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The effect of cutting depth, feed rate, and cutting angle on surface roughness in the lathe process of aluminum 6061

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Abstract

In the turning process, the machining parameters have a significant impact on the product quality. Consumers frequently request that certain industries adhere to product quality standards, especially regarding surface texture. Numerous product failures have resulted in dissatisfaction among the company's clientele because many lathe operators are fixated solely on product size drawings and are unaware of factors that can impact the surface roughness value. This investigation was conducted to ascertain how machining parameters affect surface irregularity. Variations in feed rates of 47.5 mm/min and 345.6 mm/min, cutting angles of 60° and 80°, and depths of cut of 1 mm and 3 mm were utilized to conduct the investigation on aluminum alloy 6061 specimens. The results of turning were evaluated for surface roughness using a surface roughness analyzer and a macro test to determine the structure of the surface roughness. Using the Minitab 2019 application, the obtained data was then analyzed to determine the influence of each trimming parameter working individually or simultaneously. Using the method of geometric factorial analysis, integrate the research parameters. The results indicated that the surface roughness increased as the feed rate increased; the lowest surface roughness was achieved with a depth of cut of 1 mm, a feeding rate of 47.5 mm/min, and a cut angle of 80°. In this study, the surface roughness value decreased as the cutting angle increased at lower levels of feeding rate, while the surface roughness value increased at higher levels of feeding rate.

Keywords:
Aluminum alloy 6061, feed rate, depth of cut, angle of cut, surface roughness.

1 Introduction

In the turning process, machining parameters greatly affect the quality of a product. In some repair molding industries, consumers are often asked to meet the quality of a product, especially in terms of surface roughness on molding machine parts. Most medium industrial lathe operators are only informed of the size of a product and pay little attention to machining parameters that impact the roughness level. This causes lathe operators to only focus on size and not pay attention to cutting parameters that have an impact on surface roughness values loss of time and material. To avoid this loss, in machining planning it is necessary to determine the machining variable values that can produce the desired surface quality.

Factors that affect the quality of the surface roughness of a workpiece in the machining process include cutting speed, improper flashlight position, machine vibration, poor heat treatment, and so on. Coolant also cannot be separated from the machining process, apart from acting as coolant and stabilizing the temperature of the workpiece and tool. Getting the surface roughness value of the smooth shaft from the lathe process can be done by selecting the cutting tool to determine the feeding rate and depth of cut according to the needs. The sharpness and strength of the chisel are very influential in the resulting product. The best combination of spindle speed and depth of cut for reducing workpiece roughness is the highest cutting speed and the lowest feeding rate. In addition to the high cutting speed, the depth of cut also affects the roughness of the workpiece. Because the lower the depth of cut, the lower the level of surface roughness on the workpiece.

The level of surface roughness resulting from conventional turning processes can be influenced by several parameters, such as cutting speed, spindle rotation, and depth of cut [1]–[3]. Cooling factors can also affect the surface roughness value of the workpiece. Heat on lathe chisels and workpieces can affect the surface roughness of the workpiece [4][5]. The characteristics of a surface's roughness are very important in the design of machine components, for example, in those that are related to wear and lubrication and therefore require a low roughness value [6]. In the machining process, the factors that affect surface roughness are the depth of cut and rotational speed. By adjusting the variations in the depth of cut and rotational speed of the lathe. Based on the effect of the main cutting angle, feed motion, and depth of cut on surface roughness, it can be concluded that the greater the value of the feed cutting angle, the smaller the surface roughness results, the smaller the feed motion value, the smaller the surface roughness results, and the smaller the depth of cut, the smaller the surface roughness that results. The magnitude of the cutting force is caused by the main cutting angle, feeding rate, and depth of cut. The greater the value of the cutting force, the greater the surface roughness value [7].

Cutting conditions and the geometry of a tool can affect the value of the surface roughness of the workpiece. Another factor that can affect the value of the surface roughness of the object is the feeding rate and rotation speed. The higher the feeding speed, the higher the surface roughness value, while the increase in engine speed will decrease the surface roughness [8][9][10]. The quality of the surface roughness of the object is greatly influenced by the cutting speed. The greater the depth of cut, the longer the chips will be, and conversely, a low depth of cut will result in fragments and fragments [11][12]. The cutting process dramatically affects the results of the object's surface roughness, wet cutting using a carbide chisel gets the lowest surface roughness results, while dry cutting using a carbide chisel gets the highest surface results [13]. Yufrizal *et al.* [14], investigated the cutting angle and spindle speed on the surface roughness of ST 37. The study used variations in cutting angle (80°, 85°, 90°) and spindle speed (440, 540, 740 rpm). The results showed that the best surface roughness value was obtained at a cutting angle of 80° and a spindle speed of 740 rpm of 5.76 µm. The greater the tool's removal angle, the greater the surface roughness [15][16]. Fauzi *et al*. [17], studies the feeding parameters on the surface roughness of ST 40 using a CNC lathe. The study used variations of cutting speed (90; 120; 150 m/minute), feeding motion (0.15; 0.2; 0.25 mm/rev) and depth of cut (0.25; 0.5; 0.75 mm). The results showed that the best surface roughness value was obtained at a cutting speed of 150 m/minute, a feeding motion of 0.15 mm/rev and a depth of cut of 0.25 mm of 1.034 µm. The smaller the depth of cut and the feeding motion used, the better the surface roughness value produced.

Surface roughness is an essential factor in producing a product. Most medium-sized industrial players in the manufacturing sector ignore machining variables that impact the surface roughness of the product they want to produce. As a result, machine operators only rely on trial and error to obtain roughness values. This causes labor losses, operator time, and material losses in the industry. So, it is necessary to research the influence of machining variables on surface roughness. This research aims to determine the effect of variations in feed rate, cutting depth, and cutting angle on the optimum surface roughness of aluminum 6061 for the turning process with TNMG-B23 carbide chisels. This specimen can provide information and recommendations on using optimal machining process parameters to achieve surface roughness to make the machining process more efficient.

2 Research Methods

This research used solid 6061 aluminum alloy material with a diameter of 32 mm and a length of 200 mm. Some of the tools used in this research include the TY-1630S Conventional Lathe Machine, the TNMG-B23 Carbide Chisel, measuring tools, stationery attachments, the Olympus BX-53M Macro Microscope, and the MR-220 surface roughness tester. The surface roughness tester MR-220 as shown in Fig. 1.

Fig. 1. Surface roughness tester MR-220.

This study examines the effect of cutting angle, feed rate, and depth of cut on the surface roughness of objects using conventional lathes. The variables used in this study were classified as independent and dependent variables. . This research focuses on surface roughness as the dependent variable. The parameter level values were designed based on the reference cutting conditions of previous research and were adjusted by modifying the lathe parameters. Table 1 shows the designed parameter level values.

Table 1. Machining parameters level

Machining parameters	Parameter level	
	1	2
Spindle speed (rpm)	540	540
Feed rate (mm/min)	47.5	345.6
Depth of cut (mm)	1	3
Angle cut (°)	60	80

This research was conducted by providing three test parameters with two different levels for each test. The factorial design was created using Minitab 2019 to determine the order of experiments, as shown in Table 2. The test method used is a factorial design with two levels and three factors, so the number of experimental variations is 24 or 8 experimental variations. The way to apply the data processing method using the factorial design method is to change the tuning parameters to low and high levels according to the experimental design. The experiment results were carried out three times, and the average will later be determined to obtain optimal results.

Table 2. Desain experiment of machining parameters

Experiment run	Feed rate (mm/min)	Depth of cut (mm)	Angle cut (°)
Run-1	47.5	1	60
Run-2	47.5	3	60
Run-3	47.5	1	80
Run-4	47.5	3	80
Run-5	345.6	1	60
Run-6	345.6	3	60
Run-7	345.6	1	80
Run-8	345.6	3	80

3 Results and Discussion

Turning results with a conventional TY-1630S machine using a TNMG B-23 carbide and testing with a surface roughness measuring instrument were studied to determine the effect of each variable. From observations, information was obtained that surface roughness in the machining process was influenced by machining parameters, which included depth of cut (X1), feeding rate (X2), and cutting angle (X3). For this reason, a random factorial design experiment was planned using the Minitab 2019 application to avoid uniformity in the data obtained. Data from the results of the two-level factorial design experimental pattern as shown in Table 3. Then, from this data, a geometric drawing of the experiment can be created, which can be seen in Fig. 2.

Table 3. Results of the factorial design experiment pattern

Experiment run	Feed rate (mm/min)	Depth of cut (mm)	Angle cut (°)	Average surface roughness (µm)
Run-1	47.5	1	60	6.926
Run-2	47.5	3	60	7.995
Run-3	345.6	1	60	20.309
Run-4	345.6	3	60	21.029
Run-5	47.5	1	80	6.445
Run-6	47.5	3	80	7.436
Run-7	345.6	1	80	21.090
Run-8	345.6	3	80	21.280

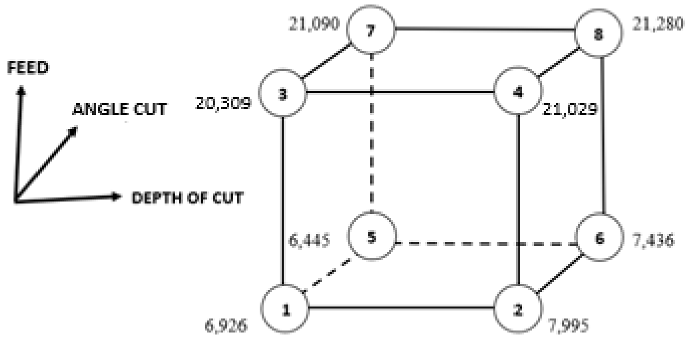
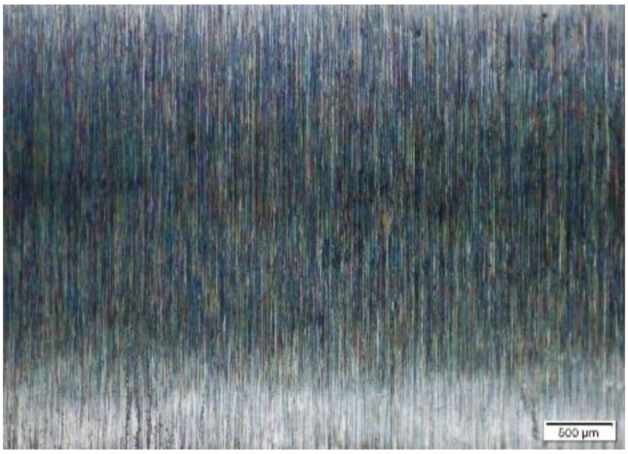


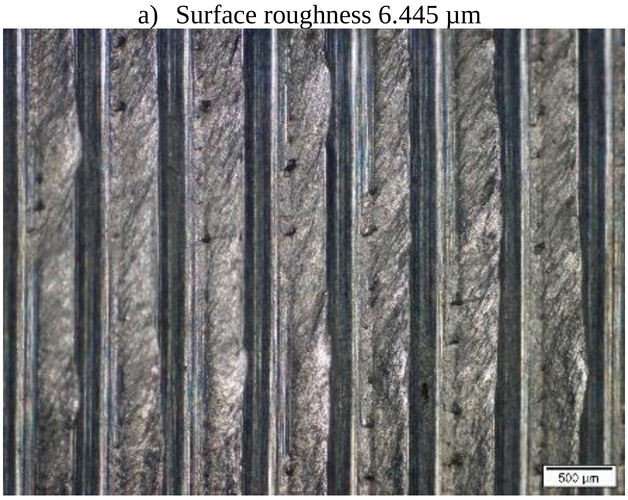
Fig. 2. Geometric results of the experiment.

Fig. 2 explains the results of the factorial design experimental pattern. The response changes from conditions 1 to 3, 2 to 4, 5 to 7, and 6 to 8 influenced the feeding rate parameter variable. The changes in response that occur from conditions 1 to 2, 3 to 4, 5 to 6, and 7 to 8 were resulted from the influence of variables on h of the cut parameter. The changes in response that occur from conditions 1 to 5, 2 to 6, 3 to 7, and 4 to 8 result from the influence of variables on the cutting angle parameters. Conditions 1 to 2 were where the cutting depth parameters are used at the upper level while the angle and feeding rate parameters were at the lower level. This condition showed an increase in surface roughness response from 6.926 µm to 7.995 µm. Condition to 3 are where the feeding rate parameters are used at the top level, while the angle and depth of cut parameters are at the bottom. This condition shows an increase in surface roughness response from 6.926 µm to 21.029 µm. Conditions 1 to 5 are where the cutting angle parameters are used at the top level, while the feeding rate and depth of cut parameters are at the bottom. This condition shows a decrease in surface roughness response from 6.926 µm to 6.445 µm. Conditions 2 to 4 are conditions where the feeding rate and depth of cut parameters are used at the top level while the cutting angle parameters are at the bottom level. This parameter shows an increase in surface roughness response from 7.995 µm to 20.309 µm. Conditions 2 to 6 are where the angle and depth of cut parameters are used at the top level while the feeding rate parameters are at the bottom. This parameter shows a decrease in surface roughness response from 7.995 µm to 7.436 µm. Conditions 3 to 4, where the cutting depth and feeding rate parameters were used at the upper level while the cutting angle parameters are at the lower level, showed a decrease in surface roughness response from 20.309 µm to 21.029 µm. Conditions 3 to 7, dictions 3 to 7 are where the cutting angle and feeding rate parameters are used at the upper level while the cutting depth parameters are at the lower level. This parameter shows an increase in surface roughness response from 21.029 µm to 21.090 µm. Conditions 4 to 8 are where the parameters of feed angle, depth of cut, and feeding rate are used at the top level. This parameter shows an increase in surface roughness response from 20.309 µm to 21.280 µm. Conditions 5 to 6 are where the depth of cut and cutting angle parameters are used at the top level while the feeding rate parameters are at the bottom. This condition shows an increase in surface roughness response from 6.445 µm to 7.436 µm. Conditions 5 to 7 are where the cutting depth parameters are used at the lower level, while the cutting angle and feeding rate parameters are at the upper level. This condition shows an increased surface roughness response from 6.445 µm to 21.090 µm. Conditions 6 to 8 are where the feeding rate, cutting angle, and depth of cut parameters are used at the top level. This parameter shows an increase in surface roughness response from 7.436 µm to 21.280 µm. Conditions 7 to 8 are where the depth of cut, cutting angle, and feeding rate are used at the top level. This condition shows an increased surface roughness response from 20.090 µm to 21.280 µm.

Fig. 4 shows the fractography results of the turning surface results from both surface roughness values (a) low and (b) high. Fig. 4 (a) results from turning using parameters of cutting depth of 1 mm, feed speed of 47.5 mm/minute, and cutting angle of 80º. Fig. 4 (b) is the result of turning using parameters of cutting depth of 3 mm, feed speed of 345.6 mm/minute, and cutting angle of 80º. Based on Fig. 4, it can be seen that the surface results that have a low roughness value are better than those with a high roughness value. Following ISO 1302, the roughness value of 6.445 µm is included in the N9 classification.



a) Surface roughness 6.445 µm



b) Surface roughness 21.280 µm

Fig. 4. Fractography of turning surface results.

Based on the factorial regression test, the influence value of each factor is presented in Table 4. Analysis of the table of factor influence (X1) 0.3825, factor influence (X2) 13.726, factor influence (X3) -0.002, factor influence (X1*X2) -0.6475, factor influence (X1*X3) 0.2080, influence (X2*X3) 0.5180, and influence (X1*X2*X3) 0.2470. Therefore, parameter (X2) is the parameter that has the highest influence on the turning process. The optimal process parameters in this study were a cutting depth of 1 mm, a feed speed of 47.5 mm/min, and a cutting angle of 80º. These parameters produce a surface roughness value of 6.445 µm or N9 according to ISO 1302.

Table 4. Estimated regression coefficients for surface roughness

Term	Effect	Coef	SE Coef	T-value	P-value
Constant		14.06	*	*	*
X1	0.3825	0.1913	*	*	*
X2	13.726	6.863	*	*	*
X3	-0.002000	-0.001000	*	*	*
X1*X2	-0.6475	-0.3237	*	*	*
X1*X3	0.2080	0.1040	*	*	*
X2*X3	0.5180	0.2590	*	*	*
X1*X2*X3	0.2470	0.1235	*	*	*

4 Conclusion

1) In turning Al 6061 with the observation variables of cutting depth, feed speed, and cutting angle, the variable that has the most influence on surface roughness is the feed speed. It can be seen that the interaction effect on the factor (X2) of the feed speed causes an interaction effect of 13.726. The second factor influencing the surface roughness value is the variable factor (X1) depth of cut, causing an interaction effect of 0.3825.
2) In this study, the lowest surface roughness value was 6.445 µm at a cutting depth variable of 1 mm with a feed speed of 47.5 mm/min and a cutting angle of 80°. In comparison, the highest surface roughness value was 21.280 µm at the variable cutting depth of 1mm with a feed speed of 345.6 mm/min and a cutting angle of 80° for further research.

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