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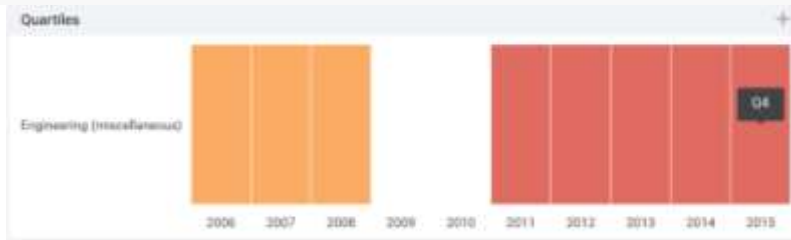
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Impact of Cryogenic Treatment and Temper to carbide tool life on turning process for Al T-6061

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Abstract

Generally to overcome the problem of cutting tool wear use coolant on metal cutting process for decrease the friction or use coating for cutting tool. Nowadays many industry develop the using of cryogenic treatment to improve wear resistance of cutting tool, for carbide tool life longer. Target of this research is to evaluate impact of cryogenic treatment and temper to carbide tool life. Method in this research use cryogenic treatment process continued with temper process of carbide tool. Carbide cutting tool as result of this process implemented on turning process for Aluminium alloy T-6061 with cutting depth (a) variation are 0,1 mm; 0,5 mm and 1 mm, while cutting speed (Vc) 70 m/minute and constant feeding motion (f) 0,1 mm/rotation, without coolant. Research analyst use analytical method and perception with digital microscope and hardness test with Rockwell. The research result are : 1. The greater of cutting depth (a), then wear of cutting tool edge (Vb) be greater, and tool life (T) be shorter. 2. Result of cryogenic treatment for 48 hours at cutting depth (a) 1 mm, cutting speed (Vc) 70 m/minute and feeding motion (f) 0,1 mm/rotation, the tool life increase 28%. At the same condition with cryogenic treatment for 48 hours and temper at 150°C for 1 hour the tool life increase to 105%. 3. For the cryogenic treatment at cutting depth (a) 1 mm the Taylor equation of tool life $VT_{0,35} = 103,6707$ and for the cryogenic treatment and temper at the same cutting depth condition the Taylor equation of tool life $VT_{0,2} = 95,06642$

Keyword: carbide tool, cryogenic treatment, tool life, temper, wear of cutting tool edge

INTRODUCTION

Cutting metal process especially on turning process, friction that happened between cutting tool and workpiece will generate heat highly, so it will make wear of cutting tool faster. This matter affect to surface roughness growth higher and decreases in tool life and also the quality of product progressively lower. Generally to solve the wear problem of cutting tool used coolant on metal cutting for decrease the friction or use coating for cutting tool. Nowadays many industry develop usage of cryogenic treatment to improve wear resistance of cutting tool, gear, and others (Thamizhmanii S. et al., 2011; Ramji B.R. et al., 2010; Kollmer K.P, 2007), so the lifetime of cutting tool become longer. It can save resharpening cost and replace time of cutting tool. Cryogenic treatment is a cooling process of materials as steel, stainless steel and others from room temperature to -320°F (-196°C) then hold at that temperature for several time (soaking time) and continued with warmness until room temperature (Singh S. et al, 2012 and Ramji B.R. et al., 2010). Rajendra K. et al. (2007) classifying that there are two type of materials treatment below room temperature, they are subzero or cold treatment and cryogenic treatment. Subzero treatment done at -145°C (-230°F) and cryogenic treatment done at -195°C in liquid nitrogen.

Biranchi N.S. (2011) show that after cryogenic treatment on cemented carbide inserts will produce fine carbide particles so it will improve hardness and wear resistance. This matter supported by result of Ramji B.R. et al., (2010), research show cryogenic treatment for Carbide Inserts used on turning process of grey cast iron can improve wear resistance to 31%.

Research that done by Amber Pawlik, et al. (2004) show for every carbide cutting tool and workpiece material that used is steel of AISI 1148 to get the tool life data and machining condition, machining process variable with spindle rotation that variation become 3 level with cutting motion (f) and cutting depth (a) constant, equation of Taylor formula from the research is obtained $V.T^{0,2574} = 521,4$.

Research that done by Budiman, H and Richard (2007), showed that the tool life and wear of carbide cutting tool for turning process of steel alloy ASSAB 760, with high cutting speed ($V_c = 170,816$ m/minute), obtained that shortest tool life is 14,756 minute, and the longest is 140,33 minute that happened at lower cutting speed ($V_c = 54,259$ m/minute). Taylor equation from research is obtained $VT^{0,378} = 379$

Result of research that done by Sudjatkoko et al. (2011), determining the tool life and wear of carbide tool for turning process of Aluminium T- 6061, with analytical method and graph obtained that exponent value (n) lifetime of cutting tool (n=0.3) and constant of tool life (C_T) = 112,5723, at high cutting speed (optimum) $V_c = 69,12$ m/minute, with shortest time (t_c) = 12 minute, with cutting depth (a) = 0,70 mm, Taylor equation of tool life $VT^{0,3} = 112,5723$.

MATERIALS AND METHODS

Workpiece that used at research is Aluminium T-6061, Carbide tool that used is carbide with chemical composition 1,25% C; 4,0% Cr; 3,6% Mo; 3,2% V; 9,3% W; and 10,0% Co (BOHLER Steel Manual). Dimension of turning cutting tool is 12 x 12 x 150 mm.

Experiment

- a. Cooling in liquid nitrogen and hold (soaking) with time variation 2 hours, 24 hours and 48 hours. Then continue with tempering process at 150°C hold (soaking) for 1 hour, then cooled on the air until room temperature.
- b. Experiment procedure on machining process

Initial experiment for verification and determine of variable level range machining process.

1. Preparing for setting of turning process data (CNC programming)
2. Material preparing of Aluminium T-6061 with length = 100mm and diameter = 22mm, gripped at main spindle.
3. Cutting tool paired on tool post, and arranged so cutting tool perpendicular to spindle axes.
4. Do the turning process accordance to determined variable (tables 1), with cutting length (l_t) = 60 mm
5. Stop turning process to note cutting time (t_c) using stop watch for 6 minute and measure the edge wear (V_B) use Digital Microscope Tips Using Measurement Function (Dino-Lite)

Variables of process and its value

In this experiment variable that determined its value level to be inquired are cutting speed (V_c) and constant cutting speed (f), while cutting depth (a) be variation.

Experiment tabulation design and its value level and for data experiment, can be seen at Tables 1.

Tables 1. Data Design of machining process cutting condition to measure weathering of edge cutting tool (V_B)

No	Untreated/ treated	Cutting Speed, V_c (m/minute)	Feeding motion, f (mm/rotation)	Cutting depth, a (mm)	Edge cutting tool wear V_B (mm)	Cutting time t_c (mnt)
1	untreated	70	0.1	0.10		6
				0.50		6
				1.00		6
2	Treated cooling in liquid nitrogen , soaking (hour)	2	70	0.1	0.10	6
					0.50	6
					1.00	6
		24	70	0.1	0.10	6
					0.50	6
					1.00	6
	48	70	0.1	0.10	6	
				0.50	6	
				1.00	6	

3	Treated Cooling in liquid nitrogen , soaking (hour) and temper 150°C for 1 hour	2	70	0.1	0.10	6
					0.50	6
					1.00	6
		24	70	0.1	0.10	6
					0.50	6
					1.00	6
		48	70	0.1	0.10	6
					0.50	6
					1.00	6

RESULT AND DISCUSSION

Based on Tables 2 the relation of cutting tool edge wear (V_B) and tool life (T) at any condition show that greater of cutting depth (a) so the wear of cutting tool edge (V_B) will be greater and lifetime of cutting tool (T) will be lower. But at cutting tool condition that cooled in nitrogen liquid with soaking for 24 hours at cutting depth $a=1\text{mm}$ show that cutting tool lifetime is bigger than at cutting depth $a=0,5\text{mm}$. The similar matter is also happened at nitrogen cooling treatment (treated) with soaking 24 hours + temper at 150°C for 1 hour, at cutting depth $a=0,5\text{mm}$, showed that tool life is bigger than at cutting depth $a=0,1\text{mm}$.

Tables 2. Wear of cutting tool edge, V_B with toollife, T and Taylor Equation at various condition with feeding motion $f = 0,1$ mm/rotation and cutting speed $V_c = 70$ m/minute

Condition	Cutting depth, a (mm)	Wear of edge cutting tool, V_B (mm)	Tool life, T (mnt)	Taylor Equation
Untreated	0.1	0.06	6.123	$VT^{0,5} = 127.6879$
	0.5	0.16	5.671	$VT^{0,5} = 120.6405$
	1.0	0.24	5.464	$VT^{0,5} = 115.6598$
Nitrogen cooling with soaking 2 hours	0.1	0.05	7.119	$VT^{0,45} = 124.8107$
	0.5	0.13	6.492	$VT^{0,45} = 117.5495$
	1.0	0.14	5.681	$VT^{0,45} = 108.1239$
Nitrogen cooling with Soaking 24 hours	0.1	0.03	7.756	$VT^{0,4} = 117.0903$
	0.5	0.07	6.759	$VT^{0,4} = 108.7966$
	1.0	0.14	7.059	$VT^{0,4} = 108.1239$
Nitrogen cooling with soaking 48hours	0.1	0.01	7.020	$VT^{0,35} = 102.0659$
	0.5	0.04	7.272	$VT^{0,35} = 101.4461$
	1.0	0.10	8.275	$VT^{0,35} = 103.6707$
Nitrogen cooling with soaking	0.1	0.03	15.354	$VT^{0,3} = 117.0903$
	0.5	0.05	11.109	$VT^{0,3} = 104.3156$

2 hours + temper at 150°C for 1hour	1.0	0.07	10.144	$VT^{0.3} = 99.15009$
Nitrogen cooling with soaking	0.1	0.02	21.648	$VT^{0.25} = 111.3037$
	0.5	0.08	22.744	$VT^{0.25} = 110.6278$
24 hours + temper at 150°C for 1hour	1.0	0.12	21.110	$VT^{0.25} = 106.0605$
Nitrogen cooling with soaking	0.1	0.01	30.278	$VT^{0.2} = 102.0659$
	0.5	0.03	26.906	$VT^{0.2} = 97.86292$
48 hours + temper at 150°C for 1hour	1.0	0.05	26.181	$VT^{0.2} = 95.06642$

Source : result of data processing

Tables 2 show the wear of cutting tool edge (V_B) at untreated condition is bigger than nitrogen cooling treatment specimen with any kind of soaking at same cutting depth ($a = 0.1\text{mm}; 0.5\text{mm}; 1\text{mm}$). Same thing shown at nitrogen cooling treatment with any various of soaking (holding for 2 hours; 24 hours ; 48 hours) at same cutting depth ($a = 0.1\text{mm}; 0.5\text{mm}; 1\text{mm}$), that wear of cutting tool edge (V_B) is bigger than nitrogen cooling treated + tempering at 150°C for 1 hour. Its opposite for tool life on untreated condition, nitrogen cooling treated and nitrogen cooling+ tempering treatment.(see Tables 2).

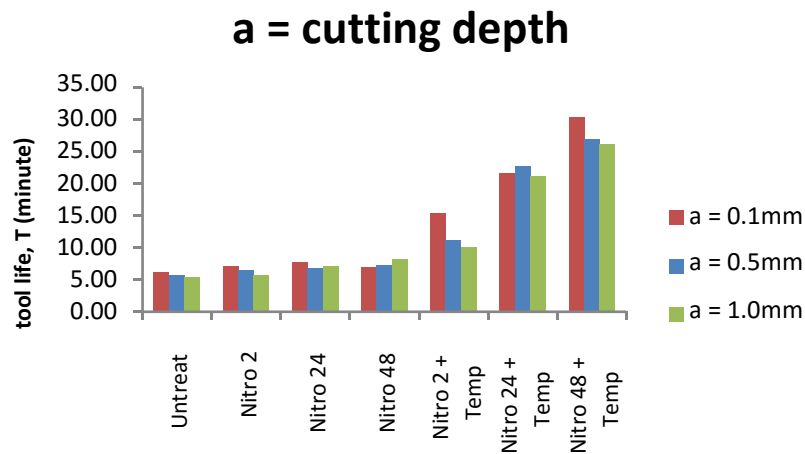


Figure 1. The tool life on various condition at various cutting depth with constant cutting speed (V_c) and feeding motion (f)

Figure 1. show the longer of soaking at nitrogen cooling process even at nitrogen cooling process + temper, the carbide tool life will longer at any cutting

depth, and its opposite the bigger of cutting depth so the carbide tool life will be shorter. Carbide tool with nitrogen cooling process + temper will have longer tool life or its T value is bigger (Figure 1).

Based on table 3 it show the highest hardness number is HRc79.7 for cutting tool that treated nitrogen cooling with soaking for 48 hours , continued by temper at 150^o C for 1 hour. The hardness number increase about 2.97% compare to nitrogen cooling treatment with same soaking without temper. The hardness increase about 3.96% for 24 hours soaking, whereas for 2 hours soaking the hardness increase 2.41%. The hardness number for carbide cutting tool without treatment is HRc 71. It show that there is hardness increasing for carbide cutting tool about 5.07% and 8.87% for nitrogen cooling treatment with soaking variation 2 hours and 48 hours. Addition for temper process, the hardness number increase 7.6% and 12.3% with soaking variation 2 hours and 48 hours. The higher of carbide cutting tool hardness will higher the life time of cutting tool. It showed that carbide cutting tool with cutting depth a = 0.1mm, feeding speed Vc = 70 m/s and feeding motion f = 0.1 mm/rotation that treated by nitrogen cooling and temper process has the least wear of edge cutting tool Vb = 0.01 (Table 3) with highest hardness number HRc79.7 and the longest life time T = 30.278 minute (Table 2).

Tables 3 Result of hardness testingfor carbide tool without treatment (untreated) and cutting tool with nitrogen cooling treatment (treated) and also nitrogen cooling + temper process

No	Condition	Hardness, HRc			Mean of Hardness, HRc	
		1	2	3		
1	Untreated	70	72	71	71	
2	treated Cooling at liquid nitrogen , soaking (hour)	2	74	75	75	74,6
		24	75	76	76	75,7
		48	77	78	77	77,4
3	treated Cooling at liquid nitrogen , soaking (hour) and temper 150 ^o C 1 hour	2	76	77	76	76,4
		24	78	79	79	78,7
		48	79	80	80	79,7

Based on Taylor equation of tool life at cutting speed Vc=70 m/minute, cutting depth a=1mm, feeding motion f = 0,1 mm/rotation the tool life with cryogenic treatment will improve to 28%. Its look like experiment that done by Ramji B.R. et al, (2010) show that cryogenic treatment of Carbide Inserts used for turning process of grey cast iron can increase the wear resistance to 31 %. Its also done by Thamizhmanii S. et al, (2011) researched Cemented carbide tools coat by physical vapour deposition (PVD) used for turning process of Inconel 718 with high speed and feeding motion. Cutting tool with cryogenic treatment have longer tool life than untreated specimen.

The carbide tool life used for turning process of Aluminium 6061 as result of cryogenic treatment and temper, its increase to 105%. This result is much greater than research done by Rupinder Singh, and Kamaljit Singh (2010), which is show turning process of crank shaft with carbide tool at cutting speed V_c 250 m/minute, the carbide tool life increase to 22,2 % after cryogenic treatment and temper. Its because of materials that turned is harder.

CONCLUSION

1. The carbide tool life used for turning process of Aluminium 6061 as result of cryogenic treatment increase to 28% compared with untreated cutting tool.
2. The carbide tool life used for turning process of Aluminium 6061 as result of cryogenic treatment and temper increase to 105% compared with untreated cutting tool.
3. Taylor equation of tool life without treatment, $VT_{0,5} = 115,6598$
4. Taylor equation of tool life with cryogenic treatment, $VT_{0,35} = 103,6707$
5. Taylor equation of tool life with cryogenic treatment and temper, $VT_{0,2} = 95,0664$
6. The greater of cutting depth hence wear of edge cutting tool be greater and its carbide tool life will shorter.

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