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Investigation of CNC Milling Machining Parameters on Surface Roughness

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Abstract

Milling Machining is a widely accepted nontraditional machining technique used to produce parts with complex shapes and configurations. The material is removed in two stages roughing and finishing, the flat end cutter removed the unwanted part of material, then finished by end mill cutter. In milling technique, the role of machining factors such as cutting depth, spindle speed and feed has been studied using Taguchi technique to find its effectiveness on surface roughness. Practical procedure is done by Taguchi Standard matrix. CNC milling is the most conventional process which is used for removing of material from workpiece to perform the needed shapes. The results and relations indicate that the rate of feed is very important factor for modeling surface roughness. The plot of S/N ratio shows that the optimum combination of the milling factors that gives the best value of surface accuracy. The best combination of milling factors has also been predicted to minimize the surface roughness.

Keywords: *Orthogonal array, surface roughness, S/N ratio, Taguchi technique.*

1. Introduction

Producing components with complex surfaces don't like producing parts with regular surfaces. This is because the big difference between complex and regular surfaces, or the freedom in designing of the complex surfaces. Now days the technique of CNC machines has been widely used in various manufacturing fields to meet the advance requirements, especially in accurate metal forming industry. Furthermore, geometric features made of complex surfaces are often produced in combination, whilst those with regular shapes are normally machined individually [1, 2]. The requirements for high performance and automated machining systems interested with the surface conditions of the part, product roughness of the machined parts is most important because of the effect on part shape, function, and product life. It is the most general used in a wide number of manufacturing processes. Milling is the popular widely used metal cutting process [3]. This paper reveal the role of some of machining factors like (feed rate, depth of cut and spindle speed) on surface roughness in CNC milling process. For these causes it is an important to keep the surface finish and consistent clearances. Between many CNC production machining techniques, milling process is a good machining technique. An important role in performance of machining, the nature of the surface plays as a best- accuracy machined surface significantly improves fatigue strength, creep life and corrosion resistance. The resulted surface from milling is affected by many parameters like temperature, vibration, rotational speed, tool shape, feed, tool path, cross-feed and other factors [4]. Machining parameter specified range plays an important action on surface quality. In milling, use of low depth of cut, high spindle speed and low feed rate are recommended to find out best surface roughness for the specified range in a material. As the applied force increased Surface roughness is increased. If we used a small nose radius at constant feed cause the higher surface roughness, with the modern production requirements of modern industries; the control of surface roughness with the surface accuracy became more important matter [5,6]. Cutting speed is the most important parameters that effect on surface roughness. The most important combinations that affect product roughness are between the depth of cut and cutting speed, and between spindle speed and feed rate. This practical investigation demonstrates the Taguchi optimization technique, which is applied to find the best surface roughness in end milling operation [7]. Aluminum alloy was the workpiece and the experiment is conducted on it by (HSS) tool with finishing pass. The machining conditions such as feed rate, rotational speed and cutting depth. Taguchi L9 orthogonal array was used to conduct the experiments.

2. Experiment and Data Collection

The experiments were designed using L9 Taguchi orthogonal array. Minitab16 was the technique that used for arrangement of experiment. Working within the Minitab16 program is done in three stages. These stages are firstly the planning stage, secondly the conducting stage, finally the analyzing stage.

A) Planning Stage

In the planning stage, the cutting factors are set according to their level and according to the table (1) which includes the cutting factors (Rotational speed, feed, cutting depth).

Table 1,
Selected input Parameter

Factor A (rpm)	Factor B (mm/min)	Factor C (mm)
1000	100	1
1250	150	1.5
1500	200	2

B) Experiments of Design

Taguchi L9 orthogonal array was used for selected input parameters experiments design as shown table (2). For this purpose, Minitab software 16 was used:

Table 2,
Experiments design using Minitab software.

Exp. no	Rotational speed- (RPM) (A)	Feed - (mm/min) (B)	Cutting depth- (mm) (C)
1	1000	100	1
2	1000	150	1.5
3	1000	200	2
4	1250	100	1
5	1250	150	2
6	1250	200	2
7	1500	100	2
8	1500	150	1
9	1500	200	1.5

C) Workpiece Material

The workpiece that used in the present paper is aluminum alloy with dimensions (50 x 50 x 25 mm). whose compositions are as follows:

Si 1.1%
Cu 4.5%
Rest Al

And has mechanical properties as follows:
Tensile Strength = 221 (MPa)
Yield Strength = 110 (MPa)
Ductility = 8.5 (%Elongation in 50 mm)

Applications
Crankcases, Flywheel, Bus, axle housing and aircraft parts.

D. Experiments Set Up

The completion of the nine samples on the CNC milling machine the surface roughness values are taken and by determining the least readability of the roughness, which is the best value, the best factors are determined through the prediction by the program Minitab. The value of S/N ratio (Means that the amount of the output signal (resulting from the process) to the error rate and the greater the value, the better the reading of the prediction) of each experiment was calculated based on equation no.1.

Fig 1. CNC Machine.

The equation is

$$SN_i = -10 \text{ x } \log \left(\frac{1}{n} \sum_{i=1}^{n} y^2{}_i\right) \quad \text{... (1)}$$

Where n = number of measurements in a trial/row, in this case, n=3, SN_i is the signal to noise ratio of ith term, and Y_i is the ith value of measured in a run/row [8].

3. Apparatus Used to Calculate Roughness Measurements

The important output properties that can be measured is surface roughness which measured in the present paper by using Pocket Surf the portable surface roughness gage Mahr Federal's patented that shown in figure (2) below. The Mahr Federal's is a surface-roughness measuring apparatus, which moves on the surface of machined parts to measure the surface roughness depending on standards, later the results displayed on LCD display. In addition, a reading of Ra was taken, which gives a passage on the surface and gives a rate of surface roughness as shown in table (3), which is considered the most widely used industry. The stylus moves a specified displacement during the movement the data processed and appear on a gage liquid crystal display.

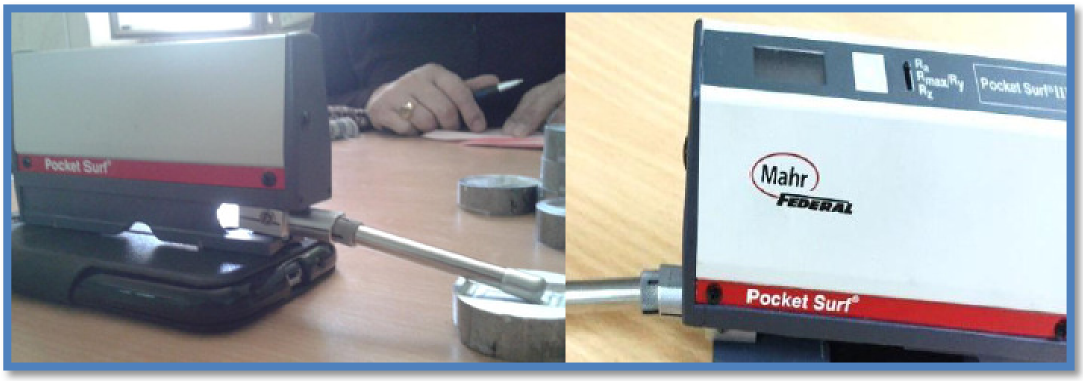

Fig 2. Pocket Surf tester

Table 3,
Surface roughness value for each Experiments.

No	Rotational speed (rpm) (A)	Feed (mm/min) (B)	Cutting depth (mm) (C)	Surface roughness (R1) (µm)	R2	R3	S/N Ratios (dbi)	MEANS
1	1000	100	1	1.781	1.975	1.927	5.5547-	1.89433
2	1000	150	1.5	2.340	2.482	2.359	7.5843-	2.39367
3	1000	200	2	2.730	2.292	2.482	7.9857-	2.50133
4	1250	100	1	1.001	1.299	1.273	1.5735-	1.19100
5	1250	150	2	1.027	1.839	1.405	3.2978-	1.42367
6	1250	200	2	1.157	1.283	1.284	1.8878-	1.24133
7	1500	100	2	0.455	0.628	0.691	4.4414	0.59133
8	1500	150	1	0.676	0.761	0.934	1.9644	0.79033
9	1500	200	1.5	4.017	4.126	4.938	12.8288-	4.36033

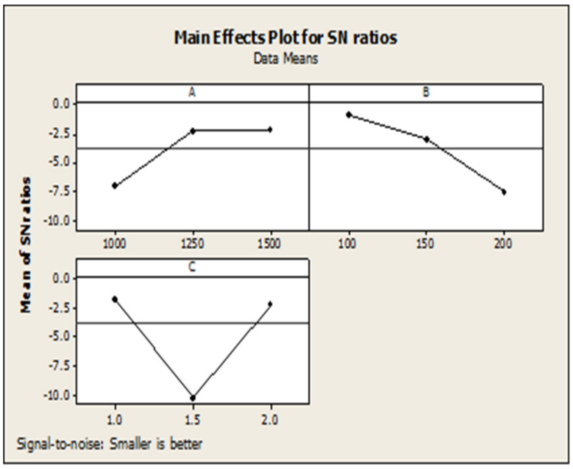

Fig 3. S/N ratio plot

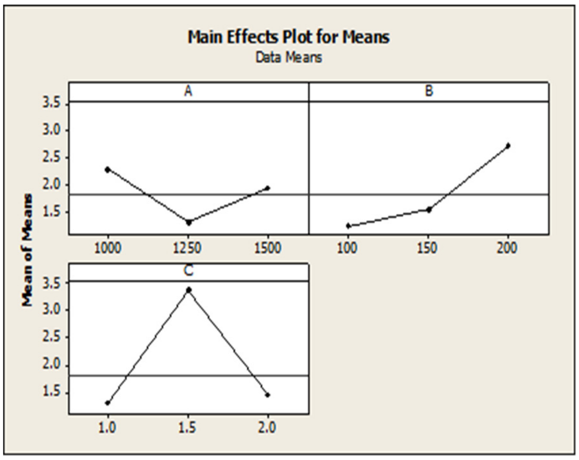

Fig. 4. Means plot.

Figure (3) shows the relationship between input parameters and S/N ratio data. While Figure (4) In this diagram, the relationship between the surface roughness value rate and each of the cutting factors is indicated with their levels and by the lowest roughness value that gives the value of the factor to the best reading. The aim of using S/N ratio as a measurement of performance is to develop a process in sensitive to noise factor. The best input parameters can be found of combination from plot (3) i.e. plote between input parameters and S/N ratio, the optimum setting of process parameters are ($A_2B_1C_1$). The selected parameters with the highest S/N ratio generally yields the optimum quality with minimum variation.

4. Calculation of The Performance

The effect of all factors on surface roughness is found according to the following equation [9]:

Average performance of factor A at level 1= $\frac{Sum\ of\ roughness}{number\ of\ levels}$ ... (2)

According to the Minitab program, the most effective factor is calculated on the cutting process known as Rank and according to Table (4). The following table shows the most effective factor is the cutting depth (Rank 1) and the lowest factor is the cutting speed (Rank 3).

Table 4,
Table for Signal / Noise Ratio

Minimum of S/N ratio is better			
Level of parameter	**A**	**B**	**C**
1	-7.0424	-0.8965	-1.7222
2	-2.2530	-2.9726	-10.2065
3	-2.1410	-7.5674	-2.1825
Delta	4.9015	6.6710	8.4844
Rank	3	2	1

5. Calculation of Optimal Surface Roughness

Let R = surface roughness average result for 9 runs

$$R = \frac{\sum_{i=0}^{9} \text{Roughness}}{9} = 1.8208$$

6. Result and Discussion

Using these data the best surface roughness can be predicted using the optimum machining conditions mentioned above and according to the relation:

Predicted Mean (Ra) = $A_2 + B_1 + C_1 - 2$(average mean) ...(3)

Where

A_2= Average of (Ra) at the second level of spindle speed

B_1= Average of (Ra) at the first level of feed rate

C_1= Average of (Ra) at the first level of depth of cut

From Table (7):

Predicted Mean (Ra) = 1.285+1.226+1.292-2*1.8208= 0.1614 µm

7. Conclusions

1. The plot of S/N ratio show that the optimum value of surface quality is found at first value of factor B, the second value of factor A and first value of factor C.

2. From the results it can be seen that the Optimum value of surface roughness is 0. 0.1614 µm.
3. Taguchi technique is the best way to determine the number of samples by introducing the effects with their levels to determine the minimum number that can be run through its matrices. The Taguchi method is widely used and found to be suitable for determining the cutting effects of the programmed milling machine.

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تأثير متغيرات التشغيل في مكائن التفريز المبرمجة على الخشونة السطحية

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الخلاصة

مكائن التفريز هو أكثر تقنية مقبولة للقطع التقليدي المستخدمة لإنتاج أجزاء لأشكال معقدة. ازالة المادة تتم على مرحلتين القطع الخشن والانهاء السطحي، القطع الخشن يتم استخدام عدة قطع ذونهاية مسطحة وإزالة الجزء المطلوب من العينة،□م في الانهاء السطحي يتم استخدام عدة قطع ذو نهاية مستديرة. في هذا البحث، تم دراسة تأ□ير عوامل التشغيل مثل عمق القطع وسرعة القطع والتغذية باستخدام تقنية تاكوشي لإيجاد افضل قيم للخشونة السطحية. يتم تحديد الجزء العملي من قبل مصفوفة تاكوشي القياسية. التفريز بالمكائن المبرمجة هو العمليات الأكثر تقليدية التي تستخدم لإزالة المعدن من المشغولة لانتاج الأشكال المطلوبة. النتائج والعلاقات تشير إلى أن معدل التغذية هو عامل مهم جدا للتأ□ير على□شونة السطح. وتظهر نسبة الاشارة للخشونة الى معدل الخطأ تعطي الأمثل بين عوامل القطع التي تعطي أفضل قيمة لدقة السطح. كما تم توقع أفضل عوامل التي تعطي افضل□شونة سطحية.