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Optimization of Parameters Affecting Magnetic Abrasive Finishing Process Using Response Surface Method

Y. Choopani, M. Khajehzadeh*,M. Razfar

Department of Mechanical Engineering, Amirkabir University of Technology, Tehran, Iran

ABSTRACT: Magnetic abrasive finishing is a nano-machining process; due to low machining temperature, this process is categorized as a cold forming process. Therefore, the machined surface is free from thermal damages such as microcracks, phase changes, burnt area and etc. In this paper, the effects of machining parameters (machining gap, work piece rotational speed and abrasive particles' type) on work piece surface roughness have been experimentally studied. To achieve this goal, a series of experimental tests were conducted on a newly developed setup and work piece surface roughness was measured. The results of experimental studies were then used to develop a mathematical model for work piece surface roughness using response surface method. The results show that there is good agreement between experimental results and model predictions. This model was then used to minimize workspace surface roughness. In the selected range of machining parameters the minimum value of surface roughness is achieved by work piece rotational speed of 373.73 rpm, machining gap of 1.98 mm and using diamond particles as abrasive. In addition, it was shown that abrasive particles' type is the most affecting parameter on work piece surface roughness.

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1- Introduction

Most of the manufacturing processes such as grinding, Electro Discharge Machining (EDM), Electro Chemical Machining (ECM), and etc., due to their nature, produce surface damages such as micro-cracks, phase transformation, tensile residual stresses, poor surface finish and etc. These damages can significantly affect work piece performance; therefore, supplementary finishing processes such as Magnetic Abrasive Finishing (MAF) are required to remove these surface damages [1]. Up to now, several research works have been done in the field of MAF. In continuation, the most recent studies published in this field will be reviewed.

In 1929, Abraham et al. [2] introduced the MAF process for the first time. They used this technique for finishing the internal surfaces of wire drawing dies. Up to now, several research works have been done to improve performance and application of MAF as a final finishing process, [1-5].

Despite the studies mentioned above, there is still lack of research works to help users in selecting appropriate finishing parameters. Therefore, in this paper, the effect of finishing parameters (including working gap, rotational speed, and type of abrasive particles) have been experimentally studied on the surface roughness of cylindrical parts made of AISI 440C stainless steel. The results of experimental study have been used to model and optimize work piece surface roughness using Response Surface Methodology (RSM).

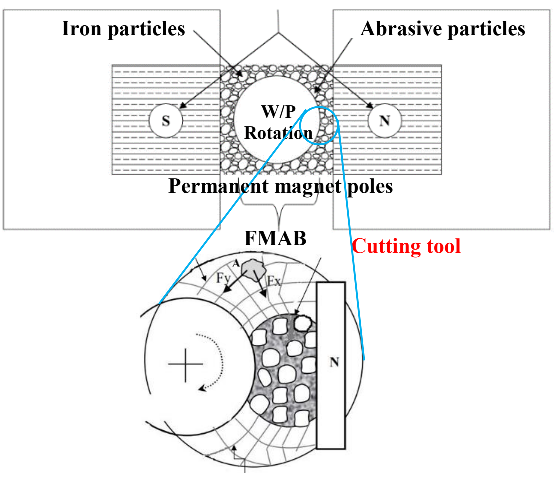

Fig. 1. Schematic illustration of the Magnetic Abrasive Finishing (MAF) process for finishing external surfaces of cylindrical parts.

2- Fundamental of MAF Process

In the MAF process, the cutting tool consists of two main parts: (1) abrasive particles and (b) iron particles. As shown in Fig. 1, the magnetic force is composed of two components (Fx and Fy). The main component is shown by Fx; this component applies magnetic force on abrasive particles along with magnetic lines and is the major factor of particle penetration into the work piece surface and hence the main cause of material removal operation.

The other component of magnetic force (Fy), make abrasive

*Corresponding author's email: mo.khajehzadeh@aut.ac.ir

Table 1. arameters and levels used in experiments.

Parameter	Level		
	1	2	3
Working gap, *A* (mm)	1	2	3
Work piece rotational speed, *B* (rpm)	250	355	500
Abrasive particles' type, *C*	SiC abrasive slurry(a)	Al_2O_3 abrasive slurry(b)	Diamond paste(c)

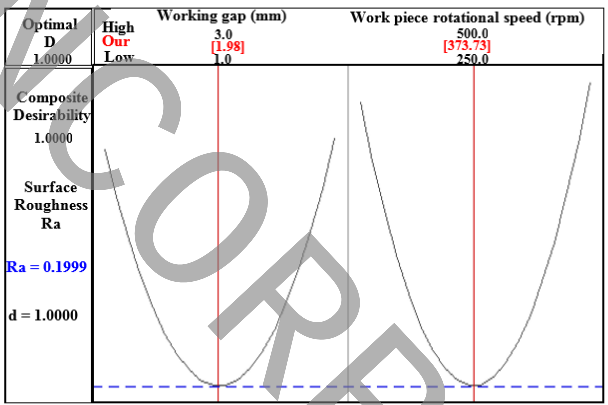

Fig. 2. Optimization results from response surface method

particles to incorporate in the finishing process. In other words, this component makes magnetic particles to connect along with the magnetic field lines between magnetic poles and creates a Flexible Magnetic Abrasive Brush (FMAB), Fig. 1. This FMAB behaves like a tool with multiple cutting edges and finishes the work surface like a mirror in nanometer range.

3- Material and Method

In this research, cylindrical AISI 440C stainless steel parts are machined with the help of lathe machine. In the next step, the samples are heat treated and their hardness is measured to be 50 HRC. Finally, the samples were ground. Then, the initial surface roughness was measured at several points and their average was reported 0.418 µm.

4- Design of Experiments (DOE)

In this study, to conduct the experiments and investigate the effect of finishing parameters (including working gap, rotational speed, and type of abrasive particles) on the work piece surface roughness, full factorial method was implemented. Therefore, three levels were chosen for each input parameter and finally 27 experiments were defined. Parameters and their levels are presented in Table 1. Also, the results of the experiments are shown in Table 2.

5- Optimization Model

In this article, using RSM, a mathematical model was developed to optimize the effect of finishing parameters (working gap, rotational speed, and type of abrasive particles) on the work piece surface roughness. Therefore, addressing this goal, all experimental data related to diamond paste abrasive

Table 2. Results of experimental tests

Run No.	*A*(mm)	*B*(rpm)	*C*	%Δ*Ra* (µm)
1	1	250	a	24.16
2	1	250	b	23.20
3	1	250	c	38.03
4	1	355	a	26.07
5	1	355	b	17.22
6	1	355	c	43.06
7	1	500	a	22.72
8	1	500	b	18.66
9	1	500	c	34.21
10	2	250	a	23.20
11	2	250	b	8.37
12	2	250	c	45.21
13	2	355	a	29.18
14	2	355	b	20.57
15	2	355	c	50.47
16	2	500	a	20.09
17	2	500	b	16.02
18	2	500	c	42.10
19	3	250	a	19.13
20	3	250	b	6.93
21	3	250	c	31.10
22	3	355	a	24.64
23	3	355	b	10.28
24	3	355	c	47.12
25	3	500	a	25.11
26	3	500	b	11.00
27	3	500	c	36.12

type with test numbers of 3, 6, 9, 12, 15, 18, 21, 24 and 27 are left in Table 2 which are the most effective ones on the improvement of surface roughness. Then, full factorial method, further design in the RSM has been defined in the working space.

6- Results and Discussion

The RSM optimization results are shown in Fig.2. It is found that surface roughness is obtained 0.1999 µm under the optimized condition of 1.98 mm working gap, work piece rotational speed of 373.73 rpm and using diamond paste as abrasive tool. In fact, surface roughness has been improved as much as 52.17 % under the optimized condition. These results are also in good agreement with experimental results (test 15 in Table 2). Moreover, from Fig. 2 it is found that the obtained point's degree of desirability is 100% which means that the design's desirability is estimated to be 1. Therefore, the optimized point is acceptable.

The results of optimizing the working gap and work piece rotational speed parameters utilizing RSM are represented in Figs. 3 and 4. Regarding these figures., as the working gap decreases, the surface roughness experiences an increase. The best surface smoothness is obtained 1.98 mm in working gap. From this point, increase in working gap reduces surface smoothness. Also from Figs. 3 and 4, it is deduced that as work piece rotational speed increases to an amount of 373.37 rpm, the surface roughness decreases, while further increase

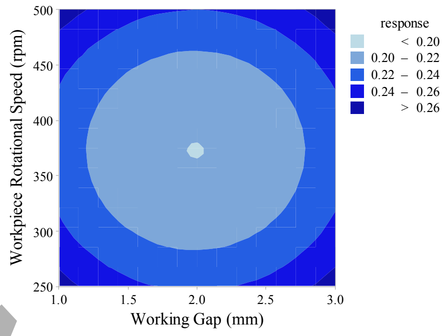

Fig. 3. 2D contour plot from the effect of the working gap and work piece rotational speed on the surface roughness

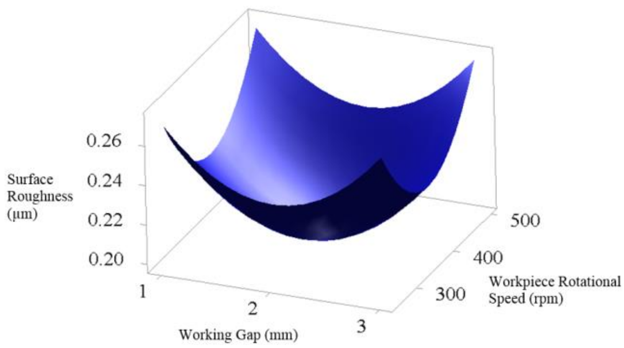

Fig. 4. 3D representation from the effect of the working gap and work piece rotational speed on surface roughness

in speed rises surface roughness.

7- Conclusions

The results are summarized here:

Results of optimization with RSM show that surface roughness has improved as much as 52.17 % under the optimized condition of 1.98 mm working gap, work piece rotational speed of 373.73 rpm and using diamond paste as an abrasive tool.

References

[1] Y. Choopani, M. Razfar, P. Saraeian, M. Farahnakian, Experimental investigation of external surface finishing of AISI 440C stainless steel cylinders using the magnetic abrasive finishing process, The International Journal of Advanced Manufacturing Technology, 83(9-12) (2016) 1811-1821.

[2] S. Abraham, Method of polishing wire-drawing dies and apparatus therefor, in, Google Patents, 1929.

[3] F. Hashimoto, H. Yamaguchi, P. Krajnik, K. Wegener, R. Chaudhari, H.-W. Hoffmeister, F. Kuster, Abrasive fine-finishing technology, CIRP Annals-Manufacturing Technology, 2(65) (2016) 597-620.

[4] G. Verma, C. Kala, , P. M. Pandey, Experimental investigations into internal magnetic abrasive finishing of pipes, The International Journal of Advanced Manufacturing Technology, 88(5-8), (2017) 1657-1668.

[5] K. Pandey, U. Pandey, P. M. Pandey, Statistical Modeling and Surface Texture Study of Polished Silicon Wafer Si (100) using Chemically Assisted Double Disk Magnetic Abrasive Finishing,. Silicon, (2018) 1-19.