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Optimization Of Cutting Parameters Of AISI 4140 Material Turning On Carbide Tool Life

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Abstract:

Optimization of cutting parameters is intended for the cutting process to determine the ability of the tool eye to make cuts in this study, the value of the optimization of the tool life for cutting parameters is varied. In this experiment, a CNC lathe with aisi material 4140 was used. Turning is done with a variation of cutting speed 190m/min, 200m/min, 210 m/min. depth of cut 0.5mm,0.6mm, 0.7mm and feed rate0.1 mm/rev, 0.2 mm/rev, 0.3 mm/rev. With an examination every five minutes to measure the wear of the tool. The data from the measurements were processed using the taguchi method with the orthogonal matrix used is L9(33). The results obtained from the calculation of ANOVA data on each cutting parameter and at each level variation are known that the feed rate has the variable that most affects the cutting speed tool has the most influential variable with the optimal combination of cutting speed 200 m / min, depth of cut 0.5mm, and feed rate 0.1mm / rev.

INTRODUCTION

The machining industry is a metal forming industry with a cutting process using machine tools. A lathe is a metal cutting machine that has the main function of processing a cylindrical workpiece with the main motion of rotating then the cutting tool moves along the workpiece, and produces chips when forming the surface of the workpiece. The turning process is one of the machining processes that have an important role in the manufacturing world.

The most important goal of the machining industry is to manufacture products with high dimensional accuracy and high quality while reducing costs and processing time in this competitive world. In addition, environmental pollution is another important aspect that must be considered by reducing the power consumption and withholding of fluids that affect ecological hygiene. (Şahinoğlu,2021).

Hard turning is used in the production of many parts, especially in automotive industries such as gears, bearings, and shafts. The advantages of hard turning compared to conventional machining processes are higher productivity, lower energy consumption, shorter setup time, better surface quality, and lower manufacturing costs

One of the products produced by the turning process using a CNC lathe is the shaft. Shaft is one of the most important parts in any machine construction. Almost all

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engines transmit power and rotation together through the shaft.

The shaft is a machine element in the form of a rod and a circular cross section, which functions to transfer rotary motion power or support a load with or without transmitting power. The shaft material uses various types of steel according to the desired construction design and one of the shaft materials is the AISI 4140 type.

Parameters in the machining process in the turning process include cutting speed, depth of cut, and feed rate. In the application of the three parameters, it affects the wear that occurs in the tool blade and of course has an effect on the shorter tool life. When wear occurs on the cutting tool, the machining process must be stopped and the cutting tool must be replaced. Of course, the time and cost of replacing cutting tools will increase processing time and production costs, besides that it will reduce production quality. Therefore, cutting tool wear that often occurs needs to be minimized to solve this problem. Wear and tool life can be reduced by controlling the cutting parameters. Based on this, the research was carried out which aims to determine how much influence the cutting parameters have on tool life and the optimum conditions for wear and tool life.

The combined effect of cutting parameters (cutting speed, feeding and depth of cut) on performance characteristics such as surface roughness and edge wear was explored by full factorial design (FFD) and analysis of variance (ANOVA). The results showed that feed was the main cutting parameter affecting surface roughness, followed by cutting speed. However, flank wear is affected by cutting speed and depth of cut interaction, although depth of cut has not been found to be statistically significant, flank wear is a function of increasing depth of cut.(Das, 2015).

Higher values of feed rates are necessary to minimize the specific cutting force. The machining power and cutting tool wear increases almost linearly with increase in cutting speed and feed rate. Coated carbide tools are superior to uncoated carbide tools and its flank wear grows smoothly than uncoated carbide tools. (Negalwade, 2014).

METHODS

This research was conducted experimentally. The data obtained were then processed using the Taguchi method.

Equipment and materials used include:

a. Workpiece

The workpiece being turned is AISI 4140 type steel with dimensions and shapes that can be seen in **FIGURE 1**.

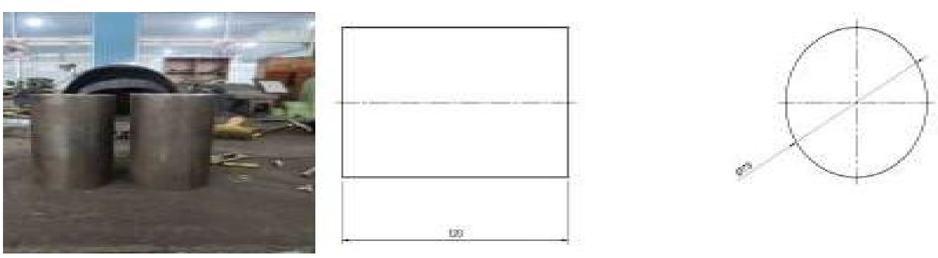

FIGURE.1 Workpiece materials AISI 4140

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TABLE 1. Element and Chemical Composition

Element	Value (%)
Carbon (C)	0.380 - 0.430
Chromium (Cr)	0.81-1.10
Iron (Fe)	96.785 - 97.77 (As remainder)
Manganese (Mn)	0.75 - 1.0
Molybdenum (Mo)	0.15 - 0.25
Phosphorous (P)	≤ 0.035
Silicon, Si	0.15 - 0.3
Sulfur, S	≤ 0.040

TABLE 2 Properties of AISI 4140

Physical Properties	Value
Hardness	197 BHN
Tensile Strength	655 MPa
Yield Strength	415 MPa
Modulus Young	190-210 GPA

Cutting tool

The cutting tool material used is carbide with a type based on the ISO TNMG 160404 standard.

Equipment

a) CNC *Lathe*

TABLE 3 Spesification of CNC*Turning*

Merk	CNC Mazak
Type	Quick Turn 8 N
Swing maximum	300m
Range between centre	290mm
Maximum spindle speer	5000 r/min
Power	7.5 Kw
Maximum torsion	9.0 kgf.m
Control	Mazantrol plus
Made in	Japan

FIGURE. 2 *CNC Lathe*

Determining the Number of Levels on Each Factor

Cutting parameters can be determined using the korloy carbide catalog

a) cutting speed

Based on the catalog, the material is AISI 4140 and the type of carbide tool TNMG160404-HA korloy, the cutting speed The levels used are: 190, 200, and 210 m/min

a) *cutting speed*

Based on the catalog, the material is AISI 4140 and the type of carbide cutting tool is TNMG160404-HA korloy, the cutting speeds used are: 190, 200, and 210 m/min.

b) depth of cut

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The depth of cut used are 0.5, 0.6, and 0.7 mm

c) feeding

The feeding used is 0.1, 0.2, and 0.3 mm/rev.

Code	Factor	1	2	3
A	Cutting speed (m/min)	190	200	210
B	Depeth of cut (mm)	0.5	0.6	0.7
C	Feeding (mm/rev?	0.1	0.2	0.3

TABLE. 4 Selected factors and levels

Orthogonal matrix

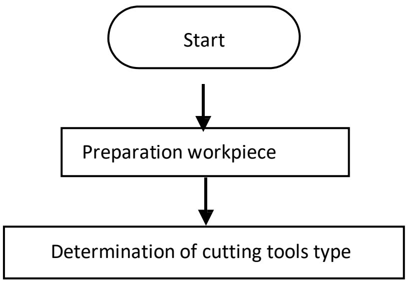
An orthogonal matrix is a matrix whose elements are arranged according to rows and columns. Columns are factors that can be changed in an experiment. Rows are combinations of levels of factors in the experiment. Table 5 shows the orthogonal matrix L9 (33), which has 3 factors and 3 levels.

Measurement method

The cutting tool insert edge wear was measured using a digital microscope. Measurements were made after the machining process lasted for 5 minutes, then the machining was continued and stopped every 5 minutes to observe and measure the wear on the cutting tool. To observe and measure cutting tool wear, the cutting tool insert is removed from the tool holder and moves the cutting tool insert on the measuring table on the surface of the digital microscope. The position of the measured cutting tool plane is adjusted so that it is perpendicular to the optical axis. In this case, the amount of edge wear can be determined by measuring the edge length (VB, mm), measuring tool wear using hiview software, by drawing a line before wear occurs to the average wear line on the flank wear of the cutting tool. The line used is 10 and then averaged to avoid errors. Flank wear can be seen in **FIGURE 3.**

FIGURE 3 TOOL WEAR

In general, the research method can be seen in the flowchart image below:



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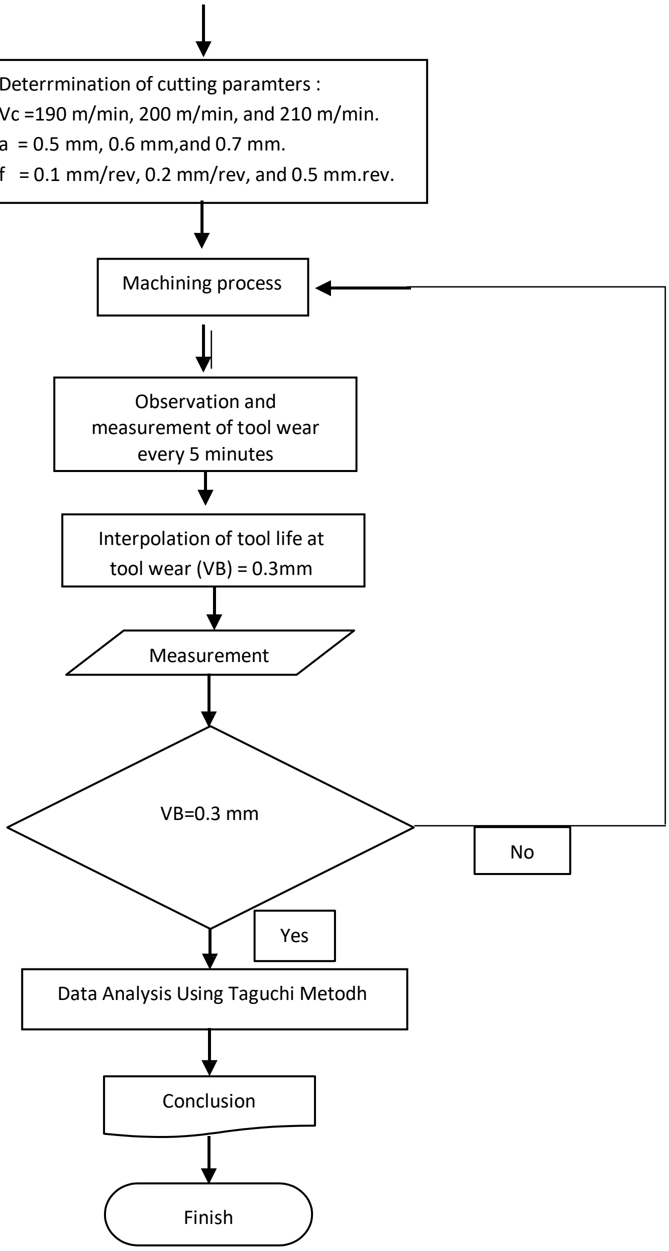

FIGURE 4. Experimental Process FlowchartRESULTS AND DISCUSSION

The experimental data are presented in **TABLE 5**.

TABLE 5. Machining Time and Tool Wear Data

Order	Running	Vc(m/min)	Feed (mm/rev)	DoC (mm)	Minute	VB (mm)
	1				5	0.047
	2				10	0.092
	3				15	0.097
	4				20	0.17
	5				25	0.19

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1	6	190	0.1	0.5	30	0.224
	7				35	0.227
	8				40	0.243
	9				45	0.25
	10				50	0.257
	11				55	0.26
	12				60	0.27
	13				65	0.298
	14				70	1.093
2	1	190	0.2	0.6	5	0.157
	2				10	0.857
3	1	190	0.3	0.7	5	1.003

4	1	200	0.1	0.6	5	0.041
	2				10	0.082
	3				15	0.116
	4				20	0.154
	5				25	0.235
	6				30	0.243
	7				35	0.25
	8				40	0.258
	9				45	0.265
	10				50	0.27
	11				55	0.285
	12				60	0.468
5	1	200	0.2	0.7	5	0.082
	2				10	0.378
	3				15	0.652
6	1	200	0.3	0.5	5	0.035
	2				10	0.065

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	3				15	0.079
	4				20	1.551
7	1	210	0.1	0.7	5	0.026
	2				10	0.215
	3				15	0.916
8	1	210	0.2	0.5	5	0.055
	2				10	0.085
	3				15	0.147
	4				20	1.279
9	1	210	0.3	0.6	5	0.086
	2				10	0.544

Based on **TABLE 5.** it is known that the value of VB in each order is not equal to 0.3 mm, therefore it is necessary to calculate interpolation or extrapolation on each order in order to obtain the time required when VB = 0.3mm, so that the tool life is obtained for each parameter combination. cuts as presented in the following table:

TABLE 6. Cutting Tool Life

No	Cutting Parameter			Tool life (menit)
	Cutting speed (m/min)	Feeding (mm/rev)	Depth of cut (mm)	
1	190	0.1	0.5	65.01
2	190	0.2	0.6	6.02
3	190	0.3	0.7	5
4	200	0.1	0.6	55.40
5	200	0.2	0.7	8.68
6	200	0.3	0.5	15.75
7	210	0.1	0.7	10.60
8	210	0.2	0.5	15.67
9	210	0.3	0.6	7.33

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Then an analysis was carried out using the Taguchi method to determine the optimal combination of cutting parameters

S/N ratio calculation

The data obtained is then transformed into the form of an S/N ratio to look for factors that affect the variance of roundness. S/N for the age characteristics of the cutting tool used is the bigger the better where the equation is as follows:

$$\text{Rasio S/N1}=-10\text{x}\log\left(\frac{1}{n}\sum\frac{1}{y_i^2}\right) \qquad (1)$$

TABLE 7. It is an experimental table that calculates the S/N value from order 1 to order 9.

TABLE 7. S /N . Ratio Calculation Results

Order	**Cutting speed (m/min)**	**Depth of cut (mm)**	**Feeding (mm/rev)**	**Tool life (min)**	**S/N Tool Life (min)**
1	190	0.5	0.1	65.01	36.25
2	190	0.6	0.2	6.02	15.59
3	190	0.7	0.3	5.00	13.97
4	200	0.6	0.1	55.40	34.87
5	200	0.7	0.2	8.68	18.77
6	200	0.5	0.3	15.75	23.94
7	210	0.7	0.1	10.60	20.51
8	210	0.5	0.2	15.67	23.90
9	210	0.6	0.3	7.33	17.30

TABLE 8. Respond S/N Ratio

Larger is better

Level	**Cutting speed**	**Feed**	**DoC**
1	21.94	30.55	28.04
2	25.86	19.42	22.59
3	20.58	18.41	17.75
Delta	5.29	12.14	10.28
Rank	3	1	2

From the **TABLE 8.**, it can be seen that the response of the S/N ratio obtained from the results of processing test data with 3 machining parameters on tool life

S/N effect calculation

Then the calculation of the effect of S/N is carried out to determine the effect of the contribution of each parameter where the value of S/N which has been previously calculated in **TABLE 8.** results of the calculation of effects for S/N.

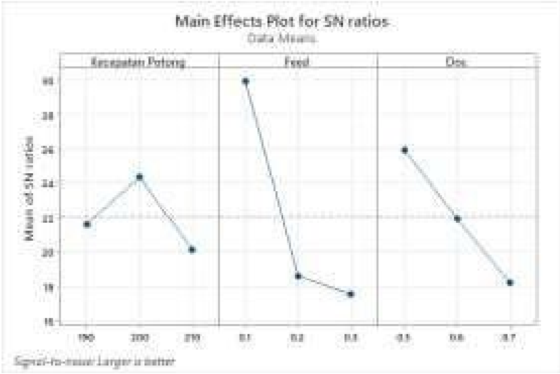

FIGURE 5. Main Effect Plot for S/N Ratio

From the graph above, it can be seen that there are 3 parameters used as parameters for testing tool life. These parameters have been processed to obtain optimal parameters. Optimal parameters obtained by cutting parameters that have the highest point. For the cutting speed parameter, the highest value is 200 m/mim. The highest value feeding parameter is found at a value of 0.1 mm/rev. While the depth of cut parameter, the highest value can be seen at a value of 0.5 mm. Based on the graph above, then to do metal cutting using a carbide cutting tool can be done by using combination of these three parameter values.

ANOVA

To determine the ANOVA value, Minitab 20 software is used. **TABLE 9**. shows the percentage value of the largest contribution test effect of the individual cutting parameters.

TABLE 9. Tool Life Contribution Test

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Kecepatan Potong	2	438.9	10.70%	438.9	219.5	0.92	0.521
Feed	2	2303.6	56.13%	2303.6	1151.8	4.82	0.172
Doc	2	883.3	21.52%	883.3	441.7	1.85	0.351
Error	2	478.0	11.65%	478.0	239.0		
Total	8	4103.8	100.00%				

Based on the **TABLE.9**, it can be seen that the contribution value of the cutting speed parameter is 10.70%, then the feeding parameter is 56.13%, and the depth of cut parameter is 21.52%. The cutting parameter that contributes the most to this research is feed motion, then the second contributing parameter is depth of cut, and the least contributing parameter is cutting speed.

Tool Life

In tool life, the most influencing variable is cutting speed, where the greater the cutting speed, the smaller the tool life. This can be seen in order 1 which has a tool life of 65.02 minutes while on order 9 the tool life is only 7.33 minutes. In order 9 this wear occurs very quickly where the growth of wear has exceeded VB=0.3 mm

The second factor that affects tool life is the depth of cut where the greater the depth of cut, the smaller the tool life. This is because the greater the depth of cut, the greater the friction between the tool and the workpiece where this contact area will cause flank wear. The last factor that affects tool life is the feeding motion where the smaller the feed motion, the greater the tool life.

CONCLUSION

Based on the results of the discussion, it can be concluded as follows:

1. The cutting parameter that contributes the most to this experiment is feed motion, then the second contributing parameter is depth of cut, and the least contributing parameter is cutting speed.
2. The optimal combination of cutting parameters on tool life is a cutting speed of 200m/min, a depth of cut of 0.5 mm and a feed motion of 0.1 mm/rev.
3. The higher the cutting speed, the smaller the tool life. The smaller the depth of cut, the greater the tool life. The smaller the feed motion, the greater the tool life

REFERENCES

1. J. Edward. Shigley and C. R. Mischke, *Standard handbook of machine design*. McGraw-Hill, 1996.

2. H. Budiman, R. Laboratorium, P. Produksi, J. T. Mesin, and T. Industri, "Analisis Umurdan Keausan Pahat Karbida untuk Membubut Baja Paduan (ASSAB 760) dengan Metoda Variable Speed Machining Test." [Online]. Available: http://www.petra.ac.id/~puslit/journals/dir.php?DepartmentID=MES

3. "AISI 4140 Chrome-Molybdenum High Tensile Steel." https://www.azom.com/article.aspx?ArticleID=6116 (accessed Feb. 24, 2022).

4. F. Yasa Utama and T. Hartutuk Ningsih, "Optimasi Parameter Pemesinan dengan Proses Bubut pada Respon Kekasaran dan Kekerasan Permukaan Material S45-C Menggunakan Metode Taguchi - Grey - Fuzzy," *Rekayasa Energi Manufaktur*, vol. 1, no. 1, Jul. 2016, doi: 10.21070/r.e.m.v1i1.169.

5. A. B. Prasetiyo, "Keywords : Taguchi Method Surface Roughness Wear of Chisel."

6. M. Y. Sobron Lubis and R. dan Moses Kamillo Tjenardi, "Investigasi Variasi Kecepatan Potong Optimal Pada Proses Pemesinan Baja Aisi 4140."

7. Das, S. R., Dhupal, D., & Kumar, A. (2015). Study of surface roughness and flank wear in hard turning of AISI 4140 steel with coated ceramic inserts. *Journal of Mechanical Science and Technology*, *29*(10), 4329-4340.

8. 8.Nagalwade, P. L., & Kale, A. V. (2014, December). Performance evaluation of TiN coated and uncoated carbide tools in turning AISI 4140 steel. In *5th International & 26th All India Manufacturing Technology, Design and Research Conference*.

9. Şahinoğlu, A., & Rafighi, M. (2021). Investigation of tool wear, surface roughness, sound intensity and power consumption during hard turning of AISI 4140 using multilayer-coated carbide inserts. *Journal of Engineering Research*, *9*(4B).