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Prediction of Tool Life of a Single Point Cutting Tool under Different Metallic Coatings

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Abstract: Machining tools often are subjected to varied types of machining forces which in turn produce many stresses. All such collectively effect various parameters like the tool life, deformation, Material Removal Rate, Surface finish etc. Coating of the workpiece making a composite material that exhibits properties usually, which cannot be achieved by either material if used alone. This project is aimed at enhancing the surface properties of the tool through coating combinations of Titanium Nitride and Titanium Aluminum Nitride using Physical vapor Deposition (PVD) technique. The tool's performance is verified using Taylor's Tool Life Equation under identical working conditions. The tool life is estimated using facing test and the best combination is determined

Index Terms: Tool Life, Physical Vapor Deposition, Taylors Tool Life Equation

I. INTRODUCTION

Machining is a multifarious concept and is driven by many factors. Tool Life heavily depends upon the material of the tool bit. Physical and chemical properties of the tool material greatly effect tool wear, Material Removal Rate, Chip Formation, Wear and tear of the tool. Efficiency of the cutting process also depends on tool material. Generally, tools are manufactured using different materials like Carbides, Tungsten, Tungsten Carbide, High Speed Steels, Ceramics and Diamonds. Every tooling material has its own specifications and advantages. technological lines can be examined, and their performance can be optimized. Some of the common coatings that are used on cutting tools are Titanium Nitride (TiN), Titanium Caro-Nitride (TiCN) Titanium Aluminium Nitride (TiALN or ALTiN) 4.Chromium Nitride (CrN), Diamond. Every coating has its own advantages and limitations. The best coating is determined based on experimentation and the specified applications like the choice of the tool geometry which involves the conditions where the tool geometry includes cutting speed, feed depth of cut etc.

II. PROBLEM STATEMENT

A. What is tool life?

Tool life is an important factor for machining tools. Tool life is the time period during which the tool remains operational. It is the time between the working of the tool and regrinding of the tool to obtain cutting edges. Generally, tool life is expressed in time, volume of material removed, number of components produced.

B. What is Physical Vapor Deposition (PVD)?

Physical Vapor deposition is commonly used coating technique to improve the tool life of tools that work at very high cutting speeds. They are specialized for Micro level and Nano level coatings. In PVD process the coating material is heated to very high temperatures to convert it into vapor phase and then condensed back as a thin film on the coating surface. The critical advantage of using PVD is it enhances the properties that involves the modification at molecular level. The PVD coatings are done in 2 ways sputtering and evaporation.

III. MAKING UP OF THE TOOL BIT

This project contains four identical tool bits. Two are coated with TiAlN as the base and TiN as the top layer (referred as TiN Tool). The remaining two tools are coated with TiN as the base coating and TiAlN as the top layer coating (referred as TiAlN tool). The coating thicknesses are 0.9 µm. The tool bits are designed as per American Association Standards as follows:

- Back Range Angle 0°
- Side Rake Angle 5°
- Back Clearance Angle 6°
- Side Clearance Angle 6°
- End Cutting Edge Angle 10°
- Side Cutting Edge Angle 30°
- Nose Radius 1/12

IV. LITERATURE SURVEY

Review on Single Point Cutting Tool

In this paper the interface and tool geometry of a Single Point Cutting Tool is studied. The authors presented the basic nomenclature of the Tool which helped us to understand them. Moreover,

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this paper also presents the effect of cutting forces on the interface of the tool. The difference between Signatures of American Standards Association (ASA) and Orthogonal Reflection System (ORS) is depicted in the paper.

Experimental and Numerical Investigation of Tool Life of Single Point Cutting Tool during Turning Process.

In this paper the pattern of temperature distribution on the surface of the single point cutting is studied and analyzed under different working parameters. Chip removal of Mild Steel using a High-Speed Steel Tool Bit is the machining setup. In order to make this study some working parameters were taken into consideration. This study was performed both numerically and experimentally. Theoretically 3-Dimensional steady state heat equation is used to study the temperature distribution. Results conclude that any change in Feed Rate and cutting speed enormously effects cutting temperature and depth of cut. This paper helped us to analyses different working parameters that are affected and that can be studied during machining process. Some of the parameters like Feed Rate, Depth of cut are considered in our Project. We understood how machining parameters effect tool life.

Tool life prediction using Bayesian probability and turning tool life

In this paper the authors present the concept of including cutting speed and feed parameters in calculation of Taylor’s Tool Life Equation i.e., updating of existing equation to accommodate these two. An uncoated carbide is taken as a Single Point Cutting Tool. The additionally considered parameters are denoted with p and q. Tests are conducted to determine the constants and later Bayesian Probability density function is applied to determine or analyze the tool life. Unlike the previous method which assumes cutting speeds and feed parameters as constants this probability function facilitates its variation. But with amenities available in an around it becomes very obsolete and complex to accommodate their variation. Moreover, in cases of lesser variations in those conventional Taylor’s Tool Life Equation is found to give better estimations.

Evaluation of high temperature characteristics and Tool Life of High Carbon and High Chromium Steel as a Single Point Cutting Tool

In this paper the authors took an alloy of High Carbon and High Chromium Steel as the material of Single Point Cutting Tool and subjected it machining. The effect of temperature or its characteristics are analyzed, and Tools Life is calculated using Taylor’s Tool Life Equation. Thus, obtained results like hardness and tool cutting velocities of the above tool is compared with High Speed Steels. The authors concluded that High Carbon High Chromium tool performs better than High Speed Steel when it is forged, and heat treated.

This paper helped us in understanding the procedure for calculation Taylor’s Tool Life. Working with Taylor’s Tool Life Equation an ambiguity comes during the calculation of constant C. Detailed and clear systematic procedure was adopted in our Project.

V. TAYLOR’S TOOL LIFE EQUATION

Taylor’s tool life equation is very commonly used for the tool life that is expressed as:

$$\mathrm{v}T^n = C$$

V= cutting speed(m/min)
T= tool life (min)
n= Constant depends upon the tool material
C= constant depends upon the tool material, workpiece material, cutting conditions

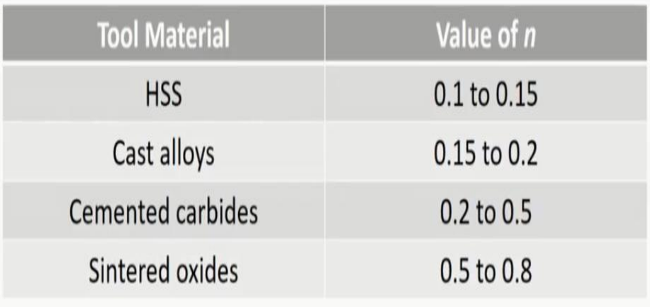
To obtain the values of **C** and **n** various experiments are been conducted at suitable feed and depth of cuts. Tool life values for a critical wear land are plotted on logarithmic co-ordinates to obtain the values of **n** and **C** graphically.

The exponent **n** can be evaluated from the relationship

$$n = \frac{\log\left(\frac{V_b}{V_a}\right)}{\log\left(\frac{T_a}{T_b}\right)}$$

Where

- V_a and V_b are any two cutting speeds
- T_a and T_b are the tool life corresponding to the cutting speeds.



Tool Material	Value of *n*
HSS	0.1 to 0.15
Cast alloys	0.15 to 0.2
Cemented carbides	0.2 to 0.5
Sintered oxides	0.5 to 0.8

Table1*:* Experimental n values for commonly used materials

VI. FACING TEST

The facing test is carried out using a lathe machine which can run at varying speeds and done by following these steps:

- The tool is fixed in the three-chuck lathe machine for facing operation. The tool transverse rapidly along the diameter at constant cutting speed.
- As the lathe spindle operates at two different speeds 400rpm and 88rpm the value of n in the equation can be calculated.
- A timer must be switched on to measure the machining time.

- Check for the wear land for every 30min duration continue facing till a wear land of 0.3mm is obtained and stop the timer.
- If the Taylor’s tool life equation is assumed to be in range of cutting speeds covered while the tool travels from, the wear land $_{lw1}$ at any time $T_{1.}$
- The Tool Life of the material is obtained by the criteria of a wear land of 0.3mm crater wear.
- The carter wear is measured under the compound microscope with the help of micrometer.
- 10divinsions on the micrometer equals to 0.1mm.
- The same procedure is repeated for other spindle speeds and tool bits.

Microscopic structures of crater wear formed after machining viewed from a Compound Microscope:

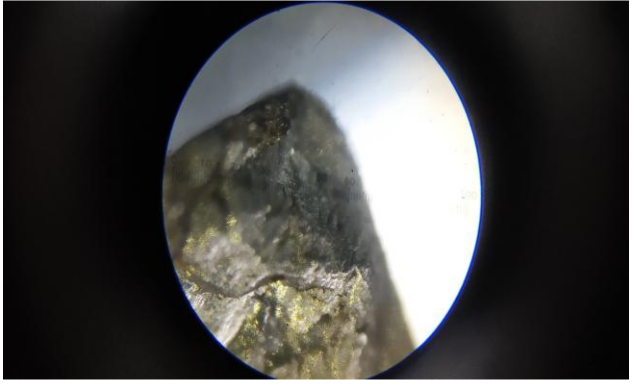


Fig 1: TiN tool at 80 R.P.M

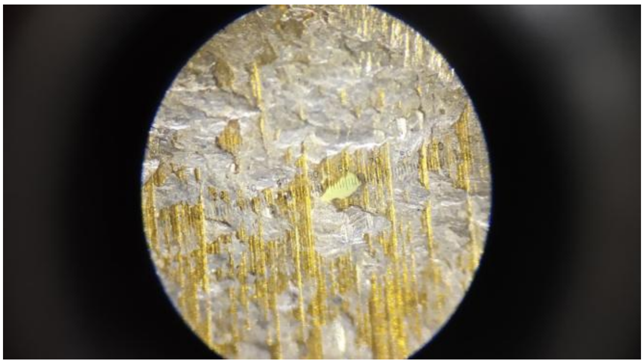


Fig 2: TiN Tool at 400 R.P.M

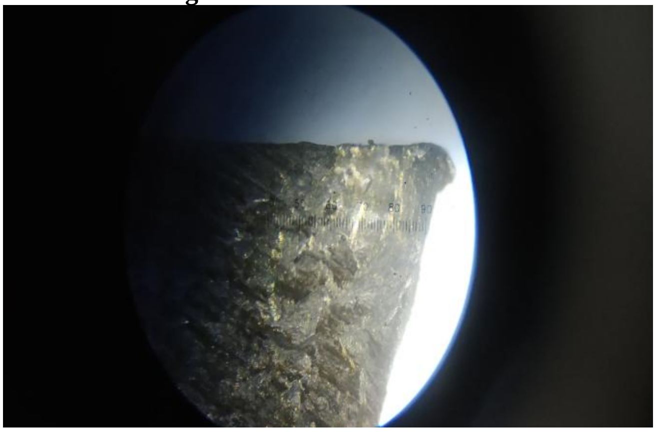


Fig 3: TiAlN tool at 400 R.P.M

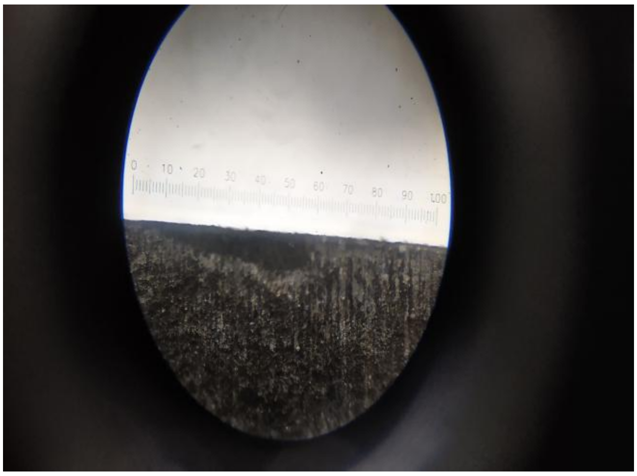


Fig 4: **TiAlN tool at 80 R.P.M**

VII. TOOL LIFE CALCULATION

For TiN Tool:

Tool Life for Specimens 1 and 2 at different speeds are given below:
@70min at 440.3m/min
@110min at 88.06m/min

For calculating the n value plot the graph between Tool life (min) vs Cutting speed(m/min)

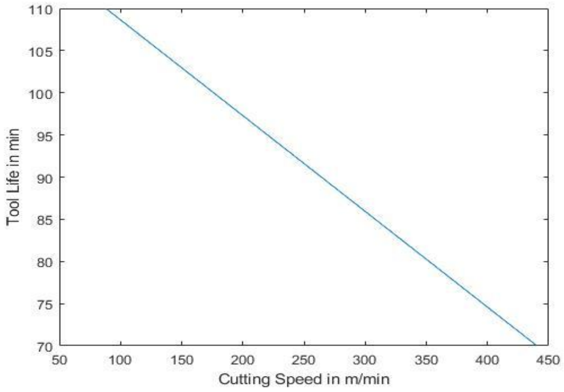


Fig 5: Graph plotted for TiN tool

Find the slope of the line to get the value of ‘n’

A= (440.3,70), B= (88.06,110)

Find the slope of AB by the formula given below.

$$\mathbf{n}=\frac{y_1-y_2}{x_2-x_2}$$

$$n=\frac{440.3-88.06}{110-70}$$

n value for TIN=0.113

C is calculated for

one-minute tool life so by

substituting T=1min in the Taylor's equation we get

$$VT^n = C$$

$$400(1)^{0.113} = C$$

C=400m/min

The **'n' and 'C'** values for **TiN tool** is 0.113 and 400m/min respectively.
It is determined that if 440.3m/min and 88.06m/min are the cutting speeds then the tool lifes are 70 and 110min respectively.

For TiAlN Tool:
Tool Life for Specimens 3 and 4 at different speeds are given below:
@335min at 440.3m/min
@670min at 88.06m/min

For calculating the n value plot the graph between Tool life (min) vs Cutting speed(m/min)

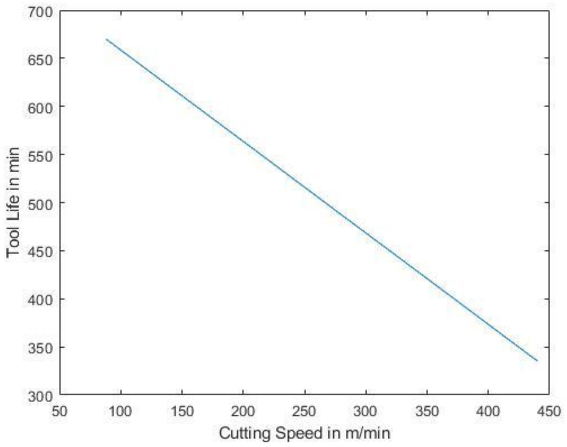


Fig 6: Graph plotted for TiAlN Tool

Find the slope of the line we get the value of 'n'

A= (440.3,335), B= (88.06,670)

Find the slope of AB by the formula given below.

$$n=\frac{y_1-y_2}{x_2-x_2}$$

$$n=\frac{440.3-88.06}{670-335}$$

n value for =0.95

C is calculated for one-minute tool life so by substituting

T=1min in the Taylor's equation we get

$$VT^n = C$$

$$400(1)^{0.95} = C$$

C=400m/min

The **'n' and 'C'** values of the **HSS** coated with **TiAlN** is 0.95 and 400m/min respectively**.**

It is determined that if 440.3m/min and 88.06m/min are the cutting speeds the tool lifes are 335 and 670min respectively.

VIII. CONCLUSIONS

Tool bits coated with Aluminum Titanium Nitride (TiAlN) obtained the highest tool life which is 4.7 times that of TiN tool bit. This is because of the enhanced of the properties that the TiAlN added to the tool. The following reasons are responsible so:

- TiN has low thermal resistance, so the chips got welded on the surface of the thus causing built up surfaces on the cutting edges.
- TiAlN has an oxide layer formed at high temperatures that prevents the chips from getting stuck on the surface.
- TiAlN has a high thermal resistance of around 800°C adding a base layer of TiN enhanced the properties more than a single coating would do.
- In TiN tool even though the base material was TiAlN it couldn't be of much interplay because of the welding of chip layer on the top of the surface.

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