Development of the *SANMOTION* 20 mm Wide Compact Cylinder Linear Servo Motor

Yuqi Tang Satoshi Sugita

1. Introduction

Most workpiece conveyance and machining operations of semiconductor manufacturing equipment, mounters, and machine tools move linearly. As such, linear motors that are capable of linear motion without using a ball screw or other linear motion conversion mechanism are widely used in these applications. The performance and functional requirements (thrust, speed, acceleration, positioning accuracy, etc.) for the linear motors used in this equipment differ depending on the application and axis motion direction.(1)

In 2014, we released a 12 mm wide compact cylinder linear servo motor, and it has been used in a wide range of equipment and applications. This linear motor is a moving magnet type (MM-Type) that has a permanent magnet on the mover that does not require power, reducing the mover weight. It is particularly suitable for short-stroke, high-acceleration applications such as vertical axes (Z-axes) of pick-and-place machines. By leveraging these features of the 12 mm model, we developed the *SANMOTION* 20 mm wide compact cylinder linear servo motor with a higher thrust and longer stroke.

This article introduces the performance, functions, and characteristics of the new 20 mm wide model in comparison with the current 12 mm wide model.

2. Development Background

Semiconductor manufacturing, inspection, and various assembly equipment (FPC bonders and lens mounters) has multiple axes to perform (vertical) pick-and-place operations. Compact cylinder linear servo motors can help downsize this equipment, simplify mechanisms, and improve productivity. To respond to greater market needs, however, the current 12 mm wide model needed a higher thrust and longer stroke. The following are the specification requirements for cylinder linear servo motors for use as vertical axes in semiconductor manufacturing, inspection, and various assembly equipment.

1) Compact, lightweight, high thrust, long stroke
2) All-in-one structure with a built-in linear encoder and linear guide
3) Multiple axes can be placed side-by-side

The 20 mm wide compact cylinder linear motor that we developed satisfies these requirements.

3. Specifications of the New Model

3.1. Appearance and composition

Figure 1 shows the appearance of the new 20 mm wide compact cylinder linear servo motor while Figure 2 shows its composition and dimensions.

The new model has an all-in-one structure with a built-in linear encoder and linear guide despite its 20 mm width. The motor consists of a mover with magnets built in a stainless steel pipe and a stator (armature) that integrates back yoke, windings, and aluminum housing.

The mover moves linearly, guided by linear bushings on both sides of the stator. By providing a back yoke on the outside of the cylindrical stator winding, we increased the magnetic flux interlinking with the coil to effectively increase thrust. This also prevents magnetic interference between axes when using multiple motors side-by-side.

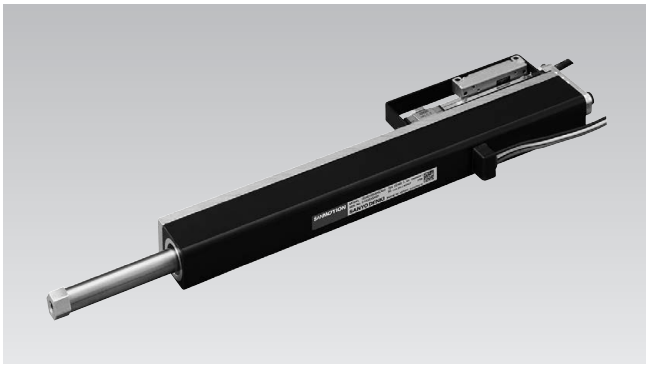

Fig. 1 Appearance of the 20 mm wide compact cylinder linear servo motor

Regarding the linear encoder, by connecting a detection scale to the mover through the anti-rotation linear guide, we ensured that the signal cable of the linear encoder does not move during operation, the same as the motor power cable. Moreover, by devising a mounting method for the linear guide, we stabilized the detection of the linear encoder. Also, with a self-lubricating linear guide used, the new model realized maintenance-free and long-term stable operation.

3.2 Performance and functions

Table 1 compares the specifications of the new and current compact cylinder linear servo motor models. Both the rated and maximum thrusts of the new model are around 3.0 times greater than those of the current 12 mm model. Furthermore, the new model has a 50 mm stroke, which is 20 mm longer than the current model's 30 mm stroke, and a 14% higher no-load maximum acceleration.

With its high thrust and long stroke in a compact body, the new model can contribute to simplifying customers' equipment and increasing its productivity. Moreover, multiple motors can be used side-by-side at intervals of 20 mm because mutual interference does not occur. This allows multiple motors to be placed side-by-side inside customers' equipment, providing customers with a greater freedom in designing high-density equipment.

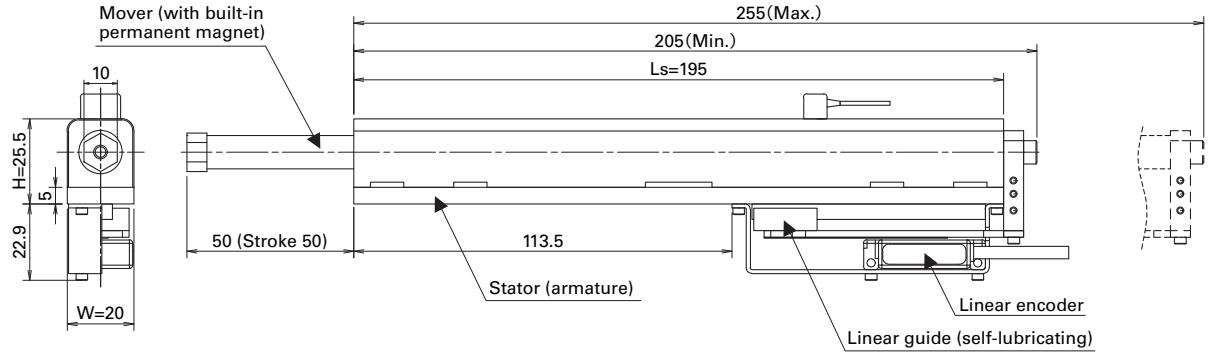

Fig. 2 Composition and dimensions of the 20 mm wide compact cylinder linear servo motor

Table 1 Specifications comparison of the new and current compact cylinder linear servo motors

Item	Symbol	Unit	Specifications	
			New model (20 mm wide cylinder linear servo motor)	Current model (12 mm wide cylinder linear servo motor)
Motor model no.	–	–	DE0BC005A05CX00	DE0AC001A03CX00
Driving method	–	–	Sinusoidal	
Excitation method	–	–	Permanent magnet (of mover)	
Magnetic pole pitch (N to N)	τ_p	mm	27	24
Armature dimensions (W × L × H)	W × L_S × H	mm	20 × 195 × 25.5	12 × 170 × 17
Rated thrust	F_R	N	15.0	5.1
Max. thrust	F_P	N	50.0	16.5
Rated speed	V_R	m/s	0.7	1.0
Maximum speed	V_{max}	m/s	1.4	2.0
Stroke	S	mm	50	30
Mover mass	M_C	g	120	45
Motor mass	M_W	g	450	192
No-load maximum acceleration	a_{max}	G	42.5	37.4
Minimum placement interval	W_p	mm	20	12
Linear encoder	–	–	Optical incremental linear encoder	
Linear encoder resolution (when multiplied by 4)	–	μm	1	

4. Product Features

4.1 Higher thrust and lower loss

To achieve a higher motor thrust and reduced loss, we increased magnetic flux, or magnetic loading, and the effective volume of coil windings, or electric loading.[2]

1) We creatively arranged mover magnets with magnetic spacers inserted between magnets, and succeeded in both increasing magnetic flux from the magnets and reducing the amount of magnets used.
   - We increased the magnetic flux interlinking with the coil by arranging the same poles of the permanent magnets to face and repel each other, and inserting magnetic spacers between magnets.
   - To maximize the magnetic flux interlinking with the coil, we optimized the dimensions of the magnets and magnetic spacers.
2) We maximized winding space by creatively arranging and processing the windings and leads. Moreover, we reduced copper loss by improving winding alignment and increasing the fill factor.

Figure 3 compares the current (I) versus thrust (F) characteristics of the new and current models. This shows that the new model generates a higher thrust than the current 12 mm model at the same electrical current. Moreover, it demonstrates excellent linearity of the characteristics.

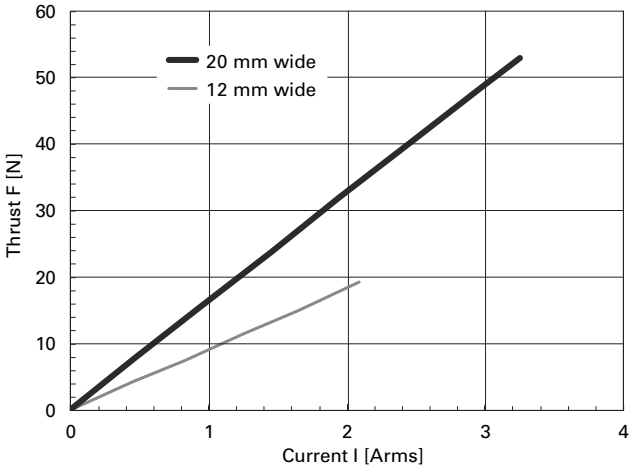

Fig. 3 Comparison of electrical current (I) vs. thrust (F) characteristics

Figure 4 compares the speed (V) versus thrust (F) characteristics of the new and current models (Instantaneous region). Compared with the current 12 mm model, the new model has a lower maximum speed. However, the new model can generate approximately 2.5 times greater thrust in the 1 m/s or less speed zone, which is its operating zone.

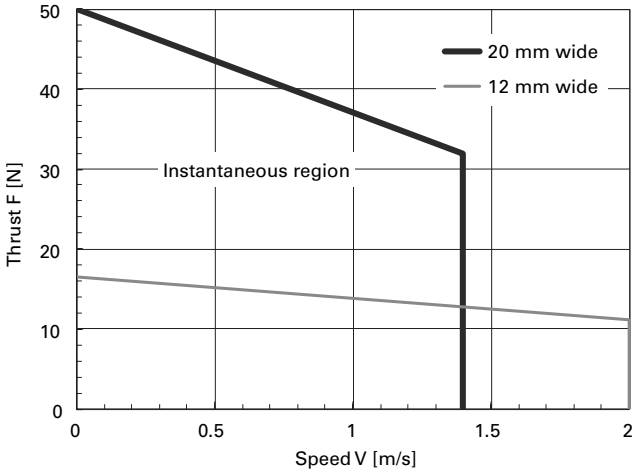

Fig. 4 Comparison of speed (V) vs. thrust (F) characteristics

4.2 Improved thrust density and maximum acceleration

We optimized the current model's magnetic circuit, magnetic pole pitch, and the combination of the number of coils and the number of poles to improve thrust, which increased the thrust density and maximum acceleration of the new model.

The thrust density (thrust per unit armature volume) is an indicator used when evaluating linear motor characteristics.[3] In the following, we define the armature volume as the volume of the magnetic circuit part (where thrust is generated) excluding the linear motion guiding apparatus (shaft guide).

Thrust density K_v can be expressed as

$$K_v = F / V_s = F / (W \times L \times H)$$

where F : thrust (continuous thrust or maximum thrust) [N]
V_s : Armature volume (magnetic circuit part) [mm^3]
W : Armature width [mm]
L : Armature length (excluding the linear motion guiding apparatus) [mm]
H : Armature height [mm]

Figure 5 shows a thrust density comparison of the new and current models Compared to the current 12 mm model, the new model has a 39.4% greater continuous thrust density and 43.7% greater maximum thrust density.

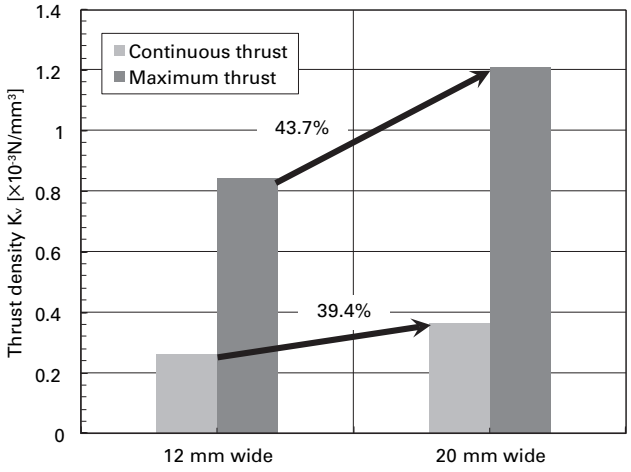

Fig. 5 Thrust density comparison of the new and current compact cylinder linear servo motors

Figure 6 shows a maximum acceleration comparison of the new and current models. The maximum acceleration was calculated using the following: Maximum thrust / mass of moving elements (mover mass + load mass). With its improved thrust density and lighter mover weight, the new model can drive heavier loads at a higher acceleration.

The maximum acceleration with zero load mass is 42.5 G for the new model and 37.4 G for the current 12 mm model. An improvement of approximately 14% was achieved.

Moreover, even with a heavier load mass, the maximum acceleration of the new model can be greater than that of the current model. The maximum load mass that the new model can move at a maximum acceleration of 1 G is 5 kg, while the current 12 mm model can only move a 1.6 kg load. In other words, the new model can drive loads approximately three times heavier than the current model.

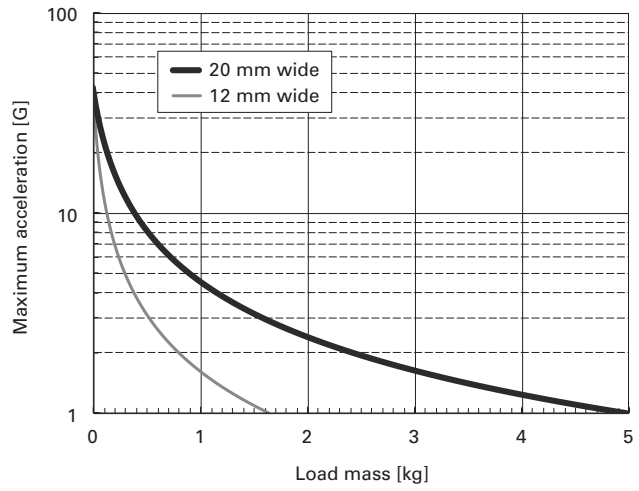

Fig. 6 Maximum acceleration comparison of the new and current compact cylinder linear servo motors

5. Conclusion

This article introduced the performance, functions, and characteristics of the *SANMOTION* 20 mm wide compact cylinder linear servo motor suited to vertical axes (Z-axes) of semiconductor manufacturing, inspection, and various assembly equipment (FPC bonders and lens mounters).

Compared to the current 12 mm model, the new model achieves a higher thrust, higher acceleration, and longer stroke.

- Rated/maximum thrust : 3 times greater
- No-load maximum acceleration : 1.14 times greater
- Stroke : 1.7 times greater

Furthermore, just like the current 12 mm model, the new model has an all-in-one structure with a built-in linear encoder and linear guide and can be used not only in single-axis applications but also in applications where multiple motors are placed side-by-side. This provides customers with a greater degree of freedom.

We believe the new and current models can be widely used in our customers' semiconductor manufacturing and inspection equipment, mounters, bonders, and wafer probers, and greatly contribute to improving performance and productivity.

References

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(3) Satoshi Sugita and three others: Introduction of Industrial Linear Servo Motors, The 2014 Annual Meeting of the Institute of Electrical Engineers of Japan (IEEJ), 5-S24-2, p.3 (2014.3)

Author

Yuqi Tang
Servo Systems Div., Design Dept. 1
Works on the development and design of linear servo motors.
Ph.D in Engineering.

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