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The Influence of Work Surface Roughness Caused By Fraising Machined with HSS Chies

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ABSTRACT

The development of production techniques is required to produce good products that have standards for the products produced, both in terms of profile shape, size precision, surface roughness, hardness, material flexibility, and others that comply with standards. The surface roughness of a product can affect its functions, such as its level of precision and ability to accept loads. This research aims to find out how much influence cutting speed and depth of cut have on surface roughness with variations in cutting speed parameters of 21 meters/minute and 26 meters/minute and for AISI 4140 steel cutting speed parameters of 12 meters/minute and 17 meters/minute and cutting depths of 0.1 mm and 0.3 mm on four types of steel with End Mill cutting blades made from High-Speed Steel with a total of 4 flute cutting blades. Next, surface roughness testing and analysis of variance were carried out to determine the influence of parameters on surface roughness. The results obtained were that the largest average surface roughness, namely Ra = 5.33 µm, occurred on AISI 4140 steel at a cutting speed of 12 m/min with a cutting depth of 0.3 mm. Meanwhile, the smallest average surface roughness, namely Ra = 0.91 µm, occurred on AISI 1045 steel at a cutting speed of 21 m/min with a cutting depth of 0.1 mm. Next, an analysis of the variance method was also carried out with the following results: cutting speed only affected S45C steel because the value of Fcount>Ftable (13.18107506 > 5.32). The depth of cut does not have a significant effect on surface roughness on all types of steel because of the comparison results Fcount<Ftable. The interaction of cutting speed and cutting depth does not affect surface roughness because the comparison shows that Fcount <Ftable for all types of steel.

Introduction

The development of production techniques is required to produce products that comply with and have certain standards. The product is seen in the profile shape, size precision, surface roughness, material flexibility, and others that comply with standards. This requires the development of production science related to design science, materials science, and innovative machining science so that products are accepted on the market. One form of progress in the production process is the discovery of machine tools, such as milling machines, lathes, scrap machines, and drilling machines. These machines will simplify the process of making machine components efficiently and with high-precision results [1][2].

In the world of machining, material selection affects the quality of a product. Material selection is adjusted to the desired product criteria. One of them is choosing the type of steel. St 42 steel is classified as low-carbon steel, which is easy to forge and easy to machine. This steel is used in the engineering field for construction steel ranging from building frames, concrete reinforcing steel, vehicle frames, nuts and bolts, as well as in machining [3,4].

Then there is also S45C steel, which is included in the medium-carbon steel group. S45C steel is a machining steel that is applied as a material for making machine components such as gears, shafts, and pulleys [5,6][7].

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AISI 4140 alloy steel is grouped as low alloy steel. The Cr and Mo alloys in steel cause the steel to have rust-resistant properties. This steel is used for sprockets and shaft parts of engines. From the way it is used, AISI 4140 alloy steel has high hardness and durability [8][9].

Previous research using AISI 304 Stainless Steel material, the results of the research obtained the smallest surface roughness value in the machining process using a 4-flute milling machine with a cutting speed of 42.2 m/minute and a cutting depth of 0.1 mm and a surface roughness value of 3,160 µm. while the best surface roughness value is found in 4 flute milling machining with a cutting speed of 26.4 m/minute and a cutting depth of 0.5 mm with a surface roughness value of 6.174 µm.

Cutting parameters such as cutting edge selection as well as appropriate cutting speed and cutting depth are important to produce good surface roughness [10] [11] [12][13].

The aim of this research is to determine the effect of cutting parameters on obtaining surface roughness values. In this study, the cutting parameters used were cutting speed and depth of cut, while the machining process carried out in the study was a vertical milling process using a conventional milling machine on St 42 carbon steel, AISI 1045 steel, S45C steel, and AISI 4140 alloy steel.

Methods

The research methodology used in this research is experimental. Starting with the milling and machining process, it continues with surface roughness testing. The research stages are described through a flow diagram as follows (**Figure 1**).

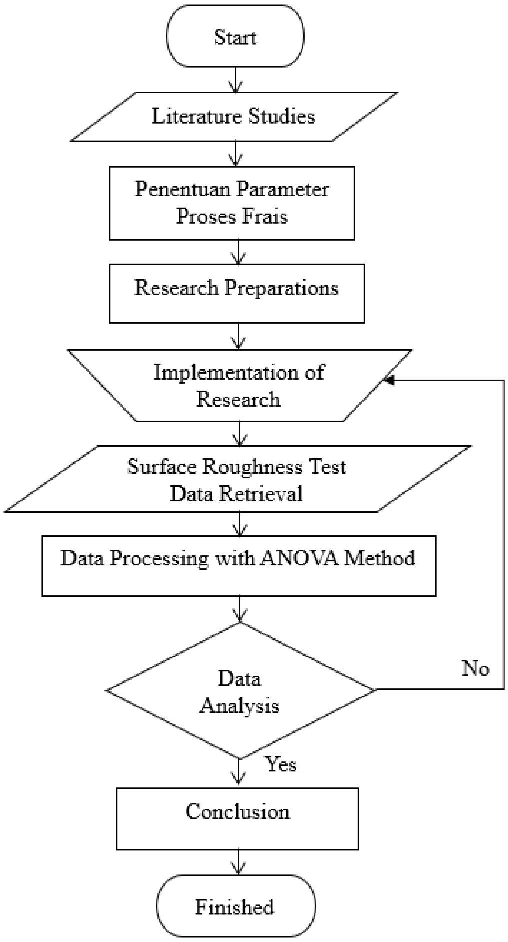

Figure 1. Research Flow Chart

Figure 1 above shows the implementation stages of surface roughness testing. The research started with a literature study related to determining machining process parameters and then preparing tools and materials. Next is the process of carrying out research and collecting data. After research, an ANOVA analysis was carried out to determine the effect of parameters on surface roughness. Finally, conclusions and suggestions are obtained. The following is an explanation of the research steps:

1. Literature Study
The initial stage was carried out by studying theoretical literature and previous calculations to discuss the surface roughness research of milling machines on four different types of steel based on previous research and references from books.

2. Determination of Milling Process Parameters
Determining the parameters for the milling machining process is adjusted to the material and type of cutting edge used. The chisel used is high-speed steel with a diameter of 20 mm and 4 flutes. To determine the parameters, follow Table 1 below:

Table 1. Cutting Speed Parameters [14]

Material	***High-Speed Steel Cutter***		***Carbide Cutter***	
	(ft/min)	***(m/min)***	***(ft/min)***	***(m/min)***
Alloy steel	40-70	12-20	150-250	45-75
Aluminium	500-1000	150-300	1000-2000	300-600
Bronze	65-120	20-35	200-400	60-120
Cast iron	50-80	15-25	125-200	40-60
Free machining steel	100-150	30-45	400-600	120-180
Machine steel	70-100	21-30	150-250	45-75
Stainless steel	30-80	10-25	100-300	30-90
Tool steel	60-70	18-20	125-200	40-60

For St42 steel, AISI 1045 steel, and S45C steel, it is classified as machining steel and uses High-Speed Steel cutting tools so that cutting speeds from 21 m/min to 30 m/min can be used. In this study, 21 m/min and 26 m/min were used.

Spindle speed for cutting speed: 21 m/min:

$$V_c = \frac{\pi . d . n}{1000}$$

$$n = \frac{V_c . 1000}{\pi . d}$$

$$n = \frac{21\ m/min . 1000}{\pi . 20\ mm}$$

$$n = 334{,}225\ Rpm$$

Spindle speed for cutting speed: 26 m/min:

$$n = \frac{V_c . 1000}{\pi . d}$$

$$n = \frac{26\ m/min . 1000}{\pi . 20\ mm} \quad (1)$$

$$n = 413{,}802\ Rpm \quad (2)$$

Meanwhile, AISI 4140 steel is classified as an alloy steel and uses High-Speed Steel cutting chisels. The permitted speed is from 12 m/min to 20 m/min. In the research, speeds of 12 m/min and 17 m/min were used.

Spindle speed for cutting speed: 12 m/min:

$$n = \frac{V_c . 1000}{\pi . d}$$

$$n = \frac{12\ m/min . 1000}{\pi . 20\ mm}$$

$$n = 190{,}985\ Rpm \quad (3)$$

Spindle speed for cutting speed: 17 m/min:

$$n = \frac{V_c . 1000}{\pi . d}$$

$$n = \frac{17\ m/min . 1000}{\pi . 20\ mm}$$

$$n = 270{,}563\ Rpm \quad (4)$$

3. Preparation of Tools and Materials

At this stage, prepare tools and materials for research. The tools used are a milling machine, end mill cutting chisels made from high-speed steel with 4 flute cutting edges, a cutting grinder, a vernier caliper, surface roughness test equipment, gloves, glasses, and a vise. The materials used in this research were St42 carbon steel, AISI 1045 steel, S45C steel, and AISI 4140 alloy steel with dimensions of 40 mm x 25 mm x 15 mm in all types of steel. The materials used in the research are shown in **Figure 2**.

Figure 2. Test specimen

Results and Discussion

After carrying out the roughness test, the roughness value results are obtained as shown in the graph in **Figure 3-6** below:

1. St 42 Steel Surface Roughness Chart

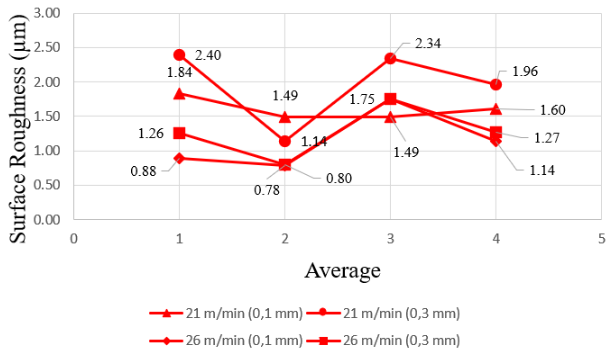

Figure 3. Effect of Cutting Speed on Surface Roughness of St 42 Steel on Cutting Depth

The cutting speed is 21 m/min, which is marked with a red line with a triangle and circle symbol. At

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a cutting speed of 21 m/min and a cutting depth of 0.1 mm, the average surface roughness results were 1.60 µm. Then, with the same cutting speed at a cutting depth of 0.3 mm, the average surface roughness was 1.96 µm.

From the results of reading the graph, it was found that the surface roughness value increased by 0.36 µm. And there is an influence of surface roughness at a cutting speed of 26 m/min, which is marked by a red line with diamond and square symbols. At a cutting speed of 26 m/min and a cutting depth of 0.1 mm, the average surface roughness was 1.14 µm. Then, with the same cutting speed at a cutting depth of 0.3 mm, the average surface roughness was 1.27 µm. From the results of reading the graph, it was found that the surface roughness value increased by 0.13 µm.

2. AISI 1045 Steel Surface Roughness Chart

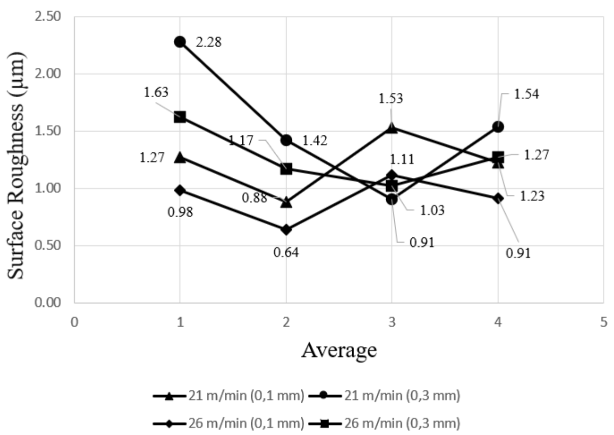

Figure 4. Effect of Cutting Speed on Surface Roughness of St 42 Steel on Cutting Depth

The cutting speed is 21 m/min, which is marked with a black line with a triangle and circle symbol. At a cutting speed of 21 m/min and a cutting depth of 0.1 mm, the average surface roughness was 1.23 µm. Then, with the same cutting speed at a cutting depth of 0.3 mm, the average surface roughness was 1.54 µm. From the results of reading the graph, it was found that the surface roughness value increased by 0.31 µm. Then a graph of the effect of cutting depth on surface roughness at a cutting speed of 26 m/min was also read, which was marked by a black line with diamond and square symbols.

At a cutting speed of 26 m/min and a cutting depth of 0.1 mm, the average surface roughness was 0.91 µm. Then, with the same cutting speed at a cutting depth of 0.3 mm, the average surface roughness was 1.27 µm. From the results of reading the graph, it was found that the surface roughness value increased by 0.36 µm.

3. S45C Steel Surface Roughness Chart

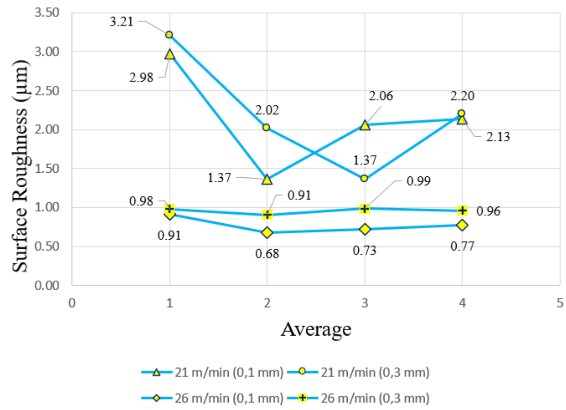

Figure 5. S45C Steel Surface Roughness Chart

The cutting speed is 21 m/min, which is marked with a yellow line with a triangle and circle symbol. At a cutting speed of 21 m/min and a cutting depth of 0.1 mm, the average surface roughness was 2.13 µm. Then, with the same cutting speed at a cutting depth of 0.3 mm, the average surface roughness was 2.20 µm. From the results of reading the graph, it was found that the surface roughness value increased by 0.07 µm. Then a graph of the effect of cutting speed on surface roughness was read at a cutting speed of 26 m/min, which was marked by a yellow line with diamond and square symbols.

At a cutting speed of 26 m/min and a cutting depth of 0.1 mm, the average surface roughness was 0.77 µm. Then, with the same cutting speed at a cutting depth of 0.3 mm, the average surface roughness was 0.96 µm. From the results of reading the graph, it was found that the surface roughness value increased by 0.19 µm.

4. AISI 4140 Steel Surface Roughness Chart

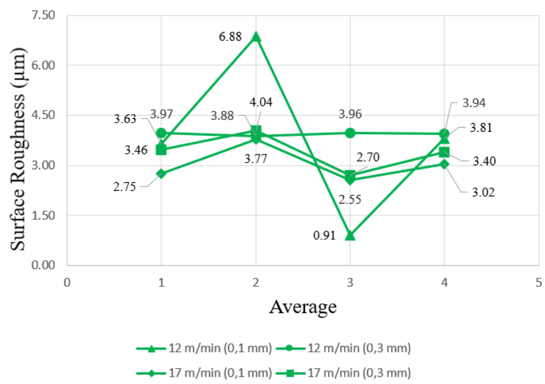

Figure 6. 4. AISI 4140 Steel Surface Roughness Chart

The cutting speed is 17 m/min, which is marked with a green line with a triangle and circle symbol. At a cutting speed of 17 m/min and a cutting depth of 0.1 mm, the average surface roughness was 3.31 µm. Then, with the same cutting speed at a cutting depth of 0.3 mm, the average surface roughness was 5.33 µm. From the results of reading the graph, it was found that the surface roughness value increased by 2.02 µm. Then a graph of the effect of cutting depth on surface roughness was read at a cutting speed of 17 m/min, which was marked by a green line with rhombus and square symbols. At a cutting speed of 17 m/min and a cutting depth of 0.1 mm, the average surface roughness was 3.02 µm. Then, with the same cutting speed at a cutting depth of 0.3 mm, the average surface roughness was 3.40 µm. From the results of reading the graph, it was found that the surface roughness value increased by 0.38 µm.

Data analysis using the Analysis of Variance method was also used to determine the significant influence of parameters on surface roughness.

1. Analysis of Variance (ANOVA) St 42 Steel

Table 2. St 42 Steel Surface Roughness ANOVA.

Source of Variation	*SS*	*df*	*MS*	*F*
Cutting Speed	1,005723	1	1,005723	3,812736506
Cutting depth	0,174725333	1	0,174725333	0,662390794
Cutting speed*Cutting depth	0,038988	1	0,038988	0,147805082
Error	2,110238667	8	0,263779833	
Total	3,329675	11		

Conclusions can be drawn using the F value for surface roughness on St 42 steel as follows:

1. For variable-cutting-speed processes
Fcount has a value of 3.812736506, and Ftable has a value of 5.32. Where Fcount<Ftable means that variations in cutting speed do not have a significant impact on the surface roughness results on St 42 steel.

2. For variable-depth cut processes
Fcount has a value of 0.662390794, and Ftable has a value of 5.32. Where Fcount<Ftable means that variations in cutting depth do not have a significant impact on the surface roughness results on St 42 steel.

3. Interaction between cutting speed and cutting depth
Fcount has a value of 0.147805082, and Ftable has a value of 5.32. Where Fcount<Ftable means that cutting speed and cutting depth do not influence each other or do not interact with the results of the surface roughness of St 42 steel.

2. Analysis of Variance (ANOVA) AISI 1045 Steel

Table 3. ANOVA of AISI 1045 Steel Surface Roughness.

Source of Variation	*SS*	*df*	*MS*	*F*
Cutting Speed	0,253752083	1	0,253752083	1,36544961
Cutting Depth	0,336340083	1	0,336340083	1,809858779
Cutting Speed*Cutting Depth	0,00226875	1	0,00226875	0,01220823
Error	1,486702	8	0,18583775	
Total	2,079062917	11		

Conclusions can be drawn using the F value for surface roughness on St 42 steel as follows:

a. For variable-cutting-speed processes
Fcount has a value of 1.36544961, and Ftable has a value of 5.32. Where Fcount<Ftable means that variations in cutting speed do not have a significant impact on the surface roughness results on AISI 1045 steel.

b. For variable-depth cut processes
Fcount has a value of 1.809858779, and Ftable has a value of 5.32. Where Fcount<Ftable means that variations in cutting depth do not have a significant impact on the surface roughness results on AISI 1045 steel.

c. Interaction between cutting speed and cutting depth
F calculated has a value of 0.01220823, and F table has a value of 5.32. Where Fcount<Ftable means that cutting speed and cutting depth do not influence each other or do not interact with the surface roughness results of AISI 1045 steel.

3. Analysis of Variance (ANOVA) of S45C Steel

Table 4. ANOVA of S45C Steel Surface Roughness.

Source of Variation	***SS***	***df***	***MS***	***F***
Cutting Speed	5,086914083	1	5,086914083	13,18107506
Cutting Depth	0,047754083	1	0,047754083	0,123739097
Cutting Speed*Cutting Depth	0,011470083	1	0,011470083	0,029720972
Error	3,087404667	8	0,385925583	
Total	8,233542917	11		

Conclusions can be drawn using the F value for surface roughness on St 42 steel as follows:

a. For variable-cutting-speed processes

Fcount has a value of 13.18107506, and Ftable has a value of 5.32. Where Fcount>Ftable means that variations in cutting speed have a significant impact on the surface roughness results on S45C steel.

b. For variable-depth cut processes

Fcount has a value of 0.123739097, and Ftable has a value of 5.32. Where Fcount<Ftable means that variations in cutting depth do not have a significant impact on the surface roughness results on S45C steel.

c. Interaction between cutting speed and cutting depth

Fcount has a value of 0.029720972, and Ftable has a value of 5.32. Where Fcount<Ftable means that cutting speed and cutting depth do not influence each other or do not interact with the surface roughness results of S45C steel.

4. Analysis of Variance (ANOVA) AISI 4140 Steel

Table 5. ANOVA of AISI 4140 Steel Surface Roughness.

Source of Variation	***SS***	***df***	***MS***	***F***
Cutting Speed	1,297576333	1	1,297576333	0,528180127
Cutting Depth	0,194565333	1	0,194565333	0,079198071
Cutting Speed*Cutting Depth	0,046376333	1	0,046376333	0,018877547
Error	19,65354267	8	2,456692833	
Total	21,19206067	11		

Conclusions can be drawn using the F value for surface roughness on St 42 steel as follows:

a. For variable-cutting-speed processes

Fcount has a value of 1.352462558, and Ftable has a value of 5.32. Where Fcount<Ftable means that variations in cutting speed do not have a significant impact on the surface roughness results on AISI 4140 steel.

b. For variable-depth cut processes

Fcount has a value of 0.668023396, and Ftable has a value of 5.32. Where Fcount<Ftable means that variations in cutting depth do not have a significant impact on the surface roughness results on AISI 4140 steel.

c. Interaction between cutting speed and cutting depth

Fcount has a value of 0.242342541, and Ftable has a value of 5.32. Where Fcount<Ftable means that cutting speed and cutting depth do not influence each other or do not interact with the surface roughness results of AISI 4140 steel.

Conclusions

From the research results, the following conclusions were obtained:

1. The largest average surface roughness value, namely Ra = 5.33 µm, occurs in AISI 4140 steel at a cutting speed of 12 m/min with a cutting depth of 0.3 mm, while the smallest average surface roughness value, Ra = 0.77 µm, occurs on S45C steel at a cutting rotation speed of 26 m/min with a cutting depth of 0.1 mm.

2. AISI 4140 steel uses lower cutting speeds, namely 12 m/min and 17 m/min, due to the higher hardness of the material compared to other types of steel. The average surface roughness produced was Ra = 3.81 µm with a cutting depth of 0.1 mm and Ra = 5.33 µm with a depth of 0.3 mm at a speed of 12 m/min. Meanwhile, at a speed of 17 m/min, the average surface roughness was obtained at Ra = 3.02 µm with a cutting depth of 0.1 mm and Ra = 3.40 µm with a cutting depth of 0.3 mm.

3. Cutting speed has an effect on surface roughness only in S45C steel because the Fcount>Ftable value

means that variations in speed have a significant impact on surface roughness (13.18107506 > 5.32), while the depth of cut parameter has no significant effect on surface roughness. on all types of steel because in all comparison results between Fcount and Ftable, the comparison Fcount<Ftable is obtained.

4. The interaction between cutting speed and cutting depth does not provide interaction or does not influence each other between the two effects, namely cutting speed and cutting depth on surface roughness. Obtained from a comparison of Fcount and Ftable. Contains conclusions from the discussion.

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Conflict of Interest
The authors declare no conflict of interest

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