Investigation of Input Parameters of MAF Process on Material Removal by using Al-1050 alloy Plate Work piece

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Abstract

Magnetic abrasive finishing (MAF) is a micro cutting process that uses magnetic field and magnetic abrasive particles to behavior the mechanism of material removal in micro-nanometer scales. One of the disadvantages of this process is low material removal rate, in this work, by an experimental method and statistical software analysis, the influence of input variable parameters like current, percent weight of abrasives, working gap and feed rate, on the flat surfaces of aluminum 1050 Plate work piece were investigated on material removal. The results of this study show that the feed rate most a significant influence on the improvement of the material removal, it has been indicated that in vitro material removal improved 75%. The mathematical model quality sufficient and is very acceptable or satisfactory as the Coefficient of Determination (R^2) is found to be 98.20% and adjusted R^2-statistic (R^2 adj) 96.50%.

Keywords: Micro cutting, magnetic abrasive finishing, magnetic abrasive particles, material removal, MINITAB software

1. Introduction

With the research and development of high performance technology industries, and at the present time, nuclear energy, aircraft components material, medical equipment, and other advanced manufacture industries need production of new shapes with ultra and high precision finishing technology. A small amount of material will be removed by conducting a relative motion between the magnetic abrasives and the work piece surface layer , so as to obtain result a finished surface like mirror finished surface,very smooth and without defects on surfaces. In order to meet these requirement specification, magnetic abrasive finishing (MAF) process, is one of the advanced methods for this objective . **[1]** It is mainly can finished different surfaces like cylindrical, flat, bolt, and complex curve shapes ,the curves that that cannot be completed finished with conventional finishing processes like, honing ,lapping and grinding etc.. **[2]** The process can also polish effectively non-ferromagnetic materials such as stainless steel ,ceramic , glass, brass and plastic not only finish ferromagnetic materials.**[3]**The MAF process due to its low cutting force, low temperature of machining (a maximum of 200° C), no surface defects on the workpiece surface **[4]** search the principles of the magnetic abrasive finishing process ,they study the effect of magnetic abrasive particles on improvement of the rate of surface roughness and the estimate cost of material removal. Showed that the rate of surface roughness was effectively reduced from 0.45 to 0.04 µm. **[5]** In this work, the influence of parameters like workpiece cutting speed, working gap and material removal (MR) mechanism system by (injection of abrasive particles slurry of Al_2O_3) in the magnetic abrasive finishing process on the external surface of cylindrical pieces of SS (AISI 440C) has been investigated by using an experimental method and statistical analysis (designing of experiments DOE) and (Analysis of Variance

ANOVA) in order to reach the low or minimum surface roughness finished (Ra) . **[6]** Investigated magnetic abrasive finishing process for the data analysis of material removal (MR) and surface roughness (Ra) using response surface method (RSM) in flat surfaces. It is noticed and observed that the material removal (MR) is significantly influenced by the magnetic powder grain size ratio and current. [7] Especially studied the finishing stainless steel workpiece material (non-ferromagnetic) and examined or investigate the effect of a working gap (mm) and cutting speed (rpm) on material removal rate (MRR) .The final results, in general, material removal (MR) increasing with increasing working gap of the work piece and decreases with decreasing cutting speed. **[8]** Studied and attention the influence of the magnetic abrasive finishing process on the materials removal rate (MRR) for Al (2024) workpiece material .Experiments, was designed according to Taguchi's orthogonal array (L27) matrix technique with eight input parameters and three levels has been choose. The parameters are, pole geometry angle ,cutting speed, working gap, doze of powder, working time, current, velocity of work piece and grain size of the powder. By using analysis, the final result used artificial neural network software and analysis of variance

(ANOVA).The concluded showed that the pole geometry has more influence on the materials removal rate MRR .

2. Objectives of Study

The aims of this paper based on the experimental tests and numerical ,we studied the finishing mechanism of plane MAF process , can be summarized in the following:,

1-Discussed the effects of input process parameters namely current, percent weight of abrasives, working gap and feed rate, on the flat surfaces of aluminum 1050 Plate then we investigate the reasons of increase the material removal.

2- Modulating vertical traditional milling machine to be suitable for experimentation of the plane magnetic abrasive finishing process and manufacturing of electromagnetic inductor ,then preparing sintering abrasive powder.

3-Make mathematical regression model between the input parameters and output response ΔMR for aluminum 1050 Plate materials

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3. Material Removal Mechanism

From Figure(1) shows the mechanism on the plane surface of (MAF) process using magnetic field. A magnetic brush creates by magnetic particles and a force line direction Fx (x-motion) and Fy (y-motion),it is calculated by (Eq. 1) **[9]:**

$$F_X = V_X\, \mu_0 H\, (\partial H / \partial x) \text{------------} (1)$$

$$F_y = V_y\, \mu_0 H\, (\partial H / \partial y) \text{-----------} (2)$$

Where :

$\mu 0$= is permeability of vacuum

V= is the volume of magnetic particle

χ =is magnetic susceptibility of particles

H =is the magnetic field intensity

$\partial H / \partial x$ and $\partial H / \partial y$= are gradients of magnetic field intensity in y and x directions,

The direction of magnetic force is changing with current frequency. Fig.1 shows the force analysis of magnetic particles in magnetic field, , but also further the progress of the throw in various random directions of magnetic particles, the data connection of the motor and magnetic pole can achieve success the movements and rotation in all directions, by that means producing and cause relative movement against with the workpiece to achieve a full. extent of plane finishing.

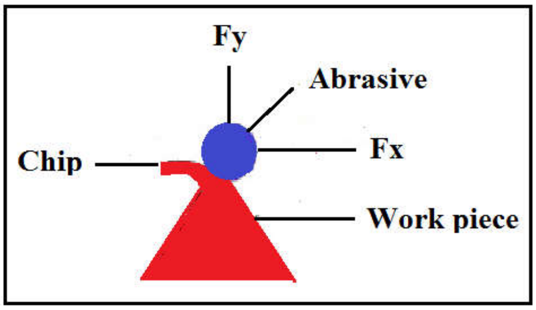


Fig.1 Schematic of mechanism on MAF process

4. Design of Experiments

4.1 Selection of Input Parameters

In the present work, some initial experiments were achieved in order to select the suitable scope on the flat surfaces of aluminum 1050 Plate using MAF process. Input variable parameters like current, percent weight of abrasives, working gap and feed rate. The selection levels and their parameters are presented in Table (1), and Table (2) presented constant parameters.

Table .1 Input parameters values

Input parameters	Levels			
	Symbol	Level 1	Level 2	Level 3
Current (amp)	X1	2	3	4
Percent weight of abrasives (%wt)	X2	33	50	67
Working gap (mm))	X3	1	2	3
Feed rate (mm/min)	X4	8	16	24

Table.2 Constant parameters

Parameter	Value
Finishing time (min)	8 (min)
Cutting speed	300 (rpm)
Work piece	Al-1050 alloy Plate
Abrasives used in (MAF)	Aluminum Oxide (Al_2O_3)

4. 2 Selection Orthogonal Array (OA)

The design of experiment (DOE) in this study based on the orthogonal array of Taguchi matrix technique was minimize the number of experiments. There are four input parameters with three levels has been choose, the values of parameters and their three levels according to orthogonal array (OA) (L9*(3^4)*) (9 experiments) are presented in Table (3), Which leads to minimize the high-required number of experiments to 9 and performance most effective experiments [10].

Table.3 Orthogonal array of Taguchi matrix technique L9 (3^4)

№	X1	X2	X3	X4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

4.3 Measuring the Response of MAF

Materials removal (MR) can be define as the amount of material removed by changing the distance or depth of the cut during this period of the process, the material removal (MR) , is measured by differences in the weight of the workpiece before and after process then the values were averaged, the MAF (W) using the delicate balance device ,with calibration done and accuracy (0.05%+0.20g) shown in Figure (2).

Δ W = ΔMR = w (before MAF) - w (after MAF)

Fig .2 Delicate balance for measuring weight

4.4 Experimental Procedure

An inductor (electromagnetic) has been manufactured and designed using for finishing flat surfaces work pieces by a vertical traditional milling machine its general purpose as shown in Fig (1)., the gap was include filled with powder (The abrasive powder was (67%) iron oxide with (33%)Aluminum Oxide (Al_2O_3) (300 µm mesh size), bounded together by wetting the powder using SAE 20W lubricant, by addition of lubricant lead to increases the adhesive force between the the Aluminum Oxide (Al_2O_3) abrasives and iron particles as well as possible between iron particles themselves and the current was applied by (DC) power supply. The other design data of electromagnetic inductor are the following The inductor was a steel rod wrapped around a coil of wires, magnetic force was generate on the working gap, between pole and work piece: The material of the iron core is made

of C 15 carbon steel, the iron core is A= 18 mm cross-section , and the length is L = 250 mm, the

number of turns is N=2500 and the diameter of the copper wire of the magnetic coil is Ø=1 mm .

See Figure (3),The material of work piece plate is a grade Al-1050 alloy plate, which it is some properties are listed in Table (4), with required size (100×35×2) mm.The conventional vertical milling machine is used to fixed the inductor by the spindle of the machine and fixed the work piece on the table of the machine Figure (4), the working gap filled with dose of powder ($6cm^3$) see Figure (5).The schematic of the system used to implement the experiments is shown in Figure (3).

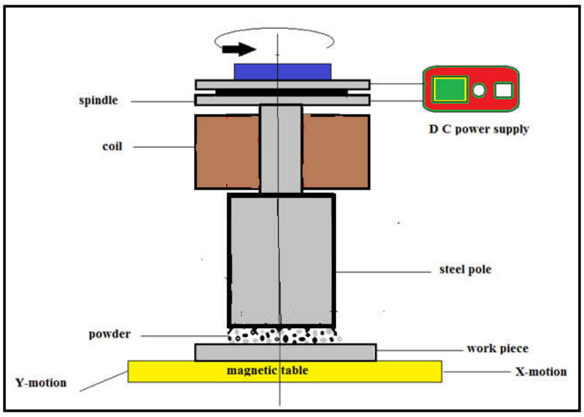
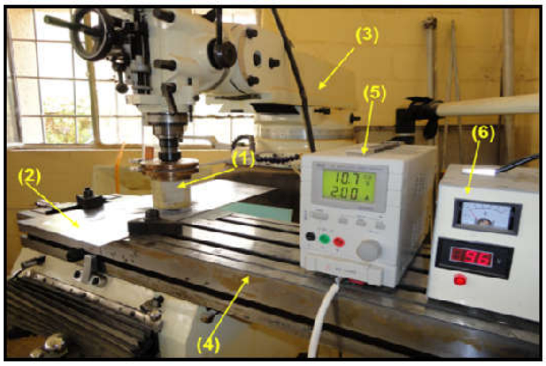


Fig.3 Electromagnetic Inductor



1-inductor 2-workpiece 3-milling machine 4-table 5-power supply 6-voltage supply

Fig.4 photograph of magnetic abrasive machine in laboratory of (Al-khwarizmi Engineering College)

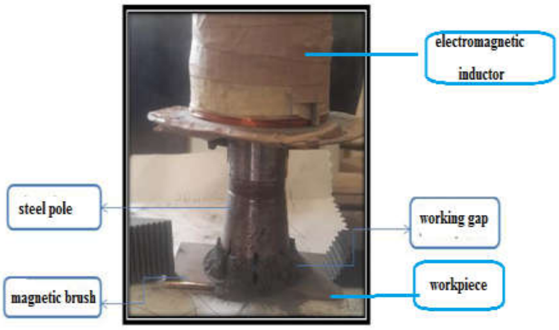


Fig.5 The working gap in the MAF process

Table 4, Chemical composition of the aluminum 1050 plat work piece [wt. %]. [11]

Composition ranges W%							Others each	Others total	AL Min
Si	Fe	Mn	Ti	Mg	Cu	Zn			
0.25	0.40	0.05	0.03	0.05	0.05	0.05	0.03	-----	99.5

Table. 4 Some mechanical properties of the aluminum 1050 plat workpiece

Properties	Tensile Strength (Mpa)	Elongation (%)	Hardness Vickers (Hv)	Density Kg/m^3
Value	150	6	44	2.71

5. Result and Discussion

Experimentation results it found that feed rate that major role on improving the output response material removal ΔMR, and can be considered as criterion the dependent variable in mathematical regression models equation, while the input parameters or predictor's factors were the current, Percent weight of abrasives (%wt), working gap and feed rate, Table (5) shows the result of experiment for Al-1050 alloy Plate material.

Table.5 Total results of experiments and data of regression models generated for Al-1050 alloy Plate and distribution of input parameters according to Taguchi matrix L9 (OA)

№	X1	X2	X3	X4	ΔMR Experiment	ΔMR, Calculted	Error
1	2	33	1	8	0.050	0.045	0.0048
2	2	50	2	16	0.141	0.137	0.0033
3	2	67	3	24	0.235	0.230	0.0048
4	3	33	2	24	0.168	0.187	-0.0199
5	3	50	3	8	0.024	0.013	0.0100
6	3	67	1	16	0.134	0.150	-0.0164
7	4	33	3	16	0.061	0.064	-0.0032
8	4	50	1	24	0.224	0.200	0.0232
9	4	67	2	8	0.020	0.026	-0.0067

5.1. Mathematical regression model for the change of material removal for Al-1050 alloy plate versus input parameters

By utilizing software (Minitab 16 statistical), finding the regression models for magnetic abrasive finishing process between the material removal ΔMR and versus input parameters are bellow. The mathematical equation is

ΔMR = - 0.0208 - 0.0220 x1 + 0.00108 x2 - 0.0128 x3 + 0.0109 x4

The result of regression model (ANOVA) analysis of variance on to the material removal ΔMR for Al-1050 alloy plate, the results in Table (6).

Table.6 Result of analysis of variance (ANOVA).

Predictor	Coefficient	P	Effect	Inductor
X1	- 0.0220	0.026	Mid significant effect	(p<0.05)
X2	- 0.011466	0.113	In significant effect	(p>0.01)
X3	- 0.0010	0.044	Mid significant effect	(p<0.05)
X4	+0.0111	0.000	significant effect	(p<0.05)

Analysis of Variance for regression model also shows some coefficient below:

R-Sq(adj) = 96.5%, R-Sq = 98.2%

P=0.001, F = 55.53

Figure (6) show plot of normal distribution probability for Δ (MR),the R-Sq(adj) = 96.5% and R-sq displayed that 98.2% of the observed output parameter in material removal for Al-1050 alloy plate was independent variable. P-value for regression model equation was significant influence P =0.001,F- Value was high F = 55.53 , The magnitude coefficients of the output response parameters for regression are listed in the Table (3). For these coefficients, linear regressions model for material removal with Al-1050 alloy plate materials could be showed in equation (1).

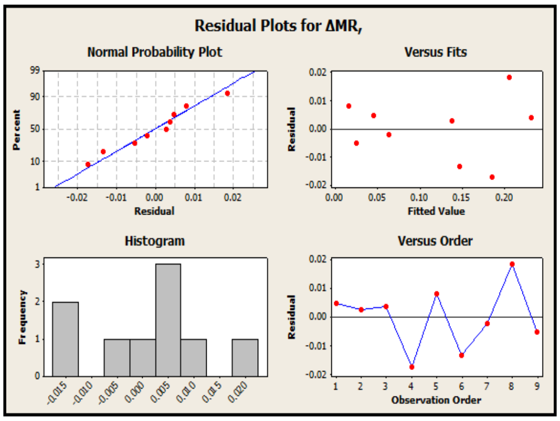


Fig.6 Plot of normal distribution probability for ΔMR

5.1.1. The influence of current and feed rate on material removal ΔMR for Al-1050 alloy plate

In spite of the four response operating parameters, all constant quantity coefficient of the mathematical linear regression equation 1,main influence of process parameters curves and analysis of variance (ANOVA) shown in Figure (7) refers to X4, have most a significant influenced parameters on the material removal ΔMR . Figure (7)-a it is notice that the decreases in ΔMR with increases of current X1 from 2 to 4 Amp effect of current (X1) that has a mild significant effect on material removal as follow increases in current from 2 to 4 Amp lead to deceases in the ΔMR from 0.14 to 0.10 mg and become better with improved to the ΔMR 28.5%. Figure(7)-d shows that the increases in ΔMR with increases of feed rate (mm/min) X4 from 8 to 24 , high feed rates lead to changes the mechanism of cutting depth of the abrasive particles (powder) therefore high feed rates increases the plastic deformation, vibration of the abrasive particles and shear force, resulting in the rapid improvement of material removal and abrasive cutting edge is increasing with the increase of finishing force action. On the other hand Feed rate has a most significant effect on material removal as follow increases in feed rate (mm/min) X4 from 8 to 24 lead to increases in the ΔMR from 0.05 to 0. 20 mg and become better with improved to the Δ MR 75%.

5.1.2. The influence of Percent weight of abrasives (%wt) and working gap on material removal ΔMR for Al-1050 alloy plate

The percent weight of abrasives (%wt) X2 has mildly significant influence on the ΔMR, comparative with feed rate , Figure(7)-b shows if the percent weight of abrasives (%wt) increases from (33 to 67) mg the ΔMR increases from 0.09 to 0.13 mg that means become better with improved in the material removal 30.76%. Working gap X3 has mild significant influence on the ΔMR because the magnetic flux density decreases with increases in the gap distance from the magnet surface and abrasive particles make micro chipping , Figure (7) –c shows if the working gap X3 increases from 1 to 3 the ΔMR deceases from (0.13 to 0.10) mg that means become better with improved in the material removal 30%.

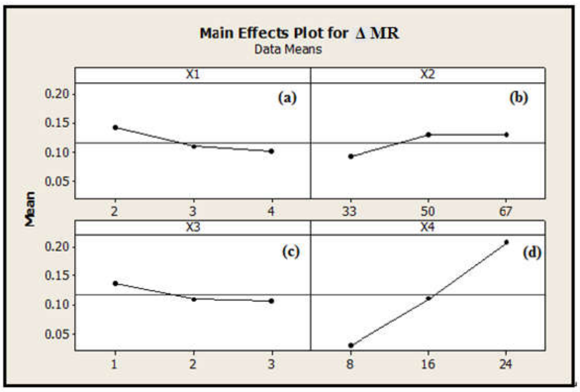


Fig.7 Main influence (effect) of process parameters in ΔMR

6. Conclusions

In this study state the main conclusions of previous results as follows:

(1) The material removal (ΔMR) increase with the increasing of the feed rate from (8-24) mg, they almost done keep of a straight or nearly straight line relationship under experimental conditions.

(2) For the analysis of the variance (ANOVA) for the materials removal , it is observed the larger influence on the materials removal Al-1050 alloy plate is the feed rate (X4) followed by the current(X1), Percent weight of abrasives (%wt) (X2) and the working gap (X3).

(3) It has been found from plot of normal distribution probability for Δ(MR),the R-sq displayed that 98.2% and R-Sq (adj) = 96.5% this mean given stronger model and material removal improved 75%

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التحقيق من معلمات الإدخال لعملية الحك الممغنط في إزالة المواد باستخدام ألواح من الا لمنيوم - 1050

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الخلاصة

عملية الانهاء بالحك الممغنط تعتبر من طرق القطع الدقيقة في أزالة المعادن والتي تستخدم المجال المغناطيسي والجزيئات الحاكة او القاشطة المغناطيسية لوصف سلوك آلية إزالة المعدن كوحدات لمقياس النانومتر الصغيرة . وأحد عيوب هذه العملية هو انخفاض معدل إزالة للمواد، ومن خلال عمل التجارب العملية وتحليل البرمجيات الإحصائية، وتأثير المدخلات المتغيرة للمعلمات مثل التيار، النسبة المئوية الوزنية للمواد الحاكة، فجوة العمل ومعدل التغذية، على الواح السطوح المستوية من مادة الألومنيوم نوع 1050 والتحقيق من إزالة المواد للعينات . أظهرت نتائج هذه الدراسة أن معدل التغذية لة تأثيرا كبيرا على تحسين إزالة المواد. وقد لوحظ أن نسبة إزالة المواد تحسنت بمقدار 75% وكانت نتائج النموذج الرياضي الاحصائي مرضية جدا حيث كانت نتيجة معامل التحديد هي 98.20% ومعامل التحديد المعدل 96.5%