Performance Study of Single DOF Linear Motor with E-shaped Electromagnet Variable Structure

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ABSTRACT**:** In order to study the effect of structural changes on the performance of linear motors, we take the linear motor system with electromagnet (EM) as a slider composed of E-shaped iron core as the research object, and analyze the levitation force F_y, driving force F_x, and torque around the center of mass T of the E-shaped EM. By changing the length of the U, V, W poles of the E-shaped core to change the structure of the EM to investigate the variation rules of the levitation force, driving force and torque around the center of mass of the E-shaped EM. Firstly, the structure change is divided into 2 groups, respectively, change 1 pole and change 2 poles, and the F_x, F_y and T of the E-shaped EM are simulated by using JMAG software. The results show that when changing the core structure of the E-shaped EM, the F_x, F_y and T will be affected, in which the F_y is affected more when the length of a single pole increases, and the F_y is reduced obviously at the beginning when a single pole decreases, but the trend of the F_y reduction tends to be stable with the increase of the reduction of a single pole; in terms of the F_x and the T, when the In terms of F_x and T, when the altered structure is symmetrically altered, there is little effect, and when the altered structure is asymmetric, the F_x and T are more affected.

KEYWORDS: linear motor, E-shaped electromagnet, structural changes, driving force, levitation force

1. INTRODUCTION

Magnetic levitation technology is widely used in many industrial fields due to its non-contact, non-lubrication and easy control. Especially, it is applied in some special occasions such as clean room or vacuum environment. Linear motor drive is a commonly used technology in clean transfer. Guo Y. [1] et. al designed a non-contact transfer device based on magnetic levitation technology, which is controlled by brushless DC control scheme. Most of the existing magnetic levitation linear drives are composed of a levitation mechanism and a drive mechanism [2], which is good to realize dust-free transmission and drive, however, this will lead to a larger device, and for the levitation type of conveyor equipment, its own gravity is too large, which will reduce the goods carried and affect the efficiency of transmission. And too large equipment will also lead to an increase in energy consumption.

Based on this, this paper proposes a magnetic levitation linear motor with an E-shaped core that is integrated with levitation and drive, and this device can realize the miniaturization of dust-free transmission and improve the transmission efficiency. However, this structure poses a big challenge to the control system, and in order to be able to better control the device, its performance and mechanical properties need to be studied. Therefore, this paper takes the structure of the E-shaped electromagnet (EM) core as the research object, and changes the structure of the EM by changing the length of the three poles of U, V, and W. It explores the effect of changing the structure of the EM on the magnetically levitated linear drive system.

2 E-SHAPED EM VARIABLE STRUCTURE DESIGN

The linear motor drive unit is shown in figure 1. It consists of a frame made of aluminum profiles, a fixed guide made of a permanent magnet array, an E-shaped EM, and a laser displacement sensor. Wherein both the drive and levitation of the device are provided by the attraction between the E-shaped EM and the permanent magnets of the linear array.

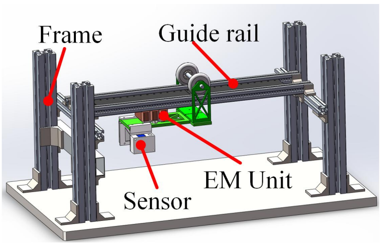


Figure 1 Linear motor drive

The force analysis of an E-shaped EM is shown in figure 2, where F_y provides the levitation force, F_x provides the driving force, and T around the center of mass causes the EM to rotate.

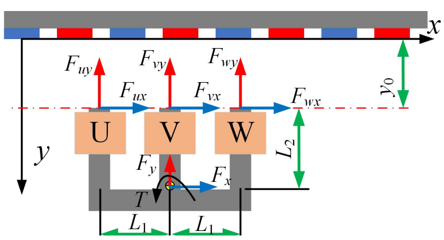


Figure 2 Force diagram of EM

The F_x, F_y and T can be calculated from equation (1).

$$\begin{cases} F_{x,y} = \sum_{i=u,v,w;j=x,y} F_{ij} = F_{uj} + F_{vj} + F_{wj} \\ T = F_{wy}L_1 - F_{uy}L_1 - F_x L_2 \end{cases} \quad (1)$$

The scheme of structural change is shown in figure 3. The purpose of changing the structure of the EM is achieved by changing the length of the U, V and W poles. Here the structure change is divided into 2 groups. (1) changing only one pole, i.e., dU=dW=0 and changing dV (changing U and W poles is similar and not listed here); (2) changing 2 poles, i.e., dU=0 and changing dV and dW; and then analyzing its *Fy*, *Fx*, and *T* through JMAG simulation.

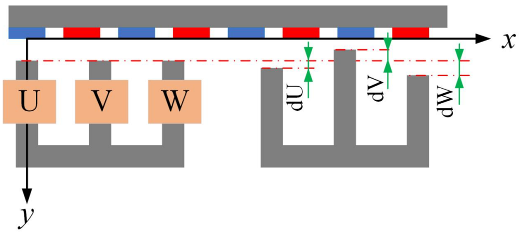


Figure 3 Variable structure design

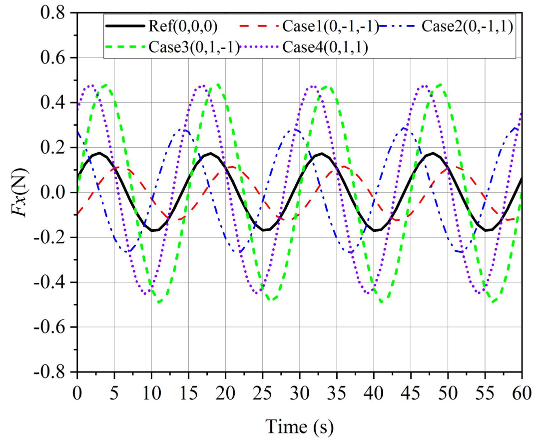
3 SIMULATION ANALYSIS

According to the EM variable structure scheme designed in Section 2, simulation analysis is carried out using JMAG and the simulation parameters are shown in table 1.

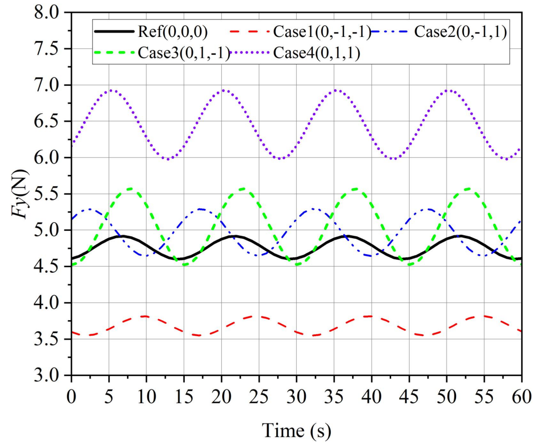
Table 1 Simulation parameters

Name	Value
Current	0 A
Permanent magnets	N35
Iron core type	SS40
Air gap	9 mm

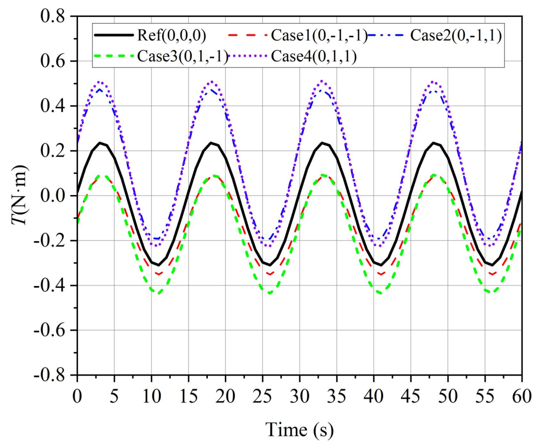
The simulation conditions are as follows: keep dU constant and vary the lengths of dV and dW ranging from -1mm to 1mm, varying by 1mm each time. let the EM and permanent magnet move relative to each other, moving by a distance of 1mm at each step, moving by a total of 60mm. solve for F_x, F_y, and T at each position, and the results are shown in figure 4.



(a) F_x



(b) F_y



(c) T

Figure 4 Simulation results

From figure 4(a), it can be seen that case1 and case2 change less, while case3 and case4 increase significantly, indicating that dV has a greater effect on the F_x. Figure 4(b) shows that case1 decreases significantly, case4 increases significantly, and case2 and case3 do not change much, indicating that the average air gap has a greater effect on F_y. Figure 4(c) shows that case1 and case3 decrease and case2 and case4 increase, indicating that the change in dW has a more pronounced effect on T.

4 CONCLUSION

This paper takes the E-shaped electromagnet of single DOF linear motor as the research object. It analyzes the change pattern of levitation force, driving force and torque around the center of mass after changing the structure of E-shaped EM, and obtains the following conclusions: (1) When the structure of E-shaped electromagnet is changed, it has an effect on F_x, F_y and T. (2) The F_y is most affected by the change of electromagnet structure and is closely related to the average air gap.

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