Study on bilateral permanent magnetic levitation elevator

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Abstract. A two-side permanent magnetic levitation elevator is designed, and the traction motor is a two-side short primary long secondary permanent magnet linear synchronous motor. The structure of bilateral permanent magnetic levitation elevator is designed, and the operating principle is analyzed. The control system of the permanent magnetic levitation elevator is studied. It is concluded that the amount of winding and permanent magnet is less, the manufacturing cost is lower, and it has good controllability.

1. Introduction
Magnetic suspension elevators have become a research hotspot in recent years because of the advantages of no contact, no mechanical friction, simple transmission structure and good controllability. Foreign countries such as Japan and Germany, domestic research institutes and universities such as Shenyang University of Technology and Wuhan University of Technology have carried out research and trial production of magnetic levitation elevators [1, 2]. Compared with the traction drive and hydraulic drive mode of the traditional elevator, it has the biggest advantages that the magnetic suspension elevator is frictionless, low noise, light vibration and high comfort. Whether the safety and good controllability of the magnetic levitation elevator can be solved is the key core of the practical application of the magnetic levitation elevator. It designs a permanent magnet magnetic suspension elevator structure with bilateral short primary and long secondary structure in this paper. It analyzes the operation principle and preliminarily studies its control system.

2. Bilateral short primary long secondary permanent magnetic maglev elevator structure
The magnetic levitation elevator can be divided into two types: car primary and hoistway primary according to the position of the primary winding. Permanent magnet linear motors are mostly generally designed for long primary and short secondary structures [3-8]. The elevator is characterized by a long hoistway length and a short elevator car length, taking into account manufacturing costs, process precision and strength, etc. In this paper, it designs a kind bilateral permanent magnet magnetic levitation elevator which adopts the bilateral hoistway secondary type structure, it is that the linear motor secondary is placed on the elevator shaft and the linear motor primary is placed on both sides of the car. The specific structure is shown in Figure 1.
The bilateral permanent magnet linear motor with long secondary structure which utilizes the primary of the winding and the permanent magnet on both sides of the car as the mover, the amount of the winding and the permanent magnet is small, it is fully utilized and the manufacturing cost is low. In the long primary structure, the mover does not have windings and permanent magnets, but the primary windings and permanent magnets are used in a large amount, it results in an increase in cost and an end effect is obvious [9]. The magnetic suspension elevator system mainly includes a car, a counterweight device, a guiding system, a primary permanent magnet linear motor, a secondary permanent magnet linear motor, a vacuum switch and a controller, it shows in Figure 2.

In order to improve the safety during using the elevator and prevent the elevator from falling accidents because of external interference or sudden power failure during operation, and for better energy saving, the bilateral permanent magnet maglev elevator designed is equipped with a weight...
device in this paper. It is that the weight device and the elevator car are respectively at both ends of the traction wire rope and are positioned by the traction sheave. In order to reduce the cost of the entire magnetic levitation elevator and have little effect on the comfort of the elevator car, the weighting device adopts a guiding system composed of a rolling guide shoe, a T-shaped guide rail and a rail frame as a conventional elevator. The guiding system consisting of bilateral permanent magnet linear motors is utilized on the elevator car side, it includes permanent magnet linear motor primary, permanent magnet linear motor secondary and controller.

In order to suspend the car, the elevator requires to be provided with auxiliary guide shoes. The clearance between the auxiliary guide shoes and the car is generally set to half of the air gap value of the primary winding and the secondary winding [10]. Because there is no auxiliary guide shoe, the gap between the primary winding of the elevator car and the secondary may become zero under the action of external disturbance power and permanent magnet. At this time, the theoretical value of the magnetic force is infinite, even if the winding current is passed. It is difficult for the electromagnetic force to push the elevator car back to the equilibrium position. Another function of the auxiliary guide shoe is to control the position of the car and the counterweight for proper operation when the elevator is installed, commissioned, overhauled or faulty properly.

3. The principle of bilateral permanent magnet magnetic suspension elevator

When the system works normally, because of the symmetry of the structure, the elevator car is in the middle of the hoistway, it is that the elevator car is suspended. When it is subjected to external disturbance power, the elevator car is offset to one side, so that the air gaps of the primary and secondary sides of the car are not the same and the position sensor can detect the change of the car position. After logical judgment, the current is applied to the primary windings on both sides of the car. Under the combined action of electromagnetic and permanent magnet force, the elevator car returns to the equilibrium point. The air between the primary winding and the secondary winding on both sides of the elevator car becomes same large, the elevator car re-stabilizes the suspension. Figure 3 is a schematic diagram of the magnetic circuit when the bilateral permanent magnet linear motor is running, the magnetic flux formed by the reaction of the permanent magnet and the armature is a tendency to synthesize magnetic flux. According to the magneto resistive minimum principle, the magnetic flux always passes through the path with the smallest reluctance and then closes, so in the following figure, the primary mover is always subjected to the rightward force and moves to the right.

If the current in the coil of Figure 3 is reversed, the primary moves to the left. Therefore, in the case where the real-time position of the mover is determined, the speed and direction of the operation of the bilateral permanent magnet linear motor can be controlled by adjusting the direction of the current in the winding and the magnitude and frequency of the current.
4. Bilateral permanent magnet magnetic suspension elevator control

As a vertical transportation vehicle, the acceleration and jerk values of the elevator have a great influence on human comfort. In order to prevent discomfort to the human body, it is necessary to strictly control the acceleration and jerk values, wherein the jerk, that is, the physiological coefficient cannot exceed 1.3 m/s³. In order to make the elevator possess higher comfort, it is necessary to achieve accurate control of the running speed of the elevator, it is to make the speed curve as smooth as possible. The elevator speed is the primary moving speed:

\[
V = (1 - s)V'_s \\
V_s = 2f\tau
\]

where \( f \) is the input frequency, \( \tau \) is the winding pole pitch.

Uniformly and continuously changing the power supply frequency of the primary winding can change the synchronous speed of the bilateral permanent magnet linear motor smoothly. According to the requirements of the traction force of the elevator in the stable operation process, the size of the traction force need be kept constant during the variable frequency speed regulation. It requires the power supply voltage to be changed accordingly, it is that the slip rate should be changed synchronously.

The schematic diagram of the structure of the drive part of the control system is shown in Figure 4. The accurate control of the traction force can be achieved by simultaneously adjusting the voltage and frequency of the primary winding [11]. At the same time, the drive module adopts vector transformation and pulse width modulation technology which can reduce motor heating and has the characteristics of energy saving and high efficiency. The control CPU gives the speed profile and controls the selector, position sensor, safety check circuit and speed curve.
5. Conclusion
(1) It designs a bilateral permanent magnet magnetic suspension elevator in this paper. The traction force is provided by a bilateral short primary and long secondary permanent magnet linear synchronous motor. The windings and permanent magnets are utilized in a small amount, are fully utilized and the manufacturing cost is low.

(2) In this paper, the magnetic levitation elevator system is equipped with a counterweight device which improves the safety of the elevator, reduces the cost of the entire magnetic levitation elevator and has little effect on the comfort of the elevator car.

(3) It shows that the control of the elevator primary winding can realize the accurate control of the elevator speed and traction force and achieve high comfort through the analysis of the control system.

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