Effect of Magnetic Strength of Three-dimensionally Arranged Magnetic Barrel Machine on Polishing Characteristics

Yu Zhang[1,#], Masato Yoshioka[2], Shin-ichiro Hira[2] and Zhuqing Wang[1]

1 Graduate School of Engineering, University of Yamanashi, 4-4-37, Takeda, Kofu, Yamanashi, Japan, 400-8510
2 Faculty of Engineering, University of Yamanashi, 4-4-37, Takeda, Kofu, Yamanashi, Japan, 400-8510
Corresponding Author / E-mail: zy605625@hotmail.co.jp, TEL: +81-055-220-8417, FAX: +81-055-220-8417

KEYWORDS: Barrel media, Distribution of media, Magnet block, Magnetic barrel finishing, Three-dimensional magnet arrangement

Commercially available magnetic barrel machines equipped with permanent magnets have certain limitations: work can only be finished effectively in limited areas of the container because permanent magnets are arranged two-dimensionally on the magnet disk. We overcame this problem by developing a new magnetic barrel machine equipped with a three-dimensional magnet arrangement. The effectiveness of the new machine has already been reported; this study improved the machine's polishing ability by changing the polarity of magnets on a magnet block. Polishing experiments confirmed the most effective arrangement of magnets on the magnet block. An alternating arrangement of north and south poles produced far superior polishing characteristics than a uniform arrangement of the same pole facing outward. Alternating polarity probably causes increased quantities of barrel media to work together. Finally, we introduced stronger permanent magnets to the magnet block, and found that the increased magnetic field also improved polishing ability.

Manuscript received: October 2, 2007 / Accepted: January 7, 2008

1. Introduction

Recently, surface finishing utilizing of magnetic energy has been developed by several researchers.[1-5] In particular, magnetic barrel finishing is frequently used during the final process of finishing the surfaces and edges of machine parts immediately before assembly.[6,7] Barrel media used in a magnetic barrel machine differ from those used in traditional barrel machines in processes such as vibratory or centrifugal barrel finishing. Barrel media used in magnetic barrel machines are made from ferromagnetic material such as carbon steel or stainless steel. Barrel media gain kinetic energy from periodic changes in magnetic fields and use this energy to polish workpieces. Magnetic barrel machines often use pin-shaped media. Either a set of permanent magnets or an electromagnet is used to produce an alternating magnetic field.[6,7] Because the permanent magnet-type machine has a simpler structure, this type of machine is often used to polish or debur, for example, small machine parts and ornaments.[8,9] The permanent type machine is also less expensive than the electromagnet type, making it preferable for some small factories. The magnetic barrel finishing method enables pin-shaped media to move faster and in more complex ways than using a traditional barrel finishing method.[10,11] To find the best finishing conditions, Yoshioka[12,13] discussed the motion of barrel media in magnetic barrel finishing.

However, the structure of the commercial magnetic barrel machine produces some disadvantages. First, barrel media circulate only to a limited height, so tall workpieces are only partially polished. Second, polishing ability is not uniform in the finishing region. To overcome these problems, we developed a new magnetic barrel machine equipped with a three-dimensional (3-D) magnet arrangement. This new machine can be constructed without drastically changing the traditional design. Our previous paper reported the new machine's improved finishing ability,[8] but did not clarify how the machine's polishing ability is related to magnetic polarity or strength of the magnetic field. In this study, we changed the polarity of magnets on the magnet block and examined how the change influenced media distribution. We also conducted experiments using stronger permanent magnets on the magnet block.

2. Experimental Setup

Figure 1 shows the structure of a traditional magnetic barrel machine; it is a commercially available MBF-100 model (Imahashi Co. Ltd., Japan). A motor rotates a magnet disk (A) on which permanent magnets (B) are mounted. An alternating magnetic field is generated in a container (C), which is placed on a top plate (D). Six permanent magnets are mounted on the magnet disk, as shown in Fig. 2. Three of these are placed in a 37-mm-diameter circle, and the rest are placed in a 75-mm-diameter circle. Each magnet is positioned so that its south pole (S) or north pole (N) faces upward, also shown in Fig. 2. All magnets are ring shaped (φ18 × φ7 × 6) and the surface magnetic flux density is 0.40 T.

During a usual finishing, the mass barrel media, water,

Copyright (c) 2008 by KSPE

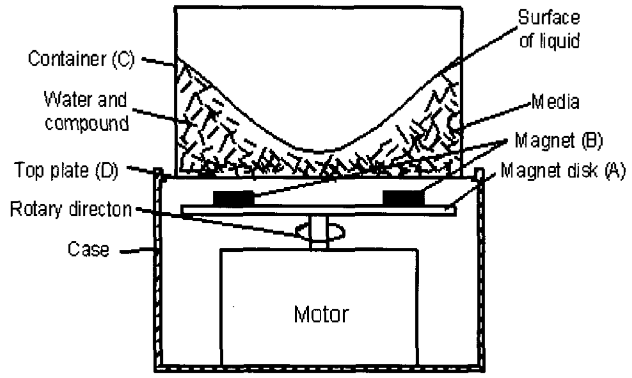


Fig. 1 Traditional magnetic barrel machine

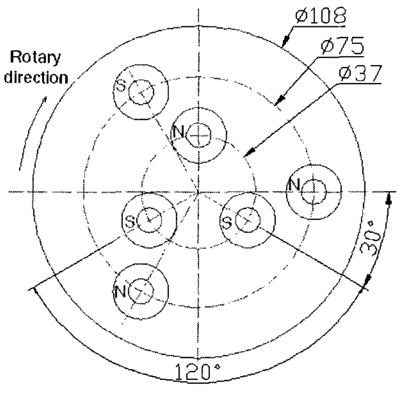


Fig. 2 Arrangement of magnets on a rotating disk

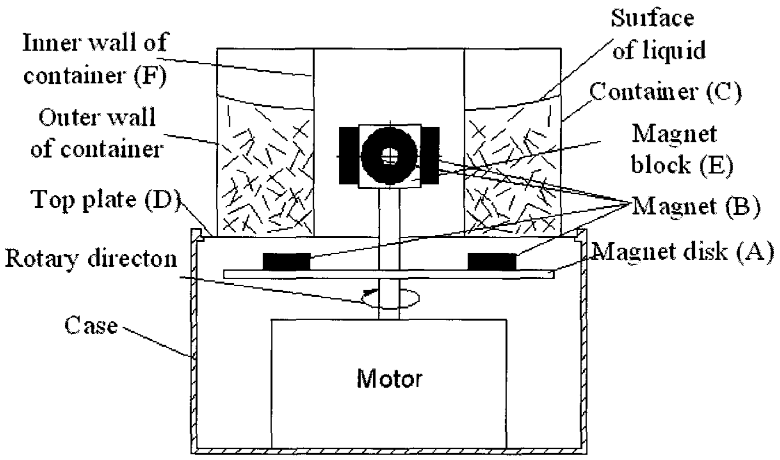
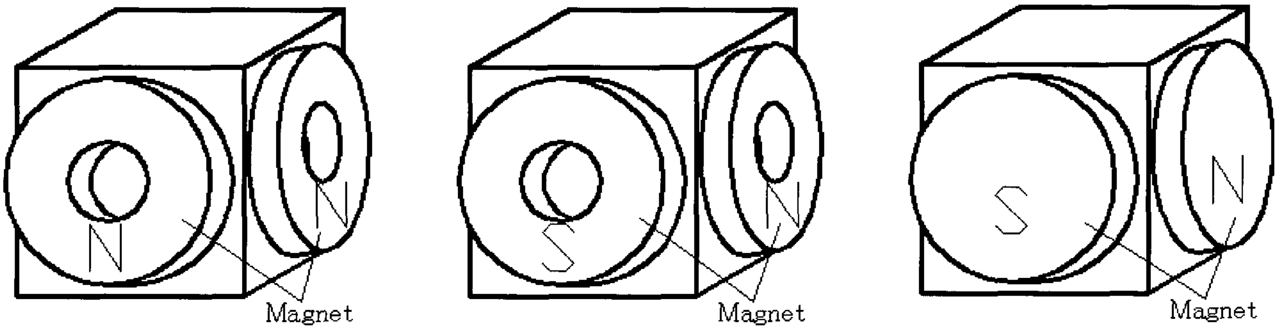


Fig. 3 Magnetic barrel machine equipped with a three-dimensional magnet arrangement



Magnet block I. Magnet block II. Magnet block III.

Fig. 4 Magnets on various magnet blocks

compound and workpieces are placed together into the container. Media are rotated by the alhernating magnetic field generated from the rotary magnet disk, and workpieces are finished by the violent media collisions. Because the magnetic field in the container is generated from below the container, it is strongest at the bottom of the container and gradually weakens in higher regions. For this reason, workpieces can only be finished to a certain height. Moreover, due to centrifugal force, media concentrate near the outer wall of the container, so workpieces placed near the center of the container are insufficiently finished.

To overcome these problems, we developed a new type of magnetic barrel machine.[2] Figure 3 shows this magnetic barrel machine, in which a magnet block (E) is attached in the center of the container, producing a 3-D magnet arrangement. An inner wall (F; 48 mm in diameter and 160 mm in height) is used to secure the magnet block in the central part of the container (100 mm in diameter and 160 mm in height).

As shown in Table 1, two types of permanent magnet are mounted on the magnetic block: ring-shaped and round neodymium magnets. Ring-shaped magnets (φ18 × φ7 × 6) have a surface magnetic flux density of 0.40 T and an attractive force of 5.6 kg. Round magnets (φ18 × 6) have a surface magnetic flux density of 0.47 T and an attractive force of 8.3 kg. Round magnets have a greater attraction force than ring-shaped magnets. One permanent magnet is mounted on each face of a square block. As shown in Fig. 4, the direction of magnetic polarity on the magnet block is also changed. The first type of magnet block has all ring-shaped magnet mounted so that all N poles face outward, and is termed 'Magnet block I.' The second type of magnet block has all ring-shaped magnets mounted so that N and S poles face outward in an alternating pattern, and is termed 'Magnet block II.' The last type of magnet block has stronger round magnets mounted so that N and S

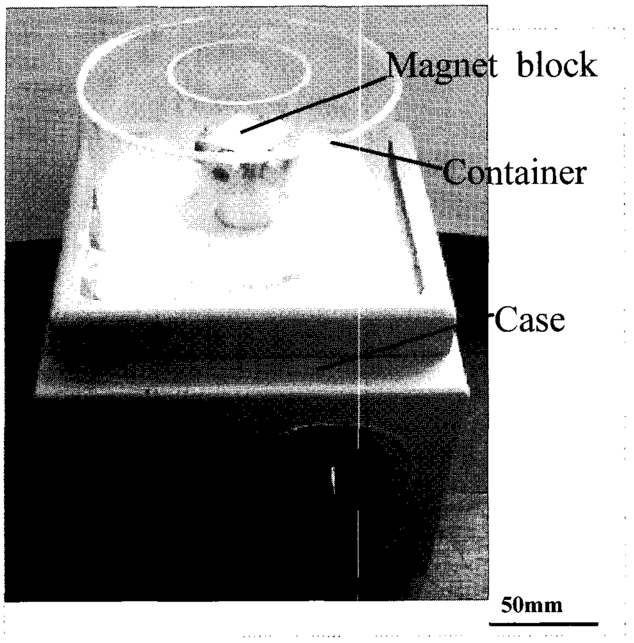


Fig. 5 Magnetic barrel machine with a three-dimensional magnet arrangement

poles face outward in an alternating pattern, and is termed 'Magnet block III.' Each magnet block is installed 25 mm above the top plate. Figure 5 shows a magnetic barrel machine equipped with a Magnet block I.

We conducted polishing experiments using the three types of magnetic blocks to determine how polishing ability can be improved using stronger magnets and which magnet block is the most efficient. We also conducted experiments using a traditional magnetic barrel machine for comparison; these results are labeled as the 'A method.' Results of experiments using magnet blocks I, II, and III are labeled 'B method,' 'C method,' and 'D method,' respectively. Table 2 summarizes all the techniques. Polishing ability refers to the polishing efficiency coefficient converted from the surface roughness of finished work; this will be defined in detail in the following section.

In all experiments, the rotation speed of the magnet disk and the magnet block remained constant at 1770 rpm. Media also remained constant: media stainless steel (SUS304) pins, 0.5 mm in diameter and 5 mm in length (about 7.7 mg). All experiments used a combination of 70 g of media, 400 cc of water, and 2 cc of compound.

3. Difference in Polishing Ability by Various Methods

Unlike our previous research,[2] in this study, we did not fix workpieces to the container, to approximate actual processing conditions. The workpieces had a relatively complicated shape: two columnar stands and a bar with a cross-shaped section (see Fig. 6). During experiments, workpieces slipped on the container's bottom surface due to the flow of liquid and media collisions, but never fell over. Workpieces were made of brass (C3604BD) and were preprocessed using a milling machine to a surface roughness (Ra) of about 1.8 μm. Workpieces revolved around a rotating axis of the magnet disk, termed a 'revolution' and rotated around their own axis, termed a 'rotation.'

Workpiece roughness was not exactly the same in different positions, so it was difficult to compare polishing ability using only absolute values of roughness after polishing. Therefore, we defined a polishing efficiency coefficient R using surface roughness (Ra) measured as follows:

$$\text{Polishing efficiency coefficient R}=\frac{Ra_{beforegrinding}-Ra_{aftergrinding}}{Ra_{beforegrinding}}$$

According to this definition, a higher R value indicates better polishing ability. We assumed that workpieces were efficiently polished if the value of R was higher than 0.02. To evaluate differences in polishing ability by height from the bottom of the container (Fig. 6), we measured the workpiece's surface roughness various heights from 15 to 40 mm after 30 min of finishing. Figure 7 presents R values at several workpiece positions for methods A–D.

Method A was efficient only to a height of about 15 mm; in contrast, methods B, C, and D were efficient to heights above 35 mm, and methods B, C, and D yielded higher R values than method A. The addition of a magnet block considerably improved polishing

Table 1 Characteristic of permanent magnet

Type	Out diameter	Surface magnetic flux density	Magnetic attractive force
Ring-shaped	φ18×φ7×6 mm	0.40T	5.6 Kg
Round	φ16×10 mm	0.47 T	8.3 Kg

Table 2 Characteristic of various methods

A	B	C	D
——	Magnet block I	Magnet block II	Magnet block III
——	Ring-shaped	Ring-shaped	Round
——	All N poles facing outward	Alternating arrangement of N and S poles	Alternating arrangement of N and S poles

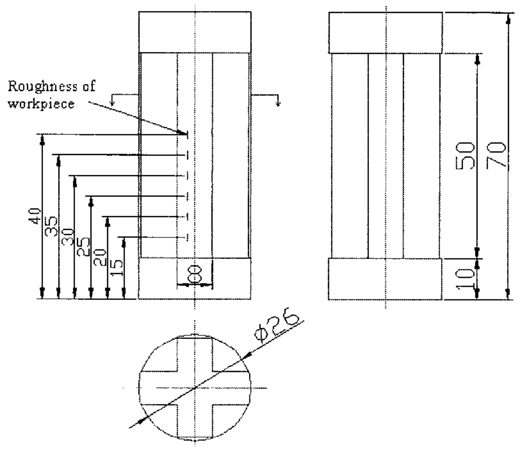


Fig. 6 Workpiece dimensions

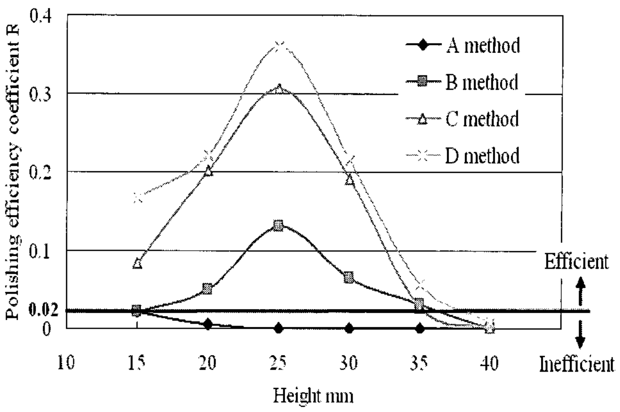
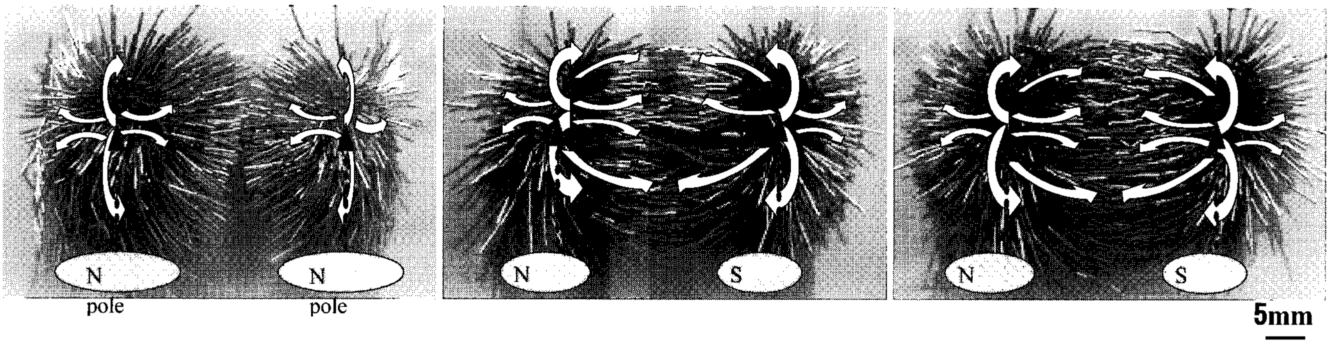


Fig. 7 Polishing efficiency coefficient R by various methods



a. Magnet block I

b. Magnet block II

c. Magnet block III

Fig. 8 Distributed media around each magnet block.

ability at higher positions. Areas of the workpiece near the magnet block were finished most effectively. Figure 7 shows differences in polishing abilities among methods B, C, and D. Methods B and C used the same ring-shaped magnets, but their polarity on the magnet block differed, which produced different polishing abilities. Method C, in which magnets were mounted with alternating polarity, yielded better polishing ability than method B, in which magnets were mounted with a uniform arrangement of the same poles facing outward. In methods C and D, magnets were mounted on magnet blocks in an identical arrangement, but the magnet strength differed; the magnets used in method D were stronger and yielded superior polishing ability. These results indicated that the polarity and strength of magnets mounted on the magnet block greatly influence polishing ability. Magnet block III, mounted with stronger round magnets and alternating poles, produced the most effective results. Throughout the experiments, polishing ability was best when the magnet block was positioned at 25 mm. Positioning magnet blocks at 15, 25, and 35 mm should produce generally uniform polishing ability.

4. Distribution of Media Attracted by the Magnet Block

The previous section showed that the strength and polarity of magnets mounted on a magnet block greatly influence the polishing ability of a magnetic barrel machine. The distribution of magnetic field generated by magnet blocks can differ; we investigated this issue by photographing the distributed media attracted by stationary magnet blocks (Fig. 8). We used the different media distributions to identify the relationship between magnetic field distribution and polishing ability. Measuring magnetic fields[14] directly would be preferable to measuring attracted media; this will require a special measuring system, which we are currently developing and will apply in our next investigation.

To eliminate the influence of the magnetic field generated by the magnet disk, we removed the magnets on the magnet disk. Figure 8 shows the distribution of media attracted by stationary magnet blocks. White arrows represent the direction of the magnetic field line; a large quantity of media appears along the magnetic field line. A blank area appears between the two N poles on Magnet block I, but this did not occur on Magnet blocks II or III. Uniformity of distribution media attracted by magnet blocks appears to influence a machine's polishing ability. Magnet blocks II and III caused very similar distribution of media. Figure 8 reveals that the same arrangement of magnetic polarity causes similar media distribution, even if magnet strengths differ. We measured the amount of media attracted by magnet blocks: Magnet block I attracted 70.5 g, Magnet block II attracted 115.6 g, and Magnet block III attracted 160.7 g. This result indicates that Magnet block III yields the strongest attractive force and Magnet block I yields the weakest attractive force. This difference in attractive force must be the reason for differences in polishing ability.

5. Conclusions

In this study, we used a 3-D magnetic barrel machine to determine experimentally how magnetic polarity arrangement on a magnet block and magnet strength affected polishing ability. We also examined the relationship between media distribution and polishing ability. Our experiments produced the following results.

1. The polarity and strength of magnets on a magnet block greatly affect the polishing ability of a magnetic barrel machine. A magnet block mounted with alternating magnetic poles and stronger magnets is more effective than a block mounted with a uniform arrangement of the same poles facing outward. A magnet block equipped with stronger round magnets yielded superior polishing ability than a block equipped with the traditional ring-shaped magnets.
2. Magnet block III attracted the greatest quantity of media, while Magnet block I attracted the least. This difference in attractive force among various types of magnet blocks must be the reason for differences in polishing ability.

REFERENCES

1. Yin, S. and Shinmura, T. "Vibration-assisted magnetic polishing," Key Engineering Materials, Vol. 329, pp. 207-212, 2007.
2. Sato, T., Yamaguchi, H., Shinmura, T. and Okazaki, T. "Study of internal field assisted finishing for copper tubes with MRF-based slurry," Key Engineering Materials, Vol. 329, pp. 249-254, 2007.
3. Ko, S. L., Baron, Y. M. and Park, J. I. "Development of face magnetic inductor with permanent magnets for deburring using MAF process," Key Engineering Materials, Vol. 329, pp. 237-242, 2007.
4. Sato, T., Yamaguchi, H., Shinmura, T. and Okazaki, T. "Study of internal finishing process using magneto-rheological Fluid (MRF)," Journal of the Japan Society for Precision Engineering, Vol. 72, No. 11, pp. 1402-1406, 2006.
5. Yin, S. and Shinmura, T. "Vertical vibration-assisted magnetic abrasive finishing and deburring for magnesium alloy," International Journal of Machine Tools & Manufacture, Vol. 44, Issues 12-13, pp. 1297-1303, 2004.
6. Imahashi, N., "Development of surface-finishing technology: A magnetic finishing machine," Journal of the Japan Society for Abrasive Technology, Vol. 44, No. 1, pp. 15-18, 2000.
7. Sugiura, O., Imahashi, N. and Mizuguchi, M. "Development of a cylindrical type magnetic barrel finishing machine," Journal of the Japan Society for Precision Engineering, Vol. 63, No. 3, pp. 399-403, 1997.
8. Zhang, Y., Yoshioka, M. and Hira, S. "Study on magnetic barrel machine equipped with three-dimensional arrangement of magnets," The Ninth International Symposium on Advances in Abrasive Technology, pp. 761-767, 2006.
9. Ko, S. L. "Measurement and effective deburring for the micro burrs in piercing operation," International Journal of the Korean Society of Precision Engineering, Vol. 1, No. 1, pp. 152-159, 2000.
10. Yamamoto, A., Kitajima, K., Takigami, A. and Watanabe, M. "Finishing performance of dry and wet barrel finishing," Journal of the Japan Society for Abrasive Technology, Vol. 42, No. 3, pp. 124-129, 1998.
11. Yamamoto, A., Kitajima, K., Sakurada, Y. and Norota, S. "Study on centrifugal barrel finishing," Journal of the Japan Society for Precision Engineering, Vol. 63, No. 3, pp. 399-403, 1997.
12. Yoshioka, M., Hira, S., Takeuchi, H. and Okahisa, Y. "Motion of barrel media in magnetic barrel finishing," Journal of the Japan Society for Abrasive Technology, Vol. 45, No. 3, pp. 131-136, 2001.
13. Yoshioka, M., Hira, S. and Takeuchi, H. "Motion of magnetic barrel media in rotary magnetic field," Proceedings of the Third International Conference on Abrasive Technology, pp. 469-475, 1999.
14. Lee, S. H., Baek, Y. S. and Jung, S. "Modeling and analyzing electromagnets for magnetic suspension systems," International Journal of Engineering and Manufacturing, Vol. 7, No. 4, pp. 28-33, 2006.
15. Hong, Y. S. and Kwon, Y. C. "Electromagnetic analysis of a flat-type proportional solenoid by the reluctance method," International Journal of Engineering and Manufacturing, Vol. 7, No. 2, pp. 46-51, 2006.