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The Effect of Depth of Cut on High-Speed Steel (HSS) Cutting Tool's Age in Low Carbon Steel Outer Turning Process

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Abstract
In the machining process, there are three parameters that need to be determined before the machining process is carried out, namely: depth of cut (a), feed motion (f) and cutting speed (v). Determination of the three parameters of the machining process will determine the quality of the product to match the desired geometry and tolerance. The three parameters of the machining process will affect tool life, where the selection of a constant depth of cut and feed motion will produce the most optimum level of tool wear. This study used several machining parameters with several variations, namely: depth of cut (a) of 0.5 mm; 0.8mm; 1.1mm; and 1.4 mm and feeding motion (f) of 0.062 mm/revolution and 0.1 mm/revolution. The machining process is carried out at a constant (n) rotation of 425 rpm. Based on the research that has been done, it was found that the tool life on the feed motion (f) = 0.062 mm/revolution is better than that on the feed motion (f) = 0.1 mm/revolution, where at (f) = 0.1 mm/revolution chisel wears out faster. Optimum cutting conditions are produced at feed motion (f) = 0.062 mm/revolution and with a depth of cut (a) = 1.1 mm where the production cost (Cp) is Rp.746.56/product.

Keywords: low carbon steel, depth of cut, feed rate, wear edge

1. Introduction

Machining technology is currently developing very rapidly, so the demands for increasing cutting tool life and optimizing the machining process are the most important things to review. One of the most widely used machine tools for machining processes is the lathe. In the turning process, the workpiece rotates according to the axis of the machine and the tool continues to move to the right or left in the direction of the axis of the lathe and cuts the workpiece. However good a lathe is, the quality of the workpiece and its work efficiency will depend on the tool used and the accuracy of the selection of machining process parameters [1].

The machining process uses a chisel as the cutting tool and the geometry of the tool is one of the most important factors that determine the success of the machining process. The tool geometry must be chosen correctly according to the type of workpiece material, tool material, and cutting conditions so that one or several objectives can be achieved. The various objectives or goals include high tool life, low cutting force or power, smooth surface, and geometric accuracy of the product. A process planner must be able to select tools or determine tool angles that are suitable for a specific type of work so that the machining process can be optimized.

The purpose of this research, among others, to determine the effect of the depth of cut on the edge wear (VB) that occurs on HSS chisels at constant rotation and varying feeding motion, to determine the optimum depth of cut in order to obtain the most economical production costs. There are several studies that have been conducted regarding the optimization of machining technology, such as research conducted optimization of cutting speed using carbide chisels with feed motion parameters. (f) varies by 0.2 mm/ rev; 0.25mm /rev; 0.3mm/rev; 0.35mm/rev; and 0.4 mm/rev; as well as varying cutting speeds (v), namely 150 m/minute, 180 m/minute, 210 m/minute, 240 m/minute, and 270 m/minute [2].

Determination of the critical edge wear limit (VB) of 0.4 mm. Research conducted the same on optimization of cutting speed with a constant feed motion parameter (f) of 0.1mm/revolution and a large depth of cut (a) of 1mm. Variation of cutting speed (v) is 100 m/minute, 150 m/minute, 200 m/minute, 250 m/minute, and 300 m/minute [3]. According to value of 65 HBR, the value of the tensile stress is 371 N/mm ^{2} or equal to 37.82 kg/mm^2 so that it can be classified as low carbon steel [4].

From these various studies, it can be seen that the optimization of the machining process is carried out based on the influence of the cutting speed. Nonetheless, the depth of cut parameter (a) is also an important machining process variable to review. This study focuses on the effect of depth of cut on the optimization of tool life so that production costs are economical.

2. Materials and Methods

Collection for using a conventional lathe with the following specifications:

2.1. Testing Machines

Machine Type	Conventional lathe
Brand	Pinocho
Type	S-90/200
Spindle Rotation	40-2200rpm
max. turning	Ø200mm _
Tool Size	25 x 25mm
Engine Power	4 Kw

2.2. Lathe Cutting Tool

Material Type	HSS
Width x length	5/8 x 6 In
Main cutting angle(kr)	90^0
Orthogonal free angle (α_o)	8^0
Free angle (α^1)	10^0
Orthogonal angles	25^0

2.3. Research Procedure

This research method was carried out under controlled conditions with several parameters kept constant. This is done in order to make it easier to analyze tool wear. Research other explain An increase in cutting speed (Vc) will accelerate the occurrence of tool edge wear (VB), so that tool life will decrease. And at the same cutting speed, the growth of edge wear (VB) will increase as the cutting time increases [5]. Cutting speed influences CVD tool blade wear plated with AISI 1045 Steel material. Faster cutting speed used, then produces low wear values. The slower the cutting speed used, then the value of the tool bit wear produced is getting bigger. Proven by the highest value of tool eye wear low, VB = 0.069 mm at speed cut Vc = 200 with depth of ingestion a = 1 mm and speed feed f = 0.2 mm/rev. and value highest tool bit wear VB = 0.124 mm [6]. These parameters are constant rotation and feed motion while the cutting speed is different. Testing these parameters is done by simulating different depths of cut to find the wear value. There is a significant influence on variation depth of burial on value surface roughness turning process using lathe Machine [7].

Data collection was carried out by examining the effect of long service time on tool life. The data obtained is then calculated and the characteristics graph can be described which shows the life of the tool.

3. Results and Discussion

3.1. Edge wear (VB)

The results of the machining process that has been carried out on low carbon steel workpieces using HSS chisels for 40 times of data collection with different feeding motions and depth of cut are shown in Tables 1 and 2.

Table 1. Edge wear data (VB) at f = 0.062 mm/rev

a(mm)	VB_1	VB_2	VB_3	VB_4	VB_5
0.5	0.015	0.034	0.049	0.088	0.095
0.8	0.012	0.029	0.042	0.075	0.097
1,1	0.018	0.032	0.044	0.072	0.098
1,4	0.016	0.024	0.043	0.079	0.096

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Table 2. Edge wear data (VB) at f = 0.1 mm/rev

a(mm)	**VB 1**	**VB 2**	**VB 3**	**VB 4**	**VB 5**
0.5	0.019	0.060	0.091	0.120	0.132
0.8	0.023	0.055	0.078	0.107	0.120
1,1	0.020	0.057	0.083	0.102	0.124
1,4	0.021	0.048	0.081	0.117	0.126

During the cutting process the edge wear (VB) will increase with increasing cutting time. The longer the HSS tool is used, the VB edge wear will also increase. Tables 1 and 2 show that a low depth of cut can reduce tool resistance. It can be seen that the smaller the depth of cut, the greater the edge wear rate (VB) and the higher the cutting speed. The increase of the cutting speed will reduce the life of the tool. Edge wear data (VB) from the results of the machining process that has been carried out can also be seen in Figures 1 and 2 which illustrate the relationship between edge wear (VB) and the number of samples taken.

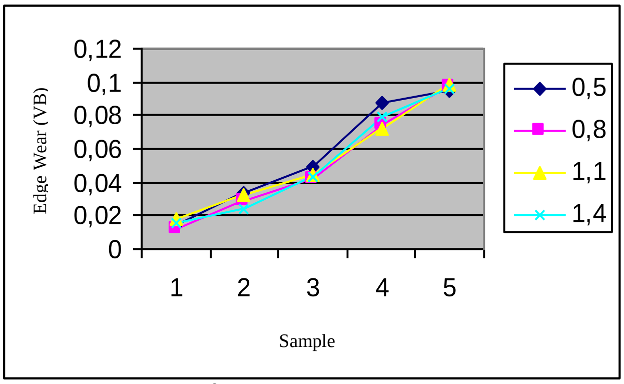

Figure 1. Graph of sample relationship and edge wear (VB) at f = 0.062 mm/rev

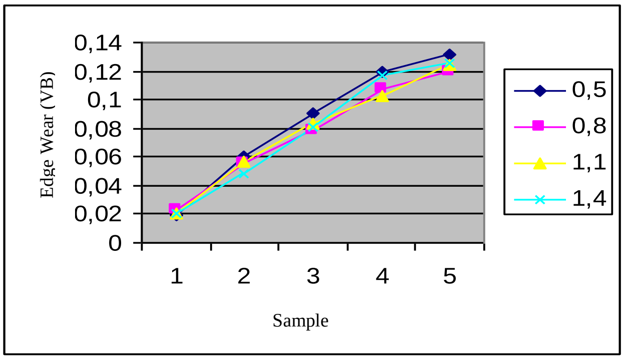

Figure 2. Graph of sample relationship and edge wear (VB) at f = 0.1mm/rev

After the data from the results of the machining process is known, the data becomes a reference for being sampled at the desired maximum VB of 0.3 mm using mathcad software. Results of data analysis. The results are shown in table 3 and 4.

Table 3. Max VB sample at f = 0.062 mm/rev

a(mm)	0.5	0.8	1,1	1,4
VB sample max	13,964	14,257	14,963	14,068

Table 4. Sample VB max at f = 0.1 mm/rev

a(mm)	0.5	0.8	1,1	1,4
VB sample max	10,298	11,937	11,647	10,740

Graphs illustrating the relationship between the maximum VB sample size of 0.3 mm and the depth of cut are shown in Figure 3 and Figure 4.

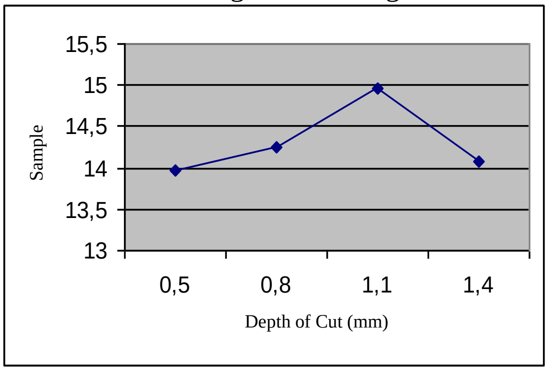

Figure 3. Graph of the relationship between sample VB max and depth of cut at f = 0.062mm/rev

The directly measured wear dimensions require stopping the machining process. Where after sampling, the tool is removed for edge wear measurement (VB) and then the tool is re-installed for the next sampling so that the resulting edge wear is not linear.

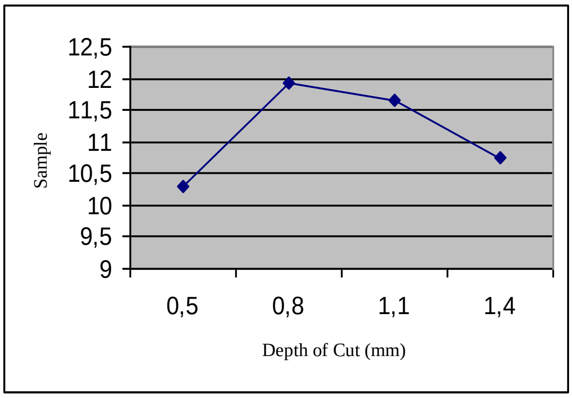

Figure 4. Graph of the relationship between sample VB max and depth of cut at f = 0.1 mm/rev

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From the graph it can be seen that at f = 0.062 mm/rev with a depth of cut (a) = 0.5 mm it produces a lower number of VB samples than the others. This shows that the edge wear on the tool increases faster, as well as at f = 0.1 mm/rev with a depth of cut (a) = 0.5 mm, it shows that the tool wears out more easily. Feeding motion which is larger in value results in rapid edge tool wear (VB).

3.3. Cutting Tool Age Calculation

Motion (f) = 0.062 mm/revolution is shown in table 5 and figure 5 , while for feeding motion (f) = 0.1 mm/revolution is shown in table 6 and figure 6 .

Table 5 . Tool life at f = 0.062 mm/revolution

Depth of cut (a,mm)	0.5	0.8	1,1	1,4
Sample at VB max (0.3mm)	13.96	14,25	14.96	14.06
Cutting time (tc, sec)	114	114	114	114
Tool life (t, seconds)	1591.9	1625,3	1705.8	1603.7

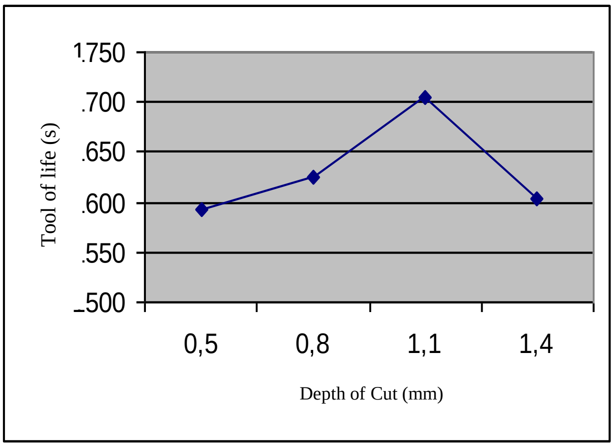

Figure 5. Graph of the relationship between cutting depth and tool life at f = 0.062 mm/rev

Table 6. Tool life at f = 0.1 mm/revolution

Depth of cut (a, mm)	0.5	0.8	1,1	1,4
Sample at VB max (0.3 mm)	10,29	11.93	11.64	10.74
Cutting time (tc, sec)	70,8	70,8	70,8	70,8
Tool life (t, seconds)	729,1	845,1	824.6	760.4

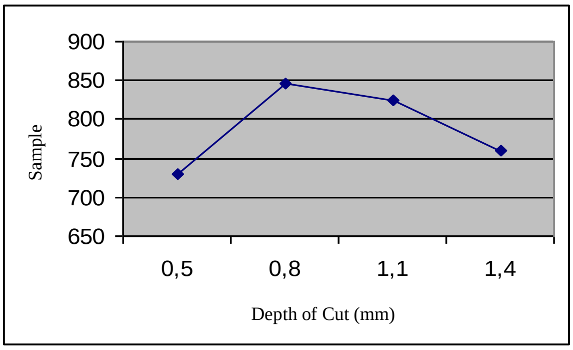

Figure 6. Graph of the relationship between cutting depth and tool life at f = 0.1 mm/rev

The wear on the edge of the tool increases relatively quickly when the tool is used. As the cutting time increases, the edge wear increases. In Figure 5 and Figure 6 above it can be seen that the ratio of tool life to the depth of cut is the same as the ratio of the relationship between the number of samples at VB max (0.3 mm) and the depth of cut. This is because the rotation (n) used does not vary, namely 425 rpm, only the feed motion is made differently so that the cutting time (tc) for each feed motion is fixed. Feeding motion which is greater in value results in a decrease in tool life so that the edge wear (VB) increases relatively quickly.

3.4. Calculation of production time

The influence of production time is very important therefore it needs to be determined to be able to achieve optimum conditions. The data below is obtained from the results of calculations and measurements using *a stopwatch* during the machining process.

Table 7. Average Production Time per product

a(mm)	0.5	0.8	1,1	1,4
Installation of workpieces; t_{LW} (seconds)	14,25	14,25	14,25	14,25
Setup; t_{AT} (seconds)	5,37	5,37	5,37	5,37
Termination; t_{RT} (second)	4,28	4,28	4,28	4,28

taking; t_{UW} (second)	4.79	4.79	4.79	4.79
Setup eqps.; t_s/n_1 (second)	15,73	15,73	15,73	15,73
non- productive; t_a (second)	44,42	44,42	44,42	44,42
Installation; t_d (second)	29.54	29.54	29.54	29.54
time; t_{c1} (second)	114	114	114	114
time; t_{c2} (second)	70,8	70,8	70,8	70,8
life; T_1 (second)	1591.89	1625,29	1705.78	1603.75
life; T_2 (second)	729,10	845,14	824.60	760.39
td $(t_c/T)_1$ (second)	2.115	2,072	1,974	2.009
td $(t_c/T)_2$ (second)	2,868	2,475	2,536	2,750
time; tm_1 (second)	160.53	160.49	160.39	160.51
time; tm_2 (second)	118.08	117,69	117.75	117.97

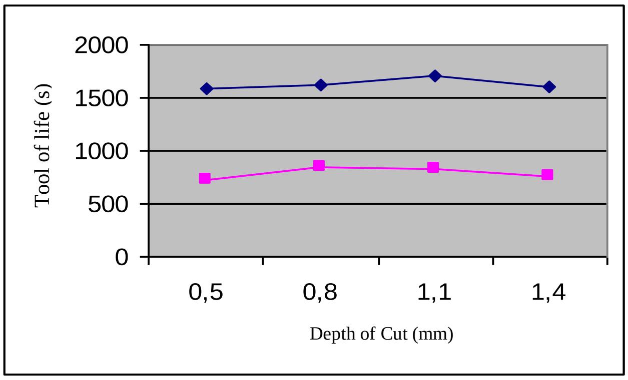

Figure 7. Tool of life graph

In this study, the fastest machining time was found on feed motion (f) = 0.062 mm/revolution of 160.394 seconds (2.67 minutes) with a depth of cut of 1.1 mm. Whereas in the feed motion (f) = 0.1 mm/rev, the fastest machining time occurs at a depth of cut of 0.8 mm of 117.695 seconds (1.96 minutes).

3.5. Calculation of Production Costs

In determining the amount of production costs, machining costs, tool costs and special equipment preparation costs must be determined in advance with the equation below.

$$Cp = Cm + Ce + Cr$$

$$= t_m \cdot c_m + c_e \cdot \frac{t_c}{T} + 0$$

1. Machining cost (C_m)
   a. Carrier fee
      Rp. 6500 / hour = Rp. 108.33/minute
   b. Machine maintenance costs, including:
      Labor = Rp. 100,000.00/month
      Grinding stone = Rp. 20,000.00/month
      Oil = Rp. 15,000.00/month
      Others = Rp. 5000.00/month
      Where the time per month = 22 days x 8 hours = 176 hours = 10560 minutes
      The machine maintenance costs are:
      Rp. 140,000.00 / 10560 = Rp. 13.26/minute
      Total machining costs (Cm);
      Rp. 108.33 + Rp. 13.26 = Rp. 121.59/minute
2. Tool cost (C_e)
   Operator fee = Rp. 6500.00/hour
   Rp. 108.33/minute
   Sculpture price = Rp. 30,000.00
   Number of sharpened = 12 times
   Sharpening time = 40 minutes/piece
   So tool cost (C_e) ;

$$= \frac{C_{otb} + r_g c_g t_g}{r_g + 1}$$

$$= \frac{30000 + 12 \text{ x } 108{,}33 \text{ x } 40}{12 + 1}$$

= Rp.6307,60/Cutting Edge

Table 8. iscu cost on feed movement = 0.062mm/rev

Variable of the production costs (Rp/product)	Depth of cut(mm)			
	0.5	0.8	1,1	1,4
Machining cost (C_m)	325,37	325,13	325.01	325,25
Chisel cost (C_e)	451.70	442,42	421.55	448,37
Production cost (C_p)	777.07	767.55	746.56	773,62

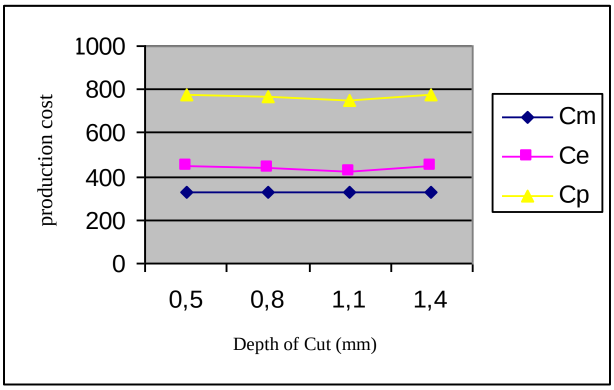

Figure 8. Graph of the relationship between production costs and cutting depth at f = 0.062 mm/rev

Variable production costs (Rp/product)	0.5	0.8	1,1	1,4
Machining cost (C_m)	239,29	238.56	238.64	239.05
Chisel cost (C_e)	612.51	528,41	541.56	587.30
Cost of production (C_p)	851.80	766.97	780,24	826.35

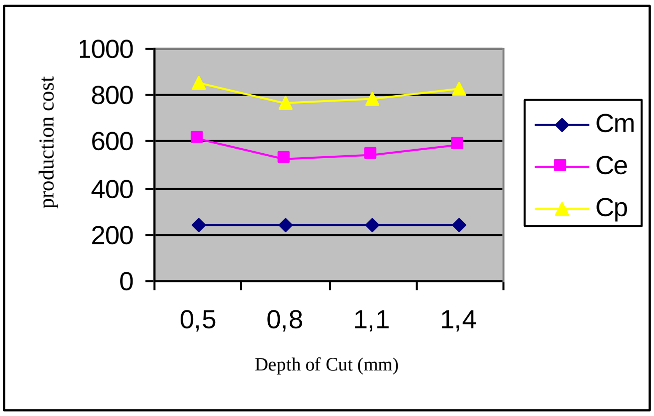

Figure 9. Graph of the relationship between production costs and cutting depth at f = 0.1 mm/rev

From the results of the calculation above, the highest production cost is Rp. 851.80 on feed (f) = 0.01 mm/rev with a depth of cut of 0.5 mm. while the lowest production cost is found in the feed motion (f) = 0.062 mm/revolution with a cutting depth of 1.1 mm in the amount of Rp. 746.56. The two graphs above show that lower production costs result from lower feed movements. The higher the feed motion used, the higher the production costs used, as also highlighted [8].

4. Conclusion

Based on the results of data analysis on the effect of depth of cut on tool life of HSS on low carbon steel materials, several conclusions are obtained, namely the difference in depth of cut gives a large change in edge wear. The feed motion (f) = 0.062 mm/revolution with a depth of cut (a) = 1.1 mm produces the highest tool life (T) of 1705.78 seconds, the feed motion has a high value (f = 0.1 mm/revolution) faster wear increases the VB edge on the tool compared to the feed motion which has a lower value (f = 0.062 mm/revolution), Low production costs occur in the feed (f) = 0.062 mm/revolution with depth of cut (a) = 1, 1mm Rp. 746.56 per product and the average machining time used (tm) = 2.673 minutes. These findings open more possible for higher tool's age and in the same time lower turnig process cost.

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