Ropeless 엘리베이터 시스템용 영구자석 선형동기전동기 구조에 관한 연구

진상민[*], 정군석[a], 주옥오[*], 조윤현[*]
동아대학교 전기공학과[*] 한라이비텍[a]

A Selection of PM-LSM Topology Structure for Ropeless Elevator System

Sang-Min Jin[*], Koon-Seok Chung[a], Yu-wu Zhu[*], Yun-hyun Cho[*]
Dong-A University[*] Hara E.B.Tech[a]

Abstract - One of the most important technical improvement required for ropeless elevator system to become practical is the improvements in overall system efficiency. Moreover, the predominant drawback of permanent magnet (PM) linear synchronous motor (LSM) is large detent force. Therefore, for the given volume the selection of high power density PM-LSM with low detent force is very imperative. In this paper, we will investigate the characteristics of thrust and detent force of PM-LSM under different motor topology structure. Finally, the long stator double-sided iron core type PM-LSM with fractional slot winding is the best choice for the ropeless elevator system.

1. Introduction

The demand on elevator system for very high building is increasing. Because it is the main vertical transportation system which is the predominant factor in the limitation of the skyscrapers height. Moreover, a third of the total area of the high building more than 100 storeys is assigned to elevators, engine rooms, and other traffic areas [1]. To improve the economic efficiency of buildings the multi-car elevator system attracts notice to the architectural planning of skyscrapers. Although the traditional rotary machine driven elevator system can be achieved, there are too many limitations. It is difficult to drive elevator cars more than two in one shaft, and the elevator car can only be operated in vertical direction. The linear motor driven ropeless elevator system can easily solve these problems. This ropless elevator system can run many cars in one shaft and make them go through to other shafts horizontally, which structures a closed loop path transportation system. To make this high efficiency elevator system become practical, one of the most important technical improvements required is the overall system efficiency [2].

Among all linear motors the permanent magnet (PM) linear synchronous motor (LSM) is most suited for ropeless elevator system [2]. Some researchers have investigated on the core-less type PM-LSM because there is no detent force [3]. However, the force density is relative lower. Therefore, in this paper we will investigate the core type PM-LSM for its high force density and focus on the selection of the topology structure.

2. Analysis and Results

2.1 Different PM-LSM Topology Structures

The PM-LSM can be divided into long-stator type and short stator type. For the short stator type PM-LSM, the armature is fixed on the mover. It is composed of iron core and windings whose weight is large. Furthermore, the power has to feed into the armature on the mover side, which needs the power cable. If the ropeless elevator system can be achieved, the contactless power supply system has to be used to eliminate the power cable. However, this contactless power supply system is very expensive and contains some losses in the power transmission that will decrease the overall system efficiency. Moreover, the power electronics devices are on the mover side, which will generate acoustic noise and make the passengers feel nervous. For the long stator type PM-LSM, the armature is fixed the elevator fit and the PM is fixed on 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 on the mover side. There is no acoustic noise can be heard by passengers. Therefore, the long stator type PM-LSM is chose as the research subject in this paper.

2.2 Different Mover Topologies

With the consideration of the manufacturing and the capacity, the flat type PM-LSM is better. In this paper, the double-sided type PM-LSM is chose for its high force density in comparison with the single-sided type PM-LSM.

In this section the mover topology structure is investigated. The mover structures can be divided into six different cases as shown in Table I. The corresponding move structures are shown in Fig. 1. Based on these mover structure, we calculate each case in the same condition such as air-gap length, stator structure. The peak values of output thrusts for different mover topology structures are shown in Fig. 2. This results indicates that the thrust of PM-LSM with PM in same direction is larger than that of PM-LSM with PM in reversed direction. In a matter of fact, the PM-LSM with PM in reversed direction is equivalent to two single sided PM-LSMs whose movers are fixed together. Therefore, the output thrust results also reveal that the power density of the double sided PM-LSM is larger than that of the single sided PM-LSM for same volume. In Fig. 2 we can see that the thrust of PM surface mounted on mover back iron is largest, next is the PM held by ferromagnetic material, the least is the PM held by non-ferromagnetic material. Therefore, case_6 is chosen for its largest force density.

Table I. Different mover topologies

	PM Direction	Mover Back Iron	Connection Material
Case_1	Reversed	Without	Non-ferromagnetic
Case_2	Same	Without	Non-ferromagnetic
Case_3	Reversed	Without	ferromagnetic
Case_4	Same	Without	ferromagnetic
Case_5	Reversed	With	
Case_6	Same	With	

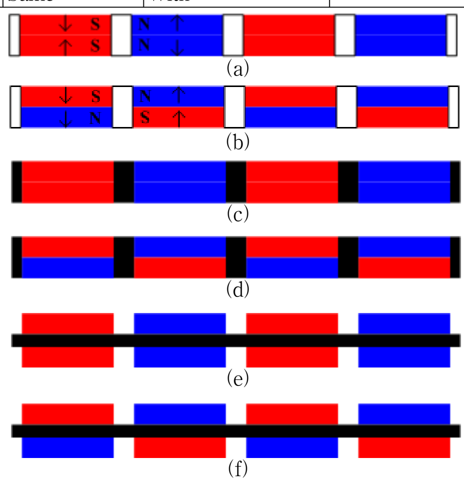

Fig. 1. Different mover topologies. (a) Case_1 (b) Case_2 (c) Case_3 (d) Case_5 (e) Case_6.

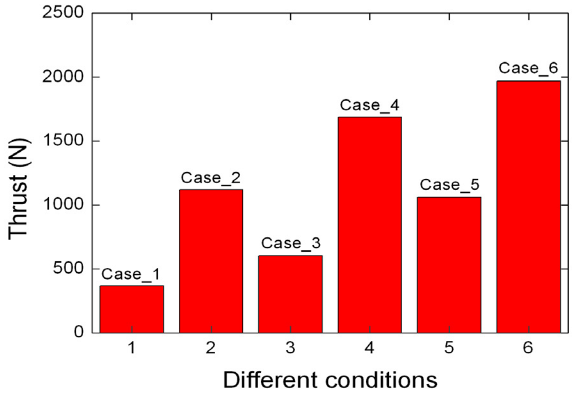

Fig. 2. Output thrust versus different mover topologies.

2.3 Different Stator Topologies

In this section we will investigate two different stator structures. They are Integral-slot winding type PM-LSM and fractional-slot winding type PM-LSM, which are shown as Fig. 3. The specifications of these two type PM-LSM are listed in Table II.

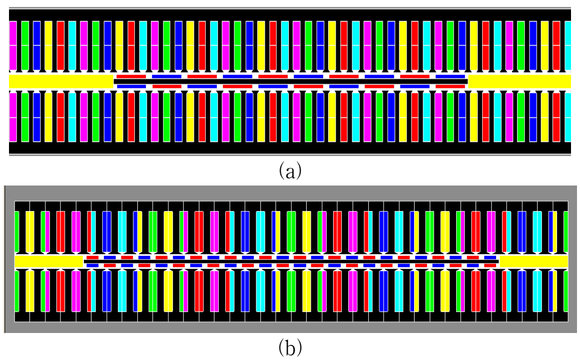

Fig. 3. PM-LSM structure (a) Integral-slot winding type (b) Fractional-slot winding type

Table II. Specifications of different winding types of PM-LSM

Items	Integral-slot winding	Fractional-slot winding
Pole pitch	60mm	24.75mm
Slot pitch	20mm	22mm
Slot width	12mm	12mm
Slot/pole/phase	1	3/8
Air-gap length	2mm	2mm
Mover length	600mm	594mm

Based on the PM-LSM structure and the specifications, we made the finite element model. For these two PM-LSM models we try to keep same slot width and air-gap, and similar mover length with consideration of actual manufacturing. Here we optimize the structures of these two PM-LSMs to investigate the detent force characteristics. To find the global optimal point, the combination of finite element method (FEM) and response surface method (RSM) is used [4].

For these two types PM-LSMs, the PM length, the PM relative displacement, and the slot opening length are chosen as the optimal factors. Moreover, the window-zoom-in method is introduced to reduce the factors region to achieve more accurate response value. The calculation process of the combination of FEM and RSM is repeated three time and twice for the integral-slot winding type PM-LSM and the fractional-slot winding type PM-LSM, respectively. The peak values of the detent force is decreased from 1487[N] and 48[N] to 21.8[N] and 4.2[N] for integral-slot and frational-slot type PM-LSMs, respectively. This indicates that the detent force of integral-slot winding type PM-LSM is larger than that of fractional-slot winding type PM-LSM. The corresponding optimized detent force curves for these two type PM-LSMs are shown in Fig.4 and Fig.5. Therefore, the fractional-slot winding type PM-LSM is chosen for the ropeless elevator system.

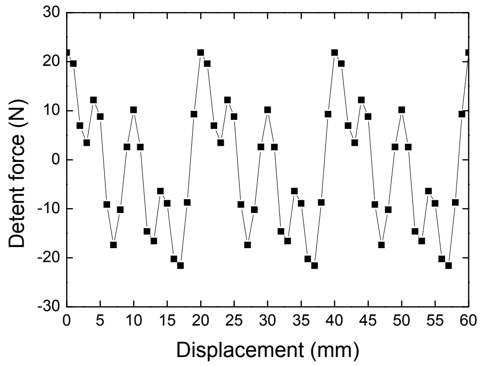

Fig. 4. Optimized detent force waveform for integral-slot winding type PM-LSM.

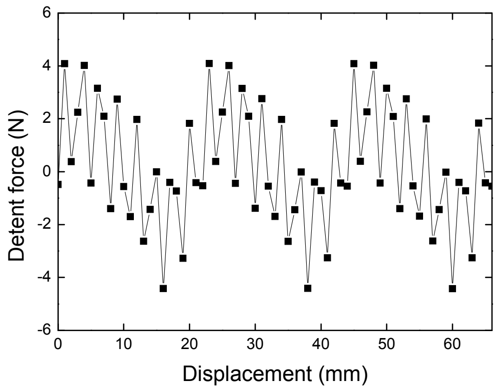

Fig. 5. Optimized detent force waveform for fractional-slot winding type PM-LSM.

3. Conclusion

In this paper, the PM-LSM with different topology structure was investigated for ropeless elevator system. The output thrusts versus different mover topology structure were calculated by FEM. Meanwhile, the elevator system should be operated smoothly. Thus, the detent force characteristics of PM-LSM with different slot winding type were analyzed by the combination of FEM and RSM. Finally, together with the consideration of the thrust and detent force characteristics, the long stator double sided iron core type PM-LSM with fractional-slot winding is the best choice for the ropeless elevator system.

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