APSAEM2010

Asia Pacific Symposium on Applied Electromagnetics and Mechanics

28 – 30 July 2010

Hotel Istana, Kuala Lumpur, MALAYSIA

Organizer
Universiti Putra Malaysia

Co-organizer
Japan Society of Applied Electromagnetics and Mechanics
Shinshu University, Japan
Kanazawa University, Japan

In collaboration with
Yayasan Ilmuwan, Malaysia

Sponsors:

UPM UNIVERSITI PUTRA MALAYSIA BERILMU BERBAKTI

信州大学 SHINSHU UNIVERSITY

YAYASAN ILMUWAN

TM Research & Development

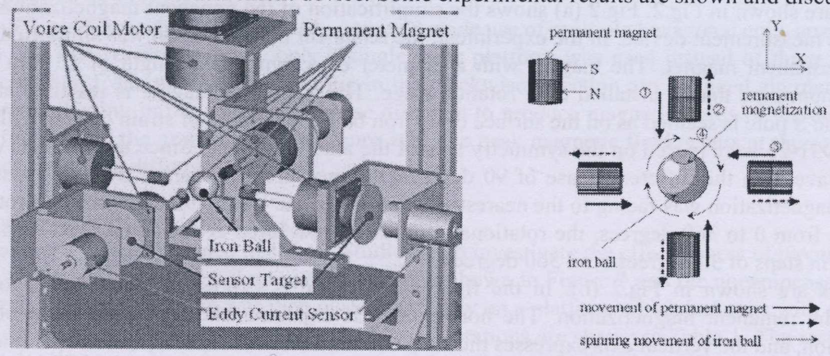
Asia Pacific Symposium of Applied Electromagnetics and Mechanics (APSAEM2010)
Kuala Lumpur, Malaysia. 28-30th July 2010

Torque Analysis of a Noncontact Spinning System Using Linearly Actuated magnets

F. Sun[1], A. Tsurumi[1] and K. Oka[1]
[1] Dept. of Intelligent Mechanical System Eng., Kochi University of Technology, Kochi, Japan

Introduction

Currently, Magnetic suspension systems that control attractive forces by adjusting the air gap between the permanent magnet and the suspended object have been proposed [1]. The noncontact manipulation systems also have been developed using the air gap control method [2] and the flux path control method [3]. Moreover, a noncontact spinning system has been proposed by means of the air gap control method using the permanent magnets and the linear actuators [4]. This paper analyzes the rotational torque characteristics of this noncontact spinning system by means of experimental examinations. In this paper, the experimental prototype and the spinning principle are introduced. Basing on the simplification of the remanent magnetizations on the surface of the iron ball, the measurement device was setup. The rotational torque was calculated and measured using the model and the measurement device. Some experimental results are shown and discussed.



(a) Illustration of experimental prototype (b) Spinning principle using permanent magnets

Fig.1 Experimental prototype and spinning principle

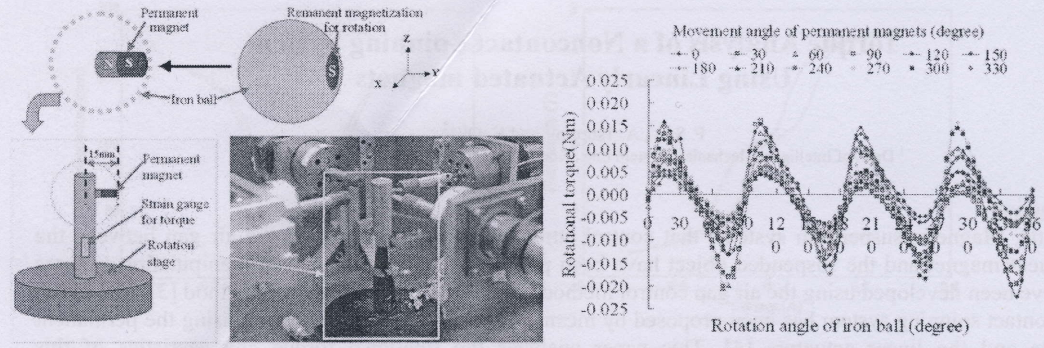
Experimental prototype and spinning principle

Fig. 1 (a) shows the illustration of the noncontact spinning mechanism. The mechanism prototype has two parts: the suspension part and the spinning part. The suspension part is at the center of device and consists of a permanent magnet, a VCM (voice coil motor), and two eddy current sensors. An iron ball as the suspended object is levitated without contact by means of the suspension part. The spinning part is at the outside of the device and consists of four same and independent units. Each unit consists of a permanent magnet, a linear actuator motors, a sensor target, and an eddy current sensor. The permanent magnet is installed on the top of slider of 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. 1 (b), which shows a plan view of an iron ball and four magnets. The suspended object in the center of the figure is an iron ball on which there exist remanent magnetization points. The strongest magnetization determines which will be the upper side of the ball during suspension. The next strongest magnetization is assumed in the horizontal plane and shown in Fig. 1 (b). This remanent magnetization causes the levitated ball to rotate about the vertical axis due to its attraction to the approaching magnet. Four magnets are installed perpendicular to each other. 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 magnet. Next, the magnet I departs from the ball and the magnet II approaches to the ball. Four magnets are driven to move by sine waves that have same amplitude, same frequency, and different phase. The phase difference between two adjacent magnets is 90 degrees. As a result, the four magnets approach the iron ball by turns. Consequently, based on the repetitions of these approaches and apartness, the magnetization continuously faces the nearest magnet and the ball is rotated.

Remanent magnetization simplification and experimental examination

In order to examine the performance of the rotational torque of this noncontact spinning mechanism, the remanent magnetization point on the surface of the iron ball was simplified to a small permanent magnet, and an experimental measurement device was setup by means of the strain gauges for torque.



(a) Simplification of remanent magnetization and measurement device (b) Measured rotational torque results

Fig.2 Measurement experiment with one remanent magnetization point as S pole

Firstly, we assume that the diameter of the iron ball is 30 mm, and there is only one remanent magnetization point as S pole on the surface of the iron ball. The simplification of the remanent magnetization and the experimental results are shown in Fig.2. Fig.2 (a) shows the simplification of the remanent magnetization and the photograph of the measurement device. In the experiment, the remanent magnetization was simplified to a small neodymium permanent magnet. The magnet with a diameter of 5 mm and a length of 15 mm was attached to an aluminum pipe that is installed on a rotation stage. The N pole of magnet is installed at the rotation center, and the S pole is seemed as on the surface of an iron ball. Two pieces of strain gauges with the type of KFG-2-350-D31-23 were pasted on the symmetry side of the aluminum pipe. Since the magnets were driven by the sine wave with the different phase of 90 degrees, the measurement started from the position when the remanent magnetization was facing to the nearest magnet. When the remanent magnetization rotated in steps of 5 degrees from 0 to 360 degrees, the rotational torque was measured at each step. And then, the magnets were driven in steps of 30 degrees until 360 degrees.

The measured results are shown in Fig.2 (b). In the figure, the torque is expressed with respect to the rotational angle of the remanent magnetization. The horizontal axis expresses the rotational angle of the remanent magnetization, and the vertical axis expresses the torque around the vertical axis, and the parameters on the top of figure express the magnets' movement angle. The intersection where the downward-sloping section of torque graph intersects the horizontal axis is called a stable point. When the remanent magnetization point is at the stable point, the torque equals zero, and if the remanent magnetization rotates around the stable point, the direction of the torque will make the remanent magnetization point return to the stable point. If the stable point moves, the remanent magnetization point will follow it. As a result, the iron ball spins.

In Fig. 2 (b), the rotational torque is varying when the remanent magnetization is rotating and the magnets are moving. However, all the stable points are concentrated in several narrow ranges. This result indicates that the mechanism can spin the iron ball only in a narrow range, but not in the whole revolution, when there is only one remanent magnetization on the surface of the iron ball. However, the iron ball has been spun successfully in actual experiment using this mechanism. Consequently, the model with only one remanent magnetization is insufficient.

Conclusion

In this paper, the prototype and the spinning principle of the noncontact spinning mechanism using linearly actuated magnets were introduced. And the torque performance was examined with one remanent magnetization by experiment. The result indicated that the model was insufficient. Now, we are examining the torque performance using some complex models with more than one remanent magnetization.

References

[1] K. Oka and T. Higuchi : "Magnetic Levitation System by Reluctance Control: Levitation by Motion Control of Permanent Magnet", International Journal of Applied Electromagnetics in Materials, Vol. 4, pp.369-375 (1994)

[2] T.S. Cui, K. Oka, and K. Masaki: "Magnetic Levitation System Using Permanent Magnet and Linear Actuator - Study of Push-Pull Levitation Mechanism", The 17th Symposium of Electromagnet and Dynamics, No.2AM5, pp. 243-248, Kochi, Japan (2005-6)

[3] Misuno, T., Hirai, Y., Ishino, Y. and Misuno, T., Flux-Path Control Magnetic Suspension System Using Voice Coil Motors, Journal of System Design and Dynamics, Vol.1, No.2 (2007), pp.147-158

[4] Y. Fujiwara, T.S. Cui, L Chen and K. Oka: "Manipulation by Linear Driving Permanent magnet -Rotation Control of Ironball-", Journal of the Japan Society Applied Electomagnetics and Mechanics, Vol. 14, No. 1 pp.126-131 (2006)