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INVESTIGATION OF SURFACE ROUGHNESS IN MODERN FINISHING PROCESS USING PERMANENT MAGNET

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ABSTRACT

This work introduces an investigation of the surface roughness (Ra) during flat plate machining utilizing magnetic abrasive finishing process (MAF). In this study three parameters (Machining time, Mesh size, and Gap) were studied. The MAF tool is made from permanent magnet and the abrasive powder is consisting of 40% of SiC and 60% Fe powder with three Mesh size (100, 250, and 400 µm). The Taguchi L9 array was used in designing the experiments. The results show that the increasing machining time caused a decrease in Ra. The increase in mesh size and the gap will increase the surface roughness. The dominant factor that affect the surface roughness was the machining time due to enough time to machine the target surface.

KEYWORDS

Surface roughness, Magnetic abrasive finishing, Gap, Mesh size, and Machining time.

1. INTRODUCTION

Presently, finishing using magnetic abrasive takes a remarkable role in the finishing of different mechanical parts, even in diminutive size parts and diverse geometries (Kumari, C. and Chak, SK., 2018). MAF was developed as a novel finishing technique in this decade, particularly for very delicate and responsive to instruments for optically, medically, engine parts, and electrical component manufacturing (Yamaguchi, H., 2006). MAF process amalgamate the magnetism properties of the ferromagnetic grains (e.g., Fe) and machining properties of the abrasive grains (e.g., Al_2O_3, SiC) to compose a malleable finish tool. MAF process is mostly suitable for the finishing of flat and cylindrical parts. The rate of removed material (MRR) and minimal Ra that could be reached through this finishing process is nearly 1 μm/min and 5 nm respectively (Komanduri, R., 1998). As soon as the abrasive grains are entered the void between the magnet poles they band together magnetically through the magnetic force lines creating a malleable Brush of Magnetic Abrasive. This malleable brush has manifold, erratic cutting edges and consequently generates a multi-edge cutting tool. The consistency and sturdiness of the brush can be changed by modifying the intensity of the magnetic field in the finishing zone. The proportional movement between the brush and the specimen execute the needful finishing action (Gill, J. S., and Singh, L., 2021).

Zhang, J. et al., (2019) have studied the impact of the angle on surface finish of the specimen manufactured by selective laser melting (SLM) is featured by scanning electron microscope and profile-meter. Magnetic abrasive finishing (MAF), as a malleable polishing method, has been evolved to polish the specimen created by SLM with various slope angles. Removal rate of the material and samples surface roughness are monitored and investigated through MAF operation. To detect the mechanism, an analytical removal rate model is invented by correlating starting Ra of specimen created by SLM with abrasive indentations depth, which finally obtained the overall the volume of material removed in the process of MAF.

Kumar, and Singh, (2020) have utilized a crossbreed finishing operation Chemical aided magnetic abrasive finishing process to machine the Inconel 718 flat sheet. Where, important process variables (weight percentage of abrasives, chemical concentration and, machining time) have been chosen. Case studies were designed by (RSM). Influence of chosen process inputs on enhancement percentage in Surface roughness has been analyzed using ANOVA. The SEM was used to distinguish variables impact on surface microstructure. The result shows that Chemical aided Magnetic abrasive finish was effectively execute to finish plane Inconel 718 workpieces and variables such as Weight percentage of abrasives, Chemical concentration and processing time have major influence on Percentage enhancement in Surface roughness.

Zou, et al., (2021) presented a finishing operation, which merge the fixed abrasive polishing process and the magnetic abrasive finishing process (MAF-FAP). To achieve the produced methodology, a finishing apparatus was evolved and finishing tests on Al_2O_3 ceramic sheets were conducted. Also, the mechanism of the (MAF-FAP) operation was studied. Furthermore, the effect of operation variables on the finishing features is investigated. Depending on the experimental outputs, this operation can produce a highly effective finish to hard and brittle materials and can achieve surfaces with Nano-scale. The sheet surface roughness of alumina is enhanced through 30 min from (202.11 to 3.67) nm.

Sun, et al., (2021) have introduced a combination of finishing methods are electro-chemical (ECM) aided magnetic abrasive finishing (MAF). The electro-chemical magnetic abrasive finishing (EMAF) was splitted into EMAF step and MAF step. This work concentrates on analyzing the finishing mechanism and finishing features of EMAF operation. Conducting a comparison with conventional MAF operation, it can be verified that finishing effectiveness was improved uncommonly and exceed 75% by EMAF operation, and the surface roughness is less in EMAF operation. The optimum experimental outputs of EMAF operation reveal that the roughness of the surface was minimized to lower than thirty nm from the initial Ra one hundred seventy-eight nm after four min in EMAF step, and the surface roughness was eventually decreased to twenty nm after ten minutes in MAF step. Moreover, the active finishing region in EMAF operation was around Seventy percent of that in MAF operation.

Ahmad, et al., (2021) a magnetic abrasive method was evolved, that is effective for the finishing of Ti-6Al-4 V. The sintering technique was utilized to enhance the magnetic abrasive. A blend of abrasive grains of Al2O3 - SiO_2 with ferromagnetic material has been used as ingredients of sintering magnetic abrasive. They investigated the morphology of the sintering abrasive using SEM, EDS, and molecular structure using the X-ray diffraction method. The results show that the abrasives were homogeneously and strongly originated in the carbonyl iron grains. In addition, roughness of magnetic abrasive finishing was investigated on the Ti-6Al-4 V specimen were conducted to estimate the effectiveness of SMA. The Ra was decreased from 1.14 to 0.85 μm was noticed and the AFM of the machined surface proved an outstanding finishing influence by the evolved sintered magnetic abrasive on Ti-6Al-4V through machining operation.

Purohit, et al., (2021) investigated the MAF tests on Al 6061 with four influential controllable operation variables have been utilize like voltage, rotational velocity, work gap, and particles size. The abrasive grain of SiC with 300 mesh size blended mechanically with powder of iron with 400 mesh size applied to generate magnetic abrasive mixture (MAF) and placed quantity of servo engine oil as a lubricant to get the required nanometer of the surface finish. It is seen that operation variables such as voltage, work gap, rotational velocity and particle size have major impact in acquiring valid surface finish.

Lida, et al., (2023) investigated the machining of inner surface of noncircular pipes with MAF technique by utilizing an auto-gaping magnetic pole system. The magnetic poles move on the workpiece surface with a consistent gap between the magnetic pole and the workpiece's exterior surface. As a consequence, magnetic densities may be kept at specified levels in order to provide uniform and effective finishing via the MAF process. The results shown that this technology for non-circular pipe inner surface finishing is qualified for improving surface roughness, lowering the values of Ra from above 0.20 μm to 0.05 μm.

Zhou, et al., (2023) suggested a new magnetic abrasive finishing approach for polishing the interior surfaces of curved tubes using a 6-axis robot equipped with a magnetic machining tool. A multi-stage MAF process was carried out based on the machining parameter characteristics to achieve an inner surface with excellent quality and efficiency. When the machining settings were suitably adjusted, the roughness of the inner surface in the first stage of machining dropped dramatically with the the mixed magnetic abrasives increases, to as low as less than 20 nm Ra in the precision finishing stage.

This work aims to investigate three parameters (Machining time, Mesh size, and Gap) on the surface roughness of AL1050 plate using a permanent magnet as a MAF tool and an abrasive powder consisting of 40% SiC and 60% Fe powder with three Mesh sizes (100, 250, and 400 μm).

2. EXPERIMENTAL PROCEDURE

Taguchi technique is the reliable way for design which gives a simple and systematic qualitative optimal design for minimizing cost. So the best way for evaluating best quality at minimum cost is Design of Experiments (DOE) (Świercz, R. et al. 2018). In the present work Taguchi L9 orthogonal array shown below in Table 1 was used to reveal the role of process conditions viz, Machining time, mesh size and gap on the surface roughness of work material whereas the other machining parameters kept constant throughout machining process.

Table 1. Taguchi design of experiments.

Machining time	Mesh size	Gap
25	150	1.25
25	300	1.75
25	450	2.25
35	150	1.75
35	300	2.25
35	450	1.25
45	150	2.25
45	300	1.25
45	450	1.75

3. WORKPIECE MATERIAL

A flat plate of AL1050 was considered in this study as a workpiece with dimensions 45x145 mm that illustrated in Fig. 1. All experiments have been carried out on NC milling machine. Chemical composition of AL1050 is given in the Table 2.

Table 2. chemical composition of AL1050

Elements	Al	Si	Fe	Cu	Mn	Mg	Ti	V	Zn
Content (%)	99.5	0.093	0.32	0.015	0.02	0.024	0.011	0.01	0.007

Fig. 1. AL1050 workpiece.

4. MAF TOOL

The MAF tool is made from permanent magnet (Nd–Fe–B) with trade code N35, with diameter of 15 mm that maintained by a shaft made from Ck 45 that illustrated in Fig. 2. below. The experimental setup of MAF tool is shown in Fig. 3.

Fig. 2. MAF tool.

Fig. 3. Experimental setup of MAF tool.

5. MAGNETIC ABRASIVE POWDER

The making of the magnetic abrasive mixture is done by blending Iron plus powder with SiC powder using resin as gathering material and then the blend was sintered in an oven to 350ºC for about 60 min. A ball mill is used to grind then a sieving machine to obtain the mixture which contain of 40% of SiC and 60% Fe powder with three mesh size (150, 300, 450) µm. Fig. 4 illustrate the abrasive powder on the tool.

Fig. 4. Accumulation of powder on the tool.

6. SELECTION OF MAF PARAMETERS

For the evaluation of the optimal machining response many input factors to be taken in considerations in the process. Regarding to the researches, it has been noticed that factors like Machining gap, Powder Mesh size and Machining time have great influence upon machining outputs. At the beginning and before machining the main MAF experiments, many experiments have been done so as to reveal the best range for the working factors. The values of other process factors are listed in Table 3.

Table 3. MAF parameters with their levels.

Factor	Level1	Level2	Level3
Machining gap (mm)	1.25	1.75	2.25
Powder Mesh size (µm)	150	300	450
Machining time (min)	25	35	45

7. RESULTS AND DISCUSSION

The experimental outputs are illustrated in Table 4. The main effect plot is shown in Fig. 5. From this figure it seen that the increasing of machining time the surface roughness decrease due to enough machining time. The increase of mesh size the surface roughness increase and also increasing the gap will increase the surface roughness.

Table 4. Experimental results.

No. of experimentation	Machining parameters levels			Ra (µm)	S/N (dB)
	Machining time (min)	Mesh size (µm)	Gap (mm)		
1	25	150	1.25	0.37	8.6359
2	25	300	1.75	0.53	5.5144
3	25	450	2.25	0.95	0.4455
4	35	150	1.75	0.29	10.7520
5	35	300	2.25	0.55	5.1927
6	35	450	1.25	0.61	4.2934
7	45	150	2.25	0.17	15.3910
8	45	300	1.25	0.09	20.9151
9	45	450	1.75	0.27	11.3727

The obtained regression equation was:

$$Ra = 0.512 - 0.02200\ A + 0.001111\ B + 0.2000\ C.$$

Where:

S/N= signal to noise ratio in decibels (dB)

A= Machining time, B= Mesh size, and C= Gap.

Table 5. Main effect for surface roughness (Ra).

Machining parameters	Average of Ra(µm)			Delta (max-min) µm	Rank
	Level 1	Level 2	Level 3		
Machining time (mim)	25	35	45	0.4400	1
Mesh size (µm)	150	300	450	0.3333	2
Machining gap (mm)	1.25	1.75	2.25	0.2000	3

The most influences factor was Machining time followed by Mesh size then the machining gap. The main effect plot for the SN ratio is shown in Fig. 6. and the normal probability plot is illustrated in Fig. 7. The main effect for Ra is shown in Table 5.

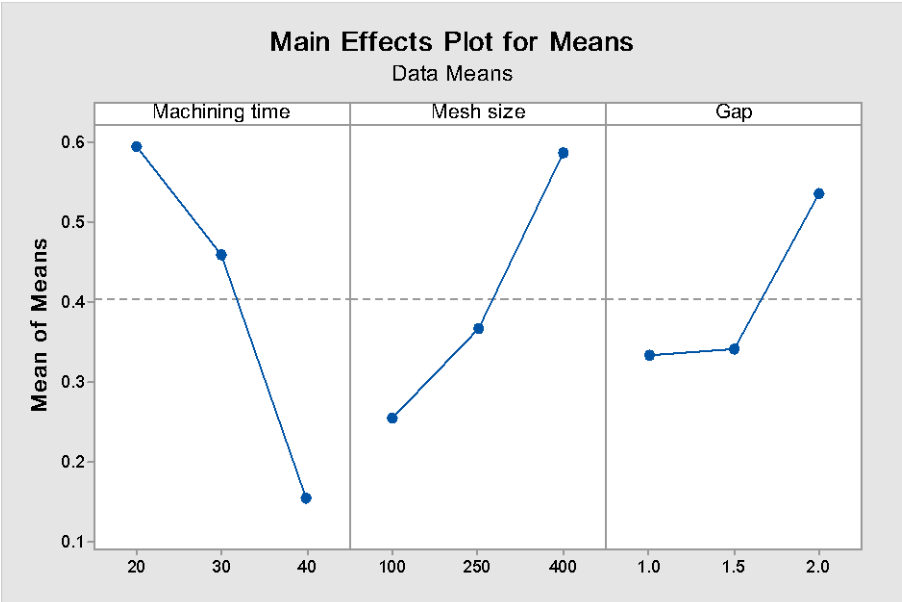

Fig. 5. Main effect plot of surface roughness.

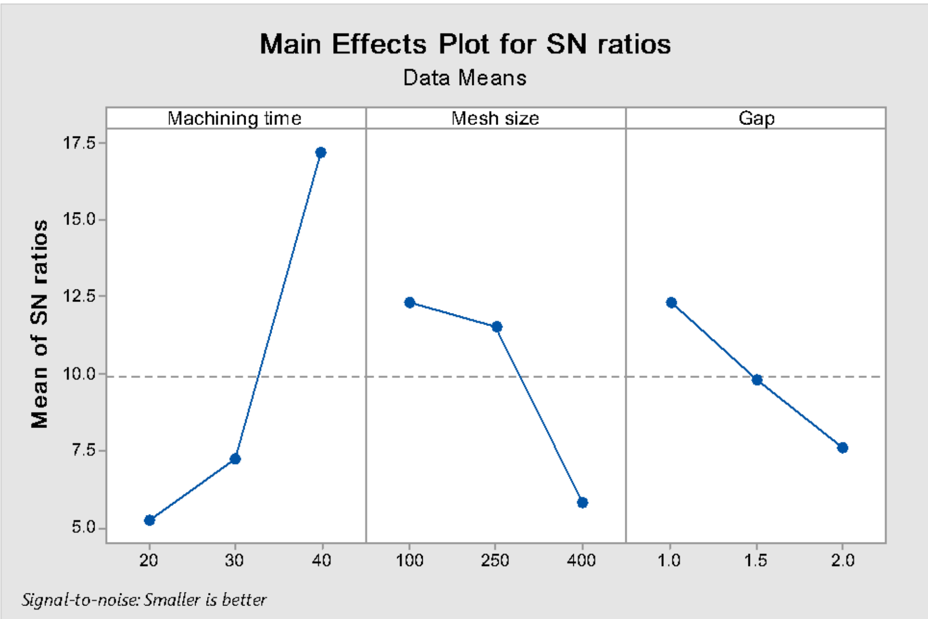

Fig. 6. Main effect plot of SN.

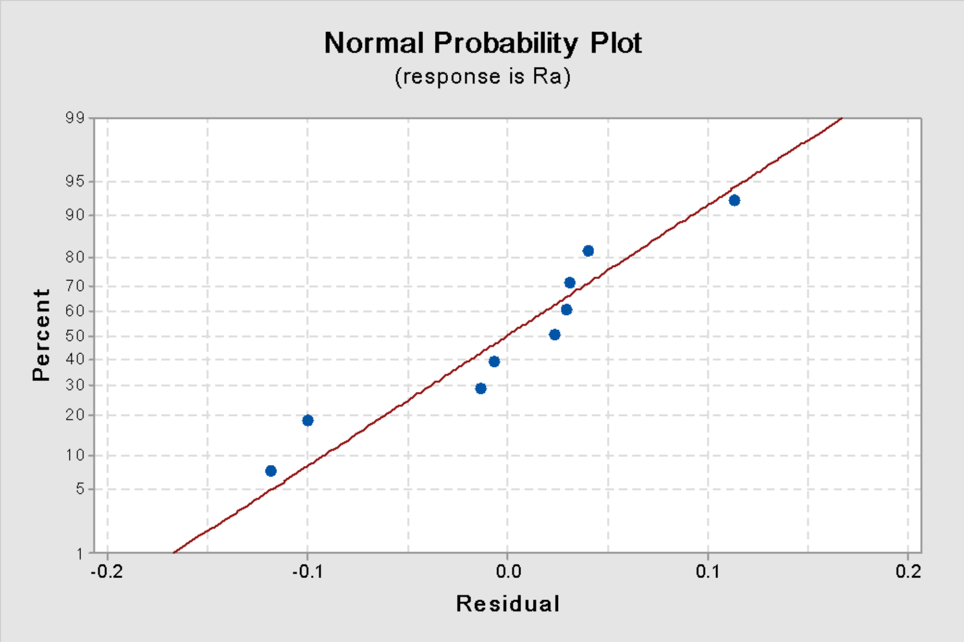

Fig. 7. The normal probability plot.

The scanning electron microscopy was used to examine the machined surface as illustrated in Fig. 8.

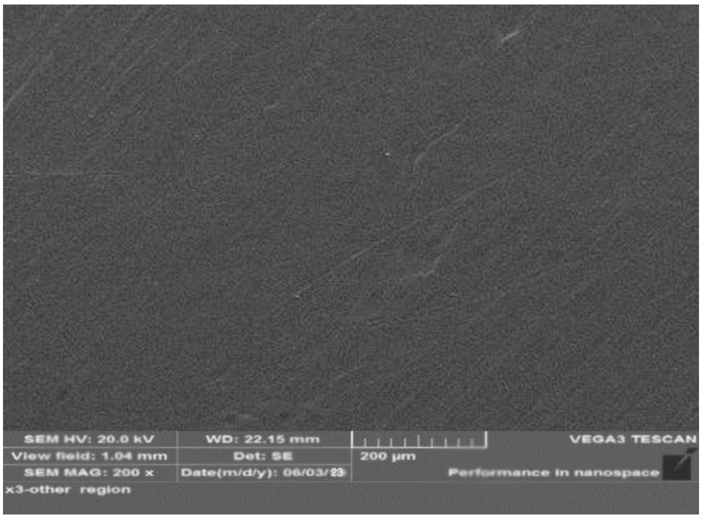

Fig. 8. SEM image of machined surface.

8. CONCLUSIONS

In this work, surface roughness has been investigated experimentally using three machining factors on AL1050 workpiece, using the Taguchi design method. The following conclusions are listed:

1- An investigation was carried out by taking in account the varying variables of (machining time, mesh size, and machining gap) with the Taguchi technique as an optimizing method.

2- The (machining time) is the most influential variable for the surface roughness due to the extra machining time with increasing this parameter.

3- Machining gap has the smaller effect on surface roughness.

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