Al-Khwarizmi Engineering Journal,Vol. 13, No. 1, P.P. 11- 19 (2017)

Al-Khwarizmi Engineering Journal

Optimization the Parameters of Magnetic Abrasive Process Using Taguchi Method to Improve the Surface Roughness

Shakir M. Mousa
Technical Institute of Al-Mussaib / Al-Furat Al-Awsat Technical University
Email: shakir.aljabiri_89@yahoo.com

(Received 10 August 2016; accepted 15 December 2016)
https://doi.org/10.22153/kej.2017.12.001

Abstract

Magnetic abrasive finishing (MAF) process is one of non-traditional or advanced finishing methods which is suitable for different materials and produces high quality level of surface finish where it uses magnetic force as a machining pressure. A set of experimental tests was planned according to Taguchi orthogonal array (OA) L27 (3^6) with three levels and six input parameters. Experimental estimation and optimization of input parameters for MAF process for stainless steel type 316 plate work piece, six input parameters including amplitude of tooth pole, and number of cycle between teeth, current, cutting speed, working gap, and finishing time, were performed by design of experiment (DOE) and response surface methodology (RSM).These six input parameters in this research were optimized for all input parameters to improve the surface layer for work piece by using signal-to-noise ratio technique. The obtained results showed that all six input parameters have an influence on the change in surface roughness(ΔRa). In addition, the results showed that the surface roughness of the work piece decreased from 1.130 to 0.370µm that means high level of improvement in the change of surface roughness (0.760)µm.

Keywords: MAF process, MINITAB software, parameters, Signal-to-Noise ratio, surface roughness, Taguchi orthogonal array.

1. Introduction

In MAF process, the working gap between the magnet pole (end face) and the work piece is filled of with magnetic abrasive particles MAPs, can be used such as bonded or unbounded powder. In the present work, bonded are prepared from ferromagnetic particles and abrasive particles. Magnetic abrasive finishing MAF techniques used for hard material [1] that because the ability of MAF to remove microchips, help to produce micro-relief layer gives higher surface properties. MAF process was universal, simplicity; improved the quality of surface roughness (Ra) more than 50 %.MAF effective process,gives good economic environment. Ferromagnetic particles' acting such as a multipoint cutting tool, and develops finishing force and pressure, leading to the influence of the magnetic field density in the working gap. 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, [2-4]. MAF is a modern relatively process of polishing begin in US in1930s, magnetic abrasive finishing MAF are famous in Russia. This process was developed and growth between 1980-2000. Many advantages of (MAF) process, it is more successful to produce different complex shapes and suitable for finishing flat surface as well as inner and outer cylindrical surfaces. Geeng-Wei Changet et al.[5] have clarified the principle working of MAF process and the finishing characteristics by using abrasive powder consist of a mechanical mixture of ferromagnetic particles and silicon carbide (SiC) abrasive with lubricant as unbounded magnetic abrasive powder. T Moriet et al.[6] have studied the characteristics of magnetic field, and explained the mechanism of MAF process for stainless steel ferromagnetic material work piece, using abrasive powder that was sintered from an total of alumina particles and iron .Taguchi design of experiments (DOE) is utilized on(MAF) process. Dhirendra et al.[7] To find out significant parameters affecting on the surface finish quality created using a mechanically abrasive powder mixture of ferromagnetic iron particles and silicon carbide (sic) abrasives. Experimental results have specified that out put parameters for a change in surface roughness (ΔRa), working gap and voltage found to be the most important significant input parameters after that cutting speed and then grain mesh number. Numerical simulation and modeling of surface roughness (Ra)in the magnetic abrasive finishing MAF process . Raghuram, et al. [8] Have suggest mathematical model for the output response surface roughness (Ra) in polishing stainless steel work piece surface. The mathematical model found to agree fairly well with the experimental set up results. Jae- Seob et al. [9] Experimental estimation and optimization of the input parameters of MAF process utilized the non- ferromagnetic material magnesium alloy AZ31B work piece were accomplished by a design of experiments (DOE) and the response surface methodology (RSM).The result show that pressure and magnetic force density of magnetic table and cutting speed of electromagnetic inductor was important significant parameters on amelioration of surface roughness (Ra) in the second-generation of MAF process. Depending on the results, the prediction models were improved by utilizing signal-to-noise ratio and response surface model and more than suitable for surface roughness after that.

This work aims to study the optimization and influence of parameters on the quality of surface of MAF for stainless steel 316 work piece, by using experimental method then finding the prediction models by using signal-to-noise ratio with the MINITAB 17 software.

2. Design of Experiments

2.1. Selection of MAF Parameters and Their Levels

In the current paper six parameters, (amplitude of tooth pole, and number of cycle between teeth, which are formed the shape of electromagnetic pole, current, cutting speed, working gap, and finishing time) with three levels for each parameter are used to study the influence of MAF method on the quality of the surface layer. The selection parameters and their levels are listed in Table (1).

Table 1 ,
Input parameters for MAF process

Input	Symbol	Levels Level 1	Level 2	Level 3
Amplitude of pole geometry (mm)	(A)	4	8	12
Number of cycles of pole geometry	(B)	4	6	8
Finishing time (min)	(C)	5	10	15
Cutting speed (rpm)	(D)	175	350	525
Current (Amp)	(E)	1	1.5	2
Working gap (mm)	(F)	1	2	3

2.2. Selection Orthogonal Array (OA) for Experiment

The designs of experiment in this work based on the orthogonal array technique were reduce the number of experiments. To investigate the performance of most effective experiments, there are six input parameters with three levels have been choose, the values of parameters and their three levels according to orthogonal array (OA) L27 (3^6) (27 experiments) were illustrate in Table (2), Which leads to reduce the high-required number of experiments to 27 effective experiments [10].

Table 2 ,
Orthogonal Array(OA)L27

№	A	B	C	D	E	F	№	A	B	C	D	E	F
1	1	1	1	1	1	1	15	2	2	3	1	3	1
2	1	1	1	1	2	2	16	2	3	1	2	1	2
3	1	1	1	1	3	3	17	2	3	1	2	2	3
4	1	2	2	2	1	1	18	2	3	1	2	3	1
5	1	2	2	2	2	2	19	3	1	3	2	1	3
6	1	2	2	2	3	3	20	3	1	3	2	2	1
7	1	3	3	3	1	1	21	3	1	3	2	3	2
8	1	3	3	3	2	2	22	3	2	1	3	1	3
9	1	3	3	3	3	3	23	3	2	1	3	2	1
10	2	1	2	3	1	2	24	3	2	1	3	3	2
11	2	1	2	3	2	3	25	3	3	2	1	1	3
12	2	1	2	3	3	1	26	3	3	2	1	2	1
13	2	2	3	1	1	2	27	3	3	2	1	3	2
14	2	2	3	1	2	3							

3. Experimental Procedure of Finishing Process

At first step in this present work the induct (electromagnetic) has designed and manufactured in the workshop , MAF machine using for finishing flat surfaces by modulating milling machine its view as shown in Fig (1), the gap was filled with powder (The abrasive powder was (67%) iron oxide with (33%) industrial diamond powder) , bounded together by wetting the powder using SAE 20W lubricant, Addition of lubricant increases the adhesive force between the iron particles and the diamond abrasives as well as between iron particles themselves shown in Fig 2, 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 characteristics of the electromagnetic inductor are, the raw material of the iron core is made of the low carbon steel (C 15), the cross-section dimensions of the iron core is A= 18 mm, the length (height) of the iron core is L = 250 mm, the magnetic coil wire is made of the copper and f the diameter is Ø=1 mm and the number of turns is ` N = 2500, the electromagnetic inductor as shown in Fig (3). The material of work piece plate is a grade stainless steel type 316, which it is chemical composition and some mechanical properties are listed in Tables (3),(4) respectively, with required size (100×35×2) mm. The conventional vertical milling machine is used to fixed the work piece on the bed table of the MAF machine and the inductor fixed by the spindle of the MAF machine, the working gap filled with dose of powder (6 cm^3).

1-inductor 2-power supply 3-rings 4-work piece 5-table

Fig. 1. Photograp of magnetic abrasive machine supply.

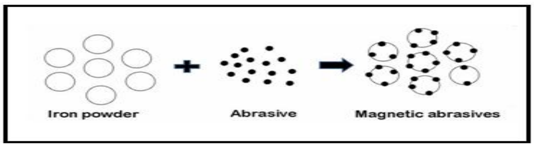


Fig. 2. Schematic of mechanical alloying.

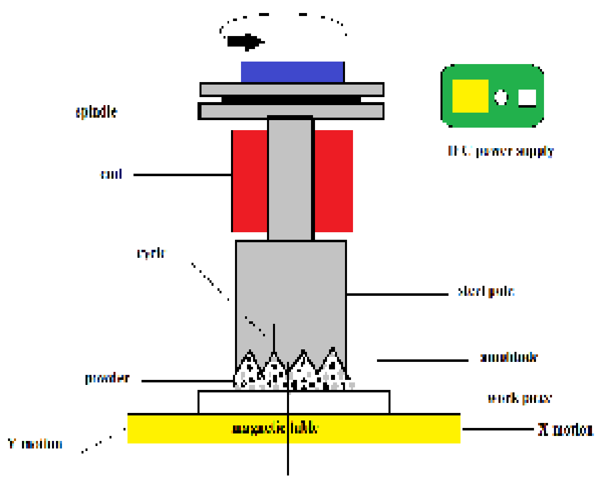


Fig. 3. Electromagnetic inductor.

Table 3,
Chemical composition of stainless steel type 316 plate [11]

		Composition ranges W%											
SER. NO.	**TYPE**	**C**	**Si**	**Mn**	**Cr**	**Ni**	**Mo**	**Zn**	**Ti**	**S**	**Fe**	**Sn**	**Mg**
1	**ST 316**	0.08	0.75	2.00	18.0	14.0	3.00	-	--	0.03	-	--	--

Table 4,
Some mechanical properties of stainless steel type 316 plate [11]

		Mechanical Properties			
	Plate Sheet Strip	**Tensile strength Mpa**	**Hardness Rockwall B**	**Elongation %**	**Yield Strength Mpa**
St 316		515	95 max	40	205

Three observed value of surface roughness (Ra) was measured, before and after finishing then finding the mean value. The change in (ΔRa), is the difference between the arithmetic mean surface roughness Ra of the work piece before and after MAF experiments. The output data measured is the surface roughness Ra Surface roughness by tester (SRT-6200) used to measure the values of Ra at three different places at same line in the work piece. The last step adjusts the value of the six input parameters (amplitude of tooth pole, and number of cycle between teeth, current, cutting speed, working gap, and finishing time) according to Taguchi orthogonal array (OA).

4. Results and Discussions

4.1. Signal-to-Noise Ratio

The criterion outputs, response ΔRa, was dependent variable in regression mathematical models, while the predictor's parameters were the number of cycles of pole geometry, cutting speed of magnetic pole , amplitude of pole geometry, finishing time, working gap and current. Table (5) shows the result of output response, experiment and regression for stainless steel 316 ferromagnetic material. The result evaluate with help the ANOVA and S/N ratio, this result mention the amelioration of the surface roughness (Ra) after MAF process. In this study, Taguchi technique was use, and the (S/N) ratio was select according to the criterion (large is better) to maximize the response. The S/N ratio calculated by using the statistical software MINITAB-17 as follows in equation (1)

$$S/N = -10\log\left(\frac{1}{n}\sum\frac{1}{y_i^2}\right) \qquad \ldots(1)$$

Where n represent the number of measurement (input) and y_i is the measured values (output).

By using the same software program to analyses the effective experimental and finding the mathematical models (regression),as follows in equation (2)

$$\Delta Ra = -1.667 - 0.0184\,A + 0.206\,B + 0.0298\,C + 0.00120\,D + 2.774\,E - 0.845\,F + 0.00008\,A*A - 0.00713\,B*B - 0.00036\,C*C - 0.000001\,D*D - 0.256\,E*E - 0.0095\,F*F - 0.0275\,A*E + 0.0181\,A*F - 0.1105\,B*E + 0.0367\,B*F - 0.0333\,C*E + 0.0147\,C*F - 0.001876\,D*E + 0.000794\,D*F \qquad \ldots(2)$$

R-sq= 93.74%

Where R-sq=Coefficient of Determination

Table 5,
Input parameters distribution according to Taguchi orthogonal array(OA) with result of experiments and regression for ferromagnetic material stainless steel 316

№	A	B	C	D	E	F	Ra ,µm before MAF	Ra,µm after MAF	ΔRa,µm Experiment	ΔRa Regression	Error
1	4	4	5	175	1	1	0.968	0.588	0.380	0.352476	0.0275238
2	4	4	5	175	1.5	2	0.989	0.623	0.366	0.454619	-0.0886190
3	4	4	5	175	2	3	1.019	0.548	0.471	0.409905	0.0610952
4	4	6	10	350	1	1	0.915	0.440	0.475	0.468952	0.0060476
5	4	6	10	350	1.5	2	1.173	0.619	0.554	0.498952	0.0550476
6	4	6	10	350	2	3	0.738	0.417	0.321	0.382095	-0.0610952
7	4	8	15	525	1	1	1.000	0.560	0.440	0.473571	-0.0335714
8	4	8	15	525	1.5	2	0.898	0.433	0.465	0.431429	0.0335714
9	4	8	15	525	2	2	1.036	0.904	0.132	0.132000	-0.0000000
10	8	4	10	525	1	2	0.970	0783	0.187	0.149611	0.0373889
11	8	4	10	525	1.5	3	0.834	0.638	0.196	0.189778	0.0062222
12	8	4	10	525	2	1	0.911	0.759	0.152	0.195611	-0.0436111
13	8	6	15	175	1	2	0.793	0.587	0.206	0.258111	-0.0521111
14	8	6	15	175	1.5	3	0.773	0.475	0.298	0.301778	-0.0037778
15	8	6	15	175	2	1	1.130	0.370	0.760	0.704111	0.0558889
16	8	8	5	350	1	2	0.900	0.571	0.329	0.314278	0.0147222
17	8	8	5	350	1.5	3	0.845	0532	0.313	0.315444	-0.0024444
18	8	8	5	350	2	1	0.702	0.236	0.466	0.478278	-0.0122778
19	12	4	15	350	1	3	0.788	0672	0.116	0.103722	0.0122778
20	12	4	15	350	1.5	1	0.673	0.421	0.252	0.249556	0.0024444
21	12	4	15	350	2	2	0.882	0.683	0.199	0.213722	-0.0147222
22	12	6	5	525	1	3	0.752	0.562	0.190	0.245889	-0.0558889
23	12	6	5	525	1.5	1	0.739	0.583	0.156	0.152222	0.0037778
24	12	6	5	525	2	2	0.722	0.599	0.126	0.073889	0.0521111
25	12	8	10	175	1	3	0.903	0.675	0.228	0.184389	0.0436111
26	12	8	10	175	1.5	1	0.804	0323	0.481	0.487222	-0.0062222
27	12	8	10	175	2	2	0.955	0.580	0.375	0.412389	-0.0373889

4.1.1. Analysis of Surface Roughness

Magnetic abrasive finishing method improved the quality of the surface; the result has been analyzed by using the Signal-to-Noise ratio method to obtain the optimal level for each process parameter that corresponded to the largest (S/N) ratio are given in Table (6-a) the means value were shown in Table (6-b) While Table (7) shows the result for S/N of each parameters at three levels to improving surface roughness, using ANOVA software. The selection optimum conditions from Table (8) were (A1, B3, C2, D1, E2, and F1). Amplitude of pole 4mm, number of cycle 8, cutting time 10 min, the cutting speed 175 rpm, the current 1.5 mm and the working gap 1mm. These optimal conditions produce the optimum surface roughness. The predicted value of (S/N) ratio from Table (8), which computed by equation:

$$\Delta Ra_{pred.} = \bar{\eta}_{sn} + (Ai - \bar{\eta}_{sn}) + (Bj - \bar{\eta}_{sn}) + (Ck - \bar{\eta}_{sn}) + (Di - \bar{\eta}_{sn}) + (Ej - \bar{\eta}_{sn}) + (Fk - \bar{\eta}_{sn}) \quad \ldots(2)$$
$$= -5\bar{\eta}_{sn} + (Ai + Bj + Ck + Di + Ej + Fk)$$

Where $\bar{\eta}_{sn}$ represent the signal-to noise of surface roughness response, Ai, Bj, Ck and Di are the signal/noise of each input parameter according to difference of optimum level for MAF parameters (A, B, C, D, E, and F).

This value is compare to determine the highest S/N ratio that always yields the optimum quality with minimum variance around the target value.

Table 6,
(a) Response Table for signal to noise ratios larger is better

level	A	B	C	D	E	F
1	-8.501	-12.607	-10.956	-8.608	-11.769	-9.094
2	-10.898	-10.738	-10.474	-10.283	-9.971	-10.999
3	-13.442	-9.496	-11.411	-13.890	-11.101	-12.748
4	4.941	3.111	0.937	5.221	1.798	3.654
Delta Rank	2	4	6	1	5	3

Table 6,
(b) Response table for means

level	A	B	C	D	E	F
1	0.4004	0.2577	0.3108	0.3961	0.2834	0.3958
2	0.3230	0.3429	0.3299	0.3361	0.3423	0.3119
3	0.2359	0.3588	0.3187	0.2271	0.3336	0.2517
4	0.1646	0.1011	0.0191	0.1690	0.0569	0.1441
Delta	2	4	6	1	5	3
Rank						

Table 7,
Experimental result and S/N ratio

No.	Enhanced Ra (µm) (mean)	S/N ratio	No.	Enhanced Ra (µm) (mean)	S/N ratio
1	0.380	-10.6923	15	0.760	-3.4526
2	0.366	-11.1191	16	0.329	-12.3597
3	0.471	-8.3360	17	0.313	-12.9563
4	0.475	-8.2458	18	0.466	-8.4502
5	0.554	-6.6323	19	0.116	-31.0568
6	0.321	-12.6529	20	0.252	-15.7031
7	0.440	-9.0691	21	0.199	-19.0935
8	0.465	-8.4732	22	0.190	-19.8280
9	0.132	-27.1309	23	0.156	-23.3498
10	0.187	-20.0873	24	0.126	-28.4043
11	0.196	-19.3315	25	0.228	-17.0774
12	0.152	-23.8764	26	0.481	-8.1121
13	0.206	-18.5624	27	0.375	-10.8424
14	0.298	-13.5556			

Table 8,
The predicted result mean and S/N of the optimum condition for ∆Ra

Mean and S/N for ∆Ra					
A	**B**	**C**	**D**	**E**	F
1	3	2	1	2	1
Mean = 0.624444			**S/N ratio= -1.46925**		

From Table 6,(a),(b) the influence of factors are determined by calculating the (Delta), the difference between the highest and lowest value of level. It should be noted that the optimum condition (A1, B3, C2, D1, E2 and F1) is not be found among the 27 tests of experiment carried out, since the orthogonal array represents only 27 from all possibilities 3^6 = 729 tests). So that ∆Ra is determined the optimum condition. In the case of improving the surface roughness, the most significant factor that has certain effect on ∆Ra for MAF process (D, A, F, B, E and C).

The predicted values for ∆Ra (mean and S/N ratio at the optimum condition (A1, B3, C2, D1, E2 and F1) the actual value of ∆Ra (mean and S/N) of MAF process improving by using optimum condition determine by analyzing the first response as shown in Table (8)

4.1.2 In order to find the effect of process parameters on the responses, the results presented in Table (9).

Table 9,
Analysis of variance for S/N ratios

Source	DF	Seq SS	Adj ss	Adj MS	F	P
A	1	0.12185	0.005697	0.005697	0.67	0.451
B	1	0.046006	0.024491	0.024491	2.87	0.151
C	1	0.001090	0.001715	0.001715	0.20	0.673
D	1	0.127883	0.000978	0.000978	0.11	0.749
E	1	0.001499	0.033248	0.033248	3.90	0.105
F	1	0.094866	0.066421	0.066421	7.79	0.038

According to analysis of variance in Table (9), the cutting velocity and number of cycle of pole geometry have a significant effect on the enhancements of surface roughness. It is clear from the ANOVA that the finishing time and the current in this condition have the least effect on the surface roughness.

4.1.3.Effect of MAF Process on the Surface Roughness

The S-to-N ratio response graph for Ra shown in Fig (4). It is clear that decrease the amplitude (A), cutting speed (D), and working gap (F) cause to improve the surface roughness. It is observed that the increase number of cycle (B) cause to improve the surface roughness. It has revealed that as finishing time(C) and the current (E) increases the surface roughness increase; further increasing the working gap (F) and current decreases the surface roughness. Mainly, improving the surface roughness (ΔRa) depends on the amplitude and cutting speed, the optimum Ra was obtained at the optimum condition.

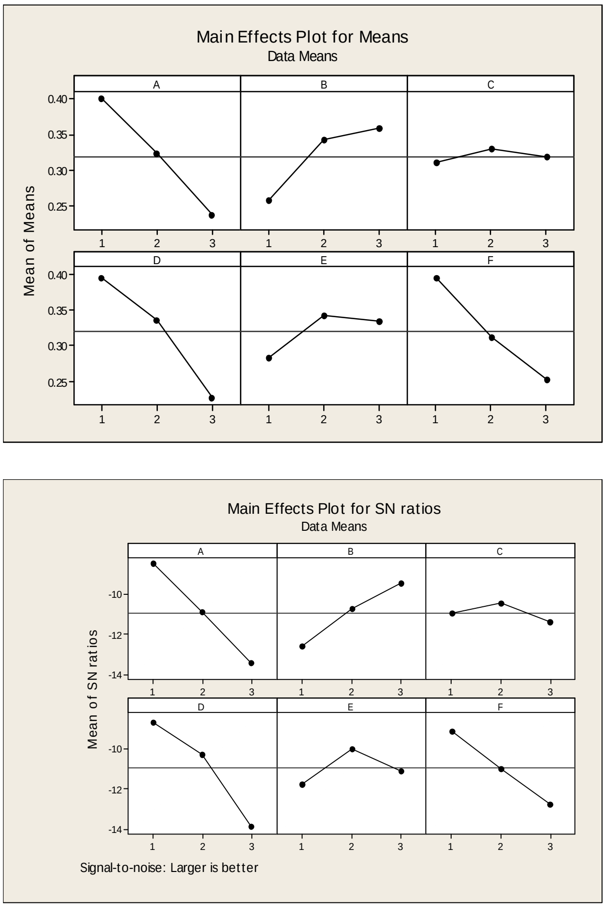
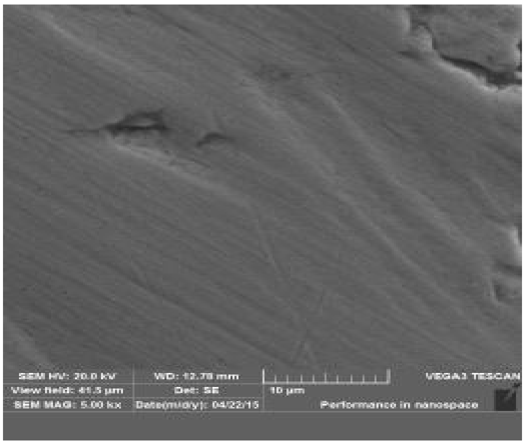
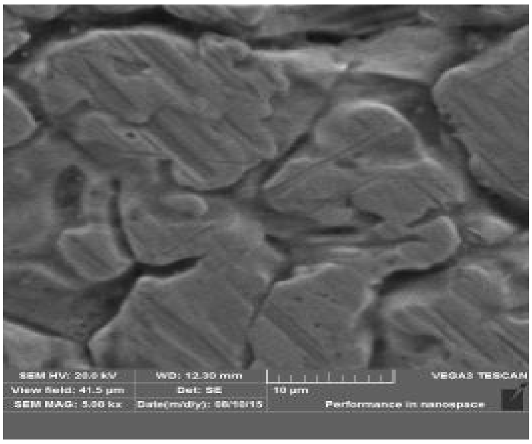


Fig. 4. Signal-to-Noise ratio response graph for surface roughness

The validity of this method for finishing the ferromagnetic stainless steel 316 plate have been also proved by obtaining scanning microscopic views of work pieces before and after MAF Fig (5). These views show the texture generated by contacting the magnetic abrasive powder in specified operating conditions with the work piece surface and the apparently smoothness occurs due to the application of the magnetic abrasive to the application of the magnetic abrasive finishing process. The highly scratched surface before MAF was smoothed and the direction of the obtained texture after MAF was changed according to the direction and the rotation of electromagnetic pole.



Before



After

Fig. 5. SEM photos of stainless steel 316 before MAF process
SEM photos of stainless steel 316 after MAF process

5. Conclusions

The present optimization concluded that the change in the Ra prediction and analysis during MAF process, the following inferences have been derive based on the results and discussion:

1. The optimum parameters are found at the (amplitude of pole 4mm, number of cycle 8, finishing time 10 min, the cutting speed 175rpm, the current 1.5Amp and the working

gap 1mm) that gives the highest value of the change in Ra.

2. The most significant factor effected on the change of Ra is (cutting speed (D), amplitude of pole (A), working gap (F), number of cycle (B), Current (E) and Finishing time (C).
3. The change in Ra has tendency to reduce with the increase the amplitude of pole, cutting speed and working gap.
4. The change in Ra give better improvement in test No 15=0.76 µm
5. The developed mathematical statistical model (regression) for change in Ra can be a desired result employed for the optimal chosen of the MAF process parameters to attain best change in Ra stainless steel 316 work piece, because the error is very small between the experiment and regression results.
6. The scanning microscopic shows the reduction in scratches and craters on the surface layer of stainless steel 316 workpiece and the surface was more smoothly after MAF process.

6. References

[1] H. Kumar,S. Singh, and P. Kumar, “Magnetic Abrasive Finishing- A review”, International Journal of Engineering Research & Technology (IJERT), vol, Issue 3, March 2013.

[2] VK ,Jain “ Advanced Machining Processes”. Allied publishers, Delhi, 2002.

[3] Yamaguchi H, and sato T, “ Polishing and Magnetic Field- Assisted Finishing”, Intelligent Energy Field Manufacturing Interdisciplinary Process Innovations, 2012.

[4] Yu. M. Baron, “ Technology of Abrasive Machining in a Magnetic Field”, Mashinostroenie, Leningrad 1975.

[5] Geeng-Wei Chang, Biing-Hwa, and Yan, Rong-Tzong Hsu, “Study on cylindrical magnetic abrasive finishing using unbounded magnetic abrasives”, International Journal of Machine Tools & Manufacture, Vol.42 (2002), pp. 575–583.

[6] T. Mori, K. Hirota, and Y. Kawashima, “Clarification of magnetic abrasive finishing mechanism”, Journal of Materials Processing Technology, Vols.143-144 (2003), pp. 682–686.

[7] Dhirendra K. Singh, V.K. Jain, and V. Raghuram, “Parametric study of magnetic abrasive finishing process”, Journal of Materials Processing Technology, Vol.149 (2004), pp. 22–29.

[8] M. G. V. S. Raghuram, Suhas S. Joshi, “Modeling of Polishing Mechanism in Magnetic Abrasive Polishing”, The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG), 1-6 October, 2008, Goa, India.

[9] Jae-Seob Kwak, Chang-Min Shin, “Parameter Optimization and Development of Prediction Model for Second Generation Magnetic Abrasive Polishing of AZ31B Plate”, Proceedings of the International Multi Conference of Engineers and Computer Scientists (IMECS), Vol.2(2011), Hong Kong.

[10] Y. M. Baron, S. L. Ko, and J. I. Park, “Characterization of the magnetic abrasive finishing method and its application to deburring”, Key Engineering Materials Vols.291-292 (2005), pp. 291-296.

[11] Joseph R. Davis ASM International, Jan 1, 1994 – "stainless steels"Technology & Engineering - 584 pages

المدخلات الامثل لعملية الحك الممغنط باستخدام طريقة تاكوشي لتحسين جودة خشونة السطح

شاكر محمود موسى
المعهد التقني المسيب/ جامعة الفرات الأوسط التقنية

الخلاصة

تعتبر عملية الحك الممغنط واحده من الطرائق غير التقليدية أو المتقدمة في الإنهاء السطحي وهذه الطريقة مناسبة للمواد المختلفة وتنيج مستوى عالٍ من الإنهاء السطحي وتستخدم القوة المغناطيسية لتسليط الضغط أثناء عملية القطع. مجموعة التجارب خطط لها على وفق مصفوفة تاكوشي وكانت بثلاثة مستويات وستة مدخلات، التقدير التجريبي وتعظيم الإفادة من المدخلات (ارتفاع الأسنان، وعدد خطوات الأسنان، والتي تتشكل شكل القطب الكهرومغناطيسي والتيار وسرعة القطع وفجوة العمل و وقت التشغيل) تم تنفيذا البحث باستخدام تصميم التجارب ومنهجية استجابة السطح، يمكن الاستفادة من هذا البحث هو لتحديد القيم المثلى لجميع المدخلات الستة التي تعطي أفضل سطح لتحسين الطبقة السطحية لمشغولة الفولاذ المقاوم للصدأ نوع ٣١٦ بأستخدام تقنية نسبة الإشارة إلى الضوضاء . وتشير النتائج بأن جميع المدخلات لها تأثير في تغير الخشونة السطحية. فضلا عن ذلك ان المحصلة النهائية أوضحت الى أن التغير في الخشونة السطحية انخفضت من (١,١٣٠- ٠.٣٧٠) مايكروميتر مما يدل على تحسن عالٍ في التغير في الخشونة السطحية مقداره (.٧٦٠و٠) مايكروميتر .