

DESCRIPTION

TITLE OF THE INVENTION: LINEAR MOTOR FIELD UNIT AND LINEAR MOTOR

[Technical Field]

[0001]

The present invention relates to a linear motor field unit and a linear motor including the field unit.

[Background Art]

[0002]

In semiconductor manufacturing apparatuses and liquid crystal display substrate manufacturing apparatuses, it is required to move a processing target accurately at low vibration in a plane perpendicular to the direction of gravitational force. A drive source allowing for individual movement on linear guides that are arranged orthogonally moves a table on which a processing target or a processing tool is placed. Since this movement is required to be accurate at low vibration, the drive source does not employ a system in which an output from a rotary motor of the type used in common processing machinery is converted by a ball screw into a linear motion, but employs a linear motor that can be translated directly.

[0003]

A general linear motor configuration has a combination of a field unit serving as a mover (or a stator) in which multiple permanent magnets are arranged for alternating polarity change and an armature serving as a stator (or a mover) having a core composed of a soft magnetic body including multiple magnetic pole teeth and a coil wound around the magnetic pole teeth. The field unit and the armature are arranged in a manner opposed to each other at a predetermined distance therebetween and an alternating current with the polarity and magnitude thereof synchronized with the traveling distance with respect to the field period of the field unit is applied to the coil to generate a thrust in the traveling direction due to attractive and repulsive forces with the permanent magnets and thereby to cause the field unit (or the armature) to move linearly with respect to the armature (or the field unit). There have been proposed linear motors of various types having such a configuration. For example, Patent Document 1 describes a linear motor including a field unit as a stator and an armature as a mover.

CITATION LIST

PATENT DOCUMENT

[0004]

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2006-527576

SUMMARY OF THE INVENTION

[Technical Problem]

[0005]

In a linear motor, a motor specific detent force is generated. Such a detent force may cause reduction and/or unevenness in the thrust of the linear motor. This problem has conventionally been addressed with a skew arrangement that provides an array of magnetic pole teeth with a certain angle.

[0006]

However, such a skew arrangement is limited in eliminating low-order components of a detent force, though effective in eliminating high-order components. In particular, it is hardly effective in eliminating the second-order components of a flux content change emerging as an end effect of the mover.

[0007]

The present invention has been made in consideration of such circumstances as described above, and an object thereof is to provide a linear motor in which a detent force including the second-order components can be reduced.

[Solution to Problem]

[0008]

A linear motor field unit according to the present invention is characterized by including a rectangular plate-shaped back yoke, multiple first permanent magnets having a rectangular shape in plan view and juxtaposed on the back yoke with the magnetic pole in alternately opposite directions, and two second permanent magnets of the same geometry having a polygonal shape in plan view, with the width thereof in the juxtaposition direction narrowed in a tapered manner from one to the other in a direction intersecting with the juxtaposition direction, and arranged at both end portions of the multiple first permanent magnets in the juxtaposition direction with the tapering direction thereof inverted with respect to each other.

[0009]

In accordance with the present invention, since the second permanent magnets are provided at the ends of the array of the first permanent magnets, it is possible to reduce a detent force including the second-order components.

[0010]

The linear motor field unit according to the present invention is characterized in that the sum of the width dimension between the ends of each of the second permanent magnets in the juxtaposition direction is approximately equal to the width dimension of the first permanent magnets in the juxtaposition direction.

[0011]

In accordance with the present invention, since the sum of the dimension between the ends of each of the second permanent magnets in the juxtaposition direction is approximately equal to the dimension of the first permanent magnets in the juxtaposition direction, it is

possible to maintain the characteristics of the linear motor.

[0012]

The linear motor field unit according to the present invention is characterized in that the ratio of the width dimension between the ends of one of the second permanent magnets in the juxtaposition direction to the other is within the range from 10:1 to 1:1.

[0013]

In accordance with the present invention, since the ratio of the dimension between the ends of the second permanent magnets is within the range from 10:1 to 1:1, it is possible to reduce a detent force including the second-order components.

[0014]

The linear motor field unit according to the present invention is characterized in that the second permanent magnets have a trapezoidal shape in plan view.

[0015]

In accordance with the present invention, since the second permanent magnets have a trapezoidal shape in plan view, it is possible to prepare the second permanent magnets easily.

[0016]

The linear motor field unit according to the present invention is characterized in that the second permanent magnets have an approximately triangular shape in plan view.

[0017]

In accordance with the present invention, since the second permanent magnets have an approximately triangular shape in plan view, it is possible to reduce a detent force including the second-order components.

[0018]

The linear motor field unit according to the present invention is characterized in that the two second permanent magnets are arranged symmetrically in plan view with respect to a predetermined point on the back yoke.

[0019]

In accordance with the present invention, since the two second permanent magnets are arranged symmetrically with respect to a point, it is possible to maintain the characteristics of the linear motor.

[0020]

A linear motor according to the present invention is characterized by including an armature having a rectangular plate-shaped substrate portion and multiple magnetic pole teeth with a coil wound therearound juxtaposed on the substrate portion and the above-described linear motor field unit.

[0021]

In accordance with the present invention, it is possible to reduce a detent force including the second-order components.

[0022]

The linear motor according to the present invention is characterized in that the armature includes an auxiliary tooth with no coil wound therearound provided at an end portion of the substrate portion in the juxtaposition direction in a manner spaced from the magnetic pole teeth, the auxiliary tooth and the magnetic pole teeth are larger at a leading end portion than a base portion thereof, and the auxiliary tooth and the magnetic pole tooth adjacent to the auxiliary tooth are opposed directly to each other in the juxtaposition direction. [0023]

In accordance with the present invention, since the leading end face of the auxiliary tooth is made coplanar with those of the magnetic pole teeth, it is possible to cause a magnetic flux to flow in between the stator in the same way as for the magnetic pole teeth. [0024]

The linear motor according to the present invention is characterized in that the armature serves as a stator and the linear motor field unit serves as a mover.

[Advantageous Effects of the Invention]

[0025]

In accordance with the present invention, it is possible to reduce a detent force including the second-order components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026]

FIG. 1 is a perspective view showing the configuration of an exemplary linear motor.

FIG. 2 is a perspective view showing the configuration of a stator with no coil.

FIG. 3 is a perspective view showing the configuration of a mover.

FIG. 4 is a plan view showing the configuration of the mover.

FIG. 5 is a side view of the linear motor.

FIG. 6 is a graph showing the detent force of the linear motor.

FIG. 7 is an illustrative view showing the configuration of another stator with no coil.

MODES FOR CARRYING OUT THE INVENTION

[0027]

Embodiments will hereinafter be described specifically using the drawings. FIG. 1 is a perspective view showing the configuration of an exemplary linear motor 100. The linear motor 100 includes a rectangular parallelepiped stator 1 elongated in one direction and a mover 2 opposed to a portion of the stator 1 with slight spacing therebetween. In the mover 2, permanent magnets (first permanent magnets) 22a, 22b and permanent magnets (second permanent magnets) 23 are juxtaposed on a rectangular plate-shaped back yoke 21. The mover 2 is arranged to move in the longitudinal direction of the stator 1 (in the direction or opposite direction of the arrow in FIG. 1). In the linear motor 100 of this embodiment, the stator 1 is achieved by an armature and the mover 2 is achieved by a field unit.

[0028]

FIG. 2 is a perspective view showing the configuration of the stator 1 with no coil 14. The stator 1 includes magnetic pole tooth parts 11, 12 and an auxiliary pole tooth part 13. The magnetic pole tooth part 11 includes a rectangular plate-shaped substrate portion 11a and two rectangular plate-shaped tooth portions 11b standing vertically on the substrate portion 11a with a predetermined distance therebetween. The magnetic pole tooth part 11 is formed such that two L shapes are coupled to each other in side view. The magnetic pole tooth part 12 includes two rectangular plate-shaped tooth portions 12b standing vertically on both end portions of a rectangular plate-shaped substrate portion 12a. The magnetic pole tooth part 12 has a U shape in side view. The tooth portions 11b and the tooth portions 12b have approximately the same shape.

[0029]

The auxiliary pole tooth part 13 includes a rectangular plate-shaped (rectangular parallelepiped) auxiliary pole tooth portion 13b standing vertically on one end of a rectangular plate-shaped substrate portion 13a. The auxiliary pole tooth part 13 has an L shape in side view. The auxiliary pole tooth portion 13b has approximately the same shape as the tooth portions 11b and the tooth portions 12b.

[0030]

The stator 1 has the following configuration. Eight magnetic pole tooth parts 11 are aligned and coupled such that tooth portions 11b are equally spaced. One longitudinal end of the thus coupled part assembly, that is, the side on which the substrate portion 11a protrudes in the traveling direction of the mover 2 is coupled with the magnetic pole tooth part 12 such that the tooth portions 12b are in parallel with the tooth portions 11b.

[0031]

The stator 1 is further configured to have the auxiliary pole tooth part 13 fixed to each longitudinal end portion, in which the tooth portions 11b and 12b are coupled to each other. The leading end faces of the tooth portions 11b, 12b and the auxiliary pole tooth portions 13b in the height direction are then made coplanar with each other and juxtaposed at predetermined intervals in the longitudinal direction of the stator 1. Further, a conductive wire is wound around each of the tooth portions 11b, 12b to form coils 14, 14, respectively. The diameter and the number of turns of the conductive wire forming each coil 14 is the same. The tooth portions 11b, 12b serve as magnetic pole teeth when a current is applied to the respective wound coils 14, 14. The magnetic pole tooth parts 11, 12 and the auxiliary pole tooth part 13, which form the stator 1, are each formed from, for example, a non-oriented magnetic steel sheet. Since the auxiliary pole tooth portions 13b with no conductive wire wound therearound (no coil formed therearound) are provided at the ends of the stator 1, the traveling range of the mover 2 (the permanent magnets 22a, 22b of the mover 2) can be expanded to a region not opposed to the tooth portions 11b (12b) of the stator 1 without thrust reduction. This is for the reason that the magnetic flux due to the end effect is absorbed and

the pullback (force against the thrust) is accordingly reduced not to undergo thrust reduction.
[0032]

FIG. 3 is a perspective view showing the configuration of the mover 2. FIG. 4 is a plan view showing the configuration of the mover 2. The mover 2 includes the back yoke 21, the multiple permanent magnets 22a and 22b, and the two permanent magnets 23. The back yoke 21 has a rectangular plate shape elongated in the traveling direction. The back yoke 21 is formed of soft magnetic metal such as rolled sheet. The permanent magnets 22a and 22b each have a rectangular parallelepiped shape. The permanent magnets 22a and 22b are neodymium magnets, ferrite magnets, samarium-cobalt magnets, etc.
[0033]

The permanent magnets 22a and 22b are juxtaposed such that the longitudinal direction thereof intersects with the longitudinal direction of the back yoke 21. The permanent magnets 22a and 22b are in a skew arrangement in which the longitudinal direction thereof makes an angle of about 3 degrees with the transverse direction of the back yoke 21. The permanent magnets 22a and 22b are arranged alternately, that is, in the order 22a, 22b, 22a, 22b, ... The permanent magnets 22a and 22b, which have the same specification, are fixed to the back yoke 21 with the magnetization direction in alternately opposite directions. The magnetization direction of the permanent magnets 22a corresponds to the normal direction of the fixation surface of the back yoke 21 and oriented toward the fixation surface. The magnetization direction of the permanent magnets 22b corresponds to the normal direction of the fixation surface of the back yoke 21 and oriented away from the fixation surface. It is noted that the magnetization direction of the permanent magnets 22a and 22b may be reversed from the directions above as long as in alternately opposite directions.
[0034]

In this embodiment, the two permanent magnets 23 each have a shape of half of each permanent magnet 22b. The two permanent magnets 23 have the same shape. The permanent magnets 23 each have a right trapezoidal shape in plan view tapered in the longitudinal direction. Given that the width of the permanent magnets 22a and 22b in the juxtaposition direction is W_0 , the permanent magnets 23 each have one width of $W_1 = 3/4 \times W_0$ in the juxtaposition direction and the other width of $W_2 = 1/4 \times W_0$. That is, the width ratio $W_1:W_2$ is 3:1. The permanent magnets 23 are provided one for one at the ends of the magnet array of the permanent magnets 22a and 22b in the juxtaposition direction. The two permanent magnets 23 are arranged such that the widened portion and the narrowed portion are positioned symmetrically with each other. That is, in FIG. 4, the permanent magnet 23 arranged to the right hand on the paper is widened downward on the paper, while narrowed upward on the paper. On the other hand, the permanent magnet 23 arranged to the left hand on the paper is narrowed downward on the paper, while widened upward on the paper. The permanent magnets 22a, 22b, and 23 are fixed adhesively to the back yoke 21 using adhesive such as epoxy-based adhesive. It is noted that the width ratio $W_1:W_2$ is 3:1 by way of

example only and not limited thereto. In other aspects, the width ratio $W1:W2$ may be such that the ratio of the width $W1$ to the width $W2$ is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or between any two of these values. In addition, the permanent magnets 23 may not have a trapezoidal shape but have a triangular shape in plan view.

[0035]

The thus arranged stator 1 and mover 2 are combined to form the linear motor 100. FIG. 5 is a side view of the linear motor 100. The mover 2 is opposed to the stator 1 in such a manner that the permanent magnets 22a, 22b face the leading end faces of the tooth portions 11b, 12b of the stator 1 with a predetermined clearance gap therebetween. Seven pairs of permanent magnets 22a (22b) included in the mover 2 are opposed to six pairs of tooth portions 11b (12b) included in the stator 1. That is, the linear motor 100 has a seven-pole/six-slot configuration. It is noted that the mover 2 theoretically includes two sets of seven permanent magnets 22a (22b), but one of the permanent magnets 22b is herein divided to provide two permanent magnets 23.

[0036]

When the coils 14 in the stator 1 is energized with a three-phase alternating current to generate a magnetic field in the tooth portions 11b (12b), the permanent magnets 22a, 22b in the mover 2 are sequentially attracted and repulsed magnetically in the magnetic field, causing the mover 2 to move linearly with respect to the stator 1.

[0037]

Next will be described the detent force of the linear motor 100. FIG. 6 is a graph showing the detent force of the linear motor 100. The horizontal axis represents the electrical angle in degree. The vertical axis represents the detent force in N (newton). In the graph shown in FIG. 6, only components of the detent force in the movable direction are shown. The positive detent force indicates the case where the detent force acts in the traveling direction. The negative detent force indicates the case where the detent force acts in the direction opposite to the traveling direction.

[0038]

The graph 61 shows the detent force when the mover 2 has a conventional configuration. In the thus conventionally configured mover 2, the two permanent magnets 23 are included as a single magnet. The graph 62 shows the detent force when the mover 2 of this embodiment is used. As shown in FIG. 6, in the case of using the mover 2 of this embodiment, the detent force is reduced to about 63% compared to the conventional case.

[0039]

This embodiment exhibits the following advantageous effects. Since the permanent magnets 23, which are each half of one of the permanent magnets 22b forming the mover 2, are arranged symmetrically at the ends of the magnet array, it is possible to reduce a detent force. Also, the permanent magnet 22b, which constitutes one pole, is divided into two and used as the permanent magnets 23, having the advantage that the characteristics of the linear

motor 100 cannot change significantly. Further, the total permanent magnets used in the mover 2 does not vary, having the advantage that the material cost cannot increase.

[0040]

It is noted that in the foregoing description, the tooth portions 11b of the magnetic pole tooth parts 11, the tooth portions 12b of the magnetic pole tooth parts 12, and the auxiliary pole tooth portions 13b of the auxiliary pole tooth parts 13 each have a rectangular plate shape. The leading ends may be formed in an inverse tapered shape. FIG. 7 is an illustrative view showing the configuration of another stator 1 with no coil 14. An inverse tapered shape is provided in which the upper leading ends of the tooth portions 11b and 12b in the height direction are, respectively, thicker than the base portions of the substrate portions 11a and 12a. Similarly, an inverse tapered shape is provided in which the upper leading ends of the auxiliary pole tooth portions 13b in the height direction are thicker than the base portions of the substrate portions 13a.

[0041]

Such an inverse tapered shape at the upper leading ends of the tooth portions 11b, 12b and the auxiliary pole tooth portions 13b in the height direction could further increase the efficiency of transmission of the magnetic flux.

[0042]

While the stator 1 is achieved by an armature and the mover 2 is achieved by a field unit in the above-described embodiment, an armature may serve as a mover and a field unit may serve as a stator.

[0043]

The present invention is not intended to be limited to the above-described embodiment, but rather include all variations and modifications without departing from the technical scope and spirit of the invention as set forth in the appended claims.

[Reference Signs List]

[0044]

100	Linear motor
1	Stator
11	Magnetic pole tooth part
11a	Substrate portion
11b	Tooth portion
12	Magnetic pole tooth part
12a	Substrate portion
12b	Tooth portion
13	Auxiliary pole tooth part
13a	Substrate portion
13b	Auxiliary pole tooth portion
14	Coil

2	Mover
21	Back yoke
22a	Permanent magnet
22b	Permanent magnet
23	Permanent magnet

CLAIMS

[Claim 1]

A linear motor field unit comprising:

a rectangular plate-shaped back yoke;

a plurality of first permanent magnets having a rectangular shape in plan view and juxtaposed on the back yoke with the magnetic pole in alternately opposite directions; and

two second permanent magnets of the same geometry having a polygonal shape in plan view, with the width thereof in the juxtaposition direction narrowed in a tapered manner from one to the other in a direction intersecting with the juxtaposition direction, and arranged at both end portions of the plurality of first permanent magnets in the juxtaposition direction with the tapering direction thereof inverted with respect to each other,

wherein the sum of the width dimension between the ends of each of the second permanent magnets in the juxtaposition direction is approximately equal to the width dimension of the first permanent magnets in the juxtaposition direction.

[Claim 2]

The linear motor field unit according to claim 1, wherein the first permanent magnets are skewed in the juxtaposition direction and wherein the angles of both end portions of the second permanent magnets in the juxtaposed direction are larger than the skew angle of the first permanent magnets.

[Claim 3]

The linear motor field unit according to claim 1 or 2, wherein the ratio of the width dimension between the ends of one of the second permanent magnets in the juxtaposition direction to the other is within the range from 10:1 to 1:1.

[Claim 4]

The linear motor field unit according to any one of claims 1 to 3, wherein the second permanent magnets have a trapezoidal shape in plan view.

[Claim 5]

The linear motor field unit according to claim 1 or 2, wherein the second permanent magnets have an approximately triangular shape in plan view.

[Claim 6]

The linear motor field unit according to any one of claims 1 to 5, wherein the two

second permanent magnets are arranged symmetrically in plan view with respect to a predetermined point on the back yoke.

[Claim 7]

The linear motor field unit according to any one of claims 1 to 6, wherein the second permanent magnets are arranged by dividing one of the first permanent magnets that is configured with a pair of the seven pairs of magnets each including two first permanent magnets whose magnetic poles are opposite direction to each other.

[Claim 8]

A linear motor comprising:

an armature having a rectangular plate-shaped substrate portion and a plurality of magnetic pole teeth with a coil wound therearound juxtaposed on the substrate portion; and
a linear motor field unit according to any one of claims 1 to 7.

[Claim 9]

The linear motor according to claim 8, wherein

the armature includes an auxiliary tooth with no coil wound therearound provided at an end portion of the substrate portion in the juxtaposition direction in a manner spaced from the magnetic pole teeth,

the auxiliary tooth and the magnetic pole teeth are larger at a leading end portion than a base portion thereof, and

the auxiliary tooth and the magnetic pole tooth adjacent to the auxiliary tooth are opposed directly to each other in the juxtaposition direction.

[Claim 10]

The linear motor according to claim 8 or 9, wherein the armature serves as a stator and the linear motor field unit serves as a mover.