Development of Compact Multi-Axis Integrated Linear Servo Motor Unit

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1. Introduction

There are two types of linear motors: a flat type[(1), (2)] and cylinder type[(3)] (cylinder linear motors). The flat type has been used for horizontal axes (X-Y tables, etc.) on electronic component mounters and semiconductor manufacturing equipment, and the cylinder type has been often used for the vertical axes (Z-axis) on PCB drilling machines and electronic component mounters.

The cylinder linear motor is suitable for applications that require fast and precise motion over short distances, but recently, its application range has been extending, such as telemanipulation systems for cell culture pipetting[(4)].

This article introduces a newly developed "compact multi-axis integrated linear servo motor unit" designed for fast, precise reciprocating motion and multi-axis applications.

First, we'll present the appearance and specifications of the new product. Next, we'll describe its features of compactness, light weight, high thrust and low friction (high precision). Lastly, we'll look at how the product is easy to customize in the number of axes and spacing between axes to best suit the user's application.

2. Appearance and Specifications of the New Product

Figure 1 shows the appearance of the new product, and Figure 2 shows its external dimensions. Table 1 shows the product specifications.

Fig. 1 New product appearance (4-axis integrated unit example)

The new product integrates multiple axes into a single unit with each axis consisting of a stator, mover, linear encoder, and frame. The mover has a structure that locks rotation using a ball spline on one side of the bearing. The stator is

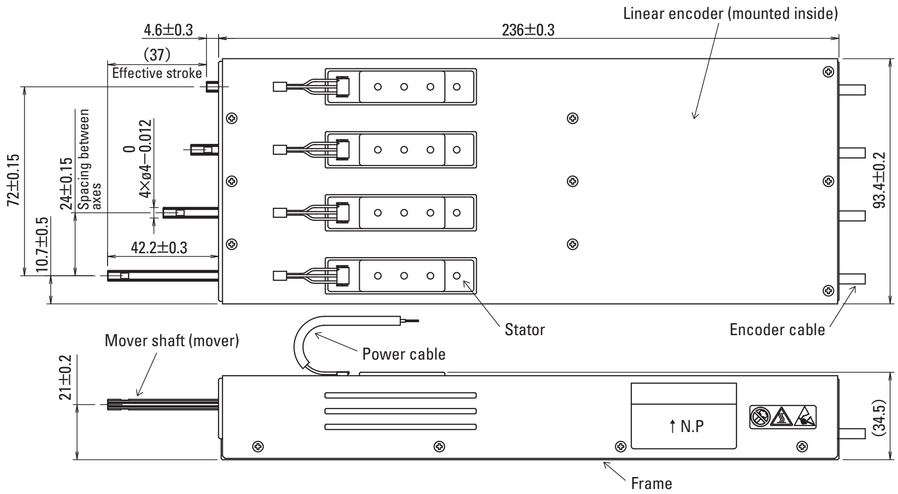

Fig. 2 Dimensions of the new product

resin-molded with the coaxiality of the bearing support and the armature coil's inner diameter ensured. The stator also comes with a power connector, allowing the power cable to be connected and disconnected.

Table 1 Specifications of the new product

Items	Symbol	Unit	Constant
Motor model no.	—	—	DM04GG011A37CX00
Power supply voltage	—	V	DC 48
Spacing between axes	—	[mm]	24
Stroke length	—	[mm]	37
Rated thrust	F_R	[N]	3.5
Maximum thrust	F_P	[N]	11
Rated speed	V_R	[m/s]	1
Maximum speed	V_{max}	[m/s]	1
Encoder resolution	—	[μm]	1

3. Product Features

3.1 Increased thrust density

Thrust density is the thrust produced per unit volume, and the greater the value, the higher the thrust with the smaller size.[1]

Figure 3 shows the motor cross section and gives an outline of the magnetic flux of our current cylinder linear servo motor model. The current model has a structure combining a cylindrical magnet, an armature coil, and a square steel sheet (back yoke), and the distance (magnetic gap) from the back yoke to the magnet is not uniform. The greater the magnetic gap, the more difficult it is for the magnetic flux to reach the back yoke, reducing the amount of effective magnetic flux affecting thrust.

Figure 4 shows the motor cross section and gives an outline of the magnetic flux of the new product. The new product has a structure combining a cylindrical magnet, an armature coil, and a cylindrical back yoke, and the magnetic gap is uniform. With this structure, the magnetic flux reaches the back yoke uniformly. This results in a greater amount of effective magnetic flux, increasing thrust. As shown in Figure 5, rated thrust density and maximum thrust density have improved by 32% and 25%, respectively, compared to the current model.

In this way, the new product is a compact, high-thrust cylinder linear motor that can drive machinery at high accelerations and frequencies.

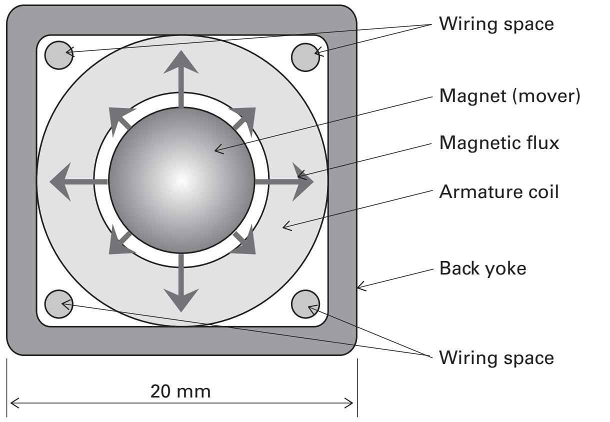

Fig. 3 Cross section view of current model (radial cross section)

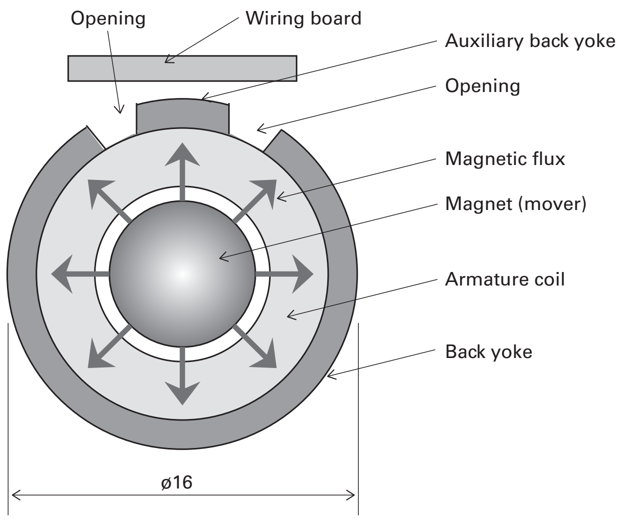

Fig. 4 Cross section view of new model (radial cross section)

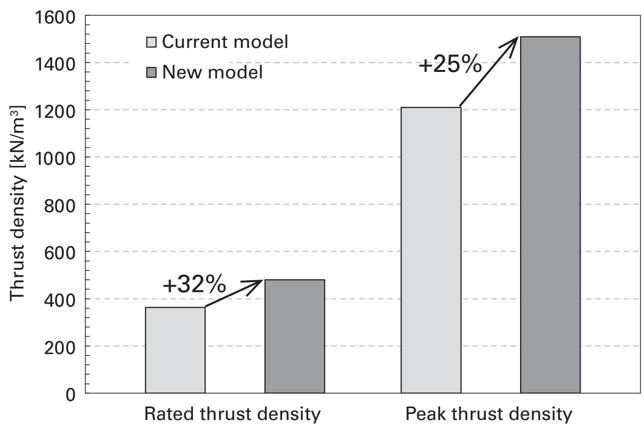

Fig. 5 Comparison of thrust density

3.2 Reduced static friction thrust

3.2.1 Improved coaxiality of fixed bearing

If the two bearings supporting the mover are installed with low coaxiality, an unbalanced load is applied to the bearings, increasing static friction thrust. Since both bearings are mounted to the fixed bearing, static friction thrust can be reduced by improving the coaxiality of the fixed bearing.

Figure 6 shows the stator cross section of the new product. With the new product, the two fixed bearings of the stator were resin-molded with the shaft core placed through them. This structure provides improved coaxiality.

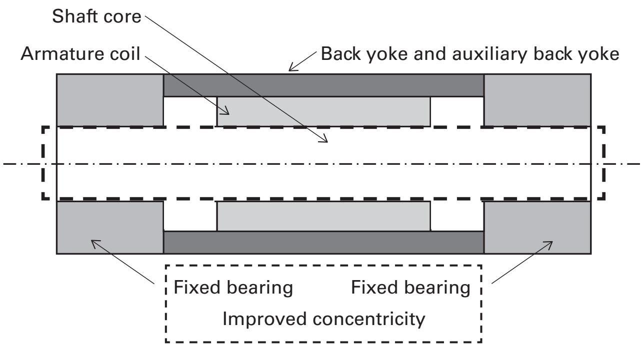

Fig. 6 Cross section view of new product's stator

3.2.2 Improved coaxiality of the mover shaft

As with the fixed bearings, the coaxiality of the mover shaft also affects static friction thrust.

Figure 7 shows the appearance of the mover. The new product has two mover shafts, each of which is securely welded to the magnet housing. To perform welding while maintaining coaxiality, the welding equipment and welding conditions were devised, which successfully improved the coaxiality between the two mover shafts.

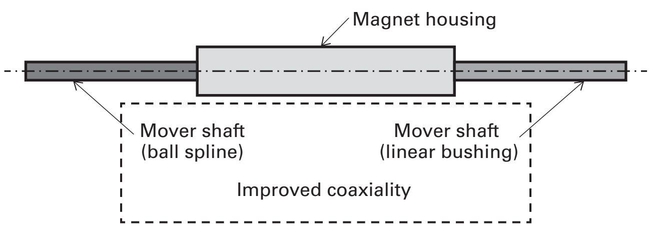

Fig. 7 Appearance of mover

3.2.3 Optimally balanced magnetic force

The current model has space for winding the armature coil inside the back yoke as shown in Figure 3. On the other hand, the new product has a cylindrical back yoke to increase the amount of effective magnetic flux affecting the thrust, leading to no winding space inside the back yoke. This raised the need for outside winding space, therefore openings were made on the back yoke. However, these openings resulted in unbalanced magnetic attractive force acting on the mover, causing the mover to be attracted to the opposite side of the openings. This increases the static friction thrust because this results in an unbalanced radial load exerted on the bearing supporting the mover. To counter this, an auxiliary back yoke was placed as shown in Figure 4, optimizing magnetic balance while securing winding space.

Figure 8 shows a comparison of before and after improving the coaxiality of the fixed bearings and the mover shafts, and static friction thrust with and without the auxiliary back yoke. Static friction thrust has been reduced by 70% in total, enabling a smooth motor driving, which offers high-precision positioning.

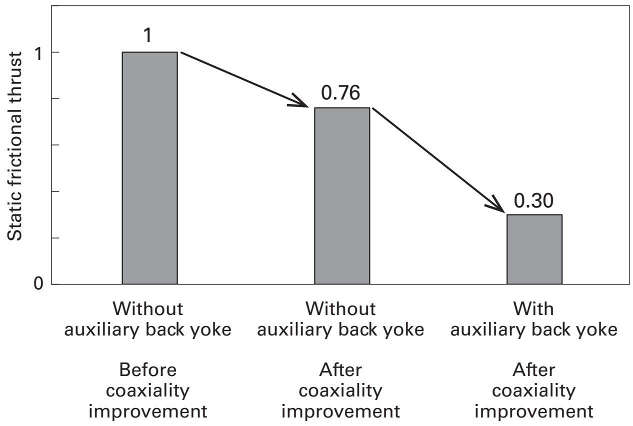

Fig. 8 Comparison of static frictional thrust

3.3 Customizability

With the new product, each linear motor is assembled with high precision in its fixed bearings and mover bearing shafts, requiring no additional adjustment even when multiple axes are combined. This design is optimized for multi-axis configurations, allowing easy customization of the number of mover shaft axes and spacing between axes. This product is suitable for applications where multiple motors are used in equipment because there is no need to adjust the installation position of each axis, greatly reducing the assembly work for customers.

4. Conclusion

This article introduced the compact multi-axis integrated linear servo motor unit which integrates multiple compact cylinder linear motors into a single unit.

The features of the new product are as follows.

1. The product is a compact, high-thrust cylinder linear motor. Thrust density has been improved by 32% (compared with the current model) by optimizing the shape of the steel sheet (back yoke) used for the motor stator. Equipment can be driven with high acceleration and high frequency, contributing to improved productivity for customers' equipment.

2. The linear motor enables smooth driving due to little friction thrust. Static frictional thrust has been reduced by 70% (compared to the current model) by improving the coaxiality of the fixed bearings and mover shaft and devising the magnetic circuit of the stator. It provides stable positioning with high precision and accuracy, contributing to higher precision in customer equipment.

3. Multiple cylinder linear servo motors can be integrated into a single unit, offering easy customization. The number of cylinder linear motor axes and spacing between axes can be laid out freely according to the customer's application. Moreover, no adjustments are required when installing the unit, significantly reducing the assembly workload for customers.

This compact, lightweight, high-thrust cylinder linear motor capable of high-precision positioning can be flexibly customized to suit the customer's equipment, contributing to the creation of new value for our customers.

References

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