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The Influence of Design and Technological Parameters on the MAF Process

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Abstract

Experimental work from Magnetic Abrasive Finishing (MAF) tests was carried out design parameters (amplitude, and number of cycle which are formed the shape of electromagnetic pole), and technological parameters (current, cutting speed, working gap, and finishing time) all have an influence on the mechanical properties of the surface layer in MAF process. This research has made to study the effect of design and technological parameters on the surface roughness (Ra), micro hardness (Hv) and material removal (MR) in working zone. A set of experimental tests has been planned using response surface methodology according to Taguchi matrix (3^6) with three levels and six factors.

The analysis of variance and instruction curves indicate some significant. X1; X4; X6 have a significant effect on the surface roughness Ra for steel, X2 has mildly significant, while X3 and X5 have insignificant effect. The results showed that roughness of workpiece decreased from 0.3 to 0.15 µm that means improved the roughness to 100%.

Keywords: *Design and technological parameters, micro-hardness, surface roughness, material of removal, MINITAB software*.

1. Introduction

Non-traditional MAF process were advanced method for technology of machining, the ability of MAF was removed microchips, in order to get the higher mechanical properties surfaces, this process has been used to produce microrelief layer. The specialty of MAF process was capability to control the flexibility of tool, ferromagnetic powder sealing by magnetic field, one can control the density and rigidity of the magnetic brush, that help to change the topography of magnetic flux in the working gap. This specialty of MAF process was differs at other finishing methods. MAF process was universal, simplicity; improved the quality of surface roughness (Ra) above 50 %. MAF effective process, gives good economic and ecological environment [1-6], by this method can finished different surfaces like cylindrical, flat, bolt, and complex shapes, for ferromagnetic materials [4].

This work aims to study the influence of design and technological parameters on the quality of surface MR, by using experimental method then finding the mathematical models with the MINITAB software.

2. Experimental Procedure

An electromagnetic inductor has designed and manufactured using for finishing flat surfaces. The inductor was a steel rod wrapped around a coil of wires, magnetic force was generate on the working gap, between pole and workpiece, the gap was filled with powder and the current was applied by (DC) power supply. See Figure 1.

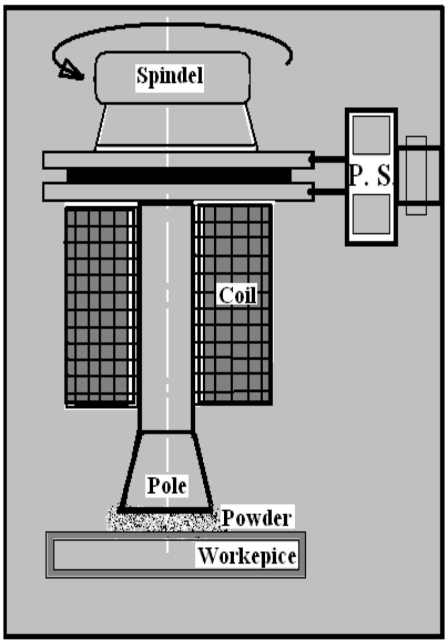

Fig. 1. Electromagnetic inductor.

The characteristic of inductor are the following:

- The materials of the core was low carbon steel C15
- The diameter of copper wire was 0.9mm
- The number of turns was N=3000 turns
- The material of pole from low carbon steel
- The abrasive powder was (65%) oxide of the iron with (35%) tungsten carbide.
- The doze of powder was (5 cm3).

There are six input parameters have been choose, the values of parameters and their three levels were illustrate in Table (1). The input parameters were applied according to the Taguchi matrix (L27) and the output was shown in Table (2).

Three observed value of change in surface roughness (Ra), weight (MR),and micro-hardness (Hv), were examined, for ferromagnetic material as steel 304, before and after polishing measured the Ra, Hv and, w then finding the value ΔRa, ΔHv, MR were averaged.

The Surface roughness Ra measured by tester SRT-6210- surface roughness, Time tester was used to measuring Hv, the MR measured through measuring the weight of the workpiece before and after process (Δw) using the delicate balance. For steel material, 27 tests were applied. The last step adjusts the value of the six input parameters according to Taguchi matrix, and fixed the workpiece on the table of the milling machine, then filled the working gap with powder ($5cm^3$).

Table 1,
Input parameters values.

Input	Symbol	Levels Level 1	Level 2	Level 3
Amplitude of pole geometry (mm)	X1	4	8	12
Number of cycles of pole geometry	X2	2	5	8
Finishing time (min)	X3	5	10	15
Cutting velocity (rpm)	X4	175	580	970
Current (Amp)	X5	1.0	1.5	2.0
Working gap (mm)	X6	1.0	2.0	3.0

3. Results and Discussion

The criterion outputs, ΔRa, ΔHv, and MR are dependent variable in regression models, while the predictor's factors were the amplitude of pole geometry, number of cycles of pole geometry, finishing time, and cutting velocity, current and working gap. Table (2) shows the result of experiment for ferromagnetic material.

Table 2,
Results of experiments for steel 304 and distribution parameters according to Taguchi matrix L27.

№	X1		X2		X3		X4		X5		X6		ΔRa, μm	Δw MR	ΔHv
1	1	4	1	2	1	5	1	175	1	1	1	1	0.292	0.001	10.5
2	1	4	1	2	1	5	1	175	2	1.5	2	2	0.278	0.0012	9
3	1	4	1	2	1	5	1	175	3	2	3	3	0.383	0.3036	8.6
4	1	4	2	5	2	10	2	580	1	1	1	1	0.387	0.0024	6.6
5	1	4	2	5	2	10	2	580	2	1.5	2	2	0.466	0.0016	10.8
6	1	4	2	5	2	10	2	580	3	2	2	2	0.233	0.0041	7.5
7	1	4	3	8	3	15	3	970	1	1	1	1	0.352	0.0026	11.5
8	1	4	3	8	3	15	3	970	2	1.5	2	2	0.377	0.002	8.7
9	1	4	3	8	3	15	3	970	3	2	3	3	0.044	0.0068	8
10	2	8	1	2	2	10	3	970	1	1	2	2	0.099	0.0098	25
11	2	8	1	2	2	10	3	970	2	1.5	3	3	0.108	0.0044	11.6
12	2	8	1	2	2	10	3	970	3	2	1	1	0.064	0.0084	9.6
13	2	8	2	5	3	15	1	175	1	1	2	2	0.118	0.0011	21.1
14	2	8	2	5	3	15	1	175	2	1.5	3	3	0.21	0.0051	22.8
15	2	8	2	5	3	15	1	175	3	2	1	1	0.672	0.0094	13.5
16	2	8	3	8	1	5	2	580	1	1	2	2	0.241	0.0013	20.7
17	2	8	3	8	1	5	2	580	2	1.5	3	3	0.225	0.0014	3.8
18	2	8	3	8	1	5	2	580	3	2	1	1	0.378	0.0063	7.7
19	3	12	1	2	3	15	2	580	1	1	3	3	0.028	0.002	15.5
20	3	12	1	2	3	15	2	580	2	1.5	1	1	0.164	0.0425	17.4
21	3	12	1	2	3	15	2	580	3	2	2	2	0.111	0.0023	26.7
22	3	12	2	5	1	5	3	970	1	1	3	3	0.102	0.0079	25.9
23	3	12	2	5	1	5	3	970	2	1.5	1	1	0.068	0.0027	8.3
24	3	12	2	5	1	5	3	970	3	2	2	2	0.038	0.0023	5.8
25	3	12	3	8	2	10	1	175	1	1	3	3	0.14	0.0017	16.8
26	3	12	3	8	2	10	1	175	2	1.5	1	1	0.393	0.0099	11.8
27	3	12	3	8	2	10	1	175	3	2	2	2	0.287	0.0055	21.7

3.1. Regression Model for Surface Roughness (Ra for Steel 304) Versus x1; x2; x3; x4; x5; x6

By using Minitab 16 statistical software, finding the mathematical statistical regression models for MAF process between the surface roughness and all six parameters are represented bellow.

Ra st. = 0.494 - 0.0196 x1 + 0.0169 x2 + 0.00079 x3 - 0.000212 x4 + 0.0423 x5 - 0.0707 x6 …(1)

The regression analysis of variance (ANOVA) on to surface finish ΔRa for steel 304.

The results of analysis were show in Table (3).

Table 3,
Result of ANOVA.

Predictor	Coefficient	P	Effect	inductor
X1	-0.019587	0.008	significant effect	$(p<0.05)$
X2	0.016852	0.072	mildly significant effect	$(p<0.1)$
X3	0.000789	0.884	insignificant effect	$(p> 0.1)$
X4	-0.000213	0.005	significant effect	$(p<0.05)$
X5	0.04225	0.438	insignificant effect	$(p> 0.1)$
X6	0.07073	0.018	significant effect	$(p<0.05)$

Analysis of Variance for regression also show:
R-Sq = 60.5%   F =5.11   P =0.003

The R-sq showed that 60.5% of the observed variable in surface roughness for steel was independent variable. F- Value was high; P-value for regression equation was significant effect. The coefficients (of output parameters) for regression are listed in the Table (3). For these coefficients, multiple linear regressions (mathematical statistical model) for surface roughness with steel materials could be expressed equation (1).

3.1.1. The Effects of Amplitude, Velocity of Pole, and Working Gap on the Surface Roughness ΔRa for Steel 304.

However for the six input factors, all coefficient of the linear regression equation 1, analysis of variance and instruction curves figure 2 indicate some significant. X1; X4; X6 have a significant effect on the surface roughness ΔRa st., curves shows that if the X1; X4; X6 increases, the surface roughness ΔRa for steel decreases. The influence of amplitude (X1) that has a significant effect on surface roughness as follow: the increases in amplitude from 4 to 12 mm lead to decreases in the ΔRa from 0.3 to 0.15 µm improved to 30%. From all six parameters.

This figure also shows that an increases in cutting velocity X4 from 175 to 970 rpm lead to reduce in the ΔRa st. from 0.3 to 0. 15 µm. In the same way decrease in working gap X6 from 1 to 3 mm lead to reduce in the ΔRa st. from 0.3 to 0.15 µm improved the surface roughness to 32%. Working gap X6 improving the surface roughness to 24%,

3.1.2. The Effect of Number of Cycles on the Surface Roughness ΔRa .

The number of cycles X2 has mildly significant effect on the ΔRa, compared with amplitude, cutting velocity and working gap. Figure 2 shows if the number of cycles increases from 2 to 9 the ΔRa st. increases from 0.15 to 0.3 µm that means improved in the surface roughness. X2 improve surface roughness to 11%, current improved the surface roughness to 3%, while X3 finishing time insignificant.

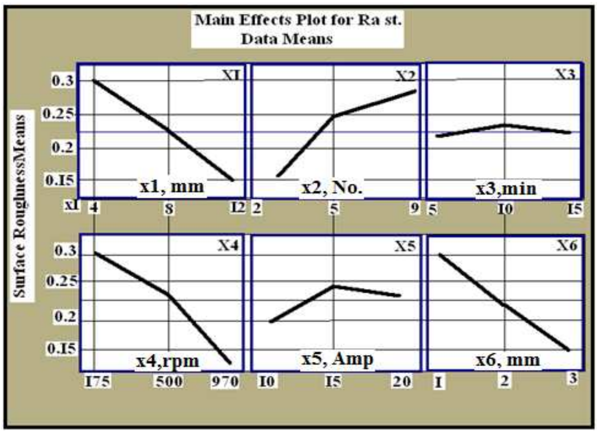

Fig. 2. Main effects of process parameters on the surface roughness ΔRa st.

3.2. Regression model for material removal MR (steel 304) versus x1; x2; x3; x4; x5; x6

By using Minitab 16 statistical software, finding the mathematical statistical regression models for MAF process between removal rate and all six parameters are represented in equation 2.

MR st. = 0.0387 - 0.00370 x1 - 0.00625 x2 - 0.00282 x3 - 0.000041 x4 + 0.0374 x5 + 0.0175 x6 …(2)

The regression analysis of variance (ANOVA) on to removal rate for steel 304

The results of analysis were show in Table (4).

Table 4,
Result of ANOVA.

Predictor	Coefficient	P
X1	-0.003695	0.259
X2	-0.006254	0.156
X3	-0.002821	0.280
X4	-0.000041	0.215
X5	0.03738	0.158
X6	0.01754	0.197

Analysis of Variance for regression also show:
R-Sq = 33.2% F-value = 1.66 P = 0.18
This regression has insignificant effect because (p> 0.1) and R-sq denotes an observation with a large standardized residual, F-value was low. See Figure 3.

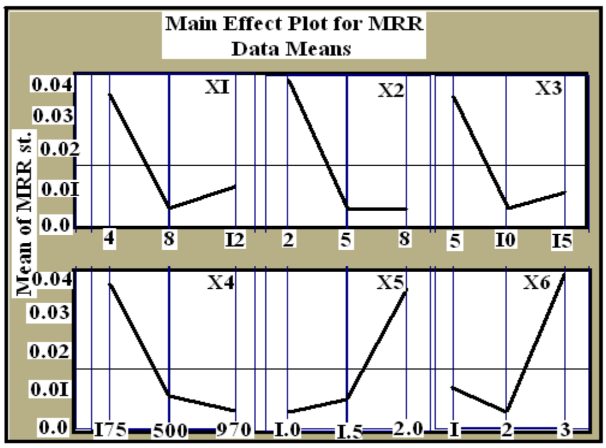

Fig. 3. Main effects of process parameters on the MR st.

3.3. Regression Model for Micro-hardness Hv (steel 304) versus x1; x2; x3; x4; x5; x6 .

By using Minitab 16 statistical software, finding the mathematical statistical regression models for MAF process between the micro-hardness Hv and all six parameters are represented bellow.

HV st. = 9.46 + 0.935 x1 - 0.430 x2 + 0.499 x3 - 0.00300 x4 - 4.79 x5 +1.39 x6 …(3)

The regression analysis of variance (ANOVA) on to micro-hardness Hv for steel 304.

The results of analysis were show in Table (5).

Table 5,
Result of ANOVA.

Predictor	Coefficient	P	Effect	inductor
X1	0.9349	0.010	significant effect	(p<0.05)
X2	-0.4296	0.337	insignificant effect	(p> 0.1)
X3	0.4989	0.072	mildly significant effect	(p<0.1)
X4	-0.003003	0.373	insignificant effect	(p> 0.1)
X5	-4.790	0.083	mildly significant effect	(p<0.1)
X6	1.388	0.318	insignificant effect	(p> 0.1)

Analysis of Variance for regression also shows:
R-Sq = 50.1% F = 3.08 P = 0.026 significant effect in the process MAF respect to micro-hardness. The R-sq showed that 50.1% of the observed variable in micro-hardness for steel was independent variable. F- Value was high; P-value for regression equation was significant effect. The coefficients (of output parameters) for regression are listed in the column above. For these coefficients multiple linear regressions (mathematical statistical model) for surface roughness with steel materials could be expressed, see equation 3.

3.3.1. The Effects of Amplitude on the Micro-Hardness ΔHv st

The effect of amplitude X1 has a significant effect on the **ΔHv** st. compared with other parameters, figure 4 show if the amplitude increases from 4 to 12 the ΔHv st. increases from 8 to 17 Mpa, and improved in the surface quality about 42%.

3.3.2. The Effects of Finishing Time and Current on the Micro-Hardness ΔHv st

The effect of finishing time X3 and current X5 have a mildly significant effect on the micro-hardness Hv compared with amplitude, figure 4 shows, if the finishing time increases from 5 to 15 the ΔHv st. increases from 8 to 17 Mpa, and improving in the surface quality about 20%. If the current increases from1to 2 Amp the micro-hardness ΔHv decreases from 17 to 12 Mpa and improved the quality to 18%.

3.3.3. The Effects of Number of Cycle, Cutting Velocity and Working Gap on the Micro-Hardness ΔHv st

The effect of number of cycle X2 and cutting velocity X4 have insignificant effect on the micro-hardness because the p-value was p> 0. 1. Improving the quality about 5%.

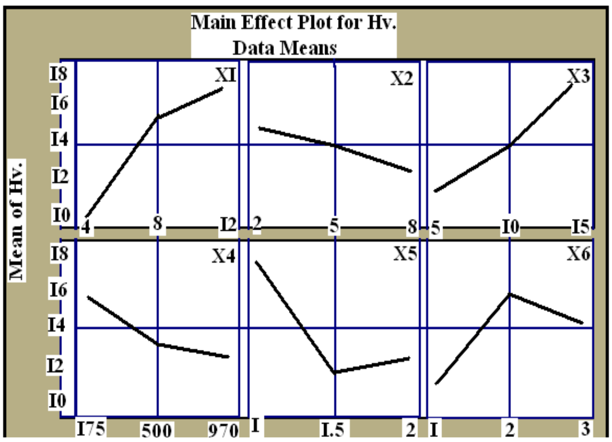

Fig. 4. Main effects of process parameters on the micro-hardness ΔHv for steel.

4. Conclusions

This study shows the influence of design and technological parameters, amplitude of pole geometry, number of cycles of pole geometry, finishing time, cutting velocity, Current and working gap on the MAF output process. Generate regression models for surface roughness, micro-hardness and material removal, and by using regression analysis of variance (ANOVA), the influence on the MAF process as follow:

The parameter X1, (the amplitude of pole geometry) has significant effect on the surface roughness Ra, which improved the surface roughness about 30%. , This parameter X1 has significant effect on the micro-hardness about 42%. While this parameter X1 has insignificant effect on the MRR.

The effect of another parameter (X2, X3, X4, X5, and X6) on the properties of the surface layer (roughness, micro-hardness, and removal rate). Were puts in Table 6.

Table 6,
Conclusions.

Parameters	**Influence on ΔRa**	**Improving ΔRa%**	**Influence on ΔHv**	**Improving ΔHv%**	**Influence on MR**
X1	Significant	30	Significant	42	insignificant
X2	Mild significant	11	insignificant	6	insignificant
X3	Insignificant	0.0	Mild significant	20	insignificant
X4	Significant	32	In significant	5	insignificant
X5	Insignificant	3	Mild significant	18	insignificant
X6	Significant	24	Insignificant	9	insignificant
Total		100%	Total	100%	

5. References

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تأثير العوامل التصميمية والتكنولوجيا على عملية التشطيب بالنحت المغناطيسي

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الخلاصة

تم تنفيذ تجارب عملية لعملية التشطيب بالنحت المغناطيسي (MAF) على وفق المتغيرات التصميمية (السعة، عدد الدورات التي شكلت شكل القطب المغناطيسي) وكذلك المتغيرات التكنولوجية (التياروسرعة القطع والفجوه و زمن التشغيل النهائي) كل هذه العوامل لها تأثير على الخواص الميكانيكيه للطبقة السطحية المشغولة في عملية (MAF). وعمد هذا البحث الى دراسة تأثير المتغيرات التصميمية والتكنولوجية على خشونة السطح (Ra)، والصلاده الدقيقة (Hv) وأزالة المعدن (MR) في منطقة العمل. وقد تم الفحص والتخطيط للتجارب بأستخدام الطرائق الاحصائية مثل منهجية استجابة السطح (RSM) وطبقاً لمصفوفة تاكوجي (3^6) صممت التجارب بثلاثة مستويات وستة عوامل اومعاملات. تحليل التباين ومنحنيات التعليم تشيرالى وجود اشارات X1,X4,X6 يكون لها تأثيركبير على الخشونة السطحية (ΔRa) لمعدن المشغولة. X2 يكون تأثيرها متوسطا، بينما يكون تاثيرX3,X5 ضئيلا . وأظهرت النتائج النهائية ان خشونة السطح للمشغولة قلت من 0.3 الى 0.15 مايكرومتر وهذا يعني ان التحسن أصبح 100% .