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E2: Study on Spinning Mechanism by Permanent Magnet Linear Actuation

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Abstract: This paper describes an analysis of torque characteristics of a noncontact spinning system using linearly actuated magnets. This noncontact spinning system spins the suspended object (here is an iron ball) without contact by the remanent magnetization and the linear movement of four permanent magnets. In this paper, the remanent magnetization point is modelled, and the rotational torque of this mechanism is calculated by IEM (Integral Element Method) analysis. The rotational torque is also measured using a measurement device with strain gauges. According to the IEM analysis results and the experimental results, the rotational torque characteristics of the noncontact spinning system are discussed.

1. Introduction

Noncontact spinning systems have been proposed. Ikuta et al. have proposed a noncontact magnetic gear acting as a transmission mechanism [1]. The authors have proposed two kinds of noncontact spinning systems using permanent magnets. One system is using the rotational disk magnets to vary the magnetic flux filed around the suspended object [2]; the other system is using the linearly actuated magnets to approach the suspended object [3]. Using these two spinning systems, the suspended objects (they are iron balls) have been spun successfully without contact. The analysis of rotational torque characteristics of the later system using the linearly actuated magnets has been done. However the iron ball could not spun [4].

In this paper, the prototype and the spinning principle are introduced. Basing on the simplification of the remanent magnetizations on the surface of the iron ball, the analysis model of IEM is created, and the rotational torque of the noncontact spinning system is calculated in several cases of the number and the position of the remanent points. And a measurement device that is similar to the analysis model is setup using strain gauges, and the measurement experiment is carried out. What model of the remanent magnetism on the iron ball can make to spin is proved.

2. Experimental Prototype and Spinning Principle

Fig.1 shows the configuration of the noncontact spinning system using linearly actuated magnets. The mechanism has two parts: one is a suspension part which consists of a permanent magnet, a voice coil motor and two eddy current sensors, and the other is a spinning part which consists of four permanent magnets and four VCMs. The spinning part is the surroundings of the device shown in Fig.1, and consists of four same and independent units. The magnet is installed on the linear actuator and is driven to approach and depart from the suspended iron ball.

The principle of the spinning mechanism can be understood from Fig.2. The suspended object in the centre of the figure is an iron ball on which there exist remanent magnetization points. This remanent magnetization causes the ball to rotate about the vertical axis due to its attraction to the approaching magnet. The figure shows that magnet I approaches to the iron ball. When the magnet is near to the ball, the remanent is attracted to the nearest magnet. Next, the magnet I departs from the ball and the magnet II approaches to the ball. This time, the stable point will be at the position of facing to the magnet II. Theoretically, repetitions of this approach-depart cycle of the four magnets can make the iron ball spin.

3. Modelling and IEM Analysis

In order to examine the rotational torque of the spinning mechanism, the remanent magnetization points were simplified as permanent magnets. As shown in Fig.3, the one pole of magnets is located on the surface of the iron ball, since the remanent magnetization points are on the surface of iron ball. And the other pole of magnets is located at the centre of the iron ball for avoiding to the impact of the rotational torque. Moreover,

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the vertical magnet is seemed as the remanent magnetization point for suspension on the top of the iron ball. The N pole of the magnet is located on the top surface and the S pole is located at the centre of the iron ball. The horizontal magnet is represented as the remanent magnetization on the side of the iron ball. Fig.4 shows the IEM analysis model with two remanent magnetization points along the equator of the iron ball. In the model, we assume that the rotational angle of iron ball expresses as θ , the drive angle of the magnets for rotation expresses as ϕ . The size of the magnet for rotation is same with those used in experimental prototype.

Using this analysis model, the rotational torque was calculated. When the remanent magnetization rotated in steps of 5 degrees from 0 to 360 degrees, the rotational torque was calculated at each step. And then, the magnets were driven in steps of 30 degrees until 360 degrees. The analysis results are shown in Fig.5, when the offset angle between two points is 45 degrees. As shown in the figure, there are various stable points where the torque line is zero crossing with falling to the right according to the driving angles. This result concludes that the spinning mechanism can be made by the structure shown in Fig. 1.

4. Conclusion

The new model of the remanent magnetism of the spinning system with permanent magnets and linear actuators has been proposed and the torque has been analysed by the calculation. As the result, the iron ball can be spun when the number of the remanent magnetization point is more than two.



Fig. 1 Noncontact spinning system

Fig. 2 Principle of spinning

Fig. 3 Model of remanent magnetism



Fig. 4 Remanent Model



Fig. 5 Torque analysis

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