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Effect of Cutting Speed on Surface Roughness AS-Scrapper ST37 Using Coated Carbide Tool

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ABSTRACT

In the lathe machining process, especially surface roughness, are greatly influenced by the cutting angle of the tool, feeding speed, cutting speed and depth of cut. Research purposes is to determine the effect of cutting conditions, namely cutting speed (v) and cutting depth (a) on the level of surface roughness (Ra) on the ST37 As Scrapper material using quantitative research methods that focus on numeric or numbers in a study. The research results obtained a value of Ra $^{\rightarrow}$= 6.063 μm at optimum cutting conditions varying a= 1 mm, v= 62 m/min, f= 0.05 mm, tc= 5.29 min.

I. Introduction

In the metalworking industry, it is always related to the metal cutting process or machining process using cutting tools. In the metal manufacturing industry, one of the main problems of concern is environmental problems, both due to products, processes and production systems. Interest in human health and ecology has led the metal cutting industry to develop cutting methods that are environmentally and health friendly, increase efficiency, reduce production costs, increase productivity and minimize cycle times [1].

Carbide tool dominate modern applications in the metal working industry and are the best choice for metal cutting processes [2]. Carbide tool have been proven to produce the best cutting results, especially in the lathe cutting process. In addition to showing good performance value, carbide tools are also tools that have good economic value [2]. With the rapid development of technology, in order to improve the performance and wear resistance of cutting tools used in the machining process, carbide tools can be further improved through the coating process. Currently, tool coating technology has been developed with various coating materials and coating methods [3]. The main function of the coating material is as a solid lubricant which functions to reduce friction and heat generation during the cutting process [3].

To obtain more complete information regarding the performance of carbide tool coating materials which are widely used in the metal cutting industry, especially to produce products made from alloy steel, it is necessary to conduct a study regarding the performance of carbide tool coatings, this is in line with the results of research [3] which reported that the performance of the coating material on coated carbide tools does not function as expected when used in milling operations for non-ferrous metal materials. In his report, he concluded that there was a new type of wear called layer delamination. Then, in a study of the characterization of mechanical and chemical loads in dry turning operations of AISI 1070 using a diamond film-coated carbide tool, abrasive layer wear occurred on the layer [4-5].

In the turning process operation, it is impossible to produce a component with a perfect level of surface integrity. One of the things we cannot avoid is deviations in the machining process so that the final product does not have maximum surface integrity. In the metal cutting process, the source of deviations in surface integrity characteristics is one or a combination of several types, namely defects or flaws, lay, waviness and roughness [6]. The surface roughness parameter (Ra) is sufficient to determine the level of surface integrity of a product.

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Surface integrity testing of AISI 1045 using coated carbide tools was carried out by [7], it was concluded that cutting conditions (v=235 m/minute; f =0.75 mm/put; a=1 mm; tc = 5.30 minutes were the most optimal conditions with a Ra value $^{\rightarrow}$ = 6.135 µm.

Based on the explanation above and the facts that have been stated by several previous researchers, that in the metal cutting process, the source of deviation in surface integrity characteristics is one of the factors, therefore it is necessary to carry out research that can explain the surface integrity characteristics of the AS-Scrapper ST37 material using the method dry turning using coated carbide tools.

And specifically, the aim of this research is to obtain surface roughness (Ra) values and optimum cutting conditions in dry machining of ST37 material using layered carbide tools for development with research design analysis of practical process results in the laboratory. It is hoped that the results of this research will provide benefits to the academic world and the metal cutting industry in general and to researchers in particular. These benefits include contributing to the provision of data and information in planning ferrous metal dry machining processes, especially information on the surface roughness of ST37.

II. Research methods

A. *Characteristics and Terminology of Lathe Process*

In this lathe process the workpiece gripped in the chuck rotates about its axis, while the tool as a cutting chisel moves translationally to slice the workpiece along the workpiece axis or against its diameter. Although the definition is simple, the metal cutting process is very complex. Figure 1. is a schematic of the lathe process, where Main Shaft Rotation (n), Infeed (f) and Depth of Cut (a).

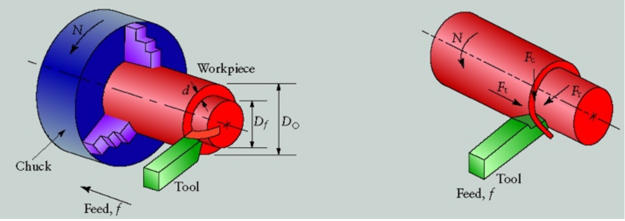


Fig 1. Schematic illustration of the lathe process

According to [9], there are five (5) basic elements in the machining process, namely:

1. Cutting speed : v (m/min)
2. Feeding speed : vf (mm/min)
3. Depth of cut : a (mm)
4. Cutting time : t_c (min)
5. Material removal rate : Z (cm3/min)

In order to be able to determine the cutting conditions, according to [8], a formula can be used for the main parameters in the lathe machining process, namely:

Cutting speed : $v = \frac{\pi.d.n}{1000}$ (m/min) (1)
d = average diameter (mm)
n = rotation of the machine (rpm)
Feeding : f = mm/put
Feeding speed : vf = f.n (mm/min) (2)
Depth of cut : $a = \frac{do-dm}{2}$ (mm) (3)
do = initial diameter (mm)
dm = final diameter (mm)
Cutting time : $t_c = \frac{lt}{Vf}$ (min) (4)
lt = machining length (mm)
Material removal rate : Z = A.v (cm^3/min) (5)

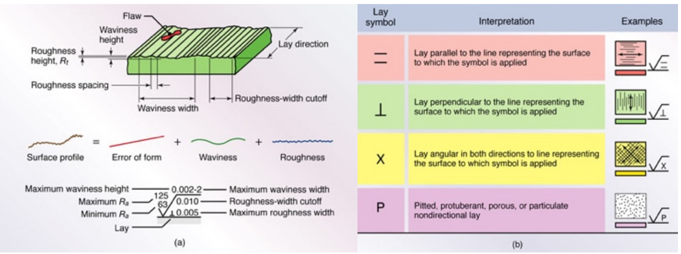
B. *Surface Packing Characteristics*

Various methods have been carried out to explain the characteristics of the surface packaging produced by a machining process, where the machining process can cause irregularities in the characteristics of the product surface packaging [9].

The irregularity of the surface packing characteristics is divided into 4 types namely:

1. Defect or Flaws: Is a product surface defect that occurs in the machining process for example holes, cracks, tears on the surface of the product.
2. Lay: Is the trace of the cutting direction of the chisel eye on the surface of the product due to the machining process.
3. Waviness: Is a periodic irregularity on the surface of the product with a wavelength that is clearly greater than the depth. This waviness can be caused by vibrations that occur during the machining process, and also due to the deflection of the chisel. Carbide tools dominate the cutting used.
4. Roughness: Roughness is almost the same as waviness but is in a smaller range

For more details regarding the irregularity of the characteristics of this surface packaging can be seen in Figure 2.



Lay symbol	Interpretation	Examples
=	Lay parallel to the line representing the surface to which the symbol is applied	√=
⊥	Lay perpendicular to the line representing the surface to which the symbol is applied	√⊥
X	Lay angular in both directions to line representing the surface to which symbol is applied	√X
P	Pitted, protuberant, porous, or particulate nondirectional lay	√P

Fig 2. (a) Terminology and symbols used to describe the surface finish (μ). (b) Surface symbols

The parameter used to determine the level of surface roughness commonly used is the arithmetic mean value (Ra), taking into account Figure 3, Ra can be obtained using the formula:

$$Ra = \frac{a+b+c+d+\cdots}{n} \tag{6}$$

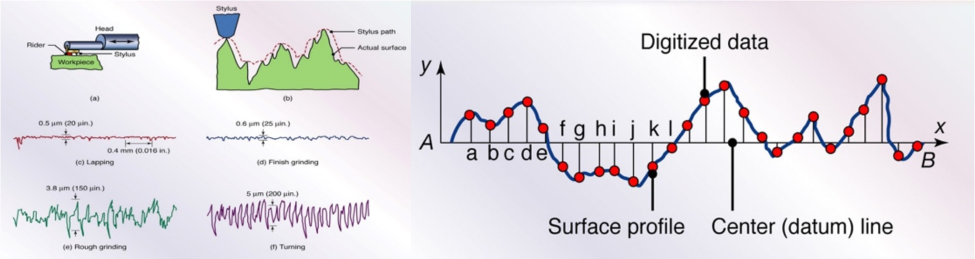


Fig 3. Surface texture of a product

C. *Dry Machining*

Through the dry machining method, it is hoped that besides being safe for the environment and also safe for health, dry machining can also reduce production costs around 16-20% [10]. However, the dry machining method also has several problems in its application, among the problems that will be encountered include the friction that occurs between the surface of the workpiece and the cutting tool, the speed of chip exit, the high cutting temperature and the problems mentioned above are all related to machining parameters

Generally used cutting fluid is stored in containers and then buried on the ground, this will obviously damage the environment and the applicable environmental laws prevent this. The metalworking fluid safety and health administration agency standard advisory committee has recommended the limit of hazardous elements in cutting fluids for machining processes, namely 0.5÷5.0 mg/m3 [10].

III. Method

A. *Materials*

ST37 is in the form of a billet (round bar), with an effective length of 160 mm and a diameter of 60 mm. This material is commonly applied to machine chisels, gears, construction, machinery industry, bridge construction, springs, etc [11]. The material for the test object is shown in Figure 3. The chemical composition, mechanical properties and hardness of this material are presented in Table 1, Table 2 and Table 3.

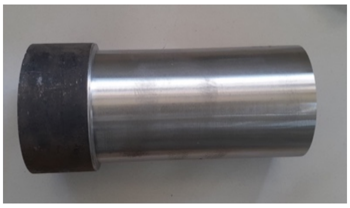


Fig 4. ST37 test object material

Table 1. Chemical composition of ST37

Table 2.

Fe (%)	**C (%)**	**Si (%)**	**Mn (%)**	**p (%)**	**s (%)**	**Cr (%)**	**Mo (%)**	**Ni (%)**	**Ni (%)**	**Al (%)**
97.8	0.796	0.258	0.790	0.025	0.011	0.151	0.089	0.008	0.039	0.055

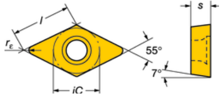
Co (%)	**Cu (%)**	**Nb (%)**	**Ti (%)**	**v (%)**	**w (%)**
0.001	0.009	0.005	0.005	0.005	0.015

Table 2. Mechanical properties of ST37

No.	Characteristic	Mark
1	Kekuatan Tarik Maksimum (MPa)	749
2	Kekuatan Luluh (MPa)	415
3	Modulus Elastis (GPa)	192
4	Poisson Rasio	0,27
5	Konduktivitas Termal (W/m-K)	44,3
6	Massa Jenis (1000 kg/m^3)	7,85
7	Titik Cair (°C)	830
8	Hardness (HRB/BHN)	90,5/165

The cutting tools used in this study were manufactured by Sandvick Coromant, namely carbide coated tools made of Titanium Aluminum Nitride (TiAlN) and Titanium Nitride (TiN) produced through the PVD process. The carbide cutting tool is ISO standard DCGX 11 T3 04-AL, with the identity GC 1105. Figure 4 shows the dimensions of the GC 1005 coated carbide tool, the specifications of the tool can be seen in Table 4 below.

Table 3. GC1005 plated carbide chisel dimensions

Type	**Dimensi (mm)**			
DCGX 11 T3 04-AL	**re**	**l**	**iC**	**S**
	0,4	**11**	**9,525**	**4**
 DCGX-AL				

B. *Tools*

1. Thurning Machine

Machining is done using a WH-530X200G lathe, the tools used can be seen in Figure 5.

Fig 5. Thurning machine WH-530X200G

3. Surface Roughness Tester

To determine the surface roughness (Ra) value of the ST37 test material after the machining process, the surface roughness measurement of the material was carried out using the Surface Roughness Tester SE300, ME-52083 Series. Surface Roughness Tester seen in Figure 6.

Fig 6. Surface roughness tester

Design of Research Activities and Set-up:

1. Setting up data collection equipment including:
    - WH-530X200G lathe and prepared coated carbide cutting tools
    - ST37 test object material
    - Surface Roughness Tester
2. Check the condition of the lathe which must be really stiff and not speeling
3. Adjust the diameter of the test object at the engine speed on the WH-530X200G lathe
4. Starting the machining step by determining the engine speed, feed (f) and depth of cut (a)
5. Execute the machining process according to predetermined cutting conditions.
6. Retrieve data on the surface roughness value (Ra) of the ST37 test material:
    - Tool holder After machining is done with the machining length (lt) of the workpiece, the tool is placed on a symmetrical stand
    - Surface Roughness Tester Place the detection indenter on the test material
    - Record of the measurement results on the monitor of the Surface Roughness Tester
    - Perform measurements at an angle of 120° for each test material.

IV. Results and Discussion

From the results of the surface roughness test (Ra) on the ST37 test material with PVD (TiAlN/TiN) coated carbide tools as presented in Table 3 and Figure 7.

Table 4. Cutting condition

No.	v (m/min)	f (mm/put)	vf (min)	a (mm)	d (mm)	d_1 (mm)	n (rpm)	lt (mm)	tc (min)	Ra (mm)
1	91	0.05	26	0.5	55	54	530	1350	5.19	7.526
2	62	0.05	17	1	56	54	355	900	5,29	6.063
3	31	0.05	8,5	1.5	59	56	170	450	5.29	31.936

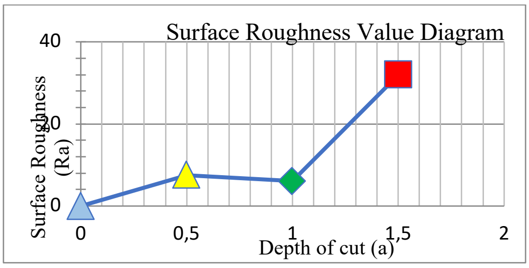


Fig 7. Surface roughness (Ra) Vs depth of cut diagram (a) cutting conditions 1, 2 and 3, PVD coated carbide (TiAlN/TiN) tools

From the test results, the surface roughness value of ST37 material machining results in cutting conditions with cutting depth (a= 0.5 mm) and cutting time (tc= 5.19 min), as presented in Table 3. In the results of the surface roughness analysis for each axis of the shaft in the analysis point area, as presented in Table 5 and Figure 8.

Table 5. Surface roughness value ST37 cutting conditions 1

Coated Carbide Tool (TiAlN/TiN) PVD			**ST37**
No.	**Line**	**Ra**	**Nilai**
1	120°	Ra_1	7.628
2	240º	Ra_2	7.508
3	360°	Ra_3	7.443
		$R\vec{a}$	**7.526**

Fig 8. Surface roughness value at cutting condition 1 (v= 91 m/min; a=0.5 mm; t_c= 5.19 min)

As can be seen in Figure 8 with cutting condition 1, the surface roughness value at each cutting degree line. On the 120° line the surface roughness value is 7.628µm, on the 240° line the surface roughness value is 7.508µm and on the 360° line the surface roughness value is 7.443µm. For the three measurement lines, the average surface roughness value obtained was 7.526µm under conditions a= 0.5 mm and tc= 5.19 min.

In investigating the surface roughness value of the machining results of the ST37 material machining results in cutting conditions with cutting depth (a= 1 mm) and cutting time (tc= 5.29 min), as presented in Table 3. In the results of the surface roughness analysis for each axis of the shaft in the analysis point area, as presented in Table 5 and Figure 9.

Table 6. Surface roughness value ST37 cutting conditions 2

Coated Carbide Tool (TiAlN/TiN) PVD			**ST37**
No.	**Line**	**Ra**	**Nilai**
1	120°	Ra_1	6.136
2	240º	Ra_2	6.026
3	360°	Ra_3	6.029
		$R\vec{a}$	**6.063**

Fig 9. Surface roughness value at cutting condition 2 (v= 62 m/min; a=1 mm; t_c= 5.29 min)

As shown in Figure 9 in the cutting condition 2, the surface roughness value at each cutting degree line. On the 120° line the surface roughness value is 6.136µm, on the 240° line the surface roughness value is 6.026µm and on the 360° line the surface roughness value is 6.029µm. For the three measurement lines, the average surface roughness value obtained was 6.063µm under conditions a= 1 mm and tc= 5.29 min

Then in the investigation of the surface roughness value of the machining results of the ST37 test material in the cutting conditions with the depth of cut (a= 1.5 mm) and the cutting time (tc= 5.29 min), as presented in Table 3. In the results of the surface roughness analysis of each axis axis in the analysis point area, as presented in Table 6 and Figure 10.

Tabel 6. Surface roughness value ST37 cutting conditions 3

Coated Carbide Tool (TiAlN/TiN) PVD			**ST37**
No.	**Line**	**Ra**	**Nilai**
1	120°	Ra_1	32.542
2	240º	Ra_2	31.725
3	360°	Ra_3	31.541
		$R\vec{a}$	**31.936**

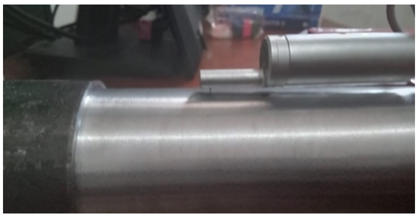


Fig 10. Surface roughness value at cutting condition 3 (v= 31 m/min; a=1.5 mm; t_c= 5.29 min)

As can be seen in Figure 10 with cutting condition 3, the surface roughness value on each line is the degree of cutting. On the 120° line the surface roughness value is 32.542µm, on the 240° line the surface roughness value is 31.725µm and on the 360° line the surface roughness value is 31.541µm. For the three measurement lines, an average surface roughness value of 31.936µm is obtained at the condition of the depth of cut a = 1.5 mm and the cutting time tc = 5.29 min.

V. Conclusion

The results of research to obtain surface roughness values (Ra) and optimum cutting conditions in dry machining of ST37 material using layered carbide tools (TiAlN/TiN) are the answer to a specific objective, where the results of the analysis of the tests are concluded as follows:

1. Cutting conditions 1: cutting speed (v= 91 m/min); ingestion (f= 0.05 mm/put); depth of cut (a= 0.5 mm) and cutting time tc= 5.19 min. Average surface roughness value = 7.526µm.
2. Cutting conditions 2: cutting speed (v= 62 m/min); ingestion (f= 0.05 mm/put); depth of cut (a= 1 mm) and cutting time tc= 5.29 min. Average surface roughness value = 6.063µm.
3. Cutting conditions 3: cutting speed (v= 31 m/min); ingestion (f= 0.05 mm/put); depth of cut (a= 1.5 mm) and cutting time tc= 5.29 min. Average surface roughness value = 31.541µm.

Results of analysis of surface integrity testing in order to obtain the best surface roughness (Ra) value at optimum cutting conditions in dry machining of ST37 material using coated carbide tools. From the 3 cutting conditions, it was concluded that cutting condition 2 with cutting speed (v= 62 m/min); emphasis (f= 0.05 mm/put); cutting depth (a= 1 mm) and cutting time tc= 5.29 minutes are the most optimum conditions with an average surface roughness value Ra $^{\rightarrow}$= 6,063µm.

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