Development of High-Thrust and Double-Sided Linear Synchronous Motor Module For Liquid Crystal Display Equipment

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***Abstract*— Recently, there is an increasing requirement for controlling linear motion up to a few hundred of millimeter strokes in the area of the liquid crystal display (LCD) production equipment. The requirements of the motion system for LCD production equipment are high acceleration and high velocity with positioning accuracy. To satisfy these requirements, it has to be designed with the high-thrust force and low velocity ripple. In this work, high-thrust and double-sided linear synchronous motor (LSM) module is proposed and the developed high-thrust and double-sided LSM module is verified by performance test.**

Keywords*—*high-thrust; double-sieded; linear synchronous motor; module; LCD equipment

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1 Introduction

Recently, there is an increasing requirement for controlling linear motion up to a few hundred of millimeter strokes in the area of the liquid crystal display (LCD) production equipment[1]. Linear positioning system with direct driving method such as piezoelectric drive and permanent magnet (PM) motor could offer significant advantages over conventional linear actuation technologies[2-3]. Among these direct driving methods, motion system using linear motor is a proper method for long stroke and high accuracy[4].

The requirements of the motion system for LCD production equipment are high acceleration and high velocity with positioning accuracy. To satisfy these requirements, it has to be designed with the high-thrust force and low velocity ripple.

In this work, high-thrust and double-sided linear synchronous motor (LSM) module is proposed, where mover having coil block and core is assembled with 2~8 coil block module according to requiring thrust force, stator having magnet and yoke is fixed with guide rail. The developed high-thrust and double-sided LSM module is verified by performance test.

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2 Configuration of LSM module

High-thrust and double-sided LSM module is consisted with mover and stator as showed in Figure 1. The mover having coil block and core is assembled with 2~8 coil block module according to requiring thrust force as showed in Figure 2. The stator having magnet and yoke is fixed with guide rail.

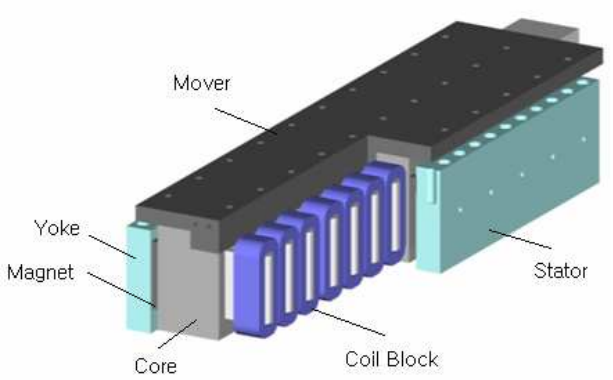
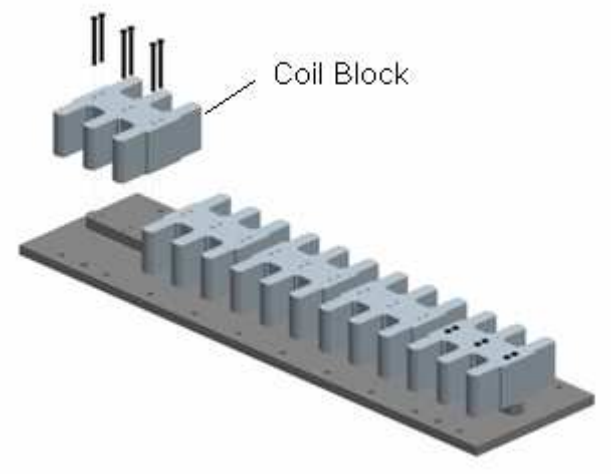


Fig. 1 Configuration of the high-thrust and double-sided LSM module



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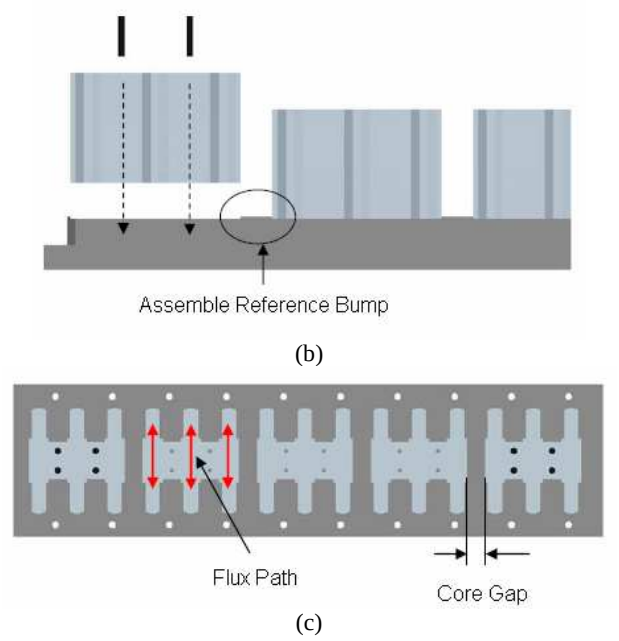


Fig. 2 Configuration of the assembled coil block and core; (a) ISO view, (b) Side view, (c) Top view

By using assemble reference bump, core gap between coil block can be adjusted in assemble process of coil block. Flux path is constructed with double side of core.

3 Design of LSM module

Requiring specifications of high-thrust and double-sided LSM module for LCD production equipment are listed in Table 1. In the design of LSM module, the shape and size of mover and stator are determined by using the electromagnetic analysis with finite element method. Figure 3 shows the finite element model of mover and stator at front, middle, and rear element of mover. In Figure 3, core shape of mover is designed to minimize the cogging force generating by magnet and core.

Table 2 lists the specifications of LSM module calculated by finite element analysis.

Tab.1 Requiring specifications of LSM module

Parameter		Value	Unit
Motor	Input voltage	440	V
	Rated thrust force	2500	N
	Max. thrust force	5000	N
	Max. velocity	1	m/sec
Driver	Power source	DC 440	V
	Peak current	96	A
	Continuous current	48	A

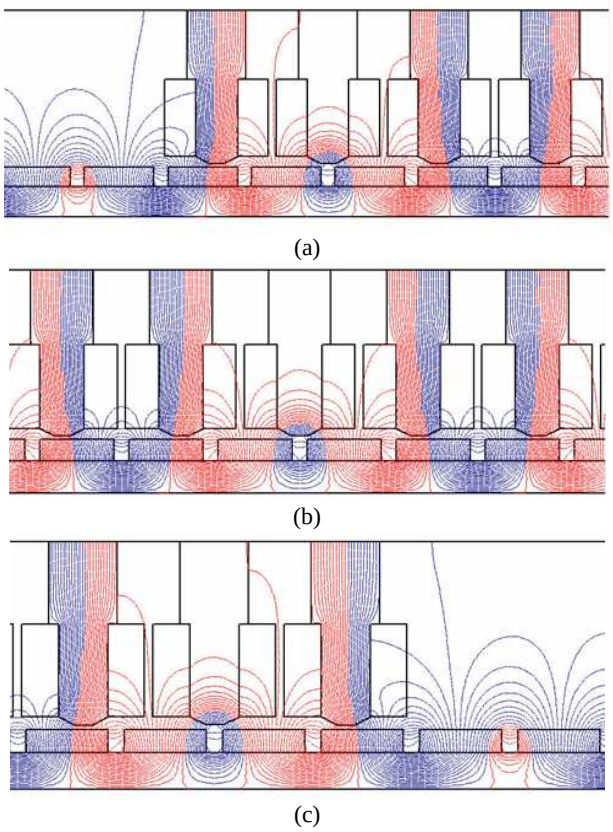


Fig. 3 Flux distribution according to finite element model of LSM module; (a) Front element (b) Middle element (c) Rear element

Tab.2 Specifications of LSM module calculated by FEA

Parameter	Value	Unit
Rated thrust force	2520	N
Thrust force constant	52.5	N/Arms
Phase current	48	A
Max. velocity	1.02	m/sec
Back EMF constant	42.1	Vrms/(m/s)
Mover weight	34.3	kg

Figure 4 shows the air gap flux density distribution according to slot number per pole and per phase. In Figure 4, air gap flux density distribution is similar to sine waveform according to slot number increasing. The LSM module having more slot number has good performance in the motor characteristics such as force ripple, efficiency, and vibration.

Figure 5 shows the back electromotive force distribution by finite element analysis. In Figure 5, back electromotive force is similar to sine waveform by magnet shape modification. Figure 6 shows the one side cogging force distribution and thrust force distribution by finite element analysis for mover moving distance.

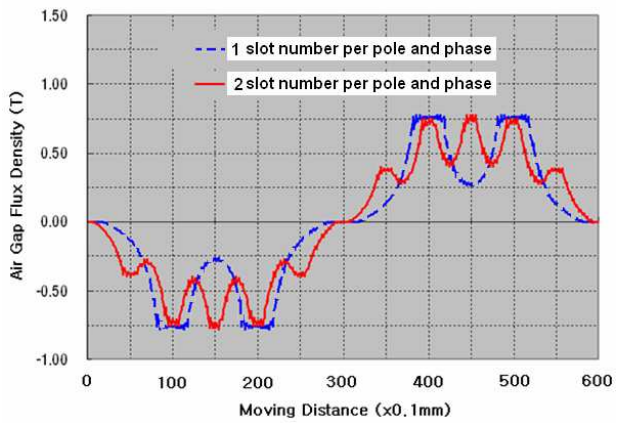


Fig. 4 Air gap flux density distribution according to slot number per pole and per phase

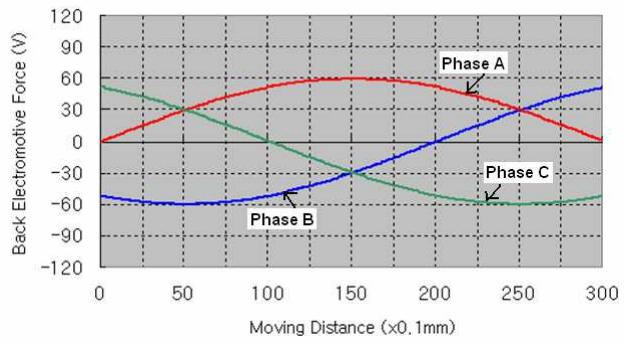


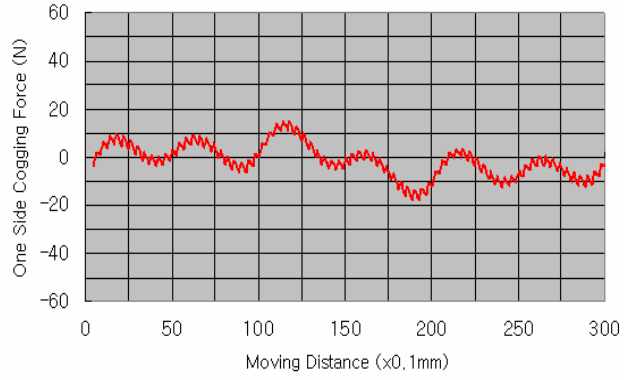
Fig. 5 Back electromotive force distribution

4 Manufacturing of LSM module

Manufacturing of LSM module is consisted with assemble of mover and stator, driving circuit for driving the assembled LSM module, and driving program for control of driving circuit.

4.1 Assemble of stator and mover

The mover having coil block and core is assembled with 6 coil block module, where coil block is fixed to core by screw. The stator having magnet and yoke is fixed with guide rail.



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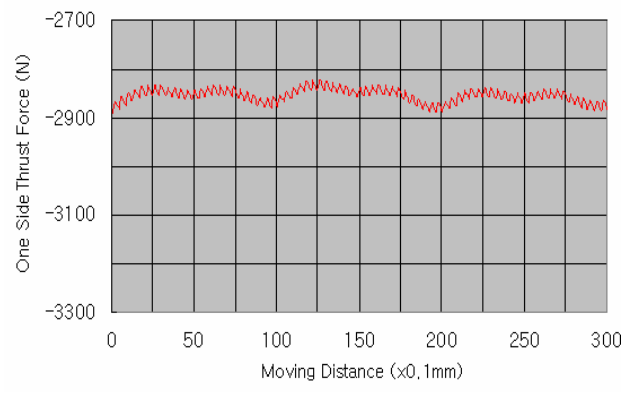

(b)

Fig. 6 Force distribution for one side; (a) cogging force (b) thrust force

4.2 Driving circuit

Driving circuit is manufactured with TMS320F1812 DSP, which has 440V input voltage, resolver input, highly speed computing function of 150MIPS having 32bit and I/O function and motor drive function. Figure 7 shows the process block diagram of developed driving circuit. Instant variation of input voltage having 440V is protected by regulation module. DC-DC converter and SMPS are used as electric power source of controller and gate driver. Current feedback and position feedback are used for current and velocity control. Thrust force control is conducted by control of current.

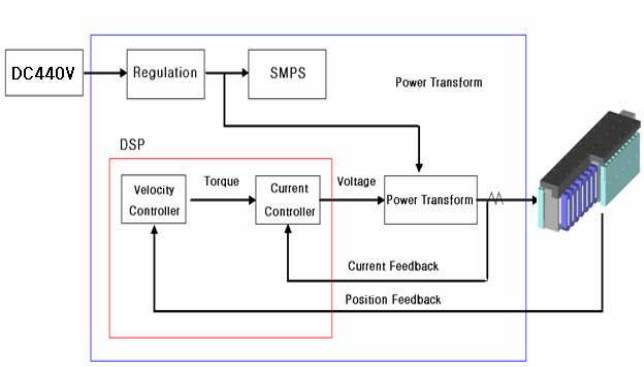

Fig. 7 Process block diagram of developed driving circuit

4.3 Control program

To drive the LSM module by using resolver input, driver program using sinusoidal driving signal is developed.

5 Experiments and results

To verify the applicability of developed LSM module to the LCD equipment, performance test is conducted.

5.1 Thrust force

The thrust force is measured by using the dynamometer. Figure 8 shows measured thrust force according to velocity condition. The thrust force for rated current is average 2.5kN for operating velocity range.

5.2 Driving current and signal wave shape

Figure 9 shows the current signal measured according to driving condition. Current ripple is dominant in reduction-load condition.

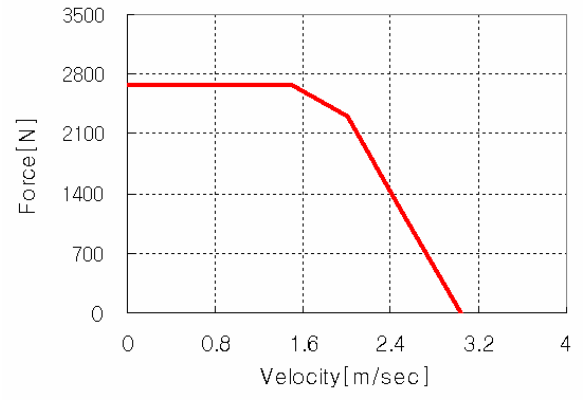

Fig. 8 Measured thrust force according to velocity condition

6 Conclusions

In this work, high-thrust and double-sided LSM module is developed by using the electromagnetic analysis with finite element method, and using the DSP. To verify the applicability of developed LSM module to the LCD production equipment, performance test is conducted. Developed LSM module has performance of 2.5kN rated thrust force and 1m/sec maximum velocity.

Acknowledgments

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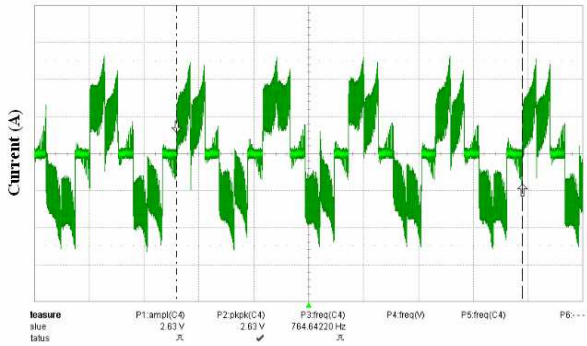
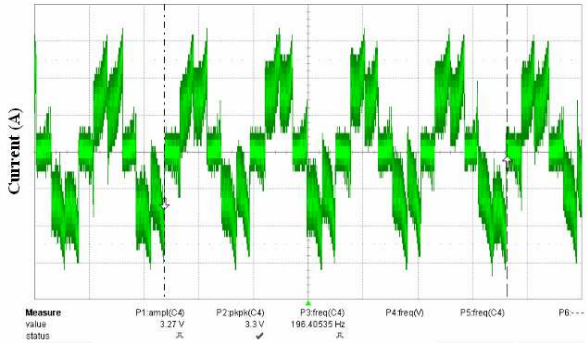


(a)



(b)

Fig. 9 Current signal measured according to driving condition; (a) no-load (b) reduction-load

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