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Effect of Cutting Parameter Toward The Surface Roughness Applied In Turning Tool Steel Material

Gatot Setyono[1*], Slamet Riyadi[2], Muharom[3], Ong Andre Wahyu Riyanto[4], Sigit Pratama[5]
[1,2,3]Study Program of Mechanical Engineering, Wijaya-Putra University (UWP)
[4]Study Program of Industrial Engineering, Wijaya-Putra University (UWP)
[5]Department of Mechanical Engineering, Adhi-Tama Institute of Technology Surabaya (ITATS)
[1,2,3,4]Jl. Raya Benowo No. 1-3 Surabaya 60197, Indonesia
[5]Jl. Arief Rahman Hakim No.100 Surabaya 60117, Indonesia
E-mail: gatotsetyono@uwp.ac.id[1], slametriyadi@uwp.ac.id[2], muharom@uwp.ac.id[3], ongandre@uwp.ac.id[4], sigitpratama@gmail.com[5].

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Abstrak

Pada penelitian ini, pengaruh radius ujung pahat dan parameter proses pemotongan terhadap kwalitas proses pemesinan secara eksperimen terhadap penggunaan material baja SKD 11. Variasi radius yang digunakan adalah 0.80 mm, 1.20 mm, 1.60 mm dan parameter proses pemotongan antara lain kecepatan potong, kecepatan pemakanan dan kedalaman potong. Metode ANOVA digunakan pada penelitian ini, bertujuan untuk menanalisa parameter proses pemotongan terhadap kualitas permukaan bendan kerja dan gaya potongan. Analisa penelitian ini menghasilkan kondisi tertentu, bahwa *feed rate* memiliki efek yang siknifikan terhadap kualitas permukaan. Akan tetapi hal tersebut bertolak belakang dengan parameter kedalaman potong yang berpengaruh terhadap gaya potong. Penelitian ini juga mengamati pengaruh radius ujung pahat terhadap kualitas permukaan yang optimal saat menggunakan radius 0.80 mm. Pemodelan regresi orde dua yang digunakan pada analisa ini menunjukkan tingkat keakurasian yang sangat bagus dengan nilai korelasi keakurasiannya kisaran 96% hingga 98%.

Keywords:
cutting parameters;
tool tip radius;
tool steel;
anova.

Abstract

In this study, the effect of the tool-tip radius and cutting process parameters on the quality of the machining process experimentally on the use of SKD 11 tool steel material. Several radius (0.80 mm, 1.20 mm, 1.60 mm) and the parameters of the cutting process, specifically feed rate, cutting speed, and depth of cut. The ANOVA method used in this study aims to analyze the cutting process parameters on the surface quality of the workpiece and the cutting force. The analysis of this research results in certain conditions in which the feed rate significantly affects surface quality. However, this is contrary to the depth of cut parameter, which affects the cutting force. This study also observed the effect of the tooltip radius on the optimal surface quality when using a 0.80 mm radius. The second-order regression modeling used in this analysis shows a very good level of accuracy, with the correlation value of accuracy ranging from 96% to 98%.

***Penulis korespondensi:**
Gatot Setyono
E-mail: gatotsetyono@uwp.ac.id

1. Introduction

Surface roughness is an essential factor for the machine tool operation process because it is closely related to the importance of the role of the machining process components. The workpiece has failed due to surface discontinuity during the manufacturing process or continuous corrosion. Therefore, the importance of this research has to analyze the impact of surface roughness on friction, wear, and fatigue of spare parts [1]. Machining processes in the modern industry have focused on obtaining maximum output quality. These qualities include the accuracy of the workpiece dimensions, surface finishing processes, optimal cutting temperatures, optimal production Levels, minimal wear of cutting tools, economical machining process costs, and increased work the results of friendly products to the environment. Cutting temperature and surface roughness are crucial characteristics in all sectors and provide a dominant aspect of assessing the accuracy of machining processes in standard turning [2]. This time, the analysis process is to define the size relative to the cutting process to produce an optimal product, especially the tiny Level of surface roughness. This research uses AL-7075-T6 material. The machining process is carried out on non-conventional machines to produce fine surface roughness. The experiment determines the feed rate, cutting speed, machining strategies, and stepover using the Taguchi-L16 data analysis method. The study identified an equal 95% confidence Level with ANOVA analysis for the average surface roughness (Ra) [3].

The study analyzes the impact of cutting tool coating materials and cutting parameters. During the experiment, the machining process used AISI-52100 steel material. This research has divided the characteristics of cutting tools with coated (TiCN-TiN) and uncoated. At the same time, the insertion geometry and substrate composition are set to the same value. The mathematical method was analyzed using RSM. The data analysis method used ANOVA to determine the parameters of cutting on the value of cutting force and surface roughness in the machining process. The study results describe that the feed rate exciting influences the surface quantity of the resulting product. However, the quality of the depth of a cut can affect the cutting force. The machining process results show that the TiCN-TiN coating can reduce the surface roughness of the workpiece. The accuracy of the roughness values obtained by 2nd-order regression modeling is 95% to 97% [4]. This experiment analyzes the spindle speed, depth of cut, feed rate, and flow rate of cutting fluid as cutting parameters that significantly affect the Level of flank wear and surface roughness using a typical TiAIN coating cutting tool. Analysis of tool roughness and wear rate using the Taguchi method application. This machining process uses mild steel material with type AISI-1015. The depth of cut during the machining process is a significant factor in the roughness of a product with a capacity of 67.5%. However, the feed rate, flow rate of cutting fluid, and cutting speed did not significantly affect the increase in surface roughness. The optimum Level of surface roughness results from a low feed rate, medium cutting speed, small depth of cut, and flow rate significant cutting. On the other hand, the cutting fluid flow rate and cutting speed with a capacity of 23% and 45.6%, respectively, represent prominent variables on the Level of tool wear. In comparison, the minimal tool wear rate is determined by the minimum parameters of cutting speed, medium depth of cut, low feed rates, and extensive flow rates cutting [5].

The research focuses on the impact of cutting parameters on surface roughness and tool wear characteristics. The research used HSS material type 300M and uses a carbide layer chisel with a lathe. It is recommended that cutting parameters such as cutting speed can significantly impact tool life, cutting temperature, and cutting force on the Level of surface roughness of the machining result. The several main procedures of tool wear rate are adhesion, abrasion, diffusion, and oxidation. In addition, titanium oxide can reduce friction against the workpiece increase the hardness in the cutting area and surface wear so that these conditions can minimize the wear of Ra [6]. This study investigates the machining process, including the feed rate, tool radius, and cutting process speed to the roughness Level. The workpiece turning process was tested using the dry method, variations in cutting speed, feed speed, and chisel type. The investigation results show that the type of cutting tool and the rate of the feeding process significantly affect the final surface roughness of a product. The results show that the small radius tool-type factor used can reduce the hardness of the workpiece. On the other hand, the large radius chisel type will impact increasing the workpiece hardness Level. This analysis shows that Inconel 718 can show more accurate results, so it can be used to investigate the integrity of the workpiece surface against the life of the tool used in the machining process [7]. This study demonstrated the impact of spindle speed, feed rate, depth of cut, and coating material on surface roughness with TiAlN/WC-C and MRR type tools. The material used is AISI-1015 with a CNC lathe, in this study using the Taguchi L9-OA data analysis method. It was used to reduce the Level of MRR and surface roughness of the workpiece. The predictive equation modeling has to determine surface roughness capacity and MRR. The results showed that TiAlN/WC-C has a natural effect on the output parameters of the machining process [8]. The research used AISI-1040 type steel material. The data analysis method of the machining process used Taguchi-L16 to determine depth of cut, feeding rate of the process, and cutting speed. The machine used in this experiment is a CNC-lathe. The cutting chisel used is a diamond type. The machining process used dry type. The results of experiments that have been investigated by the Taguchi method that these three factors dominantly affect the Level of roughness of the workpiece with an accuracy value of 94% to 95% [9].

Current research will be carried out with variations in feed rate, cutting speed, and depth on surface roughness in the machining process. The data analysis method used is Taguchi L27-AO. The machining process uses SKD-11 material (medium carbon steel), TiCN carbide coating tool and medium type CNC-lathe. Experimental data processing is done by predicting randomly. The Level of accuracy can be determined based on Taguchi estimates and experimental calculations. Furthermore, the results are expected to be more accurate and optimal.

2. Method

2.1. The substance of workpiece and cutting tools.

In this experiment, the material used is SKD-11, shaped like a round rod with a diameter of 25.4 millimeters and a length of 90 millimeters, it was medium-grade carbon steel containing 0.3%-0.6% carbon which can still be conditioned for the hardening process. It was shown in table 1. The tool used is an insert of 55 degrees TiCN carbide coating with a relief angle of 15 degrees, and 4.76-millimeter thickness, shown in table 2.

Table 1. Chemical composition of material workpiece [10].

Elemnet	C	Mn	Si	S	P	N
Weight (%)	0.4	1.70	0.60	0.060	0.060	0.010

Table 2. Chemical composition of tool insert [11].

Elemnet	Al	Ti	N	W	C	Cl	Co
Weight (%)	10.31	30.25	37.92	3.65	16.92	0.57	0.39

Table 3. Parameter of machining process

No	Parameter	Symbol	Unit	Level 1	Level 2	Level 3
A	Depth of cut	a	mm	0.50	0.75	1.00
B	Cutting speed	Vc	m/min	60	90	120
C	Feed rate	f	mm/rev	0.10	0.15	0.20
D	Tool tip radius	r	mm	0.80	1.20	1.60

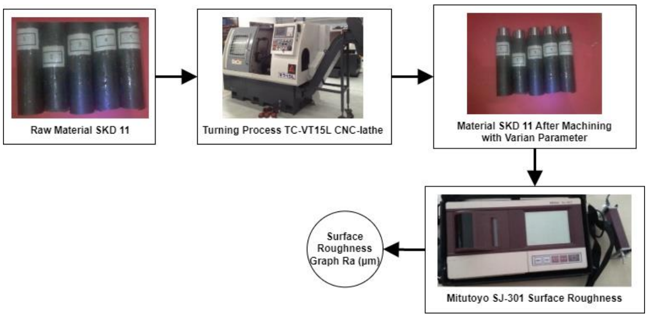

Figure 1. Surface roughness test process details.

2.2. The machining parameters

The machining process mechanism required several parameters, such as tool geometry and cutting variables. Several factors can determine the optimal and stable quality of the machining process, and it was very significant to pay attention to the combination of parameters of the depth of cut, feed rate and cutting speed that have an impact on surface roughness and tool life. CNC lathes have been widely recognized for their function and role in making a component, and they got optimal cutting and feeding quality. It is necessary to have quality components and machines that can operate optimally. The selection of components in question is the influence of the workpiece feeding [12], [13].

The turning process was carried out in wet conditions using a Fanuc Oi-Mate TC-VT15L type CNC-lathe. The experimental method used in this research is the factorial experimental method. The factorial experiment is a method that is widely used in experiments that aim to improve the quality of products and processes simultaneously to keep costs and resources to a minimum. This method is used for the Layout formulation in the test, knowing the optimal conditions of the machining parameters. Factorial experiments have the advantage of being able to see all combinations. Controlled factors are factors that are determined or controlled during the design stage. In this study, the controlled factors used are feed-rate, depth of cut, and cutting-speed, as shown in table 3.

Table 4. Predicted values and Ra experimental modeling

Num of Tests	Parameter				Code
	A	B	C	D	
1	L_1	L_1	L_1	L_1	$A_{L1}B_{L1}C_{L1}D_{L1}$
2	L_1	L_1	L_2	L_2	$A_{L1}B_{L1}C_{L2}D_{L2}$
3	L_1	L_1	L_3	L_3	$A_{L1}B_{L1}C_{L3}D_{L3}$
4	L_1	L_2	L_1	L_2	$A_{L1}B_{L2}C_{L1}D_{L2}$
5	L_1	L_2	L_2	L_3	$A_{L1}B_{L2}C_{L2}D_{L3}$
6	L_1	L_2	L_3	L_1	$A_{L1}B_{L2}C_{L3}D_{L1}$
7	L_1	L_3	L_1	L_3	$A_{L1}B_{L3}C_{L1}D_{L3}$
8	L_1	L_3	L_2	L_1	$A_{L1}B_{L3}C_{L2}D_{L1}$
9	L_1	L_3	L_3	L_2	$A_{L1}B_{L3}C_{L3}D_{L2}$
10	L_2	L_1	L_1	L_1	$A_{L2}B_{L1}C_{L1}D_{L1}$
11	L_2	L_1	L_2	L_2	$A_{L2}B_{L1}C_{L2}D_{L2}$
12	L_2	L_1	L_3	L_3	$A_{L2}B_{L1}C_{L3}D_{L3}$
13	L_2	L_2	L_1	L_2	$A_{L2}B_{L2}C_{L1}D_{L2}$
14	L_2	L_2	L_2	L_3	$A_{L2}B_{L2}C_{L1}D_{L2}$
15	L_2	L_2	L_2	L_1	$A_{L2}B_{L2}C_{L3}D_{L1}$
16	L_2	L_3	L_1	L_2	$A_{L2}B_{L3}C_{L1}D_{L2}$
17	L_2	L_3	L_2	L_1	$A_{L2}B_{L3}C_{L2}D_{L1}$
18	L_2	L_3	L_3	L_2	$A_{L2}B_{L3}C_{L3}D_{L2}$
19	L_3	L_1	L_1	L_1	$A_{L3}B_{L1}C_{L1}D_{L1}$
20	L_3	L_1	L_2	L_2	$A_{L3}B_{L1}C_{L2}D_{L2}$
21	L_3	L_1	L_3	L_3	$A_{L3}B_{L1}C_{L3}D_{L3}$
22	L_3	L_2	L_1	L_2	$A_{L3}B_{L2}C_{L1}D_{L2}$
23	L_3	L_2	L_2	L_3	$A_{L3}B_{L2}C_{L2}D_{L3}$
24	L_3	L_2	L_3	L_1	$A_{L3}B_{L2}C_{L3}D_{L1}$
25	L_3	L_3	L_1	L_3	$A_{L3}B_{L3}C_{L1}D_{L3}$
26	L_3	L_3	L_2	L_1	$A_{L3}B_{L3}C_{L2}D_{L1}$
27	L_3	L_3	L_3	L_2	$A_{L3}B_{L3}C_{L3}D_{L2}$

2.3. Workpiece surface roughness

Surface roughness is the arithmetic mean deviation from the surface mean line. This definition is utilized to specify the average value of the surface roughness. In the manufacturing industry, the surface of the workpiece has different surface roughness values, and it depends on the needs of the tool to be used in the machining process. Surface roughness values have different quality values (N); surface roughness quality values have been classified according to ISO standards, where the smallest value is N_1 which has a value (Ra) of 0.025 µm, and the highest is N_{12} which has a value (Ra) of 50 µm [14].

This research uses the Mitutoyo SJ-301 surface roughness measuring instrument, and this tool is ISO standard which could measure to observe the surface roughness with optimal quality. This Surface Roughness tester can show some of the data are the parameter values and the graph on the surface roughness. The surface roughness measuring instrument can be seen in Figure 1.

2.4. Experimental design

In this research, three process parameters were selected. One process parameter has two Levels. The experimental design was determined using the Taguchi method [13]. The experiment was carried out randomly with several replications to overcome the disturbance parameters during the machining process, as shown in Table 4.

2.5. S/N Ratio design prediction

The implementation of the engineering system is determined by manipulating the production factors, which can be carried out in three categories, namely the control factors that affect the process on the variables measured by the signal to disturbance ratio, the cue factors that do not affect the S/N ratio or the process and the factors that do not affect S/N ratio and process average [15].

2.6. Research process

The first stage of this research begins with collecting reference data from national, international journals, proceedings, and literature books relevant to the research topic. In the second stage, we will make preparations for selecting materials, cutting parameters and the machine used. In the third stage, we carry out the work process based on variations in data collection that have been determined in the laboratory. In the fourth stage, we perform calculations based on existing data collections, and then the data analysis process is carried out using linear regression comparisons. The fifth stage of the results of the data analysis resulted in the conclusions of this study, as shown in Figure 2.

This study uses an experimental method. Experimental design is the simultaneous evaluation of two or more factors or parameters on their ability to affect the average yield and or variability of the combined results of the characteristics of a particular product or process. It determines the effect of factors or parameters on the average results effectively, and an analysis is carried out to determine which factors are influential and to know the maximum results obtained. The experimental method used in this research is the factorial experimental method. The factorial experiment is a method widely used in experiments that aim to improve the quality of products and processes simultaneously to keep costs and resources to a minimum. This method is used for the Layout formulation in the test, knowing the optimal conditions of the machining parameters and knowing the performance of roughness surface. Factorial experiments have the advantage of seeing all the existing combinations.

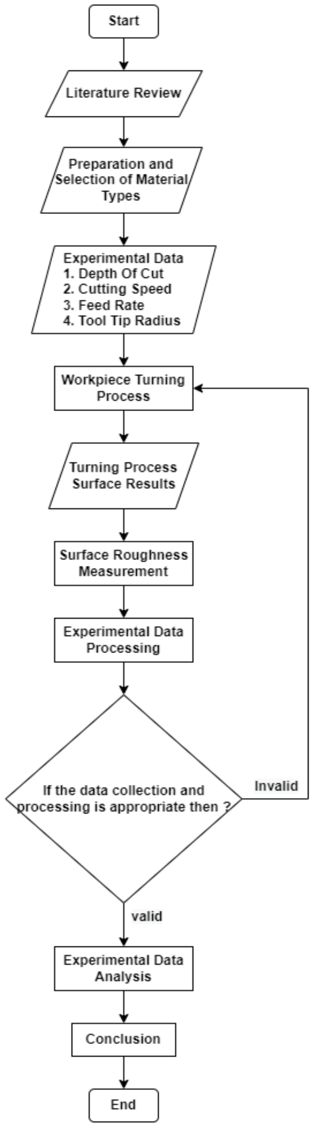

Figure 2. Process of Research.

3. Result And Discussion

In this research, the Taguchi method has been used to show that the desired value represents the signal while the unwanted value represents the nature of the noise output. Taguchi's method utilizes the S/N ratio to estimate deviations from quality characteristics rather than the desired value. The test data for the S/N ratio values, and the surface roughness values are shown in Table 5. The S/N values and surface roughness are used in the L-27 orthogonal arrangement. Factor A, B, C and D are placed in rows 1, 2, 5 and 9. The interactions between the cutting speed and feed factors are A-B, between cutting speed and cutting A-C and between feed and cutting B-C, which are placed in rows 3, 6 and 8. Taguchi recommends that analyzing data using the S/N ratio provides the optimum value with little variation. The average value obtained is close to the target value. The test results were analyzed by checking the main effect of the factor on the surface roughness value.

Table 5. Test results for Ra value and S/N ratio

Num of Tests	Code	Ra (µm)	Ratio S/N
1	$A_{L1}B_{L1}C_{L1}D_{L1}$	2.78	-7.89
2	$A_{L1}B_{L1}C_{L2}D_{L2}$	1.58	-3.86
3	$A_{L1}B_{L1}C_{L3}D_{L3}$	1.68	-3.97
4	$A_{L1}B_{L2}C_{L1}D_{L2}$	1.72	-4.75
5	$A_{L1}B_{L2}C_{L2}D_{L3}$	2.08	-6.12
6	$A_{L1}B_{L2}C_{L3}D_{L1}$	1.28	-2.21
7	$A_{L1}B_{L3}C_{L1}D_{L3}$	1.19	-1.46
8	$A_{L1}B_{L3}C_{L2}D_{L1}$	1.15	-0.86
9	$A_{L1}B_{L3}C_{L3}D_{L2}$	1.27	-2.17
10	$A_{L2}B_{L1}C_{L1}D_{L1}$	1.03	-0.53
11	$A_{L2}B_{L1}C_{L2}D_{L2}$	1.12	-0.81
12	$A_{L2}B_{L1}C_{L3}D_{L3}$	1.18	-1.42
13	$A_{L2}B_{L2}C_{L1}D_{L2}$	1.40	-3.12
14	$A_{L2}B_{L2}C_{L1}D_{L2}$	2.27	-7.25
15	$A_{L2}B_{L2}C_{L3}D_{L1}$	1.07	-0.62
16	$A_{L2}B_{L3}C_{L1}D_{L2}$	1.18	-0.88
17	$A_{L2}B_{L3}C_{L2}D_{L1}$	1.22	-1.98
18	$A_{L2}B_{L3}C_{L3}D_{L2}$	1.43	-3.18
19	$A_{L3}B_{L1}C_{L1}D_{L1}$	1.23	-2.06
20	$A_{L3}B_{L1}C_{L2}D_{L2}$	1.13	-0.84
21	$A_{L3}B_{L1}C_{L3}D_{L3}$	1.16	-0.89
22	$A_{L3}B_{L2}C_{L1}D_{L2}$	1.55	-3.27
23	$A_{L3}B_{L2}C_{L2}D_{L3}$	1.19	-1.04
24	$A_{L3}B_{L2}C_{L3}D_{L1}$	1.42	-3.19
25	$A_{L3}B_{L3}C_{L1}D_{L3}$	1.26	-2.13
26	$A_{L3}B_{L3}C_{L2}D_{L1}$	1.16	-0.82
27	$A_{L3}B_{L3}C_{L3}D_{L2}$	0.92	0.26

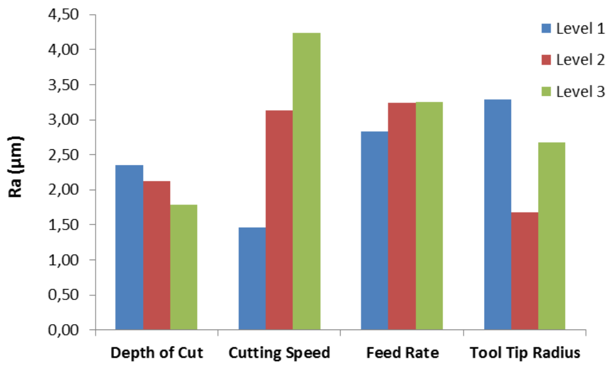

Figure 3. Response Ra for surface roughness values

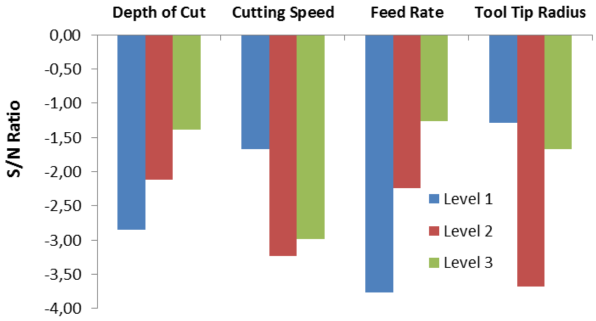

Figure 4. S/N response for surface roughness values

The test results are analyzed by checking the main consequent of the factor on the surface roughness value, as shown in Figure 3. The S/N ratio generated from each Level can be calculated based on the depth of cut, feed speed, cutting speed and tip of the tool radius. The S/N ratio can be distinguished from a maximum and a minimum; this is also shown in Figure 4. Feed rate and tooltip radius are the two factors that give the greatest delta value. The two factors resulted in a value of 3.75 and 3.68, respectively. Based on Taguchi's prediction that the difference in the largest value gives a more significant effect, it can therefore be concluded that the feed rate will increase, which results in a significant decrease in the surface roughness value.

Previous researchers found that the surface roughness value is highly dependent on the feed rate and the cutting tool geometry. Because the three types of tools used have different geometries, the impression of tool geometry is significant to the surface roughness [16]. ANOVA analysis can determine the most significant factor of all factors and determine the effect of each interacting factor. Table 6 shows the significant feed rate values and tooltip radius, where the P-value is 0.000. its means that the feed rate and tooltip radius give a very necessary impression on the surface roughness value, of which the standard value of significance is 0.05. On the other hand, the cutting speed and depth do not make a significant impression. Meanwhile, the feed rate and tool tip radius contribution are 48.25% and 39.23%, respectively. From these results, it can be concluded that bribery gives a greater contribution than other factors.

Table 6. ANOVA variance for surface roughness S/N ratio

Code	DF	Variant (V)	SS	Percent (P)	F	P Contribution (%)
A	2	6.54	13.09	0.33	1.37	1.44
B	2	208.09	416.18	0.00	43.13	47.15
A-B	4	11.21	44.86	0.17	2.32	5.09
C	2	7.34	14.88	0.32	1.68	1.91
A-C	4	1.37	4.95	0.76	0.27	0.68
B-C	4	2.34	11.56	0.54	0.67	1.56
D	2	3.42	236.34	0.00	35.67	38.89
Error	6	3.78	27.87	0.00	0.00	3.28
Total	**26**					**100**

The interactions between cutting speed and feed rate (A-B), cutting speed and in cutting (A-C) and feed rate and deep cutting (B-C) were also significant. The significant values are 0.170 for A-B, 0.76 for A-C and 0.54 for B-C. The factor that gives the most significant impression of the surface roughness is the feed rate in the machining process. Therefore, the quality Level of the surface roughness of the machining process can be controlled by determining the appropriate feed rate. It was recommended to specify the feed rate and cutting speed to impact the optimal material processing process.

Surface roughness performance can be predicted by calculating the average value prediction for minimum surface roughness [17]. In the same way, the maximum S/N ratio is evaluated by determining, under certain conditions, if the smallest surface roughness value is acceptable. By utilizing this prediction, it can be concluded that the machining process produces the best surface roughness value (Ra= 0.14 m). Ra= 0.14 m is the smallest value compared to the test value. Confirmation rather than testing is important to ensure optimum machining conditions. On the other hand, the optimum state for the surface roughness S/N ratio is 3.26 dB.

4. Conclusion

The analysis of the turning process on tool steel materials used several parameters to produce the followed conclusions. The design of the Taguchi method is suitable for determining the optimum state of the TC-VT15L CNC-lathe machining in terms of obtaining a low surface roughness value. The S/N ratio approach and ANOVA concept could produce analytical data with almost the same value. The most significant factors for the surface roughness value during turning are the feed rate and tooltip radius, which are 48.25% and 39.23%, respectively. The optimum machining conditions to get the ideal surface roughness values are at a cutting speed of 120 m/min, feed rate of 0.10 mm/rev, cutting of 0.50 mm and tooltip radius of 0.80 mm.

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