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Study the Effects of Machining Parameters on Surface Roughness for Free Form Surface Using Taguchi Method

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Abstract

The surface finish of the machining part is the mostly important characteristics of products quality and its indispensable customers' requirement. Taguchi robust parameters designs for optimizing for surface finish in turning of 7025 AL-Alloy using carbide cutting tool has been utilized in this paper. Three machining variables namely; the machining speeds (1600, 1900, and 2200) rpm, depth of cut (0.25, 0.50, 0.75) mm and the feed rates (0.12, 0.18, 0.24) mm/min utilized in the experiments. The other variables were considered as constants. The mean surface finish was utilized as a measuring of surface quality. The results clarified that increasing the speeds reduce the surface roughness, while it rises with increasing the depths and feeds. Using the analysis of variance, it found that the most effective variable is cutting speed with (53.85%) and the depths has the smallest influence with (20.09%). The data set from the experiments was appointed for implementing the optimum procedure, depending on the principle of Taguchi way. The result of calculation with the experimental outcome was in good agreement.

Keywords: *feeds, surface finish, surface roughness, taguchi.*

1. Introduction

Machining technologies case includes size components diminishing, enhancement of the surface quality, tightest tolerance and manufacture accuracies, reduce cost, reduce size of batches and diminished weight etc. [1]. The surface finish of the machining part is one of the mostly important part quality characteristic. The actual profile of surface is the superposition of errors for the form, roughness and waviness. The deviation is define in international standard. The surface finish greatly effects on the functional performance of mechanical part like as fatigue strength, wear resistance, holding a lubricant and ability of distributing, transmission and heat generation, resistance of corrosion etc [2,3]. The average surface roughness (*Ra*) was select as characteristics of surface roughness in operation of turning, which is the mostly utilized standard variable of surfaces finish. In cutting processes, we have two sharps and sometimes contrary requirement. The first one with high qualities surface while the second one with high productions rates. However, more than one theoretical model involved approximations and simplification in relations with reality machining processes and doesn't take in to accounts any imperfection in chips formation and surfaces finish. Consequently, the solution of the analytical in general wasn't accurate enough to utilize practically [4]. These mathematical (statistical) ways and approaches integrated experimentally, thus it provides sufficient calculations of precision of the reality condition in which the machining operation happen. This work demonstrates the applications of the Taguchi technique to identify the optimum turning variables for surfaces finish in dry machining of Al-alloy.

2. Theoretical Considerations

This work introduces a mathematical representation for the curves mathematical which include parametric representations, in addition to propose the derivation of the curve. An adopting way for generating the tool paths have been implemented depending on CAM program package. The equations of parametric curves describe the dependable and undependable variable in term of parameters. The equations can convert to nonparametric forms by eliminate the dependable and undependable variable from the equations. An equation of the Parametric for free-form surface is constructed by two variables (u), and the vector of parametric functions representing the coordinate's position of the curve [5].

P (u) = [x (u), y (u), z (u)] u from [1, 0] … (1)

In this paper Bezier technique illustrated for representing the proposed study curve. Using the fifth order degree with six control points to each single curve to represent the profile curve of the product, and the equation of the proposed Bezier curve is

$$P(u) = [u^5 \;\; u^4 \;\; u^3 \;\; u^2 \;\; u \;\; 1] \begin{bmatrix} -1 & 5 & -10 & 10 & -5 & 1 \\ 5 & -20 & 30 & -20 & 5 & 0 \\ -10 & 30 & -30 & 10 & 0 & 0 \\ 10 & -20 & 10 & 0 & 0 & 0 \\ -5 & 5 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \\ P_5 \\ P_6 \end{bmatrix} \quad \dots (2)$$

2.1 Theory of Taguchi Method

The method concept is based on that the manufacturing quality should be measure by the amount of deviation from the required values [6,7]. Taguchi technique is used a statistical measuring of performances call signal to noise ratio taken from control theory to analyzing the result [8]. In this way, the term 'signal' refers to the desirable values of mean for the outputs characteristics and the term 'noise' refers to the standard deviation. In this paper will be using L9.

$$S/N = -10 \log[1/n \textstyle\sum_{i=1}^{n} (\frac{1}{y^2})] \quad i=1, 2, \dots n \quad \dots (3)$$

Where n are the measurements of input y^i refers to the measurements value of output. The input parameter of nine simple are Design with using MINITAB16 program.

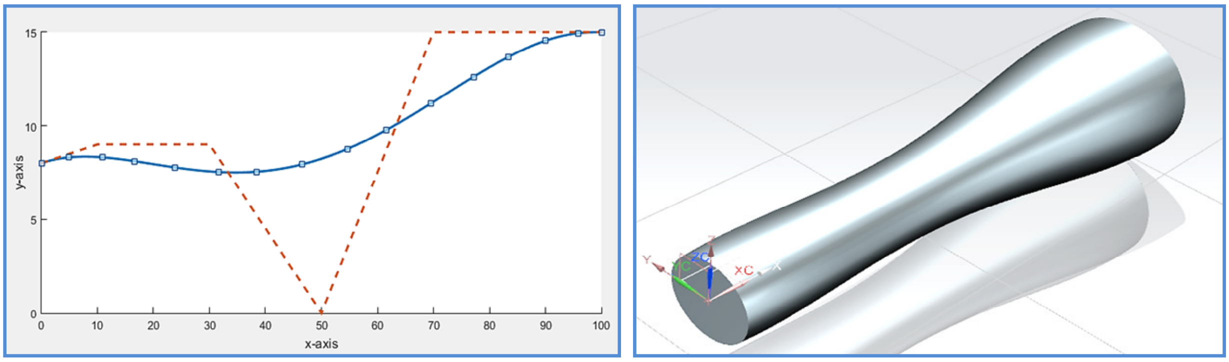
3. Implementation the Work

The equipment of the implementations which utilized in the work is dividing in two parts:

3.1 Software Requirement

The creation of CAD/CAM modeling has been implemented using designing programs package for the purpose of constructing and reconstructing the surface, transferring the CAD data, beside to generating the tool paths and post- processing that required to implement the machining process. These operations illustrated using MATLAB and UG-NX9 program.

MATLAB software is allowing matrix manipulation, implementation of algorithms and plot function. Curve have been modeled using Bezier depends on the algorithm includes the control point matrices. UG-NX is a program and advanced CAD/CAM developing, it is provides integrated design management of parametric model and machining as shown in Fig. 1.



(a) **(b)**

Fig. 1. Implementing the CAD model: (a) Bezier curves using MATLAB, (b) Achieving the model using UG-NX software.

3.2 Hardware Requirements

The Hardware equipment that used in this work consists of the computer and CNC turning machine.

3.2.1 CNC Turning

The turning process carried out in this work on CJK6132 Standard turning machine model 2000 CE TUV has been utilized that illustrated in Fig. 2. The machine specification is shown in Table 1. The machine is located at University of technology/ workshop and training center.

Fig. 2. C-TEK turning (CNC machine).

Table 1,
Specifications of C-TEK CNC turning machine

Swing over bed	Φ 320mm
Range of speed(variable)	(100~2500) r/min
Max X-axis travel	(160) mm
Max Z-axis travel	(500) mm
X rapid traverse	(5) m/min
Z rapid traverse	10m/min
Min input unit	0.001mm

3.2.2 Cutting Tools

Cemented carbides have high hardness over a high thermal conductivity, wide range of temperatures, high Young's modulus making them die materials and effective tool for a range of applications [9]. It is suitable for machining at higher speeds than those which can be used for tungsten carbide. Typical cutting speeds are: 30 to 150 (m/min). Carbide cutting tool was used in this work as shown in Fig. 3.

Fig. 3. Carbide Cutting tools.

3.2.3 Tester of Surface Roughness

Pocket Surf is instrument that utilized for measuring the parts surface roughness after the turning illustrated in Fig. 4. It's a reliable surfaces roughness gauge and an economical priced device. The specification of the instrument is shown in Table 2.

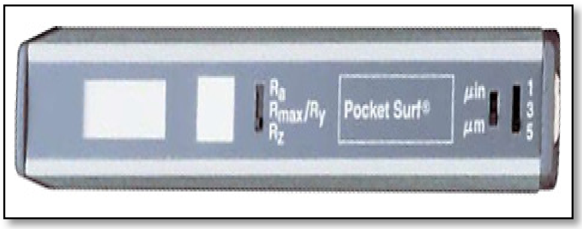


Fig. 4. Tester of Pocket Surf.

Table 2,
Specifications of the surface roughness tester

Measuring Ranges:	Ra (0.03) - (6.35) µm.
	Ry (0.2) - (25.3) µm.
	Rz (0.2) to (25.3) µm.
Weight:	435 g.
Totally Dimension	140 x 76 x 25 mm.
Display Resolution	0.01 µm

3.2.4 Material of the Workpiece

7025 Aluminum alloy is selected to be machining with chemically compositions of the samples illustrated in Table 3.

Table 3,
The chemical compositions for Aluminum 7025.

Si%	Mn%	Cu%	Mg%	Pb%	Cr%	Ni%
0.16	0.216	2.14	1.55	0.07	0.090	0.012
Zn%	Ti%	Ga%	V%	Fe%	Other%	AL%
4.93	0.038	0.01	0.007	0.42	0.132	90.21

This alloy have cut to nine parts. Each specimen has a dimension of (Diameter 30 and Height 120) mm as shown in Fig. 5.

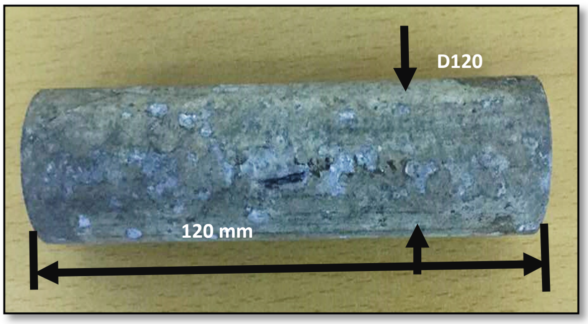


Fig. 5. Work piece dimension.

3.3 Tool path Generation and Simulations

The process that follows designing and representing the CAD models is tool paths generation utilizing UG-NX9 program. using different values of cutting condition (Speed, Depth of cut and feed) as shown in Table 4 and makes the simulations for the entire process beside to obtaining the G-code of the program that created in the paper using UG-NX9 package is shown in Fig. 6.

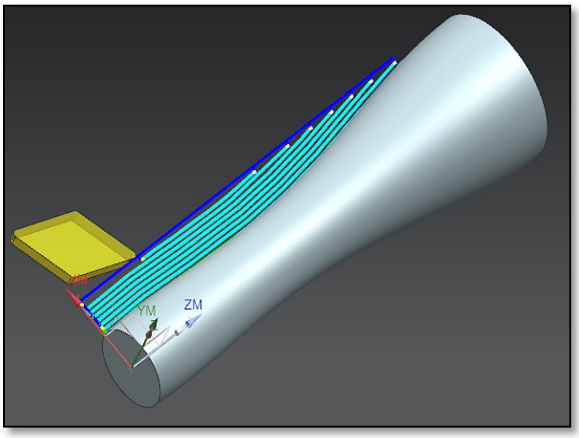


Fig. 6. Generating the tool paths and simulation using UG-NX9.

Table 4,
Parameters level

Cutting speed (rpm)	1600	1900	2200
Depth of cut (mm)	0.25	0.50	0.75
Feed rate(mm/min)	0.12	0.18	0.24

The three machining variables that implemented on the experimental work for the (9) work pieces i.e. Speeds, Depths of cut and feeds clarified with Table 4. The resultant shape of the samples after implementing is illustrated in Fig. 7.

Fig. 7. Final sample shape of turning.

Different conditions for each experiment producing the samples, depending on these conditions a various values of surface roughness have obtained. Fig. 8. Clarify the measurement of surface roughness using the Pocket surf probe.

Fig. 8. Measuring the Surface roughness

4. Results and Discussion

This section demonstrates and discuses the results values of the surface roughness is depend on the three- level parameters depth of cut, speed of cutting and feed rate. Analyzing the output result carried out utilizing variance analysis method for finding the optimal machining factors with the aid of Minitab software. After implementation the experimental part on the 9 parts with three parameters are shown in Table 5.

Table 5,
Reading of Surface Roughness and S/N Ratio

No.	Cutting Speed (rpm)	Depth of cut (mm)	Feed rate (mm/min)	Ra1	Ra2	Average of Ra	S/N Ratio
1	1600	0.25	0.12	0.93	1.13	1.030	-3.424
2	1600	0.50	0.18	1.30	1.21	1.255	-0.965
3	1600	0.75	0.24	1.12	2.10	1.610	-4.521
4	1900	0.25	0.18	0.91	0.87	0.890	1.707
5	1900	0.50	0.24	1.36	0.99	1.175	1.462
6	1900	0.75	0.12	0.89	0.95	0.920	2.908
7	2200	0.25	0.24	0.87	0.69	0.780	3.285
8	2200	0.50	0.12	0.66	0.74	0.700	6.131
9	2200	0.75	0.18	1.11	0.96	1.035	4.506

4.1 Effect of Cutting Speeds, Depths of Cut and Feed Rates on Surface Roughness

Fig. 9 to 11 clarifies the effects of depths of cut, cutting speeds, and feed rates on the resultant surface roughness. It is noting that increasing the cutting speed decreases the surface roughness; this mens that the high cutting speed improving the surface roughness. While the rise in the feed rates and depths of cut led to increase in surface roughness, the cutting speeds influence on the friction which is decreased with increasing the cutting speeds.

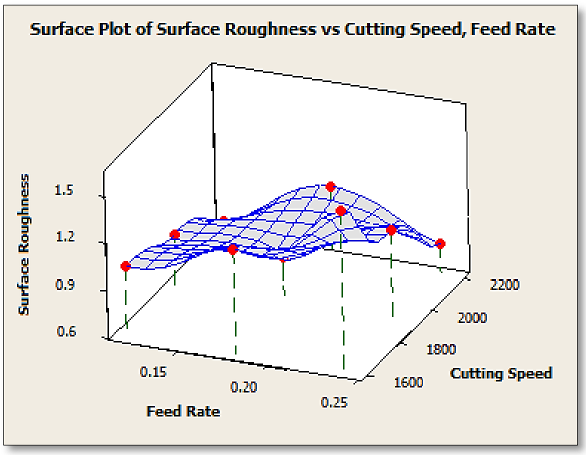


Fig. 9. Cutting speed and feed rate Effect on surface roughness.

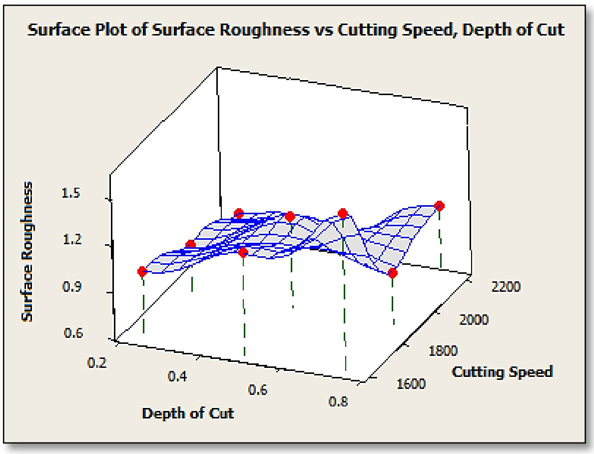


Fig. 10. Cutting speed and depth of cut Effect on surface roughness.

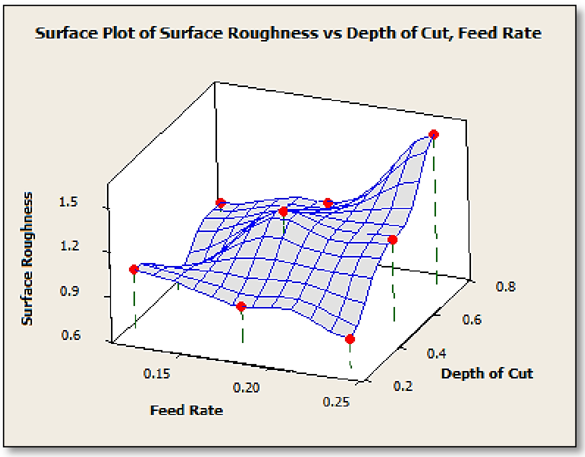


Fig. 11. Effect of depth of cut and feed rate on surface roughness.

4.2 Variance Analysis (ANOVA)

Analyzing the result of experiments have been implemented using variance analysis method (ANOVA) for finding the influence of turning variables on surface finish that depend on cutting variables Depths of cut, Speeds and feed rates. The results of the analysis of variance for surface finish are shown in Table 6.

Table 6,
Variance analysis of the proposed parameters.

Source of variance	Degree	Sum of squares	F ratio	P (%)
Cutting Speed(rpm)	2	0.3282	3.50	53.85
Depth of cut(mm)	2	0.1247	0.77	20.46
Feed rate (mm/min)	2	0.1407	0.90	23.09
Error ,e	2	0.0158		2.75
Total	8	0.6094		100

The *F* ratio value of 3.5 for the cutting speed is greater than the other variables shown in Table (5). Consequently, the most effective variable is the cutting speed with (53.85%) which is about twice of the feed rate of (23.09%), while the depth of cut has a small effect with (20.46%). The contribution percent are given in Fig. 12, clarifying the most effective variables of the entire process among the conditions of machining which is cutting speed (rpm).

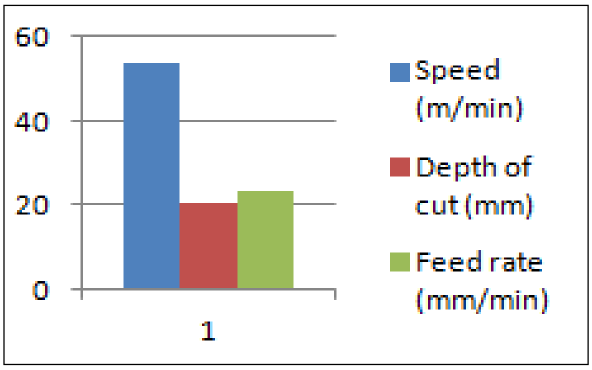


Fig. 12. Influential effects based on percentage of distributions.

4.3 Optimal Condition

The main effect plot is utilized to find out the optimum condition of design to give the optimal surface roughness through select the best regions by use of Minitab software. Fig. 13 Shows the main effects plots of the surface finish. That plot shows the variations of response (3) variables individually, such, depths of cut, cutting speeds and feed rates separately. The result are showing the optimum condition for surface finish which is: cutting speed at level-3 (2200 rpm) depth of cut at level-1(0.٥٠ mm) and feed rate at level-1(0.12).

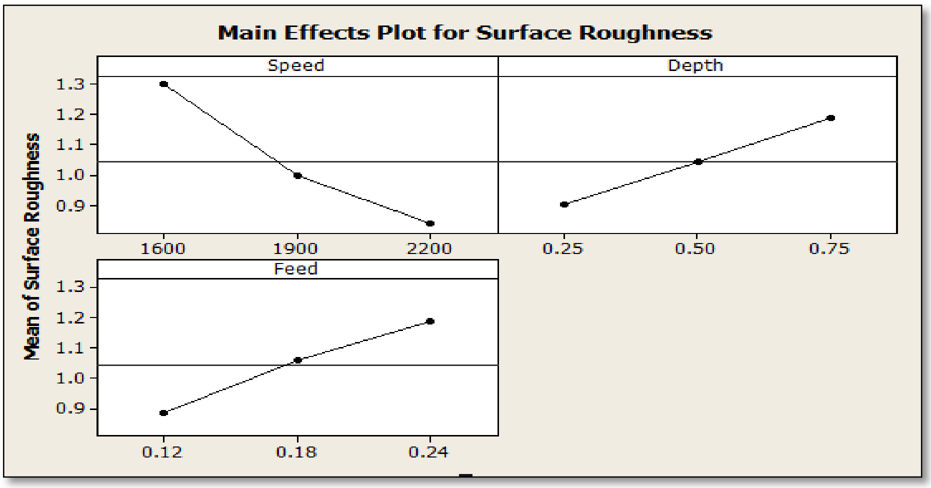


Fig. 13. Main Effect Plots for surface roughness.

5. Conclusion

From this work, the following conclusions were drawn:

1. The experimental results show the main effects of process parameters on surface roughness for 7024 AL-alloy. The surface roughness decreases with the increasing in cutting speed. Surface roughness reduces with decreasing feed. The surface roughness increases with increase in depth of cut.
2. The optimal conditions for minimum surface roughness were: cutting speed at level-3(2200 m/min), depth of cut at level-1(0.25 mm), and feed at level-3(0.12 mm/min).
3. From analysis of variance the most effective variable is the cutting speed with (53.85%) which is almost greatest influential among the other parameters, and depth of cut is have a small effect with (20.46%).
4. Analyzing the results by answering the following: How the experimenter has set up the process such that it is insensitive to the uncontrollable factors

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دراسة تأثير متغيرات التشغيل على الخشونة السطحية للسطوح الحرة باستخدام طريقة تاكوشي

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الخلاصة

ان الانهاء السطحي للأجزاء المشغلة يعد من اهم الخواص لجودة المنتجات المصنعة والاكثر تطلبا للمستهلك. تم استخدام طريقة تاكوشي لتصميم التجارب للحصول على افضل خشونة سطحية في عملية الخراطة باستخدام المكائن المبرمجة لسبيكة المنيوم نوع ٧٠٢٤ بواسطة عدد قطع كاربيدية والتي تم استخدامها لهذا البحث. ثلاثة متغيرات للتشغيل وهي: سرعة القطع (١٦٠٠، ١٩٠٠، ٢٢٠٠) دورة/ دقيقة، عمق القطع (٠,٢٥، ٠,٥٠، ٠,٧٥) ملم و معدل التغذية (٠,١٢، ٠,١٨، ٠,٢٤) ملم/دقيقة تم استخدامها للتجارب العملية. فيما تم تثبيت باقي المتغيرات التشغيلية الاخرى. تم اخذ معدل الانهاء السطحي كمؤشر لجودة السطح. اظهرت النتائج ان زيادة سرعة القطع تعمل على تقليل الخشونة السطحية، بينما تزداد الخشونة بزيادة كل من عمق القطع ومعدل التغذية. تم استخدام تقنية تحليل تباين العناصر(انوفا) وجد ان اكثر المتغيرات تأثيرا هو سرعة القطع بنسبة (٥٣,٨٥%) بينما عمق القطع هو الاقل تأثير بنسبة (٢٠,٠٩%)، من خلال التجارب تم تحديد افضل ظروف لتحديد افضل خشونة سطحية بالاعتماد على طريقة تاكوشي، حيث اظهرت النتائج مقبولية جيدة للعملية.