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Analysis and Effect of Cutting Parameters on The Surface Roughness of Type 4140 Steel in The Dry Milling Process

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Abstract - Currently in the world of metal cutting industry, wet machining is still carried out and machining experts continue to strive to reduce the use of coolant so that benefits can be obtained from economic, environmental and operator safety aspects. One of the criteria for determining machining quality is surface roughness. Surface roughness is influenced by machining parameters such as cutting speed, feed depth and feed rate as independent variables. The aim of the research is to obtain surface roughness values for type 4140 steel workpieces due to spindle rotation speed and feed depth, which uses a carbide endmill as a cutting tool. Research activities were carried out with 9 specimens each for dry machining and wet machining using variations in machine spindle rotation of 1200 rpm, 1400 rpm and 1600 rpm with feed depths of 0.5 mm, 0.75 mm, 1 mm. Data processing uses the statics method with a normal distribution curve to obtain surface roughness data. To determine the roughness value of the machined surface, it is tested using a Surface Test measuring instrument. The surface roughness obtained from machining under optimum conditions for dry machining is 1.699 µm, 2.778 µm and 2.868 µm at a machine spindle rotation of 1600 rpm. while those carried out using wet machining obtained respective results of 1.602 µm, 2.654 µm and 2.815 µm at a machine spindle rotation of 1600 rpm. So optimum cutting/slicing is obtained at a spindle rotation speed of 1600 rpm with Ra = 1.699 µm for dry machining while for wet machining the surface roughness value Ra = 1.602 µm is obtained at a spindle rotation speed of 1600 rpm. The comparison of the results of dry machining (Ra= 1.699 µm) and wet machining (Ra= 1.602 µm) to obtain the most optimum Ra surface roughness value is not significant, so it is a good opportunity that dry machining technology can be applied to the metal cutting industry although Until now, many people still use wet machining processes using cutting fluids to cut steel meta

Keywords : Steel 4140, surface roughness, dry milling

1. INTRODUCTION

Until now, milling machines are one of the machine tools that have an important role in the machinery and manufacturing industry. It is called a vertical milling machine if the machine spindle axis is perpendicular to the surface of the machine table. The machining process is a process carried out to change the shape of a workpiece by removing some material from the workpiece so that it becomes the desired product using a machine tool. One example of a machining process using machine tools is a machining process using a milling machine [1]. Machining through the milling process produces a flat surface where the reduction of the workpiece occurs due to the contact of the rotating cutting tool with the workpiece [2]. The issue of surface quality of a workpiece plays an important role which must also be considered in relation to surface roughness

Every workpiece that is machined using a milling process has a surface quality level that must be met [3]. Fabrication of a workpiece as a test specimen using a vertical milling machine with an end mill

cutter rotating perpendicular to the surface of the workpiece, each tooth making a cut where the cutting direction will affect the level of surface roughness in the milling process [4]. The machining process using vertical milling will certainly produce an increase in temperature due to friction between the cutting tool and the workpiece which can cause tool failure. One effort to reduce the rate of tool wear is to provide coolant (cooling liquid) which can reduce the temperature of the tool. However, the use of cutting fluids certainly requires quite large costs from an economic aspect and the environmental impact continues to increase [5].

As a result of wet machining, the steam and aerosols produced by the coolant can pose a health risk to workers/operators if not managed properly. Therefore, the researchers tried to conduct experiments with the dry machining method. Dry machining is the main choice to increase the service life of cutting tools, especially when cutting with steel, cast iron and some stainless materials [6]. Until now, observation and evaluation of surface roughness have been developed, where measuring surface roughness is carried out using various different measurement systems [7]. To obtain the desired component surface quality through milling, a type of end mill is used. The selection of cutting parameters must be well controlled during machining, including cutting speed, feed rate and also depth of cut. Improper selection of machining parameters will cause the cutting tool to wear out quickly and become damaged [8]. There are a number of processes that can be used to produce raw materials in any desired form from the initial stage to the final stage. Among various machining processes, end milling is one of the most widely used material removal processes in industry [9]. Cutting operations on end mills can be carried out as simply as face milling on a flat surface using a rigid cutter or milling on very complicated parts [10]. Endmill cutter cutting tools have a big influence on the level of surface roughness. The number of flutes and endmill material are taken into account to obtain a good roughness level [11]. Cutting speed is the most significant cutting parameter followed by feed rate and depth of cut [12]. Spindle rotation speed and feed speed affect surface roughness [13]. The

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higher the surface quality produced. Therefore, to obtain quality products in the form of a high level of precision and good surface roughness, it needs to be supported by the right machining process[14]. From the explanation above, it is deemed necessary to conduct a surface study of machining results, especially type 4140 steel material which is usually applied as shafts, gears, bolts, couplings, spindles, piston pins, hydraulic machine shafts and others.

The depth of feed really determines the surface roughness of the machining results, where the greater the feed depth, the greater the surface roughness value for 4140 steel with a cutting knife for milling machines, namely a 12 mm carbide endmill [15].

By using test statistics it will be possible to obtain an optimum comparison of wet machining and dry machining through the vertical milling process and the studies carried out include surface roughness which can define surface roughness values as a function of cutting conditions which are an independent variable.

2. RESEARCH PURPOSES

1. To obtain the surface roughness value of type 4140 steel with variations in spindle rotation speed and feed depth.
2. Obtaining a cutting parameter has a good opportunity to realize the dry milling process in machining
3. Compare the dry milling process and the wet milling process where surface roughness is a function of cutting conditions.

3. MATERIALS,TOOL AND METHODS

3.1 Material

The chemical composition of 4140 steel material is Cr = (0.88-1.10) %, Si = (0.15-0,30) %, Mn = (0.75-1,00) %, P = 0.035 %, S = 0,04 %, C = (0.38-0.43) %, Mo = (0.15-0,25) %. As for the mechanical properties: density = (7700-8030) kg/m^3, Modulus young = (190-210) Gpa. Tensile strength = 655 Mpa. Yield strength = 450 Mpa, Brinell Hardness = 197 HB.

3.2 Equipment

The tools used in the testing were a vertical milling machine, a surface test as a tool to obtain roughness values and a 12 mm carbide endmill.

4. METHODS

Testing of steel workpieces as test specimens was carried out experimentally. To carry out the cutting process, it is carried out by milling the surface of a cylindrical workpiece for type 4140 steel.

The cutting of the workpiece is given variations in the rotation speed of the machine spindle depth of feed. The first, second and third tests were carried out each with 3 cuts for spindle rotation speeds of 1200 rpm, 1400 rpm and 1600 rpm with an ingestion depth of 0.5 mm; 0.75mm; 1mm. So there are 9 cutting tests to get the roughness value of the machined surface using a surface test tool.

Surface roughness data for dry machining with 9 machining tests, the results of which will be compared with surface roughness data for wet machining. To obtain the most optimum cutting conditions, observations and data analysis were carried out by comparing data on dry machining and wet machining. Data treatment in dry machining and wet machining uses a static method with a normal distribution curve.

5. RESULTS AND DISCUSSION

Machining results from the vertical milling process for dry machining and wet machining with graphical results as follows.

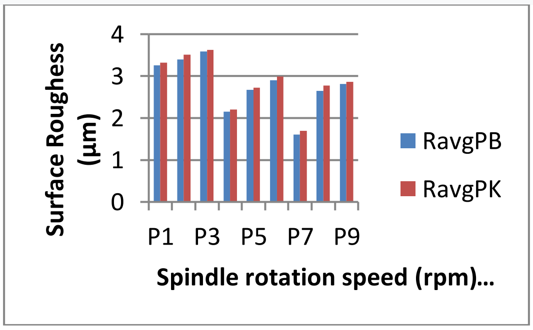

Figure 1. Relationship between machining test results and surface roughness.

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The machining results of the vertical milling process from AISI 4140 steel metal material in Figure-1 show the curves of the results of dry machining and wet machining using a 12 mm 4 flute endmill carbide cutter. Machining tests on type 4140 steel were carried out 9 cutting tests with the independent variables being cutting speed and feed depth. From the 9 specimens tested, a smaller surface roughness level was obtained at a spindle rotation speed of 1600 rpm (P7, P8, P9) for dry milling and wet milling processes.

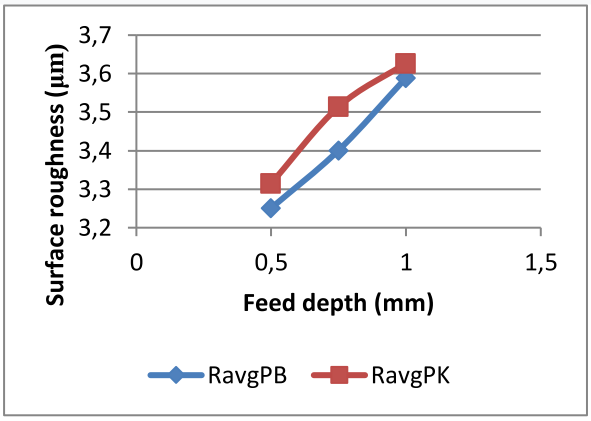

Figure 2. Curve of the relationship between depth of infeed and roughness at n = 1200 rpm.

Surface roughness Ra as a function of burial depth can be seen in figure-2. Figure-2 shows 2 relatively linear parallel curves, namely RavgPK and RavgPB as surface roughness data from machining through dry milling and wet milling. With a variation in depth of 0.5 mm; 0.75mm; 1mm, the surface roughness values obtained are RavgPK (average surface roughness of dry machining) respectively, namely 3.315 µm, 3.514 µm, 3.627 µm and RavgPB values (average surface roughness of wet machining) respectively 3.251 µm, 3.401 µm, 3.589 µm. The RavgPK curve is above the RavgPB curve which is far from the x-axis reference plane, meaning that the RavgPK curve is not better than the RavgPB curve because the roughness level gain is greater, although not significant.

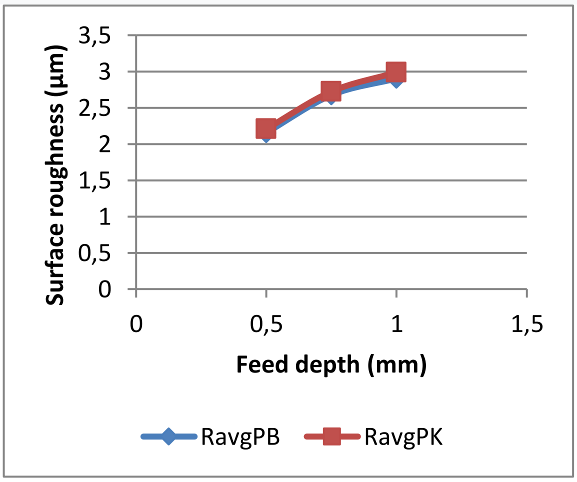

Figure 3. Relationship between depth of ingestion and roughness at n = 1400 rpm

Figure-3 shows 2 curves that coincide with each other, namely RavgPK and RavgPB as surface roughness data resulting from machining through dry milling and wet milling. With a variation in depth of 0.5 mm; 0.75mm; 1mm obtained the surface roughness value RavgPK (dry machining average surface roughness) respectively, namely 2.208 µm; 2.724 µm; 2.988 µm and the RavgPB (wet machining average surface roughness) value of 2.156 µm respectively; 2.674 µm; 2.903 µm. Even though the two RavgPK curves and the RavgPB curve coincide, they can be compared as shown in the data. With the RavgPK curve and RavgPB curve coinciding, it means that the surface roughness gain is almost the same but not significant

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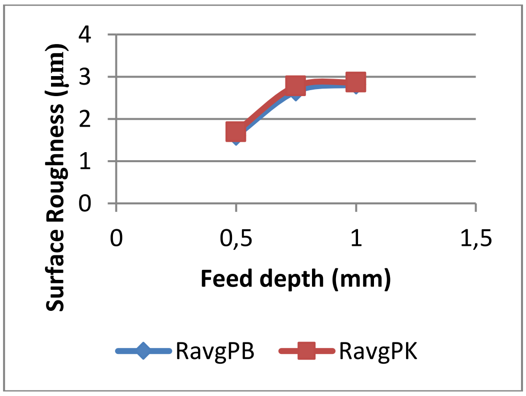

Figure 4. Relationship between depth of ingestion and roughness at n = 1600 rpm

The ratio of dry and wet machining in the vertical milling process can be seen in figure-4 where from the two curves, namely the RavgPK curve, it is obtained that it is 1.699 µm; 2,778 µm 2,868 µm and RavgPB curves 1,602 µm respectively; 2,654 µm 2,815 µm with a burial depth of 0.5 mm; 0.75mm ;1mm. After observing these data, the surface roughness results are almost the same because the RavgPK curve and RavgPB curve coincide with each other.

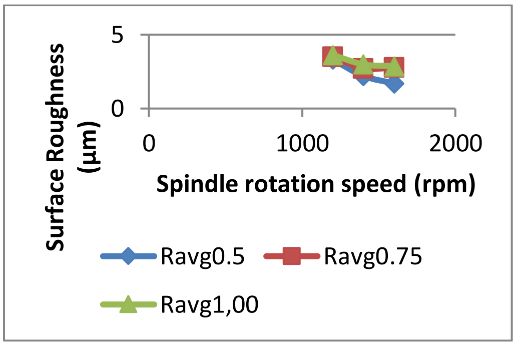

Figure 5. The relationship between spindle rotation speed and roughness in the dry process.

Figure -5 shows 3 curves where surface roughness is a function of spindle rotation speed. Machining with a dry milling process for a spindle rotation speed of 1200 rpm gives a Ra value of 3.315 µm; 3.514 µm 3.627 µm as well as Ra value 2.208 µm; 2.724 µm; 2,988 for 1400 rpm rotation.

Meanwhile, for a spindle rotation speed of 1600 rpm, Ra values were obtained, respectively, 1.699 µm; 2.778 µm and 2.868 µm. Obtaining surface roughness values from the three curves above was carried out at a depth of 0.5mm; 0.75mm; 1mm. Observations were made from the three curves for a spindle rotation speed of 1200 rpm; 1400 rpm and 1600 rpm means that testing specimens 7, 8, 9 at a spindle rotation speed of 1600 rpm approaching the x-axis plane means that it provides a better curve because in terms of the Ra value it is smaller than the other 2 curves.

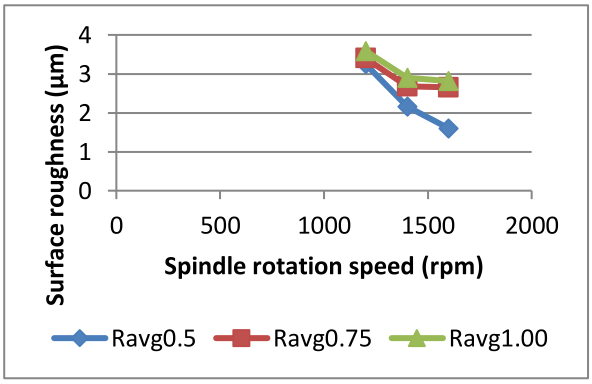

Figure 6. The relationship between spindle rotation speed and roughness in the wet process.

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Figure -6 shows 3 curves where surface roughness is a function of spindle rotation speed. Machining with a wet milling process for a spindle rotation speed of 1200 rpm gives a Ra value of 3.251 µm; 3,401 µm 3,589 µm as well as Ra value 2,156 µm; 2.674 µm; 2,903 for 1400 rpm rotation. Meanwhile, for a spindle rotation speed of 1600 rpm, Ra values were obtained, respectively, 1.602 µm; 2.654 µm and 2.815 µm. Obtaining surface roughness values from the three curves above was carried out at a depth of 0.5mm; 0.75mm; 1mm. Observations were made from the three curves for a spindle rotation speed of 1200 rpm; 1400 rpm and 1600 rpm, in fact the spindle rotational speed of 1600 rpm for testing specimens 7,8,9 is close to the direction of the x-axis plane (independent variable) which means it gives a better curve because the Ra value is relatively smaller.

Surface roughness analysis with statistics

H_0 : There is no change in Ra avg between dry and wet machining

H_1 : There is a Ra avg difference between dry and wet machining

Through dry and wet machining data, it is obtained:

$$\bar{X}_1 = \frac{1{,}699 + 2{,}778 + 2{,}868}{3} = 2{,}357$$

$$\bar{X}_2 = \frac{1{,}602 + 2{,}654 + 2{,}815}{3} = 2{,}448$$

$$S_{d1} = \sqrt{\frac{\sum (X_1 - \bar{X})^2}{n-1}}$$

$S_{d1} = 0{,}659$,

$S_{d2} = 0{,}667$ and

$S_P = 0{,}662$

Test statistics

$$Z = \frac{\overline{X_1} - \overline{X_2}}{S_P\sqrt{\frac{1}{n}+\frac{1}{n}}} = \frac{2{,}357 - 2{,}448}{0{,}662\sqrt{\frac{2}{3}}}$$

$$Z = \frac{-0{,}091}{0{,}540} = -0{,}168$$

$$\alpha = 0{,}05 \;;\; Z_{\frac{\alpha}{2}} = Z_{0{,}025} = 1{,}96$$

Test criteria : Reject Ho if $Z > Z_{0{,}025}$ or $Z < -Z_{0{,}025}$

So Ho is accepted where there is no significant difference, which is a value of 1.96 obtained based on the table.

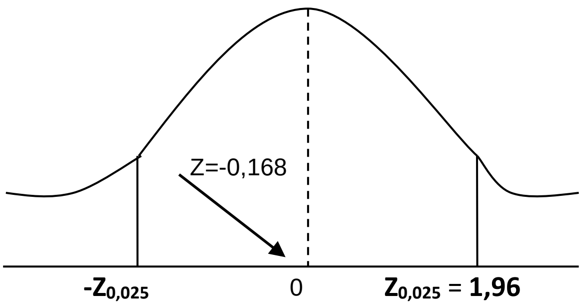

Figure 7. Test statistics with statistical methods for normal distribution curves

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Table 1. ANOVA untuk RavgPB

Sumber	Jumlah Kuadrat (Sum of Squares)	df	F	P-value
C(n)	1.864.134	2	14.031.990	0.01556
C(f)	0.952588	2	7.170.459	0.04756
Residual	0.265698	4		

Table 2. ANOVA untuk RavgPK

Sumber	Jumlah Kuadrat (Sum of Squares)	df	F	P-value
C(n)	1.826.694	2	13.990.159	0.01564
C(f)	0.949850	2	7.274.645	0.04650
Residual	0.261140	4		

6. CONCLUSION

1. From Figure 1, it can be seen that the dry milling process which is carried out without cutting fluid and wet milling which uses cutting fluid can provide a bar chart
2. characteristic where the Ra roughness value obtained in the specimen test is 7.8.9 (1600 rpm) which is smaller (lowest bar chart).
3. Compared with specimen testing 1,2,3 (1200 rpm) and testing 4,5,6 (1400 rpm) because the spindle rotation speed increases for a feed depth of 0.5mm; 0.75mm; 1mm.
4. Figure-2 shows 2 curves as ratios for dry machining Ravg and wet machining Ravg which are aligned relatively linearly on the x-axis reference plane. Meanwhile, figure-3 and figure-4 show each with 2 curves that coincide with each other, which are almost the same, namely the RavgPK and RavgPB data, which means they are not significant. From these three images, the greater the depth of ingestion, the greater the surface roughness obtained.
5. Figure-5 shows 3 curves in the dry milling process, where surface roughness is a function of spindle rotation speed. The data observed from the three curves shows that there is a variation in spindle rotation speed of 1200 rpm; 1400 rpm and 1600 rpm, in fact testing specimens 7, 8, 9 at a spindle rotation speed of 1600 rpm gives a better curve compared to the other 2 curves because the Ra value obtained is smaller which is close to the x-axis plane as well as for the wet milling process in Figure 6 . The comparison of the two images for the dry milling and wet milling processes is not significant because the relative surface roughness Ra values are not much different, almost almost the same. The greater the spindle rotation speed, the smaller the surface roughness gain value.
6. Application of statistical methods with a normal distribution curve obtained a test statistic Z = -0.168 in Figure 7, so from observations with a normal distribution curve the test statistical value falls in the area Z0.025 = 1.96, so it is acceptable that the Ra value of dry machining and wet machining is not significant in obtaining the Ra value with the consequence of applying the dry milling process is an opportunity to apply it.
7. The results of the ANOVA calculations in the table for RavgPB and RavgPK use a simpler model where the results show that comparisson between RavgPB and RavgPK in the anova table is not significant

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