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THE INFLUENCE OF CUTTING SPEED VARIATION IN TURNING OF AISI 304 MATERIALS ON WEAR AND TOOL LIFE COATED CARBIDE CUTTING TOOLS

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ABSTRACT

Tool life is machining data which is related to machining process. The aim of this research is to determine the tool life, tool wear and Taylor's tool life equation value of coated carbide insert when used in turning process of AISI 304 stainless steel. By completing this research, the tool life of coated carbide insert will be known and can be estimated when different cutting speed for given feeding speed and depth of cut are used. The experiment was done by using cutting speed which was varied whereas feed rate and depth of cut were fixed during the turning process until the tool wear value of each cutting speed reaches 0.3 mm (V_B = 0.3 mm). Taylor's tool life equation was obtained as $V_C T_L^{0.939}$=2968 and value of tool life of 29 minutes 10 seconds for low cutting speed and 15 minutes 36 seconds for high cutting speed.

Key words: Tool life, tool wear, coated carbide, stainless steel, turning

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1. INTRODUCTION

The insert of cutting tool can still be used as long as it does not exceed the wear limit. The time to reach the cutting tool wear limit value is known as tool life. Tool life is very important to know, because if the cutting tool wear, will certainly affect the roughness of the workpiece surface, and the effect will affect the increased machining costs, by knowing the optimal conditions of tools life of cutting tools, it will provide significant benefits in the process of machining to produce good surface roughness and economical machining costs. In metal cutting, the interactions among tool, chip, and workpiece always cause tool wear and other damages to the tool, such as plastic deformation, chipping, and thermal and mechanical cracks. The time of contact between the chip/workpiece and the tool is low due to the high relative speeds.[1] Generally, the manufacturer of the cutting tool insert provides recommendations for using cutting parameters. However, there is no detailed information about tool life limitations. In the actual application, the tool life obtained is not the same as that informed by the catalog of cutting tools, because it is influenced by the parameters used, workpiece material, cooling usage, and actual temperature during the process machining.

The dry cutting is always preferred in the field of environmental friendly manufacturing. But there are some materials, which are sticky in nature like nickel-chromium and titanium base alloys and stainless steel etc., these materials when machined dry tend to stick to tool face leading to tool failure and result in poor surface finish on machined surface.[2]

Poor performance of the tool at the lower cutting speeds can be explained by the influence of the heat on the cutting tool. That is because, metal cutting involves

the generation of large amount of heat and in the machining of AISI 304 stainless steel it is not dissipated rapidly due to the low thermal conductivity of this material. The heat generation principally occurs in three areas: the shear zone, rake face and at the clearance side of the cutting edge.[3]. At temperatures above ~200◦C (as were observed in both the dry and MQL machining processes), phase transformation is not expected to occur in Ni Ti alloys. Instead, the workpiece will be in stable austenite phase that behaves like other conventional elastic–plastic metals. Conversely, in the cryogenic machining, the material exhibits phase-transforming super elastic behavior that follows the Clausius–Clapeyron relationship of increasing.[4].

Based on that, a lot of research was done to determine the tool life of an insert. One of them is Hendri Budiman and Richard's research where the insert was analyzed using Taylor's tool life equation. In their research, carbide insert was used in turning process of ASSAB 760 alloy steel and Taylor's tool life equation was obtained as ${V_C T_L}^{0.378} = 379$.

In this research, coated carbide insert was used in turning process of AISI 304 stainless steel with variated cutting speeds, fixed feeding speed and depth of cut, dry machining.

Dry machining leads to increased cutting temperature, which makes chips softer and ductile. These chips adhere to the workpiece and tool surfaces causing tool chipping, chip entanglement, and damage to the workpiece surface.[5].

AISI 304 steel finds its application in air craft fittings, aerospace components such as bushings, shafts, valves, special screws, cryogenic vessels and components for severechemical environments. They were also being used for welded construction in aerospace structural components. Most of the components require certain machining in different machines. [6].

The aim of this research is to analyze the wear on the cutting tool as a result of the influence of cutting speed of the tool on AISI 304 stainless steel machining to determine the constant values of n and C in the Taylor tool life equation.

2. RESEARCH METHOD

The method used in this research was experimental method by using variated cutting speeds. Every cutting speed was experimented by doing taper turning until it reached V_B value of 0.3 mm.[8]. V_B value is the limit of the cutting tool edge wear value when performing metal cutting processes. During the experiment, there were five variated cutting speeds with fixed feeding speed and depth of cut and without coolant.

Used equipment and material in this research were:

- CNC turning machine "Mazak ICK Turn 8N"
- Tool holder "Widax PCLNR 2020K12".
- Coated carbide insert "CNMG 120404-MA UE6020"
- AISI 304 stainless steel round bar Ø 37.2mm

- Digital microscope "Jenco" with 50 x magnification.

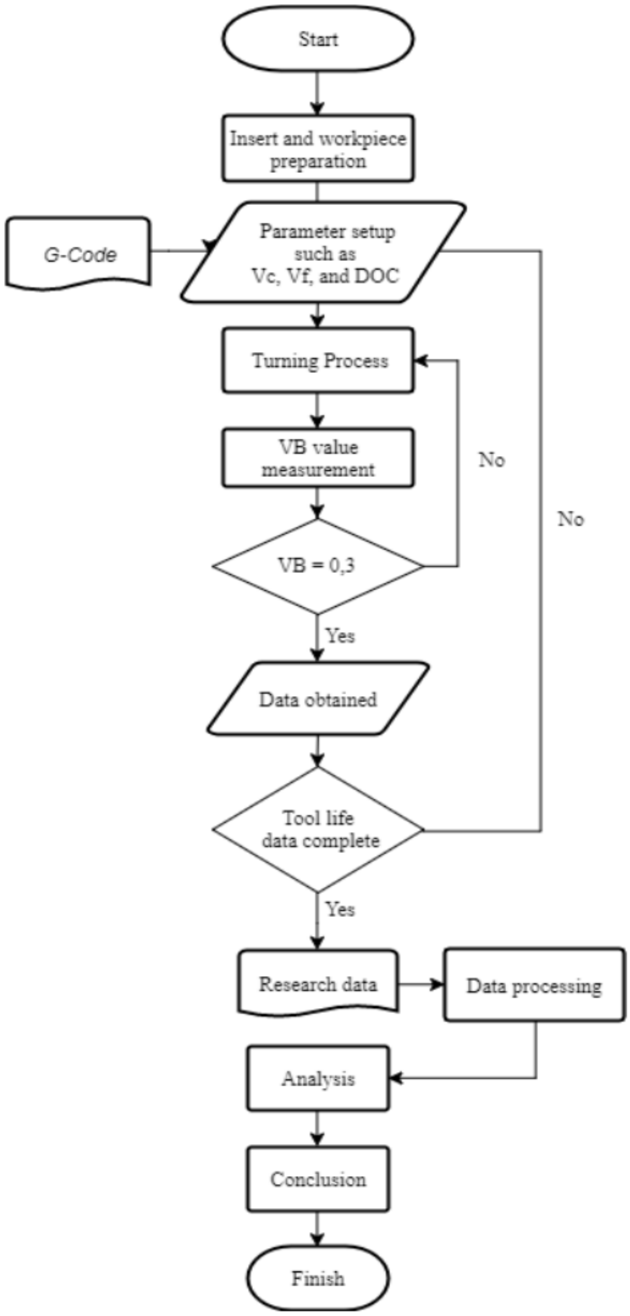

Figure 1 Research Flowchart

The research began by deciding the machining parameter:

Table 1 Machining Parameter

Cutting Speed (*Vc*)	Feeding Speed (*Vf*)	Depth of Cut	Coolant
Vc_1 =125 m/min			
Vc_2 = 150 m/min			
Vc_3 = 175 m/min	330 mm/min	0.5 mm	
Vc_4 = 200 m/min			
Vc_5 = 225 m/min			

The degree of taper used was 20° with the depth of cut was 0.5 mm, therefore, the taper length obtained for every pass was 27.2 mm. Then, taper turning began, for every 5 minutes, the insert examined on the digital microscope to determine the V_B value if it had exceeded 0.3mm, if so, then the tool life forgiven cutting speed would be recorded. When it reached the wear limit, the insert changed and the taper turning process continued using different cutting speed.

After all the required V_B value and tool life data recorded, data processing was done to determine Taylor's tool life equation. [9].for coated carbide in turning of AISI 304 stainless steel using:

$$Vc \,. T_L{}^n = C \tag{1}$$

where:

Vc = cutting speed (m/min)

T_L = tool life (min)

n = tool life exponent

C = Taylor constant

Using derivative equation of Taylor's tool life equation.[10]., the value of tool life exponent (n) for coated carbide could be calculated:

$$Vc_1\left(T_{L_1}\right)^n = Vc_5\left(T_{L_5}\right)^n = C \tag{2}$$

becomes:

$$\left(\frac{Vc_5}{Vc_1}\right) = \left(\frac{T_{L_1}}{T_{L_5}}\right)^n \tag{3}$$

With the tool life exponent had obtained, therefore Taylor's tool life equation for coated carbide in turning of AISI 304 stainless steel could be determined and obtained. And then, graphs showing the influence of cutting speed on tool life and tool wear would be made.

3. RESULTS AND DISCUSSION

Following tables are the tool life of insert for each cutting speeds:

Table 2 Experimental Result for Vc 125 m/min

Tool Wear Value (V_B)					
Minutes	Grid 1	Grid 2	Grid 3	Grid 4	Total
		V_B(mm)			
5	0.05	0.06	0.06	0.07	0.06
10	0.06	0.12	0.06	0.08	0.08
15	0.10	0.20	0.16	0.21	0.17
20	0.10	0.26	0.20	0.23	0.20
25	0.17	0.24	0.26	0.33	0.25
30	0.21	0.29	0.35	0.39	0.31

Table 3 Experimental Result for Vc 150 m/min

Tool Wear Value (V_B)					
Minutes	**Grid 1**	**Grid 2**	**Grid 3**	**Grid 4**	**Total V_B (mm)**
5	0.07	0.1	0.08	0.06	0.08
10	0.08	0.15	0.13	0.1	0.12
15	0.16	0.22	0.23	0.16	0.19
20	0.21	0.24	0.26	0.24	0.24
25	0.26	0.33	0.29	0.23	0.28
30	0.36	0.39	0.41	0.42	0.40

Table 4 Experimental Result for Vc 175 m/min

Tool Wear Value (V_B)					
Minutes	**Grid 1**	**Grid 2**	**Grid 3**	**Grid 4**	**Total V_B (mm)**
5	0.08	0.12	0.09	0.1	0.10
10	0.1	0.16	0.12	0.12	0.13
15	0.2	0.24	0.2	0.17	0.20
20	0.26	0.38	0.25	0.17	0.27
25	0.31	0.4	0.37	0.21	0.32

Table 5 Experimental Result for Vc 200 m/min

Tool Wear Value (V_B)					
Minutes	**Grid 1**	**Grid 2**	**Grid 3**	**Grid 4**	**Total V_B (mm)**
5	0.09	0.15	0.11	0.11	0.12
10	0.14	0.2	0.09	0.1	0.13
15	0.2	0.27	0.21	0.21	0.22
20	0.29	0.38	0.29	0.29	0.31

Table 6 Experimental Result for Vc 225 m/min

Tool Wear Value (V_B)					
Minutes	**Grid 1**	**Grid 2**	**Grid 3**	**Grid 4**	**Total V_B (mm)**
5	0.14	0.19	0.14	0.19	0.17
10	0.16	0.2	0.17	0.2	0.18
15	0.18	0.24	0.38	0.29	0.27
20	0.37	0.54	0.61	0.48	0.50

Using interpolation, the time needed to reach V_B value of 0.3 mm could be calculated.

Table 7 Tool life

Vc (m/min)	Tool life (min)
$Vc_1 = 125$	$T_{L_1} = 29'10''$
$Vc_2 = 150$	$T_{L_2} = 25'58''$
$Vc_3 = 175$	$T_{L_3} = 23'3''$
$Vc_4 = 200$	$T_{L_4} = 19'19''$
$Vc_5 = 225$	$T_{L_5} = 15'36''$

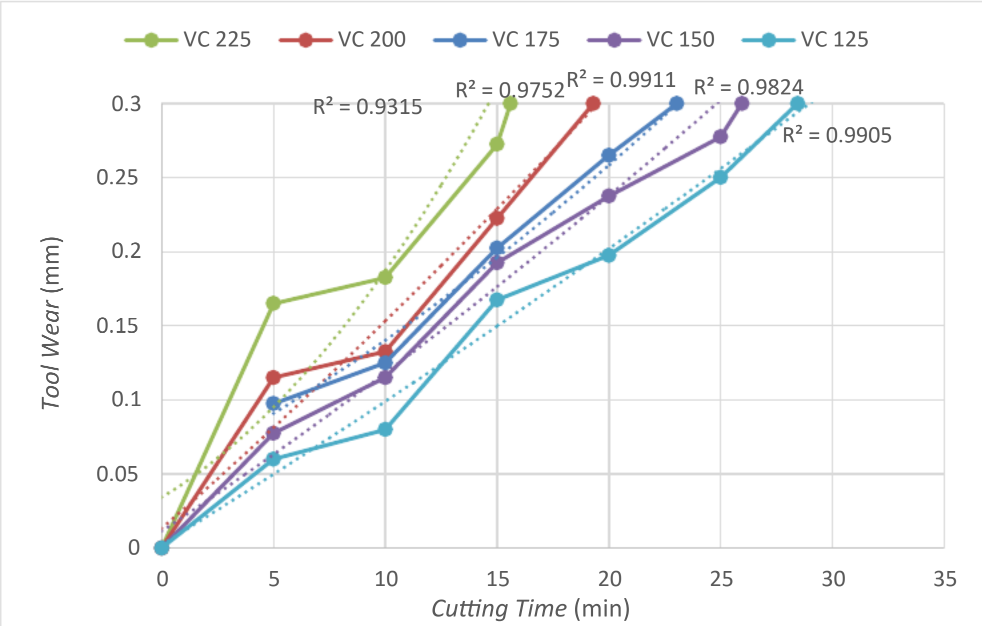

Figure 2 Cutting time Vs Tool Wear

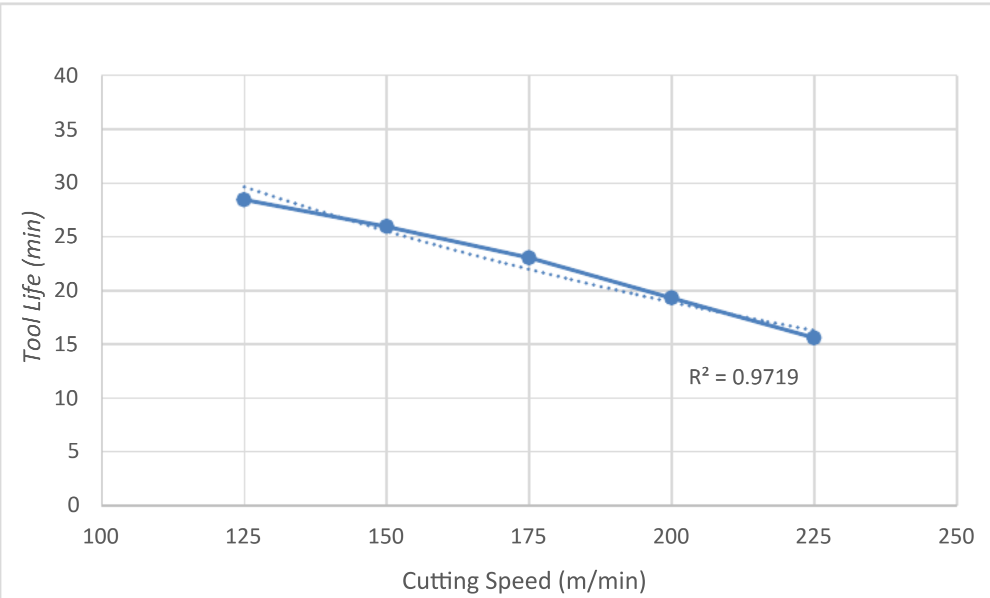

Figure 3 Tool Life Vs Cutting Speed

Using Taylor's tool life equation, put Vc_1, Vc_5, T_{L1}, and T_{L5} values into eq. (3), therefore Taylor's tool life equation for coated carbide in turning of AISI 304 stainless steel is obtained as $Vc.T_L{}^{0.939} = 2968$

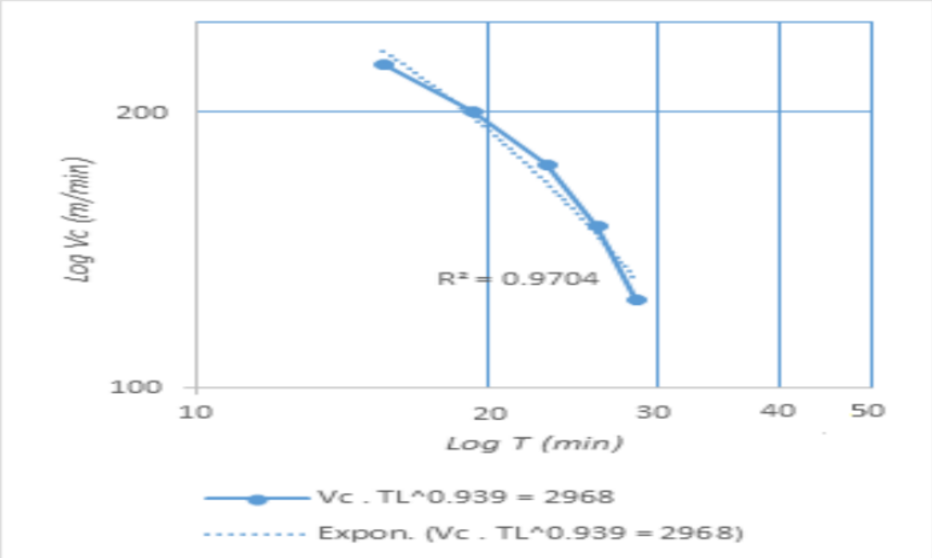

Figure 4 Coated Carbide Tool Life in *log-log* Scale

In the machining process with cutting speed (Vc) 125 m / min, the insert of cutting tool has a tool life of 29 minutes 10 seconds. The growth of tool wear occurs relatively slowly. In the 15th minute, wear and tear on cutting tools begins to appear. Wear is affected by abrasive processes and adhesives. Friction between these chips and inserts is what causes abrasive processes, on the other hand, an abrasive process occurs due to the build-up of material on the insert, also known as BUE (Built-Up Edge). With increasing machining time running, material built-up will cause wear and crater to become larger gradually.

While at cutting speed (Vc) 150 m / min, the cutting tool insert has a tool life of 25 minutes 58 seconds. Wear growth is slightly faster than the cutting speed (Vc) wear growth of 125 m / min. Wear on the cutting tool is affected by abrasive processes and adhesives. Crater wear that occurs at this cutting speed has a value of wear depth that is less than the previous cutting speed, BUE is built up to the nose insert radius.

Machining process at cutting speed (Vc) 175 m / min, cutting tool insert has a tool life of 23 minutes 3 seconds. Wear on the cutting tool is affected by abrasive processes and adhesives. BUE does not build that much at this cutting speed, therefore, the crater wear that occurs at this cutting speed is still smaller than at low cutting speeds.

Can be seen at cutting speed (Vc) 200 m / min, cutting tools inserts have a tool life of 19 minutes 19 seconds. Crater wear that occurs at the cutting tool insert is quite critical. The adhesive process and the adhesive process, however, the adhesive process. The abrasive cutting speed is very important, where the crater wear depth at this cutting speed is 0.13 mm.

For cutting speed (*Vc)* 225 m/min, the insert had tool life of 15 minutes 36 seconds. Just as before, the wear occurred was affected by abrasive and adhesive processes, however, on cutting speed (*Vc)* 225 m/min the wear growth was faster than the previous four cutting speeds.

4. CONCLUSIONS

The conclusion of this research is obtained Increasing the cutting speed will cause the wear growth becomes faster, hence shorten the tool life. Tool life exponent value and Taylor constant for coated carbide inserts in turning of AISI 304 stainless steel are $n = 0.939$ and $C = 2968$, therefore, the Taylor's tool life equation is obtained as $Vc \,.\, {T_L}^{0,939} = 2968$.

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