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Tool life investigation of carbide cutting tools in the turning of cast iron material.

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Abstract. Tool life is an important thing to consider in the process of metal cutting. Before the machining process is done, it is necessary to know how long a cutting tool is capable of cutting before wear occurs. However, it is difficult to predict the life of the cutting tool, because each cutting tool has different characteristics in cutting metal. The research was conducted aimed at predicting the life of cutting tool using the Taylor equation, but the n and C constants contained in the equation vary for each type of cutting tool used in cutting workpieces. Through the experiment of cutting metal using a lathe, the cutting tool was observed and measured for wear, so that there was a limit to the value of the wear edge of the V_B tool by 0.4 mm. The three cutting speed variants used in the cast iron machining are 180, 210 and 249 m / min. Observations were made every 10 minutes machining was stopped to be measured using a Digital Microscope if the wear value of the cutting tool has not been achieved, then machining continues. The worn cutting tool is no longer used in machining, then uses the new cutting tool. The results of the study showed that the increase in cutting speed had an effect on the wear rate that occurred in the cutting tool. The extended equation for Tool life of Taylor is obtained by $Vc. Tl.^{0.81} = 5011.87$

1. Introduction

The metal formation can be done using machine tools, one of which is the turning process. Workpiece materials such as cast iron have strong hard properties but are brittle, therefore we need cutting tools that have a high strength to do the cutting of hard metals. Often to increase the rate of production, the machining parameters used such as cutting speed, depth of cut, the feed rate is increased, this can give effect to the processing time can be shorter, but the effect of tool life is shorter. This is certainly very ineffective in the machining process because the cutting tool will always be replaced so that it creates non-productive time for the replacement of the cutting tools. The wear of cutting tools often occurs when the machining process is carried out to cut hard metals at high speeds, so it is not known how long the cutting tools can perform their functions at a cutting speed used. Therefore, it is necessary to predict cutting tool life when machining with varying cutting speeds. Through the experimental method and the development of tool life equations Taylorequations,this research was carried out to obtain an extended value of Taylor equitation tool life. The aim of this research is to predictive values of tool life cutting tools when the turning of cast iron workpieces so that it is known how long the life of cutting tools are used for various cutting speeds used.

With the development of metal materials, namely increasing the hardness and strength of workpieces, material cutting tools are also developing. Developed back in the 1970s and 1980s, TiC, TiCN, TiN, Al_2O_3, and TiAIN still remain the most frequently used tool coating materials. They are still the basis for modern high-performance coatings, although there is still potential for performance improvement by adjustments of the coating architecture. In particular diamond, TiB_2, and AlCrN are amongst the later, yet nonetheless successfully introduced coating systems [1].

The dimensions of wear cutting tools determine the limits of tool life. Thus, the growth of cutting tools' wear determines the end of performance cutting tools. The growth of flank wear begins with relatively fast growth shortly after the cutting of the workpiece, and then rapid growth occurs again when the cutting speed increases as the workpiece diameter have decreased. When the wear growth begins to recur quickly, it is considered a tool life limit.

The wear process of a tool point, which is largely dependent on the cutting parameters, is an important factor. The wear of a tool point leads to a deterioration in the quality of the machined surface and, consequently, to lower efficiency and productivity [2].

The research conducted by Chen et al concluded that the accurate tool life models for both WTVC8 and WC8 have been constructed based on Taylor’s equation. The models show that cutting speed has the most significant effect on tool life, followed by the depth of cut and feed rate. The tool life models can serve as quantified guidance for cutting performance optimization [3].

The tool wears analysis result indicated that the MQL condition provided 10% less flank wear and 30% less crater width as compared to the dry condition [4].

Increasing the cutting speed increases the wear in the cutting edge – mainly in higher feed rates [2]. Low tool life and material removal rate are among the main problems in the machining of the superalloys. The effects of tool material and cutting parameters on the machinability of superalloys have been investigated in various studies. Cemented-carbide cutting tools are widely implemented for cutting operations of superalloys at cutting speeds below 30 m/min [5].

Cutting speed, feed rate and the product of cutting speed had a significant effect on tool life and the interaction effect of cutting speed, feed rate and the product of feed rate influenced tool life insignificantly.Additionally, for tool life, cutting speed with a percentage contribution of 55.84% was the most significant factor [5].

2. Method and Material

This research was carried out using a Mazak CNC Lathe

1. Lathe machine CNC “Mazak ICK Turn 8N”

Figure 1. Lathe CNC Machine

Lathe Machine	CNC Mazak Type Quick turn 8N
Made by	Japan
Maximum Swing	300mm
Range between center	290mm
Maximum Spindel speed	5000 r/min
Power	7,5 kW (750 –5000r/min)
Maximum Torsion (T)	9,0 kgf.m (60-750 r/min)
Control	Mazatrol Plus

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2. Toolholder Type MTGNR2020K16

Figure 2. Toolholder Type MTGNR2020K16

3. Coated Carbide Cutting Tool type TNMG 160404

Figure 3. Coated Carbide Cutting Tools Type TNMG 160404

4.The workpiece is Gray Cast Iron with characteristic below :

Table 1. Characteristic of Cast Iron

Figure 4. Gray Cast Iron

Density	706 x 10^3 – 734 x 10^3 kg/m^3
Modulus Elastic	124 GPa
Thermal Expansion (20°C)	9,0 x $10^{-6}C^{-1}$
Specific Heat Capacity (25°C)	490 j/(kg x K)
Conductivities Thermal	53,3 W/(m x K)
Electrical resistivitality	1,1 x 10^{-7} Ohm x m
Tensile stress	276 MPa
Hardness	180 – 302 HB, Hardness Brinell

5. Observation and measurement of cutting tools wear is done using a digital microscope below :

Figure 5. Digital Microscope

Experimental procedure

Experimental turning process is done by varying the use of three cutting speeds namely (Vc1) = 180 m / min, (Vc2) = 210 m / min and (Vc3) = 240 m / min. Feeding speed (V_f) = 344 mm/min and depth of cut (DoC) of 1 mm. Then the turning process is carried out on the cast iron workpiece, for observation and measurement of wear that occurs on the cutting tools, then each machining runs for 10 minutes, the turning process is stopped to observe and measure the wear that occurs on the cutting tools surface (as for the flank wear of criteria cutting tools are determined if the wear value has reached V_B = 0.4 mm).[6] If on the observation and measurement, the cutting edge wear value of the tools has not reached the specified criteria limit, then the machining process is continued so that the cutting tool reaches the specified wear value limit.

3. Result and Discussion

Based on observations and measurements of cutting tool wear every 10 minutes until the cutting tool wears with a value of 0.4 mm can be seen in the following figure:

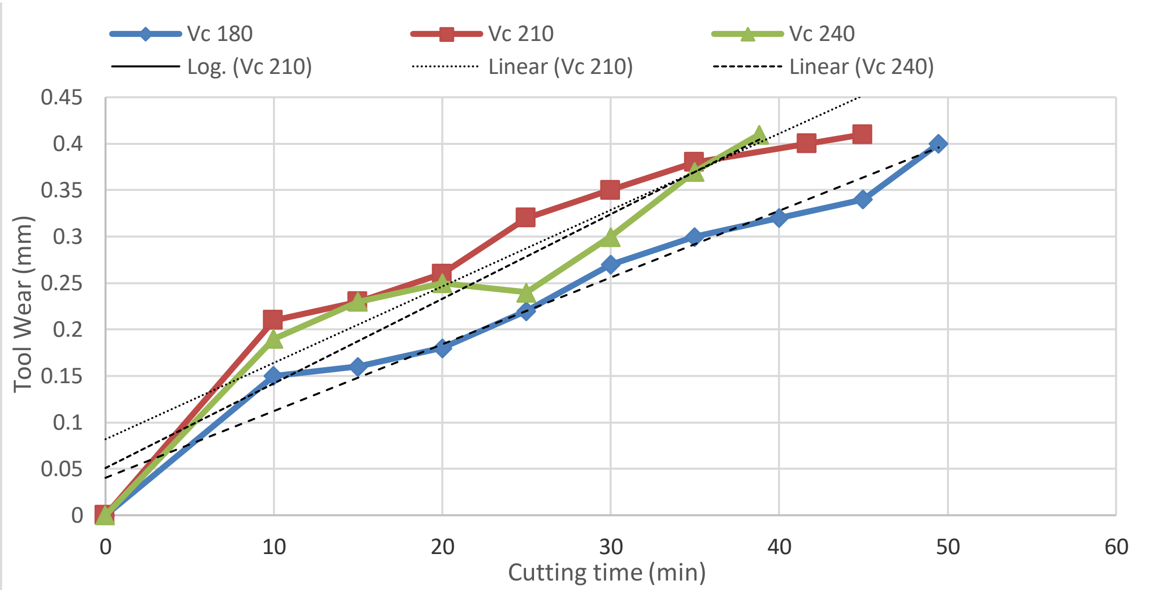

Figure 6. Tool wear of coated carbide tool

Based on graphic above, For each cutting speed, tool life is obtained as shown in Table 2.

Table 2. Tool life of Cutting Tools

Cutting speed, Vc (m/min)	Tool life, Tl (minute)
180	49’47”
210	41’40”
240	38’ 50”

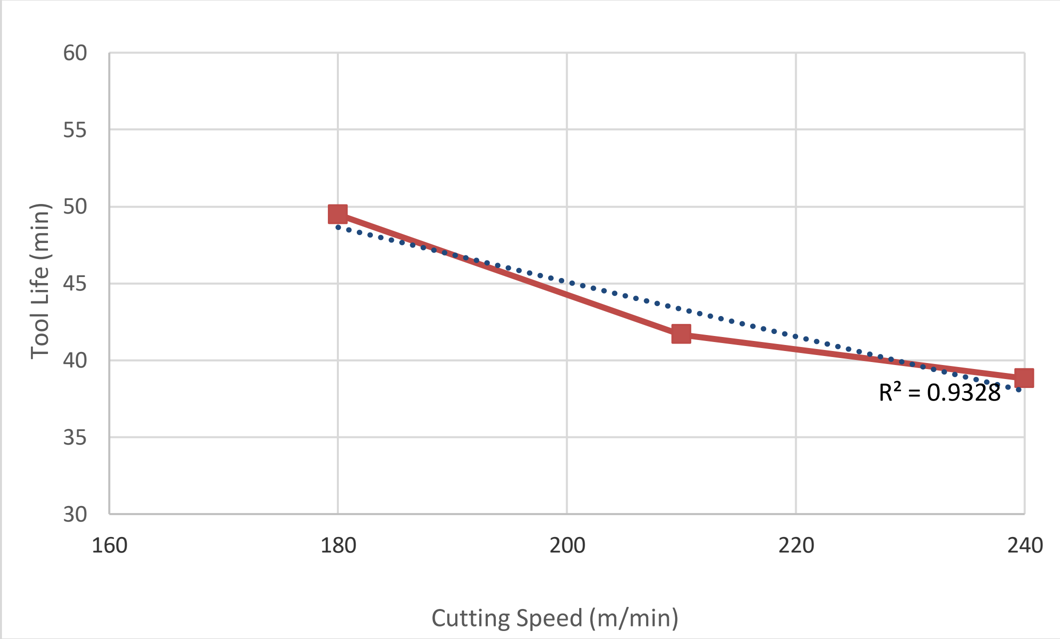

Figure 7. The Influence of Cutting Speed on Tool Life

When turning is done at cutting speed (Vc) 180 m/min, coated carbide cutting tools are able to cut the cast iron workpiece and finally reach the specified wear limit with a time of 49 minutes 47 seconds. At this cutting speed, the wear value that occurs is relatively long compared to the use of other cutting speeds. The wear that occurs in the cutting tools is caused by the adhesion process, this is due to chips that are attached to the cutting tool, known as the Built-Up Edge (BUE), besides that, abrasive processes are also caused by friction between the chips and the cutting tool surface. The increase in high cutting wear occurred in the 50th minute.

Then the machining process is carried out at cutting speed (Vc) 210 m/min, in this condition, the cutting tool wears at 41 minutes 40 seconds. Wear of the cutting tool occurs at this cutting speed which occurs faster than the previous cutting speed. Wear that occurs at the cutting speed is caused by abrasion and adhesion. BUE that occurs at the radius tool nose is much thinner than the 180m / min speed of the nose. Besides, in the machining process, there is a noise that is caused by friction that occurs on the cutting tool and workpiece.

When the cutting speed (Vc) is increased to 240 m / min, the performance of the cutting tool can perform its function only up to 26 minutes 53 seconds. At this cutting speed, the cutting tool starts to wear due to the process of adhesion, abrasion and plastic deformation. This is due to the increase in cutting speed resulting in friction in the contact area of the cutting tool resulting in relatively high temperatures. The effect of the high temperature has an effect on the properties of the cutting tool material so that the part of the cutting tool's contact area becomes weaker and finally adhesion occurs.

By using the Tool Life Taylor equation, it can be predicted the use of tool life for a variety of cuttingspeeds.[8]

$$Vc. T_L^n = C$$

Where :

Vc = Cutting speed (m/min)

T_l= tool life (min)
n= Eksponen of tool life
C =Constanta Taylor

To obtain the constants n and C from this equation, the machining time data obtained from the table above are substituted in the log equation and become [7]:

Log Vc + n log Tl = C
Log Vc + n log Tl = Log Vc_3-Log Vc_1
n (logTl_1-log Tl_3) = log Vc_3-logVc_1

$$n = \frac{(logVc3 - logVc1)}{(logTl1 - logTl3}$$

$$n = \frac{2.34 - 2.25}{1.69 - 1.58} = \frac{0.09}{0.11} = 0.81$$

Tan ϴ = n
ϴ = $\tan^{-1}$.0,81
ϴ = $\tan^{-1}$.n
= 39.77^0

The slope (n) value for the log graph is 0.81, then:

Log Vc + n log Tl = C
1.43 + 0.81(1.58)=log C
Log C = 3.70
C = 5011.87

Then Taylor's tool life equation becomes

$$Vc.\ T_l^{0.81} = 5011.87$$

From the results of the experiments that have been carried out by entering these data into the log-tool tool life equation, a similarity of the extent of tool life equitation is obtained. Using these equations, tool life predictions can be made, and it can be known how long the cutting tool can cut metals with various types of cutting speed variations. This will certainly help operators in preparing the number of cutting tools that must be provided before the machining process is carried out, and this is very helpful in calculating the cost of machining processes that occur.

4. Conclusion

The conclusions obtained from this study are as follows:
Increased cutting speed has an effect on increasing temperature in the cutting tool's friction plane, resulting in abrasion wear on the cutting tool.
The wear occurs in the flank wear of the cutting tool is abrasive wear.
The cutting speed is a greater effect contributing to the wear of the cutting tool compared to the feed rate.When turning is done at cutting speed (Vc) 180 m / min, coated carbide cutting tools are able to cut the cast iron workpiece and finally reach the specified wear limit with a time of 49 minutes 47 seconds. At this cutting speed, the wear value that occurs is relatively long compared to the use of other cutting speeds.When the cutting speed (Vc) is increased to 240 m / min, the performance of the cutting tool can perform its function only up to 26 minutes 53 seconds. At this cutting speed, the cutting tool starts to wear due to the process of adhesion, abrasion and plastic deformation. This is due to the increase in cutting speed resulting in friction in the contact area of the cutting tool resulting in relatively high temperatures.

Obtained the extended Taylor tool life equation to predict the tool life of the cutting tool is,
$Vc.\ Tl^{0.81} = 5011.87$

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