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Calculation 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 affect various parameters like the tool life, deformation, Material Removal Rate, Surface finish, etc. The workpiece's coating makes a composite material that exhibits properties that cannot be achieved by either material. This Project aims to enhance the tool's surface properties through coating combinations of Titanium Nitride and Titanium Aluminium Nitride using the 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 the facing test, and the best combination is determined.

Keywords - *Tool Life, Physical Vapor Deposition, Taylors Tool Life Equation*

I. INTRODUCTION

Machining is a different 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 much effect tool wear, Material Removal Rate, Chip Formation, Wear and tear of the tool. The 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 specifications and advantages. Technological lines can be improved, and their performance can be optimized. Some of the conventional coatings that are used on cutting tools are Titanium Nitride (TiN), Titanium Cabro-Nitride (TiCN), Titanium Aluminium Nitride (TiAlN or ALTiN), Chromium Nitride (CrN), Diamond. Every coating has its advantages and limitations. The best coating is determined based on experimentation and the specified applications like the tool geometry, cutting speed, feed depth of cut, etc.

II. PROBLEM STATEMENT

A. *What is tool life?*

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

B. *What is Physical Vapor Deposition (PVD)?*

Physical Vapor deposition is a commonly used coating technology to improve the tool life of tools that operate at very high cutting speeds. This is specialized for Micro-level and Nano level coatings. The coating material is heated to very high temperatures in the PVD process to convert it into the vapor phase and then condensed back as a thin film deposited on the coating surface. The critical advantage of using PVD is it enhances the properties at the 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 to as TiN Tool). The remaining two tools are coated with TiN as the base and TiAlN as the top layer coating (referred to as the TiAlN tool).
The coating thicknesses are 0.9 µm. The tool bits are designed according to the American Association Standards:

- 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 REVIEW

A. Review on Single Point Cutting Tool

In this paper, the tool geometry of a Single Point Cutting Tool is studied. The authors presented the fundamental nomenclature of the tool, which helped us to understand them. Moreover, this paper also presents the effect of cutting forces on the interface of the tool. The difference between the American Standards Association (ASA) Signatures and the Orthogonal Reflection System (ORS) is depicted in the paper.

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

In this paper, the temperature distribution pattern on the single point cutting surface is studied and analyzed under different working parameters. Chip removal of Mild Steel using a High-Speed Steel Tool Bit is the study comparison. Some working parameters are taken into consideration. This study is analyzed both numerically and experimentally. The 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 affects cutting temperature and depth of cut. This paper helped us to analyses different working parameters that affect the machining process. Some of the parameters like Feed Rate, Depth of cut are considered in our Project. We understood how the machining parameters affect tool life.

C. Tool life prediction using Bayesian probability and turning tool life

In this paper, the authors presented the concept of including cutting speed and feed parameters in the calculation of Taylor's Tool Life Equation, i.e., updating the existing equation to accommodate these two. An uncoated carbide is taken as a Single Point Cutting Tool. The additional parameters considered 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 feeds parameters as constants, this probability function facilitates variables. But with amenities available in and around, it becomes very obsolete and complex to accommodate their variation. Moreover, in lesser variations, Taylor's Tool Life Equation is found to give better estimations.

D. 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 Single Point Cutting Tool material and subjected it to machining. The effect of temperature is analyzed, and Tool Life is calculated using Taylor's Tool Life Equation. The results like hardness and tool cutting velocities of the above tool are compared with High-Speed Steels. The authors concluded that the 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, and ambiguity comes during constants C and n. A similar 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:

$$VT^n = C$$

V= cutting speed(m/min)

T= tool life (min)

n= Constant (varies with the tool material)

C=constant (varies with tool material, workpiece material, cutting conditions.

To obtain the values of **C** and **n,** various experiments are conducted at suitable feed and depth of cuts. Tool life values for a critical wear land are plotted on logarithmic coordinates 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

Fig 1: Experiment 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 Taylor's tool life equation is assumed to be in the range of cutting speeds covered while the tool travels from, the wear land lw1 at any time T1.
- 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 a micrometer.
- 10 divisions on the micrometer equal to 0.1mm.
- The same procedure is repeated for other tools at different spindle speeds.

Microscopic Structures of crater wear formed after machining when looked from a compound microscope:
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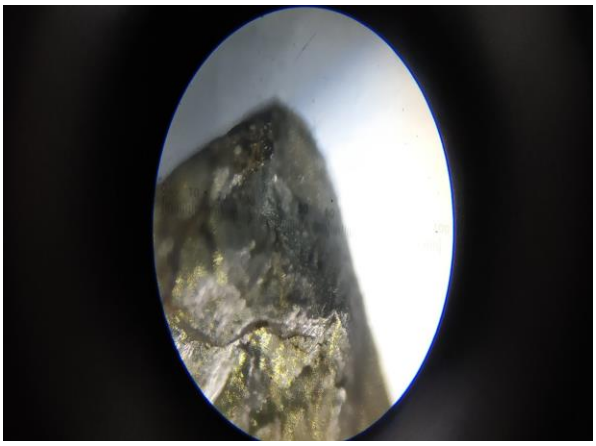

Fig 2: TiN at 80 RPM

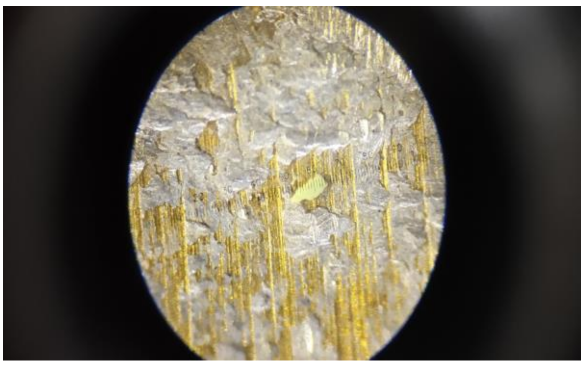

Fig 3: TiN at 400 RPM

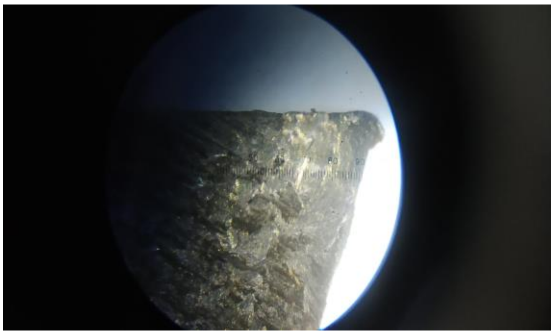

Fig 4: TiAlN at 80 RPM

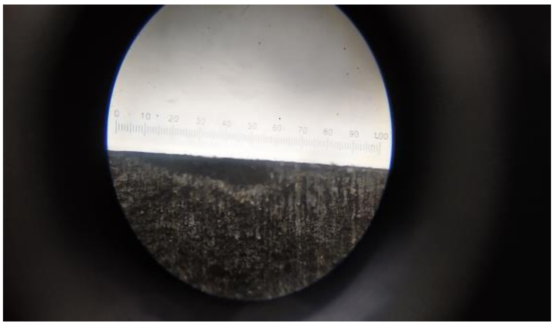

Fig 5: TiAlN at 400 RPM

VII. TOOL LIFE CALCULATION

For TiN Tool Bit:

Tool Life for TiN 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)

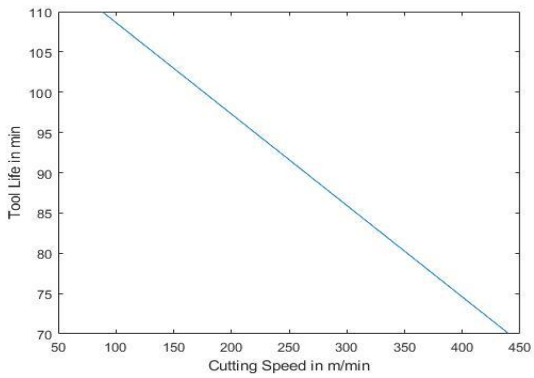

Fig 6: Cutting Speed vs. Tool Life

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.

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

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

n value for TiN=0.113

C is calculated for one-minute tool life, so by substituting T=1min in Taylor's equation, we get

$$VT^n = C$$

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

C=400m/min

The **'n' and 'C'** values for the **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 lives are 70 and 110min, respectively.

For TiAlN Tool Bit:

Tool Life for TiAlN Tool Bits 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)

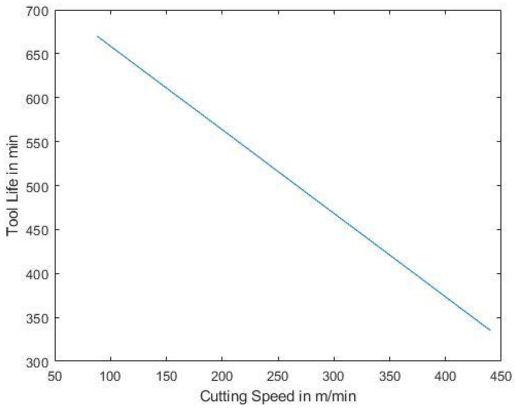

Fig 7: Cutting Speed vs. Tool for TiAlN

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 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 lives are 335 and 670min, respectively.

VIII. CONCLUSIONS

Tool bits coated with Aluminium Titanium Nitride (TiAlN) obtained the highest tool life, which is 4.7 times that of the 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, thus causing built-up surfaces on the cutting edges.
- TiAlN has an oxide layer formed at high temperatures that prevent 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 the TiN tool, even though the base material was TiAlN, it couldn't be of much interplay because of the chip layer's welding on the top of the surface.

REFERENCES

[1] *"Effect of cutting parameters on the degree of work hardening and tool life during high-speed machining of Inconel 718,"* pp. 483–489, 2012.
[2] "*Tool Wear Assessment During Machining of Inconel 718*," Procedia, 2017.
[3] "*Structure, properties, and wear performance of Nano multi-layered TiAlCrSiYN/TiAlCrN coatings during machining of Ni-based aerospace superalloys*," Surf. Coatings Technol., vol. 204, no. 21–22, pp. 3698–3706, 2010.
[4] M.Dhanenthiran, "*An Investigation of the Effect of Process Parameters in Turning Operation on Cast Iron*" SSRG International Journal of Mechanical Engineering 3.2 (2016): 6-9.
[5] *NPTEL Lecture on Tool Life* https://www.youtube.com/watch?v=-R-fySRLa9Q.
[6] *NPTEL Lecture on Taylor's Tool Life Equation* https://www.youtube.com/watch?v=kISJkcSAjEI
[7] *Tool Life and Equation* https://www.youtube.com/watch?v=8CV3K6k-g-&feature=youtu.be
[8] J.L.Endrino, G. S. Fox-Rabinovich, and C. Gey, "*Hard AlTiN, AlCrN PVD coatings for machining of austenitic stainless steel*," Surf. Coatings Technol., vol. 200, no. 24, pp. 6840–6845, 2006.
[9] B.Wang, Z. Liu, Q. Yang, "*Investigations of yield stress, fracture toughness, and energy distribution in high-speed orthogonal cutting,"* Int. J. Mach. Tool. Manuf. 73 (2013) 1–8.
[10] R.S.Pawade, S.S. Joshi, P.K. Brahmankar, "*Effect of machining parameters and cutting edge geometry on surface integrity of high-speed turned Inconel 718"*, Int. J.Mach. Tool. Manuf. 48 (2008) 15–28.

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