A Study of Effect on Tool Life of Single Point Cutting Tool by Using Various Cutting Parameters

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Abstract : This study involves the performance analysis of various machining parameters like spindle speeds, feed rates and depth of cut on the tool life of a single point cutting tool during turning operation on lathe machine. For this several experiments are carried out without coolant or cutting fluids. During experiments HSS and Tungsten carbide tool materials are used. Work piece material is mild steel. For both tool materials and work piece material machining is done by varying machining parameters to obtain the relation between machining or cutting parameters and tool life. The results are showing that if there is increase in machining parameters like spindle speed, feed rate and depth of cut, it will affect the tool life.

Index Terms **- Machining, Tool Life, Spindle Speeds, Cutting fluid, Feed Rate, Depth of Cut.**

I. INTRODUCTION

In the modern era, the industrial growth has been increased so far especially from last three decades. Most structural components are made of mild steel or medium carbon steel. Mild steel material is commonly used due to its ease of availability, economical cost aspect, properties and ease of machining as per requirement. Most of the machining industries are using metal cutting process to give a final shape to the metal. Either conventional or advanced type of machining can be done on these kinds of materials. For machining the proper selection of machine tools, cutting tools and cutting fluids is required. The machining will be effective when the proper cutting tool with proper geometry is used. For that the knowledge of various machining parameters related to cutting tools is must as these are playing very important role in effective machining.

Most of metal cutting processes involve turning, milling and drilling operations. In this work HSS and Tungsten Carbide tools are used. Work piece material is mild steel. The machining is done in specific conditions like without cutting fluid and with controlled spindle speeds, feed rated and depth of cut. This study involves the performance analysis of various machining parameters like spindle speeds, feed rates and depth of cut on the tool life of a single point cutting tool during turning operation on lathe machine. Taylors Tool Life equations or such type of various equations can be used to predict the behavior of cutting tools. The limitations are they required number of constant terms, assumptions and ideal situations which are practically different from theoretical work. These constants are to be selected from various data sources which is a tedious task on shop floor. The approach of this work is different in this manner which is based on only the real time observations obtained during actual machining [3].

Tool life: It generally indicates the amount of satisfactory performance or service provided by a new cutting tool or a cutting point till it is satisfactorily works after which it needs replacement or reconditioning. The major causes of tool life reduction are mechanical breakage, rapid plastic deformation, tool wear during machining and work piece material.

Taylor's tool life equation: It depends upon various machining parameters like Cutting Velocity (V), Feed (S) and Depth of cut (D). The basic Taylor's Tool Life equation which is based only on Cutting Velocity (V) is as follows:

$$VT^n = C \qquad (1)$$

Where, T= Machining time in minutes, n = Taylor's tool life exponent and C is constant. The values of constants 'n' and 'C' are dependent on the tool work materials and the cutting environment (cutting fluid application) [1]. To consider the variation in Feed (S) and Depth of cut (D) the above equation can be modified as:

$$VT^nF^aD^b = C \qquad (2)$$

Where, values for the various constants like C, n, a and b can be obtained from Machining Data Handbooks or manuals.

II. LITERATURE REVIEW:

Tremendous amount of work has been carried out on the analysis of tool life by experimentations or by numerical investigations. Sunday Joshua Ojolo and Olugbenga Ogunkomaiya [6] carried out the investigation to study the effects of machining parameters on tool life under dry machining environment. Three cutting tool materials (HSS, tungsten carbide insert tool, DMNG carbide insert tool) and work materials (medium carbon steel, mild steel, brass) were examined for experimentation. Various range of machining parameters was selected for the experiments by using the Taguchi experimental design method. Analysis of variance (ANOVA) parameters on tool life was determined to get the level of importance of the machining. By using the analysis of signal-to-noise (S/N) ratio, the optimum machining parameters combination was obtained. The relationship between cutting parameters and tool life was obtained. Their experimental results shown that, the spindle speed had the most significant effects on tool life followed by feed rate and the depth of cut.

C. J. Rao, et al, [1] optimized the process parameters which are significant in improving the process efficiency of cutting tool to determine the optimal process parameters used to predict cutting forces, tool life and surface finish. For this work empirical relations are used and modified. In this work aluminum work material is taken and tungsten carbide as tool material is selected. During experimentation various cutting parameters like depth of cut, speed and feed are considered. For the different conditions such as tool life, surface finish and cutting force parameters were calculated. The results showed that as the cutting force, MRR and cutting speed increases, the tool life decreases. The MATLAB results are used to show the best surface finish output and the optimum process parameters with better life.

Pankaj Kumar Sahu, et al, [4] did different experiments for economical and efficient machining on aluminum material. For that different parameters like spindle speed, feed and depth of cut have been investigated. Experimentation conducted by varying one parameter and keeping other two fixed to obtain maximum value of each parameter. Taguchi method is used for optimization of various machining parameters to reduce the number of experiments. The main effects have been calculated while operating range is found by experimenting with top spindle speed and taking the lower levels of feed and depth of cut. The relation between changes in hardness caused on the material surface due the turning operation is also investigated. Also the percentage contribution of various process parameters affecting hardness also determined.

K.C. Sharma and Krishna Agrawal [3] investigated the use of Taguchi parameters and used ANOVA to design and optimize the surface roughness and tool tip temperature in turning operations. For that single point carbide Cutting Tool is used. They developed empirical model for surface roughness and metal removal rate on aluminum turning by conducting experiments by means of non-linear regression with logarithmic data transformation. Their study shows that the Taguchi method and ANOVA analysis are suitable for optimizing the tool geometry under given cutting parameters with the minimum number of trials. To optimize the surface roughness prediction at maximum MMR, the programming is done under the selected machining conditions.

Ramakant Rana, et all [5] reviewed the work on the requirements for optimization of Tool wear so that its life could easily be predicted and optimized. Their prediction from the review work to optimize the turning process parameters like depth of cut, speed, feed, nose radius, material and type of tool, and even work piece material etc using Taguchi method for maximizing the tool life and minimizing the surface roughness by experimental setup. They concluded that Taguchi technique will help to finalize the number of levels with orthogonal array and thus finalizing the number of experiments. They also stated that the signal to noise ratio will help to optimize the behavior of quality characteristics of work piece.

Devanand R. Tayade and Dheeraj S. Deshmukh [2] used the particle swarm optimization technique to optimize cutting and geometric parameter like cutting speed, feed, depth of cut and rake angle. The objective was to study and predict the tool wear evolution and tool life in orthogonal cutting. For better experimental results of the optimum designed tool, the regression technique is used for generation of mathematical model. They developed relational model by using Buckingham's π-theorem.

III. EXPERIMENTAL PROCEDURE:

A CNC turning machine with a spindle speed range from 800 to 1200 rpm used for the experimentation. The machining center was driven by an electric motor of 5 kW rating. The experiment was conducted in a controlled environment i.e., dry machining. Tool life was determined by using an empirical relation. Total length of effective cut was divided by the product of feed rate and spindle speed. The data from experimentation was collected for each workpiece material using separately HSS and Tungsten carbide tool. The cutting parameters and their combinations are shown in Table 1.

Table3. 1. Cutting parameters and their combinations

Sr. No.	Cutting Parameter	Combination of Cutting Parameter		
1	Spindle Speed (*N, rpm*)	1200	1000	800
2	Feed Rate (*f, mm/rev*)	0.3	0.2	0.1
3	Depth of Cut (*d, mm*)	1.0	0.75	0.5

The feed rate f in mm can be calculated from

$$f = (24.5 \text{ x } f_{IN})/1000 \qquad (3)$$

Where, f_{IN} = Feed rate in inch per revolution.

The tool life is estimated from

$$RPM \text{ x } f = mmPM \qquad (4)$$

$$T = L \text{ x } 60/mmPM \qquad (5)$$

Where, RPM = Revolution per minute, $mmPM$ = mm per minute, L = Length of effective cut, T is Tool life in second [6].

IV. RESULTS AND DISCUSSION

After several experimentations the tool life values for mild steel material are recorded. The tool materials were HSS and Tungsten Carbide. Table 2 shows Tool life obtained against various Cutting parameters and their combinations. Graphs are also obtained during experimentation.

Table 4.1. Tool life obtained against various cutting parameters and their combinations

Sr. No.	Tool Material Type	Cutting Parameters			Tool Life for Work Piece Material (seconds)	Observations / Remark
		Cutting Speed (rev/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Mild Steel	
1	HSS	1200	0.3	1	76	Shortest Tool Life
2	Tungsten Carbide				203	
3	HSS	1000	0.2	0.75	183	Intermediate Tool Life
4	Tungsten Carbide				429	
5	HSS	800	0.1	0.5	340	Longest Tool Life
6	Tungsten Carbide				758	

Case-I: Effect of Spindle Speed on Tool Life when feed rate constant:

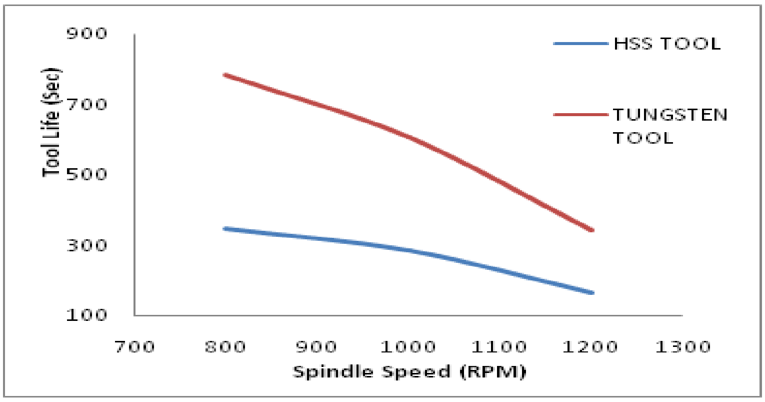

Fig.4. 1. Tool life vs. spindle speed keeping feed rate of 0.1 mm/rev constant

From figure 1, As the spindle speed increased from 800 to 1200 rev/min, HSS tool life seems to be reduced from 348 s to 164 s i.e., 53 % reduction at constant feed 0.1 mm/rev. Also for same parameters and tungsten carbide tool, the tool life seems to be reduced from 783 s to 344 s i.e., by 56 % . From Figure1, it can be observed that longer tool life can be obtained with a combination of spindle speed 800 rpm and feed 0.1 mm/rev.

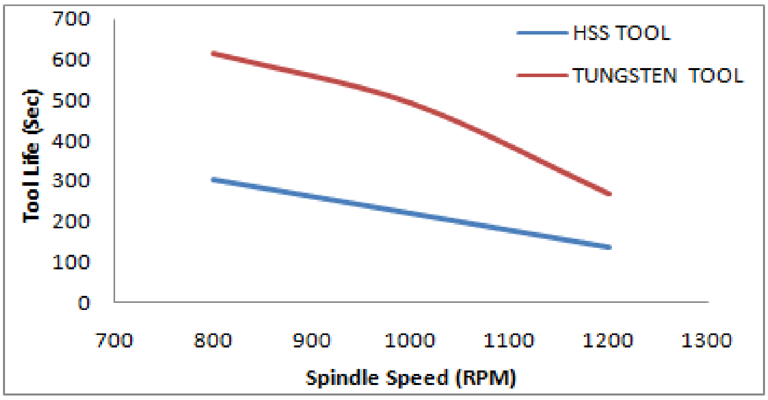

Fig. 4.2 Tool life vs. spindle speed keeping feed rate of 0.2 mm/rev constant**.**

Similarly, at constant feed rate of 0.2 and 0.3 mm/rev, the decreasing tool life is observed when speed increases from 800 to 1200 rev/min. These results are agreed with S. J. Ojolo et al [6]. Their work shows that the life of cutting tools is better when the machining parameters are low. When feed rate was 0.3 mm/rev, the HSS tool life decreased rapidly from 256 to 81 seconds as the spindle speed increased. Same kinds of trends and results are observed when tungsten carbide tool is used. As the feed rate and other cutting parameters are increasing, the tool life decreases.

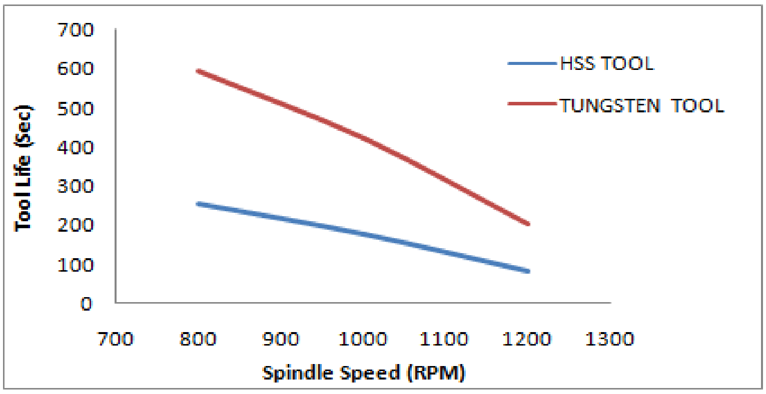

Fig. 4.3. Tool life vs. spindle speed keeping feed rate of 0.3 mm/rev constant.

Case-II: Effect of Feed Rate on Tool Life when Spindle Speed constant:

From figure 4, As the feed rate increased from 0.1 to 0.3 mm/rev, HSS tool life observed to be reduced from 341 s to 247 s i.e., 28 % reduction at constant spindle speed of 800 rpm. Also tungsten carbide tool life seems to be reduced from 752 s to 560 s i.e., 25 % reduction at constant spindle speed of 800 rpm. From Figure 4, it can be observed that longer tool life can be obtained with a combination of spindle speed 800 rpm and feed rate 0.1 mm/rev.

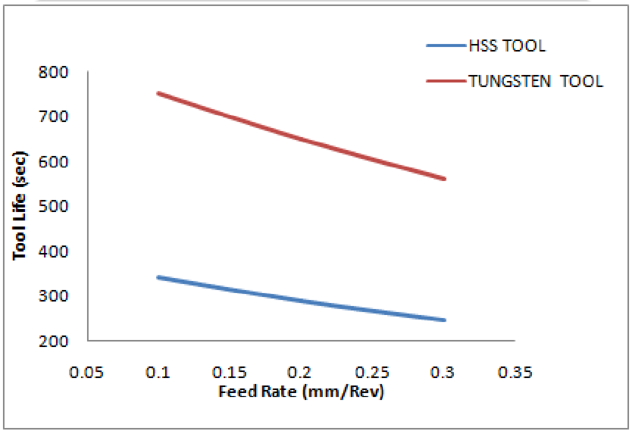

Fig. 4.4 Tool life vs. feed rate keeping spindle speed at 800 *rpm* constant.

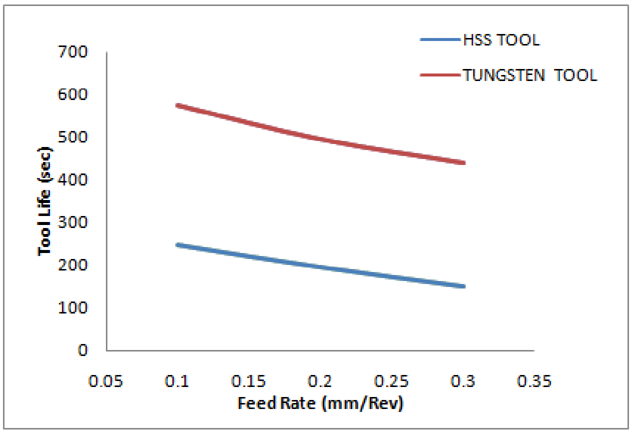

Fig. 4.5. Tool life vs. feed rate keeping spindle speed of 1000 rpm constant.

Similarly by observing the figures 5 and 6, at constant spindle speed of 1000 and 1200 rpm, the decreasing tool life is observed when feed rate increases from 0.1 to 0.3 mm/rev. These results are also agreed with S. J. Ojolo et al [6]. When feed rate was 0.3 mm/rev, the tungsten carbide tool life decreased rapidly from 344 to 206 seconds i.e., by 40% as the spindle speed increased. Same kinds of trends are observed when HSS tool is used. Increase in spindle speed and other cutting parameters resulted in decreased tool life.

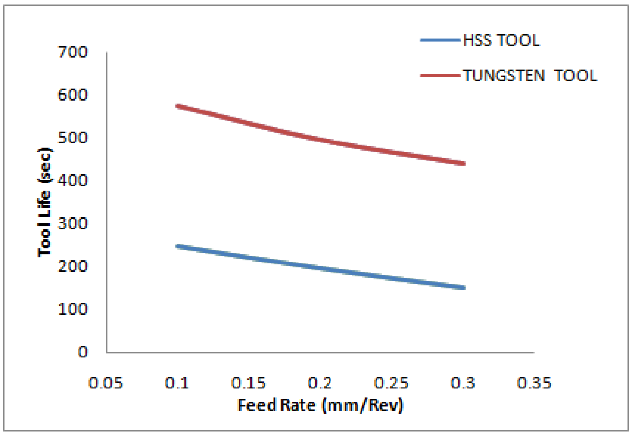

Fig.4.6. Tool life vs. feed rate keeping spindle speed of 1200 rpm constant.

Case-III: Effect of Increase in Depth of Cut on Tool Life when Spindle Speed remains constant:

From figure 7, As the depth of cut of cutting tool increases from 0.5 to 0.1 mm, HSS tool life resulted in reducing side from 340 to 244 seconds i.e., 28 % reduction at constant spindle speed of 800 rpm. Also the tungsten carbide tool life seems to be reduced from 758 to 579 seconds i.e., by 24 % at constant spindle speed of 800 rpm. From Figure 7, it can be observed that longer tool life can be obtained with a combination of spindle speed 800 rpm and depth of cut 0.5 mm.

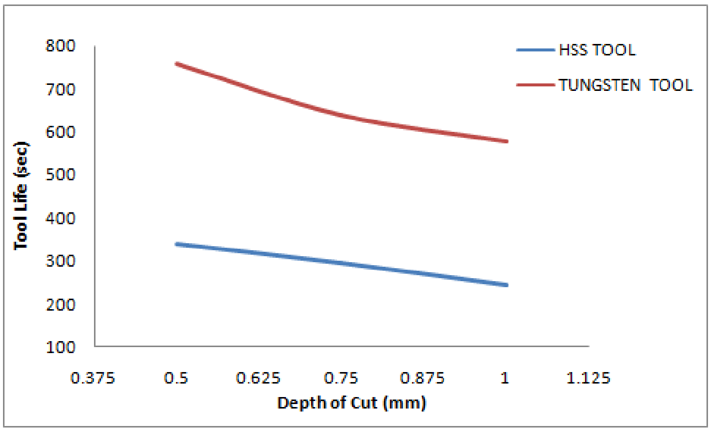

Fig. 4.7 Tool life vs. depth of cut keeping spindle speed of 800 rpm constant.

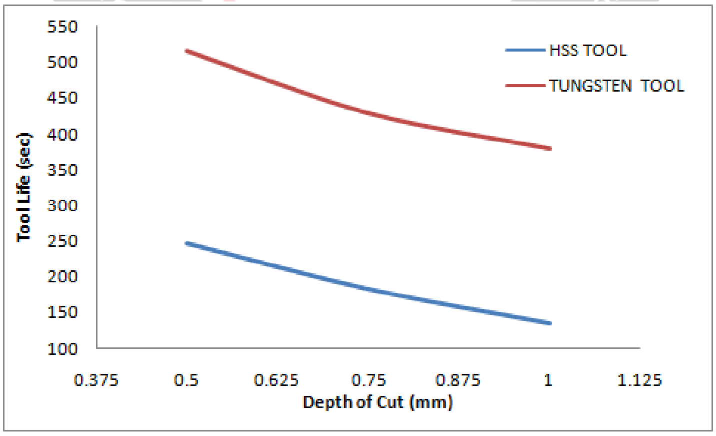

Fig. 4.8. Tool life vs. depth of cut keeping spindle speed of 1000 rpm constant.

Similarly by observing the figures 8 and 9, at constant spindle speed of 1000 and 1200 rpm, the decreasing tool life is observed when depth of cut of cutting tool is increases from 0.5 to 1.0 mm. These results are also agreed with S. J. Ojolo et al [6]. When depth of cut was 1 mm, the tungsten carbide tool life decreased rapidly from 340 to 203 seconds i.e., by 40% as the spindle speed increased. Same kinds of trends are observed when HSS tool is used. The tool life if HSS tool life decreased from 142 to 76 seconds i.e., by 54%. Increase in depth of cut of cutting tool and other cutting parameters resulted in decreased tool life.

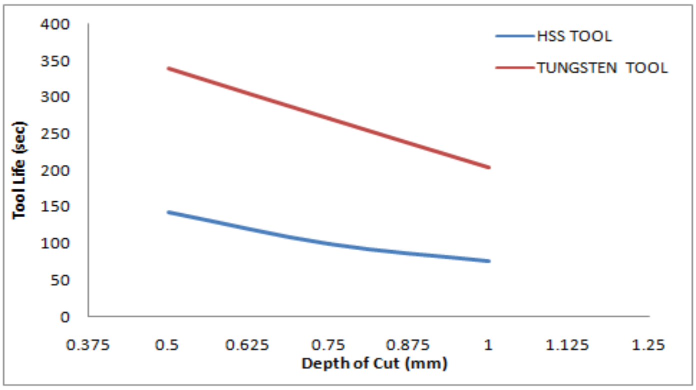

Fig. 4.9. Tool life vs. depth of cut keeping spindle speed of 1200 rpm constant.

V. CONCLUSION:

In this work mild steel is taken as a workpiece material and HSS and Tungsten Carbide as tool material. By using different machining parameters like spindle speed, depth of cut of machining and feed rate at controlled conditions the tool life, were observed. The results showed that the increase in spindle speed, feed rate or depth of cut, affects the tool life i.e., reduces tool life. The better results for tool life in HSS or tungsten carbide tool were obtained with 800rpm spindle speed, 0.1 mm/rev feed rate and 0.5 mm depth of cut. The lowest tool life was observed with 1200rpm spindle speed, 0.3 mm/rev feed rate and 1.0 mm depth of cut.

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