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408 NONCONTACT ROTATION CONTROL FOR SUSPENDED IRON BALL USING DISK MAGNET

Feng SUN and Koichi OKA

Department of Intelligent Mechanical Systems Engineering, Kochi University of Technology,

Kami City, Kochi, Japan, oka.koichi@kochi-tech.ac.jp

ABSTRACT

This paper proposes a new noncontact spinning mechanism using disk magnets and rotary actuators. In this spinning mechanism, a magnetically suspended object is spun around the vertical axis by rotary disk magnets. In this paper, the structure of the proposed mechanism is introduced, and examination results using four rotary magnets are shown.

MOTIVATION

A noncontact spinning mechanism has been developed using permanent magnets and linear actuators for spinning a suspended object [1]. In that system, four magnets in horizontal plane approach to the levitated object in turn, and the object spins and pulsates.

This paper proposes a new noncontact spinning mechanism using disk magnets and rotary actuators in place of magnets and linear actuators. Depending on the arrangement of the numbers of magnets and the phases of their magnetic poles, the levitated object has an equilibrium attractive force in the horizontal plane. Consequently, there is no pulsation in the spinning suspension state theoretically.

SPINNING PRINCIPLE

The principle of the spinning mechanism can be understood from Figure.1, a plan view of the iron ball and four disk magnets. When the iron ball is levitated in the vertical direction by a permanent magnetic suspension system, the four disk magnets are arranged around the levitated ball and in the same horizontal plane as the ball. Each magnet has two magnetic poles in the radial direction (see Figure.1). The magnetic poles of the four disk magnets are arranged in a parallel configuration, and reverse between two adjacent magnets. All the disk magnets rotate at same speed.

The remanent magnetization on the surface of the iron ball is used here for spin control. The iron ball has various remanent magnetizations. The strongest magnetization determines which will be the upper side of the ball during suspension. The next strongest

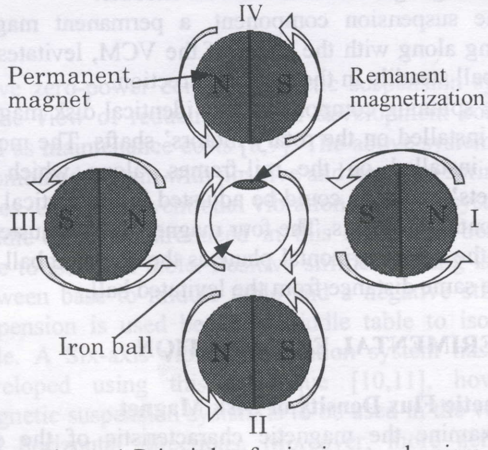


Figure.1 Principle of spinning mechanism

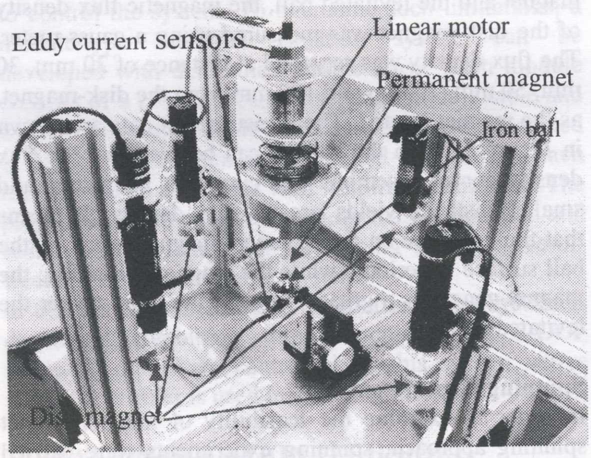


Figure.2 Photograph of noncontact spinning mechanism

remanent magnetization, indicated in Figure.1, causes the ball to rotate about the vertical axis due to attraction to the four disk magnets. We assumed the remanent magnetization is N. In the situation shown in Figure.1, the remanent magnetization is attracted by disk magnet I, and will rotate so as to face disk magnet I. At the same time, the four magnets are each rotating. Consequently, when the remanent magnetization faces magnet I, the iron ball has rotated 90 degrees, and the four magnets have rotated 90 degrees as well. At this point, the remanent magnetization will then be attracted to magnet II. Theoretically, repetitions of this attraction-rotation cycle can make the iron ball spin at the same rotation speed as the four magnets.

NONCONTACT SPINNING MECHANISM

Figure.2 is a photograph of the proposed noncontact spinning mechanism. The mechanism has two parts: the suspension component, which consists of a permanent magnet, a VCM (voice coil motor) and two eddy current sensors; and the spinning component, which consists of four disk magnets and four rotary motors, each containing a gear reductor and an encoder.

In the suspension component, a permanent magnet, moving along with the slider of the VCM, levitates the iron ball steadily in the vertical direction.

In the spinning component, four identical disk magnets were installed on the rotary motors' shafts. The motors were installed on the rail-frames, along which the magnets' positions could be adjusted in the vertical and horizontal directions. The four magnets were adjusted to be in the same horizontal plane as the levitated ball and all the same distance from the levitated ball.

EXPERIMENTAL EXAMINATION

Magnetic Flux Density of Disk Magnet

To examine the magnetic characteristic of the disk magnet and the influence of the distance between the magnet and the levitated ball, the magnetic flux density of the disk magnet was measured using a gauss-meter. The flux density was recorded at distance of 20 mm, 30 mm, 50 mm, 70 mm and 100 mm from the disk-magnet, as the magnet rotated. The measurement data are shown in Figure.3. From the data, it can be seen that the flux density curves resemble sine curves at all points, and smaller distance yields greater flux density. It means that the influence on the remanent magnetization on the ball surface is periodic while the magnet is rotating; the magnet generates a greater force at the point nearer the levitated ball.

Spinning Experiment

In order to examine the feasibility of the noncontact spinning approach, spinning experiments were carried out with the prototype at the distance of 75 mm between the disk magnets and the levitated ball.

When the ball was suspended steadily and was in a relative static state, a rotation speed of 0.5 rps was input into the control system of the spinning part, and then all disk magnets were driven to rotate at the same rotation speed. Consequently, the levitated ball began to spin from the zero rotation state due to attraction of the second remanent magnetization to the rotation magnets.

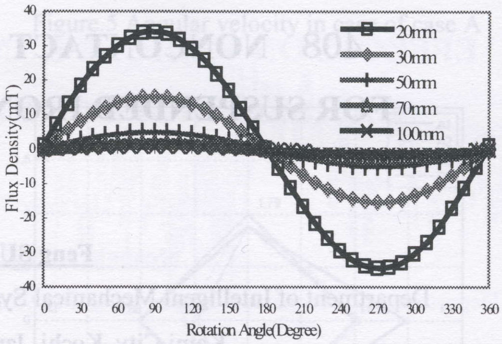
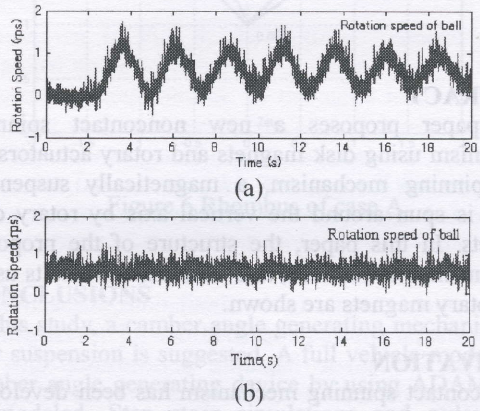


Figure.3 Magnetic flux density of disk magnet



(a)

(b)

Figure.4 Experimental results of rotated ball

The spin direction was opposite that of the rotation magnets.

Figure.4 (a) shows the experimental results that the ball's rotation speed responds to the rotation speed of the magnets. The rotation speed of the magnets was input after approximately 2 second, and the responses were recorded for 20 seconds. Figure.4 (a) indicates that while the magnets begin to rotate, the levitated ball is spun as well. However, the ball's rotation speed is fluctuating, the average approximately equals to the speed of the magnets. After several minutes, the ball's rotation speed becomes stable as shown in Figure.4 (b).

CONCLUSION

A noncontact spinning method using disk magnets and rotary motors has been proposed. A prototype of the spinning system was constructed to verify the proposed method. Noncontact spinning experiments using the prototype were performed. The examination results indicate that a levitated iron ball can be spun using the remanent magnetizations and the rotation disk magnets.

REFERENCES

1. Oka, K., Fujiwara, Y., Cui, T.S. and Chen, L., "Noncontact Spinning Mechanism Using Linearly Actuated Magnets", in Proc. Int. LDIA2005 Symp., pp.552-555, 2005.