

STUDYING THE EFFECT OF CUTTING SPEED AND FEED RATE ON TOOL LIFE IN THE TURNING PROCESSES

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ABSTRACT:- In this paper, a thorough investigation has been carried out to study the effect of cutting speed and feed rate on tool life at constant depth of cut equal to (1mm) with no cooling fluid. Different cutting speed and feed rate with constant depth of cut are used to optimize these variables for maximum life can be obtained experimentally. The experiments were conducted on the fermented low alloy steel and using high hardness cutting tool of Tungsten Carbide. It was found that the longest life of cutting tool is at cutting speed (66.88 m / min) and feed rate (0.72 mm / rev), where the life of cutting tool is(388.3 min). The shortest life of cutting tool occurring at cutting speed of (263.76m/min) and feed rate (0.8 mm / rev), where the value of the life is about (0.274 min). Thus, we clear note that the cutting speed and feed rate have a direct impact on the longevity of the kit.

Keywords:- Tungsten Carbide, Tool life, Tool wear, Turning processes, Cutting tool.

1- INTRODUCTION

The recent developments in the area of material science require better understanding and behavior of the engineering materials during processing. To understand the characteristics of a new cutting tool, many experiments (such as cutting force experiment, cutting temperature experiment, anti-striking experiment, etc) should be conducted to obtain an enormous amount of experimental data⁽¹⁾.

In metal cutting operations, temperature develops at the chip – tool interface due to the plastic deformation developed at the primary shear plane and friction at the tool – chip interface. This temperature rise effects the tool wear and its life, and surface integrity of material generated and temperature are also connected the use of process parameters and thermo physical properties of work piece and tool materials, including the heat thermal

conductivity, thermal diffusivity and heat transfer coefficient . So it is important to choose the correct parameters for satisfy the increasing demands of sophisticated component performance, longevity and reliability⁽²⁾.

The most commonly altered variables in turning are the machine setup parameters. Cutting speed, feed rate, and depth of cut have a very significant impact on the surface quality. They directly impact the physical effects of adhesion and ploughing. Speed and feed become particularly important as they affect tool failure and wear⁽³⁾.

During turning one of the most important factors is tool wear whether it is soft or hard work pieces. The primary tools wear are classified as flank wear, crater wear and nose wear, are important wear which will affect the smoothness of the product, cost of operation and performance. Tool wear is caused by the normal load generated by interaction between tool work piece and tip which shown in fig.(1). Tool wear which results in tool substitution, is one of the most important economical penalties, so it is very important to minimize tool wear, and optimizing all the cutting parameters like depth of cut, cutting velocity, feed rate and cutting fluids⁽⁴⁾.

2- SELECTING CUTTING PARAMETERS

The cutting speed is calculated from rotating speed for any turning operation as the following⁽⁵⁾.

$$V_c = \frac{\pi DN}{1000} \text{-----(1)}$$

Where,

N: spindle speed (r.p.m)

V_c: cutting Speed (m/min)

D: work diameter (mm), π : 3.14

3- TOOL WEAR

It has been recognized widely that tool life can be divided into three phases characterized by three different flank wear processes as shown in fig.(2)⁽⁶⁾.

(i) Break-in.

(ii) Normal wear.

(iii) Abnormal or catastrophic wear.

The sudden rise in wear rate observed during the abnormal tool wear phase (phase iii), is of interest here as an indication of the need for tool replacement. Because many factors affect tool wear, the wear curve usually fluctuates and is not smooth.

4- TOOL LIFE (Taylor's Equation)

$$V_c \times T^n = C \quad \dots(2)$$

V_c = Cutting speed (m/min)

T = Tool life (min)

n & C = constants determined by the work material, tool material, tool design, etc.⁽⁷⁾ .

5- THE FACTOR AFFECTING CUTTING SPEED

The following factors influence on the cutting speed permitted by the tool⁽⁸⁾.

- Physio-mechanical properties of the metal being machined.
- Material of the cutting tool.
- Rate of feed and depth of cut.
- Tool geometry.
- Size of the tool flank.
- Cutting fluid used.
- Maximum permissible amount of tool wear.
- Type of machining being performed.

6- EFFECT OF THE CUTTING SPEED ON TOOL LIFE

It has been established experimentally that there is a definite relationship between the cutting speed and tool life: With increasing cutting speed tool life was decreased⁽⁹⁾.

7- EFFECT OF THE METAL BEING MACHINED.

The physio-mechanical properties of the work metal have a large influence on the cutting speed permitted by the tool. This influence is predetermined, by the heat generated in cutting and the heat distribution between the chip, work, tool and the surrounding medium⁽⁸⁾.

8- EFFECT OF THE FEED AND DEPTH OF CUTTING

Since the rate of feed and depth of cutting have an influence on the cutting forces and temperature, they strongly affect on the speed permitted by the tool. Increased cutting speed and depth of cut result in increased temperatures at the cutting zone. At elevated temperatures chemical wear becomes a leading wear mechanism and often accelerates weakening of cutting edge; resulting in premature tool failure (chipping), namely edge breakage of the cutting tool. In addition, it is noticed that when feed rate is increased, residual stresses change from compressive to tensile⁽¹⁰⁾. An investigation showed that hardness greatly influences the material properties accounting for high variation in flow stress properties. Residual stresses become more compressive as work piece hardness increases⁽¹¹⁾.

9- EXPERIMENTAL SET UP

9.1 Machine

The cutting tests have been carried out on an (SN 40B-50B) lathe as shown in Fig.(3). The machine specifications are listed below.

- Type and model: universal center lathe SN 40B-50B.(M/C)
- Manufacturer: Czechoslovakia, Tos Trencin.
- Total power of machine without extra equipment: 6.6 KW for 50Hz.
- Spindle speed (22.4-2000) r.p.m
- Feed rate (0.08-6.4) mm/rev.
- Center length 1500 mm.

9.2 Work Piece Material

Low alloy steel work pieces with hardness of BH 348 are used after fermented; the chemical compositions are given in Table (1).Fig.(4,5)illustrate the work piece photograph and dimension .

Table (1): Chemical Compositions of Workpiece Material.

No.	Metal	% Low alloy steel	No.	Metal	% Low alloy steel
1.	F _e	93.9	9.	P	0.0618
2.	C	0.543	10.	Cu	0.226
3.	Si	0.278	11.	S	0.005
4.	Mn	0.709	12.	Ti	0.005
5.	Cr	0.801	13.	V	0.724
6.	Mo	0.283	14.	W	0.015
7.	Ni	2.6	15.	B	0.0014
8.	Al	0.0315			

9.3 Cutting Tools

Single High hardness Tungsten Carbide cutting tool is used to perform turning process, its chemical composition is shown in table (2). Each experiment was carried out with new sharp tool in order to keep the cutting conditions unchanged. The cutting-test were conducted without coolant and, as result, totally 20 experiments were performed. Tests were replicated at least three times for each experimental condition and calculate its average.

10-TOOL SPECIFICATIONS

The tool geometry is:

- Rake angle (γ) = 20°
- Relief angle = 80°
- Primary approach angle = 45°
- Secondary approach angle = 30°
- Nose angle = 60°

Table (2): Chemical Composition of Cutting Tool.

No.	Metal	% Carbide Tungsten	No.	Metal	% Carbide Tungsten
1.	F _e	64	8.	Co	7.38
2.	C	1.85	9.	Cu	4
3.	Si	1.8	10.	Nb	3
4.	Mn	3.49	11.	Ti	0.134
5.	Cr	3.15	12.	V	1
6.	Mo	6	13.	W	4
7.	Ni	0.005	14.	Al	0.183

11. SAMPLE OF CALCULATION

1. By Using Graphical Method.

The relation between cutting speed and time is drawn on log scale as the following graph.

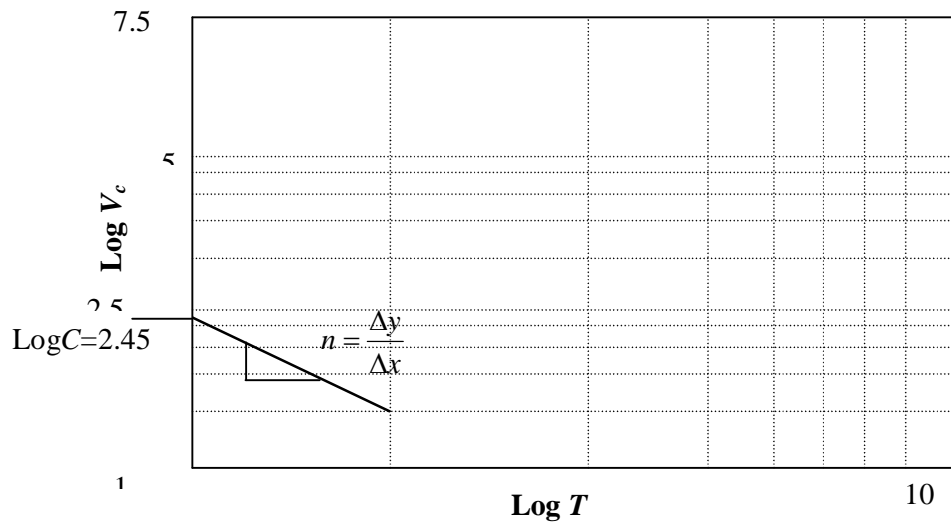


Fig.(6): Relation between cutting speed and time at log scale.

$$\text{Log } C = 2.45$$

$$C = 281.8$$

$$n = \frac{\Delta y}{\Delta x}$$

$$n = \frac{0.431 - 0.357}{2.126 - 1.825} = 0.245$$

2. by using Equation Method

$$\text{Log } V_1 + n \text{Log } t_1 = \text{Log } C \quad \dots\dots(3)$$

$$\text{Log } V_3 + n \text{Log } t_3 = \text{Log } C \quad \dots\dots(4)$$

By Solving Eq. (3) in (4)

$n = 0.242$, Substituting in Equation (4) we get:

$C = 282$, Use Taylor's Equations (equ.2) gives

$$V_c \times T^n = C$$

$$T = 388.3 \text{ Min}$$

12- RESULTS AND DISCUSSION

The raw data for the experimental results: where f =feed rate (mm/rev)

- $f = 0.72$ $C = 282$ $n=0.242$
- $f = 0.8$ $C =188.36$ $n=0.26$
- $f = 0.96$ $C =269$ $n=0.237$
- $f = 1.12$ $C =264$ $n=0.24$

Table (3): raw data for the experimental results.

No	dp (mm) (depth of cut)	Vc(m/min.)	f (mm/rev)	Tool Life (min.)
1.	1	66.88	0.72	388.3
			0.8	53.79
			0.96	353.6
			1.12	307.2
2.	1	94.2	0.72	97.17
			0.8	14.89
			0.96	58.26
			1.12	76.44
3.	1	133.76	0.72	21.89
			0.8	3.74
			0.96	18.98
			1.12	17.11
4.	1	188.4	0.72	5.27
			0.8	1
			0.96	4.46
			1.12	4.09
5.	1	263.76	0.72	1.45
			0.8	0.274
			0.96	1.08
			1.12	1.01

Figure (7) shows the relationship between tool life and feed rate for different speed. It is clear that the tool life decreases with increase feed rate up to 0.8(mm/rev) then begins to increase with increasing the feed rate for different speed. Also it is noted that maximum life occurred with minimum speed for all feed rate value.

The effect of increased feed is more complicated. It is clear from fig(7)that before the value of 0.8mm/rev feed rate, increased feed had a detrimental (decrease in tool life) effect on tool life. This trend was reversed beyond the critical feed rate value of 0.8mm/rev, where increased feed actually improved tool life by a small amount (at lower speed level). However, this phenomenon can be attributed to the fact that increased feed rate reduced tool life in

minutes, but actually increased the amount of material that could be removed by the tool. The later seems a more reasonable metric for tool life, as it relates directly to the number of parts that can be machined with the tool at a given depth of cut. In addition, it is noticed by Tugru reference ⁽¹⁰⁾ that when feed rate is increased, residual stresses change from compressive to tensile. In a recent study, Guo and Liu reference ⁽¹¹⁾ studied the effect of work piece hardness on residual stresses during turning process. They found that residual stresses become more compressive as work piece hardness increases. The hardness greatly influences the material properties accounting for high variation in flow stress properties. Knowing this, it is reasonable to argue that with increment of temperature (to some extent) in shear zone there is a reduction in surface hardness will be occurred.

Thus depending on above conclusion the stress developed in the shear zone may be transformed from compressive to tensile at the critical value of 0.8 mm/rev .So beyond this point of inflection, both cutting forces between rubbing surface and cumulative temperature generated at the plastic zone, begin to reduce which make an increment in the tool life as shown in figure (7).

Figure (8) shows the continuous decrease in the tool life as the cutting speed increased for all value of the feed rate. This result is coinciding with that obtained by Musialek et al reference ⁽¹⁰⁾.

From the two figures (7) and (8) we can note that the effect of cutting speed was more dominant than the effect of feed rate, which leads to the conclusion that for improved tool life, slower cutting speeds should generally be selected in combination with suitable feed rates. Because material removal rate is linearly related to both feed rate and cutting speed, halving the cutting speed while doubling the feed rate maintains an equivalent removal rate. There are, however, limitations on acceptable feed rates determined by the ability of the cutting tool to withstand increased cutting loads without fracture.

13- CONCLUSIONS

Hard turning is an emerging technology that can potentially replace many grinding operations due to improved productivity (increasing production efficiency, high speed machining), increased flexibility (increasing the range of material that can be machined), decreased capital expenses (saving in cost), and reduced environmental waste. A limited understanding about the wear and failure of the cutting tools used in turning remains one of the biggest obstacles to further implementation of this technology. To understand both the

wear behavior and life, full tool life studies were performed for a test of twenty cutting conditions.

In this experimental study, the effect of turning parameters such as cutting speed and feed rate at constant depth of cut on machining characteristics of fermented low alloy steel was investigated. Summarizing the main features of the results, the following conclusions may be drawn.

1. The effect of feeding value at (0.8 mm/rev) is clear on tool life giving shorter tool life in all cases.
2. The cutting speed has an inverse influence on tool life and it was more dominant than the effect of feed rate.
3. Hard turning, machining low alloy steel parts that are hardened usually about BH 348, can be performed dry using high hardness cutting tool of Tungsten Carbide.
4. The economics of the process must be justified, which requires a better understanding of tool wear patterns and life predictions.
5. In order to gain a greater understanding of the turning process it is necessary to understand the impact of each of these variables, but also the interactions between them. It is impossible to find all the variables (feed rate, cutting speed, depth of cut, work piece hardness, cutting edge geometry, etc) that impact tool life in turning process. In addition, it is costly and time-consuming to discern the effect of every variable on the output.
6. Considering these conclusions, further research will be conducted to develop other prediction for the effect of the other variables.

14- REFERENCES

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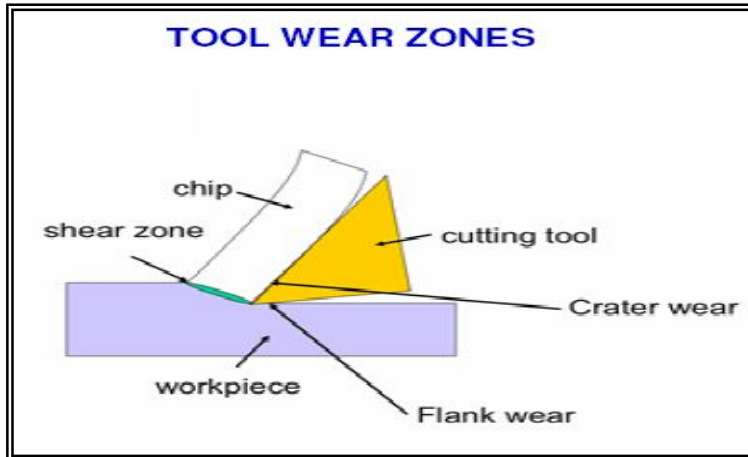


Fig. (1): Schematic diagram of tool wear zone

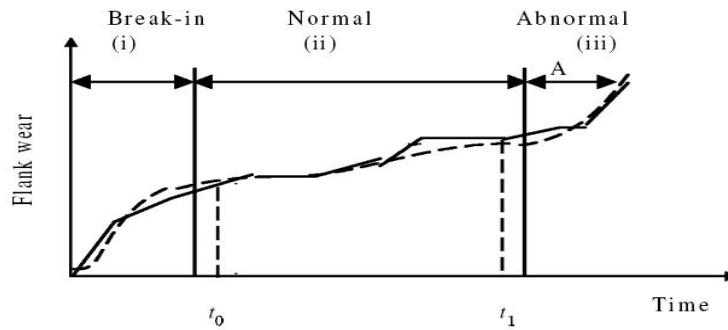


Fig. (2) Tool wear phases.

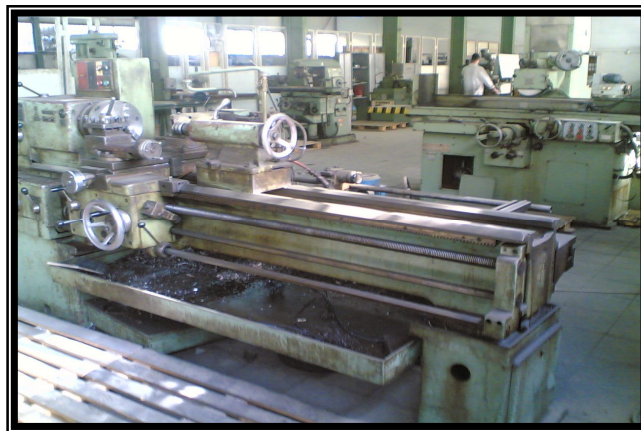


Fig. (3): Universal Turning Machine Model (SN 40B-50B).



Fig. (4): Work Piece.

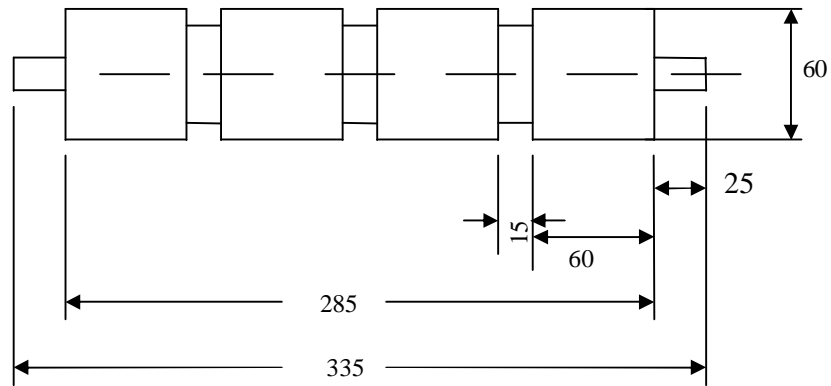


Fig. (5): schematic diagram of work Piece dimension

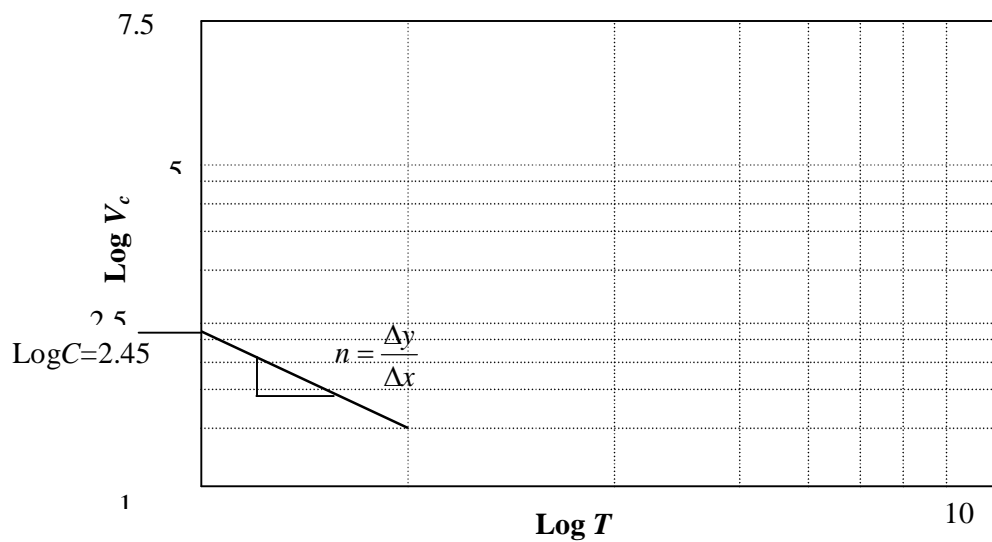


Fig.(6): Relation between cutting speed and time at log scale.

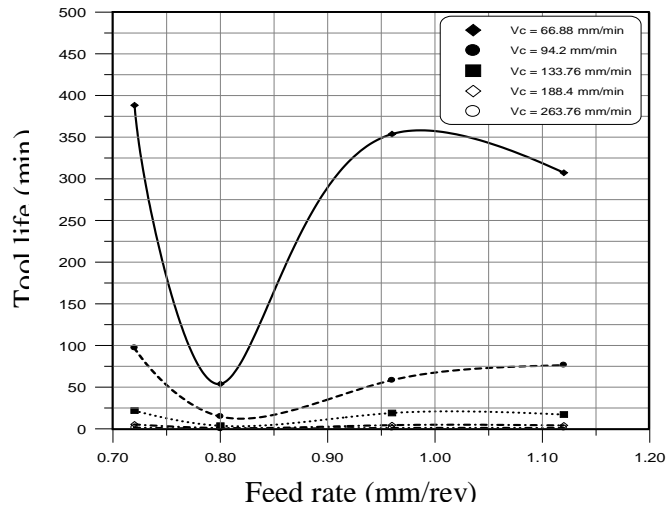


Fig. (7): Comparison between tool life and feed rate for turning at different cutting speed

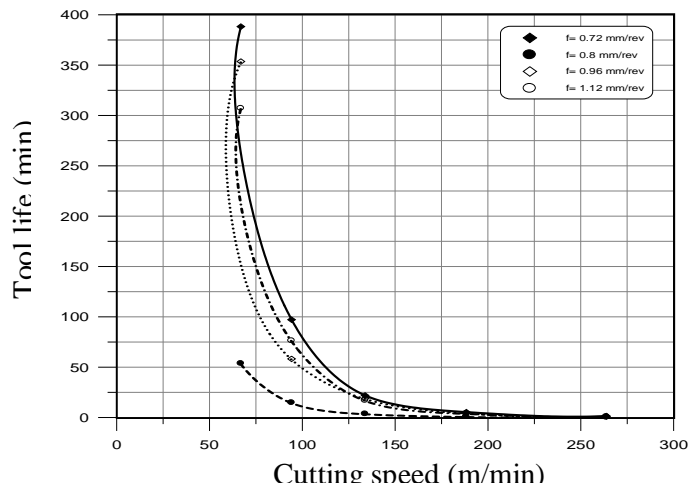


Fig. (8): Comparison between tool life and cutting speed for turning at different feed rate.

دراسة تأثير سرعة القطع ومعدل التغذية على عمر الـعدة في عمليات الخراطة

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الخلاصة

في هذا البحث تم اجراء استقصاء عميق لدراسة تأثير كل من سرعة القطع ومعدل التغذية على عمر الـعدة بثبوت عمق القطع المساوي (1mm) وبعدم استخدام سائل تبريد. تم استخدام سرع قطع ومعدلات تغذية مختلفة بثبوت عمق القطع لاختيار افضل هذه المتغيرات لاقصى عمر للعدة يمكن الحصول عليه عملياً. اجريت التجارب على سبيكة من نوع (Low Alloy Steel) المخمر و بأستخدام عدة قطع من (Carbide Tungsten) عالي الصلادة. وبعد اجراء التجارب وجد ان اطول عمر للعدة المستخدمة كانت عند سرعة القطع (66.88 m/min) وبمعدل تغذية (0.72mm/rev) حيث كان عمر الـعدة (388.3min). أما اقصر عمر للعدة فكان عند سرعة القطع (263.76m/min) وبمعدل تغذية (0.8 mm/rev) حيث كان عمر الـعدة (0.274 min). وبذلك نلاحظ بأن لسرعة القطع ومعدل التغذية لها التأثير المباشر على اطالة عمر الـعدة .