TOOL LIFE AND SURFACE ROUGHNESS OPTIMIZATION IN CONVENTIONAL MACHINING

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ABSTRACT: *Tool life and surface roughness, not only affects product quality & power consumption but also has a significant influence on productivity. This cause economical loses like spoiling of work piece or lessening of surface quality as well as product quality. Objective of this research paper is to investigate optimum spindle speed w.r.t surface roughness and tool life. Tunsten Carbide cutting inserts coated with PVD technique are used in conventional turning process on mild steel. Minimum surface roughness is observed on 1000 RPM keeping feed rate and depth of cut as constant. Maximum theoretical tool life is calculated on the basis of Taylor's tool life equation, which is subjected to minimum spindle speed 300 RPM. It is clear from the experimental results that increasing cutting speed resulted in decreasing tool life due to increasing temperature by metal to metal frictional contact. Increasing temperature damaged tool nose radius and ultimately cause low surface finish. Maximum surface finish is corresponding to increasing spindle speed. High surface roughness achieves at low speed keeping depth of cut 0.2mm and feed rate as constant 0.10 mm/rev throughout the experimentation. Experimental results reveal that surface roughness is directly proportional, while tool life is inversally proportional to the spindle speed.*

Keywords: Surface Roughness, Tool Life, Depth of Cut, Feed Rate, Spindle Speed

1. INTRODUCTION

Tungsten carbide was developed in 1928 to meet increasing industrial and production requirements. Single point cutting tools in traditional machining has been one of the popular and oldest of cutting tools. One of the core properties of tungsten carbide in single point cutting tools is to withstand against high tool tip temperature.

A lot of work has been carried out to find optimum parameters in turning operation. More sophisticated machines are introducing day by day to maximize productivity and improving quality of product.

Nomenclature

MRR	Metal Removal Rate in mm/sec
n	Taylor's tool life exponent
D	Depth of cut in mm
T	Machining time in sec
S	Feed rate in mm/rev
V	Cutting velocity in mm/sec
F	Cutting force in N
Ra	Average surface roughness

Lathe machine is basic and most traditional material processing machine in conventional type. Workpiece is held in rotating chuck and single point cutting tool is used to process the material in round bar form.

i. Surface Integrity

Every part has some profile of texture which varies according to its structure and the way it has been manufactured. Surface can be split down in to three main categories Waviness, Surface roughness and Form. Ra is the internationally recognized and most used parameter of surface roughness. It is the arithmetic mean of the absolute variance of the roughness texture from the mean line.

ii. Tool life

In true sense tool life is satisfactory performance of cutting tool before getting blunt. In R&D sections and in shop floor tool life is defined as following

- In R& D organizations total machining time recorded for cutting edge on which it perform with full satisfaction. Tool life is abruptly affected by tool wear including crater wear and central wear. Tool life is length of actual time by which a tool goes in wear.
- In shop floor tool life is satisfactory serviceable time in any production concern before reconditioning.

Tool life is calculated in minutes in R & D organizations and is dependent on number of work pieces in production shops manufactured by a new tool. Taylor has proposed a equation for measuring tool life with the help of cutting parameters consist of cutting speed, feed rate and depth of cut. Taylor's equation in general is

$$VT^{n}=C$$

Where C is a constant and n is Taylor's tool life exponent. Another modified version of tool life equation is

$$VT^{n}\ F^{a}\ D^{b}=C$$

Where 'T' is time in minutes, V is cutting speed, D is depth of cut and C is constant and values of n, and C is available in machining data Hand book. Values of C, n, a, and b for mild steel is taken as 260, 0.2, 0.21 and 0.11 respectively.

iii. Previous Work

Although hand some work has been done on tool life and surface roughness evaluation using coated and uncoated surface roughness. Coated carbide inserts give better resistance against tool wear and roughness of worked surface. Chamfered edges provide a significant enhancement in tool life as it is commonly observed that tool wear is maximum in exit point of material removal. Failure rate is found to be high at exit side as compared to entry side. Chamfered edges provide proper clearance while working on steel [1]. Tool wear and surface roughness were determined using Taguchi L9 using coated and uncoated cutting inserts. Input parameters on tool wear and surface roughness are selected to conduct experimentation during intermittent cut. It is found experimentally that abrasive wear is present in both coated and uncoated inserts. At higher speed coated tools give more surface finish as compared to uncoated cutting tools but tool wear rate becomes more rapid. Uncoated inserts performance is satisfactory at medium speed. High wear occurs on high speed during intermittent cut with uncoated tools whereas feed rate has dominant effect on surface roughness. An equation has been derived for tool wear and surface roughness using regression analysis [2]. This study covers un-coated, PVD and CVD coated cutting tools on AISI 1030 steel using different processing parameters. Experimental results were executed on artificial neural networks (ANN) to optimize processing parameters. TiN-coated CVD tool gives minimum roughness of surface as compared to TiAlN-coated and AlTiN-coated PVD. Coefficient of friction and thermal conductivity influenced by material type, number of coating layer, coating method and average roughness of surface [3]. Optimum cutting parameters are found using Taguchi method during a turning operation of AISI 1030 steel with TiN-coated tools.L9 orthogonal arrays was used to optimize the parameter for improving performance. Machining performance in case of turning is based on roughness of machined surface. Advantages of orthogonal arrays are estimation of cutting parameters with reduced number of experimentations [4]. Multilayer CVD coated and uncoated carbide inserts analyzed in this study with respect to flank wear and surface roughness. TiN-coated carbide inserts having much micro hardness as compared to uncoated inserts gives better resistance to abrasion. Roughness of surface improved in coated inserts than uncoated ones along with low coefficient of friction and high diffusion properties of TiN on substrate material. Coated inserts bears 30 percent incremental tool life than uncoated carbide. It is conclude that total machining cost per part is significantly lower than that of uncoated carbide tooling ultimately causing minimum downtime and establishes more savings. Experiments conducted on AISI D2 high carbon high chromium steel in the shape of round bar of 40 mm diameter and 200 mm length [5]. AISI 1050 steel is processed to investigate roughness of surface and cutting forces. Research focused on the influence of tool geometry on the surface finish acquired in turning of AISI 1040 steel. RSM (Response surface methodology) was used and a prediction model formed related to average surface roughness using experimental data collected by different experiments [6]. Experimental study was made to determine the effect of cutting parameters on surface roughness in dry high speed milling of tool steel using two cutting tools. The cutting parameters were taken into consideration is feed per tooth and spindle speed of rotating cutter. Experiments were conducted in down-cut and up-cut milling based on the experimental results. The effect of diameter of cutter on the surface roughness was analyzed. The minimum surface roughness can be obtained in high speed cutting of processing steel but rapid cutting tool wear is observed in experimentation [7]. Research paper [8] represents the effects of processing parameters onto the surface roughness through a mathematical model develop by data gathered from series of experiments. Work piece material was cold worked steel AISI P20. Two inserts used in this experiments one is CVD coated and other one is PVD coated. It is concluded in research article [9] that there are many other aspects of tool wear rather than mechanical and chemical aspects like thermo-chemical which directly affect tool life. High speed tends to increase cutting temperature increases diffusion and oxidation process. A similar wear tends to occur during high speed machining which is called central wear. It is experimentally analyzed that this type of wear connected with federate. PVD coated tools in case of milling, provides greater wear resistance as compared to uncoated ones [9]. Tool life, surface finish and vibration were studied during machining of nodular cast iron with ceramic tool. Results shows tool life is minimum with alumina ceramic insert while machining nodular cast iron and concluded that this tool inserts are not useful for cutting nodular cast iron. It is also revealed in this research surface finish is not affected by flank wear but cutting speed, feed and depth of cut has its impact on surface roughness [10]. PVD coated carbide and CBN tools were studied during milling operations. P30 and K 10 grade carbide was coated with four kinds of coating materials like TiN, TiCN, TiAlN and multi-layered TiAlN/AlCrN. CBN tools gives better surface performance in case of high speed machining, the coated carbide tools have no advantage from surface roughness perspective [11].

2. EXPERIMENTAL DESIGN

i. Cutting Tool, Machine and Material

PVD (Physical Vapor Deposition) TiN-coated ISO designated TNMG 160408 Tungsten Carbide inserts are used experimental investigation to find out tool life and surface roughness. Tungsten carbide is available in powder form and pressed in specific tool dies to form inserts. Its Young’s modulus is round 550 GPa and is stiffer than steel in three times. Precision center lathe manufactured by PRIMA Lahore, is used for machining. PRIMA precision center lathe is best suited for experimental purpose in conventional lathe machines. Mild steel is processed by different combination of spindle speed with constant feed rate and depth of cut. Tool life is measured with MRR (Metal Removal Rate). Spectroscopic analysis results the constituents of work piece material is tabulated in Table-1.

Table-1:

C%	Si%	P%	S%	Mn%	Cr%
0.18	0.4	0.040	0.040	0.8	--

ii. Surface Roughness Measurement

The Surtronic-25 is a shift able, self-contained instrument for the measurement of surface texture and is suitable for use in both the laboratory and workshop. The instrument is usually powered by an alkaline battery. Three measurements were taken through Surtronic-25 at different locations to measure average surface roughness in Ra.

iii. Tool Life Measurement

The expansion of Taylor’s tool life equation used in calculating the parameters i.e. $V\,T^n\,F^a\,D^b=C$. The exponents b” and a” are to be drawn experimentally for each combination of cutting set. “n” a constant based on cutting tool material and C is based on tool and on work piece. Value of n for carbide tools ranges from 0.2 to 0.25 in reported literature.

iv. Machining Conditions

Turning operations were carried out on low carbon steel under dry machining on various cutting speeds. Cutting speed, feed rate and depth of cut has prominent effect on surface roughness and tool life as per previous research. Many researchers find that higher feed rate caused greater surface roughness ultimately results in spoiling of work surfaces. 0.10 mm/sec feed rate and 0.2 mm depth of cut kept as constant with varying spindle speed.

v. MRR calculation

Metal removal rate is calculated in mm^3/sec. MRR is volume removed in unit time from a work piece in turning operations. We can calculate metal removal rate as per mentioned formula.

MRR= (weight of workpiece material - weight of work piece after cutting)/work piece material Density.

3. RESULTS AND DISCUSSION

Experiments have been performed on conventional lathe using different combination of Spindle speed and selecting the feed rate and cutting depth as constant.

Table-2: Results against varying spindle speed by keeping depth of cut 0.2 mm and feed rate constant at 0.10 mm/rev.

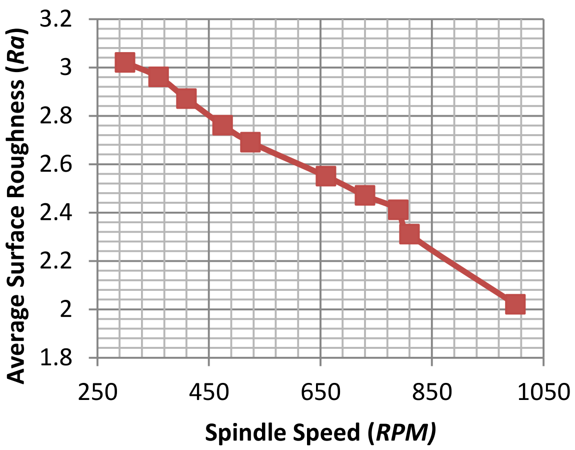
Experiment No	*Speed (RPM)*	*Machining time*	*MMR (Metal Removal Rate) mm3/sec*	*Tool life (min)*	*Surface Roughness (Ra) µm*
1	300	30.08	18	94.12	3.02
2	360	28.91	26	82.49	2.96
3	410	28.71	34	67.48	2.87
4	475	28.62	41	56.55	2.76
5	525	27.52	52	48.32	2.69
6	660	27.27	64	37.43	2.55
7	730	27.09	71	26.16	2.47
8	790	26.92	79	19.28	2.41
9	810	25.87	85	14.38	2.31
10	1000	24.71	91	9.59	2.02

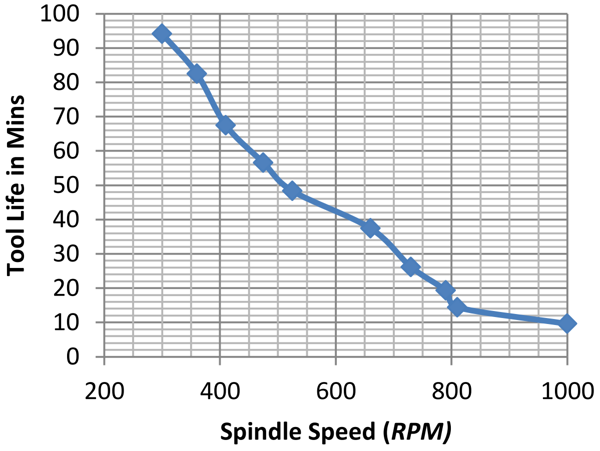
Roughness of surface reduced with the increasing of spindle speed. Ra 1.02µm was observed with the combination of 1000 RPM and 0.10 mm/rev keeping depth of cut constant at the rate of 0.2 mm. Experimental results illustrates that upon 300 RPM maximum tool life achieved with the combination of constant feed rate and depth of cut. Minimum MRR value gives the better tool life. PVD coating has incremental effects on tool life corresponding with better surface finish.

There are many other factors as well which strongly effects surface roughness and tool life including rigidity of machines, work piece homogeneity, accuracy of object and skilled machine operator.

There are two graphs which show average Surface Roughness and tool life with varying spindle speed. Depth of cut taken as 0.5 mm and feed rate kept at constant 0.15 mm/rev.

Average Surface Roghness & Tool Life with respect to cutting speed. In both graphs red line shows an average surface roughness trend while blue line shows trend of tool life corresponding to cutting speed.





Graph trend shows that surface roughness increases with decreasing spindle speed and tool life decreasing with increasing spindle speed.

4. CONCLUSIONS

Roughness of turned surface and tool life has been observed on different processing parameters using depth of cut and feed rate constant.

- TiN-PVD coated cutting inserts have incremental effect on life of cutting tool and decremented effect on surface roughness w.r.t spindle speed.s
- Research reveals that surface roughness decreases as the cutting speed increases but tool life decreases.
- Maximum tool life 94.4 minutes achieved at lowest speed 300 RPM. It shows higher speed causes wear due to increasing temperature.
- Minimum average surface roughness was observed at maximum spindle speed.
- Optimum parameters for surface roughness is 1000 RPM while for tool life it is 300 RPM keeping depth of cut constant.

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