Development of High-Acceleration, Energy-Saving SANMOTION Linear Servo Motor

Akihiko Takahashi Hiroyuki Sato

1. Introduction

Linear servo motors are increasingly demanded in applications that require high-speed operation and high-precision positioning, such as surface mounters and lithography equipment. In recent years, they are growingly used in medical devices for higher precision. The advantage of using them is that they can easily achieve high speed and high precision by directly driving equipment linearly without using a rotary-to-linear motion conversion mechanism such as a ball screw.[1]

To improve the speed and precision of customer equipment, it is essential to improve the thrust characteristics of the linear servo motor that drives the equipment while also reducing the motor size, weight, and energy usage (loss reduction). In addition, the motor size affects the size and mass of the parts used in the motor mounting mechanism. Furthermore, the motor's heat generation causes thermal expansion in the motor mounting mechanism in equipment, which undermines the precision of the equipment.

To overcome these challenges, we developed a compact, high-acceleration, energy-saving linear servo motor. The new product is a flat type linear motor with core.

In this article, we begin by showing the specifications and appearance of the new product. Next, we describe its structure and characteristics and present its features taking an example of an XY cartesian robot.

2. Specifications and Appearance of New Product

Figure 1 shows the new linear servo motor, and Table 1 shows its specifications.

The new product consists of a magnet rail (stator) of permanent magnets and a laminated armature coil (mover) facing each other across an air gap.

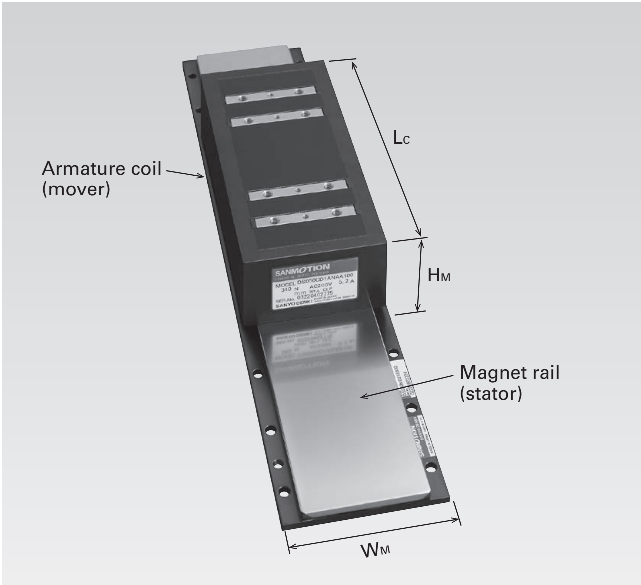


Fig. 1 Appearance of new product

Table 1 Specifications of new product

Items	Symbol	[Unit]	Flat type with core	
			Current product	New product
Coil model no.	–	–	DS045CC1AN	DS050CD1AN
Magnet rail model no.	–	–	DS045MC	DS050MD
Rated thrust	F_C	[N]	260	340
Maximum thrust	F_P	[N]	500	630
Coil length[1]	L_C	[mm]	130	145
Motor width	W_M	[mm]	65	71
Motor height	H_M	[mm]	48.5	48.5
Coil mass	M_C	[kg]	1.8	2.15
Magnet rail mass	M_{mr}	[kg/m]	3	3.5

(1) Excluding the hall sensor

3. Specifications of the New Product

3.1 Structure and features

3.1.1 Improved thrust

Figures 2 and 3 show examples of a linear servo motor installed in equipment. The thrust of a linear servo motor is produced in the area (thrust area S) where the armature coil (mover) and magnet rail (stator) face each other. Our current product secured high thrust by increasing the thrust area S in the direction of the motor width W_M.

However, the increased motor width resulted in an increase in the size and mass of the equipment as well as the amount of motor materials.

Therefore, as shown in Figure 3, the new product secured high thrust by increasing the thrust area S rather in the direction of the motor motion (coil length L direction) not in the motor width W_M direction. This reduces the motor installation width W_A to W_B, resulting in increased thrust without significantly increasing the size of the equipment.

Figure 4 shows a comparison, between the current and new products, of the equipment volume required to install a linear servo motor to produce the same thrust. Compared to the current product, the new product requires 10% less space of customer equipment.

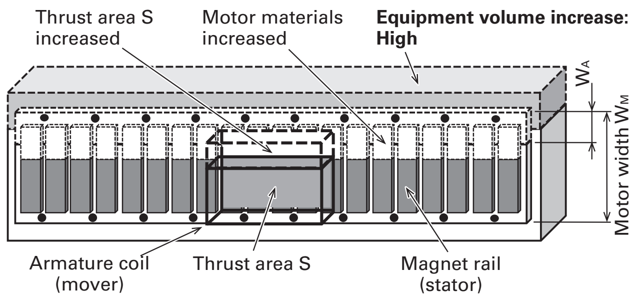


Fig. 2 Installation example of current linear servo motor

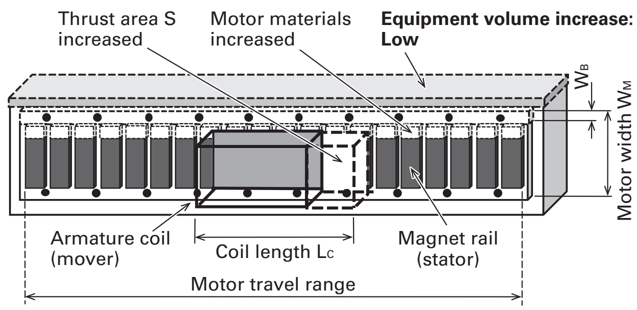


Fig. 3 Installation example of new linear servo motor

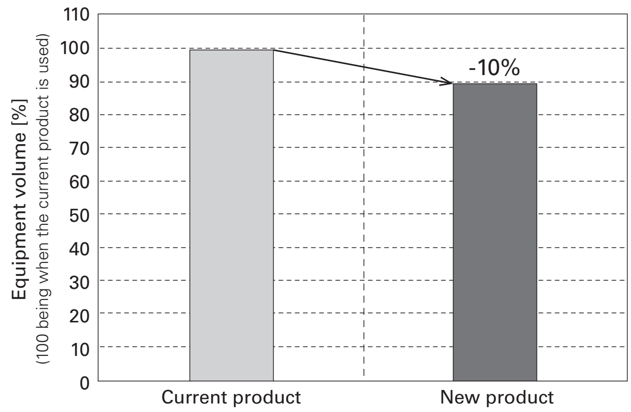


Fig. 4 Equipment volume required for linear servo motor installation (with the same thrust)

3.1.2 Improved energy efficiency (reduced losses)

Figure 5 shows the thrust area of the armature coil (mover) of an iron-core linear servo motor. Compared to the current product, the new product has a reduced end-winding, which is irrelevant to thrust, height H_A by redesigning the winding around the iron core. This reduces the end-winding volume to whole winding ratio while simultaneously reducing copper losses by increasing the ratio of the coil conductor area over the total slot area (slot fill factor).

Figure 6 shows a comparison of the end-winding volume to whole winding ratio. In the new product, the end winding occupies 11% less volume of the whole winding volume than the current product.

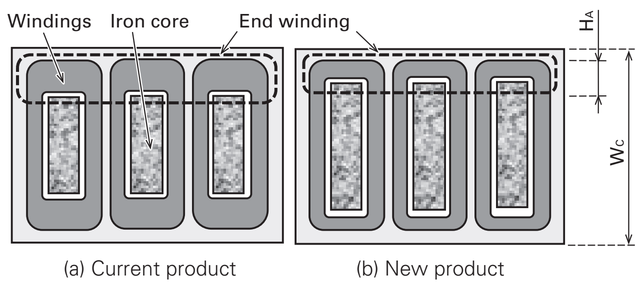


Fig. 5 Comparison of winding structure (reduced end winding)

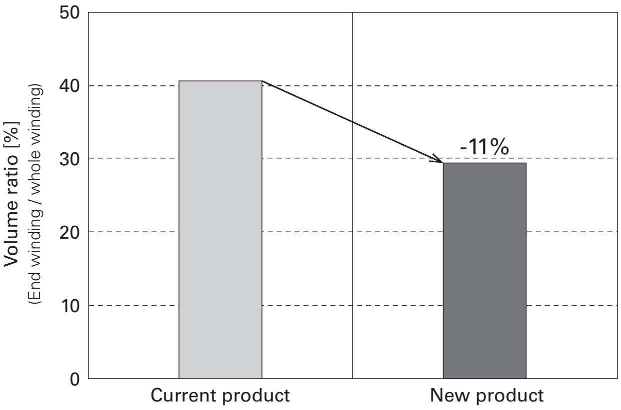


Fig. 6 Comparison of winding volume

3.2 Thrust density and maximum acceleration

3.2.1 Thrust density

Figure 7 shows a comparison of thrust density. Thrust density is the thrust per unit volume, and the greater the value, the higher the thrust and the more compact the linear servo motor.(1) The new product has a redesigned motor structure that optimizes the magnetic circuit and winding layout. As a result, compared to the current flat type linear servo motor with core, the new product achieves a 12% higher rated thrust density and 8% higher maximum thrust density.

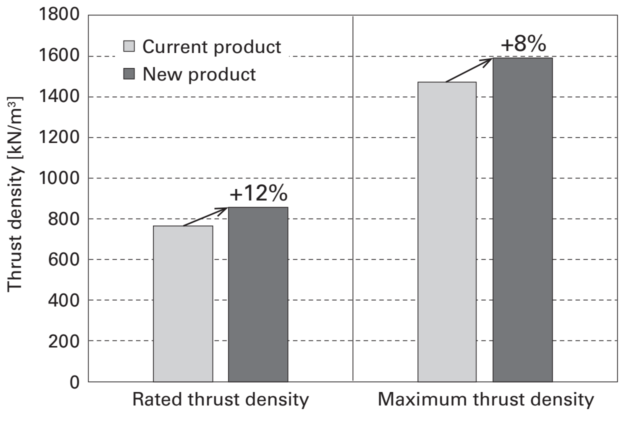


Fig. 7 Comparison of thrust density

3.2.2 Maximum acceleration

Figure 8 shows the relationship between load mass and maximum acceleration. Acceleration is expressed as the equation (1) below using the motor thrust and mass (mover coil mass + load mass). The new product has achieved size and weight reductions through its improved thrust and thrust density. As a result, it has a higher maximum acceleration assuming that the load mass is constant. This can contribute to improving equipment productivity.

$$A_{MAX} = F / (M_L + M_C) \quad \ldots (1)$$

F : Thrust [N]

M_L : Load mass [kg],

M_C : Coil mass [kg]

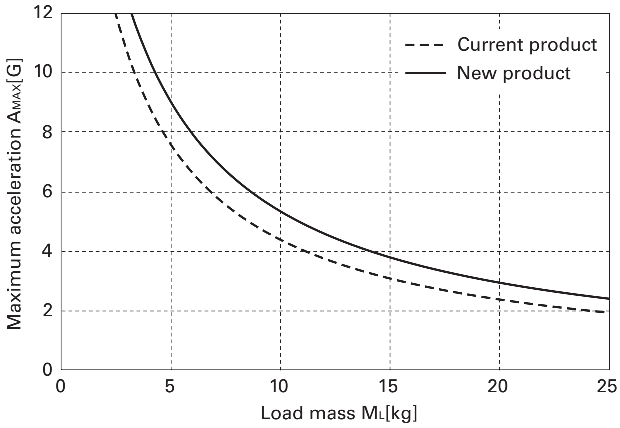


Fig. 8 Comparison of maximum acceleration

3.3 Improved energy efficiency (reduced losses)

Figure 9 is the copper loss comparison between the new and current products. The new product, with its reduced end winding volume and increased space factor, reduces losses by more than 15% compared to the current product.

This reduction in losses reduces the temperature rise of the motor, which suppresses thermal expansion in equipment, contributing to improving the equipment precision.

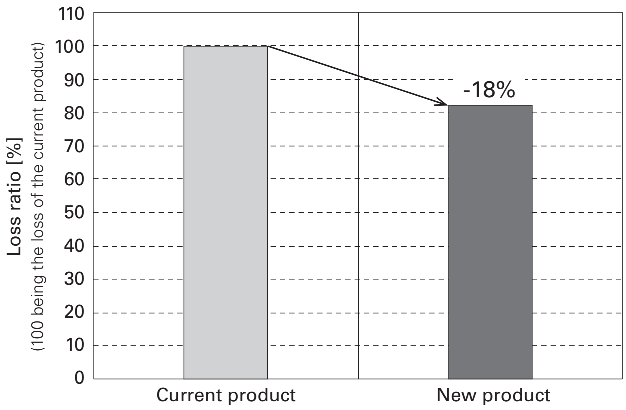
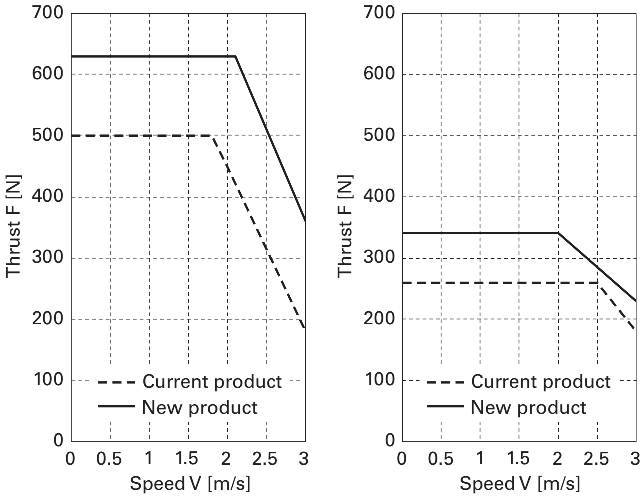


Fig. 9 Comparison of losses (copper losses)

3.4 Thrust vs. speed characteristics

Figure 10 compares the thrust F versus speed V characteristics. The new product improves thrust in all operating ranges from low speed to high speed compared to the current product thanks to the optimized windings and improved thrust density. In particular, compared to the current product, the new product improves thrust in the continuous zone, resulting in higher acceleration and reduced downtime during continuous operation. This can contribute to shortening equipment cycle times.



(a) Instantaneous zone (b) Continuous zone

Fig. 10 Thrust vs speed characteristics (at 200 V input)

4. Configuration Example

Figure 11 shows the new product applied to the upper X-axis of an XY cartesian robot as an application example.

In the current product, the thermal expansion in the upper X-axis moving slider due to the motor heat undermined the positioning precision of the equipment.

The new product suppresses heat generated from the motor by reducing motor loss. This reduces the amount of thermal expansion that occurs in the moving slider.

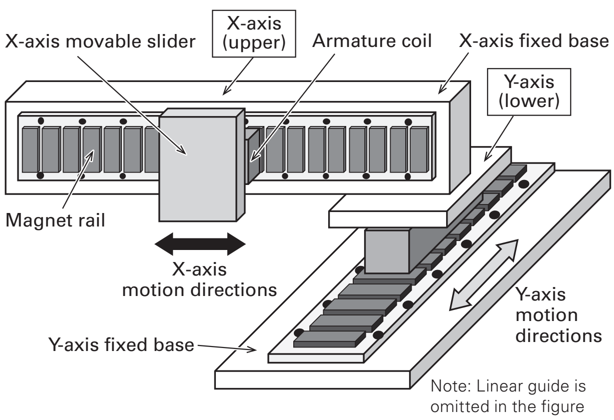


Fig. 11 Illustration of XY cartesian robot mechanism

Figure 12 compares the thermal expansion in the upper X-axis moving slider when the motor generates heat. When the new product is used, the upper X-axis moving slider thermal expansion can be reduced to about 1/2 of that of the current product.

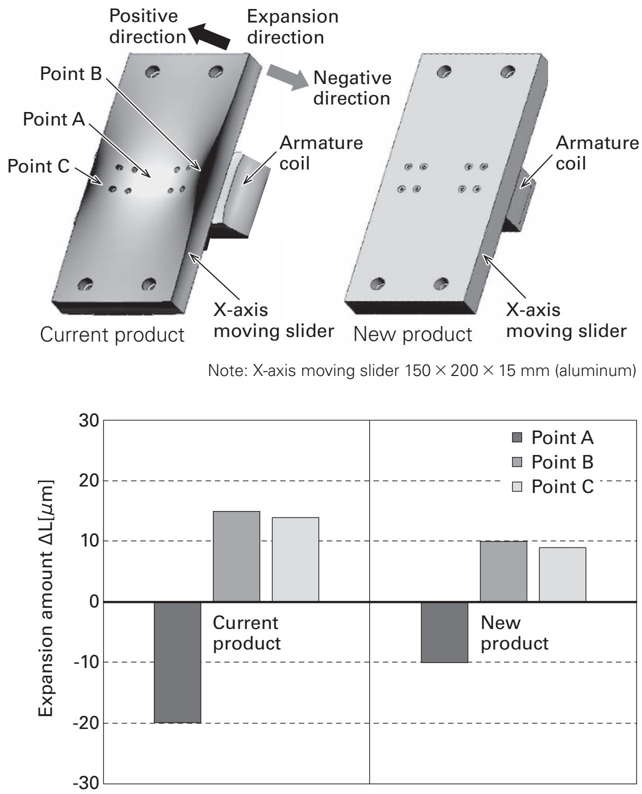
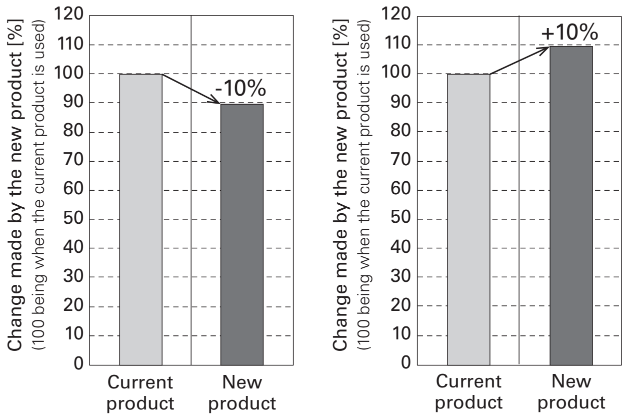


Fig. 12 Thermal expansion in moving slider (analyzed results)

Figure 13 compares, between current and new products, the effect on the lower Y-axis when the upper X-axis moving slider is driven at the same acceleration. Compared to the current product, the new product improves the acceleration of the lower Y-axis by reducing the volume and mass of the upper X-axis fixed base. This reduces the overall size of the XY cartesian robot system and improves its productivity without increasing the size of the motor for the lower Y-axis. Table 2 shows the effect of using the new product to an XY cartesian robot system.



(a) X-axis fixed base mass (b) Y-axis acceleration

Fig. 13 Weight reduction in X-axis fixed base and effect on Y-axis

Table 2 Benefits when new product is used in XY cartesian robot

	Current product	New product
X-axis (moving slider)	Thermal expansion: High	Thermal expansion: Low
X-axis (fixed base)	Mass/volume: High	Mass/volume: Low
Y-axis	Acceleration: Low	Acceleration: High

5. Conclusion

In this article, we introduced the structure and features of our newly developed high-acceleration, energy-saving *SANMOTION* linear servo motor, as well as an example of its application example. The features of the new product are as follows.

(1) High thrust while being compact and lightweight (Increased thrust density)

By optimizing the motor structure and winding layout, we improved the rated thrust density and the maximum thrust density by 12% and 8%, respectively (compared to the current product).

This enables high acceleration (high response) for the equipment.

(2) Improved energy efficiency (low losses)

By reducing the end winding volumecoil end and improving the space factor, we reduced losses by more than 15% (compared to the current product).

This reduces the thermal expansion that occurs in the equipment due to the heat generated by the motor heat, contributingand contributes to higher precision of equipmentoperations.

(3) Contribute to downsizing and improved productivity of customer equipment

With the reduced motor size and weight and the increased thrust, the new product contributes to improving the productivity of equipment while minimizing the size of the equipment's motor-mounting mechanism.

We believe that the new product will contribute significantly to the improved productivity and precision of customer equipment.

Reference

(1) Yasushi Misawa and 2 others: “Development of Compact, Core-equipped SANMOTION Linear Servo Motors” SANYO DENKI Technical Report No. 37, pp. 35-38 (2014.5)

(2) Hiroyuki Sato and 3 others: “Development of a compact, large thrust, low magnetic attractive force linear servo motors” SANYO DENKI Technical Report No. 41, pp. 35-39 (2016.5)

Author

Akihiko Takahashi
Servo Systems Div., Design Dept. 1
Works on the development and design of linear servo motors.

Hiroyuki Sato
Servo Systems Div., Design Dept. 1
Works on the development and design of linear servo motors.