Some investigations on Magnetic Abrasive Finishing of Aluminium Alloy

Sachindra J. Doshi & Ketan S Vaghosi
Assistant Professor, Mechanical Engineering, Government Engineering College, Bhavnagar.

Received: July 18, 2018 Accepted: October 04, 2018

ABSTRACT *Magnetic abrasive finishing (MAF) process was novel and invented in the early 1930s, but no significant breakthrough and commercial application is observed. This original research work comprises observations on finishing of Al alloy 6061 using magnetic abrasive finishing process. A dedicated setup was prepared to carry out magnetic abrasive finishing. In this process Al alloy workpiece was kept inside the niobium ring magnet and Al_2O_3 abrasive particles with Fe_2O_3 magnetic particles kept between magnet and work piece. The working gap between magnet and work piece can be filled with the loosely bounded abrasive with iron oxide powder that form a Magnetic abrasive flexible brush (MAFB). The magnetic abrasive flexible brush carries out the fine surface finishing operation by controlling working gap. Surface roughness was studied on 18mm Al alloy rod with Al_2O_3 and Fe_2O_3 particles. Surface roughness was improved by 29.9% to 71.21%. Also A value decreased and has range from (0.849-2.018 μm) based on the 9 experiments which have been carried out. The improvement of surface finish is almost 29.9%-71.21%. The analysis of the Taguchi method established that, in general mixture ratio significantly affect the finishing process while spindle speed has minimal influence.*

Keywords: *Magnetic Abrasive Finishing (MAF) Process, Abrasive powder (Al_2O_3), Iron Oxide (Fe_2O_3), Surface Roughness, Al alloy*

Introduction

Magnetic abrasive finishing (MAF) process was novel and invented in the early 1930s, but no significant breakthrough and commercial application is observed. Material removal in MAF process is carried out by Magnetic abrasive flexible brush (MAFB), formed by the loosely bounded abrasive with iron oxide powder. MAFB remain present in work gap between workpiece and ring magnet as shown in figure 1.

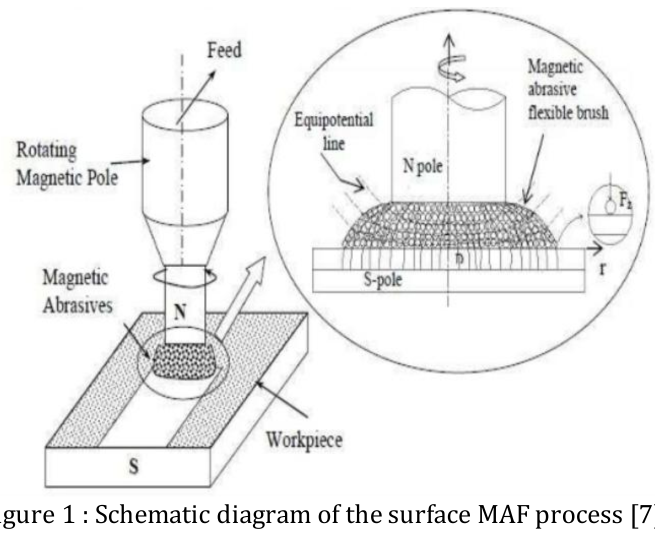

Figure 1 : Schematic diagram of the surface MAF process [7]

In MAF process primary cutting forces are controlled by controlling working gap formed between the magnet and the work piece, which in turn provide depth of cut to the machining operation. Generally iron powder (Fe_2O_3) is used as Magnetic Abrasive Particles and alumina oxide Al_2O_3 or silicon powder is used as abrasive particles. Magnetic abrasive powder provides bonding of abrasive particles and bonded surface behave as a grinding surface for finishing operation.

Literature Review

The Magnetic Abrasive finishing process was invented in early 20th century. Since then contribution of researchers is tabulated in chronological order as follow.

Table 1 Contributions of various researchers

Sr. No.	Observations / Contribution	Authors
1	"Ra value decreased from 7μm to 0.2μm in Internal finishing process where large iron particles and abrasive particles are mixed uniformly and kept between the magnetic poles."	T Shinmura et al. [1]
2	"In the abrasive finishing process, the semi-solid mass of the abrasive, which is flexible to change its form and follow the surface irregularities, removes material both the peaks and valleys of the surface. The magnetic abrasive finishing process is useful for smoothing a surface with high material removal rate."	Hitomi Yamaguchi & Takeo Shinmura [2]
4	"The magnetic field distribution defines the magnetic abrasive configuration and the magnetic force acting on the abrasive, and has a predominant effect on the abrasive behavior. The abrasive smooth rotary motion improves surface finish quality by the accumulation of the unidirectional scratches of the cutting edges of the abrasive and that the irregular abrasive jumbling enhances the material removal. "	Hitomi Yamaguchi & Takeo Shinmura [3]
5	"MAPF process on non-magnetic stainless steel with the use of loosely bounded MAPs has been carried out. The working gap and circumferential speed of work piece are the parameters which significantly influence the material removal, change in surface roughness value (Ra), and percent improvement in surface finish."	V.K. Jain at el.[4]
6	"Due to its superior hardness and polyhedron shape, steel grit is better suited to magnetic abrasive finishing. The larger FP particle size will obtain not only greater material removal but also superior surface roughness. To obtain better surface roughness, a smaller SA particle size should be used."	Chang G W et al. [5]
7	"Most of the normal force concentrates within the area of 1 mm radius and the degree of concentration is larger than that of the magnetic flux density distribution in Magnetic abrasive finishing."	T. Mori et al. [6]
8	"The role of magnetic field strength in MRAFF process is clearly distinguished, as at zero magnetic field conditions no improvement in surface finish is observed, and the improvement is significant at high magnetic field strength. Even magnetic flux density of 0.1521 T is capable of removing to some extent."	S Jha, V.K. Jain [7]
9	"Voltage is the most significant parameter followed by working gap. However, the effects of grain mesh number, and rotational speed seems to be very small. From the main effects of the process parameters, it is concluded that within the range of parameters evaluated, a high level of voltage (11.5 V), a low level of working gap (1.25 mm), a high level of rotational speed (180 rpm), and a high level of grain mesh number are desirable for improving ΔRa."	D Singh at el. [8]
10	"The SEM/AFM analysis showed that the finished surface has fine scratches which are farther distant apart resulting in smoothened surface. These fine scratches would also disappear by using finer abrasive particles. If refreshing of the ferromagnetic and abrasive particles can take place during MAPF, then it would give more uniform surface after MAPF in lesser time."	D K Singh at el. [9]
11	"The magnitude of the normal magnetic force is relatively higher near the edge of the magnetic pole due to the edge effect. The surface roughness of the work piece can be found in almost the same way by providing the intermittent motion to the tool either along the x-axis or y-axis. These simulated results compare favorably well with the experimental results after finishing for a period of 4 min."	S.C. Jayswal et al [10]
12	"MRR increases with the increasing of the rotational speed of magnetic pole. They almost keep a linear relationship under given experimental conditions. There is an optimal magnetic abrasive particle size 30–50% for TiC/Fe (35%), which results in maximum material removal rate."	Yan Wang et al. [11]
13	"A setup was developed of ball-shaped magnetic pole with special grooves to form a flexible magnetic brush which increases a high finishing efficiency. The working gap has the largest impact on the finishing quality. Accordingly, a proper working gap (2.5 mm) can reduce surface imprints and increase quality."	C T Lin et al. [12]

14	"The maximum percentage improvement in surface roughness for simply mixed magnetic abrasives and Silicon Carbide was approximately 18%. Influencing critical parameters are magnetic abrasive type and particles and its volume, magnetic flux density, workpiece material, finishing gap, rotational speed."	R Rampal et al. [13]
15	"The optimum parameters are amplitude of pole 4mm, number of cycle 8,finishing time 10 min, the cutting speed 175rpm, the current 1.5Amp and the working gap 1mm that gives the highest value of the change in Ra."	Shakir Mousa [14]
16	"The MAPF process can be successfully used for the finishing of various materials, such as Mg alloys, Al alloys, STS 304, zircon ceramics, SS 305, SS 316, and brass."	Lida Heng et al. [15]
17	"Magnetic abrasive finishing proved to be suitable for finishing of UNS C26000 brass material. It can be used for soft and ductile materials. With increase in rotational speed, quantity of abrasives, mesh size and machining time the surface roughness decreases."	Atul Babbar et al. [16]
19	"MAF process development is still under research phase, there is not any commercial set up developed to finish intricate shapes and irregular geometries. Hybrid MAF process with ultrasonic vibration of the abrasive particles can provide further improved finishing."	S. Doshi [17]

Experimental Details

3HP engine lathe is used to develop a setup for Magnetic Abrasive Finishing. A fixture as shown in figure 2 is fabricated to house niobium magnet. Fixture is mounted on the tool post and fixed firmly. A workpiece is clamped between four jaw chuck and tail stock through niobium magnet as shown in figure. Fixture is placed in with great accuracy and is concentric to the headstock, spindle axis and magnet axis also maintains the working gap of 1 mm between the magnet and work piece.

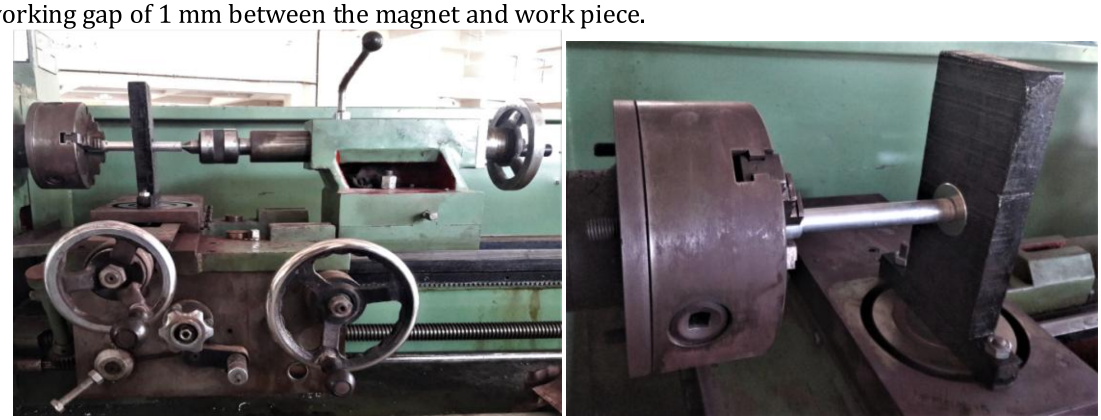

Figure 2 : Experimental Setup on Lathe Machine

The fixture is made up of wood material for the Magnetic Abrasive Finishing (MAF) setup for experimental analysis is shown in the figure 2 and its NX model is also developed as depicted in figure 3.

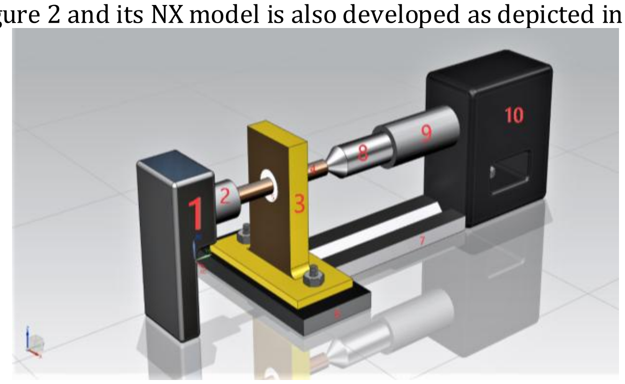

Figure 3 : NX model of Setup on Lathe Machine

Neodymium Permanent Magnet (NdFeB, Grade N52) is used for providing magnetic effect bearing dimensions 20 mm ID x 40 mm OD x 10 mm thick and 0.1919 T magnetic strength. It provide working gap of 1 mm in which abrasive Al_2O_3 powder and FeO powder mixture is maintained during the finishing process.

Aluminium alloy, 6061 grade is used as a workpiece with 20 mm diameter and 150 mm length. Diameter of rod is reduced to19 mm in order to provide 1 mm working gap.
Alumina oxide (Al2O3) powder with 600 mesh size as shown in figure - 4 is used as abrasive and Iron oxide powder (FeO) with mesh size 500 is used as magnetic powder.

Figure 3 : Aluminium oxide -600 mesh & Iron Oxide -500 mesh

Portable Surface Roughness Tester is used to measure surface roughness and Ra value for 0.8 mm stroke length.

Experiment methodology: Taguchi design of experiment method is used to design the experiment. L9 orthogonal array is selected with 3 factors with 3 levels on the base of primary experiments and literature review as shown in table 2.

Table 2 : Factors and their levels

FACTORS	LEVELS		
	1	**2**	**3**
Mixture Ratio ($FeO:Al_2O_3$) w/w	1:1	2:1	3:2
Cutting Speed (m/min)	14.70 m/min	22.61 m/min	35.33 m/min
Time (mins)	2	3	4

Experiments and Results

As mentioned in preceding para that L9 orthogonal array is selected and experiments with 3 replications of each with 3 replications of surface roughness measurement of each sample is carried out. Details of experiments and derived results are mentioned in table 3. Initial measured surface roughness of workpiece was 2.835 μm.

Table 3 : Experiments and Results

Experiment No.	Control Factors			Mean Surface Roughness (Ra), μm	ΔRa	S/N Ratio (dB)
	Mixture Ratio	V (m/min)	T (min)			
1	1:1	14.6952	2	0.816	2.018	1.7662
2	1:1	22.608	3	0.913	1.921	0.7905
3	1:1	35.325	4	1.793	1.041	-5.0716
4	2:1	14.6952	3	1.800	1.035	-5.1054
5	2:1	22.608	4	1.985	0.849	-5.9552
6	2:1	35.325	2	1.143	1.691	-1.1632
7	3:2	14.6952	4	1.426	1.408	-3.0823
8	3:2	22.608	2	0.835	2.000	1.5662
9	3:2	35.325	3	0.935	1.900	0.5837

Since the objective function (Surface Finish) is smaller-the-better type of control function, was used in calculating the S/N ratio. The S/N ratios of all the experiments were calculated and tabulated. Main effects plot for SN ratios on Surface roughness is depicted in figure 5 showing effects of various parameters over the surface roughness.

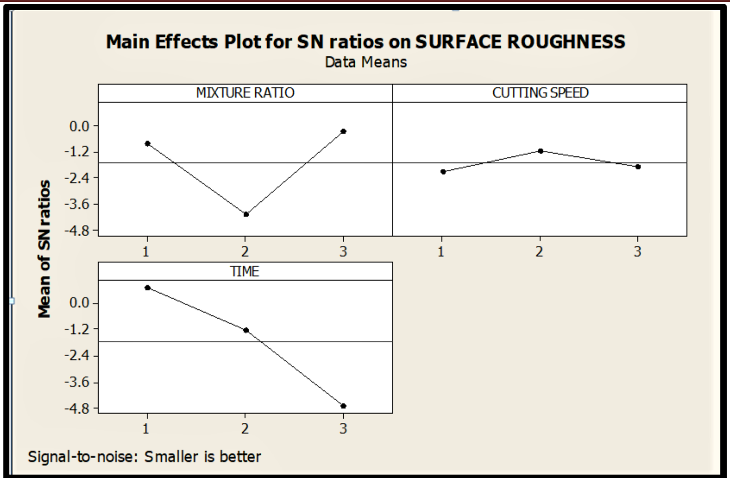

Figure 4 : Main effects plot for SN ratios on Surface roughness

The factor levels corresponding to the highest S/N ratio were chosen to optimize the condition. From these linear graphs it is clear that the optimum values of the factors and their levels are time (2 mins), mixture ratio (3:2) and spindle speed (400 rpm)

Conclusion

In the present work, MAF fixture has been designed for lathe machine. The performance of the fixture has also been studied. MAF process on Aluminium alloy 6061 with the use of loosely bounded MAPs (Al_2O_3 600 mesh and FeO 500 mesh) has been carried out.

It is concluded from the results that time and mixture ratio (FeO: Al_2O_3) of work piece are the parameters which significantly influence the material removal, change in surface roughness value (ΔRa), and percent improvement in surface finish and circumferential speed or spindle speed (0.91%) is least significant.

Magnetic Abrasive Finishing (MAF) process was experimented on the Aluminium work piece with working gap of 1 mm. It was observed that the surface roughness value decreased and improvement of surface finish is almost 29.9%-71.21%.

Using the Taguchi method the optimum process parameters that are time (2 mins), mixture ratio (3:2) and spindle speed (400 rpm) were selected.

References

1. Shinmura, Takeo, and Hitomi Yamaguchi. "Study on a new internal finishing process by the application of magnetic abrasive machining: internal finishing of stainless steel tube and clean gas bomb." JSME international journal. Ser. C, Dynamics, control, robotics, design and manufacturing 38, no. 4 (1995): 798-804.
2. Yamaguchi, Hitomi, and Takeo Shinmura. "Study of the surface modification resulting from an internal magnetic abrasive finishing process." Wear 225 (1999): 246-255.
3. Yamaguchi, H. and Shinmura, T., 2000. Study of an internal magnetic abrasive finishing using a pole rotation system: Discussion of the characteristic abrasive behaviour. Precision Engineering, 24(3), pp.237-244.
4. Jain, V.K., Kumar, P., Behera, P.K. and Jayswal, S.C., 2001. Effect of working gap and circumferential speed on the performance of magnetic abrasive finishing process. Wear, 250(1), pp.384-390.
5. Chang, G.W., Yan, B.H. and Hsu, R.T., 2002. Study on cylindrical magnetic abrasive finishing using unbonded magnetic abrasives. International Journal of Machine Tools and Manufacture, 42(5), pp.575-583.
6. Mori, T., Hirota, K. and Kawashima, Y., 2003. Clarification of magnetic abrasive finishing mechanism. Journal of Materials Processing Technology, 143, pp.682-686.
7. Jha, S. and Jain, V.K., 2004. Design and development of the magnetorheological abrasive flow finishing (MRAFF) process. International Journal of Machine Tools and Manufacture, 44(10), pp.1019-1029.
8. Singh, D.K., Jain, V.K. and Raghuram, V., 2004. Parametric study of magnetic abrasive finishing process. Journal of materials processing technology, 149(1), pp.22-29.
9. Singh, D.K., Jain, V.K., Raghuram, V. and Komanduri, R., 2005. Analysis of surface texture generated by a flexible magnetic abrasive brush. Wear, 259(7), pp.1254-1261.
10. Jayswal, S.C., Jain, V.K. and Dixit, P.M., 2005. Modelling and simulation of magnetic abrasive finishing process. The International Journal of Advanced Manufacturing Technology, 26(5), pp.477-490.
11. Wang, Yan, and Dejin Hu. "Study on the inner surface finishing of tubing by magnetic abrasive finishing." International Journal of Machine Tools and Manufacture 45, no. 1 (2005): 43-49.

12. Lin, C.T., Yang, L.D. and Chow, H.M., 2007. Study of magnetic abrasive finishing in free-form surface operations using the Taguchi method. The International Journal of Advanced Manufacturing Technology, 34(1), pp.122-130.
13. Rampal, Er Rohit, and Tarun Goyal. "Fabricating The Magnetic Abrasive Finishing Setup On Lathe"International Journal of Advance Research in Science and Engineering, 6(12), pp 1361-1366
14. Mousa Shakir M. "Optimization the Parameters of Magnetic Abrasive Process Using Taguchi Method to Improve the Surface Roughness." Al-Khwarizmi Engineering Journal 13, no. 2 (2017).
15. Heng Lida, Yon Jig Kim, and Sang Don Mun. "Review of Superfinishing by the Magnetic Abrasive Finishing Process." High Speed Machining 3, no. 1 (2017): 42-55.
16. Babbar. Atul, and Parminderjeet Singh. " Regression Model and Optimization of Magnetic Abrasive Finishing of Flat Brass Plate" Indian Journal of Science and Technology, Vol 10(31), pp 1-7.
17. S J Doshi, “An empirical review on Magnetic Abrasive Particle Finishing”, International Journal of Research and Analytical Reviews, 5(3) (2018), pp 116a-119a