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Surface Roughness and Roundness Optimization on Turning Process of Aluminium Alloy with Taguchi Method

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ABSTRACT

In this study, surface roughness and roundness were established as process parameters on turning process of Aluminium Alloy by using Taguchi Method. Taguchi design of experiments (DOE) is used to analyze the effect of each parameters design. The four parameters are nose radius (nr), spindle speed (n), depth of cut (a) and feeding (f). The observed value is denoted by using surface roughness and roundness. From this result, it can be concluded that the optimum design based on surface roughness is chosen as optimum turning process parameter for this study. It can be found that nr *have stronger influence on the observed value. The optimum design is a product with* nr *= 1.2 mm, n = 1000 rpm,* a *= 0.25 and* f *= 0.056 mm based on surface roughness evaluation.*

Keywords: *Nose Radius, Surface Roughness, Roundness, Taguchi Method*

Introduction

A quality product is used as standardization in determining whether a product is acceptable or not. The important turning product qualities are surface

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roughness and roundness. Factors affecting surface roughness and roundness on machining parameters are cutting tool specifications, workpiece, and the cutting process parameter. Surface roughness study on machining process had been developed with a number and several of process parameters. This research study the effect of machining parameters such as cutting speed, feed rate, depth of cut, tool nose radius and lubricant on surface roughness for turning En-31 steel, [1]. This research also studies the machining parameters effect of cutting speeds, feed, and the nose radius of the cutting tool by using a constant depth of cut to observe surface roughness for Particulate [2]. The model of surface roughness development, based on the response surface method, is to investigate the machining parameters such as feed rate, tool geometry, nose radius, and machining time in dry turning process [3]. In other observed value, which is roundness, the purpose is to understand which process parameters affect the roundness and hardness of a surface on a stainless steel turning. Based on the result, it can be found that cutting speed and feed rate does not affect roundness [4]. Therefore the purpose of this work is to analyze the effect of cutting parameters on the roundness of AISI 1045 cylindrical bars.The effect of Taguchi method L9 orthogonal array, S/N ratios and ANOVA were used with cutting speed, feed rate and depth of cut as turning parameters and with roundness as the response variable. The result of the analysis show that the cutting speed is the most influencing parameter out of the three parameters under study followed by the other two parameters, feed rate and depth of cut, both have an almost equal effect on surface roundness. Finally, the results are further confirmed by a confirmation run [5]. The text should be right and left justified. The optimization method was used to develop the optimum process parameter by using Taguchi Method. This presents the application of Taguchi method and the utility concept for optimizing the machining parameters in turning of free-machining steel using a cemented carbide tool [6]. It also studies various parameters which affect the surface roughness. Turning experiments on AA - 6061 T6 was used by using CNC LT-16 turner with carbide tipped tool and the cutting parameters selected were feed, spindle speed, depth of cut and tool nose radius [7]. The results obtained were analyzed using ANOVA and the regression equation for predicting the surface roughness was developed. From these study, it can be concluded that Taguchi method provides the tool for optimization method on machining process to enhance the quality product. However, the effect of machining parameters on the surface roughness and roundness of the turned part has only been studied by a few researchers. Therefore, this study continues and develops process parameter optimization of Aluminium Alloy by using Taguchi Method. Nose radius (nr), Spindle speed (n), depth of cut (a) and feeding rate (f) will be used as process parameters to find the optimum levels for the surface roughness and roundness.

Research Objectives and Methods

All the experiments have been performed on a 2-axis TU 2A CNC lathe at a nose radius (nr) 1.2, 0.8 and 0.4 mm, spindel speed (n) 1000,1150,and 1250 rev/min, depth of cut (a) 0.25, 0.35 and 0.50 mm, and feed rate (f) 0.056, 0.058 and 0.060 mm/rev with workpiece material used were Aluminium Alloy (AA - 6061-T6) and carbide tool as shown in Table 1. Carbide tool geometry is shown in Figure 1 along with the material composition of uncoated carbide tool. The specimens were machined on a precision lathe and the surface roughness profiles and indices were obtained from MITUTOYO SURFTEST : SJ – 301 roughness measuring instrument (Evaluation length = 4.0 mm, Cut-off length = 0.8mm, vertical magnification 1000 and horizontal magnification 20), and roundness deviation of the turned bar was measured with the help of dial indicator of Mitutoyo. The analyzed data configuration of the experimental setup for the analysis of surface roughness is illustrated schematically in Figure 2. All statistical works including principal component analysis were obtained with the help of MINITAB Version R15 statistical software. The smaller the objective function selected is, the better. The chips were collected and studied under a microscope for their morphology and chip formation behaviour.

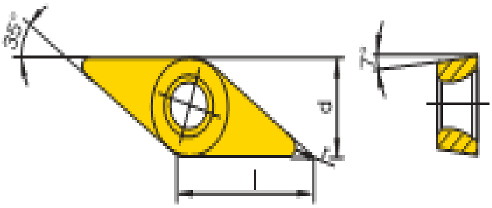

Figure 1: Carbide tool Geometry

With a method of quick stop, the chip formation pattern was studied with photos from digital camera. The Chip thickness is measured on a Dino-lite Digital Microscope pro-2009 (ANMO Electronic Corporation), magnification 500. The chip formation was studied by interrupted cut with the chip still attached to workpiece.

Table 1: Material Data

No	Type	Material	Dimensions	Codefication
1	Tool	Carbida	(7.75x6.35) mm	DCGT-070204FN-27M20
2	Workpiece	Aluminium Alloy	(100 x 22) mm	AA-6061-T6

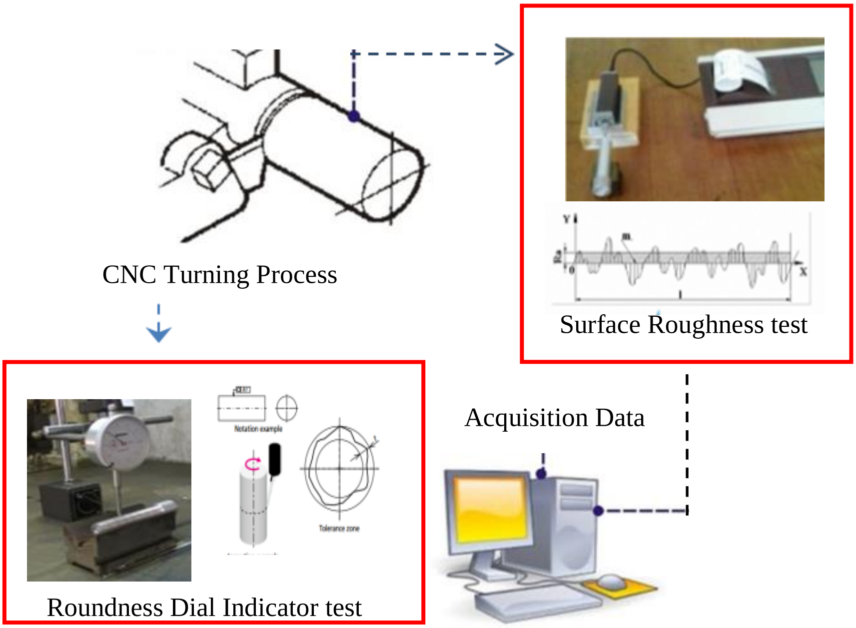

Figure 2: Schematic diagram research experiment setting

The experimental design consists of a series of experiments to be performed in sequence to evaluate the response measurement of Taguchi Orthogonal array. This study focused on the effect of turning parameters and experiments were performed with 4 factors and 3 level, each factor controlled with 9 experimental runs based on orthogonal array L_9 (3^4) [8]. Table 2 presents the 4 factors of process parameters to be varied, namely; nose radius (nr), Spindle speed (n), the depth of cut (a) and feed rate (f) with 3 Level for each factor. Measurement of surface roughness is done by using a surface roughness tester (SR) and roundness deviation measurement is produced by using dial indicator.

Table 2: Process parameters and their levels

Code	**Parameter**	**Unit**	**Level 1**	**Level 2**	**Level 3**
A	Nose radius	mm	0.4	0.8	1.2
B	Spindle speed	rev/min	1000	1150	1250
C	Depth of cut	mm	0.25	0.35	0.50
D	Feed rate	mm/rev	0.056	0.058	0.060

Results and Discussions

The main effects from the observation of the surface roughness and roundness are obtained in accordance with Table 3, for each turning parameters at different levels were calculated.

Tabel 3: L9 Orthogonal Array Result of Surface roughness and Roundness measurements after turning

Model	nr (A)	n (B)	a (C)	f (D)	Surface Roughness (μm)	Roundness (μm)
1	0.4	1000	0.25	0.056	0,97	5.32
2	0.4	1150	0.35	0.058	1,55	5.63
3	0.4	1250	0.50	0.060	1,87	5.79
4	0.8	1000	0.35	0.060	1,00	5.50
5	0.8	1150	0.50	0.056	0,86	5.63
6	0.8	1250	0.25	0.058	1,19	5.64
7	1.2	1000	0.50	0.058	1,07	5.79
8	1.2	1150	0.25	0.060	0,81	5.64
9	1.2	1250	0.35	0.056	0,66	5.74

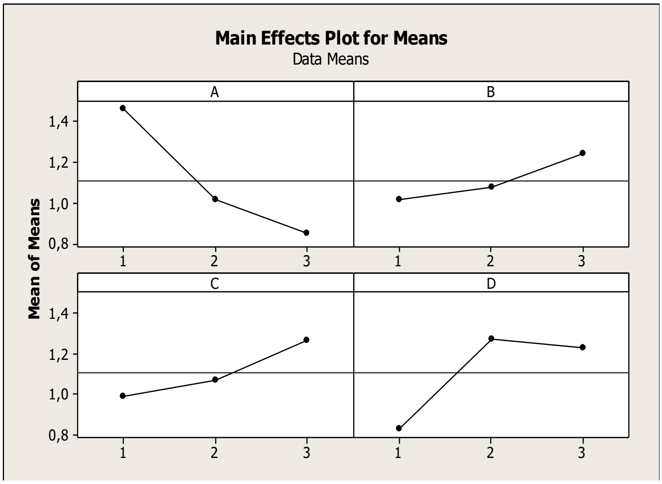

Figure 3: The main effects of surface roughness of each factor for various levels

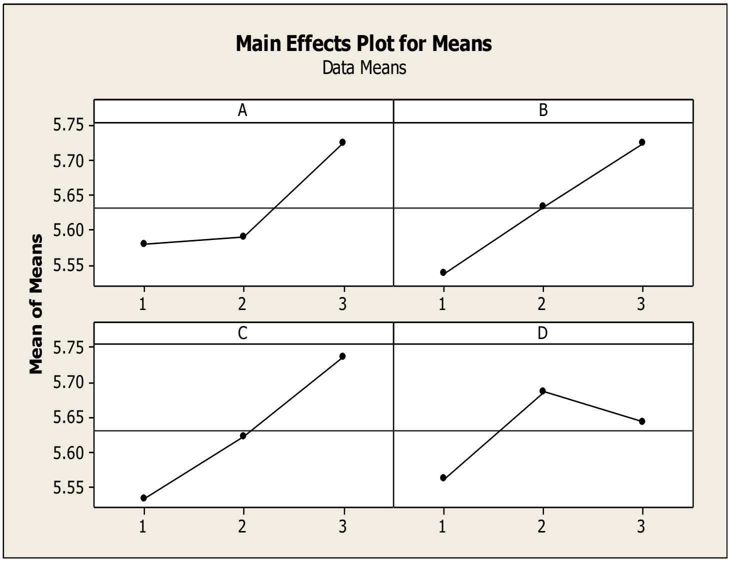

Figure 4: The main effects of roundness of each factor for various level conditions

The optimum design of turning process product based on the results of the optimum condition of each of the observed values are illustrated in Figure 3 and 4, both show the main effects plot which was obtained using Minitab version 15 statical software. The smaller the objective function selected is, the better. Both response tables for surface roughness and roundness suggest a different optimum condition as shown in Table 4.

Table 4: Optimum design of turning process product

Factor	**Based on Surface Roughness**		**Based on Roundness**	
	Level Description	**Level**	**Level Description**	**Level**
A (nr)	1.2	3	0.4	1
B (n)	1000	1	1000	1
C (a)	0.25	1	0.25	1
D (f)	0.056	1	0.056	1

The experimental confirmation test is the final step in verifying the results obtained based on Taguchi's design approach. The confirmation experiment is a key step and is highly suggested by Taguchi to verify the experimental results. In this study, a confirmation experiment was conducted by utilizing the levels of the optimal design parameters ($A_3B_1C_1D_1$) and ($A_1B_1C_1D_1$). The result of Experimental confirmation test is shown in Table 5. From this result, it can be concluded that Taguchi optimum design based on surface roughness is chosen as optimum turning process parameter for this study due to the production of the optimum value observed (Surface Roughness = 0.55 µm and Roundness = 5.61 µm). It can be found that *nr* have stronger influence for the observed value based on surface roughness evaluation. The relationship between the nose radius and surface roughness is inversely proportional. This is due to the run out during the machining process, the short cut of the machining process on the workpiece, and the stiffness increase, which would affect the value of surface roughness and roundness on the product [12].

Table 5: Experimental confirmation test

Candidate Optimum design	**Observed value**	
	Surface Roughness (µm)	**Roundness (µm)**
($A_3B_1C_1D_1$) Based on Surface Roughness	0.55	5.61
($A_1B_1C_1D_1$) Based on Roundness	0,97	5.32

From the measurement results, it can be seen that the surface roughness decreases with the increasing of nose radius (nr) and it has the same trend with the previous study [9-11]. The nose radius parameter affects the occurrence of chip formation on turning process [12]. If nose radius is smaller, the number of shear contact area increase and produce a high surface roughness as shown in Figure 5.

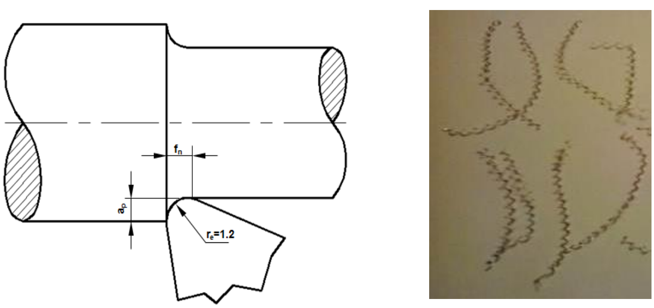

Figure 5: Sketch diagram of nose radius influence to surface roughness

Chip formation type can be predicted by using cutting slenderness ratio (δ), with value range δ = 2-20 will produce continuous chip type [12,13]. Figure 6 shows the δ value for each model. Figure 7 of chip type visualization proved that all models produce continuous chip type when entering the value range of cutting slenderness ratio (δ).

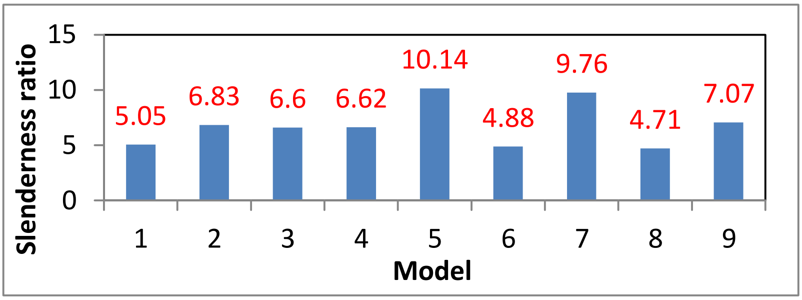

Figure 6: Cutting slenderness ratio on each model

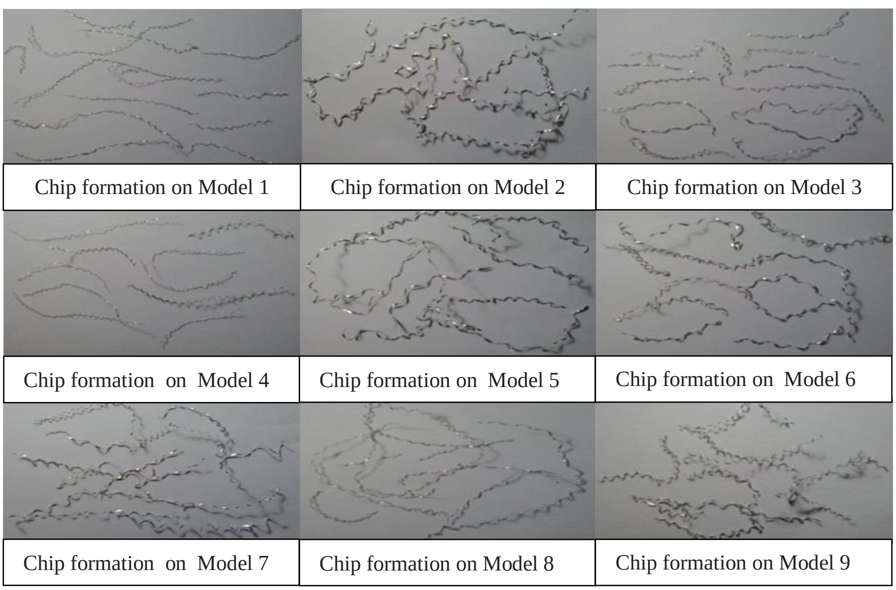

Figure 7: Continues chip type on different nose radius for various level conditions

Conclusion

This paper has discussed an application of the Taguchi method for optimizing turning parameters in turning of Aluminium Alloy using Carbide inserts at three levels of cutting parameters.

This paper discusses four cutting parameters which are nose radius, spindle speed, depth of cut and feed rate with surface roughness and roundness as the response variable. Based on experimental data, It can be concluded that the optimum design based on surface roughness usually decreases with the increase in nose radius nr = 1.2 mm, n = 1000 rpm, a = 0.25 and f = 0.056. The optimum design is chosen as optimum turning process parameter for this study due to the production of the optimum value observed (Surface Roughness = 0.55 µm and Roundness = 5.61 µm).

The relationship between the nose radius and surface roughness inversely is proportional. This is due to the run out during the machining process, the short cut of the machining process on the workpiece, and the stiffness increase, which would affect the value of surface roughness and roundness on the product.

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