

Introducing Linear Servo Motor System

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1. Introduction

Linear servo motors are attracting attention due to their high-speed controllability as a direct drive mechanism that has a linear motion. Development has long been awaited, but the market for linear servo motors has not expanded due to the difficulty of producing a general-purpose mechanism and due to the high cost. Their major applications have been limited to office equipment and semiconductor manufacturing equipment.

There are two types of industrial-use linear servo motor depending on the application: one is for position setting with a relatively shorter stroke, and the other is for transportation.

The main market for the linear servo motor of position setting use is mainly semiconductor and LCD product manufacturing equipment. However, in recent years, the field of application has expanded to the machine tool market. The world's first such application was a machine tool developed by Ingersoll Inc. in 1993 which contained a linear servo motor developed by Anorad Inc. In Japan, a machine tool, the LMT96 (machining center), with linear servo motor was released in '96JIMTOF. In the "Hannover EMO97", as many as 21 machine tools containing a linear servo motor were exhibited, indicating that companies are actively conducting research on linear servo motors built in machine tools.

The linear servo motor for transportation use, on the other hand, has been used to transport relatively light-weight products at high speed for semiconductor manufacturing equipment, medical diagnosis equipment and automobile machinery. Recently, there are plans to use such a motor for robot movement for longer distances.

These trends toward increasing use of linear servo motor in applied machine tools will have far-reaching effects on other industries.

2. Background of Development

To increase efficiency in the manufacturing industry, there is strong demand for an actuator that offers high-speed operation (shorter tact time) and a compact configuration. Most actuator applications are in linear motion, so when such linear motion applications are implemented using rotary mechanisms at present, conversion mechanisms such as cams, gears and links are needed to convert the rotary motion into the linear motion. This places a limit on high-speed operation. In order to achieve high-speed operation exceeding this limit and also a compact configuration, the linear servo motor system is the optimum system.

The linear servo motor is an important medium- to long-term target regarding servo motors in our company. After completing initial investigations, in collaboration with

research institutes and universities, we have entered the development phase. The world's leading developers of linear servo motors are Anorad, Indoramat, and Kollmorgen, and we now have the good fortune to be working with Kollmorgen: after reviewing their catalogs and other materials, their superiority was clear, and we signed a contract to serve as the sales representative of Kollmorgen in order to best utilize development resources.

Three series of linear servo motor, the linear guide system with core developed by Kollmorgen, the linear guide system without core developed by Kollmorgen, and the cylinder system with core developed by us, were released at the System Control Fair 97 and 97 International Robot Fair held in October 1997 (see [photo](#)).

3. Features of Linear Servo Motor

(1) The linear servo motor is a direct drive system. Because it is a highly stiff system without backlash in the mechanisms, high response and high accuracy positioning is possible. However, a decelerator cannot be used unlike the rotary type, and it is susceptible to external disturbances. To compensate for these shortcomings, a control system such as feed forward control must be added to the servo amplifier when the amplifier is rotary motor use.

(2) Because it has no motion conversion mechanism, the linear servo motor generates almost no dust and is ideal for equipments requiring cleanliness. But the motor itself cannot be housed in a fully closed (airtight) structure, so countermeasures must be taken to prevent the exposed permanent magnet from adhesion of chips, iron powder, oil and dust stains. When a linear scale is attached to the system, the same countermeasures are required.

4. Product Introduction

4.1 Positioning of Linear Servo Motor

The positioning of the three types of linear servo motor with respect to the rotary type is shown in [Fig. 1](#). All of the three models that we have developed are LSM (linear synchronous motor).

4.2 Linear Guide System with Core

The linear guide system with core is relatively heavy and has a large force. Its heating is 50% compared with its conventional equivalent.

The new product has the following features:

(1) Large force

(2) Low cogging

[Specifications] Maximum force 300 to 16,000 N

Continuous force 150 to 8,000 N

[Applications] Traveling axis of robot,
long-distance transportation system

The linear motor of the linear guide system generally has a velocity of 1 to 3 m/s and acceleration of 2 to 3 G, whereas the newly developed motor has a velocity of 5 m/s or more and acceleration of 5 G or more. As shown in [Fig. 2](#), the force of the new motor is 1.6 times that of other manufacturers' permanent magnet motors. In other words, the size is reduced by at least 60% for a motor having the same force. As shown in [Fig. 3](#), the loss is around 60% of that of motors having the same force. The key benefits of linear motors to machinery equipment manufacturers are compactness and small loss.

output axis.

(3) The movable block is the magnet while the coil is stationary. This eliminates the moving cable and ensures high reliability.

(4) Because the moving magnet is fitted to the inner diameter of the stator coil with a good balance, the magnetic induction forces are offset against each other, thus prolonging the life of the bearings.

(5) The winding is wound around a bobbin structure that offers good workability.

(6) Products having a longer stroke are difficult to develop due to the structure.

(7) A large force can be obtained when compared with the LPM (Linear Pulse Motor) cylinder system.

(8) Because the mass of the movable block is small, a high acceleration can be obtained.

(9) A patent for the system of the linear synchronous motor (LSM) is being applied for.

The outline drawing and main specifications of the cylinder system with core are shown in [Fig. 6](#).

5. Conclusion

In order to enlarge the linear motor market, not only low price, reducing heat loss technique, downsizing and control technique must be developed, but the development of peripheral technologies for using the linear motor is also a major factor.

There are still problems to solve regarding the control technology such as improved resistance to external disturbance, higher speed operation, improved positioning accuracy, reduced velocity deviation, synchronous control, and so forth. We will conduct research on the following topics in the future.

(1) We will develop a linear motor amplifier that can solve the problems related to direct drive control, and use it in common with the rotary type.

(2) We will develop a SERCOS interface version for connection with "S-MAC".

(3) We will develop the setup software.

Regarding the peripheral technologies, we are working in the following areas:

- Linear guide: Allowable velocity, allowable acceleration, stiffness, vibration, noise
- Linear scale: Low price, high accuracy, high resolution, high response, dustproof, oil protection, braking, holding brake, installation technology

In developing these technologies, we must solve problems based on the concept of the linear motor in combination with mechanical equipment.

Nobuji Suzuki

Joined company in 1966

Servo Systems Division

Worked on design and development of rotating machines and linear motors

Yoshitomo Murayama

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Servo Systems Division, Servo Engineering Dept.

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Satoshi Sugita
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Servo Systems Division, Servo Engineering Dept.
Worked on design and development of linear motors

Kenichi Fujisawa
Joined company in 1992
Servo Systems Division, Servo Engineering Dept.
Worked on design and development of servo amplifiers

Outside view of Linear Servo Motors(three series)

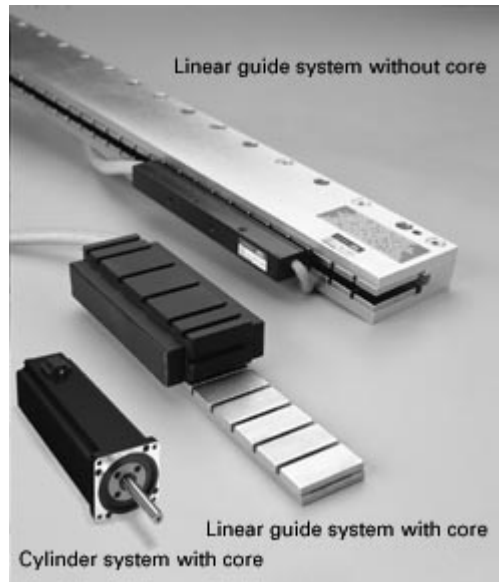
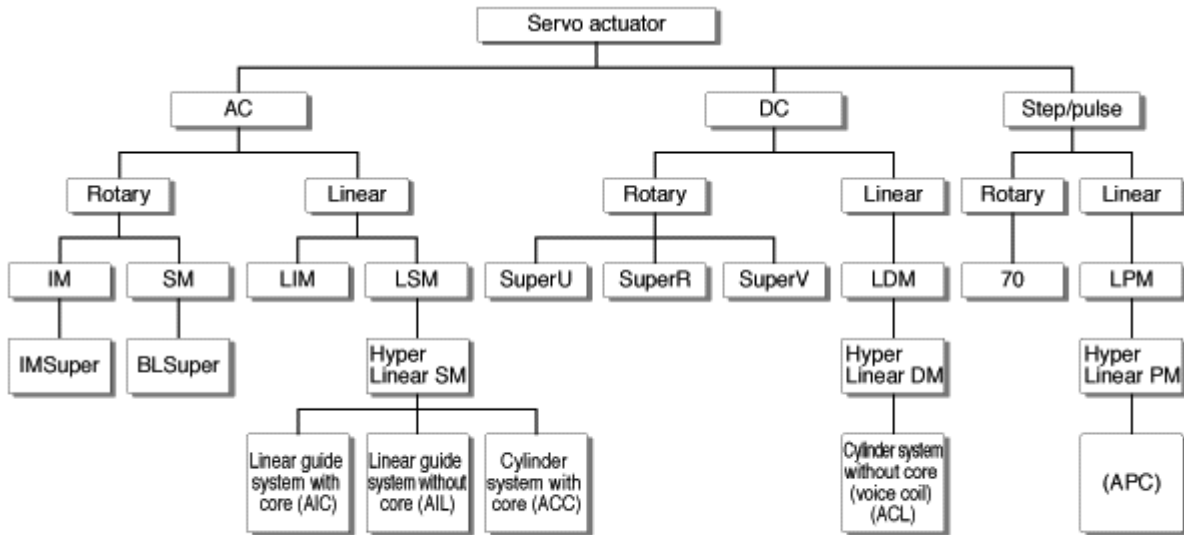


Fig.1 Positning of Linear Servo Moter



Hyper Linear is the name of the linear servo motor.

Super is the name of the rotary servo motor.

Fig.2 Comparison of force with other manufacturers

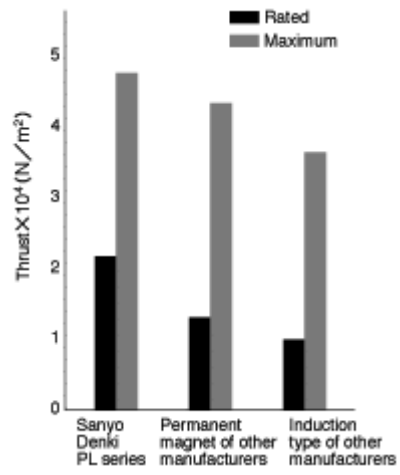


Fig.3 Comparison of force/power consumption characteristics with other manufactureres

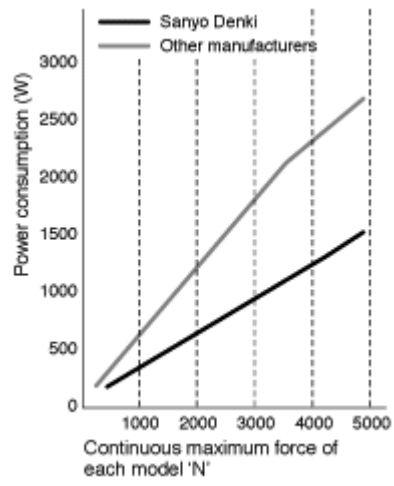
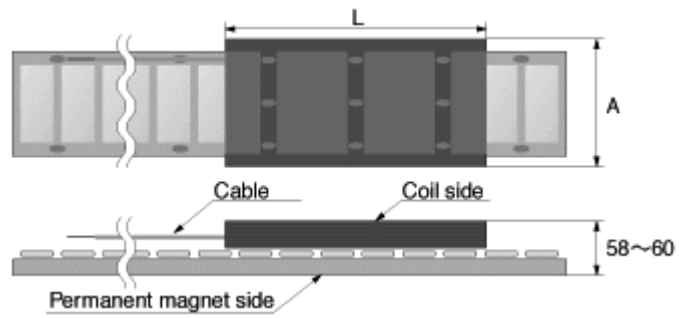
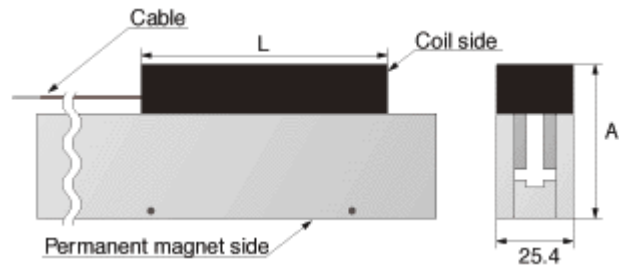


Fig.4 Outside view of linear guide system with core, AIC series.



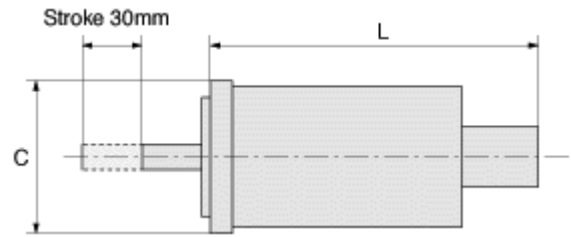
Type	Maximum force(N)	Continuous force(N)	L(mm)	A(mm)
1	300	147	200.2	65
2	500	270	200.2	85
3	600	294	376.2	65
4	900	441	552.2	65
5	1000	590	200.2	135
6	1000	540	376.2	85
7	1200	810	552.2	85
9	2000	1280	200.2	235
10	2000	1179	376.2	135
11	2000	1080	728.2	85
12	3000	1767	552.2	135
13	4000	2474	376.2	235
14	4000	2358	728.2	135
15	6000	3711	552.2	235
16	8000	4947	728.2	235
17	16000	9890	1104.4	335

Fig.5 Outside view of linear guide system without core, AIL series



Type	Maximum force(N)	Continuous force(N)	L(mm)	A(mm)
1	120	38	110.7	78.0
2	200	61	110.7	98.0
3	240	76	206.7	78.0
4	360	114	302.7	78.0
5	400	123	206.7	98.0
6	480	152	398.7	78.0
7	600	184	302.7	98.0
8	800	245	398.7	98.0

Fig.6 Outer dimensions of cylinder system with core,ACC series



Model	Dimensions[mm]		Maximum Force Fc [N]	Continuous force Fp [N]	Mass of movable block Kg
	C:sq	L:total length			
ACC07-094	76	295	100	200	1.7
ACC08-094	86	305	200	400	1.95
ACC08-136	86	350	300	600	2.35
ACC12-094	120	305	420	1000	2.4