Study of Intermittent Stator PM-LSM Control Method by a Position Detector Using Hall element

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Abstract-Previously, our laboratory has proposed a Intermittent Stator permanent magnet linear synchronous motor as long-distance conveying equipment of industrial equipment. The sensor to detect the mover position uses the linear encoder so far. Because the wiring for this linear encoder limits the movement of the mover, it is unsuitable as the sensor of the long distance transportation device. Therefore, this paper proposes the mover position detection with the hall element as a position detector that takes the place of the linear encoder.

I. INTRODUCTION

Recently, permanent magnet type linear motor (PM-LSM) with high speed and a high acceleration and deceleration is used as an industrial conveying device. Now, the structure that the movement of the mover is not limited is preferable, considering the long distance transportation. Therefore, primary side on ground is suitable for the structure of PM-LSM in this case. However, it is thought that it is necessary to suppress an initial cost because an initial cost soars when the stator is spread over the ground. Then, stator intermittent arrangement PM-LSM (ISPM-LSM) is proposed at our laboratory[1].To control the LSM, a position sensor for detecting the position of the mover is required. When PM-LSM is controlled, the position sensing device to detect the position of the mover is needed. This sensor consists of the magnetic response type multi-gap head put on the scale material and the mover where magnetism is recorded. Therefore, because the decrease in the degree of freedom of the mover is caused by its wiring, the linear encoder is not suitable for the conveying of the long distance. Then, we propose to use the hall element as a position sensing device of the mover by putting the Hall element on the space that was born by the arrangement of the stator in intermittent.

This paper describes the method of controlling the mover position detection and the speed when the Hall element is used. Moreover, we examine the significance of the Hall element by comparing the linear encoder with the case where the hall element is used.

II. STRUCTURE OF THE EXPERIMENTAL APPARATUS

A. Composition of ISPM-LSM

The velocity control simulation of ISPM-LSM is performed as a means for comparing the performance as a position transducer. The composition of ISPM-LSM of this laboratory is shown in Fig. 1, and each parameter is shown in Table 1.

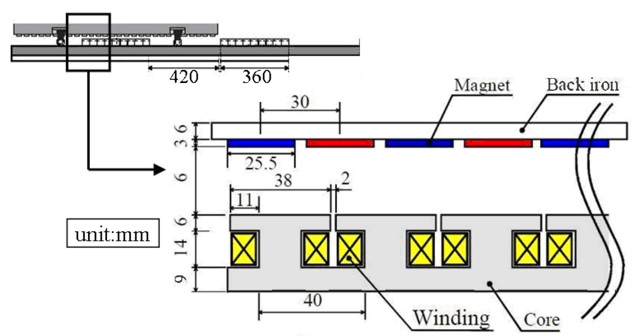

Fig.1.Dimensions of the experimental apparatus

Table 1: Specification of experimental device.

Item		Value(Unit)
Number of Magnet	P'	28(Pieces)
Number of Pole	P	12(Poles)
Number of Slot	S	9(Slots)
Pole Pitch	τ_p	30(mm)
Armature Resistance	R_a	1.55(Ω)
Inductance(overlap)	L_a	39.8(mH)
Inductance(non-overlap)	L_a'	38.3(mH)
Induced Voltage Constant	K_e	13.9(Vs/m)
Thrust Constant	K_f	13.9(N/A)
Mass of mover	M	20(kg)

B. Control and the block diagram of IS PM-LSM

An ISPM-LSM system configuration figure is shown in Fig. 2. As shown in a figure, it controls by the linear encoder or a Hall device using the value of the detected mover position. SSR (solid state relay) is used as a switch for changing the current sent through a stator. ISPM-LSM is controlled by a d-q axis of coordinates.And current PI control and a speed PI controller are incorporated for rate control. The parameter of a controller is shown in Table 2.
Next, a block diagram is shown in Fig. 3 at ISPM-LSM.

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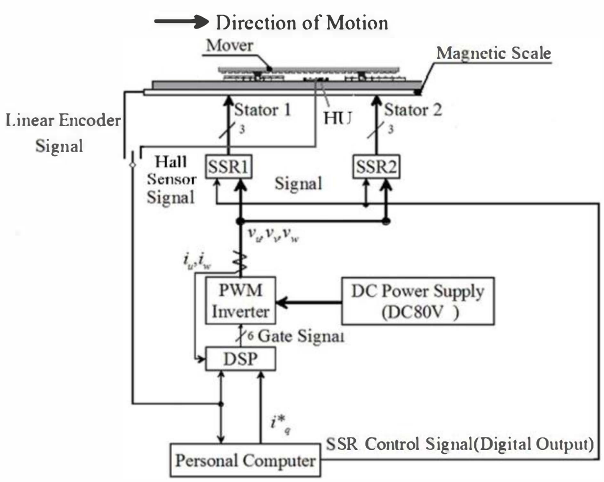

Fig.2. ISPM-LSM system configuration figure

Table I Gain parameter of PM-LSM system

Parameter		Value
Speed controller proportional gain	K_{Pv}	170
Speed controller Integral gain	K_{Dv}	15
Current controller proportional gain	K_{pi}	29.9
Current controller Integral gain	K_{Di}	775

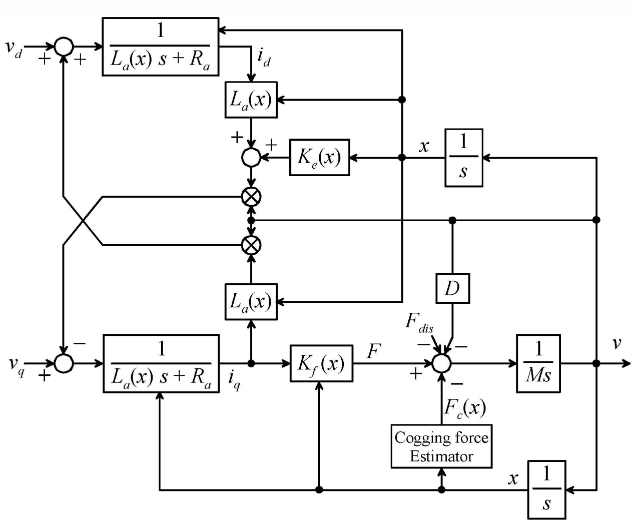

Fig.3. Block diagram of the stator of the *d*-*q* coordinate system.

where, D=damping coefficient, F_c=cogging force (N). moreover Since a stator is intermittent arrangement, $K_e(x)$ and $L_d(x)$ are variables which change with positions[2].

A simulation is performed in consideration of these.

Table2 Gain parameter of PM-LSM system

Parameter		Value
Speed controller proportional gain	K_{Pv}	170
Speed controller Integral gain	K_{Dv}	15
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III. THE MOVER POSITION DETECTION METHOD BY A HALL ELEMENT

A. About Hall element

Here, the Hall element used for detection of a mover position is explained. The Hall device uses the Hall effect which generates electromotive force by giving magnetic flux perpendicularly to the element which is sending constant current. Therefore, it can detect magnetic flux in real time, and it can be installed, without barring movement of a mover. Moreover, this is a budget price and is a sensor suitable for long-distance conveyance. The Hall unit which uses these three Hall elements was manufactured. Moreover, magnetic flux is measured from this. Hall element which was used this time is the EQ-711L of Asahi Kasei Corporation.

B. Position detection of a mover

Position calculation using a Hall element can be performed by using the sine wave of two-phase which is electric angle phase difference 90deg.However, in order to carry out high-precision calculation, it is necessary to lessen a harmonics ingredient. If there are few harmonics ingredients, high-precision calculation can be performed. Therefore, Hall unit which acquires the sine wave of three-phase which are phase difference 120deg was manufactured. The dimensional drawing of HU is shown in Fig. 4.

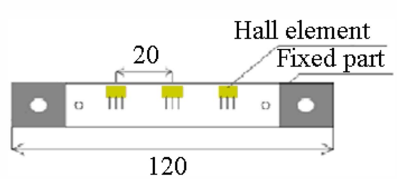

Fig.4.Hole unit dimensional drawing

In order to acquire the signal of phase difference 120deg, the hole unit was created so that the distance between Hall element might be set to 20mm. And three-phase alternating-current graph measured from the produced hole unit is shown in Fig.5.

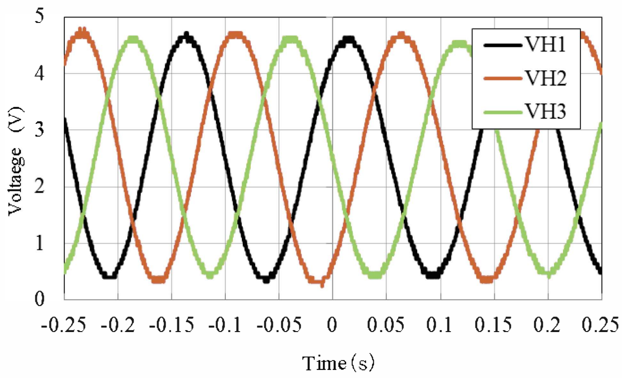

Fig.5. The measured waveform by HU

Next, a position x is computed from electric angle theta e obtained by performing three-phase to two-phase transformation for position calculation. For conversion an equation is shown in a equation (4) from a equation (1)[3], and the waveform after conversion is shown in Fig. 6 from Fig.5 .

$$V_{H\alpha} = \sqrt{\frac{2}{3}}\left(V_{H1} - \frac{V_{H2}}{2} - \frac{V_{H3}}{2}\right) \quad (1)$$

$$V_{H\beta} = \sqrt{\frac{2}{3}}\left(\frac{\sqrt{3}V_{H2}}{2} - \frac{\sqrt{3}V_{H3}}{2}\right) \quad (2)$$

$$\tan\theta_e = \tan\left(\frac{\pi}{\tau_p}x\right) = \frac{V_{H\alpha}}{V_{H\beta}} \quad (3)$$

$$x = \frac{\tau_p}{\pi}\tan^{-1}\frac{V_{H\alpha}}{V_{H\beta}} \quad (4)$$

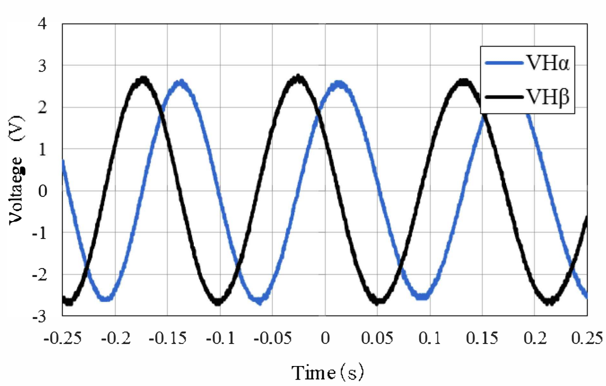

Fig.6.Three-phase to two-phase transformation waveform

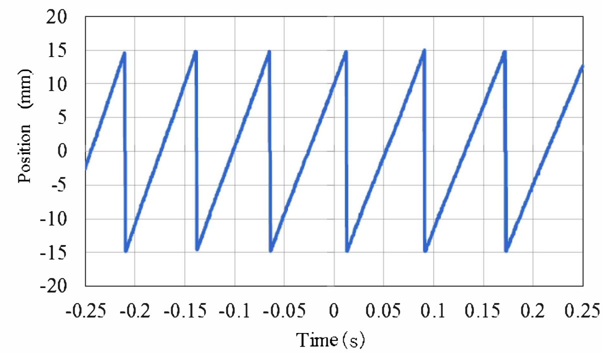

Fig.7.Position calculation waveform

3-phase waveform was able to be changed into 2-phase waveform shown in Fig.6 from the equation (1) and the equation (2). Furthermore, it was able to change into the waveform shown in Fig. 5 from the formula (3) and the formula (4).Here, one cycle of sawtooth wave is 180 deg on an electric angle. Therefore, when moving a mover 30mm, sawtooth wave progresses only 180 deg. From this, it has checked that the pole pitch which is 30mm was in agreement with one cycle of sawtooth wave.

C. Pulse output and position calculation by the microcomputer

The value acquired from a Hall element is processed using a microcomputer. This time, SH7211 by a Renesas Electronics Corporation was used. SH7211 builds in functions, such as a multifunctional timer unit, a 12-bit A/D conversion machine, and an 8-bit D/A converter. As stated previously, the hole voltage obtained from HU was able to be changed into A for computing a mover position. However, if a position is outputted using a D/A conversion function in the state of a sawtooth wave, it is difficult to acquire it with sufficient accuracy for an analog signal. Therefore, the calculated position signal needs to be changed into a digital value (pulse). Then, SH7211 performs conversion on a pulse wave from a sawtooth wave. Moreover, a pulse wave corresponds to advance of a mover, and retreat, and considers position resolution as the output set to 1mm by quad edge evaluation .The flow chart for outputting it is shown in Fig. 8. Moreover, the position waveform and pulse wave measured from the oscilloscope are shown in Fig. 12.

This program calculates hole voltage to a position signal, and changes it into the electric angle of 0~90deg.Moreover, when 90 degrees progresses on an electric square, a mover will progress 15mm.And as for T in Fig. 8, 2.25 is substituted. By doing so, a position signal distinguishes the pulse value P= 1 (High) and the pulse value P= 0 (Low) on the basis of half cycle 11.25deg of a pulse, and is changed into four pulse waves. And the pulse of B-phase which shifted from the pulse of this A-phase 90 deg is outputted by the same view. Distinction of direction is attained by comparing these. Moreover, since a total of eight pulses are generated while progressing 15mm, position resolution is set to about 1mm.As mentioned above, it is possible to use a Hall device as a position transducer of a mover.

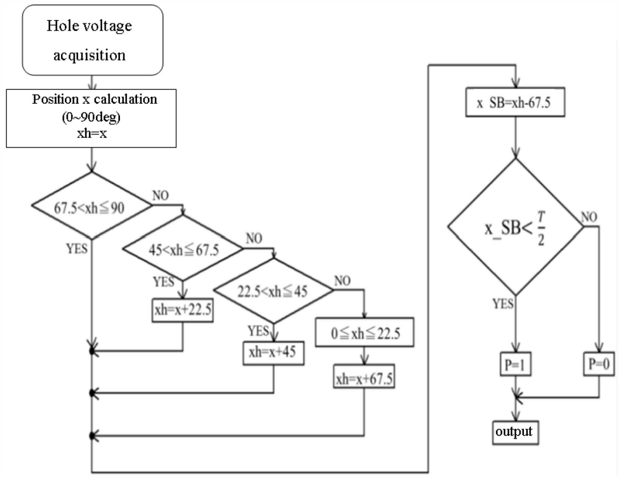

Fig.8.The flow chart of a pulse wave output

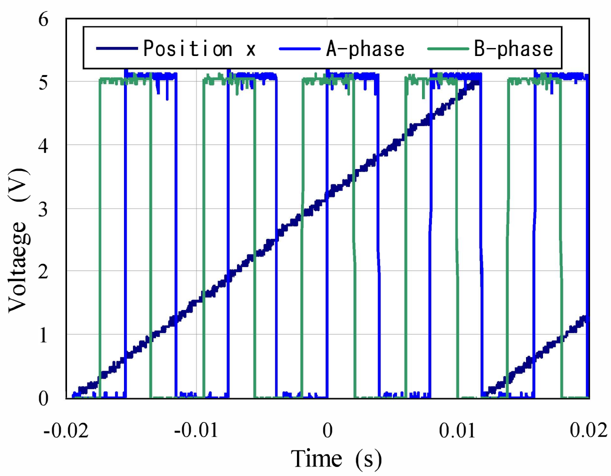

Fig.9. A position calculation waveform and a pulse shape

IV. Comparison of the Position Detection Method

When velocity control of PM-LSM is carried out using the position transducer of a linear encoder and each Hall device, the significance as a detector of a Hall device is confirmed. The velocity control simulation which carries out a trapezoid drive as shown in a figure was performed. Control cycles are 0.1msec. At this time, the simulation result when using each position transducer is shown in fig.10.

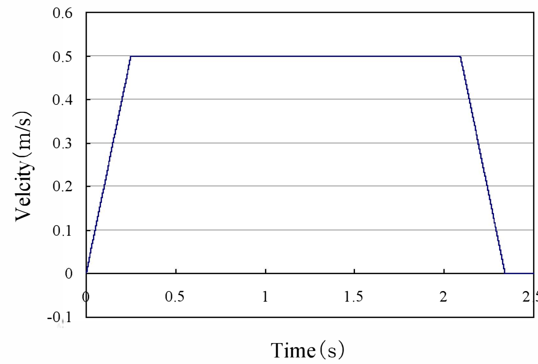

Fig.10.Command Velocity

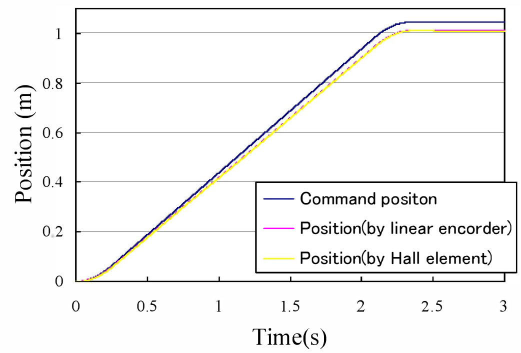

Fig.11.Position-time characteristic

The same result was obtained with both of the position transducers from the figure. In both of the cases, there are a little deviations compared with an instruction position, but It turns out that they are followed in the position. This cause is having applied only the velocity control loop and disturbance power. Therefore, it can use as a position transducer of Hall device ISPM-LSM.

V. Conclusions

This paper described development of the position transducer which used the Hall element, and the velocity control. The position calculation method using a Hall device and the speed simulation using it were performed. From this, it has checked that a Hall device was effective as a position calculation machine. However, the number of the hole units used for this examination was one. Therefore, it does not support a long distance. The position detection method corresponding to long distance using plural hole units needs to be established. Moreover, it is necessary to consider a actual machine drive

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