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The Influence of the Magnetic Abrasive Finishing System for Cylindrical Surfaces on the Surface Roughness and MRR

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Abstract

Magnetic abrasive finishing (MAF) is one of the advanced finishing processes, which produces a high level of surface quality and is primarily controlled by a magnetic field. This paper study the effect of the magnetic abrasive finishing system on the material removal rate (MRR) and surface roughness (Ra) in terms of magnetic abrasive finishing system for eight of input parameters, and three levels according to Taguchi array (L27) and using the regression model to analysis the output (results). These parameters are the (Poles geometry angle, Gap between the two magnetic poles, Grain size powder, Doze of the ferromagnetic abrasive powder, DC current, Workpiece velocity, Magnetic poles velocity, and Finishing time). This work includes the classification of the MAF system, implementation of MAF machine and magnetic poles, preparing ferromagnetic abrasive powder by mix the iron oxide with industrial diamond powder and studying the effects of magnetic abrasive finishing on the MRR and surface roughness. MINITAB software was used to estimate the influence of the Magnetic Abrasive Finishing (MAF) parameters on the MRR and Surface Roughness for a cylindrical duralumin (2024) workpiece. The results show that the poles geometry angle has the biggest influence on MRR (30.18%) followed by Finishing time, Gap, Magnetic poles velocity, Workpiece velocity, Current, Doze, and Grain size powder, respectively. Also the results show that the workpiece velocity has the biggest influence on the surface roughness (23.80%) followed by Doze, Gap, Current, poles geometry angle, Magnetic poles velocity, Grain size powder, and Finishing time, respectively. Regression results show that the decreasing of poles geometry angle from 30°to -30° leads to increasing MRR. While the decreasing of the workpiece velocity from (679 rpm) to (567 rpm) leads to increase the Roughness.

Keywords: *Magnetic Abrasive Finishing process, Regression model, Material Removal Rate, Surface Roughness.*

1. Introduction

The MAF process removes a very small amount of material by indentation and rotation of magnetic abrasive particles in the circular tracks. The working principle of MAF method is that the workpiece is kept between the two poles of a magnet. The working gap between the workpiece and the magnet is filled with magnetic abrasive particles. A magnetic abrasive flexible brush (MAFB) is formed, acting as a multipoint cutting tool which pushes against the workpiece surface and develops finishing pressure, due to the effect of the magnetic field in the working gap [1-3].

Finishing is a type of machining technology for greatly increasing the surface quality of a machined object while maintaining stable precision and improving the machining precision grade [4]. Surface finish has a vital influence on important functional properties such as wear resistance and power losses due to friction on most of the engineering components [5]. In external finishing of cylindrical surface that shown in Fig. 1, cylindrical workpiece rotates between the magnetic poles, the magnetic abrasive powder filled the both gaps on either side between the workpieces and magnetic poles [2]. In MAF, magnetic abrasives which play the role of cutting tools are very crucial in ensuring finishing of desired quality and accuracy. Magnetic abrasives can be of different types like mechanical mixture of abrasives and magnetic powder, sintered type, bonded type, and unbonded type.

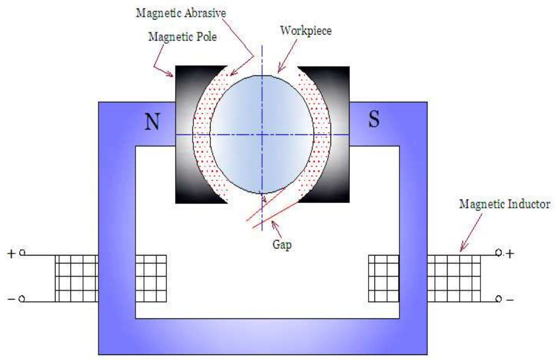

Fig. 1. Scheme of magnetic abrasive finishing (MAF): External finishing.

2. Prevoius Literatures

Yahya M. Hamad [6] has implemented the MAF method for finishing and improving the quality of the ferromagnetic stainless steel 420 plate. It was found that changing the operation parameters (working gap, coil current, feed rate, and table stroke) will affect the quality of workpiece surface. **Wang and Hu** [7] proposed MAF process for producing highly finished surfaces of tubes. This study showed the feasibility of using a MAF with a mixture of conventional abrasives and ferrous particles for the internal finishing of three kinds of metal tubes, such as Ly12 aluminum alloy, 316L stainless steel and H62 bras.**F. Djavanroodi** [8] has studied the parameter that affects surface roughness in MAF process on a brass shaft of CuZn37. These parameters are: intensity of the magnetic field, workpiece velocity and finishing time. It has been shown that the intensity of magnetic field has the most effect on finishing process, a higher intensity in magnetic field, results in a higher change in surface roughness, increasing finishing time results in decreased surface roughness and a lower workpiece velocity leads to a lower surface roughness. **Jae-Seob and Tae-Kyung** [9] was performed MAF on the magnesium material and design of experimental method using the Taguchi method was applied to evaluate parameter's effect on the surface roughness using Fe powder and boron nitride as magnetic abrasive powder, it was seen that better surface roughness could be obtained by applying the MAF process.

3. Regression Model

Regression is a statistical measure that attempts to determine the strength of the relationship between one dependent variable (MRR & Surface roughness) and a series of other changing variables (known as independent variables) (Poles geometry angle, gap between the two magnetic poles, grain size powder, doze of the ferromagnetic abrasive powder, DC current, workpiece velocity, magnetic poles velocity, and finishing time). The two basic types of regression are linear regression and multiple regressions. Linear regression and multiple regressions which are use two or more independent variables to predict the outcome. The general form of each type of regression is:

Multiple Regression: $Y = a + b_1X_1 + b_2X_2 + b_3X_3 + ... + b_tX_t + u$ …(1)

Where:
Y= the variable that we are trying to predict
X= the variable that we are using to predict Y
a= the constant
b= the slope
u= the regression residual

Regression takes a group of random variables, thought to be predicting Y, and tries to find a mathematical relationship between them. This relationship is typically in the form of a straight line (linear regression) that best approximates all the individual data points.

4. Taguchi Array

The Taguchi arrays can be derived or looked up. Small arrays can be drawn out manually; large arrays can be derived from deterministic algorithms. Generally, arrays can be found online. The arrays are selected by the number of parameters (variables) and the number of levels (states).

5. Experimental Work

5.1. MAF System Parameters

First step in the experimental work was the classification of MAF system into: (1) machine parameters (2) fixture (3) tool (4) workpiece (5) electro-magnetic system (6) MAF output. This parameter includes all the input and output parameters have been used in the MAF process that is shown in Fig.2. Solid duralumin 2024 material with cylindrical shape was chosen to be a workpiece with a diameter of 60 mm, and Length of 300 mm, it is having a high strength and fatigue resistance. The chemical composition and some properties of duraluminum 2024 are given in table 1.

5.2. Design and Implementation of MAF Machine

MAF Machine for the cylindrical surface has been designed and manufactured in the Al-Khwarizmi engineering college workshop; the basic components that have been used to form the MAF machine illustrated as following: (1) Two Gearbox motor (Changeable Velocities), (2) solid iron square shaft (32 mm), with a length of (890 mm), (3) Copper wires (1 mm) diameter that have been used to manufacture the magnetic coils. (4) Lathe machine that has been used as a base frame of the MAF machine, (5) Insulated base that has been manufactured from the Perspex material. (6) Two power supply one for the coil to control the magnetic and the other to control the velocity of motors, (7) Electrical motor used for rotating the workpiece, (8) Stand for carry the whole MAF machine which has been carried out some modifications on it to suit their required purpose, (9) Two axial shafts. The manufacturing of the MAF machine has been done by the following steps: (a) the solid square shaft has been perforated from the two sides with depth of 100 mm and 11 mm diameter according to the diameter of the magnetic poles. (b) Bending the solid square shaft in the form of Horseshoe from the two sides to make the two basic magnetic poles. (c) Prepare two discal barriers for the purpose of winding the copper wire. (d) Insulating the solid square shaft from the two discal barriers and then turn the copper wire around the shaft with number of turns equal to 1600 cycle to form the magnetic coil. (e) Manufacturing three couples of magnetic poles for the purpose of polarization the ferromagnetic abrasive powder. The magnetic poles have been designed and manufactured to rotate each against the other to maintain a high magnetic field, maintain a biggest amount of the ferromagnetic abrasive powder and to avoid the centrifugal force. Fig.3 shows the whole MAF machine.

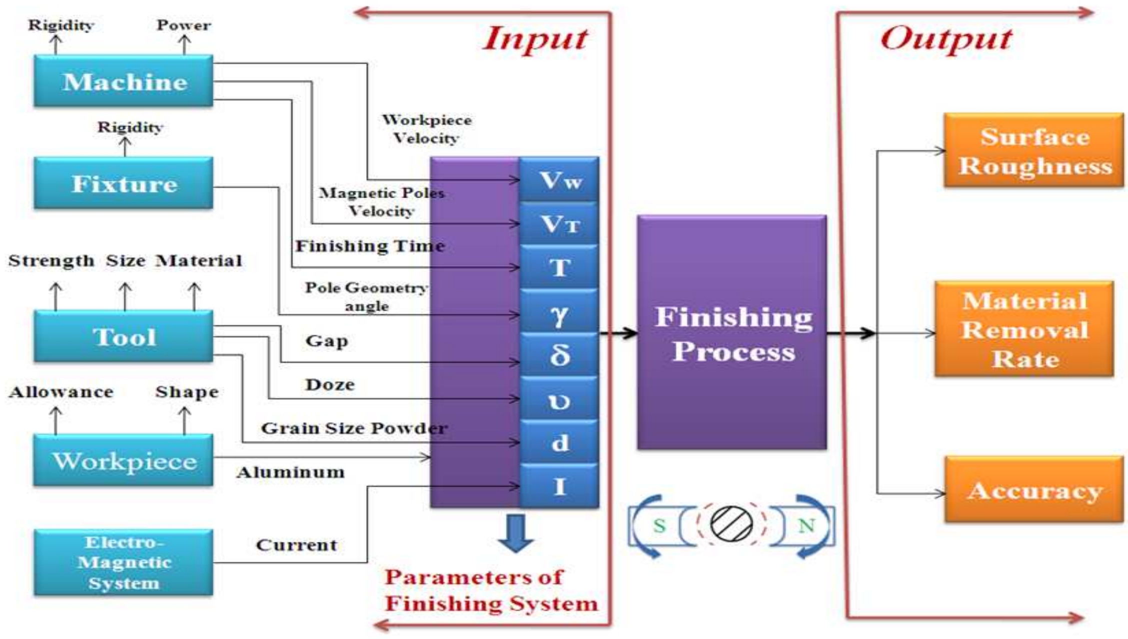

Fig. 2. Input and output for the Finishing System for MAF.

Table 1,
The chemical composition and Properties of duraluminum 2024.

Chemical Composition	Cu	Mg	Mn	Al	Properties	ρ (g/cm^3)	E (Gpa)	T_m (°C)
W%	4.4	1.5	0.6	93.5	Value	2.78	73	500

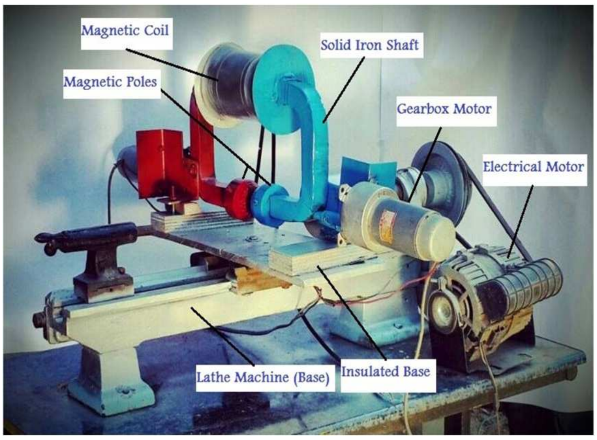

Fig. 3. Photograph of the MAF Machine.

5.3. Preparing the Ferromagnetic Abrasive Powder

Ferromagnetic abrasive powder is an essential part in the MAF process; The preparing of the ferromagnetic abrasive powder was done by mixing 67% from Iron Oxide with 33% from industrial diamond using liquid epoxy and then enter this mixture in to a furnace at a temperature between 300 - 400°C for a time of 45 minute, then remove it from the furnace and leave it to air-cool, after that we grind it by using a high speed grinder , finally we use a sieve to extracted three types of powder grain size diameters (100, 200, and 300 μm).

5.4. Manufacturing of Magnetic Poles

Three couples of magnetic poles have been designed according to three different angles (30°, 0°, and -30°); a rounded iron shaft has been used to manufactured these magnetic poles, using the lathe machine to obtain the desired shapes and then toothing them with milling machine in a form of projections triangular as shown in Fig.4.

Fig. 4. The three manufactured magnetic poles.

5.5. Selection of Input Parameters Values

In this work eight inputs parameters have been choose with three levels according to the classification of MAF system. The values of inputs parameters illustrated in table 2. The input parameters is been applied it on a set of experiments, according to the Taguchi array (L27), which deals with the number of the input parameters, and the number of level, so that L27 has been selected.

Table 2,
Inputs parameters values.

Input Parameter	**Level 1**	**Level 2**	**Level 3**
Poles Geometry angle (deg.)	30	0	-30
Gap (mm)	1.5	2.5	3.5
Grain Size Powder (μm)	100	200	300
Doze (cc)	18	24	30
Current (Amp.)	3	6	9
Workpiece Velocity (rpm)	567	629	679
Magnetic Poles Velocity (rpm)	208	347	496
Finishing Time (Sec)	30	45	60

6. Experimental Results of MAF Processes

After all the experiments of MAF process was completed, the weight and the surface roughness for each workpiece were calculated. The weight is calculated as the following: ΔW = weight (Before MAF) – weight (After MAF), while ΔRa calculated using surface roughness tester, (TR-220) and by the measuring for each workpiece three times before MAF and three times after MAF, and get the midrange value, then we take the difference between the two cases. Fig.5 shows the duraluminum workpiece before and after the MAF process. Based on the experiments of the MAF process, a set of input / output training data for the regression models is generated. Table 3 shows this data set in both cases of consideration the material removal rate and surface roughness is the outputs.

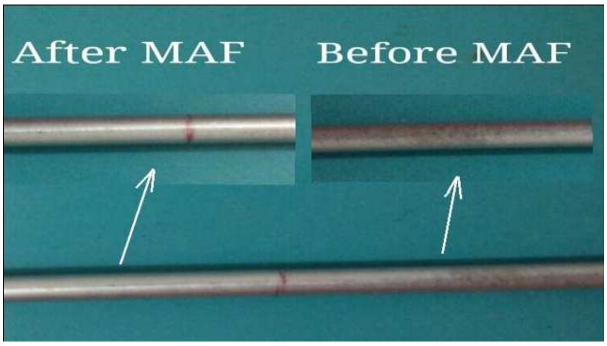

Fig. 5. Duralumin workpiece before after MAF process.

Table 3,
Training data sets for the proposed mode.

W.P No.	Poles geometry angle (deg.)	Gap (mm)	Grain size powder (μm)	Doze (cc)	Current (Amp.)	Workpiece velocity (rpm)	Magnetic poles velocity (rpm)	Finishing time (Sec.)	ΔW (g)	ΔRa (μm)
1	30	1.5	100	18	3	567	208	30	0.0018	0.029
2	30	1.5	100	18	6	629	347	45	0.0027	0.036
3	30	1.5	100	18	9	679	496	60	0.0019	0.002
4	30	2.5	200	24	3	567	208	45	0.0007	0.007
5	30	2.5	200	24	6	629	347	60	0.0007	0.039
6	30	2.5	200	24	9	679	496	30	0.0003	0.092
7	30	3.5	300	30	3	567	208	60	0.0018	0.053
8	30	3.5	300	30	6	629	347	30	0.0006	0.08
9	30	3.5	300	30	9	679	496	45	0.0003	0.074
10	0	1.5	200	30	3	629	496	30	0.0051	0.147
11	0	1.5	200	30	6	679	208	45	0.0054	0.016
12	0	1.5	200	30	9	567	347	60	0.0072	0.289
13	0	2.5	300	18	3	629	496	45	0.0059	0.203
14	0	2.5	300	18	6	679	208	60	0.0073	0.144
15	0	2.5	300	18	9	567	347	30	0.0059	0.089
16	0	3.5	100	24	3	629	496	60	0.0152	0.006
17	0	3.5	100	24	6	679	208	30	0.0061	0.069
18	0	3.5	100	24	9	567	347	45	0.0126	0.054
19	-30	1.5	300	24	3	679	347	30	0.394	0.07
20	-30	1.5	300	24	6	567	496	45	0.001	0.218
21	-30	1.5	300	24	9	629	208	60	0.0135	0.015
22	-30	2.5	100	30	3	679	347	45	0.0014	0.078
23	-30	2.5	100	30	6	567	496	60	0.0258	0.11
24	-30	2.5	100	30	9	629	208	30	0.0286	0.042
25	-30	3.5	200	18	3	679	347	60	0.0197	0.052
26	-30	3.5	200	18	6	567	496	30	0.0216	0.059
27	-30	3.5	200	18	9	629	208	45	0.0215	0.05

7. Results and Discussion

7.1. Regression Model

By using MINITAB software the regression equation for estimate the surface roughness and MRR has been obtained as the following:

$$y1\ (\Delta W) = -0.076 - 0.000956\ X1 - 0.0185\ X2 + 0.000186\ X3 - 0.00011\ X4 - 0.00655\ X5 + 0.000342\ X6 - 0.000007\ X7 - 0.00137\ X8 \quad \ldots (2)$$

$$y2\ (\Delta Ra) = 0.136 - 0.000522\ X1 - 0.0181\ X2 + 0.000289\ X3 + 0.00208\ X4 + 0.00115\ X5 - 0.000317\ X6 + 0.000186\ X7 + 0.00012\ X8 \quad \ldots (3)$$

Where:
X1: Poles Geometry angle (deg).
X2: Gap (mm).
X3: Grain Size Powder (µm).
X4: Doze (cc).
X5: Current (Amp).
X6: Workpiece Velocity (rpm).
X7: Magnetic Poles Velocity (rpm).
X8: Finishing Time (Sec).

7.2. The Effect of Poles Geometry Angle (X1)

The relationship between poles geometry angle x1 with MRR y1 and surface roughness y2 shown in Fig. 6.The mean value of y1 at x1 = -30° is 0.0585667 g, at x1 = 0° is 0.00785556 g, and at x1 = 30° is 0.0012 g. poles geometry is affected by 30.180 % on the MRR; decreasing x1 from 30° to -30° leads to increasing MRR. The best value of poles geometry angle in this case is (-30°). While the mean value of y2 at x1 = -30° is 0.0771111 µm, at x1 = 0° is 0.113 µm, and at x1 = 30° is 0.0457778 µm. poles geometry angle is affected by 10.053 % on the surface roughness; decreasing of x1 from 30° to 0° leads to increasing Ra, but decreasing it from 0° to -30° leads to decreasing Ra. The best value of poles geometry angle in this case is (0°).

7.3. The Effect of Gap (X2)

The relationship between gap x2 with MRR y1 and surface roughness y2 shown in Fig. 7. The mean value of y1 at x2 = 1.5 mm is 0.0480667 g, at x2 = 2.5 mm is 0.00851111 g, and at x2 = 3.5 mm is 0.0110444 g. gap is affected by 18.126 % on the MRR; decreasing x2 from3.5 to 2.5 mm leads to decrease MRR, but decreasing it from 2.5 to 1.5 mm leads to increase MRR. The best value of gap in this case is (1.5 mm). While the mean value of y2 at x2 = 1.5 mm is 0.0913333 µm, at x2 = 2.5 mm is 0.0893333 µm, and at x2 = 3.5 mm is 0.0552222 µm. gap is affected by16.133 % on the surface roughness; decreasing of x2 from 3.5 to 1.5 mm leads to increasing Ra. The best value of gap in this case is (1.5 mm).

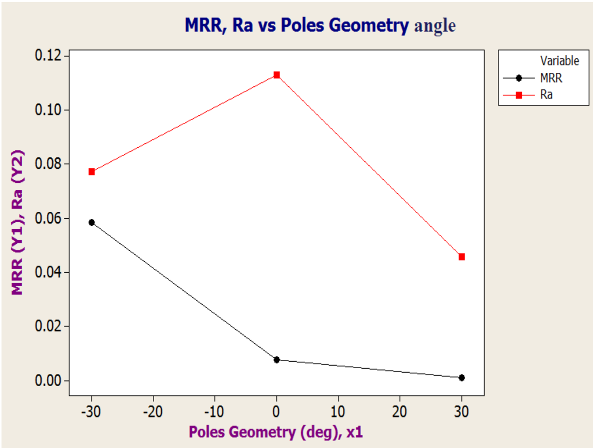

Fig. 6. The relationship between X1 and y1, y2.

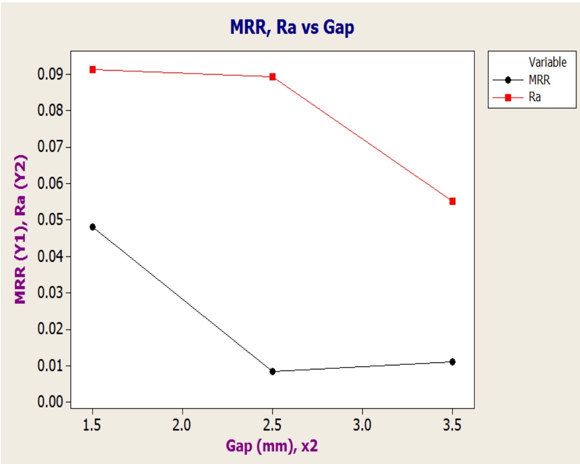

Fig. 7. The relationship between X2 and y1, y2.

7.4. The Effect of Grain size powder (X3)

The relationship between grain size powder x3 with MRR y1 and surface roughness y2 shown in Fig.8. The mean value of y1 at x3 = 100 µm is 0.0106778 g, at x3 = 200 µm is 0.00913333 g, and at x3 = 300 µm is 0.0478111 g. The grain size powder is affected by 1.156 % on the MRR; increasing x3 from 100 to 200 µm leads to decrease MRR, but increasing it from 200 to 300 µm leads to increase MRR. The best value of grain size powder in this case is (300 µm), while the mean value of y2 at x3 = 100 µm is 0.0473333 µm, at x3 = 200 µm is 0.0834444 µm, and at x3 = 300 µm is 0.105111 µm. The grain size powder is affected by 7.088 % on the surface roughness; increasing the grain size powder from 100 to 300 µm leads to increasing Ra. The best value of the grain size powder in this case is (300 µm).

7.5. The Effect of Doze (X4)

The relationship between doze x4 with MRR y1 and surface roughness y2 shown in Fig. 9. The mean value of y1 at x4 = 18 cc is 0.00981111 g, at x4 = 24 cc is 0.0493444 g, and at x4 = 30 cc is 0.0084667 g. Doze is affected by 3.407 % on the MRR; increasing x4 from 18 to 24 cc leads to increasing MRR, but increasing it from 24 to 30 cc leads to decreasing MRR. The best value of doze in this case is (24 cc), while the mean value of y2 at x4 = 18 cc is 0.0737778 µm, at x4 = 24 cc is 0.0633333 µm, and at x4 = 30 cc is 0.0987778 µm. doze is affected by 18.063 % on the surface roughness; increasing x4 from 18 to 24 cc leads to decreasing Ra, but increasing it from 24 to 30 cc leads to increasing Ra. The best value of doze in this case is (30 cc).

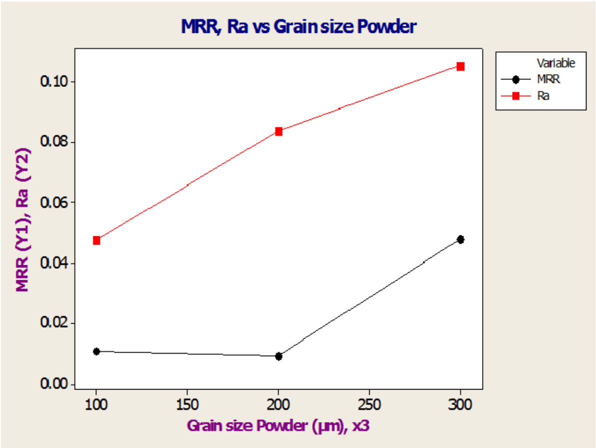

Fig. 8. The relationship between X3 and y1, y2.

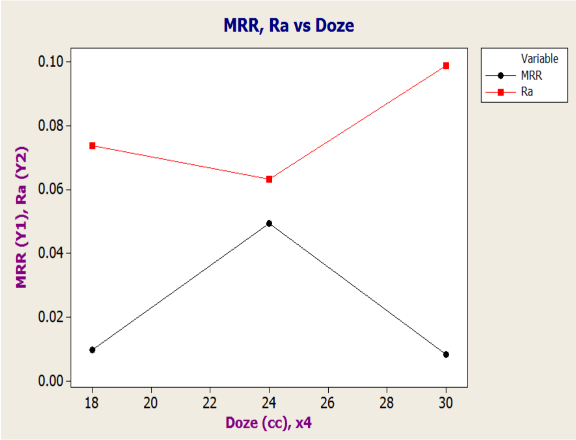

Fig. 9. The relationship between X4 and y1, y2.

7.6. The Effect of the Current (X5)

The relationship between current x5 with MRR y1 and and surface roughness y2 shown in Fig. 10. The mean value of y1 at x5 = 3 Amp is 0.0495111 g, at x5 = 6 Amp is 0.00791111 g, and at x5 = 9 Amp is 0.0102 g. Crrent is affected by 4.935 % on the MRR; decreasing x5 from 9 to 6 Amp leads to decrease MRR, but decreasing it from 6 t0 3 Amp leads to increasing MRR. The optimal value of current in this case is (3 Amp), while the mean value of y2 at x5 = 3 Amp is 0.0716667 µm, at x5 = 6 Amp is 0.0856667 µm, and at x5 = 9 Amp is 0.0785556 µm. Current is affected by 13.394 % on the surface roughness; increasing x5 from 3 to 6 Amp leads to increase Ra, but increasing it from 6 t0 9 Amp leads to decreasing Ra. The best value of current in this case is (6 Amp).

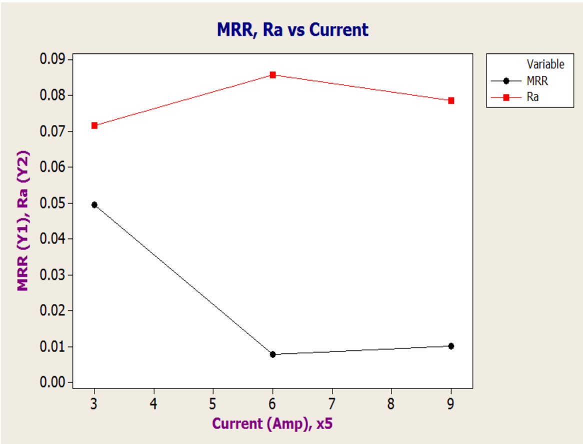

Fig. 10. The relationship between X5 and y1, y2.

7.7. The Effect of Workpiece Velocity (X6)

The relationship between workpiece velocity x6 with MRR y1 and surface roughness y2 shown in Fig. 11. The mean value of y1 at x6 = 567 rpm is 0.00871111 g, at x6 = 629 rpm is 0.0104222 g, and at x6 = 679 rpm is 0.0484889 g. The workpiece velocity is affected by 5.199 % on the MRR; increasing x6 from 567 to 679 rpm leads to increase MRR. The best value of workpiece velocity in this case is (679 rpm), while the mean value of y2 at x6 = 567 rpm is 0.100889 µm, at x6 = 629 rpm is 0.0686667 µm, and at x6 = 679 rpm is 0.0663333 µm. The workpiece velocity is affected by 23.805 % on the surface roughness; decreasing x6 from 679 to 567 rpm leads to increase Ra. The best value of workpiece velocity in this case is (567 rpm).

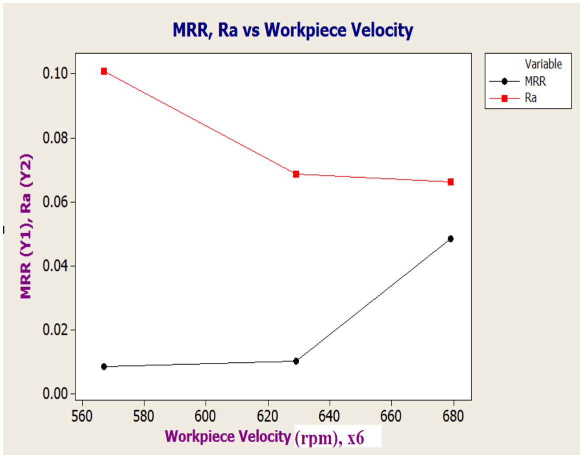

Fig. 11. The relationship between X6 and y1, y2.

7.8. The Effect of Magnetic Poles Velocity (X7)

The relationship between magnetic poles workpiece velocity x7 with MRR y1 and surface roughness y2 shown in Fig. 12. The mean value of y1 at x7 = 208 rpm is 0.00963333 g, at x7 = 347 rpm is 0.0494222 g, and at x7 = 496 rpm is 0.00856667 g. The magnetic poles velocity is affected by 9.748 % on the MRR; increasing x7 from 208 to 347 rpm leadS to increase MRR, but increasing it from 347 t0 496 rpm leadS to decrease MRR. The best value of magnetic poles velocity in this case is (347 rpm), While the mean value of y2 at x7 = 208 rpm is 0.0472222 µm, at x7 = 347 rpm is 0.0874444 µm, and at x7 = 496 rpm is 0.101222 µm. The magnetic poles velocity is affected by 7.431 % on the surface roughness; increasing x7 from 208 to 496 rpm leads to increase Ra. The best value of magnetic poles velocity in this case is (496 rpm).

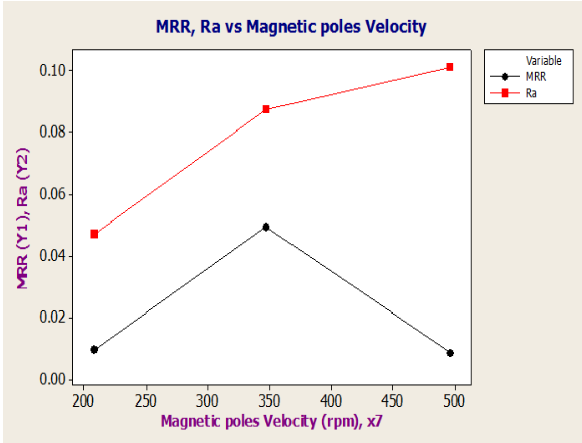

Fig. 12. The relationship between X7 and y1, Y2.

7.9. The Effect of finishing time (X8)

The relationship between finishing time x8 with MRR y1 and surface roughness y2 shown in Fig. 13. The mean value of y1 at x8 = 30 sec is 0.0515556 g, at x8 = 45 sec is 0.00572222 g, and at x8 = 60 sec is 0.0103444 g. Finishing time is affected by 27.246 % on the MRR; decreasing x8 from 60 to 45 sec leads to decrease MRR, but decreasing it from 45 t0 30 sec leads to increasing MRR. The best value of finishing time in this case is (30 sec), while the mean value of y2 at x8 = 30 sec is 0.0752222 µm, at x8 = 45 sec is 0.0817778 µm, and at x8 = 60 sec is 0.0788889 µm. finishing time is affected by 4.029 % on the surface roughness; increasing x8 from 30 to 45 sec leads to increase Ra, but increasing it from 45 to 60 sec leads to decreasing Ra. The best value of finishing time in this case is (45 sec).

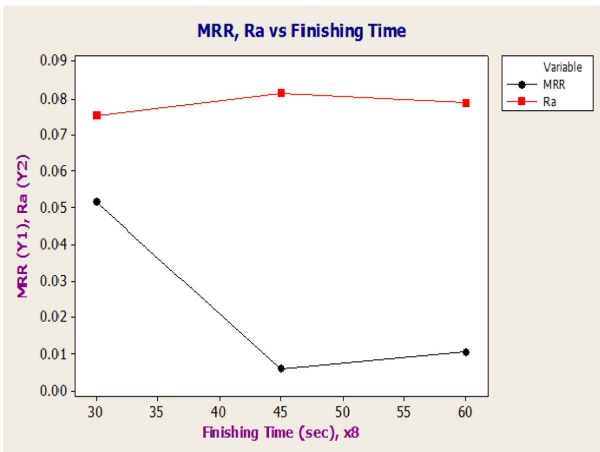

Fig. 13. The relationship between X8 and y1, Y2.

8. Conclusions

1. Analysis the regression model for surface roughness and MRR using ANOVA show the effect of each parameter on the output as the below table:

Parameter	Ra %	MRR %
Pole geometry x1	10.053	30.180
Gap x2	16.133	18.126
Grain size x3	7.088	1.156
Doze x4	18.063	3.407
Current x5	13.394	4.935
Velocity of w.p x6	23.805	5.199
Pole velocity x7	7.431	9.748
Finishing time x8	4.029	27.246

2. The curves show that the decreasing of pole geometry angle to (-30) lead to increasing MRR. While the decreasing of workpiece velocity to (567 rpm) lead to increase Ra.

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تأثير نظام الانهاء السطحي بالحك المغناطيسي للسطوح الأسطوانية على خشونة السطح و معدل إزالة المواد

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الخلاصة

التشغيل بالتجليخ المغناطيسي هي إحدى عمليات التشغيل الحديثة التي تنتج مستوى عالٍ من جودة السطح والتي يعتمد عملها أساساً على المجال المغناطيسي. هذا البحث تناول دراسة تأثير نظام التشغيل بالتجليخ المغناطيسي على معدل إزالة المواد وخشونة السطح من خلال ثمانية مدخلات لعملية التشغيل بالجلخ المغناطيسي تم اختيارها مع ثلاث مستويات تبعاً لمصفوفة تاكوشي عن طريق أستخدام انموذج الأنحدار. هذه المدخلات هي: (زاوية الاقطاب المغناطيسية، الخلوص،حجم حبيبات المسحوق، كمية المسحوق، التيار، سرعة المشغولة، سرعة الاقطاب المغناطيسية، و وقت التشغيل). هذا العمل تضمّن تصنيف نظام التشغيل بالجلخ المغناطيسي، تصنيع ماكنة التشغيل بالجلخ المغناطيسي والأقطاب المغناطيسية، و تحضير مسحوق الجلخ المغناطيسي عن طريق خلط أوكسيد الحديد مع مسحوق الماس الصناعي ودراسة تأثير عملية التشغيل بالتجليخ المغناطيسي على معدل إزالة المواد وخشونة السطح. برنامج الـ(MINITAB) تم أستخدامه لتخمين تأثير متغيرات عملية التشغيل بالجلخ المغناطيسي على معدل إزالة المواد وخشونة السطح لمشغولة الألمنيوم (٢٠٢٤) الأسطوانية الشكل.

أظهرت النتائج أن زاوية الاقطاب المغناطيسية لها التأثير الأكبر على معدل إزالة المواد بنسبة ٣٠.١٨% يتبعها (وقت التشغيل، الخلوص، سرعة الاقطاب المغناطيسية، سرعة المشغولة، التيار، كمية المسحوق، حجم حبيبات المسحوق) على التوالي. كما أظهرت النتائج ان السرعة المشغولة لها التأثير الأكبر على خشونة السطح بنسبة ٢٣.٨٠% يتبعها (كمية المسحوق، الخلوص، التيار، زاوية الاقطاب المغناطيسية، سرعة الاقطاب المغناطيسية، حجم حبيبات المسحوق، و وقت التشغيل) على التوالي. وأظهرت نتائج انموذج الأنحدار أن تناقص زاوية الاقطاب المغناطيسية من ٣٠° الى ٣٠°- تؤدي الى زيادة معدل إزالة المواد. بينما تناقص السرعة المشغولة (٦٧٩ rpm) الى (٥٦٧ rpm) يؤدي الى زيادة خشونة السطح.