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Analysis of Cutting Parameters Affecting the Surface Roughness Value of Amutite Steel With A 50 mm Diameter Facemill on the Fu100 Lagoon Milling Machine Using Statistical Methods

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The Lagun FU100 Milling Machine (LFR 26) is a type of milling machine located at the Bandung Manufacturing Polytechnic. There is a surprising opinion that the Lagun Milling machine is rarely used, both for student academic activities and production purposes. Generally milling machines can achieve a surface roughness of 0.32-25 µm. Appendix 3 shows the results of the surface roughness of the grinding results. So this research was carried out to prove that this machine can reach surface roughness standards, and also to state that this machine is still suitable for use for production activities or student academic activities and to prove that this machine can still produce products of good quality. In this study, the three parameters evaluated were cutting speed, feed rate, and depth of cut. Through experiments and statistical analysis, it was found that RPM at a medium level produced the lowest roughness value of 0.340, while cutting depth at a high level produced the smoothest surface roughness with a value of 0.330. Feed rate at the medium level also shows the lowest surface roughness results with an average of 0.330. The research results show that the smoothest surface that can be produced is 0.2883, this value is at level N4. In addition, the Lagun FU100 milling machine was declared suitable for use in achieving the desired roughness value, demonstrating the ability of this machine to produce surfaces with the expected quality standards.

1. Introduction

Milling machines are essential tools in manufacturing, used to produce flat surfaces on workpieces through the action of rotating cutting tools. These machines are favored in production environments for their versatility, enabling a range of manufacturing processes. The milling process involves the interaction between the rotating cutting tool and the workpiece, where variations in machining parameters—such as cutting speed, depth of cut, and feed rate—can significantly impact the surface roughness of the finished product. Proper regulation of these parameters is critical to achieving surface finishes that meet established quality standards.

Evaluating the performance of a milling machine typically involves assessing various parameters, including mechanical and electrical conditions, the effectiveness of the cooling system, the sharpness and suitability of the cutting tool, and the machine's ability to achieve the desired surface roughness. Surface roughness is a key indicator of a machine's suitability for continued use, particularly in production and educational settings.

At the Bandung Manufacturing Polytechnic, the FU100 Lagun Milling Machine (LFR 26) is one such machine used for both student academic activities and production purposes. Despite its capabilities, the machine is reportedly underutilized. Generally, milling machines can achieve surface roughness within the range of 0.32-25 μm, but there is a need to verify whether this machine can consistently meet these standards. This study aims to analyze the impact of milling parameters—specifically spindle speed, feed rate, and depth of cut—on the surface roughness of amutite steel using a facemill cutter. The research will employ the Taguchi method to identify optimal parameter combinations and Anova to determine the most influential factors affecting surface roughness.

The primary objectives of this study are to find the optimal combination of milling parameters for achieving the desired surface roughness on amutite steel, to assess the influence of each parameter, and to determine the machine's suitability for both production and educational purposes based on its ability to produce high-quality surface finishes. The findings of this research are expected to provide valuable insights for improving product quality in the manufacturing industry, particularly in processes involving the machining of amutite steel with carbide facemill cutters.

2. Method

This study investigates the influence of milling parameters on the surface roughness of amutite steel using the FU100 Lagun Milling Machine. The research follows a structured approach, beginning with the identification of the problem and a thorough literature review. The problem, along with the research objectives and scope, was defined with a focus on the surface roughness of amutite steel machined using a 50 mm diameter facemill cutter. To design the experiments, the Taguchi method was employed, incorporating three key factors: spindle speed, depth of cut, and feed rate. Each factor was tested at three different levels, resulting in a total of nine experiments.

For the experimental setup, the FU100 Lagun Milling Machine (LFR26) was selected due to its availability and suitability for the specific requirements of the study. A 50 mm diameter facemill cutter equipped with Korloy SNMX 1206 ANN MM inserts was utilized for machining the workpieces, which were made of amutite steel blocks measuring 50×75×90 mm. These materials were chosen because of their common use in precision tooling applications. To measure the surface roughness, initial assessments were performed using a Rugotest, followed by more precise measurements with a Mitutoyo Surface Roughness Tester.

The experimental procedure involved the preparation of the workpieces by facing them to ensure flat surfaces, after which the experiments were conducted according to the predefined levels of spindle speed, depth of cut, and feed rate. Surface roughness was initially assessed using Rugotest, and the data was further validated using the Surface Roughness Tester for greater accuracy.

For data analysis, the Taguchi method was applied to identify the optimal combination of milling parameters that influence surface roughness. If the collected data followed a normal distribution, ANOVA was employed to evaluate the significance of each factor and their interactions on surface roughness. In cases where the data did not meet the normality assumptions, the Kruskal-Wallis test was used as a non-parametric alternative to compare the medians across different parameter levels, helping to identify any significant differences in surface roughness.

3. Result and Discussion

This study collected data from the workpiece cutting process using parameter combinations determined by the Taguchi method, focusing on spindle speed (rpm), depth of cut (DOC), and feed rate. The cutting process was performed with various combinations of these parameters to observe their effects on the measured response, specifically the surface roughness of the workpiece. To ensure accuracy and minimize variability, each parameter combination was tested three times. The results from these three replications provided a reliable dataset for analysis.

Table 4. 1Surface roughness results after comparison with rugotest

Rpm	Doc	F	REPLIKASI		
			1	2	3
910	0,6	220	N7	N7	N7
910	1,2	365	N7	N7	N7
910	1,8	550	N7	N8	N7
1280	0,6	365	N7	N7	N7
1280	1,2	550	N7	N6	N7
1280	1,8	220	N6	N6	N6
1700	0,6	550	N6	N6	N7
1700	1,2	220	N7	N6	N6
1700	1,8	365	N7	N6	N7

Table 4.1 presents the roughness levels of workpieces after machining with specific parameter combinations. Initially, roughness was assessed using the Rugotest method, which relies on visual and tactile evaluation. However, due to its subjective nature, additional measurements were taken using a surface roughness tester, providing more accurate and objective results.

Table 4. 2 Results of surface roughness with 1st repetition

Pengulangan ke-1							
Percobaan Ke-	Rpm	Doc	Feed	Titik		Rata-rata (μm)	Kekasaran
	(rev/min)	(mm)	(mm/min)	A (μm)	B (μm)		
1	910	0,6	220	0,71	0,69	0,7	N6
2	910	1,2	365	1,3	1,28	1,29	N7
3	910	1,8	550	1,36	1,37	1,365	N7
4	1280	0,6	365	1,1	1,12	1,11	N6
5	1280	1,2	550	0,97	1,08	1,025	N6
6	1280	1,8	220	0,4	0,43	0,415	N5
7	1700	0,6	550	0,54	0,56	0,55	N5
8	1700	1,2	220	0,27	0,29	0,28	N4
9	1700	1,8	365	0,14	0,25	0,195	N4

Table 4. 3 Results of surface roughness with 2nd repetition

Pengulangan ke-2							
Percobaan Ke-	Rpm	Doc	Feed	Titik		Rata-rata	Kekasaran
	(rev/min)	(mm)	(mm/min)	A (µm)	B (µm)	(µm)	
1	910	0,05	220	0,69	0,7	0,695	N6
2	910	0,1	365	1,3	1,33	1,315	N7
3	910	0,15	550	1	0,87	0,935	N6
4	1280	0,05	365	1,09	1,11	1,1	N6
5	1280	0,1	550	1	0,96	0,98	N6
6	1280	0,15	220	0,4	0,45	0,425	N5
7	1700	0,05	550	0,85	0,86	0,855	N6
8	1700	0,1	220	0,25	0,28	0,265	N4
9	1700	0,15	365	0,29	0,25	0,27	N4

Table 4. 4 Surface roughness value with 3rd repetition

Pengulangan ke-3							
Percobaan Ke-	Rpm	Doc	Feed	Titik		Rata-rata	Kekasaran
	(rev/min)	(mm)	(mm/min)	A (µm)	B (µm)	(µm)	
1	910	0,05	220	0,75	0,74	0,745	N6
2	910	0,1	365	1,3	1,31	1,305	N7
3	910	0,15	550	0,96	0,93	0,945	N6
4	1280	0,05	365	1,02	1,06	1,04	N6
5	1280	0,1	550	0,96	0,99	0,975	N6
6	1280	0,15	220	0,39	0,36	0,375	N5
7	1700	0,05	550	0,9	0,88	0,89	N6
8	1700	0,1	220	0,28	0,26	0,27	N4
9	1700	0,15	365	0,21	0,26	0,235	N3

From the results of measurements carried out three replications, the average surface roughness value for 9 combinations of machining parameters was obtained as follows:

Table 4. 5 The result of surface roughness using surface roughness tester

Percobaan Ke-	Rpm	Doc	Feed	Rata-rata (µm)	Kekasaran
	(rev/min)	(mm)	(mm/min)		
1	910	0,05	220	0,7133	N6
2	910	0,1	365	1,3033	N7
3	910	0,15	550	1,0817	N6
4	1280	0,05	365	1,0833	N6
5	1280	0,1	550	0,9933	N6
6	1280	0,15	220	0,4050	N5
7	1700	0,05	550	0,7650	N6
8	1700	0,1	220	0,2717	N4
9	1700	0,15	365	0,2333	N4

The results of data collection using a surface roughness tester can be seen in Appendix A

Data Uniformity Test

1. Average x

$X=\sum_{i=1}^{n} xi$

$X = \frac{0,7+1,29+1,365+\cdots+0,235}{27}$

$X = \frac{20,55}{27}$

X = 0.761111111

2. Standard deviation

$SD = \sqrt{\frac{\sum(xi-x)^2}{n-1}}$

$SD = \sqrt{\frac{(0,7-0,76111111)^2+(1,29-0,76111111)^2+(1,365-0,76111111)^2+\cdots+(0,235-0,76111111)^2}{27-1}}$

$SD = \sqrt{\frac{3,806}{26}}$

SD = 0.383

3. Limits of control

BKA = x + 3.SD

BKA = 0.761111111+ 3(0.383)

BKA = 1.91

BKB = x - 3.SD

BKB = 0.76111111- 3(0.383)

BKB = -0.39

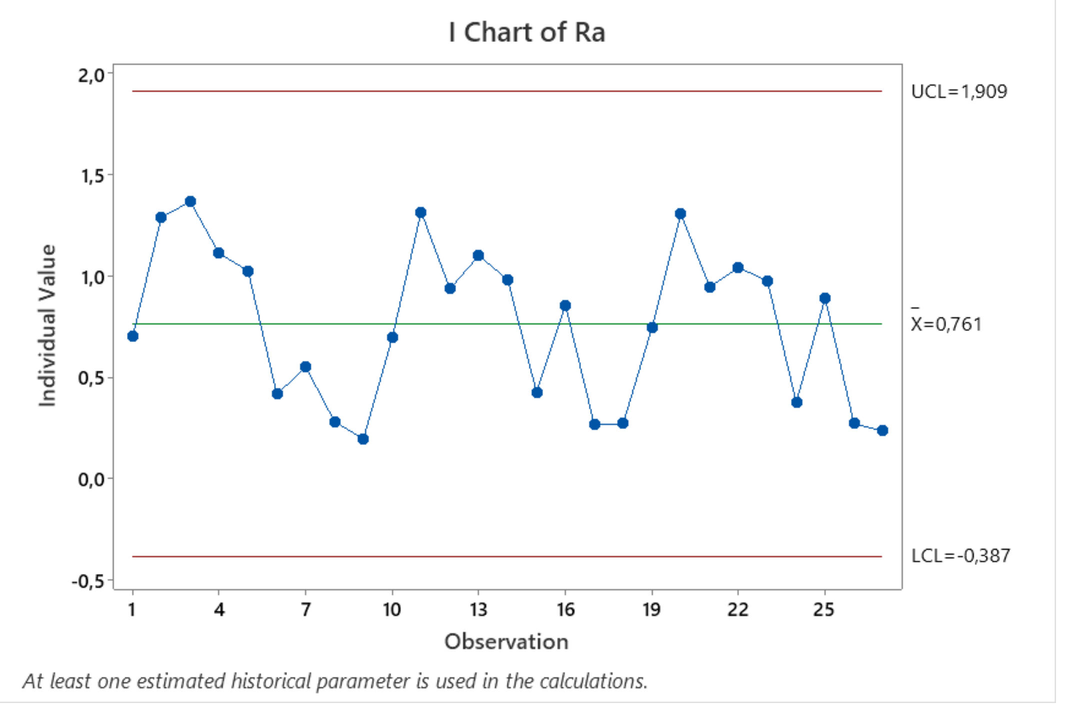

Figure 4. 1 Data uniformity test results with min-tab software

Figure 4.1 shows a surface roughness control graph created using Minitab software. These graphs are used to monitor the stability of the manufacturing process and identify possible problems. From the picture, it can be concluded that the machining process is controlled and stable. This is because all individual grades fall between UCL and LCL. There are no points that are outside the control boundaries, indicating that there are no problems with the process.

Data Normality Test

After data collection, a normality test is carried out to find out whether the distributed data is normal or not. The data normality test was carried out using Minitab software using the Kolmogorov-Smirnov method. So the following hypothesis is used:

H0 = Normal distributed data

H1 = Abnormally distributed data

P-Value > 0.05 then H0 is accepted, H1 is rejected

P-Value < 0.05 then H0 is rejected, H1 is accepted

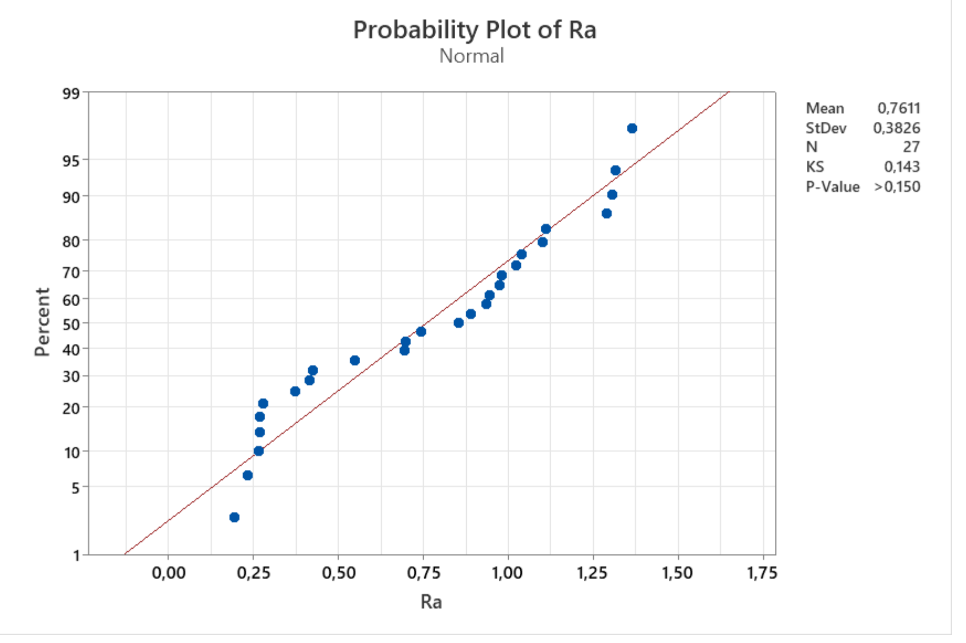

Figure 4. 2 Surface roughness normality test results

Figure 4.2 displays the results of a normality test on the "roughness" variable using Minitab software. The key statistics include a mean roughness of 0.7611, a standard deviation of 0.3876, and a sample size (N) of 27. The Kolmogorov-Smirnov (KS) value is 0.143, and the P-Value is less than 0.150.

Since the P-Value is greater than 0.05, the null hypothesis (H0) is accepted, indicating that the roughness data is normally distributed. This is further supported by the Normal Probability Plot, where the data points closely follow a straight line, confirming the normal distribution. As a result, statistical methods like ANOVA, which assume normality, can be applied to this data.

Anonymous

Table 4. 6 Anova results using minitab

Analysis of Variance						
Source	DF	Adj SS	Adj MS	F-Value	P-Value	Persentase
RPM	2	1,7304	0,8652	45,72	0	45%
DOC	2	0,476	0,23802	12,58	0	13%
FEED	2	1,2213	0,61063	32,27	0	32%
Error	20	0,3785	0,01892			10%
Lack-of-Fit	2	0,1775	0,08874	7,95	0,003	5%
Pure Error	18	0,201	0,01116			5%
Total	**26**	**3,8062**				

From **table 4.6** it can be concluded that:

Rpm

H0: Rpm factor has no effect on the Roughness Value

H1: Rpm factor affects the Roughness Value

P-Value = 0,000 --> P-Value < Alfa (5%) --> Tolak H0

"The difference in level at Rpm has been shown to have an effect on the Roughness Value"

Doc

H0: Doc factor has no effect on the Roughness Value

H1: Doc factor affects the Roughness Value

P-Value = 0,000 --> P-Value < Alfa (5%) --> Tolak H0

"The difference in levels in Doc is proven to have an effect on the Roughness Score"

Feed

H0: Feedrate factor has no effect on the Roughness Value

H1: Feedrate factor affects the Roughness Value

P-Value = 0,000 --> P-Value < Alfa (5%) --> Tolak H0

"Level differences in the Feed are shown to have an effect on the Roughness Value"

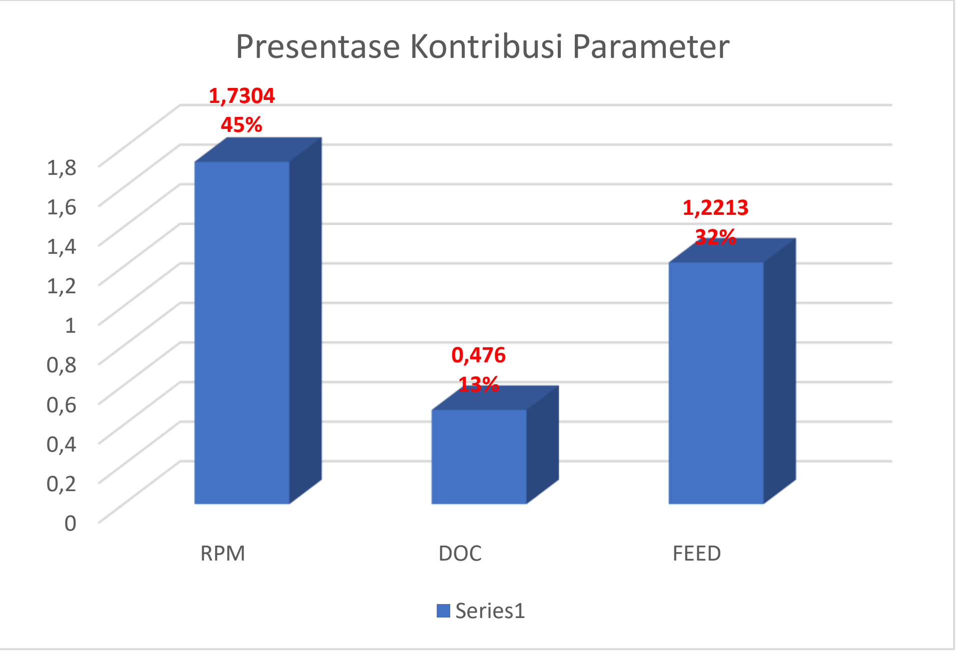

Figure 4. 3 Contribution percentage parameter

Figure 4.1 visually compares the three categories: RPM, DOC, and FEED. RPM has the highest value at 1.7304, contributing 45% to the total, making it the most significant factor. The order of influence from highest to lowest is RPM, FEED, and DOC. Following the ANOVA analysis, a Tukey test was conducted to compare the average scores across these levels.

Table 4. 7 Tukey Pairwise Comparisons: RPM

Tukey Pairwise Comparisons: RPM					
Grouping Information Using the Tukey Method and 95% Confidence					
RPM	N	Mean	Grouping		
910	9	1,03278	A		
1280	9	0,82722		B	
1700	9	0,42333			C
Means that do not share a letter are significantly different.					

Table 4.7 shows that the Low level (910) produces an average Roughness Value = 1.03278, Medium (1280) produces an average Roughness Value = 0.82722, High (1700) produces an average Roughness Score = 0.42333.

Table 4. 8 Tukey Pairwise Comparisons: DOC

Tukey Pairwise Comparisons: FEED					
Grouping Information Using the Tukey Method and 95% Confidence					
FEED	N	Mean	Grouping		
550	9	0,946667	A		
365	9	0,873333	A		
220	9	0,463333		B	
Means that do not share a letter are significantly different.					
Tukey Pairwise Comparisons: DOC					
Grouping Information Using the Tukey Method and 95% Confidence					
DOC	N	Mean	Grouping		
1,2	9	0,856111	A		
0,6	9	0,853889	A		
1,8	9	0,573333		B	
Means that do not share a letter are significantly different.					

Table 4.8 shows that the Low level (0.6) produces an average Roughness Value = 0.853889, Medium (1.2) produces an average Roughness Score = 0.856111, High (1.8) produces an average Roughness Score = 0.573333.

Table 4. 9 Tukey Pairwise Comparisons: FEED

Table 4.9 shows that the high level (550) produces an average Roughness Value = 0.946667, Medium (365) produces an average Roughness Value = 0.873333, low (220) produces an average Roughness Score = 0.463333.

4. Conclusion

This study successfully identified the optimal combination of parameters to improve the surface roughness of amutite steel using the Taguchi method. ANOVA analysis revealed significant differences among the parameters, with RPM, depth of cut, and feed rate each impacting the surface roughness differently. The smoothest surface was achieved with high RPM, low feed rate, and optimal depth of cut, using carbide inserts. The Lagun FU100 milling machine proved effective in achieving the desired roughness in amutite steel. Additionally, it was found that a cutting speed of 270 m/min yielded the lowest average roughness. However, insert wear was noted in the

9th experiment, indicating the need for timely replacement to maintain accuracy and consistency.

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