Magnetic Force Comparison of Permanent Magnet Linear Synchronous Motor with Different Topology Structures

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***Abstract*—To make the ropeless elevator system be come practical, one of the most important requirements is the high force density. The slotted iron core type permanent magnet linear synchronous motor (PMLSM) seems to be the best choice except the large detent and normal forces. Therefore, in this paper we will investigate the characteristics of detent force, normal force, and thrust of PMLSM under different motor topology structures. Finally, the long armature double-sided slotted iron core type PMLSM with fractional slot winding is selected for the best performance.**

***Index Terms*— Permanent magnet linear synchronous motor, response surface methodology, finite element methods.**

I. INTRODUCTION

In comparison with other type linear motors, for instance, linear induction motor (LIM) and linear switched reluctance motor (LSRM) [3], the permanent magnet linear synchronous motor (PMLSM) is most suitable for ropeless elevator system because of the high force density. Therefore, in this paper we will investigate the slotted iron core type PMLSM and focus on the selection of the topology structure.

II. PMLSM TOPOLOGY STRUCTURES COMPARISON

A. Different PMLSM Topology Structures

The PMLSM can be divided into long-/short- armature types. For the short-armature type PMLSM, the armature is fixed on the mover. It is composed of iron core and windings of which the weight is large. Furthermore, the power has to be fed into the armature on the mover side, which needs the power cable. Moreover, the mover side is with the power electronics devices that will generate acoustic noise and make the passengers feel nervous. For the long-armature type PMLSM, the armature is fixed to the elevator fit and the PM is fixed to the mover, thus, the contactless power supply system is not needed, and the weight of the mover is relative smaller. Also, the electronics devices are not fixed to the mover side. No acoustic noise can be heard by passengers. Therefore, the long-armature type PMLSM is more suitable for the ropeless elevator.

B. Different Mover Topologies

In this section the mover topology structure is investigated. The surface mounted mover structure of double-sided PMLSM can be divided into two types. One is permanent magnet (PM) in reversed direction, and the other is PM in same direction. Then we construct two finite element (FE) models with same parameters for both armature and PM mover sides except the PM directions. The output thrusts of these two PMLSM models calculated in same condition. it can be seen that the output thrust of PMLSM with PM in same direction is much larger. Therefore, the PMLSM with PM in same direction is chosen for the elevator system.

III. PMLSM CHARATERISTICS CALCULATIONS

A. Detent Force Minimization

The PMLSM structures can be divided into integral- and fractional-slot winding types. In this section we will investigate the detent force in detail, together with other characteristics, for instance, output thrust and normal force. The design requirement and PMLSM specifications are listed in Table I.

TABLE I
SPECIFICATIONS OF PMLSM

Items		Unit	Value
Design requirement	Output thrust	[N]	12000
	Detent force	[N]	<12
	Rated speed	[m/s]	0.5
Stator	Back-iron height	[mm]	11
	Stator length	[mm]	2754
	Slot pitch	[mm]	34
	Tooth length	[mm]	15
	Lamination length	[mm]	200
Mover	Pole pitch	[mm]	38.25
	PM length	[mm]	>28
	PM height	[mm]	5
Air-gap	Air-gap length	[mm]	2

We can minimize the detent force by optimal design of some factors using finite element methods(FEM) and response surface methodology(RSM) .

In this paper the PM length PM_L, the PM group shifting length PM_SFL, and the slot opening length SL_OPL shown in Fig. 1 are chosen as the optimal factors.

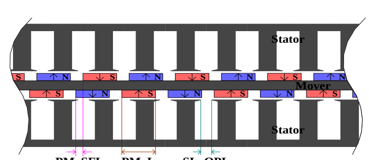

Fig. 1. Optimal factors in PMLSM

B. *Thrust and Normal Force Characteristics*

The detent force characteristics are strongly dependent on the air-gap length. For our PMLSM model the air-gap length is 2mm that is small for the achievement of high force density. It is well-known that both the detent force and thrust decrease as the air-gap increases. In this section the detent forces versus the air-gap length from 2mm to 5mm are investigated. The waveforms are shown in Fig. 2. The amplitudes of detent forces are significantly reduced to less than 2.5N when the air-gap length is larger than 3mm. Furthermore, the detent force curve is smoother as the air-gap length increases. It seems that the larger the air-gap length is, the better the detent force is. The thrust waveforms for different air-gap lengths are shown in Fig. 3. The curves of them are similar. However, the amplitude decreases greatly as the air-gap length increases. The peak value of the thrust of PMLSM with 5mm air-gap length is only 8532N that is only 68% to that of PMLSM with 2mm air-gap length. Therefore, both of the detent force and the thrust should be taken into the consideration for the selection of the PMLSM.

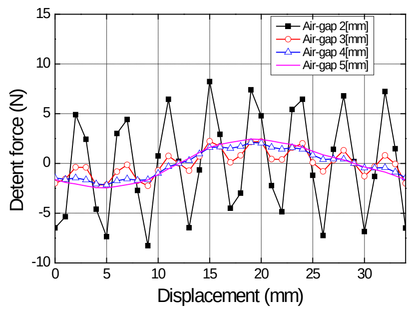

Fig. 2. . Detent force of PMLSM with different air-gap length

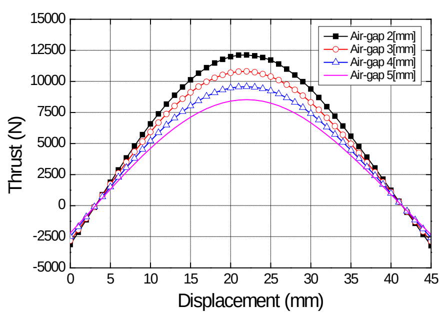

Fig. 3. Thrust of PMLSM with different air-gap length.

In same condition the amplitude of normal force is 4607N that is a burden to the elevator guide way system. To cancel out this normal force we propose the PMLSMs group structure shown as Fig. 4. The original PMLSM with 200mm lamination length is now divided into two 100mm laminated PMLSMs group. The stator structures of these two PMLSMs are exactly same. The only difference between these two PMLSMs is the PM group shifting direction shown as Fig. 4(a) and Fig. 4(b). The corresponding normal forces characteristics are illustrated as Fig. 5. The normal forces of Fig. 4(a) and Fig. 4(b) have the same amplitude that is half of the original PMLSM. However, the directions of them are reversed. And the sum of these two normal forces is almost zero. Most of importance is that both the detent force and output thrust have no change. Therefore, this PMLSMs group structure has good effect on the suppression of normal force.

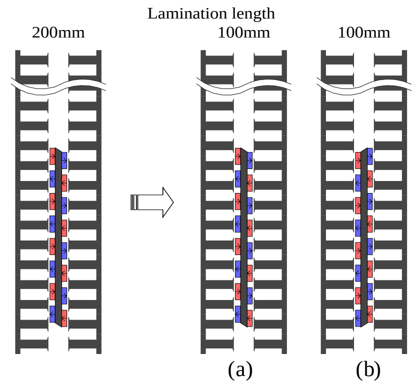

Fig. 4. Schematic drawing of PMLSMs group structure.

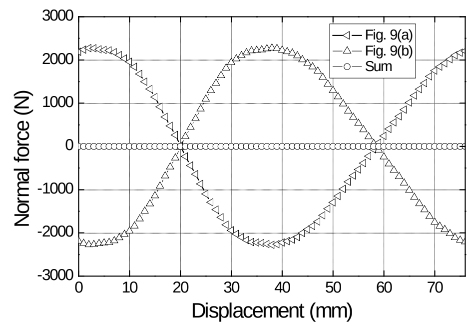

Fig. 5. Normal forces characteristics of PMLSMs group structure.

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