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Research on gap sensor and position sensor for high speed maglev train

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Abstract Maglev has got a lot of attention as a new transportation method due to its superior characters, such as high speed operation, low energy consumption, high level safety control, and environment friendly. Compare with conventional wheel on rail trains, maglev train suspends on the track, so suspension gap is a crucial parameter related to safety operation. Due to its non-contact and high speed operation, real-time control is highly enhanced. To ensure reliable and safety operation, precise suspension gap and position and speed information are needed. Suspension gap are measured by gap sensor and position and speed information are collected by position sensor, these information are sent to control center for operation control. This paper is to investigate and compare the working principle of gap sensor and position sensor.

***Keywords* :** High speed maglev train, Gap sensor, Position sensor

1. Introduction

The function of high speed maglev train is based on the theory of linear synchronous motor (LSM). The suspension electromagnets act as rotor of LSM, and the coils fixed on the guideway to drive the train act as long stator. Traction system provides traveling magnetic field for long stator to drive the train back and forth according to the relative location information between the rotor and the long stator. As one of the key technologies of high speed maglev train, sensor system plays a very important role. Because maglev train suspends around 8mm above the track and operates at highest speed of 530 km/h, if any part of the gap sensor and position sensor system has error, the whole system will collapsing down. In this paper, we are going to discuss the principle of sensor system for maglev train.

The rest of this paper is organized as follows, in section 2 will introduce principle of eddy current sensor, section 3 lists considerations to design sensor system for maglev train, section 4 shows different point and common point of gap sensor and position sensor and some simulation results, and conclusions are made in the final part.

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2. Principle of eddy current sensor

Eddy current sensor is widely applied to many industries, due to its characteristics, such as non-contact, wide dynamic response range and flexibility. Eddy current senor is one kind of inductive sensor. Electrical excitation exerted to detecting coil generate magnetic field to space. Affected by this magnetic field, eddy current will be generated on the surface of detected target. Eddy current has skin effect, and skin depth is related to excitation frequency. The amount of generated eddy current is related to detected target, such as its physical properties, dimension and displacement gap to the detecting coil.

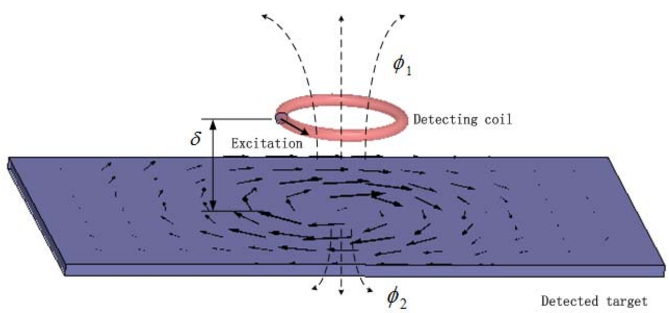


Fig. 1 Principle of eddy current sensor

As shown in figure 1, magnetic field Φ_1 is generated by high frequency excitation exerted to detecting coil and magnetic field Φ_2 is generated by eddy current. Directions of Φ_1 and Φ_2 are opposite to each other, and this will change equivalent inductance of the detecting coil. Equivalent inductance corresponds to displacement gap δ. After demodulation, filtering and signal processing of coil output, we can find the corresponding displacement gap.

3. Considerations to design sensor system for maglev train

Stable operation control needs gap sensor get precise suspension gap for control system. To get suspension gap of maglev, sensor system should detect long stator pack of the synchronous linear motor. Because of tooth-slot structure of long stator pack, limited installment space, complicated temperature and magnetic field environment, common eddy current senor cannot realize suspension gap measurement. So special design is needed to overcome tooth-slot structure, temperature drift, and magnetic field interference, also we need to take care of linearity, dynamic behavior and communication interface. [1]

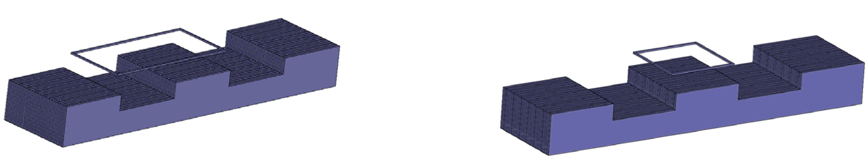
Tooth-slot structure: suspension gap is the distance between coil face and tooth face of long stator. Suppose suspension gap is constant, when detecting coil moves along tooth-slot structure, gap is different at tooth face and slot face. So equivalent inductance of detecting coil will change according to the special structure, and consequently sensor output varies along the stator. It is difficult for control system to distinguish the reason of variable output. It could be tooth-slot structure or suspension gap really changed. Finally, we cannot ensure stable operation.

Position detection is very important for control system, because the traction system needs precise location and speed information to carry out the traction task normally and reliably. To get precise position data, absolute positioning and relative positioning are required. Relative positioning is used to get high-accuracy position data and absolute positioning is used to eliminate cumulated errors from relative position signals. Absolute positioning is a different sensing system, and it is not going to be discussed here, you can refer to [2] for more information. Position sensor means relative position sensor for the rest of this paper. Long stator pack of the synchronous linear motor with on tooth-slot structure is scanned to get precise relative position.

Thanks to the tooth-slot structure, precise relative positioning can be realized [3][4], but same with suspension gap sensor, design is constrained by limited installment space, complicated temperature and magnetic field environment. It needs to overcome temperature drift and magnetic field interference as well, and also we should consider linearity, dynamic behavior and communication interface.

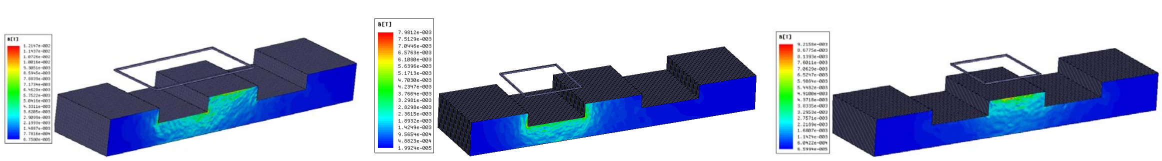
4. Comparison of gap sensor and position sensor

Long stator is made of laminated silicon steel, so eddy current can't be generated on the face of tooth and slot. However, interaction of magnetic field and electric field still works on sensor coil and laminated stator pack and it will be proved by simulation results shown in figure 3. Gap sensor and position sensor both can be called inductive sensor. Design of gap sensor should avoid effects induced by tooth-slot while position sensor needs to count the number of tooth-slot and post process sensor output to get precise position. Prototype of gap sensor and position sensor design is shown is figure 2. Gap sensor covers a cycle of tooth-slot so as to be less sensitive to distance difference from detecting coil to tooth face and slot face, and position sensor only faces a tooth or a slot to be more sensitive to distance variation.

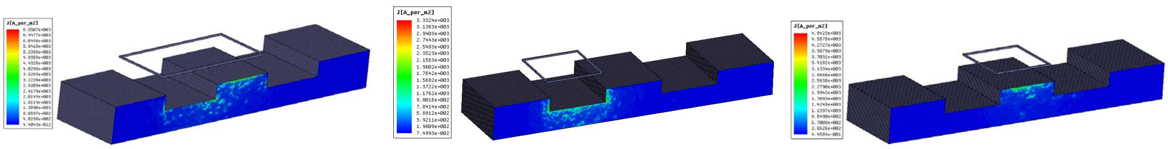


(a) Gap sensor (b) position sensor

Fig. 2 Prototype design



(a) Magnetic flux density



(b) Current density

Fig. 3 Simulation result of detecting coil and tooth-slot long stator pack

5. Conclusion

Some researchers call gap sensor eddy current sensor, it’s not strictly correct, but we can call both gap sensor and position sensor inductive sensor. Magnetic field generated by high frequency excitation works on high permeability silicon steel and current is generated on the side surface of lamination slices, and magnetic field of this current will affect detecting coil in turn. By observing relationship of distance variation and sensor output and post processing collected data, we can get suspension gap and position information for control system.

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