pole pieces having a set of two coils radially arranged therebetween about said drive screw, and a pair of capacitance detecting nut means are respectively secured to opposite sides of the stator nut being insulatively spaced therefrom for detecting the capacitance between said nut means and said drive screw, whereby such capacitance may be conducted to control means for controlling the movement of said linearly movable support means.

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