Analysis and experimental verification of the suspension system of a bearingless linear slider using four E-type iron core units

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Abstract. In semiconductor manufacturing, the process of manufacturing various components and wiring on silicon wafers requires high cleanliness. Although traditional magnetic levitation slider devices can eliminate mechanical contact and suppress dust, suspension devices, and propulsion devices are usually used separately. The actuator using a linear motor generates about 10 times the suction force in the upward direction compared to the driving force. This configuration optimizes energy utilization to the maximum extent while minimizing energy losses incurred by separate utilization of suspension and driving devices, while concurrently streamlining the overall structure [1]. This study used four sets of E-type electromagnets to design a linear slider that can simultaneously utilize buoyancy and propulsion forces. By using an E-type iron core, the electromagnet can be miniaturized. Replace the torque in the rotating electric motor with propulsion force, and replace the bearing support force with buoyancy force. Through suspension and disturbance experiments, the device was subjected to a 1N impact and returned to stability after 3 seconds. The experimental results proved that the device has good response characteristics.

1 Structure and working principle

As shown in Figure 1, the structure of a bearingless linear slider device consists of four sets of electromagnets and a permanent magnet stator track. Each electromagnetic unit adopts a structure of winding independent coils on each protruding pole of the E-type iron core. On the guide rail of the stator, the permanent magnet is alternately configured with N and S poles relative to the gap surface. The main magnetic flux is generated through this permanent magnet, and the magnetic circuit is controlled by applying current to the coils of the iron core at each protruding pole.

Regarding propulsion, the principle of propulsion is the same as that of a typical linear synchronous motor by applying three-phase AC to three coils. The width ratio of the pole head of the electromagnetic iron core to the permanent magnet on the guide rail is 3:4, which can offset the propulsion force generated by each protruding pole. The propulsion of the device is carried out in an open loop manner, and the speed of propulsion can vary according to the cycle of three-phase alternating current. The displacement in the x-axis direction and the torsion around the z-axis of the device become passively stable through the restoring force of the permanent magnet. The three degrees of freedom of movement, pitch, and roll in the upward direction are active control. By changing the magnitude of three-phase AC, they can be controlled by the upward buoyancy of each unit.

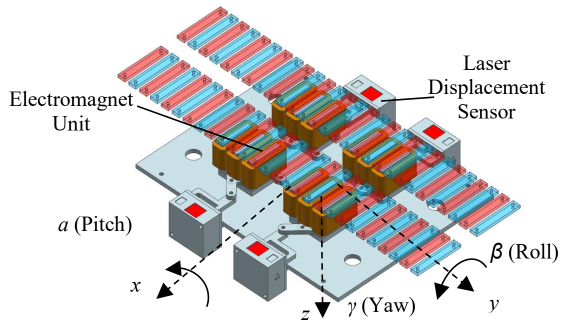

Fig. 1 Structure of suspension system

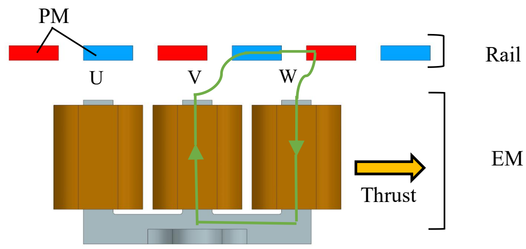

Fig. 2 Electromagnetic unit walking principle

2 Experimental result

A prototype of a bearingless linear slider was made using four electromagnetic units, and suspension and impact resistance experiments were conducted. Use laser sensors to measure the displacement of four points, convert them into the center of gravity displacement, pitch, and roll, and control them for three degrees of freedom. Add load on the platform to confirm the step response. In this floating experiment, the phase difference of the three-phase alternating current is 0 degrees. A closed-loop control diagram of the platform system was established in Matlab/Simulink, and the response characteristics of the system were verified. As shown in Figure 3, at 5s, a step disturbance was applied by placing a 1N load on the corner of experimental platform 1. The control parameters of the air gap in the *z*-direction are P=1400 and D=18; The control parameters for pitch are P=140, D=4: The control parameters for Roll are P=138, D=3. After the signal is given for 3 seconds, the system stabilizes the suspension. The results indicate that the system has good position response characteristics.

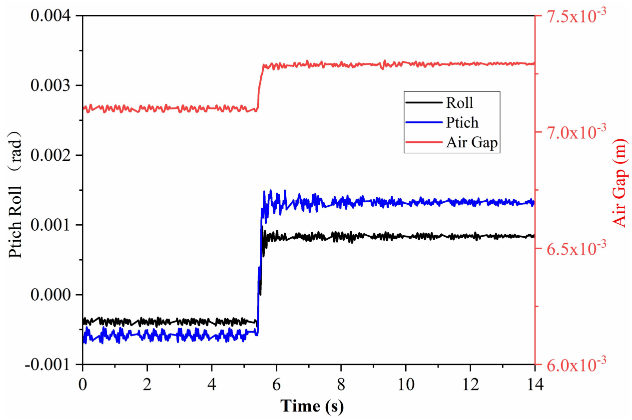

Fig. 3 Step response(0 deg)

3 Conclusion

The article introduces the structure and working principle of a bearingless linear slider. The experimental research shows that the system recovers stable suspension after 0.2s under the impact of 1N, which proves that the system has good step response characteristics.

References

[1] Annasiwaththa B I, Oka K, Harada A. Magnetically levitated linear slider with a non-contact power transfer method[J]. International Journal of Applied Electromagnetics and Mechanics, 2017.