Improvement the Hardness of Stainless Steel 321 by Magnetic Abrasive Finishing Process

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Abstract

Magnetic Abrasive Finishing (MAF) process which is a non-traditional polishing technique, is suitable for variety of engineering materials, producing high quality surfaces of parts. An experimental setup study is made to carry out MAF process to improve surface layer quality and hardness of stainless steel grade 321 plate. This study uses two different magnetic pole shapes such as conical magnetic pole without grooves and conical magnetic pole with six grooves. The finally results show that the conical magnetic pole with six grooves can create best surface layer quality and improve hardness in (MAF) process. The process parameters are the applied number of pitches between grooves, finishing time, cutting speed of magnetic pole, voltage, and volume of powder (dose). The magnetic abrasive powder consisted of silicon carbide SiC, particle size 300μm, SiC (65%), it is mixed with the ferromagnetic iron particles (iron powders), particle size 300μm, Fe (35%). Taguchi matrix L18 for five input parameters with mixed level design (2-3) levels was used for designing the experiments and optimal values evaluation for all parameters to improve the hardness. By using MINITAB software data was analyzed, the results indicate that empirical equation (mathematical predicted models) represents the relation of the input parameters with the change in micro Vickers Hardness. The most significant parameters on change in hardness are volume of powder (42.34%) and number of pitches between grooves (25.30%).

Keywords: magnetic abrasive finishing MAF parameters, micro Vickers hardness, MINITAB software, Taguchi matrix, Conical magnetic pole, Stainless steel.

1. Introduction

Conventional finishing processes like grinding and lapping stratify uncontrolled high force and pressure on the workpiece, which may lead to micro cracks and substantial normal stresses. To overcome these drawbacks of conventional finishing processes magnetic field supported finishing process has been developed. Magnetic field supported abrasive finishing uses the magnetic abrasive particles under a magnetic field to finish the layer surface of the work piece with controlled pressure and forces [1].Due to the fact the magnetic flux controlling its cutting force and pressure is merging with flexibility of magnetic brush form which decreases the possibility of generated micro cracks on the surface of the workpiece. In (MAF) the gap between the workpiece and the magnetic pole is full of with abrasive powder that is formed by the magnetic flux. This configuration of the brush and attitude such as multipoint cutting tool [2]. The damage often happen by extravagant penetration of hard abrasive grains into the surface of the workpiece. Therefore, in MAF it is possible to obtain very smooth surface finish and high accuracy with barely any surface damage. The requisite force is produced by controllable magnetic field energy. By using alumina or silicon carbide abrasive grains mixed into ferromagnetic particles (iron) the micro-cutting action in MAF process.[3]The principle of work and basic theory of the MAF process was researched by Shinmura et al [4], was notify that surface roughness value (Ra) and material removal increase as the grains size of particle (mesh) diameter increases. Shinmura et al. [5] have clarified the working principle of MAF process and accomplished that the surface finish (*R* max) decreases with decreases in working gap and increase in flux density. (*R* max) has been done on flat stainless steel grade (SUS 304) of 1.2mm thickness with the value as low as 0.25μm, Singh et al. [6] Investigated the most important effective parameters on surface quality such as applied voltage on electric magnet, working gap, mesh size abrasive powders and rotational speed on stainless steel plates using Taguchi design of experiments. They found that applied pressure on electric magnet and working gap as the more effective variable parameters on surface quality Safavi et al [7]. Finished a plate of aluminum using the MAF process.They investigated the most effective parameters with variation of surface roughness on the basis of design of experiments, analysis of variance and regression [8] Vahdati and Sadeghinia finished aluminum flat plates using the finishing abrasive process. They investigated effective parameters such as the percentage of combined abrasive particles, lubricant value, and relative hardness between the work piece and abrasive particles using design of experiments. They also assume a regression model that created a relationship between parameters and surface roughness and hence extracted optimum condition to reach the best surface roughness Ko et al. [9] analyze a more details characteristics of the performance. They achieved experiments to confirm the effect of each condition, rotational frequency of the inductor, volume of powder (dose), feed rate and working gap. Singh et al. [10] applied Taguchi design of experiments to find out important parameters influencing the surface quality generated using MAF process. The parameters used are: (1) voltage (DC) applied to the electromagnet, (2) working gap, (3) rotational speed of the magnet, and (4) abrasive size (mesh number). Raghuram, Suhas S,Joshi. [11] have suggested mathematical model for the surface roughness in finishing stainless steel workpiece. The model was suitable with the experimental results. Ali H. Kadhum et al. [12] depict how Taguchi design of experiments(DOE) is utilized to find response parameters effecting the surface finish quality created in MAF process. There are variable parameters, like the working gap, coil current , feed rate and volume of powder portion that are which have a large effect on surface quality. Nazar kais M. Naif [13] In this present work aimed MAF process was done on the alloy brass grade (CuZn33) design of experimental (DOE) and work piece material of process was used to estimation parameters effect on the hardness (Hv).The important results are the process is very capable of productions surface layer hardness (Hv) improvement in scope value of (99Hv to 120.6Hv). This work display design and development of (MAF) process setup for flat or plane surfaces, the main objective of this work is change in surface layer finish and improvement in hardness**,** (MAF) process was performed using stainless steel grade 321 plate metal work piece for flat surface ,and then to obtain an empirical equation (mathematical models) representing the relation of the input parameters with the change in Vickers Hardness with the MINITAB software .

2. Experimental Details

2.1. Design and implementation of electromagnetic inductor

First step in the experiment work is design and manufacture MAF equipment for flat surface, which was designed and manufactured in the workshop in laboratory is shown in Figure 1.

1. Electromagnetic inductor,
2. D.C Power supply,
3. Slip rings, 4. Workpiece, and 5. Table.

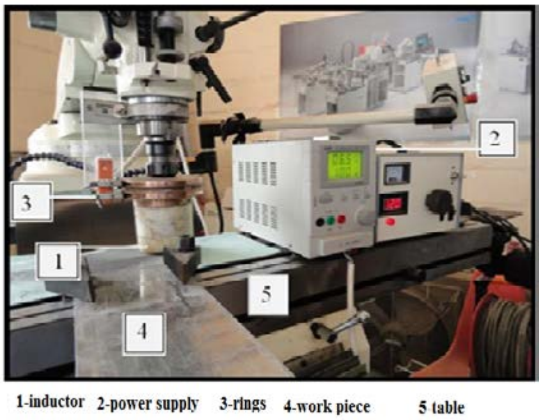
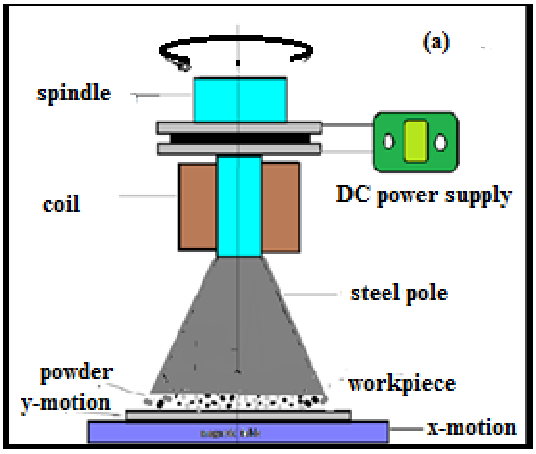


Figure 1: Photograph of Magnetic Abrasive Machine

From Figure (2) shows a schematic diagram of a plane MAF process. The trunk of electromagnetic inductor was stationary on the mandrel by the shank and incorporated into the hole of a milling machine spindle. The coil was located inside the inductor trunk and slip brushes at top plane to bind the coil with a constant current source was applied by D.C. power supply. The working gap between the workpiece surface and magnetic pole is full of by abrasive powder**.** Electromagnetic inductor drawn to show how the mechanism system occurs in the MAF process

According to Faraday's Laws, electromagnetic inductor made of a steel rod covered around a coil of copper wires. when the power supplied to the coil pressure and magnetic force is produced between the work piece and the electromagnetic pole forming a flexible brush. When the brush rotates together with the magnetic pole being compressed toward the flat surface of work piece and then material removal into small pieces with repeated sharp blows (chopping) or chips as shown in Figure(.3).



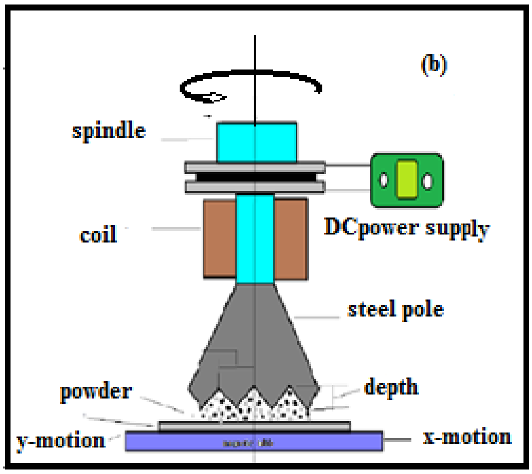


Figure 2 : Electromagnetic Inductor **(a)** Conical magnetic pole without grooves **(b)** Conical magnetic pole with radial grooves

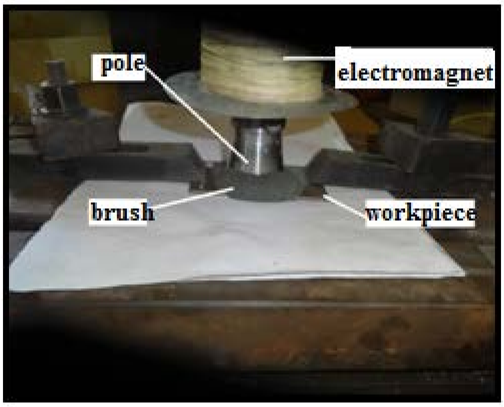


Figure 3 : Magnetic brush formed between the electromagnet pole and work piece

The characteristics of the electromagnetic inductor are the following:

- The material of the iron core is mild carbon steel,
- The cross-section area of the iron core is A= 14 cm^2,
- The length of the iron core is L = 30 cm,
- The diameter of the copper wire of the magnetic coil is Ø=0.9 mm,
- The number of turns is N = 3000.

2.2. Work piece and powder specifics

In this study, MAF process is achieved utilizing the advanced experimental setup on stainless steel 321 plate flat work piece. The chemical composition ranges and some mechanical properties of work piece material is given in Table (1). Several attempts preparing were made to get suitable magnetic abrasive powder, included mixing of iron oxide (Fe_2O_3) (iron powders), particle size 300µm, (35%),with silicon carbide (SiC) particle size 300µm, (65%) .

Table 1: Some Properties of Stainless Steel Type 321 Plate [14]

Composition ranges W% TYPE **ST 321**								
C	Si	Mn	Cr	Ni	Ti	P	Fe	S
0.08	1	2.	17	11	0.15	0.04	68	0.03

Mechanical Properties TYPE **ST 321**				
Plaet Sheet Strip	Tensile strength Mpa	Hardness Vickers	Elongatino %	Yield Strength Mpa
	585	157	55	240

2.3. Manufacturing of Conical Poles

2.3.1 Conical Magnetic Pole

The form of magnetic pole end face is an very important privacy in this work of experimental design. Tow kind different forms made from iron shaft mild steel have been used to manufacturing this magnetic pole to be conical magnetic pole**,** by using different machines for example lathe machine to obtain the desired shape shown in the photograph Fig 4 (a). The circumference of conical magnetic

pole has the maximum flux density where as the center point has the minimum magnetic flux density ,in this case when the magnetic brush formed from the magnetic abrasive powder will be concentrated in the circumference of the magnetic pole. Because of friction between the magnetic brush and the end face of the conical magnetic pole , this result lead to change or distortion the shapes of particles of magnetic powder and wear out magnetic pole, therefore conical magnetic pole becomes smooth end face and loses the task of finishing process. Finally this design of conical magnetic pole is appear mild significantly (lacking) for (MAF) process.

2.3.2. Conical Magnetic Pole with Six Grooves

In order to perfection and raise the efficiency of MAF process and decrease drawback in the conical magnetic pole, it was redesigned the end face to include six grooves according to pitches (6) and depth (9 mm), the new design of magnetic pole shown in the photograph Figure (4), (b) is obtains. The purpose of the redesigned to decrease the circumference area in the conical magnetic pole and increase magnetic flux density and predicts that a conical magnetic pole with six grooves increases magnetic flux density in the working gap and it creates a strong magnetic brush that presses on the work piece to a achieve MAF process. The results reveal the magnetic pole with six grooves which resists wearing and gives significant tool life at last leading to improve micro Vickers Hardness**.**

Figure 4 : (a) Photograph of Conical magnetic pole **(b)** Photograph of Conical magnetic pole with six grooves

2.4.Taguchi Experimental Design and Operating Parameters

Experimental of design (DOE) by using Taguchi matrix is considered as a highly influential design for the limitation of effect parameters of a advanced manufacturing process. In the present study, used an orthogonal array (OA) (L18 experiments) there are five input parameters with mixed level design (2-3) levels ,is considered for determining the influence of operating variables parameter on Vickers Hardness**.** According to orthogonal array(OA) illustrated in Table (2), which causes to decrease the required number of experiments to 18 effective experiments.

Table 2: Orthogonal ArrayL18

№	A	B	C	D	E	№	A	B	C	D	E
1	1	1	1	1	1	10	2	1	1	3	3
2	1	1	2	2	2	11	2	1	2	1	1
3	1	1	3	3	3	12	2	1	3	2	2
4	1	2	1	1	2	13	2	2	1	2	3
5	1	2	2	2	3	14	2	2	2	3	1
6	1	2	3	3	1	15	2	2	3	1	2
7	1	3	1	2	1	16	2	3	1	3	2
8	1	3	2	3	2	17	2	3	2	1	3
9	1	3	3	1	3	18	2	3	3	2	1

In this current research five input operating parameters, pitches between grooves which form the shape of electromagnetic pole, and four operating parameters (finishing time, cutting speed, voltage, volume of powder), with mixed level design (2-3). Two levels for (A) parameter and three levels for each parameters (B, C, D, and E) are used to study the effect of MAF process on micro Vickers Hardness.The selection of operating parameters and their levels is listed in Table (3)

Table 3: Operating parameters for MAF process

Input	Levels			
	Symbol	Level 1	Level 2	Level 3
Number of grooves	(A)	1	6	---
Finishing time (min)	(B)	3	6	9
Cutting speed (rpm)	(C)	150	350	550
Voltage (volt)	(D)	20	35	50
Volume of powder(cm^3)	(E)	3	5	7

2.5 Measuring the Response of MAF

When all the experiments of MAF process is finished, the Hardness for each work piece were calculated (Hv) the hardness was measured in 18 pieces, before and after the MAF process for each work piece the differences in HV values were averaged, three times after and before MAF process at the same location have called (Hv), The change in micro hardness (Hv) calculate by using equation (1) and (larger difference the better) .

ΔHv = Hv after MAF – Hv before MAF ….(1)

The results of the experiments of the MAF process an given ,with a set of input and output parameters andpercentage improvement in micro Vickers hardness for each experiment, Table 7 shows this data. Finally micro hardness tester (MICRONET), was used as shown in Figure (5).

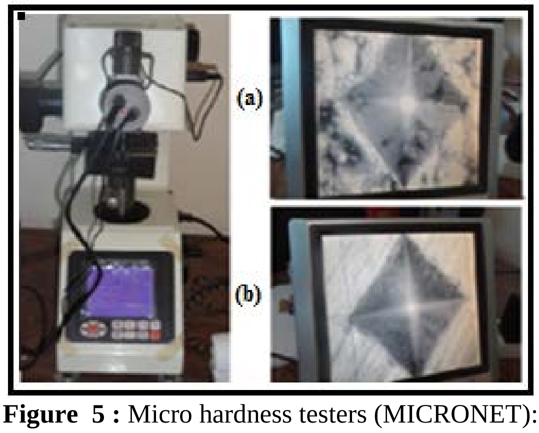


Figure 5 : Micro hardness testers (MICRONET): **(a)**Image for work piece before MAF process **(b)**Image for work piece after MAF process

2.6. Experimental Procedures

The experiments were adopted according to the following procedures

1.In order to get in more accurate experiment results, all work pieces must be cleaned after the end of each

experiment. Machine vice is made such that the parallelism maintained between work piece and end face magnet pole groups with the assist of slip gauges.

2. Working gap is set by using slip gauges, after setting the gap, both the work piece and end face magnet pole are checked accurately with reference such as the table of the machine.

3. The magnetic powders are prepared just before the beginning of each experiment with various, amounts (dose) of volume, working gap is full of with magnetic abrasive powders and the electromagnet is magnetized, because the collecting with magnetic brush shape and flexibility of magnetic powder , magnetic field the mixture of iron oxide powder and abrasive particles is attracted towards magnet and then forms a magnetic brush.

4. Scanning micrographs of surface micro relief for work piece before and after MAF process are utilized to show the image topography of surface.

3. Results and Discussion

The effect of five input parameters, pitches between grooves, which form the shape of electromagnetic pole, and four operating parameters (finishing time, cutting speed, voltage, volume of powder) with mixed level design (2-3).Three levels for each parameter (B, C, D, and E) and two levels for (A) parameter are used to study the influence of MAF process on micro-Vickers Hardness discussed. The results of experiments and regression models are generated for stainless steel 321 and the accepted absolute relative error (residual) results an listed in Table 4

Table 4 Results of experiments and regression models generated for Stainless steel 321 and distribution parameters according to Taguchi matrix L18 (OA)

No	A	B	C	D	E	Response		Absolute Relative Error
						Δ(Hv) Experi--ment	Δ(Hv) Regre-ssion	
1	1	3	150	20	3	19.619	19.813	0.19444
2	1	3	350	35	5	19.044	18.905	0.13888
3	1	3	550	50	7	17.469	17.997	0.52777
4	1	6	150	20	5	19.927	20.205	0.27777
5	1	6	350	35	7	19.352	19.297	0.05555
6	1	6	550	50	3	16.052	16.163	0.11111
7	1	9	150	35	3	18.727	18.422	0.30555
8	1	9	350	50	5	18.152	17.513	0.63888
9	1	9	550	20	7	18.652	18.680	0.02777
10	6	3	150	50	7	21.630	21.380	0.25000
11	6	3	350	20	3	20.405	20.322	0.08333
12	6	3	550	35	5	19.830	19.413	0.41666
13	6	6	150	35	7	21.722	21.722	0.00000
14	6	6	350	50	3	18.422	18.588	0.16666
15	6	6	550	20	5	19.922	19.755	0.16666
16	6	9	150	50	5	19.522	19.938	0.41666
17	6	9	350	20	7	21.022	21.105	0.08333
18	6	9	550	35	3	17.722	17.972	0.25000

3.1. Regression Model for Micro Vickers Hardness (Hv for stainless steel 321) Versus A, B, C, D, and E.

Minitab 16 statistical software program, has been utilized to analyses the effective experimental ending findings by the mathematical statistical models (regression) equation in un-coded units for MAF process between the micro Vickers hardness and all five parameters are represented bellow.

The regression model equation (2) is:

Δ(Hv) = 20.4 + 0.293 A - 0.117 B - 0.00479 C - 0.0461 D + 0.371 E ……... (2)

Analysis of model summary of Variance for regression also shows Table 5.

R-Sq = 95.9% , R-Sq (adj) = 94.2%

Table 5: Analysis of Variance

	Coef	Seq SS total	T	P
Predictor Constant	20.3990	34.5125 **Seq SS** Regression	44.31	0.000
A	0.29333	8.7316	8.88	0.000
B	-0.11667	2.3882	3.46	0.005
C	-0.004791	4.3002	9.48	0.000
D	-0.046111	4.4693	6.84	0.000
E	0.37083	14.6125	7.33	0.000

Equation (2) can be utilized, to predict the output parameter (response) ΔHv in the MAF process. From the ANOVA, the variance ratio (F) value is utilized to measure the significance parameter of the regression, standard value of F at 95% confidence interval of(α = 0.05) [15]., P-value for regression equation has significant effect. The results of analysis an shown in Table 6.The R-sq, R-sq(adj), shows that 95.9% , 94.2% respectively(strong model) of the observed variable in micro Vickers hardness for stainless steel 321 plate is an independent variable. Figure (6) shows plot of normal distribution that is higher than level of confidence *(α* = 0.05*)*, it can be concluded that the assumption normal distribution of errors is satisfied and the obtained plot is like a straight line.

3.2. Influence of Operating Parameters on Percentage ratio Improvement in Micro Vickers Hardness

From Figure.(7) displays the main (master) effects of process operating parameters on percentage ratio of improvement in micro Vickers hardness. The master effects of the number of pitch of pole geometry and volume of powder on the responses are quite significant in terms of finishing time , cutting speed and voltage ,and Table7shows results of percentage of improvement of micro Vickers hardness of stainless steel grade 321 (larger difference the better) at various process parameters.

Contribution of each parameter affecting the change in hardening obtained from the MINITAB-statistical software calculate by using equation (3) and listed in Table 8.

Percent contribution of each parameter = Seq SS $_{Regression}$ / Seq SS $_{total}$ ……..(3)

Where

Seq $_{ss}$= Sum of Squares

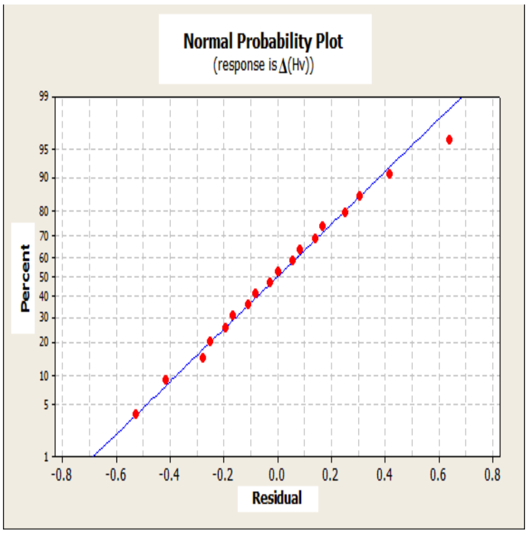


Figure 6 : Plot of normal distribution probability for ΔHv

Table 6: Regression analysis of variance (ANOVA) on to micro Vickers hardness for stainless steel 321plat

Predictor	Coefficient	P	Effect	inductor
A	0.29333	0.000	significant effect	($p<0.05$)
B	- 0.11667	0.005	significant effect	($p<0.05$)
C	- 0.00479	0.000	significant effect	($p<0.05$)
D	- 0.04611	0.000	significant effect	($p<0.05$)
E	0.37083	0.000	significant effect	($p<0.05$)

Table 7: Results of percentage of improvement of micro Vickers hardness of stainless steel 321 at various process parameters

№	A	B	C	D	E	Responses			
						HV Before MAF	HV After MAF	ΔHv Experiment	ΔHv %
1	1	3	150	20	3	165.3	184.9	19.6	11.9
2	1	3	350	35	5	156.5	175.5	19.0	12.2
3	1	3	550	50	7	145.8	163.2	17.4	12.0
4	1	6	150	20	5	154.9	174.8	19.9	12.9
5	1	6	350	35	7	153.0	172.3	19.3	12.7
6	1	6	550	50	3	149.6	165.5	16.0	10.7
7	1	9	150	35	3	161.7	180.4	18.7	11.6
8	1	9	350	50	5	158.4	176.5	18.1	11.5
9	1	9	550	20	7	151.1	169.7	18.6	12.3
10	6	3	150	50	7	156.9	178.5	21.6	13.8
11	6	3	350	20	3	154.6	175.0	20.4	13.2
12	6	3	550	35	5	150.2	170.0	19.8	13.2
13	6	6	150	35	7	149.1	170.8	21.7	14.6
14	6	6	350	50	3	157.6	176.0	18.4	11.7
15	6	6	550	20	5	152.6	172.5	19.9	13.1
16	6	9	150	50	5	158.4	177.7	19.5	12.4
17	6	9	350	20	7	151.3	172.3	21.0	13.9
18	6	9	550	35	3	164.0	181.7	17.7	10.8

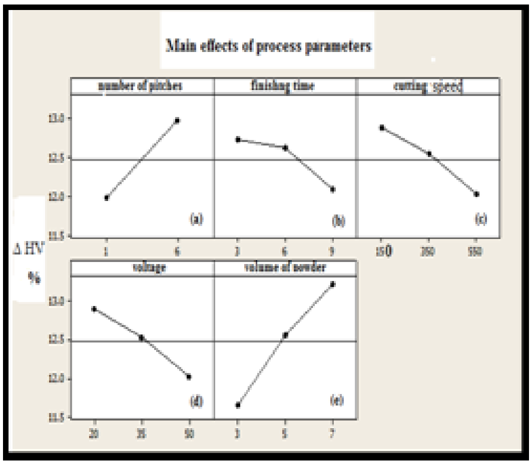


Figure 7 : Main effect of process parameters in % ΔHv

Table 8: Percentage of Contribution of Parameters Influencing Δ*Hv*

Input	Parameters	**ΔHv%**
A	Number of pitches (grooves)	25.30
B	Finishing time (min)	6.92
C	Cutting speed (rpm)	12.46
D	Voltage (volt)	12.95
E	Volume of powder (cm^3)	42.34
Total		100%

3.2.1 Effect of Number of Pitches

From Fig 7 (a) it is observed that the significant in % ΔHv which is obtained with increases in number of pitches grooves. Resulting the highest flux density concentrated in the circumference of conical magnetic pole , leading to the magnetic abrasive powder is concentrated in the circumference of the magnetic pole with six grooves. This results generates a strong magnetic brush that presses on the work piece and friction between the magnetic brush and ends face of the magnetic pole. Hence, magnetic pressure leads to increase in normal magnetic force that resulting in increase in ΔHv% of work piece due to the work surface hardening action, and improved the micro-hardness about by 25.30%.

3.2.2 Effect of Finishing Time

From Fig 7 (b) shows plots of the ΔHv% variation according to the finishing time, when finishing time increases, magnetic abrasive brush is more engaged with the work piece and micron chipping increases hence a higher material removal is achieved. This could be due to the fact that at the beginning of the process the abrasive particle are much sharper than towards the end of process, a high rate of change in surface roughness can be seen. As it is evident, that the increases finishing time, the flux density of the flexible magnetic brush reduce, therefore the finishing time increases the change in hardness ΔHv% decreases, and improved on the micro-hardness about 6.92%.

3.2.3 Effect of cutting speed

From Fig 7 (c) it is observed that the ΔHv% decreases with the increase in cutting speed of the electromagnet pole, because the gap is fixed (3mm) between the work piece and magnetic pole therefore the pressure decreases and normal magnetic force marginally significant reduces with increase in cutting speed of magnetic pole , resulting to reduces in hardness. This reduction in normal magnetic force can be attributed to splashing of the few amount abrasives ,from the machining working gap, at higher revolution per mints, and improved on the micro-hardness about 12.46%.

3.2.4 Effect of Voltage

According to Fig7(d) it is evident that voltage has insignificant effect behavior onΔHv%, when the voltage increases the ΔHv decreases because that formation of flexible magnetic abrasive brush is strong at higher voltage of the electromagnet pole. Therefore creates higher flux density and many number of lines of magnetic force in a working gap .In this case strength energy as well as area of contact of the work piece with magnetic brush increases with increase in voltage leads to indentation on the top surface of work piece, leading to decrease in %ΔHv, and improved on the micro-hardness about 12.95%.

3.2.5 Effect of Volume of powder

From the Fig 7 (e) it is observed that increases significantly in % ΔHv is obtained with increases in volume of powder. It is because flexible magnetic abrasive brush contains more particles that are abrasive and specific permeability of the magnetic brush increases with abrasive mass or volume and thus the pressure is increased. The magnetic force lines generated power to apply pressure from the magnetic abrasives to the work piece. Hence, micro cutting increase and normal magnetic force increase by magnetic pressure that resulting the effect in work surface hardening action and increase % ΔHv of work piece, and improved on the micro-hardness about 42.34%.

3.3 Optical microscopic photos

Figure (8) shows SEM photographs of the workpiece surface layer after and before MAF process. Microscopic views have detected that the highly scratched and craters on surface before MAF was changed according to the direction and the rotation of electromagnetic pole.The abrasives are random (an normal) in form hence the variation in the depth of cut and penetration of abrasives in the surface layer of material during the smoothing process as a result of the pressure and temperature, leading to plastic deformation occurs in the surface layer of material. Therefore indicating the (MAF) process is very suitable and useful to improvement the surface layer and increases in micro hardness of stainless steel material.

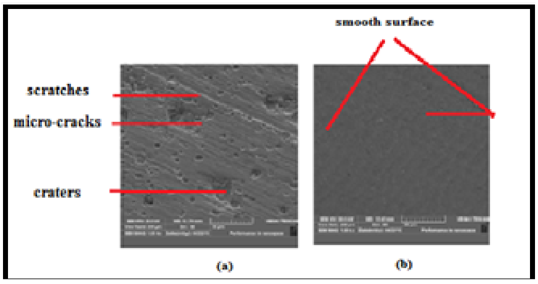


Figure 8 : (a) SEM photos of stainless steel 316 before MAF process, **(b)** SEM photos of stainless steel 316 after MAF process

4. Conclusions

This study stated the advancement of an experimental setup for MAF process in order to improved micro Vickers hardness was performed on stainless steel 321 plate material, by the hardening of surface layer takes place due to formation, by using Taguchi experimental of design (EOD) method was applied to estimate the operating parameters of the MAF process.

1. Improvement of hardening of surface layer in the (MAF) process was obtained in range of 149.1Hv - 170.8Hv (larger difference the better).
2. From the scheme of main effects of the process operating parameters, it is finished that parameters estimated, a high level of number of Pitches (6), a low level finishing time (3), a low level cutting speed (150 rpm), a low level of voltage (20 V), a high level of volume of powder(7), this values are best for improving the micro Vickers hardness of the stainless steel 321 plate material.
3.The parameters that significantly affected on the micro Vickers hardness, from the experimentation, is found to be the highly significant operating parameter is volume of powder improved on the micro-hardness about 42.34%.However, the effects of number of Pitches and improved on the micro-hardness about 25.30% but cutting speed of electromagnet, finishing time and voltage seem to be very small significant.
4. linear regression models for change in Hv indicate that the change in hardness increase with

in number of Pitches and volume of powder while it decreases with increase in finishing time, cutting speed and voltage.

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تحسين صلادة الفولاذ المقاوم للصدأ نوع 321 بواسطة عملية التنعيم بالحث الممغنط

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الخلاصة

تعتبر عملية التنعيم بالحث الممغنط تقنية غير تقليدية في الانهاء السطحي، وهي مناسبة لمختلف المود الهندسية مع انتاج أسطح عالية الجودة من قطع الغيار . در ست الإعدادات التجريبية لغرض تنفيذ عملية الحث الممغنط لتحسين نوعية الطبقة السطحية والصلادة لصفائح الفولاذ المقاوم للصدأ نوع 321. استخدمت هذه الدراسة اثنين من الاقطاب المغناطيسية المختلفة الشكل مثل قطب مغناطيسي مخروطي و قطب مغناطيسي مخروطي ذو أخاديد. وأظهرت النتائج أن القطب المغناطيسي المخروطي ذو الأخاديد يكون ألافضل في توليد الطبقة السطحية وتحسين الصلادة في عملية الحك الممغنط . مدخلات العملية التي تم تطبيقها هي عدد (ألاخاديد)، وقت التشغيل، سرعة القطع للقطب المغناطيسي، الفولتية, وحجم المسحوق (كمية المسحوق). يتكون مسحوق الحك المغناطيسي من كاربيد السيليكون ويستعمل كوسيط بنعومة (300 مايكروميتر) وتركيز (65٪) ويمزج مع مسحوق جزيئات الحديد المغناطيسية بنعومة (300 مايكروميتر) وتركيز (35 ٪) . لتصميم التجارب والتقيمم الامثل للمدخلات استخدمنا مصفوفة تاكوشي لـ 18 وهي مصفوفة مكونة من خمس مدخلات مع مستويات تصميمية مختلطة (2-3) لتحسين نوعية الطبقة السطحية والصلادة. تم تحليل النتائج با ستخدام برنامج رياضي احصائي المنيتاب. وأظهرت محصلة النتائج إلى أن المعادلة التجريبية (النموذج المتوقع الرياضي) التي تمثل العلاقة بين مدخلات العملية مع الطبقة السطحية والصلادة بان المتغيرات التي لها أكبر تأثير في تحسين الطبقة السطحية و الصلادة هي كمية المسحوق وعدد (ألاخاديد) على التوالي.وأن أكبر عوامل مؤثر هو كمية المسحوق حيث حسن الصلادة بمقدار 42.34% ثم عدد (ألاخاديد) تحسنت الصلادة بمقدار25.30%.