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DESIGN OF NOVEL CONTACT-FREE DISK SUSPENSION AND ROTATION SYSTEM UTILIZING DIAMAGNETIC GRAPHITE

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ABSTRACT
The energy-saving actuation system is a valuable element in various industry fields using micro mechatronics technology. In the recent five years, we have produced some kinds of proto-model of novel contact-free disk suspension and linear motion devices by using diamagnetic graphite (Pyrolytic Graphite: PG) plate. Especially, a contact-free linear drive by using PG plates and small piece magnets is very useful as an extremely energy saving actuation technique. Very recently, we got a unique result as a successive acceleration motion of PG plate on Halbach PM array. We are getting ready to confirm it by using ring Halbach PM array.

INTRODUCTION
In 1996, we have designed a novel permanent magnet array made of concentric circles arranged in Halbach structure. We could realize the contact-free suspension of PG disk on the surface of this novel ring permanent magnet array without mechanical support [1]. Moreover, we revealed that an interesting performance that can be used, in conjunction with diamagnetic levitation, to move PG plates without any contact with the use of small PM piece [2].
By linear PM array of limited length, we cannot confirm the truth of successive acceleration motion of PG plate. Therefore, we want to confirm a unique successive acceleration motion of PG plate by using ring PM arrayed in concentric circle and endless.
In this paper, we will present several interesting observation facts, and describe that preliminary design for the contact-free rotation drive of PG disk on ring Halbach PM array by using a novel technique for successive acceleration motion on passive magnetic levitation of diamagnetic PG plate.

CONTACT-FREE PG DISK SUSPENSION
We have designed a novel PM array made of magnets disposed in concentric circles and arranged in a Halbach structure as shown in Figure 1. This novel ring Halbach PM array is constructed with several arc-shaped PM pieces (Nd-Fe-B) with parallel magnetization.
As shown in Figure 2, stable magnetic levitation of diamagnetic PG disk is realized by the unique magnetic field of surface of the novel ring Halbach PM array. Disk PG sample in Figure 2 (named hole-type disk), the diameter is about 54mm (inner hole is about 12mm diameter), thickness is 1.3mm, and weight is 4.85g. Stable passive magnetic levitation of hole-type PG disk sample is carried out holding an air gap about 1.2mm. In payload performance of PG disk samples, the hole-type PG disk had been loaded with about 9g maximum and performed a stable rotation without any contact.

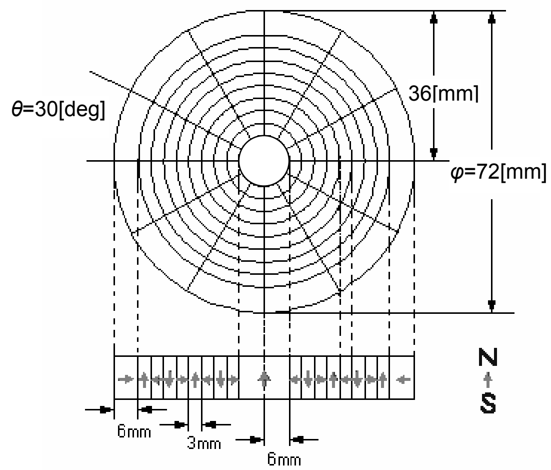

FIGURE 1: Design of novel ring Halbach PM array.

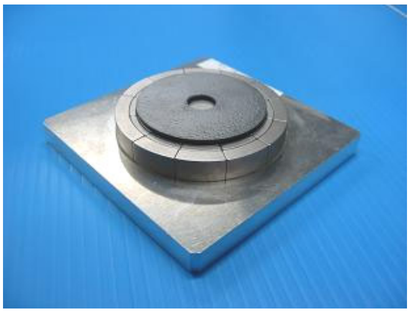

FIGURE 2: Stable magnetic levitation of PG disk (hole-type) on proto-model ring Halbach PM array.

Moreover, contact-free rotation of the PG disk can be carried out without any mechanical support. And, it seems that the magnetic friction in the rotation direction of this system by using diamagnetic graphite PG is very small. That is, if it is true, it will be thought that it is possible to rotate PG disk for a long time only by giving very small energy.

LINEAR DRIVE TECHNIQUE OF PG PLATE

In case of the setting of PG plate on Halbach PM array as shown in Figure 3 and Figure 4. The acceleration motion (along to x direction on the rail) of PG plate is performed by the approaching of a small PM piece to the PG plate.

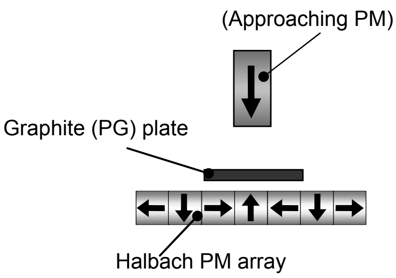

FIGURE 3: Layout of an approaching magnet for the drive of PG plate on Halbach PM array (N-N magnetic polar arrange).

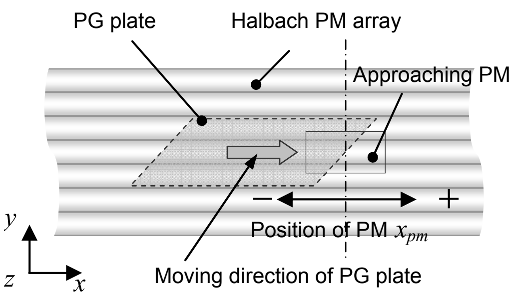

FIGURE 4: Relation of the setting position between the PG plate and an approaching PM for the acceleration motion on Halbach PM array.

On the acceleration motion direction of a PG plate, it depends on the magnetic pole relation between the PM piece and Halbach PM array. For example, if the polarity of a permanent magnet as shown in Figure 3 (N-N magnetic polar arrange) is given to the right end of the PG plate in Figure 4, the PG plate will carry out acceleration motion rightward in Figure 4. On the other hand, if we have done the approaching to a PG plate by an opposite polar magnet, the acceleration motion leftward will be performed.

SUCCESSIVE ACCELERATION MOTION

One-way motion by asymmetric PG plate sample

When the parameter of an approaching PM (Nd-Fe-B, 10.5×5.5×4.2 [mm], B=0.27[T]) is constant, we are already obtaining an observation result that the acceleration power and the motion speed depend on the edge angle of a PG plate [3]. In case of the PG plate with asymmetrical edge angle (e.g. 45[deg] and 90[deg]) in Figure 5, the acceleration motion is observed in one direction. It is because that one-way motion of an asymmetrical PG plate sample can be performed by the difference of magneto-dynamics acting on both edges as shown in Figure 5(a) and Figure 5(b). In addition, we confirmed this fact of one-way motion of asymmetrical PG plate sample by an experiment as shown in Figure 6.

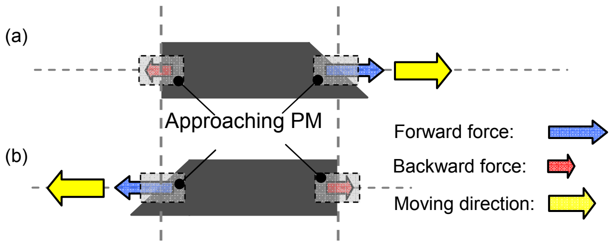

FIGURE 5: One-way motion caused by difference of magneto-dynamics in both edge of PG plate.

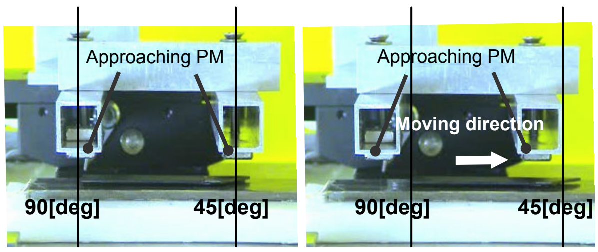

FIGURE 6: Observation of one-way motion by an asymmetrical PG plate sample.

Successive acceleration motion of PG plate sample

Figure 7 shows the principle of successive acceleration motion by single asymmetrical PG plate sample under the arranged approaching PM pieces in series. In case of this illustration, the magnetic pole pitch of approaching PM (L_{PM}) is equal to the edge length on center of PG plate sample (L_{PG}). We can see that the principle of successive motion in one direction of single PG plate is caused by the case shown in Figure 5 and Figure 6.

On the other hand, Figure 8 shows the principle of successive acceleration motion by a coupled asymmetrical PG plate sample under the arranged approaching PM pieces in series. Twin PG plate (PG1 and PG2) are stuck on a non-conductive thin film as keeping space and balance. In case of coupled PG plate sample, the magnetic pole pitch of approaching PM (L_{PM}) is equal to the edge length (L_{PG}) and space between two samples (D_{PG}). Therefore, four magnetic poles operate to all edge of coupled PG plate sample at one time. Then, one-way motion of coupled PG plate sample actually performs by total difference of magneto-dynamics.

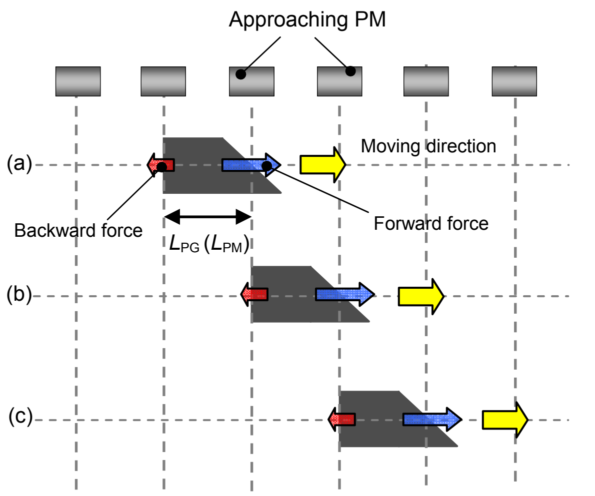

FIGURE 7: Principle of successive acceleration motion by single PG plate with asymmetrical edge.

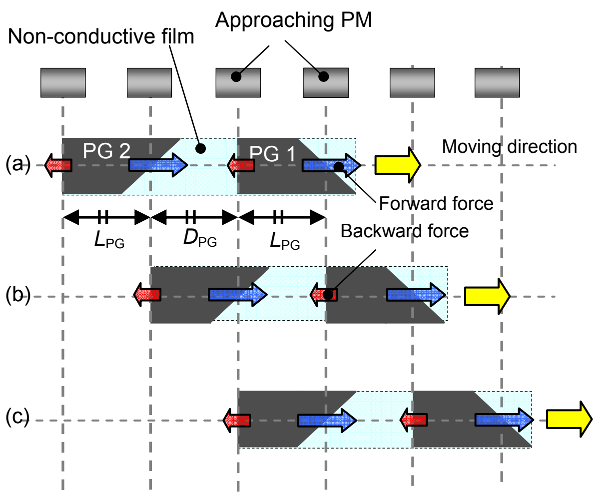

FIGURE 8: Principle of successive acceleration motion by coupled PG plate with asymmetrical edge.

We present an experimental fact of successive acceleration motion by PG plate as follows. Figure 9 shows an experimental set with the arranged eight approaching PM (Nd-Fe-B, 10.5×5.5×4.2 [mm], B=0.27[T]) pieces in series on Hybrid-type PM array. Brand-new Hybrid-type PM array is constructed by composite structure that sandwiched an iron plate in PM plate of same magnetic pole. Moreover, magnetic flux distribution on Hybrid-type PM array is quite similar to Halbach PM array's one.

Figure 10 shows layout of arranged approaching PM piece on Hybrid-type PM array. In condition for smoothly successive acceleration motion of this experimental set, magnetic pole pitches of the arranged eight approaching PM pieces are a half of length of PG plate (e.g. L_{PM}=12.5mm, L_{PG}=25.0mm).

At above condition, magnetic flux density distribution close to arranged some approaching PM piece on Hybrid-type PM array was observed as shown in Figure 11.

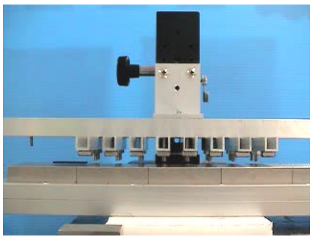

FIGURE 9: Experimental set for successive acceleration motion by single PG plate on Hybrid-type PM array.

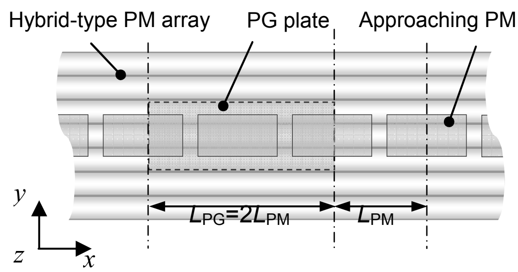

FIGURE 10: Layout of arranged approaching PM piece on Hybrid-type PM array.

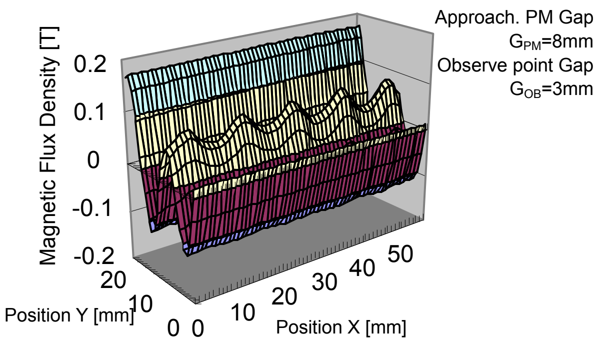

FIGURE 11: Magnetic flux density map close to arranged approaching PM pieces on Hybrid-type PM array.

DESIGN FOR ROTATIONAL DRIVE OF PG

Concept of the rotational drive system by PG disk

By using the one direction motion performance of PG plate as in Figure 6 and Figure 9, we will be performing the experiment in verification of rotation motion of the PG disk putting on several small asymmetrical PG plate on ring Halbach PM array as shown in Figure 12.

To realize a rotation motion of PG disk, at first, it is necessary to design the layout of arranged approaching PM pieces and the shape of PG piece to fit ring Halbach array. Figure 13 shows the layout of arranged approaching PM pieces on ring Halbach PM array, and shows arc-shaped PG plate with asymmetry edge fitting to width of three layer of ring Halbach PM array.

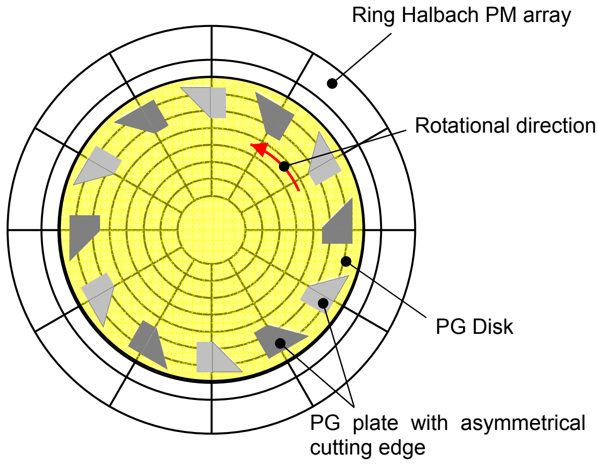

FIGURE 12: Preliminary design concept for the rotation drive of PG disk on ring Halbach PM array by using a novel technique for the acceleration motion of PG plate.

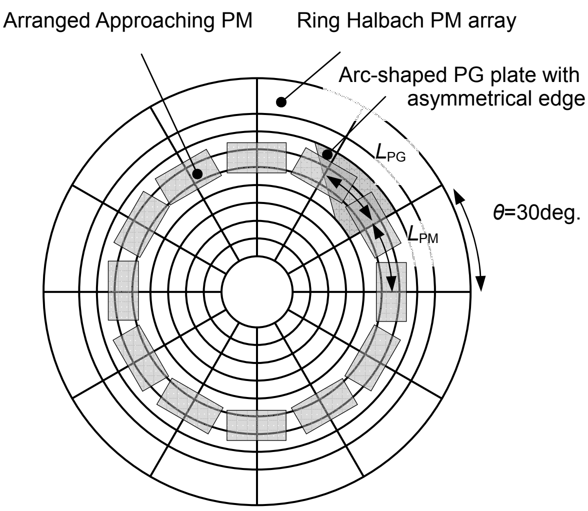

FIGURE 13: Layout of arranged approaching PM pieces and arc-shaped PG plate on ring Halbach PM array.

Magnetic flux distribution close to arranged approaching PM piece on ring Halbach PM array

In Figure 14, it is shows that magnetic flux density distribution close to arranged some approaching PM piece on ring Halbach PM array. It can be seen that this unique magnetic flux density map is reflected the result of Hybrid-type PM array.

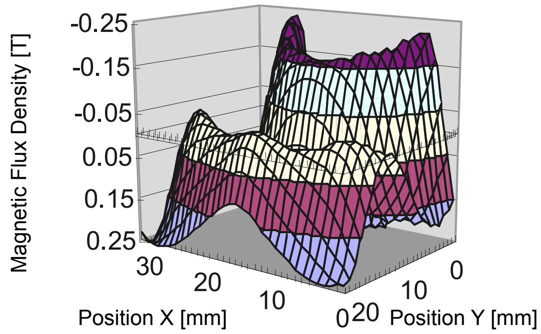

FIGURE 14: magnetic flux density distribution close to arranged some approaching PM piece on ring Halbach PM array.

CONCLUSION

To realize successive acceleration motion of PG plate on ring Halbach PM array, we designed a modified layout of the arranged approaching PM pieces and the arc-shaped PG plate for novel ring Halbach PM array. It seems that a change of magnetic flux density of periodic undulation along to concentric circle in Figure 14 acts on an asymmetric PG plate as rotation motion with magneto-dynamics. We are confirming the successive acceleration motion by a brand-new arc-shaped PG sample, now.

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