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Research Paper

Effect of Cutting Parameters on Surface Roughness in Dry Machining of S45C Steel Using Carbide Tools

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ABSTRACT

Wet machining is still carried out in the metal cutting industry today; machining experts continue to work to reduce the use of coolant so that benefits for the environment, economy and operator safety can be obtained. The research aims to obtain cutting conditions which have a good chance of realizing the concept of dry machining on S45C steel regarding surface roughness. The research was carried out using 9 specimens by statics method with a normal distribution curve where S45C steel turning using uncoated carbide chisels was carried out on dry machining and wet machining. Machine spindle rotation of 700 rpm, 1000 rpm and 1300 rpm can be converted in the amount of cutting speed, then for infeed 0.15 mm/r, 0.2 mm/r, 0.25 mm/r and the depth of cut remains 1 mm. Machining S45C steel is selected for optimum cutting conditions on wet and dry machining. Machined surface roughness was tested using the Surface Test measuring instrument. The surface roughness obtained for dry machining was 1.602 µm, 1.667 µm and 2.041 µm for dry machining while for wet machining the results were 1.521 µm, 1.593 µm respectively and 1.915 µm. So, the most optimum cutting is obtained in cutting conditions with a cutting speed of 87.92 m/min at 700 rpm machine spindle rotation with Ra = 1.602 µm for dry machining while wet machining obtains a surface roughness value of Ra = 1.521 µm on wet machining. Comparison of the results of dry machining (Ra= 1.602 µm) and wet machining (Ra= 1.521 µm) to obtain the optimum surface roughness value Ra is not significant, so it is a good opportunity for the possibility of a dry machining technology to be applied to the metal cutting industry even though today many still use the wet machining method of turning using a cutting fluid to cut metal.

***Keywords*:** S45C steel, cutting parameters, surface roughness, dry turning

INTRODUCTION

Up to now, machine tools are needed to make machine components and others to meet the needs of the manufacturing or metal cutting industries. Lathe is a machine that can change the size or shape of the workpiece by cutting the workpiece with a chisel. The workpiece is held by a handle mounted on the end of the shaft, then the workpiece rotates following the spindle rotation[1]. Today's CNC Lathes are much more sophisticated and automatic. CNC Lathes are widely used in various factories and companies around the world and are used for various functions and uses. CNC Lathes are generally used for the manufacturing process of various goods, where the workpiece is gripped and rotated and the cutting tool is positioned for the outer diameter and inner diameter operations such as shafts and pipes. This CNC lathe is suitable for parts that have a symmetrical/circular shape and an axis that can be gripped on a spindle (turntable shaft). Currently, turning for wet machining in the metal cutting industry is still used for cutting steel metal[2]. Metal cutting in the metal cutting industry uses a cutting fluid (coolant) which aims to reduce high temperatures with the consequence of being able to extend the tool life conditions in order to obtain surface integrity; one of which is surface roughness[3]. Actually, for temperature factors, residual stress, plastic deformation, tears and cracks can also affect the surface condition of the machining results[4].

The use of cutting fluid in wet machining for a long time will have an adverse effect on the environment and health, therefore, efforts are made to reduce it[5]. When dry machining is performed on S45C steel, the following may be encountered:

1. S45C steel has less hardness and ductility, so without a cutting fluid it will cause quite high friction and heat.
2. The decrease in cutting speed and the adhesion of the chips to the surface will result in continuous chips with relatively tough workpiece properties.
3. Application on dry machining will cause the machined surface hardness to be higher.

The finer the surface of the machining results is, the better the mechanical properties will be. The use of cutting fluid in the machining process with S45C steel creates a number of problems, namely production costs, worker safety and health and environmental impacts. To overcome this, it is necessary to change the machining method from wet machining to dry machining so as to reduce production costs and avoid environmental pollution. From the explanation above it is deemed necessary to study the problem of machined surface roughness of S45C steel as a material for making machine components.

The research purposes are to determine the variation of the spindle speed on the surface roughness of the workpiece on S45C steel, to obtain a cutting parameter with a good chance of realizing dry turning, and to compare wet and dry machining in which surface roughness is a function of cutting conditions.

LITERATURE REVIEW

A machine used in the manufacturing industry would quickly produce components for the engineering sector in large quantities. Like the name of CNC itself, every work from CNC uses a well-formed computer system to produce goods that match precision. The most dominant advantage is the speed in the production process so it is very suitable for mass production. When the cutting process takes place, the contact area between the chip and the tool will increase in temperature. Because the contact area suffers from very high temperatures and pressures, the tool will experience wear[6]. If the workpiece is too hard, the tool will wear out and crack easily when cutting a workpiece that is too hard[7].

S45C Steel

S45C steel is very widely used as material for machine components, both transmission components, or other construction components in machine construction or machine tools. S45C is a type of medium carbon steel which has a carbon content of 0.50%. This material has good mechanical properties so it is widely used in the manufacture of engines, motor shafts, jigs, automotive parts[8]. The standard condition of the workpiece with a ratio of length and diameter of more than 10 is not recommended[9].

Surface Roughness

Surface properties such as roughness are critical to the functionability of machine components. Understanding is done by the mechanism of producing surfaces, which can be used to optimize the machining process and improve the function capabilities of components[10]. Many investigations have been carried out to determine the effect of parameters such as infeed rate, tool nose radius, cutting speed and depth of cut on surface roughness[11]. Surface roughness decreases with increasing nose radius and small nose radius chisel. The correlation between surface roughness, tool tip radius and infeed[12] is given by the following empirical formula:

$$Ra = \frac{0{,}0321.f^2}{rc} \quad (\mu\,\text{m}) \qquad (1)$$

Based on equation (1), the f is the feed and is the radius of the tool corner with a constant of 0.8.

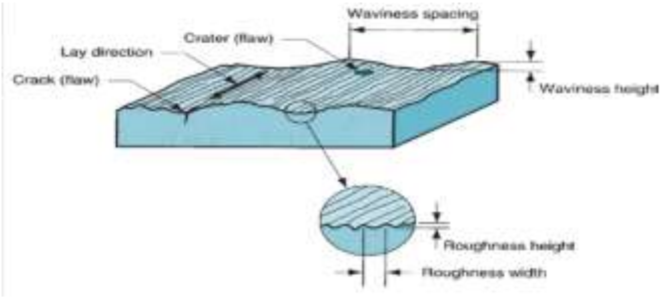


Figure 1. Standard terminology of surface specimen

Roughness values R_a μm	***Roughness grade number***	***Roughness grade symbol***
50	N12	~
25	N11	▽
12.5	N10	
6.3	N9	▽▽
3.2	N8	
1.6	N7	
0.8	N6	▽▽▽
0.4	N5	
0.2	N4	
0.1	N3	▽▽▽▽
0.05	N2	
0.025	N1	

Figure 2. Symbols of surface roughness

The description of the surface texture includes:

1. Roughness is a final form of irregular deviation on a smaller scale than waves.
2. Direction (Lay) is the direction of the main surface waveform and can generally be seen by the naked eye.
3. Wave (Waviness), a repeated deviation from a flat surface, shaped like a wave on the surface of the water. Waves are measured as the space between crests adjacent waves (wave width) and height between wave crests and troughs Waves may be caused by tool deflection, workpiece, curvature of forces or temperature, vibration and lubrication imbalances or heat variations in the system during the manufacturing process.
4. Defect is a random irregularity in the material, such as scratches, then cracks, holes, depressions, layers and inclusions[4].

Dry Machining

Dry machining reduces the cost of machining operations, eliminates the need for disposal of used cutting fluids and purchases of coolant, removes production shutdowns of machining cleaners and improves worker safety and health. Dry machining will also provide a cleaner workpiece environment such as no oil adhering to the workpiece. In addition, anger will become uncontaminated. The cost advantages of dry machining include no coolant, no coolant pump, no filter purchases and no metal cleaner sales[13].

Carbide Chisel

The chisels used in the metal cutting process are tungsten carbide chisels alloyed WC-TiC+CO which is a type of carbide cutting chisel for steel (steel cutting grade). This tool is used to machining test specimens from S45C steel.

Statistical Equations

H_0: There is no change in Ra_{avg} between dry and wet machining

H_1: There is a difference in Ra_{avg} between dry and wet machining

$$S_{d1} = \sqrt{\frac{\sum (X_1 - \bar{X}_1)^2}{n-1}} \qquad (2)$$

$$S^2_P = \frac{(n_1 - 1).S_{d1}^{\ 2} + (n_2 - 1)S_{d2}^{\ 2}}{n_1 + n_2 - 2} \quad (3)$$

$$Z = \frac{\bar{X}_1 - \bar{X}_2}{S_P\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad (4)$$ [14]

MATERIALS AND METHODS

The tools used are CNC lathes, surface tests and carbide insert chisels.

Figure 3. CNC lathe

Figure 4. Surface test (surface roughness testing specimen)

Figure 5. Tool holder (chisel-cutting tool holder)

Figure 6. Carbide chisel insert as workpiece cutting tool

Figure 7. S45C steel metal material with dimensions of diameter D = 50 mm and length of workpiece L = 30 cm (300mm)

Table 1. Chemical composition and mechanical properties of S45C steel

Chemical composition (%)		Mechanical Properties	
C	0.42-0,48	Density kg/m^3	7700-8030
Si	0.15-0,35	Modulus young (Gpa)	190-210
Mn	0.6-0,9	Tensile strength (Mpa)	569 Standard 686 quenching,
P	0.03 max	Yield strength (Mpa)	343 Standard 490 quenching,
S	0.035 max	Brinell Hardness (HB)	160-120 anelead

To perform S45C steel machining with a dry machining cylinder shape which is given a variation of the spindle rotation speed which can be converted to the amount of cutting speed. The first, second and third tests were carried out each with 3 cuts for spindle rotation speeds of 700 rpm, 1000 rpm and 1300 rpm with feed (f) 0.15 mm/r ; 0.2mm/r ; 0.25 mm/r and the depth of cut remains (a) 1 mm. So there are 9 cutting tests to get the machined surface roughness value using a surface test tool. Dry machining surface roughness data with 9 cutting tests will be compared with the results of wet machining surface roughness data. To obtain the most optimum cutting conditions, observations were made by comparing data on dry machining and wet machining. Data treatment on dry machining and wet machining uses a statics method with a normal distribution curve.

RESULTS AND DISCUSSION

Data from achining result obtained from dry and wet machining is shown in Fig. 8.

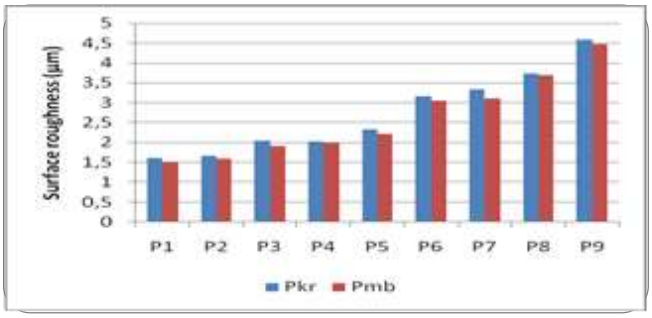


Figure 8. Relationship between machining results and surface roughness

The machining results in the lathe process of S45C steel metal material in Fig. 8 show that the machining of steel which was carried out 9 times the cutting test with the independent variable cutting speed as the roughness value Ra was obtained increased/increased due to changes in the feed f which increased from 0 .15mm/r ; 0.20 mm/r to 0.25 mm/r at a constant depth of cut of 1 mm. Data on the roughness values for dry machining and wet machining tend to increase in line with increasing cutting speed so that in the end the ratio of Ra values on dry machining and wet machining is not significant which is relatively close to the same and not much different.

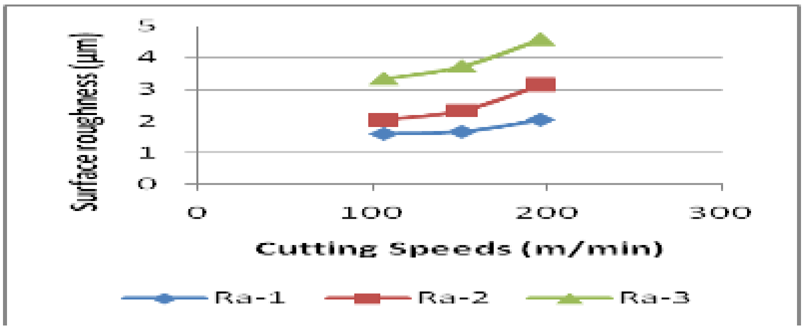


Figure 9. The relationship between cutting speed and roughness in dry machining

Surface roughness Ra as a function of cutting speed can be seen in Fig. 9 showing that for variations in cutting speed, respectively (105.504 m/min; 150.72 m/min; 195.936 mmin) and also different feed f (0.15 mm/r; 0.2 mm/r;0 ,25 mm/r) of which the cutting speed is 105,504 m/min related to the surface roughness Ra-1 1,602 µm respectively; 1.667µm ; 2.041 µm shows a lower Ra value and is close to the x-axis reference plane compared to a cutting speed of 150.72 m/min with a Ra-2 roughness of 2.207 µm; 2.325µm ; 3.154 µm and the Ra-3 roughness curve is far from the x-axis reference plane, meaning that the Ra value obtained is greater than the Ra-2 surface roughness.

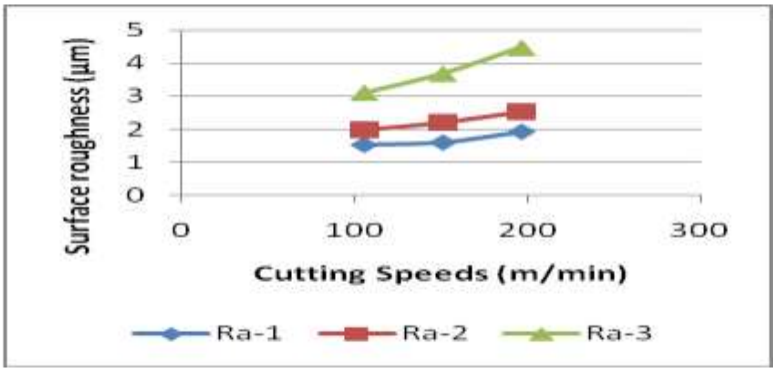


Figure 10. Correlation between cutting speed and roughness in wet machining

Fig. 10 shows that for variations in cutting speed, namely (105.504 m/min; 150.72 m/min; 195.936 mmin) and also different feed f (0.15 mm/r; 0.2 mm/r;0 ,25 mm/r) of which the cutting speed is 105,504 m/min related to the surface roughness Ra-1 1,521 µm respectively; 1.593µm ; 1.915 µm shows a lower Ra value and is close to the x-axis reference plane compared to a cutting speed of 150.72 m/min with a Ra-2 roughness of 1.987 µm; 2.211µm ; 2.542 µm and the Ra-3 roughness curve is far from the x-axis reference plane, meaning that the Ra value obtained is greater than the surface roughness of Ra-2 and Ra-1.

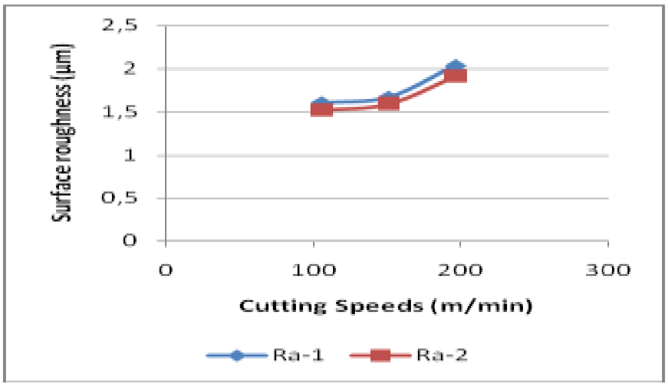


Figure 11. Optimum cutting surface roughness

The comparison of dry and wet machining in dry turning yields a curve in Fig. 11 where the two curves seem to coincide with each other because the surface value of Ra is almost the same, in other words, the value of Ra is not significant, however, dry machining is very possible to be applied to the metal cutting industry and manufacturing. The cutting parameters related to surface roughness are infeed speed and chip-producing speed as shown below.

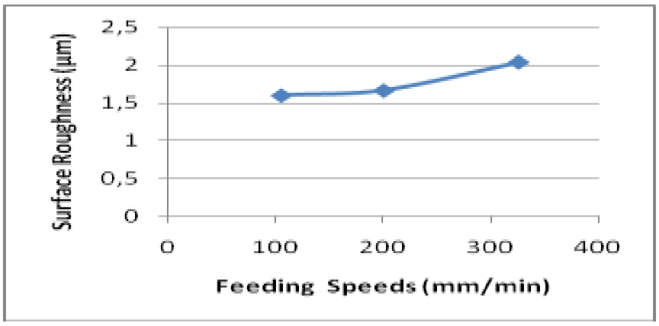


Figure 12. Vf's relationship with Ra

From Fig. 12, surface roughness as a function of infeed speed is used for spindle rotational speeds of 700 rpm, 1000 rpm and 1300 rpm and infeed (f) 0.15 mm/r because it has a Roughness value Ra smaller than the others such as for infeed 0.20 mm/r and infeed 0.25 mm/r. Fig. 12 shows that the greater the value of the feed speed, the value of the surface roughness Ra also increases.

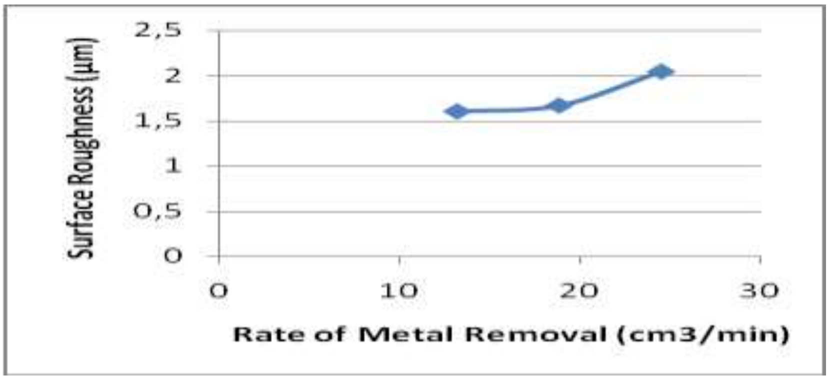


Figure 13. Z's relationship with Ra

From Fig. 13, surface roughness as a function of chip-producing speed is used for spindle rotational speeds of 700 rpm, 1000 rpm and 1300 rpm and feed (f) 0.15 mm/r because it has a smaller Ra roughness value than the others such as for feeding 0.20 mm/r and feeding 0.25 mm/r. Fig. 13 shows that the greater the value of the chip-producing speed, the value of the surface roughness Ra also increases.

Surface roughness analysis with statistics

H_0 : There is no change in HV_{avg} between dry and wet machining

H_1 : There is a difference in HV_{avg} between dry and wet machining

Through dry and wet machining data obtained:

$$\bar{X}_1 = \frac{1.602+1.1667+2.041}{3} = 1.770$$

$$\bar{X}_2 = \frac{1.521+1.593+1.915}{3} = 1.676$$

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

S_{d1} = 0,253 , S_{d2} = 0,209 dan S_P = 0,232

Test statistics:

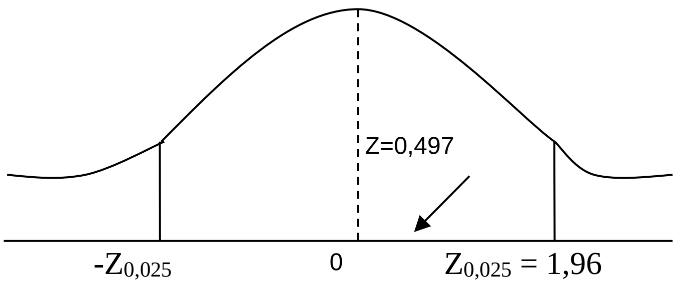
$$Z = \frac{\bar{X}_1 - \bar{X}_2}{S_P\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = \frac{1,77-1,676}{0,232\sqrt{\frac{1}{3}+\frac{1}{3}}}$$

$$z = \frac{0,094}{0,232\sqrt{0,667}} = \frac{0,094}{0,232 .0,817}$$

Z = 0,497

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

Test criteria : Reject H_0 if $Z > Z_{0,025}$ atau $Z < -Z_{0,025}$. Then H_0 is accepted where there is no significant difference, where the value of 1.96 is obtained based on the table.



CONCLUSION

1. In Fig. 8 dry machining and wet machining shows that the cutting tests P1, P2, P3 with an infeed of 0.15 mm/r obtained a Ra value lower than the other cutting tests with an infeed of 0.20 mm/r and 0.25 mm/r. From Fig. 11 there are 2 curves coincide with each other, the Ra value of dry machining is almost identical, that the cutting speed is 105.504 m/min converted from the machine spindle rotation speed of 700 rpm and feed (f) 0.15 mm/r with depth of cut (a) 1 mm is not the most optimum cut for dry machining because the surface roughness value Ra is greater (1.602 µm) than the surface roughness for wet machining, namely . 1.521µm
2. From Fig. 9 dry machining with 3 curves is carried out at different cutting speeds (105.504 m/min; 150.72 m/min;195.936 mmin) and also at different f feeds (0.15 mm/r; 0.2 mm/ r; 0.25 mm/r) that the Ra-3 roughness curve is not the optimum cutting because the far x-axis reference plane means that the Ra-3 roughness is greater than the Ra-1 and Ra-2 roughness but Ra-1 is the optimum cutting caused closest to the x-axis reference plane.
3. Fig. 10 shows 3 curves in wet machining for different cutting speeds (105.504 m/min; 150.72 m/min;195.936 mmin) and also for different feed f (0.15 mm/r; 0.2 mm/r;0.25 mm/r) that the roughness curve Ra-1 is the optimum cut because the surface roughness curve Ra-1 is close to the x-axis reference plane, meaning that the dominant Ra-1 value is smaller than the other surface roughness curves, namely Ra-2 and Ra-3.
4. Comparison of the optimum cutting curve between dry machining and wet machining shows that the surface roughness curve Ra-1 on wet machining is more optimum than the surface roughness curve for dry machining. Although the surface roughness value for wet machining (1.521µm) is more optimum than the surface roughness for dry machining (1.602 µm), machining applications may have a chance to be realized because the ratio of surface roughness values on dry machining and wet machining is not significant.
5. From Fig. 8, 9 and 10 it turns out that there is an increase in the cutting speed (m/min), so the curve shows that the value of surface roughness is increasing, followed by an increase in feed f as well.
6. The relationship between ingestion speed and chip-producing speed is shown in Fig. 12 and 13 that as the rate of ingestion and chip-producing speed increases, the surface roughness also increases. The acquisition of the Ra roughness value is small because the feed given is also small, namely 0.15 mm/r for turning steel metal.
7. The application of the statistical method with the normal distribution curve is related to the test statistic Z = 0.497, so from observations with the normal distribution curve, the value of the test statistic becomes the $Z_{0.025}$ = 1.96 area; it is acceptable that the Ra values for dry machining and wet machining are not significant.

Declaration by Authors
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