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Effect of cutting speed on milling process on surface roughness of ST-37 steel material workpiece

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Abstract

The importance of the surface roughness value of a workpiece must be of concern to students and machine operators because the surface roughness of the workpiece becomes a benchmark for the use of a component in the machining plane and one of the significant influences on the surface roughness of the workpiece is the cutting speed parameter. To examine the extent of the effect of cutting speed on surface roughness, testing and analysis of the machining process results were carried out by varying three cutting speeds according to the material range and the type of cutting tool used. This study uses an experimental method, with the research object using steel ST-37 by making cuts on the surface. Test result data obtained that the average roughness price per rotation speed is (Ras) = 4.01μm for Cs 20 with a rotation speed of 530.78 Rpm. (∑Ras) = 2.84μm for cs 25 with a rotation speed of 663.48Rpm. (∑Ras) = 2.59 μm for cs 30 with a rotation speed of 796.18Rpm. With the roughness grade on the N8. So the conclusion in this study is that the higher the engine rotation speed, which is influenced by high cutting speed, the lower the surface roughness of the resulting workpiece.

Keywords: Cutting Speed, Surface Roughness, ST-37 Steel, Cutting Downcut.

1. Introduction

The machining process is essential in making a product. The product will be used maximally and adequately if the product's size is by what it should be. In addition to the machining plane size component, the surface quality of a workpiece plays an important role that must also be considered. Every workpiece that is worked with the milling process has a surface quality level that must be met. Therefore, to get maximum results besides careful planning and calculations, correct processing methods are also needed.

Several parameters must be taken into account in the milling process: machine rotation speed, cutting speed, feeding, and thickness of material erasures. "Rotation speed, cutting speed, feeding and cutting depth have a big influence on the life of the milling knife and the quality of the working surface, so the selection should receive special attention" [1]. With the cutting parameters that must be considered, a milling machine operator must also look at the type of steel material to be cut because the type of steel used has very different parameters in terms of the use of parameters.

Steel is an alloy of iron and carbon, with carbon content up to a maximum of 1.5%. The carbon occurs in the form of iron carbide because of its ability to increase the steel's hardness and strength [3]. Steel material has a maximum carbon content level of 1.5%, and it is an amalgamation of carbon and iron. To increase the hardness of steel, it takes carbon in the form of iron carbide as an additional element. The elemental content of other elements is also present in steel in addition to the content of the main ingredients consisting of iron and carbon. There are thousands of other metal alloys that have different compositions. The carbon content, typically less than 15%, significantly affects the steel's mechanical

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properties. The range of varying carbon concentrations makes steel classified into several levels, namely low carbon steel, medium carbon steel, and high carbon steel, which contains less than 0.3% carbon, 0.3% - 0.6% carbon, and 0.6% - 1.5% carbon respectively [4].

One of the medium carbon steels, such as ST-37 steel, has the equivalent of AISI 1045, while the carbon chemical content of this steel is: 0.5%, Manganese: 0.8%, Silicon: 0.3% [4]. Apart from the contents contained in the ST-37 steel, there are still many other elements, with a hardness of 170 HB and tensile strength of 650 - 800 N/mm^2 [4]. ST-37 steel can be used without heat treatment directly, but if a particular application is required, then ST-37 steel is required heat treatment[4].

Steel ST-37 is most widely used in a series of machines, where the steel has a low carbon content and has a steel tensile strength value of 37 kg/mm^2. ST-37 steel is used in machining components often used, such as gears, shafts, nuts, bolts, etc., because of its ductile nature and ease to work with a forged machine. Treatment of ST-37 steel is also often done in the milling process to manufacture these components.

1.2 Milling Process Parameters

1.2.1 Cutting Speed

Mathematically, the cutting speed of a material cannot be calculated because each material has its own characteristics according to its type of material. For ST-37 steel, the material cutting speed is at point 3 of the ST 34 to ST 50 steel stretch with cutting speed (cs) between 20 m/minute to 30 m/minute, and the following is the price of cutting speed for various materials and can be seen in table 1:

Table 1. Material Cut Speed

No.	Material	The amount of cutting speed (cs) (m/min)
1	Steel > ST 70	10-14
2	Steel ST 50 s / d ST 70	14-21
3	Steel ST 34 s / d ST 50	20-30
4	Cast iron	14-21
5	Brass, hard bronze	30-45
6	Copper, soft bronze	40-70
7	Plastic	40-60
8	Pure aluminum	300-500
9	Aluminum Alloy	70-120

Source:[5]

1.2.2 Machine Rotation Speed (Spindle Machine)

"Rotation speed is the ability of the engine speed in one minute" [5]. In the cutting process with a frais machine, the rotation of the machine/workpiece can be adjusted because the cutting speed for each type of material is different and has been set by default.

The rotation speed used depends on the cutting speed and the milling knife's diameter. The formula for calculating engine speed is:

$$n = \text{rpm}\frac{\boldsymbol{cs}}{\boldsymbol{\pi.d}} \quad \text{Eq. 1}$$

To equate the Cs unit that has units of m / minute and the cutter diameter that has units of mm, the formula changes to:

$$n = \text{rpm}\frac{\boldsymbol{cs.1000}}{\boldsymbol{\pi.d}} \quad \text{Eq. 2}$$

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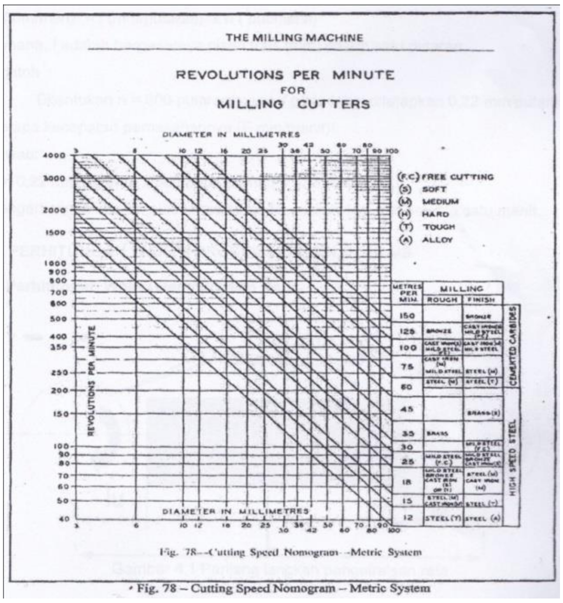
Information :

Cs : cutting speed (m / min)
d : blade diameter (cutter) (mm)
π : constant (3.14)
n : spindle rotation (rpm)

Determining the rotation rate of the CNC Milling machine, a table such as the following can also be used:

Table 2. Cutting Speed and Milling Machine Rotation



Source:[5]

1.2.3 Feeding Speed (Feeding)

The feeding speed is the speed that delivers the workpiece towards the milling knife so that it is shriveled or cut [6]. For feeding (feeding), a feeding table that has units of mm / minute is usually attached to the frais machine. Feeding on the device applies to automatic mode. Then the formula is:

$$F = fz. Z. n \quad \text{Eq. 3}$$

Information :

F = *Feeding* (mm / minute)
fz = *feed* per tooth of the milling knife (mm / tooth)
Z = many teeth of the milling knife
n = spindle rotation (Rpm)

1.3 Milling Machine Cutting Method

The milling process has two methods of relative direction of the milling machine table's feeding motion to the blade's rotation, namely, the downcut method and the uppercut method [2]. In short, the downcut cutting method can be interpreted by the downcutting method; the direction of rotation of the cutting edge in this method is in the same direction as the feeding motion of the milling machine table. Meanwhile, the uppercut method is an upward cutting with the direction of rotation of the cutting edge in the opposite direction to the milling machine table's feeding motion. These cutting methods affect the yield of the steel material to be sliced.

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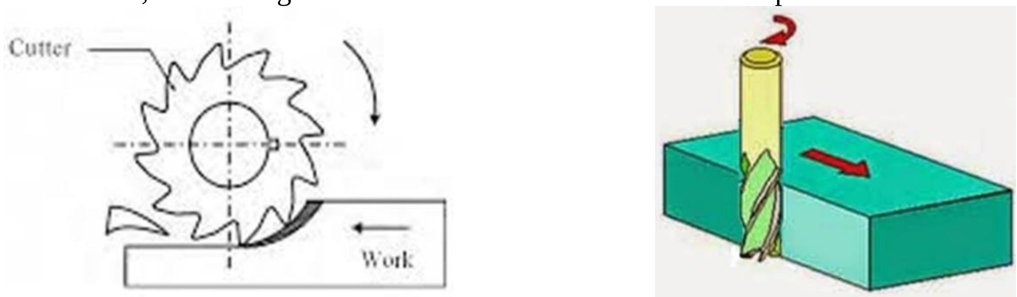
1.3.1 Downcut Method (Down Cutting)

In this method, the direction of rotation of the cutting tool is in the same direction as the milling machine table's feeding motion. By using this method, a sturdy machine construction is needed because it has a high initial force and causes the workpiece to be more stressed.

In the downcut process, the cutting begins on a surface with a well-defined cut thickness but requires a high initial force, and the engine construction must be robust with a slip-back free transmission [7].



a. b.

Figure 1. a Downcut Process, b End Mill Downcut [7]

1.3.2 Uppercut Method (Milling Up)

In this method, the direction of rotation of the cutting tool is the opposite of the milling machine table's feeding motion. The initial force required is relatively low but results in a slightly scarred surface. In the uppercut process, the blade teeth enter at a minimum depth, and the initial force is relatively low [7]. This method was used before more robust machines were invented.

a. b.

Figure 2. a Uppercut Process, b End Mill Uppercut [7]

1.4 Surface Roughness Parameters

Measurement, the level of roughness and characteristics of a surface, has been determined by the general standards used are International standards (ISO R468) and American standards (ASA B 46.1-1962), which discuss surface qualities such as height, width, and direction of surface patterns [11].

Signing for the maximum allowable average roughness price (Ra) is done by writing on the triangle symbol. In writing, the unit must use the unit applied to the technical drawing, namely inches or metric. For the minimum roughness value Ra if required, then write it under the maximum roughness figure. Ra has a roughness class range from N1 to N12 according to the predetermined standard.

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Table 3. Price Standard and Ruggedness Class

Roughness Price Ra (µm)	Roughness Class	Sample Length (mm)
0.025	N1	0.008
0.005	N2	0.25
0.1	N3	
0.2	N4	
0.4	N5	0.8
0.8	N6	
1.6	N7	
3,2	N8	
6.3	N9	2.5
12.5	N10	
25	N11	8
50	N12	

Source: [8].

1.4.1 Price tolerance Ra

The roughness tolerance value also has the arithmetical mean roughness value Ra; it is the same as the size tolerance (hole and shaft). The roughness price ranges from N1 to N12 according to each material's roughness class. Ra has a range of values starting from 25% down and 50% upwards for the amount of tolerance for the price. The following shows the average roughness values along with the allowable tolerances.

Table 4. Average Roughness Price Ra and Permissible Tolerances

Roughness Class	CLA Price (µm)	Price Ra (µm)	Tolerance N -25% to + 50%	Long Sample (mm)
N1	1	0.0025	0.02-0.04	0.08
N2	2	0.05	0.04-0.08	0.25
N3	4	0.0	0.08-0.15	
N4	8	0.2	0.15-0.3	
N5	16	0.4	0.3-0.6	0.8
N6	32	0.8	0.6-1.2	
N7	63	1.6	1,2-2,4	
N8	125	3,2	2,4-4,8	
N9	250	6.3	4,8-9,6	2.5
N10	500	12.5	9.6-18.75	
N11	1000	25.0	18.75-37.5	8
N12	2000	50.0	37.5-75.0	

Source:[9]

During the milling process observation, students and operators who operate CNC milling machines do not know or pay attention to precise cutting parameters related to the quality of the workpiece surface, both the downcut and the uppercut cutting method and the steel material that will be used in the cutting process. Because all parameters, material types, and cutting methods described in this introduction significantly affect the roughness of an object, it will be by the demand for components from an industry.

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2. Method

In this research, the authors use a quasi-experimental method. A quasi-experimental analysis is applied to control certain conditions to obtain the effect sought [10].

This research object is Steel Material ST-37. It has been cut using a CNC milling machine with a 12 mm diameter HSS end mill cutter, using the downcut cutting method with variations in cutting speed. Then the surface roughness test of the ST-37 steel material was carried out with the Mitutoyo SJ-201P Surface Tester measuring instrument with the measuring method scratching the measuring instrument's tip on the touch side of the measuring instrument the surface of the workpiece that had been sliced. The data obtained are then processed for the research results.

Figure 3. Objects of Research on Steel Materials ST-37.

2.1. Parameter Planning

2.1.1 Engine Rotation Speed

The rotation speed is calculated based on the cutting-rate speed in this study. For low carbon steel in table 1 Cs = 20-30 mm / minute, then for the Cs that the researchers took varied three variations, namely 20, 25, and 30. And do not enter the rpm value two digits behind the machine's comma.
Then the engine rotation speed:

1) Rotation speed for Cs 20

$$n = \frac{1000.Cs}{\pi.D} = \frac{1000.20}{3{,}14\ .12} = 530{,}78\ rpm$$

2) Rotation speed for Cs 25

$$n = \frac{1000.Cs}{\pi.D} = \frac{1000.25}{3{,}14\ .12} = 663{,}48\ rpm$$

3) Rotation speed for Cs 30

$$n = \frac{1000.Cs}{\pi.D} = \frac{1000.30}{3{,}14\ .12} = 796{,}18\ rpm$$

2.1.2 feeding

The engine rotation speed was obtained after varying the Cs, then the feeding was determined with a feed value per tooth of 0.05 mm for each engine rotation speed with a cutting thickness of 1 mm.

1) F = fz. Z. n = 0.05 x 4 x 530.78 = 106.15 mm / min
2) F = fz. Z. n = 0.05 x 4 x 663.48 = 132.69 mm / min
3) F = fz. Z. n = 0.05 x 4 x 796.18 = 159.23 mm / min.

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3. Results and Discussion

The test results of the variations in cutting speed are obtained in Table 5.

Table 5. Surface Roughness Value of ST-37 Steel Material

Rotation Speed (rpm)	***Feeding (mm / min)***	**Value of Surface Quality of Objects**			**∑Ras**	**Roughness Class**
		T1	T2	T3		
530.78	106.15	4.26	3.95	3.83	4.01	**N8**
663.48	132.69	2.93	2.84	2.75	2.84	**N8**
796.18	159.23	2.64	2.56	2.59	2.59	**N8**

Based on the data table of the surface quality test results above, in the downcut cutting method, the average roughness price per rotation speed is (∑Ras) = 4.01µm for Cs 20 with a rotation speed of 530.78 Rpm. (∑Ras) = 2.84 µm for Cs 25 with a rotation speed of 663.48 Rpm. (∑Ras) = 2.59 µm for Cs 30 with a rotation speed of 796.18 Rpm. With the roughness grade on the N8. The following is a presentation of the roughness value in Figure 3 below:

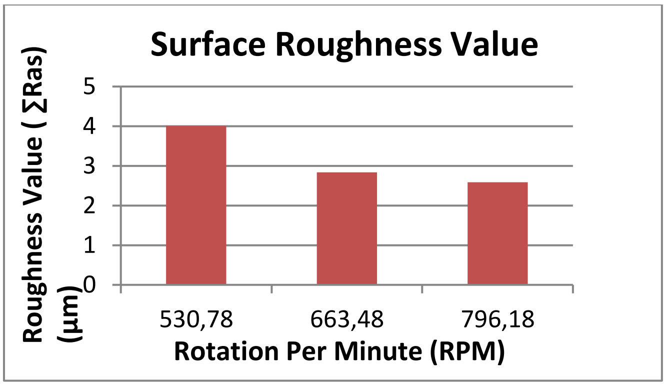

Figure 3. Graph of Surface Roughness Value

Cutting speed in cutting objects process using a CNC Milling machine dramatically affects the workpiece's surface quality. This can be seen in the results of tests carried out with the data in table 5, showing that for Cs 20 with a rotation speed of 530.78 Rpm, the roughness value (∑Ras) = 4.01µm. For Cs 25, with a rotation speed of 663.48 Rpm has the roughness value (∑Ras) = 2.84 µm. For Cs 30 with a rotation speed of 796.18 Rpm, the roughness value (∑Ras) = 2.59 µm. The higher the engine rotation speed, which is influenced by high cutting speed, the lower the surface roughness value of the resulting workpiece. Each product that is produced must determine the object's surface roughness value according to the quality that must be met [11].

4. Conclusion

To sum up, it can be concluded that the effect of the roughness value of an object on the cutting Speed of ST-37 steel is the higher engine rotation speed is influenced by high cutting speed, the lower the surface roughness of the resulting workpiece. The test results state that the lowest roughness value is at Cs 30 with a rotation speed of 796.18 Rpm, the roughness value (∑Ras) = 2.59 µm. Besides, cutting speed is a parameter that significantly influences the roughness value because the cutting speed will also affect the feeding value every time the cutting speed changes,

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