International Journal of Scientific & Technical Development
(A Peer-Reviewed Bi-Annual Journal) ISSN: 2348-4047

Comparison of the performance of sintered abrasives to glued abrasives using a rotating magnetic field finishing setup

***Jagdeep Singh Gill **Lakhvir Singh**
*Research Scholar, Mechanical Engineering Department, IKGPTU, Kapurthala, Punjab, India
**Mechanical Engineering Department, Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, Punjab, India
Corresponding Author Email ID: erjsgill@gmaol.com

Abstract
Magnetic abrasive finishing is a method of creating high-quality finishes by moving magnetic abrasive particles across the workpiece. The magnetic abrasive particles are composite powder containing hard abrasive grains in a ferromagnetic matrix. Magnetic abrasive finishing relies heavily on a cutting tool formed from magnetic abrasive particles. In the present work, a comparison has been made between the performance of sintered abrasives and glued abrasives. A rotating magnetic field finishing setup is used to conduct experimentation. Experiments were carried out to determine the effect of rotational speed and abrasive quantity on surface roughness. Improvement in surface roughness is taken as the performance parameter. The best result for the sintered magnetic abrasives was at 425 rpm and 6 g abrasive, with an improvement in the surface roughness value of 84.4%. In the case of the glued magnetic abrasives, the best result was at 575 rpm and 6 g of abrasive, with a surface roughness improvement of 65.65%. Sintered magnetic abrasives offer a more significant improvement in surface roughness for the same parameters than glued magnetic abrasives.
Keywords: Magnetic abrasive finishing, Sintering, Surface roughness, Abrasive.

Introduction

High-quality finishes by moving magnetic abrasive particles across the workpiece. The magnetic abrasive particles are composite powder containing hard abrasive grains in a ferromagnetic matrix. Magnetic abrasive finishing relies heavily on a cutting tool formed from magnetic abrasive particles. Surfaces of different shape, size, and material can be finished using this process. It produces very fine surfaces. Shinmura et al. [1] investigated the influence of the grain diameter of the abrasive particles on the material removal and the surface roughness during magnetic abrasive finishing. They discovered that the finishing pressure is affected by the magnetic flux density, the relative permeability of the ferromagnetic substance, and the volume ratio of a ferromagnetic substance contained in the magnetic abrasive particles, rather than the diameter of the MAP or the abrasive grains. Kreman et al. [2] used magnetic abrasive finishing estimating machining time to minimize roundness errors on cylindrical carbon steel specimens. They found that the greatest reduction in runout (OOR) occurs at the beginning of the machining process and that MAF is not affected by runout. The influence of the working gap and the peripheral speed of the workpiece on the performance of the finishing process with magnetic abrasives have been studied by Jain et al. [3]. They used loosely bound magnetic abrasive particles (made from a homogeneous mixture of iron and aluminum oxide particles) and Servospin-12 lubricating fluid to conduct experiments on a cylindrical stainless steel workpiece. Based on their findings, they found that increasing the working distance or reducing the peripheral speed of the workpiece generally reduced the amount of material removed. As the peripheral speed of the workpiece increases, so does the surface quality.To predict the surface e roughness, Raghuram and Joshi [4] performed a parametric study and analytical modeling of the MAP process of stainless steel sheets (SUS304). They found that the size ratio, the surface clearance of the tool work surface, the polishing speed, the diameter of the magnetic abrasive and the polishing time have a significant influence on the value of the surface roughness. Mulik and Pandey [5] examined the effects of voltage, mesh count, revolutions per minute (RPM) of the electromagnet, and weight percent of the abrasive. The response was measured as the percentage change in surface roughness. The mesh count has been shown to have the greatest influence on the percentage change in surface roughness, followed by the% weight of the abrasive, the speed of the electromagnet and the voltage. Givi et al. [6] investigated the influence of the speed of the permanent magnet poles, the working gap between the permanent magnet and the workpiece, the number of cycles and the weight of the abrasive particles on the MAF of aluminum alloy sheets using the experimental technique. According to the researchers, the number of cycles, the working gap and the rotational speed are the elements that have a great influence on the surface roughness. Kang et al. [7] investigated the use of sintered diamond-based magnetic abrasives for internal magnetic grinding of SUS304 stainless steel. They investigated how the distance between the workpiece and the magnet affected the percentage improvement in surface polish as well as the rotation speed of the magnetic poles, the percentage of abrasives in the iron matrix and the processing time. Accordingly, machining time, diamond abrasive%, and pole rotation speed all have a significant impact on PISF. The SEM images of the samples before and after MAF show that the surface has improved significantly after the finishing process. Kadhum et al. [8] developed a magnetic inductor for polishing flat surfaces produced by a vertical milling machine. They used a Taguchi experiment to see how coil current, working gap, powder component volume, and feed rate affected the surface quality of non-ferromagnetic (7020 aluminum alloy) and ferromagnetic (410 stainless steel) workpieces. They found that with non-ferromagnetic materials, the amount of powder and the working gap are more important properties than current and feed. In contrast to the amount of powder and the feed speed, the current and working gap are important parameters for ferromagnetic materials. Verma et al. [9] developed a new tool for polishing holes, grooves and vertical surfaces based on the MAF method. They used the CCD approach to assess tool performance and examine the influence of variables such as speed, magnetic flux density, abrasive size, and abrasive weight percentage on the PISF of stainless steel (SS304) tubes. In completing an SS304 pipe, they found that the magnetic flux density was the most effective parameter, followed by the speed of rotation. Hang et al. [10] developed a new ultra-precise magnetic abrasive process for wire material that uses a rotating magnetic field. They tested the influence of variables such as the magnetic field speed, the vibration frequency of the wire workpiece and the unlimited magnetic abrasive grain size on the change in surface roughness and the removed diameter of AISI 1085 steel wire material. With a magnetic abrasive grain size of 0.5 m and a vibration frequency of 10 Hz at 800 rpm for 60 seconds, there are the best conditions for finishing workpieces made of wire material. The roughness of the original surface has been reduced from 0.25 m to 0.02 μm. Wu et al. [11] used a low-frequency alternating magnetic field to remove groove edge burrs and to improve the surface quality of the group through a magnetic abrasive finishing technique. They investigated the influence of the magnetic pole shape on the finishing qualities, and found that arc groove poles have higher magnetic flux density than flat, conical, concave, convex and flat groove poles. During high speed magnetic grinding machining of alumina ceramic rods, Song et al. [12] examined the influence of input parameters such as diamond grain size, vibration frequency and diamond paste weight on output reactions such as surface roughness, diameter variation, roundness and removed weight. Under ideal conditions, they achieved a surface roughness of 0.01 μm and a roundness of 0.14 μm. To treat beta titanium wire with a magnetic abrasive finishing process, Nam et al. [13] used a multiple transfer movement approach. They found that a surface roughness Ra of 2000 rpm, a particle size of 1 m and a machining time of 300 seconds gave the best surface roughness Ra. The roughness of beta surface titans improved from 0.32 μm to 0.05 μm. With a processing time of 300 seconds, the effect of the finishing gap shows that a gap of 3 mm has a higher processing power than a gap of 5 mm. For the magnetic abrasive finishing of aluminum samples, Lee and Chang [14] used a horizontal magnetic field structure of the transverse type. During their research, they found that white aluminum oxide is superior to green silicon carbide when it comes to aluminum samples. Within 2-3 minutes after the final examination, they reach a fine surface of Ra 0.06 μm. During the magnetic abrasive finishing process, Xie and Zou [15] studied the effect of changing the current mode on magnetic flux and finishing force. During their research, they discovered that pulsed current can achieve a better material removal rate compared to static magnetic fields and sinusoidal alternating magnetic field values. To increase the flatness of flat surfaces, Zang and Zou [16] proposed a variable speed magnetic loop finishing process. They changed the speed of the finishing tool to manage the machining time on the workpiece surface and make it flatter. In order to achieve homogeneity of the magnetic flux over the magnetic pole surface, they constructed a small magnetic pole with a diameter of 1 mm.

It is seen from literature review that most of the studies related to magnetic abrasive finishing process are concerned with evaluating the affect of process parameters on the surface finish. So, the present work is undertaken to compare the performance of sintered abrasives and glued abrasives. Aluminium oxide powder is mixed with iron powder in a ratio of 20:80 to produce abrasives. A rotating magnetic field finishing setup is used to conduct experimentation. Experiments were carried out to determine the effect of rotational speed and abrasive quantity on surface roughness. Improvement in surface roughness is taken as the performance parameter. Aluminium tubes are taken as workpiece material in the present study.

2. MATERIAL AND METHOD

2.1 EXPERIMENTAL SETUP

The photograph in Figure 1 shows a machine used for finishing workpieces with magnetic abrasive. The experimental setup for finishing the aluminum tube in the MAF process consists of four cylindrical permanent magnets mounted on a stainless steel chuck. The steel chuck serves two purposes: on the one hand as a carrier for the magnets and on the other hand as an isolator for separating. The magnets can move radially up and down to vary the gap between the workpiece and the magnet surface. This arrangement offers flexibility to process workpieces of different sizes. The magnetic chuck can be rotated at the desired speed with a DC motor.

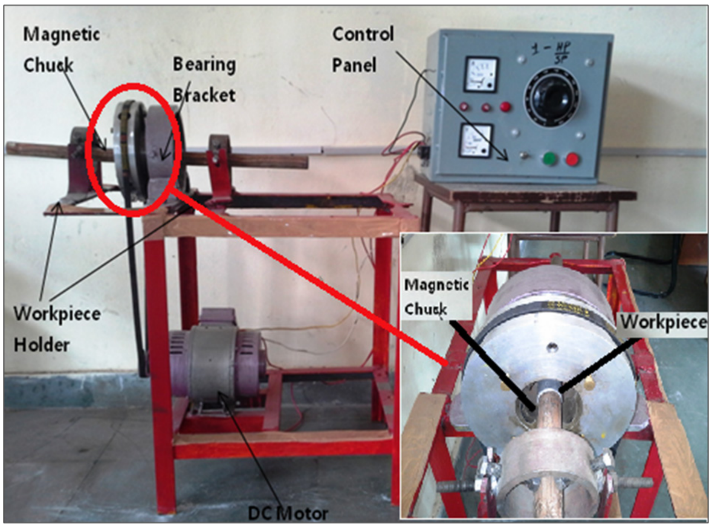

Fig.1 Photographic view of the MAF setup

2.2 MAGNETIC ABRASIVES

The magnetic abrasive particles are composite powder containing hard abrasive grains in a ferromagnetic matrix Two types of magnetic abrasives were prepared for experimentation one is sintered abrasives and other is glued abrasives. Aluminium oxide with mesh size 100-300 is used as abrasive material and iron powder with mesh size 300 is used as ferromagnetic material for preparing magnetic abrasives for the experimentation. Aluminium oxide powder is mixed with iron powder in a ratio of 20:80 to produce abrasives. For preparing sintered magnetic abrasives, the powder mixture was compacted in a cylindrical shape die and then sintered in an H2 environment for 2 hours at 1150°C. Sintered compacts were crushed into small particles for preparing abrasive powder. Figure 2 shows a photograph of the sintering setup. To make glued magnetic abrasives, Fevitite bonding tubes are properly mixed with the mixture of aluminium oxide and iron powder so that the mixture soaks up the bonding glue. This mixture takes a day to dry properly. A large pellet was created. Then this compact was mechanically crushed into fine powder to form magnetic abrasives.

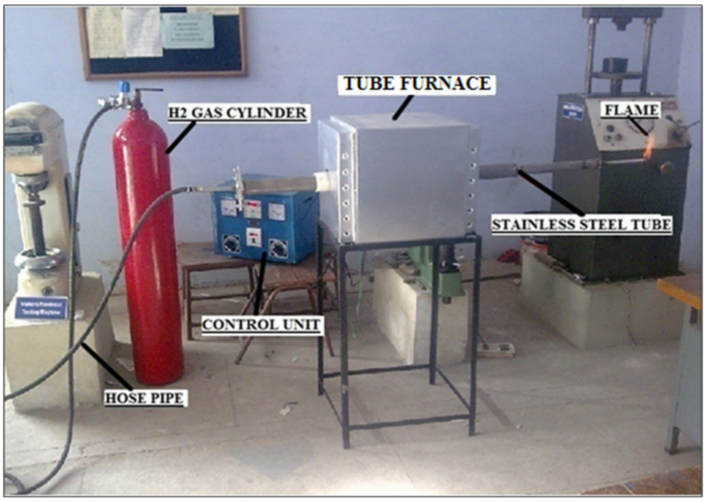

Fig.2 Photograph of the sintering setup

Fig.3 Photograph of Fevitite bonding tubes

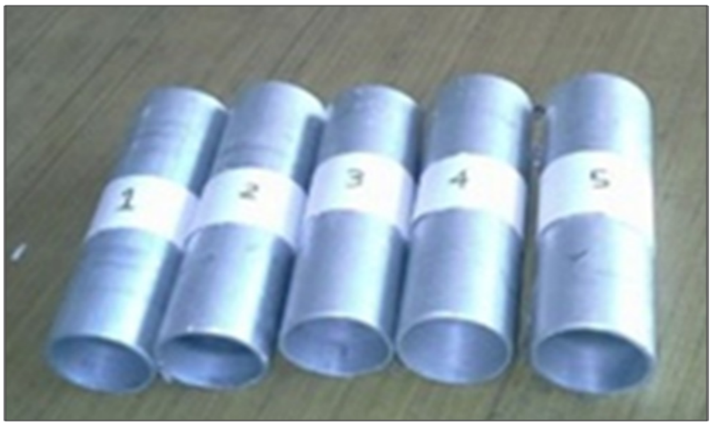

Fig.4 Photograph of workpieces

2.3 MAGNETIC ABRASIVES

Table 1 shows the experimental conditions. The magnetic abrasive particles are introduced into the workpiece. These particles combine to form a flexible magnetic abrasive brush in the workpiece. The rotation imparted to the chuck causes the magnetic field to rotate, causing the magnetic abrasives to rotate with a tangential force which, along with the normal force, develops pressure on the inner surface of the workpiece. This pressure is responsible for the abrasion of the inner surface of the pipe by magnetic abrasive particles. Since the improvement in surface roughness is considered a performance parameter, it is necessary to measure the surface roughness before and after the finishing process. The surface roughness is measured by using Mitutoyo surface roughness tester (Model SJ 210) at four locations inside the pipe before and after finishing, and its mean value is used as the final value for calculating the improvement in surface roughness. The improvement in surface roughness is calculated as follows:

$$ISR = \frac{(Initial\ roughness - Final\ roughness)}{Initial\ roughness} X100$$

TABLE 1: EXPERIMENTAL CONDITIONS

Workpiece Material	Aluminium tube (ϕ 50 x 2mm)
Machining time	60 min
Lubricant	Light Oil(10% of the quantity of abrasives)
Type of the abrasives	Sintered and Glued
Abrasive percentage	20%
Response	Improvement in Surface roughness

3. RESULTS AND DISCUSSION

The main aim of this experiment was to compare the performance of sintered abrasives with glued abrasives and to determine the effect of rotational speed and abrasive quantity on surface roughness.

3.1 Effect of Rotational speed on surface roughness with 6g of abrasives

Table 2 shows the effect of changing the speed of rotation of magnetic poles on the ISF using 6 g of magnetic abrasive. The results of Table 2 are shown in the form of a graph. As shown in Figure 5, the ISF of sintered magnetic abrasives is higher than that of glued abrasives. Each case shows a similar trend with an increase in ISR followed by a decrease, but the values are different in both situations. The ISR grows up to 425 rpm on sintered magnetic abrasives before decreasing. For glued abrasives, the ISR increases to 575 rpm before falling off.

TABLE 2: Experimental Conditions

Speed (r.p.m)	Size (μm)	Gap (mm)	Qty of MA (g)	ISR with SA (%)	ISR with GA (%)
350	163	3	6	65.6	47.99
425	163	3	6	84.03	55.37
500	163	3	6	78.98	58.27
575	163	3	6	76.1	65.65
650	163	3	6	71.4	59.7

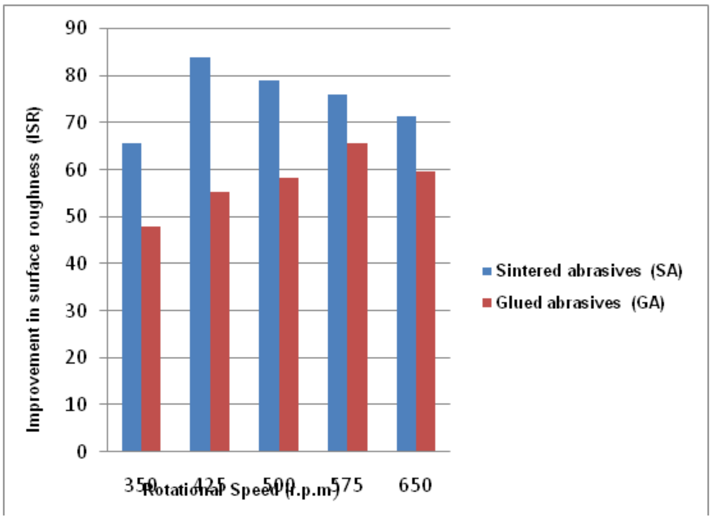

Fig.5 Effect of rotational speed (r.p.m) on ISR with 6g of abrasives

3.2 Effect of Rotational speed on surface roughness with 8g of abrasives

Table 3 shows the effect of changing the speed of rotation of the magnetic poles on the ISF using 8 g of magnetic abrasive. The results of Table 3 are shown in the Figure 6 in the form of a graph. The results show a similar trend as observed in Section 3.1, but the value of the ISR is different. The ISR grows up to 500 RPM on sintered magnetic abrasives before decreasing. For glued abrasives, the ISR increases to 425 RPM before falling off. This difference is caused by a change in the permeability of the work area due to a change in the amount of abrasive. This change leads to a change in the cutting force acting in the area.

TABLE 3: Experimental Conditions

Speed (r.p.m)	Size (µm)	Gap (mm)	Qty of MA (g)	ISR with SA (%)	ISR with GA(%)
350	163	3	8	53.50	51.9
425	163	3	8	57.2	55.8
500	163	3	8	72.02	46.87
575	163	3	8	51.1	42.97
650	163	3	8	41.11	37.78

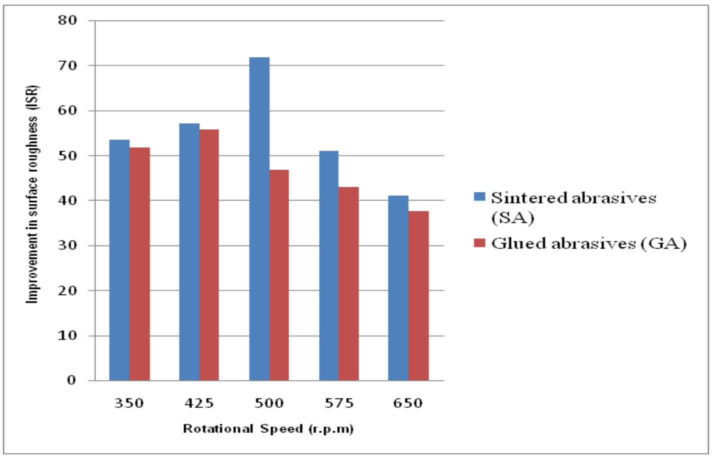

Fig.6 Effect of rotational speed (r.p.m) on ISR with 8g of abrasives

3.3 Effect of Quantity of abrasives on surface roughness with 425 rpm speed of poles

Table 4 shows the effect of changing the amount of abrasive on the ISR at a pole rotation speed of 425 rpm. The results of Table 4 are shown in Figure 7 in the form of a graph. The ISR grows up to 6g on sintered magnetic abrasives before decreasing. For glued abrasives, the ISR increases to 8 g before it falls off. This is because after a certain value the abrasives start to fall or get mixed up instead of moving with the rotating magnetic field.

TABLE 4: Experimental Conditions

Qty of MA (g)	Size (µm)	Gap (mm)	Speed (r.p.m)	ISR with SA (%)	ISR with GA(%)
4	163	3	425	64.7	50.3
6	163	3	425	84.4	55.37
8	163	3	425	57.2	55.8
10	163	3	425	46.39	45.95

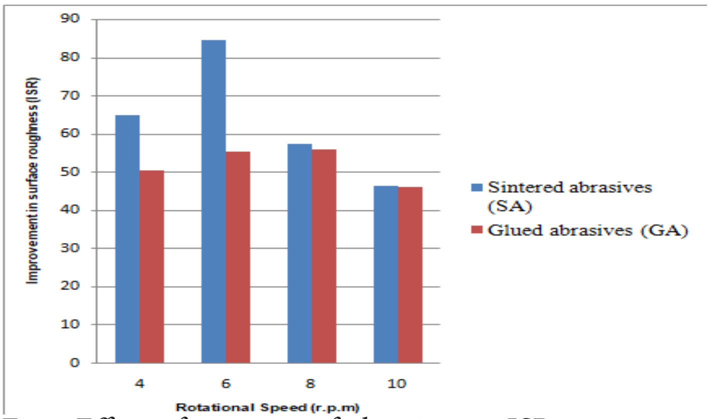

Fig.7 Effect of quantity of abrasive on ISR at 425 rpm speed of poles

3.4 Effect of Quantity of abrasives on surface roughness with 575 rpm speed of poles

Table 5 shows the effect of changing the amount of abrasive on the ISR at a pole rotation speed of 425 rpm. The results of Table 5 are shown in Figure 8 in the form of a graph. The results show that the ISR grows up to 6g on sintered magnetic abrasives and glued abrasives before it falls off.

Table 5: Experimental Conditions

Qty of MA (g)	Size (µm)	Gap (mm)	Speed (r.p.m)	ISR with SA (%)	ISR with GA (%)
4	163	3	575	75.1	64.47
6	163	3	575	76.1	65.65
8	163	3	575	51.1	2.97
10	163	3	575	49.4	36.93

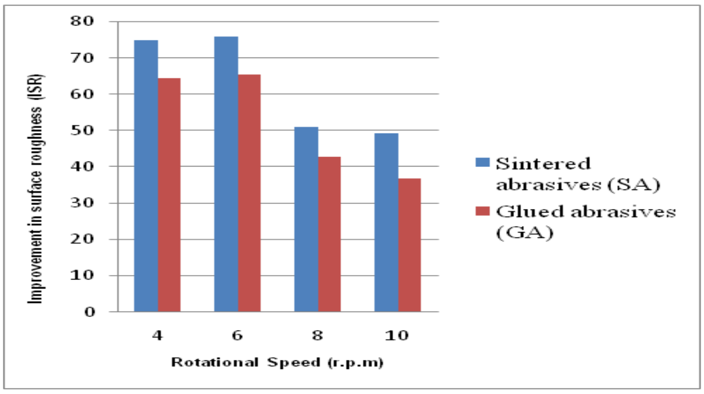

Fig. 8 Effect of quantity of abrasive on ISR at 425 rpm speed of poles

3.5 Surface morphology

In order to get to know the resulting surface better, microscopic photographs were taken of samples before and after the magnetic abrasive finishing process. Figure 9 (a) shows an untreated surface, while Figures (b) and (c) show surfaces that have been processed with sintered and glued abrasives, respectively. The results show that both abrasives removed scratches and sanding marks, although the results obtained with the surfaces obtained with sintered abrasives (SA) are superior to those obtained with bonded abrasives (GA).

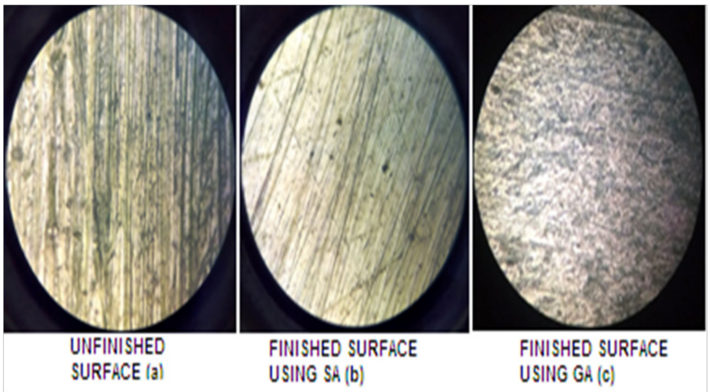

Fig. 9 Microscopic images of unfinished and finished surface

4. CONCLUSIONS

Following is a summary of conclusions from this study:

1. The best result for the sintered magnetic abrasives was at 425 rpm and 6 g abrasive, with an improvement in the surface roughness value of 84.4%.
2. In the case of the glued magnetic abrasives, the best result was at 575 rpm and 6 g of abrasive, with a surface roughness improvement of 65.65%.
3. Sintered magnetic abrasives offer a more significant improvement in surface roughness for the same parameters than glued magnetic abrasives.
4. Microscopic photographs of the final surfaces also confirmed the experimental results that sintered magnetic abrasives gave better surface results than glued magnetic abrasives.

REFERENCES

[1] Shinmura, T., Takazawa, K., & Hatano, E., "Study on Magnetic Abrasive Finishing- Effects of Various Types of Magnetic Abrasives on Finishing Characteristics", Bull. Japan Society of Precision Engineering, 21(2), 1987, 139-141.

[2] KREMAN, G. Z., ELSAYED, E. A., & REBEIRO, J. L., "Machining time estimation for magnetic abrasive processes", INT. J. PROD. RES., 32(12), 1994, 2817-2825.

[3] Jain, V., Kumar, P., Behera, P., & Jayswal, S.,"Effect of working gap and circumferential speed on the performance of magnetic abrasive finishing process", Wear, 250(1-12), 2001, 384-390.

[4] Raghuram, M. V., & Joshi, S. S., "Modeling of Polishing Mechanism in Magnetic Abrasive Polishing", The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics(IACMAG) 1-6 October 2008 ,Goa .344-352.

[5] Mulik, Rahul S., and Pulak M. Pandey. "Magnetic abrasive finishing of hardened AISI 52100 steel." The International Journal of Advanced Manufacturing Technology, vol. 55, no. 5-8, 2010, pp. 501–515.

[6] Givi, Mehrdad, Alireza Fadaei Tehrani, and Aminollah Mohammadi. "Polishing of the aluminum sheets with magnetic abrasive finishing method." The International Journal of Advanced Manufacturing Technology 61.9-12 2011, 989-98.

[7] Kang, Parmvir Singh, et al. "FINISHING OF SUS 304 STAINLESS STEEL BENT TUBES USING MAGNETIC ABRASIVE FINISHING." Mechanica Confab, vol. 2, no. 3, 2013, pp. 123–130.

[8] Kadhum, Ali H, et al. "The Effect of Magnetic Abrasive Finishing on the Flat Surface for Ferromagnetic and non-Ferromagnetic materials." Al-Nahrain University, College of Engineering Journal (NUCEJ), vol. 18, no. 1, 2015, pp. 66–75.

[9] Verma, Girish Chandra, et al. "Experimental investigations into internal magnetic abrasive finishing of pipes." The International Journal of Advanced Manufacturing Technology, vol. 88, no. 5-8, 2016, pp. 1657–1668.

[10] Heng, L., Yin, C., Han, S., Song, J. and Mun, S., "Development of a New Ultra-High-Precision Magnetic Abrasive Finishing for Wire Material Using a Rotating Magnetic Field", Materials, 12(2),2019, p.312.

[11] Wu, J., Yin, S., Xing, B. and Zou, Y., "Effect of magnetic pole on finishing characteristics in low-frequency alternating magnetic field for micro-groove surface" The International Journal of Advanced Manufacturing Technology, 104(9-12), 2019, pp.4745-4755.

[12] Song, J. et al., "Micro-Machining Characteristics in High-Speed Magnetic Abrasive Finishing for Fine Ceramic Bar", Metals, 10(4), 2020, p.464.

[13] Nam S, Kim J, Mun S., "Magnetic Abrasive Finishing of Beta-Titanium Wire Using Multiple Transfer Movement Method." Applied Sciences. 10(19), 2020, 6729.

[14] Lee P, Chang J., "A magnetic abrasive finishing (MAF) platform utilizing horizontal transverse magnetic field magnetized by permanent magnets." Microsystem Technologies, 27(6), 2020, pp.2499-2506.

[15] Xie H, Zou Y., "Study on the magnetic abrasive

finishing process using alternating magnetic field—discussion on the influence of current waveform variation." The International Journal of Advanced Manufacturing Technology, 2021; 114(7-8), pp. 2471-2483.

[16] Zhang, Y., & Zou, Y., "Study of corrective abrasive finishing for plane surfaces using magnetic abrasive finishing processes." Nanotechnology and Precision Engineering. 4(3), 2021, 033001.