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Tool Wear Detection of Cutting Tool Using Matlab Software

S.P. Patil, D. M. Tilekar

Abstract— **Tool wear in machining processes is directly related to the quality of machined surfaces. Tool wear needs to be measured in order to evaluate if the tool reaches its design life and should be replaced. The present work focuses on measurement of tool wear through image processing. It facilitates for capturing images of tool in a fixed plane. Images of tool have been captured before and after machining by digital camera setup. These images are processed using MATLAB and tool wear has been evaluated. In the present work, Design of Experiment (DOE) with Taguchi L9 Orthogonal Array (OA) has been explored to produce 9 conditions for turning operation and studied the performance of multilayer coated (Al_2O_3+TiC+TiN+AlCrN) ceramic tool in machining of hardened AISI 4340 steel (46 HRC) under dry machining and compared with that of uncoated ceramic tool on CNC machine. Flank wear was measured using gray scale analysis of that image. The cutting variables were cutting speed (125-175 m/min), depth of cut (0.25-0.63 mm) and feed rate (0.10-0.25 mm/rev).The highest tool wear for multilayer coated and uncoated ceramic tools were 0.364 and 0.639 mm respectively which associate to cutting speed of 175 m/min and depth of cut of 0.63 mm. This imaging method is more useful to measure the tool wear economically.**

Index Terms **– Tool Wear, MATLAB, Grayscale, Orthogonal Array,Multilayer Coating**

I. INTRODUCTION

Many authors used machine vision as a system for studying tool wear. Kurada et al. [1] designed a machine vision system that can measure flank wear. They were using image threshold to bring out wear area.

Kerr et al. [2] used a monochrome CCD camera to capture images from the tool nose.Methods included edge operators, texture information, histogram analysis, Fourier transform and fractal properties of the image were tested to compare their results in extracting the wear information from the tool. Texture information was found to be the most useful and accurate in measuring the extent of the wear. However, the system was not implemented to be used in-cycle, since the tool had to be removed from the tool holder.

T. Selvaraj et al. [3] designed an image processing tool to determine the amount of wear accumulated on single point cutting tool after successive machining operations. The tool wear was estimated by comparing the gray scales of the images. The processing and analysis of the acquired image had been done using the MATLAB software.

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S.P. Patil, Mechanical Engg. Department, University of Pune, Dr. D.Y. Patil College Of Engg.,Ambi,Pune, India.

D. M. Tilekar, Mechanical Engg. Department, University of Pune, Dr. D.Y. Patil College Of Engg.,Ambi,Pune, India

The aim of this paper is to investigate the performance of multilayer (Al_2O_3+TiC+TiN+AlCrN) coated and uncoated ceramic cutting tool under dry machining of hardened AISI 4340 (46 HRC) under various cutting conditions in terms of tool wear. To achieve this goal, turning tests were conducted with a CNC machine using commercially available ceramic cutting inserts with different cutting conditions. Tool wear of cutting tool will examine by using imaging method.

Tool wear:

The wear is the surface damage or removal of material from one or both solid surfaces as a result of relative motion to one another. Wear can be mainly classified into three groups:
• One term is the appearance of scar: e.g. pitted, spilled, scratched, polished, crazed, gouged and scuffed;
• The second way is in terms of physical mechanisms which remove the material or cause the damage, e.g. adhesion, abrasion, fatigue and oxidation;
• And the third is the conditions surrounding the wear situations, e.g. lubricated wear, unlubricated wear, metal-to-metal sliding wear, rolling wear, high stress sliding wear and high temperature metallic wear.

Wear is a dynamic and complex process which incorporates surface and material properties, operating conditions, stresses, lubricant oil film and geometry. Wear, as friction, is not a material property, but a system response. Operating conditions affect interface wear. Due to complexity of a wear process, monitoring of wear is not an easy task. Different approaches and different measures have been used to determine amounts of wear, both qualitatively and quantitatively.

The life of a cutting tool can be terminated by a number of means, although they fall broadly into two main categories:

1. Gradual wearing of certain regions of the face and flank of the cutting tool
2. Abrupt tool failure

Considering the more desirable

1. The life of a cutting tool is therefore determined by the amount of wear that has occurred on the tool profile and which reduces the efficiency of cutting to an unacceptable level, or eventually causes tool failure.
2. When the tool wear reaches an initially accepted amount, there are two options,
   i. To resharpen the tool on a tool grinder, or
   ii. To replace the tool with a new one. [4]

Wear zones:

Flank wear and crater wear are the most important measured forms of tool wear. Flank wear is most commonly used for wear monitoring. According standard ISO 3685:1993 for wear measurements, the major cutting edge is considered to be divided in to four regions, as shown in Figure:

- Region C is the curved part of the cutting edge at the tool corner;
- Region B is the remaining straight part of the cutting edge in zone C;
- Region A is the quarter of the worn cutting edge length b farthest away from the tool corner;
- Region N extends beyond the area of mutual contact between the tool workpiece for approximately 1-2 mm along the major cutting edge. The wear is notch type.

The width of the flank wear, VBB is measured within zone B in the cutting edge plane PS (Figure) perpendicular to the major cutting edge. The width of the flank wear land is measured from the position of the original major cutting edge. The crater depth, KT, is measured as the maximum distance between the crater bottom and the original face in region B. [4]

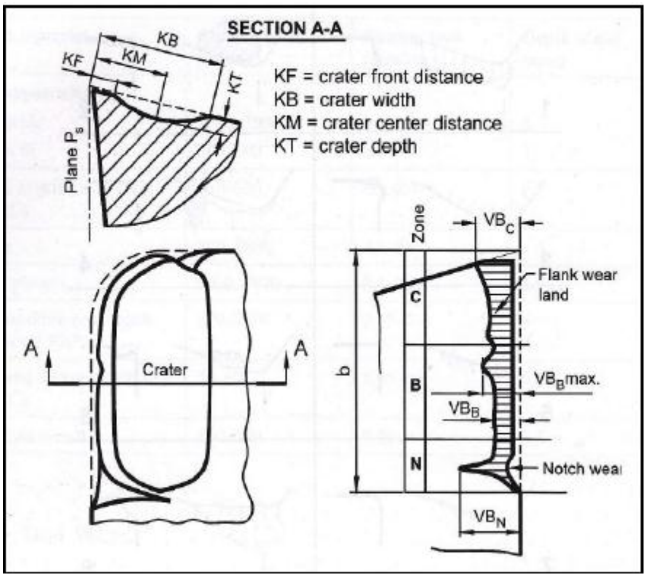


Figure 1: Types of tool wear according to standard ISO 3685: 1993

Tool wear mechanism:

The general mechanisms that cause the tool wear is summarized in Figure . There are abrasion, diffusion, oxidation, fatigue and adhesion. Most of these mechanisms are accelerated at higher cutting speeds and consequently cutting temperatures. In the context of cutting tool wear three groups of causes can be qualitatively identified: mechanical, thermal and adhesive. Mechanical types of wear, which include abrasion, chipping, early gross fracture meanwhile mechanical fatigue, are basically independent temperature. Thermal causes with plastic deformation, thermal diffusion and oxygen corrosion as their typical forms, increase drastically at high temperatures and can accelerate the tool failure by easier material removal by abrasion or attrition.

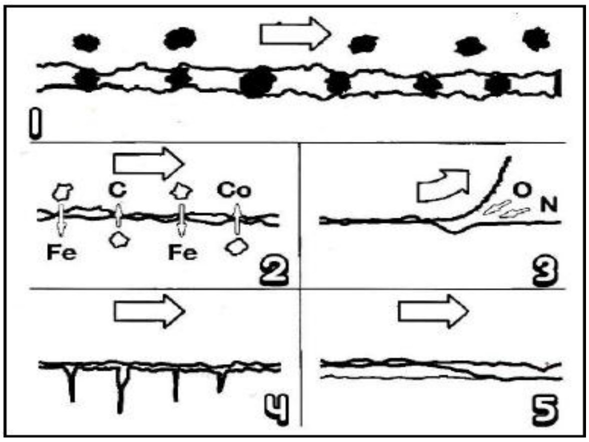


Figure 2: Evolution of the flank wear land VB_B as a function of cutting time for different cutting speeds

Abrasion wear occurs when hard particles slide against cutting tool, primarily on the flank surface. The hard particles come from either work material’s microstructure, or are broken away from the cutting edge by brittle fracture. Moreover, they can also result from a chemical reaction between the chips and cutting fluid when machining steels or cast irons alloyed with chromium. Abrasive wear reduces the harder the tool is relative to the particles in high temperatures, and generally depends on the machining distance. Adhesive or attrition wear are the most significant types of wear at lower cutting speeds. Attrition wear is not a temperature dependent, and is most destructive of the tools in the low cutting speed range, where high speed steels often give equal or superior performance. Attrition may cause substantial changes in surface texture. At high cutting speed, temperature-activated wear mechanisms including diffusion (solution wear), chemical wear (oxidation and corrosion wear), and thermal wear (superficial plastic deformation due to thermal softening effect) occur.

The criteria most commonly used for ceramics are as follows:

a) The maximum width of the flank wear land VB, max. = 0,6 mm if the flank wear land is not regularly worn in zone B;
b) The average width of the flank wear land VBB = 0,3 mm if the flank wear land is considered to be regularly worn in zone B. [4]

II. METHODOLOGY

1. Before starting the machining operation the tool insert image was captured and it is to be taken as reference image.

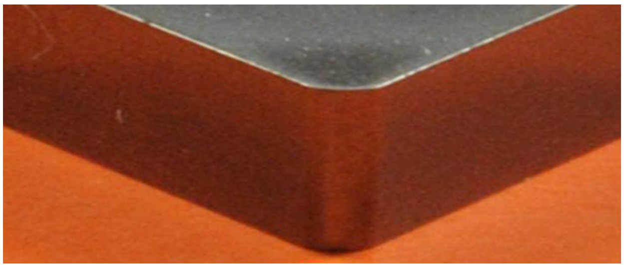


Figure 3: Reference tool image

2. The tool was fitted in the tool holder of the machine and the machining processes had been done.

Figure 4: Fitting of insert in the tool holder

3. The parameters speed, feed & depth of cut of machining operation were noted.

4. After every machining interval the insert was removed and the image was captured.

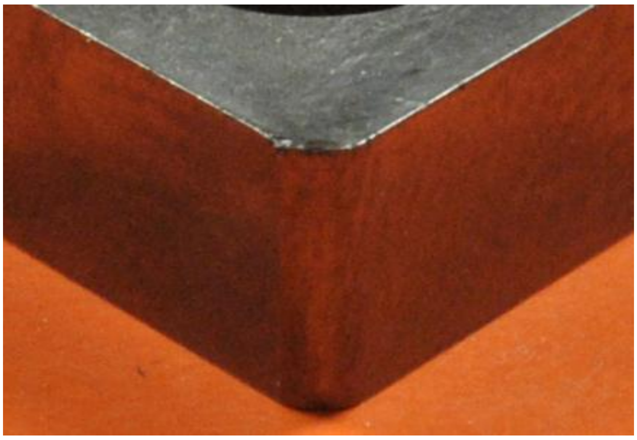


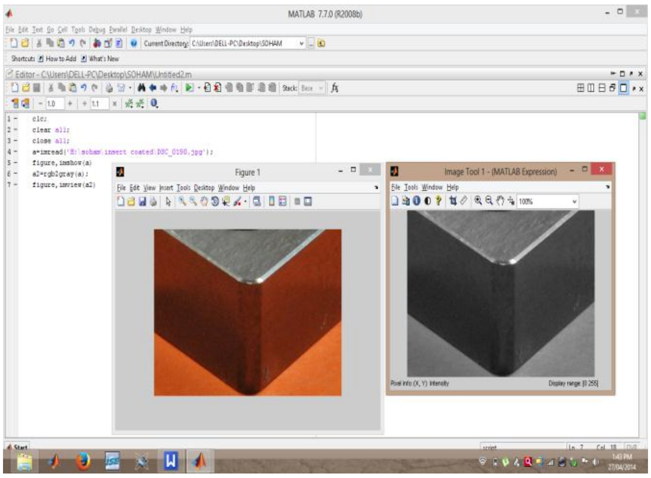
Figure 5: Worn out tool image

5. The RGB image taken from the vision had been converted into gray scale image and the gray scale values are calculated using MAT Lab.

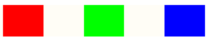
Estimation of the wear tool gray value and the tool wear value in simple MATLAB program is listed below.

The simple program used for conversion of RGB image and the estimation of wear value of tool is given below. [3]

```
clc;
clearall;
closeall;
a=imread('image location');
a1=imresize(a,[100 100]);
figure,imshow(a1)
a2=rgb2gray(a1);
figure,imview(a2)
```

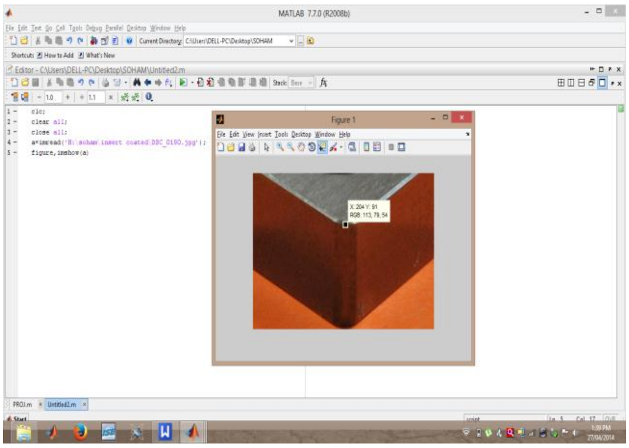


On a computer monitor, cell phone screen, or digital camera screen, different colors are displayed by varying the amounts of red, green, and blue light that shines through the pixels. This is known as the RGB color model. Pure red, green, and blue look like this:



The RGB encoding of pure red is (255,0,0), pure green (0,255,0), and pure blue (0,0,255). In all RGB encodings, the first value is the amount of red, the second value is the amount of green, and the last value represents the amount of blue. The range of the three numbers is 0 to 255.

Grayscale images are rendered in black, white, and all the shades of gray in between. The RGB encoding of any gray values is a set of three equal numbers, i.e., (x, x, x), where x is some integer between 0 and 255. For instance, white is (255,255,255), black is (0,0,0) and medium gray is (127,127,127). The higher the numbers, the lighter the gray.



Suppose the RGB value of a color is (r, g, b), where r, g, and b are integers between 0 and 255. The grayscale weighted average, x, is given by the formula as below,

$$x = 0.299r + 0.587g + 0.114b.$$

For uncoated reference image grayscale value can calculated as given below:

$$x = 0.299*(113) + 0.587*(79) + 0.114*(54).$$

$$x = 86.316$$

For 1st reading, the grayscale weighted average, x, is given by the formula,

$$x = 0.299*(86) + 0.587*(53) + 0.114*(38).$$
$$x=61.157$$

Then wear was calculated.

Wear = 0.291mm

III. RESULTS

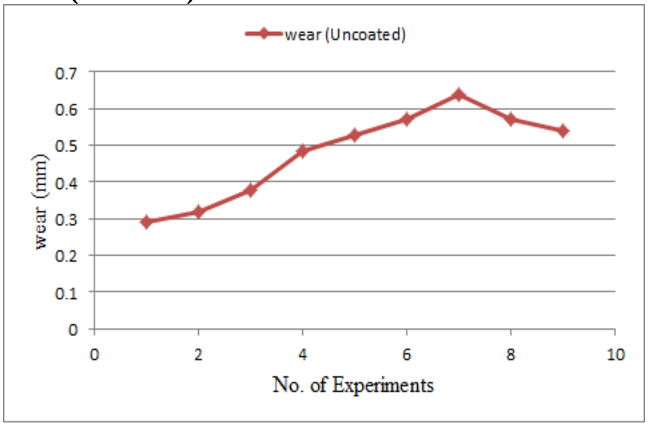
The above value of wear is for the 1st cutting condition of uncoated insert. Using the above procedure, wear is calculated for remaining cutting conditions, of uncoated and coated, which is shown in table below:

Table 1: Flank wear data for hard machining of AISI 4340 steel.

Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Wear (mm) Uncoated	Wear (mm) Coated
125	0.10	0.25	0.291	0.041
125	0.16	0.40	0.318	0.098
125	0.25	0.63	0.376	0.159
150	0.10	0.40	0.4833	0.180
150	0.16	0.63	0.526	0.244
150	0.25	0.25	0.570	0.256
175	0.10	0.63	0.639	0.364
175	0.16	0.25	0.570	0.377
175	0.25	0.40	0.538	0.371

IV. DISCUSSION

Wear (Uncoated)



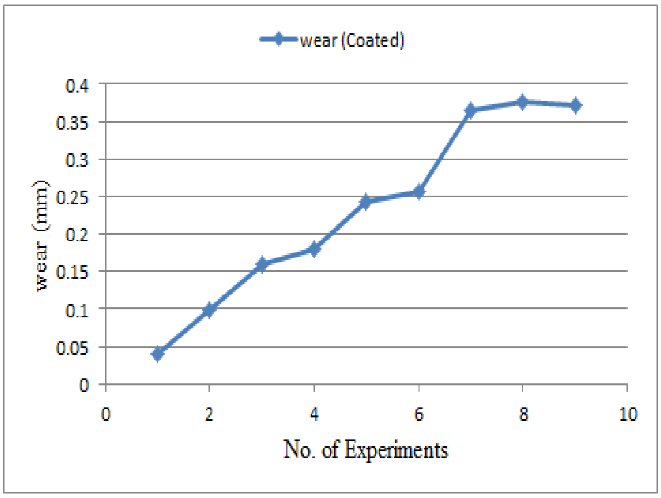
Graph 1 -Chart of wear (uncoated) v/s. No. of Experiments

The graph is of uncoated insert for wear. The x axis represents Experiment No. and the y axis represents the wear value. From the graph it can be observed that for 1st condition the wear is minimum (i.e.0.291 mm) while for 7th condition the wear is maximum (i.e.0.639 mm). The criteria recommended by ISO 3685:1993 to define the effective tool life is VB_B,max = 0.6 mm. Hence, the value of wear exceeds the limiting value for 7th condition.

Thus, we conclude that the tool has failed for 7th condition.

Wear (Coated)

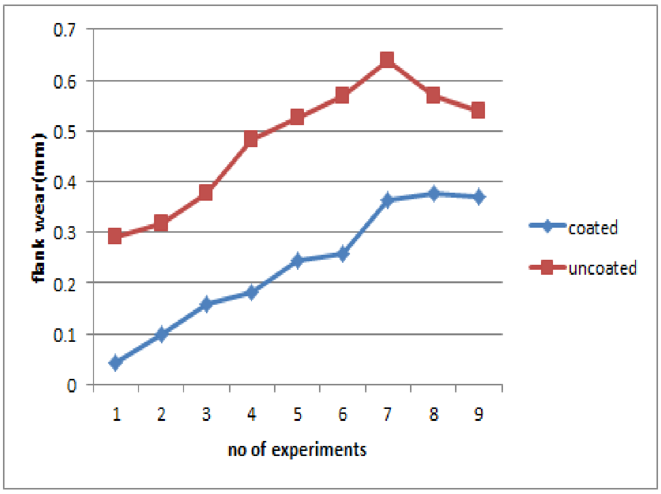
The graph is of coated insert for wear. The x axis represents Experiment No. and the y axis represents the wear value. From the graph it can be observed that for 1st condition the wear is minimum (i.e. 0.041 mm) while for 8th condition the wear is maximum (i.e. 0.377 mm).



A. Graph 2 - Chart of wear (coated) v/s. No. of Experiments

The criteria recommended by ISO 3685:1993 to define the effective tool life is VB_B,max = 0.6 mm. Hence, the value of wear does not exceeds the limiting value for all the condition. Thus, we conclude that there was no tool failure for all the conditions.

Comparison of uncoated and coated tool



Graph 3 - Chart of wear v/s. No. of Experiments

The above graph is of coated insert for wear. The x axis represents Experiment No. and the y axis represents the wear value. The red curve represents the values of wear for different conditions of uncoated insert and the blue curve represents the values of wear for different conditions of coated insert.

From the above graph it is clear that, the wear is less for coated insert than the uncoated.

V. CONCLUSION

- The off line tool wear by gray scale analysis was used to calculate wear of ceramic tool. Tool wear can be easily calculated for any tool by simply capturing the image of that particular tool and comparing with reference image of the same tool. The gray scale value of reference image and worn out image are determined and also measurement of tool wear was done. The same program may be used for online machine system if some additional features are included in the program such as edge detection algorithm, reduction of image noises and orientation of the tool.

- Multilayer coated and uncoated ceramic inserts have been assessed with respect to flank wear.

- The highest tool wear for multilayer coated and uncoated ceramic tools were 0.364 and 0.639 mm which associate to cutting speed of 175 m/min and depth of cut of 0.63 mm.

- During machinability study in hard turning. It is observed that, the tool wear for multilayer TiN+ AlCrN coated ceramic insert is higher than the uncoated ceramic insert under extreme cutting conditions of hard turning of AISI 4340 steel (46 HRC). The uncoated ceramic insert fails (for 7^{th} condition) as it exceeds the maximum value for flank wear in hard turning at extreme parametric range selected.

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S.P. Patil, Mechanical Engg. Department, University of Pune, Dr. D.Y. Patil College Of Engg.,Ambi,Pune, India.

D. M. Tilekar, Mechanical Engg. Department, University of Pune, Dr. D.Y. Patil College Of Engg.,Ambi,Pune, India