

Title: COMMUTATED MOVING COIL LINEAR MOTOR

This invention relates to commutated moving-coil linear motors which are applicable to various carrying, conveying and transporting means.

5 Commutated moving-coil linear motors of the kind referred to may be effectively contributive, for example, to remote-controlled or automated opening and closing of curtains and are formed to be small and bilaterally shiftable within a guide frame with curtain
10 rings, so as to constitute a carrying means for the curtains through the curtain rings.

Linear motors have been increasingly widely utilised as carrying, conveying and transporting means in recent years, and are generally classified into moving-magnet
15 type and moving-coil type. In U.S. Patent No. 4633108 of J. von der Heide et al, there is shown a linear motor of the moving-magnet type in which a permanent magnet plate is shiftable in magnetic gaps formed in magnetic circuits of a plurality of linearly disposed
20 electromagnetic devices. In this moving-magnet linear motor, however, there has been a problem that the electromagnetic devices acting as a stator means are required to be always supplied with electric power so that electromagnetic coils of the respective devices are
25 always kept in a heat generating state so that heat generation is increased.

In another U.S. Patent No. 4151447 of J. von der Heide et al, on the other hand, a moving-coil linear motor is disclosed in which permanent magnets as the stator means
30 are disposed in two rows and flat armature coils of two-

phase motor are disposed to be movable within a magnetic gap between the rows of the permanent magnets. In this arrangement, the electric power is supplied to the movable flat coils only when they are driven as a mover
5 means so that the heat generation of the coils may be reduced to a large extent. With this arrangement, however, the flat coils movable in the magnetic gap between the two rows of the permanent magnets require the magnetic gap to be of a size larger than the
10 thickness of the flat coils so as to be defective in that the magnetic efficiency is lowered and the entire size of the motor has to be enlarged. Further, this motor shows the use of the flat armature coils but is not suggestive to the provision of cores, so that there
15 remains a problem that magnetic efficiency cannot be sufficiently improved in this respect.

In still another U.S. Patent No. 4439698 of Der-Jong Chen, a moving-coil linear motor is shown to comprise a rail assembly having a power supply pattern and a
20 solenoid assembly of three-phase coils formed to be movable along the rail assembly. This linear motor is a so-called reluctance type in which no permanent magnet is employed but a ferro-magnetic piece is included in the rail assembly to be attracted by the solenoid
25 assembly for its movement. Since the motor of this reluctance type is relatively low in torque, there involves a problem that the entire motor size has to be made larger in order that a larger torque is to be attained, in addition to an inherent drawback that the
30 magnetic efficiency cannot be sufficiently increased due to the absence of any core. Further, the moving solenoid assembly is so formed as to surround the rail

assembly, so that there is still another problem that any support member cannot be provided to the rail assembly at its intermediate position except for both end portions and an elongated rail assembly becomes
5 insufficient in respect of support strength.

In the case of a further moving-coil linear motor disclosed in U.S. Patent No. 4641065 of Osamu Shibuki et al, a two-phase moving coil assembly U-shaped in section is mounted on a stator means of an array of plate-shaped
10 permanent magnets magnetised to have opposite polarities in their thickness direction, so that the U-shaped coil assembly will enclosingly oppose substantially three consecutive side faces of the permanent magnets, and an exciting current is supplied to this moving coil
15 assembly through brushes from a power feeding pattern provided along the permanent magnet array. An arrangement in which this linear motor of Shibuki et al is applied to curtain opening and closing has been disclosed in Japanese Utility Model Application Laid-
20 Open Publication No. 1-103385 of Shigeru Sakagami et al, assigns to the same assignee as in the present case. In this linear motor and applied arrangement, however, no technique of employing any core in the moving coil assembly while keeping the assembly compact has yet been
25 reached and the problem that the magnetic efficiency cannot be remarkably improved has been still left unsolved.

According to an embodiment in the foregoing U.S. Patent No. 4633108 of J. von der Heide et al, in addition,
30 there is disclosed a moving-coil linear motor, in which a mover means is formed by winding coils in three phase system on respective three pole shoes in a series with

respect to a core, and this mover means is disposed to oppose through a magnetic gap a stator means including a row of permanent magnets and to be movable along this stator means. While this motor includes the core in the moving coils of the mover means, the core is shown to be merely opposed at one surface to one surface of the permanent magnets with the magnetic gap interposed, and the magnetic circuit is caused partly to have a relatively long path lying across the other surface of the core and the other surface of the permanent magnets, so that there still has remained the problem that the magnetic efficiency is not sufficiently improved. Further, in this linear motor, the core is made common throughout the three-phase coils so that there has been a problem in that the core has to be large enough for not allowing the linear motor to have a curved path of a relatively small radius.

A primary aim of the present invention is, therefore, to provide a moving-coil linear motor which is provided with cores in the moving coils to remarkably increase the magnetic flux density in the gap for extremely effective improvement in the magnetic efficiency, while still realising dimensional minimisation of the entire motor to a sufficiently satisfiable extent.

According to the invention, there is provided a commutated moving-coil linear motor comprising a stator means including a permanent magnet array disposed in said stator means to extend in the longitudinal direction thereof and magnetised to have opposite poles in the direction of the width of said array and also in the longitudinal direction of the array opposite poles

alternately at regular intervals, and a mover means mounted for movement along the stator means by means of an electromagnetic force, said stator means having therein a power feed pattern disposed to extend in the
5 longitudinal direction of the stator means, said mover means including three-phase cores, U-shaped in section for opposing at both leg parts of said U-shape both side faces of said permanent magnet array of said stator means disposed between said both leg parts, and three-
10 phase moving coils wound on both leg parts of said cores in bipolar system with end portions of the leg parts extending from the coils, the power feed pattern in said stator means applying through brushes to said moving coils alternately positive and negative voltages for
15 exciting electromagnetically both leg parts to provide thereto sequentially magnetic repulsion and attraction with respect to both side faces of the permanent magnet array.

The invention will now be described in detail, by way of
20 example, with reference to the drawings, in which:-

Figure 1 is a fragmentary perspective view of one embodiment of a moving coil linear motor according to the present invention, with part cut away;

Fig. 2 is a perspective view of a mover means in the
25 linear motor of Fig. 1 viewed at a different angle from that of Fig. 1;

Fig. 3 is an exploded perspective view of the stator and mover means for explaining the structure of the linear motor of Fig. 1;

Fig. 4 is a fragmentary plan view of the power feed pattern in the linear motor of Fig. 1;

Figs. 5 to 12 are respectively explanatory views for the operation of the linear motor of Fig. 1;

- 5 Fig. 13 is a schematic perspective view, to an enlarged scale, of a part of the mover means in the linear motor of Fig. 1 for explaining its structure;

- Fig. 14 is a schematic perspective view, to an enlarged scale, of a core in the linear motor of Fig. 1 for
10 explaining its structure;

Fig. 15 shows in a plan view a base of the mover means in the linear motor of Fig. 1;

Fig. 16 is a front elevation of the base shown in Fig. 15;

- 15 Fig. 17 is a schematic perspective view of a part of the mover means of another embodiment of a linear motor according to the present invention;

Fig. 18 is a perspective view, to an enlarged scale, of a core in the mover means of Fig. 17;

- 20 Fig. 19 is a plan view of the base of the mover means shown in Fig. 17;

Fig. 20 is a front elevation of the base shown in Fig. 19;

Fig. 21 is a perspective view of the array of permanent magnets according to another embodiment of a linear motor according to the present invention;

Fig. 22 is a sectional view, to an enlarged scale, of
5 yet another embodiment of a linear motor according to the present invention applied to a carrier means for opening and closing curtains; and

Fig. 23 is a perspective view of the carrier means shown in Fig. 22.

10 Referring to Figs. 1 and 2, there is shown here an embodiment of a commutated moving-coil linear motor according to the present invention, in which the linear motor 10 generally comprises a stator means 11 and a mover means 12. The stator means 11 comprises an
15 elongated guide frame 13 substantially U-shaped in section, a permanent magnet array 14 extending substantially over the entire length of the frame 13 and disposed in a recessed part 13a formed longitudinally in the inner bottom wall of the guide frame 13 and a power
20 feed pattern 15 secured to one longitudinal side wall of the guide frame 13. The stator means 11 functions as a guide for the mover means 12.

The permanent magnet array 14 is provided in an elongated flat plate shape as shown in Fig. 3, and is so
25 magnetised as to have alternately opposite poles, i.e., N and S poles, at regular intervals in the longitudinal direction and also for opposing poles in the direction of the width of the array to have opposite polarities. The permanent magnet array 14 is preferably mounted on
30 the guide frame 13 by urging a longitudinally extending

projection 16 in the recessed part 13a into a groove 17 extending longitudinally in the permanent magnet array 14. Here, each N pole and each S pole mutually adjacent in the longitudinal direction of the permanent magnet array 14 form a pair having a length L, as shown in Fig. 3. On the other hand, the power feed pattern 15 comprises, as shown particularly in Fig. 4, upper and lower conductor parts 19 and 20 arranged above and below along the side wall of the guide frame 13 through an insulating zone 18 extending in the longitudinal direction of the frame 13 in zigzag pattern turning at right angles at a constant pitch. In this case, the insulating zone 18 is made to have a width $L/6$ at its respective portions 18a lying in the width direction of the power feed pattern, and respective portions projecting in the width direction of the upper and lower conductor parts 19 and 20 are made to have a length $L/3$ in the longitudinal direction of the pattern 15.

The mover means 12 is formed in an electromagnetic device assembly of three-phase structure with respect to a flat plate-shaped base 21. Three cores 22, 22a and 22b respectively formed by a laminate of flat U-shaped iron plates are mounted on the base 21, preferably seated in recesses made in the base, and coils 23, 23a and 23b are wound in bipolar system respectively on each of the cores 22, 22a and 22b, so as to form the moving coils of the mover means. Respective parallel leg portions of the U-shaped cores 22, 22a and 22b are disposed on both sides of the permanent magnet array 14 and disposed within the recessed part 13a of the guide frame 13 at extended ends of both legs so as to oppose the permanent magnet array 14 disposed between the core legs, while shoe members 24 and 24a preferably of an

insulating material are mounted each across the three leg portions on each side of the array 14 throughout the three cores 22, 22a and 22b. These shoe members 24 and 24a are disposed each between one side face of the permanent magnet array 14 and the opposing side wall of the recessed part 13a of the guide frame 13, so that clearance between the said one side face of the permanent magnet array 14 and the opposing side wall of the recessed part 13a can be prevented from becoming excessively large or small and the leg portions of the cores 22, 22a and 22b are assured to be freely movable reciprocatingly in stable manner without substantial play with respect to the guide frame 13.

Further, brushes 25, 25a and 25b are provided respectively for each of the cores 22, 22a and 22b on one side and are connected to the coils 23, 23a and 23b. The brushes are contactable with the power feed pattern 15 on the inner side wall of the guide frame 13. Preferably, these brushes 25, 25a and 25b are mounted on brush supporters 26, 26a and 26b secured to one 24a of the shoe members 24 and 24a. The flat plate-shaped base 21 is formed to have longitudinal side edges 21a and 21b which are thinner than other portions, and the base 21 is mounted on the guide frame 13 with the thinned side edges 21a and 21b engaged in guide grooves 13b and 13c made adjacent longitudinal opening edges of both side walls to oppose each other, so that the mover means 12 can be stably slidable with respect to the stator means 11.

When, in the foregoing structure of the mover means 12, the length of the respective cores 22, 22a and 22b in the longitudinal direction of the mover means 12 is l_1 , this length l_1 is set to be smaller than the foregoing

length $L/3$, i.e. $l_1 < L/3$, and respective electromagnet devices with the cores 22, 22a and 22b and moving coils 23, 23a and 23b wound on these cores are also provided to be of a longitudinal length smaller than $L/3$. The
5 respective brushes 25 and 25a for the respective phases are disposed to be at intervals also of $L/3$ and to pass substantially through the centre of the power feed pattern 15 in its width direction (see broken line in Fig. 4), or in the height direction of the side walls of
10 the guide frame 13, so that the positive and negative power voltages will be alternately applied through the brushes 25, 25a and 25b to the respective moving coils 23, 23a and 23b.

The operation of the foregoing moving-coil linear motor
15 10 according to the present invention shall be referred to here. The exciting power is fed in any known manner from the power feed pattern 15 through the brushes 25, 25a and 25b to the respective three-phase moving coils 23, 23a and 23b which are wound in the bipolar system so
20 as to be reverse directional at their respective coil portions wound on the leg portions of each core so that a current will be caused to flow, for example, in a clockwise direction through one of such two coil portions but in a counterclockwise direction through the
25 other coil portion, in each of the coils 23, 23a and 23b. Accordingly, when one of the leg portions of each core is excited to be N-pole, the other leg portion is excited to be S-pole. Assuming here that the brushes 25, 25a and 25b of the mover means 12 sliding along the
30 power feed pattern 15 are in contact therewith at three positions 01, 02 and 03 as shown in Fig. 4 by small double circles, then the mover means 12 will be at such

position as in Fig. 5 where the current is fed to two moving coils 23 and 23b so that the leg portions of the cores 22 and 22b will be of such polarities as shown in Fig. 5, whereby there is caused an electromagnetic repulsion between both leg portions of the core 22 and an opposing pair of the magnetic poles in the permanent magnet array 14 whereby an electromagnetic attraction is caused to occur between another core 22b and another opposing pair of the magnetic poles in the array 14, the mover means 12 being thus subjected to a driving force acting in a rightward direction in Fig. 5.

As the mover means 12 is caused to shift by the above driving force to reach the position shown in Fig. 6, the brushes 25, 25a and 25b are in contact with the power feed pattern 15 at three points M1, M2 and M3 as shown in Fig. 4 by small single circles, where the current is now fed to two moving coils 23 and 23a so that the leg portions of their cores 22 and 22a will be of such polarities as shown in Fig. 6, whereby an electromagnetic attraction is caused to occur between the leg portions of the core 22 and the foregoing other pair of the magnetic poles in the permanent magnet array 14 whereby an electromagnetic repulsion takes place between the leg portions of the adjacent core 22a and opposing pair of the poles in the array 14, the mover means 12 being thus subjected to a driving force acting in a rightward direction in Fig. 6.

In response to such sliding movement of the brushes 25, 25a and 25b along the power feed pattern 15, the magnetic polarity of the respective cores 22, 22a and 22b is changed over sequentially as shown in Figs. 7 to 12 so that the cores 22, 22a and 22b will be

sequentially driven to move along the permanent magnet array 14, and eventually the mover means is slidably moved along the guide frame 13 of the stator means 11. During such movement of the mover means 12, as has been
5 briefly referred to, the mover means 12 is allowed to move stably along the stator means 11 without substantial lateral play, since the shoe members 24 and 24a mounted commonly to the cores 22, 22a and 22b are disposed between both side faces of the permanent magnet
10 array 14 and both side wall faces of the recessed part 13a in the guide frame 13 while the side edges 21a and 21b of the base 21 are engaged in the guide grooves 13b and 13c of the frame 13. That is, it is effectively made possible to overcome the problem that the cores 22,
15 22a and 22b are caused to tilt or deviate with respect to the permanent magnet array 14 so as to collide therewith to impair the driving force given to the mover means 12 and physically damage the array 14. More particularly, the mover means 12 of the linear motor 10
20 according to the present invention incorporates effectively the cores 22, 22a and 22b, so that the motor 10 can be remarkably improved in magnetic efficiency and the driving force with respect to the mover means 12 can be also remarkably increased. Assuming here that the
25 driving force to the mover means 12 may be limited to be of the same level as that in conventional coreless type linear motors, the motor may be sufficiently made smaller in size, as will be readily appreciated.

In the moving-coil linear motor 10 of the foregoing
30 arrangement, further, it is possible to provide thereto a coupling member 27 which is secured to the base 21 as shown schematically in Fig. 13, for coupling the motor to some other constituting member of the carrying or

transporting means. When the cores formed with the laminate of iron plates and made to be of the longitudinal length ℓ_1 are made to have a width ℓ_2 as shown in Fig. 14, on the other hand, the base 21 may be
5 required only to be set in the longitudinal length to be slightly larger than $3\ell_1$ and in width to be slightly larger than ℓ_2 , and the size reduction is to be realised taking into account these respects.

It is preferably, on the other hand, that the base 21 is
10 formed to have recesses 28, 28a and 28b respectively of longitudinal length ℓ_1 and width ℓ_2 , as shown in Figs. 15 and 16, so that the respective cores 22, 22a and 22b will be seated in these recesses 28, 28a and 28b. It is desirable in this case to set the recesses 28, 28a and
15 28b at intervals of $L/3$.

Further, as shown in the embodiment illustrated in Figs. 17 to 20, it is also preferable to form the base and cores in such a manner that engaging projections 49A, 49B; 49Aa, 49Ba; and 49Ab, 49Bb are provided to side
20 walls of recesses 48, 48a and 48b in the base 41 and engaging grooves 42A, 42B; 42Aa, 42Ba; and 42Ab, 42Bb are provided in both lower side faces of the cores 42, 42a and 42b so that when the cores 42, 42a and 42b are placed in the recesses 48, 48a and 48b in the base 41,
25 the projections 49A ... 49Bb engage in the respective grooves 42A ... 42Bb.

In the embodiment of the moving-coil linear motor shown in Fig. 21 on the other hand, the motor may comprise as the stator means a permanent magnet array 54 made of a
30 curved material which may be cut to a suitable length for freely setting the longitudinal length of the array.

For this type of the material, practically, a rubber magnet material may be employed. With this arrangement, the length of the permanent magnet array 54 and eventually of the stator means in its longitudinal direction can be set to be the most preferable in accordance with dimensional and the like conditions at an installed position of the linear motor.

In the above arrangement of the linear motor of the present invention, further, the respective cores corresponding to the respective coils are divided so as to form mutually independent magnetic circuits, unlike an arrangement in which the cores are coupled by means of a magnetic member. For this reason, the base which supports these cores may be fabricated with a resilient member or the cores may be mutually coupled through flexible joints and, as will be appreciated by any skilled in the art, the linear motor can readily be made movable along a curved path.

In Figs. 22 and 23, there is shown an example in which the moving-coil linear motor according to the present invention is applied to a carrier means for opening and closing curtains, with the substantially same constituent parts as those in the embodiment of Figs. 1-3 denoted by the same reference numerals as those used in Figs. 1-3 but added by 90. In this case, the guide frame 103 forming the stator means 101 is expanded in the height direction (downward in Figs. 22 and 23 but upward in Fig. 1) to define a further chamber 103A for accommodating therein a shifting means 120 while a bottom wall 121 of this chamber 103A is formed to have a slit 103B extending in the longitudinal direction of the frame 103 for passing therethrough curtain rings or hangers. The base 111 is disposed in an intermediate

position in the height direction of the guide frame 103, and is provided with the coupling member 117 which is L-shaped in cross-section and which extends into the chamber 103A to dispose its extended end right above the slit 103B. To this extended end of the coupling member 117, the curtain hanger 123 is joined preferably to be integral with the member 117, while the hanger 123 carries wheels 122 and 122a at its upper part disposed inside the chamber 103A for rolling along opposing edges of the slit 103B and its lower part extends through the slit 103B downward to the exterior. Within the chamber 103A, further, a cover member 124 which is substantially L-shaped in section is engaged in locking portions 125 and 126 in the chamber 103, so as to extend between the base 111 and the wheels 122a and the hanger 123, for preventing any foreign matter from entering into the upper part of the guide frame 103. Other constituents and their functions are substantially the same as those in the embodiment of Figs. 1-3.

In the above described carrier means for curtains with the linear motor of the present invention, power fed through the power feeding pattern 105 and brushes 115 to the coils 113 (shown here only ones for one phase in Figs. 22 and 23) with desired polarities in a state where curtain rings (not shown) are hung to the hanger 123, then the carrier means is caused to slide in a desired direction along the longitudinal direction of the guide frame 103 so that opening or closing of the curtains can be realised. It should be appreciated that no weight of the curtains and so on is imparted to any other members disposed above the base 111 during the sliding movement of the carrier means so that the carrier means can be smoothly driven to slide in a relatively low load state.

CLAIMS

1. A commutated moving-coil linear motor comprising a stator means including a permanent magnet array disposed in said stator means to extend in the longitudinal direction thereof and magnetized to have opposite poles in the direction of the width of said array and also in the longitudinal direction of the array opposite poles alternately at regular intervals, and a mover means mounted for movement along the stator means by means of an electromagnetic force, said stator means having therein a power feed pattern disposed to extend in the longitudinal direction of the stator means, said mover means including three-phase cores, U-shaped in section for opposing at both leg parts of said U-shape both side faces of said permanent magnet array of said stator means disposed between said both leg parts, and three-phase moving coils wound on both leg parts of said cores in bipolar system with end portions of the leg parts extending from the coils, the power feed pattern in said stator means applying through brushes to said moving coils alternately positive and negative voltages for exciting electromagnetically both leg parts to provide thereto sequentially magnetic repulsion and attraction with respect to both side faces of the permanent magnet array.

2. A motor according to claim 1, wherein said stator means comprises an elongated guide frame having on an inner wall thereof a projection extending in the longitudinal direction of said guide frame, and said permanent magnet array is provided with a recess extending in the longitudinal direction of the array for receiving said projection of the guide frame.



3. A motor according to claim 2, wherein said projection is disposed substantially in the centre of an inner wall of a recessed part formed in the guide frame to extend in the longitudinal direction, said permanent magnet array being fitted to said projection spaced from opposing side walls on both sides of the inner wall in said recessed part.

4. A motor according to claim 3, wherein said both leg parts of said cores have end portions disposed on both sides of said permanent magnet array with a clearance between each side face of the permanent magnet array and each of said opposing side walls of said recessed part, and shoe members respectively mounted in common to said end portions of the cores on each side of the permanent magnet array.

5. A motor according to any preceding claim, wherein said mover means further includes a flat plate-shaped base for mounting thereto said cores carrying said moving coils wound thereon, and said guide frame is substantially U-shaped in section and having in opposing inner wall surfaces a pair of guide grooves for guiding both side edges of said base.

6. A motor according to claim 5, wherein said side edges of the base are thinner than the other portions of the base.



7. A motor according to claim 1, wherein said stator means comprises an elongated guide frame in which a chamber including an upper part and a lower part is defined, said upper part accommodating therein said mover means, said lower part accommodating therein a shifting means interlocked with said mover means and having in a bottom wall a slit extending in the longitudinal direction of said guide frame, and said mover means includes a flat plate-shaped base for mounting thereto said cores carrying said moving coils wound thereon, said base being provided with a connecting member for connecting the base to said shifting means which carries wheels rollable along both side edges of said slit, and said shifting means being extended partly out of said slit for coupling the shifting means to an object to be shifted.

8. A moving coil linear motor substantially as described herein with reference to the drawings.

