EFFECT OF CUTTING PARAMETER ON THE TOOL LIFE OF THE UNCOATED CARBIDE TOOL DURING TURNING USING MINIMUM QUANTITY LUBRICATION (MQL)

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ABSTRACT: Titanium alloy is one of the advance material that has unique characteristics; difficult to cut and higher chemical reactivity. However, this material always receive many demands from the aerospace, medical and automotive industries. During turning of titanium alloy, the issues that always discussed are rapid tool wear and high cutting temperature. During the time the rapid tool wear take places, it automatically influence the life of the cutting tool. This studies focused on the effect of minimum quality lubrication (MQL) technique during turning titanium alloy Ti-6Al-4V ELI on the tool life of uncoated carbide. From the experiment, the longest tool life that recorded is 54.22 minutes obtained at the minimum cutting parameters while the shortest tool life is 1.50 minutes obtained at the maximum combinations of cutting parameters.

KEYWORDS: *Minimal Quantity Lubrication; Turning; Ti-6Al-4V ELI; Tool Life; Carbide Tool*

1.0 INTRODUCTION

Titanium alloy are widely used and receive more attention in industry especially in the aerospace, oil and gas industries and medical instrument [1]. These kinds of materials have specific properties like high wear resistance, low thermal conductivity and have good strength at high temperature. However, the surface integrity of titanium alloy might be damaged throughout machining process because of the high temperature at the cutting area and poor machinability behavior of titanium alloy [2-3]. Moreover, titanium alloy also possess high chemical reaction with any type of cutting insert.

High speed machining used in the machining operation in order to improve the production while increasing the product quality and minimizing the manufacturing costs [4]. High speed machining is now known as one of the new technology that might improve the accuracy, performance and quality of the workpiece[5]. Besides, the machining period and machining costs could be reduced by using this technology compared to conventional process. During high speed machining titanium alloy will be effect from the heat that produced in cutting zone and reduced the tool life immediately. Previously, Elshwain [6] has proposed the consumptions of cutting fluid for cooling when the process machining of nickel and titanium could reduced the heat that generated during machining operation. Therefore, the tool life is increase and at the same time minimize the tool wear.

Good handling of the cutting zone temperature using an effective cooling technique enhance tool life of the cutting tool during machining titanium alloys material. In order to manage the temperature rises during machining, several technique of coolant like the solid coolants or lubricant, cryogenic cooling , compressed air or gases and minimum quantity lubrication (MQL) have been utilized [7]. Isik [8] noted the usage of cutting fluid at high speed machining could reduced tool wear. In this study, MQL is applied during machining process to decreased the tool wear while increase the tool life. MQL is known as a new cooling method that allow diminish the amount of cutting fluids then leads to reduced cutting fluid costs and machine cleaning cycle time [9]. Surprisingly, the operation cost of MQL in turning application is reasonable compared to conventional lubrication due to the quantity of coolant used. The utilization of MQL is around 50 mL/h compared to the 1000 mL/min in conventional lubrication [10]. This new cooling technique also well known as micro lubrication or near dry lubrication [11]. Previously some researcher found that the MQL is one of the key technology of environment-friendly sustainable manufacturing compare to conventional cooling should be managed properly because it can affect not just to the workers but to the environment [11–13]. Besides, conventional cooling also give environmental pollutant and the government has strict restrictions on controlling the disposal of the waste of the cutting fluid [14]. The crucial point for this paper was to study the effect of MQL, against the tool life of the uncoated carbide cutting tool when machining operation of titanium alloy Ti-6Al-4V ELI.

2.0 EXPERIMENTAL METHODS

2.1 Material of workpiece

In this experiment, the workpiece that involved is belong to the α+β alloy group which is Ti-6Al-4V ELI and contains more than 50% of the titanium alloy production. This α+β alloy has a high strength compare to nearly alpha alloys and widely used in an annealing, solution-treated or aging states. Table 1 below illustrate the chemical composition of titanium alloy in weight %.

Table 1: The Chemical composition of titanium alloy in weight % [15]

Chemical compositions wt. (%)										
Al	C	Fe	H	N	O	S	Si	V	Y	Ti
6.1	0.08	0.22	0.0031	0.006	0.12	0.003	0.03	3.8	0.005	Balance

2.2 Cutting Tool Material

In the machining experiments, the cutting insert that was used are uncoated carbide insert, CNGG 120408 H13A. The insert consists of 16.4 wt% cobalt and 83.6 wt% tungsten carbide. This type of tool is recommended by previous study as it can maintain their excellence like high strength and hardness especially when machining titanium alloys [16]. This cutting tool also can be used at high cutting speed machining and temperature [2].

2.3 Machining Test

The experimental investigation were execute on a Tornado T4 CNC lathe using GE Fanuc Series 21i-TB as a controller using minimum quality lubrication (MQL) as a coolant. Detailed cutting parameters were used in machining are summarized in Table 2. The experiment matrix are design by using the Design Expert Software Version 7 based on the Box-Behnken method . In this experiment, all cutting tool tested according to the tool life criterion which is an average flank wear (Vb_{avg}) of 0.3 mm. The flank wear (Vb) was measured by using a 3D optical microscope Perthometer.

Table 2: Cutting parameters were used in machining

Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)
120	0.1	0.4
170	0.15	0.5
220	0.2	0.6

3.0 RESULTS AND DISCUSSION

This section is focused on the cutting parameter effect on the tool life of the uncoated carbide during turning by using MQL. Besides the cutting fluids, the tool life also affected by the feed rate, cutting speed and depth of cut. Table 3 shows the experimental result for tool life of uncoated carbide cutting tool (H13A) that used at the time of turning titanium alloy Ti-6Al-4V ELI under MQL condition. Refer to Table 3, 54.22 minutes is the highest tool life while the lowest tool life is 1.50 minute obtained from the combinations of cutting speed 120 m/min; feed rate 0.1 mm/rev; and depth of cut 0.5 mm; and cutting speed 220 m/min; feed rate 0.15 mm/rev; and depth of cut 0.6 mm respectively.

Referring to the Table 3, these cutting parameter were selected to show the interaction between cutting parameters toward tool life of uncoated carbide (H13A). Figure 1 shows the tool life uncoated, H13A at constant cutting speed, 170 m/min and various depth of cut and feed rate values. The cutting speed 170 m/min was selected as to compare the influence of feed rate on the tool life. From the Figure 1, the value of the tool life decline when the feed rate increased from 0.1 to 0.2 mm/rev.

Besides, the value of the tool life also decreased as the value depth of cut increased from 0.4 to 0.6 mm. This trend shows when increasing the depth of cut during the machining process , the temperature generated was directly increased. The high temperature produced has resulted in the tool losing its hardness thus accelerating the wear rate of the cutting tool [17]. In addition, the increase in depth of cut straightly influenced the cutting force and this might influence the performance of the cutting tool [18]. On the other hand, Diniz and de Oliveira [19] stated that cutting at low cutting speed will result in low temperatures and improve the life of the cutting tool.

Table 3: Tool life (minute) of uncoated carbide cutting tool (H13A) that used during machining Ti-6Al-4V ELI under MQL condition

Run	Cutting Speed, Vc (m/min)	Feed Rate, f (mm/rev)	Depth of Cut, doc (mm)	Tool life, H13A (min)
1	220	0.15	0.4	10.09
2	170	0.2	0.6	2.13
3	220	0.15	0.6	1.50
4	120	0.1	0.5	54.22
5	170	0.15	0.5	3.80
6	220	0.1	0.5	11.92
7	120	0.15	0.4	28.15
8	170	0.15	0.5	5.13
9	170	0.1	0.4	11.76
10	170	0.1	0.6	7.31
11	220	0.2	0.5	1.81
12	170	0.2	0.4	5.22
13	120	0.2	0.5	12.84
14	170	0.15	0.5	4.72
15	120	0.15	0.6	13.80
16	170	0.15	0.5	5.46
17	170	0.15	0.5	4.15

Figure 2 shows the bar chart for tool life obtained at constant feed rate for various cutting parameters. The feed rate 0.15 mm/rev was selected to compare the effect of depth of cut on the tool life at various cutting speed. From Figure 2, it can be witnessed that the tool life value for the uncoated tool, H13A decreased drastically from 28.15 minute to 10.1 minute when the cutting speed raised up from 120 to 220 m/min significantly. Generally, increasing in the cutting speed reduced the tool life. This is due to the increasing of cutting speed proportianately with cutting temperature at the cutting edge of the tool [15]. Razak et al. [5] also discovered that the high temperature that produced can cause the strength of the material decrease and plastic deformation occured. Therefore, the increase in the value of the cutting speed will affect the wear stage on the flank surface and the deformation of the tool edges. Besides, the increasing in depth of cut also directly increased the contact area between the cutting tool and workpiece, then cause the cutting force value becomes greater [15, 20]. The high cutting force contributed to the tool failure due to the shear generates in the cutting zone when the temperature increase.

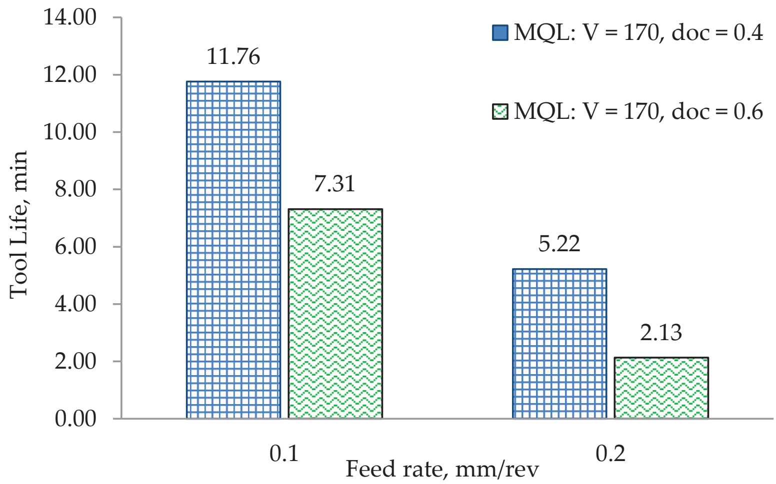

Figure 1: Tool life (min) uncoated H13A at constant cutting speed, 170 m/min and various depth of cut and feed rate

The same opinion is given by Thakur et al. [21] where the contact area and the cutting parameter is reduced it can help in reduced the shear strength at the cutting zone significantly.

Figure 3 shows the effect of change in value for feed rate and cutting speed. The depth of cut 0.5 mm is selected to compare the effect of cutting speed on the tool life at the various feed rate. In the machining, other than cutting speed and depth of cut, feed rate also one of factors that influences tool life of the cutting tool. It can be shown in Figure 3, when the value of feed rate increasing from 0.1 to 0.2 mm/rev, the value of the tool life significantly decreased. At the feed rate 0.1 mm/rev the tool life that was recorded is 54.22 minutes. However, when the feed rate increase to 0.2 mm/rev, the tool life become 12.84 minutes. This is because the increasing of feed rate value causes the increasing cutting parameter at the tool edge and encourage the plastic deformation take places [21-22]. Besides, the plastic deformation also can be main factor to the wear mechanism of cutting tool material during machining titanium alloy mainly in high-speed machining. This is due to the existence of high stress and high temperature near to the cutting edge [6].

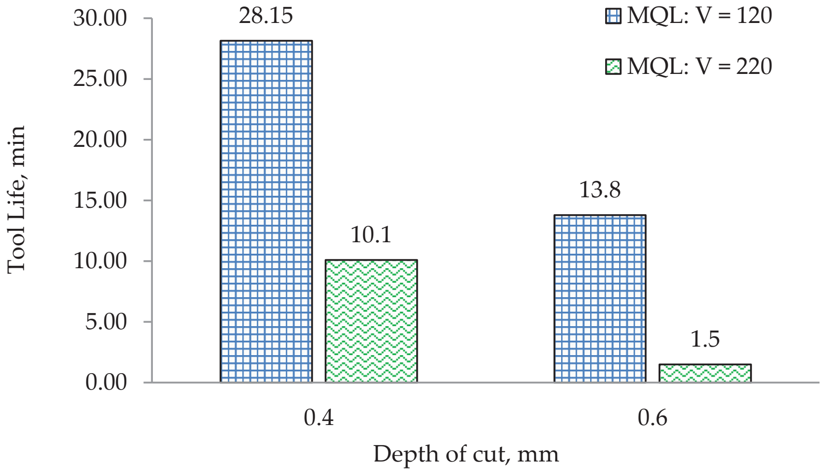

Figure 2: Tool life uncoated H13A for several value depth of cut and cutting speed on the constant feed rate, 0.15 mm/rev

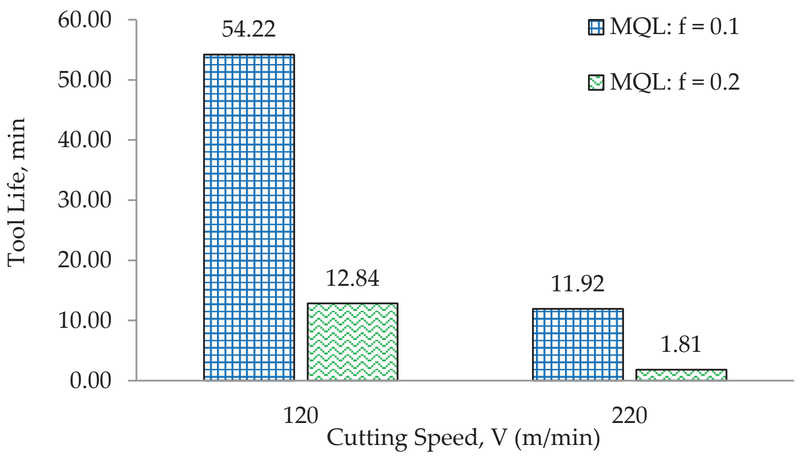

Figure 3: Tool Life of uncoated H13A for several value cutting speed and feed rate on the constant depth of cut, 0.5 mm

4.0 CONCLUSION

As a conclusion, the changes in the cutting speed, depth of cut as well as feed rate will directly influenced the tool life value. The tool life is inversely proportional to cutting parameter (cutting speed, feed rate and depth of cut) due to increasing cutting temperature when cutting process. Based on the result, the most significant cutting parameter toward tool life is cutting speed followed by feed rate and depth of cut.

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