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Optimization of Surface Roughness in CNC Turning of SS 304 Stainless Steel Using Respon Surface Methodology

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Abstract

Surface roughness is one of the important indicators in assessing machining results, especially in stainless steel (SS 304). This study aims to determine the influence of machining parameters, namely spindle speed, feeding speed, and feeding depth on the surface roughness of stainless steel material (SS 304) in the turning process using the mori seiki sl-25 CNC machine. The research was conducted using the Response Surface Methodology (RSM) method and the experimental design of Box-Behnken Design (BBD) to obtain the best combination of parameters. Previous research has only examined two variables separately without considering the feed rate at the same time. The results of this study show that among the 3 factor variables, only one factor, namely the speed of interpretation that can reject Ho with a value of f calculated as 4.79>4.77, which means that the speed of interpretation has a significant influence on the degree of roughness compared to other variables.

Keywords: CNC; Surface Roughness; Stainless Steel; Surface Response Methodology; Box-Behken Design

Abstract

Kekasaran permukaan merupakan salah satu indikator penting dalam menilai hasil permesinan khususnya pada material stainless steel (SS 304). Penelitian ini bertujuan untuk mengetahui pengaruh parameter pemesinan, yaitu kecepatan spindle, kecepatan pemakanan, dan kedalaman pemakanan terhadap kekasaran permukaan material stainless steel (SS 304) pada proses pembubutan menggunakan mesin CNC MORI SEIKI SL-25. Penelitian dilakukan dengan menggunakan metode Response Surface Methodology (RSM) dan desain eksperimen Box-Behnken Design (BBD) untuk memperoleh kombinasi parameter terbaik. Penelitian sbelumnya hanya mengkaji tentang dua variabel secara terpisah tanpa mempertimbangkan feed rate secara bersamaan. Hasil penelitian ini menunjukan diantara 3 variabel faktor hanya satu faktor yaitu kecepatan pemaknan yang dapat menolak Ho dengan nilai f hitung 4,79>4,77, yang artinya kecepatan pemaknan memberikan pengaruh yang signifikan terhadap tngkat kekasaran permkaan dibandingkan dengan variable faktor yang lainnya.

Keywords: CNC; Kekasaran Permukaan; *Stainless Steel;Respon Surface Methodology; Box-Behken Desain*

1. Introduction

CNC (Computer Numerical Control) is the result of the integration between compotoric technology and mechanical technology. CNC is a machine that is operated using the N code and the G code. The operating system uses a computer with numeric language and is continued by the operator to run the CNC machine to avoid work process errors [1]**.** CNC is a good choice in the manufacturing industry now because of the increasing needs of consumers and require the same good quality, and fast workmanship, this can be fulfilled by CNC because it can be operated automatically and semi-automatically [2]. CNC lathe machines are commonly used to form cylindrical objects such as shaft making and others [3].

The quality of a product can be judged from the level of surface roughness of the workpiece produced in the machining process [4]. The high surface roughness, especially in salty component products, makes the product quickly wear and the material accelerates the occurrence of damage to the engine components. To obtain a surface roughness that meets the standard, the machining factor greatly affects the surface roughness of the material produced. Factors that affect the roughness of the surface include speed spindle, feeding depth, feeding speed, engine conditions, as well as the use of coolant used during the machining process [5]. Cutting speed is the ability of the cutting tool to cut the workpiece in a matter of m/min [6]. Feeding speed is the speed of the cutting tool in making cuts to the workpiece in mm/min [7]. Feeding depth is the difference between the surface of the workpiece after cutting and before the cutting [8].

The workpiece material and the tool material selected in the machining process also have an influence on the level of surface roughness produced in the machining process [9]. Stainless steel *(SS 304)* belongs to the group of stainless steel types Austentik which contains the element chromium about 18–19.5%. This type of steel is one of the most commonly used materials in various industrial sectors, as it has good mechanical properties as well as high resistance to corrosion [10]. Stainless steel (*SS304)* Being the material used in this study because this maerial is most often used in various fields of the food industry, especially in machine components such as shafts, a good roughness value is needed so that these components are not easily worn and easily damaged.

Research conducted by [11] about Surface roughness due to variation in parameters in the process Roughing CNC Turning with the parameters used in the form of speed spindle with levels of 1990, 2100, and 2300 rpm. The speed of the food used is 0.18; 0,23; and 0.28 mm/rev. Produces the lowest roughness found in speed spindle 2300 rpm and feeding speed of 0.18 mm/put with the resulting roughness value of 2.17μm.

Research conducted [12] about the analysis of feeding motion and the type of cooling medium on the roughness of the metal surface turned on the SUS304 material. The parameters in this study are feeding motion, namely 0.11 mm/put, 0.15 mm/put, and 0.19 mm/put. While the type of cooling media used is Fumio Lube Fumicool *794* and 16S suncut oil lubricant. From these parameters, the lowest roughness value was found in the feeding motion parameter of 0.11 mm/put and the 16S suncut lubricating oil cooling medium with a roughness value of 0.770μm, while the highest roughness value was found in the parameter with a feeding motion of 0.19 mm/put with the cooling medium Fumio Lube Fumicool 794 with a roughness value of 3,942μm.

Various studies on the machining process of Stainless steel 304 material show that there is an influence of machining parameters on surface roughness. Previous research has focused on one or two bound variables. This approach has not been able to show a complete picture of the interaction between parameters. In addition, some studies only conduct comprehensive analysis without utilizing more comprehensive statistical models such as the Response Surface Methodology. This condition causes the unavailability of a prediction model used to determine the optimal combination of machining parameters in Stainless Steel 304 material. Research on the machining of SS 304 stainless steel has been carried out by various researchers, but the scope and approach used still leaves room for deepening. Studies conducted by [13] For example, it shows that the fuzzy logic method is able to predict the roughness value of the surface, but the approach does not provide a comprehensive picture of how the interaction between machining parameters affects the final result [1]. The results of the predictions produced are more dominant in estimation, so the real contribution of changes in spindle speed, feeding rate, and feeding depth has not been noticed. In addition, the study conducted [14] focuses on the optimization of the AISI 304 machining process but in the context of the milling process, while the cutting characteristics of the turning are different so that the findings cannot be applied directly to the CNC turning process [3]. Based on these gaps, research is still needed that combines experimental approaches and quantitative modeling using the Response Surface Methodology (RSM), especially with Box–Behnken (BBD) designs, so that the simultaneous relationship between spindle speed, feeding speed, and feeding depth to the surface roughness of SS 304 can be more fully understood.

Based on the above background, the author is interested in conducting research on the influence of machining parameters on the Mori Seiki SL-25 cnc lathe on the surface roughness of Stainless steel material (*SS304).*

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2. Materials and methodology

The Mori Seiki SL-25 CNC machine is used in the machine used in this study to obtain surface roughness results on the material. The parameters used in this study are spindle speed variation, feeding speed variation, and feeding depth variation.

2.1. Tools and Materials

The cutting blade used in this study is type CNMG120404-MA and uses grade M according to the type of material used [15]. Specifications This cutting tool has a geometric shape, namely a diamond with an angle of 80◦, an example of a cutting tool can be seen in Figure 1 below.

Figure 1. Insert Carbide CNMG 120404 - MA

The material used in this research is stainless steel (SS304) with the specified workpiece size being Ø25 X 100 mm.

2.2. Research stage

The workpiece with an initial diameter of 25.4 and a length of 10 mm was carried out using a Mori Seiki SL-25 CNC lathe machine and using a CNMG120404-MA type chisel. The parameters used in this study can be seen in table 1 below.

Table 1. Machining Parameters

Yes	Parameters	Level		
		1	2	3
1	Spindle *speed* (RPM)	1200	1400	1600
2	Feeding Speed (mm/put)	0,14	0,15	0,16
3	Feeding depth (mm)	0,15	0,175	0,2

Data processing using Surface Methodelogi Response to understand the relationship between the parameters used and the resulting surface roughness response. This method is often used to optimize processes and find the best desired conditions. Box-Behnken Design was chosen in this study to allow researchers to explore the interaction between parameters with a small number of experiments [15]. Experimental design with the Box-Behken Design can be seen in the following table 2.

Table 2. Rancangan Box-Behken Design

Yes	Spindle *speed* (RPM)	Feeding speed (mm/put)	Depth of nutrition (mm)
1	1200	0,14	0,175
2	1600	0,14	0,175
3	1200	0,16	0,175

4	1600	0,16	0,175
5	1200	0,15	0,15
6	1600	0,15	0,15
7	1200	0,15	0,2
8	1600	0,15	0,2
9	1400	0,14	0,15
10	1400	0,16	0,15
11	1400	0,14	0,2
12	1400	0,16	0,2
13	1400	0,15	0,175
14	1400	0,15	0,175
15	1400	0,15	0,175

2.3. Workpiece Testing

Surface roughness is the arithmetic average deviation from the surface profile to the center line. Some of the factors that affect this level of roughness include the size of the chisel, the parameters of the cutting process, the shape of the geometry, as well as imperfections in the material and disturbances in the flow of anger [16].

Surface roughness is a measure of the degree of micro-irregularity on the surface of a material measured from a specific reference point. This roughness value is usually expressed in several parameters, among others Roughness Average (Ra), Total Roughness (Rt), and Maximum Roughness (Rmax) [17]. Although a smooth surface is generally considered ideal, there are various factors that affect the roughness value, such as the parameters of the machining process, the skill of the operator, and the condition of the machine used.

The measurement of surface roughness in this study uses a surface roughness tester with the type Mitutoyo SJ-210. Standardization of measurement uses ISO 4287. The presence of ISO 4287 ensures that the interpretation of surface roughness measurement results is consistent and can be compared with cross-research, especially when metal reinforcement processes such as turning require precise surface quality.[18] Surface roughness data collection is carried out at a workpiece diameter of Ø25mm with a measurement path length of 30 mm with 3 repetitions at different points on one workpiece to get validation of the results.

3. Results and discussion

3.1. Surface Roughness Test Results Data

The machining process is carried out as many designs as have been determined, the machining process can be seen in Figure 2 below.

Figure 2. Workpieces that have been avoided by the machining process

Data from surface roughness measurements carried out with the tool Surface roughnes test The Mitutoyo SJ-210 can be seen in Table 3 below.

Table 3. Surface Roughness Test Results Data

Yes	Spindle speed (rpm)	Feeding speed (mm/put)	Depth of nutrition (mm)	Roughness (Ra)			Correspondence (Date)
				1	2	3	
1	1200	0,14	0,175	0,253	0,250	0,237	0,246
2	1600	0,14	0,175	0,400	0,412	0,419	0,410
3	1200	0,16	0,175	0,854	0,840	0,837	0,843
4	1600	0,16	0,175	0,837	0,855	0,837	0,843
5	1200	0.15	0,15	0,795	0,788	0,781	0,778
6	1600	0.15	0,15	0,497	0.454	0,451	0,467
7	1200	0.15	0,2	1,127	1,119	1,141	1,129
8	1600	0,15	0,2	0,755	0,782	0,766	0,767
9	1400	0,14	0,15	0,407	0,403	0,413	0,408
10	1400	0,16	0,15	0,453	0,445	0,439	0,445
11	1400	0,14	0,2	0,243	0,233	0,248	0,241
12	1400	0,16	0,2	0,559	0,578	0,593	0,576
13	1400	0,15	0,175	0,223	0,260	0,229	0,237
14	1400	0,15	0,175	0,574	0,566	0,569	0,569
15	1400	0,15	0,175	0,381	0,385	0,378	0,382

3.2. Variant Analysis (ANOVA)

Variant analysis was carried out to find out whether the variable had an effect on the response produced. The analysis process uses a hypothesis test, by comparing the value of F calculated with the F table. Data processing in this study uses Minitab software. Minitab software is commonly used to search and process research data. The analysis table of variants can be seen in the following table.

Table 4. Analysis Table Of Variants

Analysis of variance						
Source	DF	Seq SS	Adj SS	Adj ms	F value	P value
Type	9	0.726303	0.726303	0.080700	1.57	0.321
Linear	3	0.325124	0.325124	0.108375	2.11	0.217
Rpm	1	0.033670	0.033670	0.033670	0.66	0.455
Feeding speed	1	0.245700	0.245700	0.245700	4.79	0.080
Error	5	0.256494	0.256494	0.051299		
Lack of fit	3	0.201088	0.201088	0.067029	2,42	0.306
Pure error	2	0.0055406	0.0055406	0.027703		
Total	14	0.982797	0.982797			

After data processing using minitab software, a hypothesis test was carried out to find out which variables had the most effect on the response. In the hypothesis test, if Fcal > from Ftabel then the initial hypothesis is rejected. Ho in this study is a variable factor that does not have a significant influence on the response with an f table value of 4.77. Based on Table 4 above, it can be concluded that among the 3 factor variables, only one factor, namely the speed of interpretation can reject Ho with a value of f calculated 4.79>4.77, which means that the speed of interpretation has a significant influence on the roughness of the equation compared to the other factor variables.

3.3. Analysis of the relationship of parameters to the resulting response

The surface roughness values that have been obtained in table 3 are analyzed and presented in the form of graphs that can be seen in figures 2, 3, and 4 below.

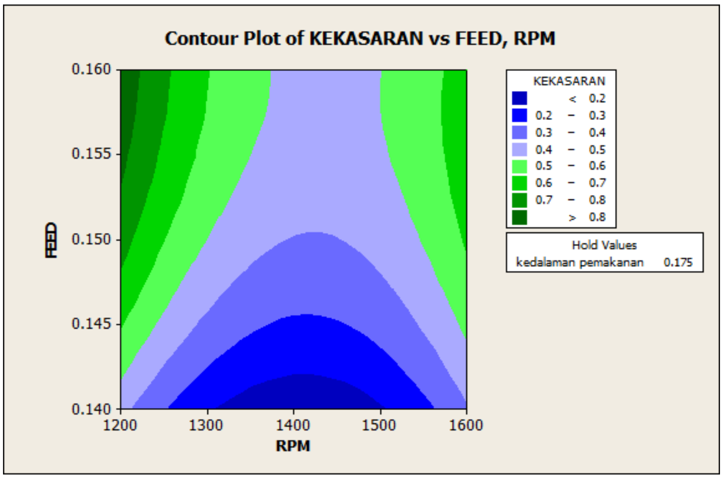

Figure 3. Rough Plot Contour Chart Vs Spindle Speed, Feeding Speed

Based on the graph above, it can be analyzed that the best roughness is found in the low feeding speed area, which is 0.14 mm/put with a spindle speed of 1400Rpm. The higher the spindle speed used when combined with the high feeding speed it results in increased surface roughness.

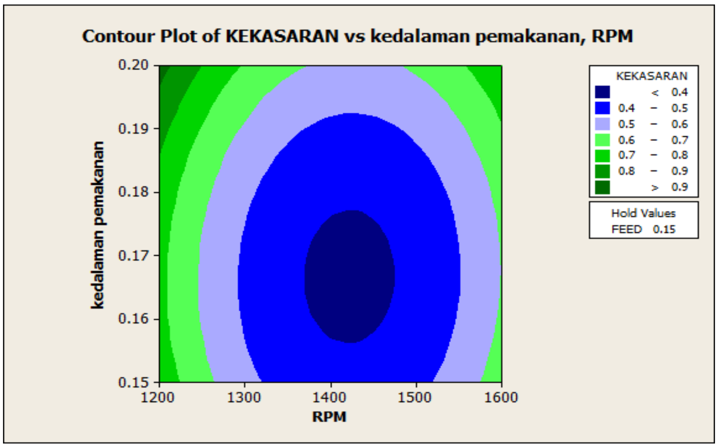

Figure 4. Plot Contour Graph Roughness Vs Spindle Speed And Feeding Depth

The lowest surface roughness is found at a spindle speed of 1400 Rpm with a feeding depth of 0.17mm. Based on the graph on the diagram, it can be concluded that the farther away from the point, the roughness value of the surface increases. Spindle speed that is too low or too high with a large depth will result in a high level of roughness.

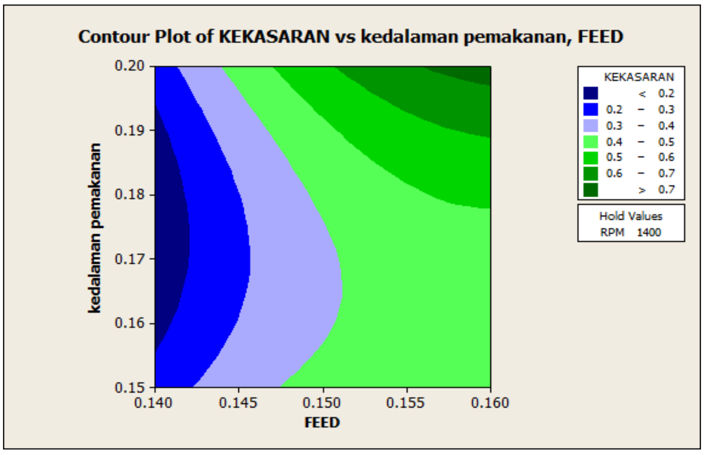

Figure 5 Plot Contour Graph Roughness vs Feeding Depth and Feeding Speed

Based on the graph above, it can be analyzed that the roughness of the surface increases as the speed of feeding and the depth of the surface increases. The lowest result of surface roughness was found at a feeding speed of 0.14 mm/put with a feeding depth of 0.17 mm so it can be concluded that the feeding speed and depth if you want a low roughness, then use a feeding speed and a low feeding depth.

4. Conclusion

The results of the analysis that have been carried out on the roughness value of the surface from three factors, namely spindle speed, feeding speed, and feeding depth. Based on the results of the hypothesis test on the variance analysis where f is calculated > Ftabel proves that Ho is rejected which means that feeding speed has the most significant effect of the three variable factors that affect surface roughness. Meanwhile, spindle speed and feeding depth do not provide much of a significant response to surface roughness. The parameter with the lowest surface roughness result in stainless steel material (SS 304) can be obtained by varying the spinde speed parameter of 1400 Rpm with a feeding speed of 0.15 mm/put with a feeding depth of 0.175 mm, found in the 13th (thirteenth) workpiece with a surface roughness result of 0.237μm which is the lowest value of 15 experiments in accordance with the BBD model. Further research can be used to develop this study by adding other variables such as the use of refrigerant type and material removal rate, and further research can use different analysis methods to gain a comprehensive understanding of the interaction between parameters.

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