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Tool Wear Monitoring By Image Processing

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Abstract - Tool wear measurement is of great concern in machining industry, as its affects the surface quality, dimensional accuracy and production cost of the material components. In this study, machine vision system based on digital image processing was developed for measurement of tool wear. Tool wear images were captured and flank wear was measured using gray scale analysis of that image. To increase the tool life (i.e. minimization of tool wear) and more material removal for the required surface roughness in machining the parameters such as speed, feed, and depth of cut are to be optimized. Optimization has significant practical importance particularly for machining operation.

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.

The aim of this paper is to design 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 have been done using the MATLAB software.

II.CUTTING TOOL WEAR AND MEASUREMENT OF TOOL WEAR

ISO standard 3685:1993 is the standard for measuring the wear for wear experiments when using a single-point turning tool. The word "single-point" refers to the fact that the tool cuts the material with a single point. Figure 1 depicts a cutting tool. However, the ordering of the sides is dependent on the application. Major flank is the cutting edge, while minor flank faces the newly cut surface and the face receives the material being cut and forms chips. The type of cutting tool presented in Figure 1 has four usable cutting edges, one on each side of the tool. Of these, the most useable for measuring are the major flank and the face as the standard gives threshold values for wear experiments on the wear types occurring on the two sides. The standard also defines four definitions namely tool wear, tool wear measure, tool- life criterion, and tool life which are defined as follows:

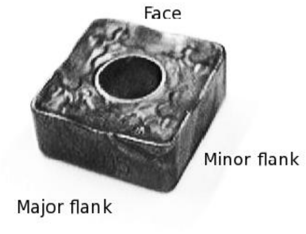

Figure 1 Image of cutting tool

a. Tool wear

The change of shape of the tool from its original shape, during cutting, resulting from the gradual loss of tool material or deformation.

b. Tool wear measure

A dimension to be measured to indicate the amount of tool wear.

c. Tool-life criterion

A predetermined threshold value of a tool wears measure or the occurrence of a phenomenon.

d. Tool life

The cutting time required to reach a tool-life criterion. According to the ISO standard 3685:1993, there are multiple types of wear and phenomena, which can cause tool-life criterion to be fulfilled. Most important of the wear types are flank wear and crater wear.

Flank wear is present in all situations and it is the best known type of wear. It can be found on the major flank of the tool. Crater wear appears on the face of the tool as a crater. Crater wear is the most commonly found wear on the face of the tool.

The wear process itself changes under the influence of different conditions. However, three main factors contributing to the wear are known: adhesion, abrasion and diffusion.

Adhesion occurs when the work material, that the tool is cutting, welds onto the tool. This happens because of the friction between the tool and work material, which generates heat. When these welds are broken, small pieces of the tool are lost. Abrasion is mechanical wear resulting from the cutting action, where the tool grinds itself on to the work material. Diffusion wear occurs on a narrow reaction zone between the tool and work material. In diffusion wear the atoms from the tool move to the work material. This usually accelerates the other two wear processes as the tool material is weakened. Figure 2 shows the general curves of flank wear. The wear is typically characterized by rapid initial wear, a linear increase of the wear in the middle of the tool life and finally a rapid increase of the wear rate before the tool breaks completely.

While the general shape of the curve stays the same, cutting conditions or cutting parameters affect the tool life, i.e. the gradient of the curve, especially the linear section. Most important cutting parameters in relation to tool wear are cutting speed, denoted by V, and cutting feed, denoted by f. Of these speed is considered to have the most effect on the tool life.

The importance of cutting speed can also be seen from the Taylor's equation as the formula relies only on the cutting speed to estimate tool life.

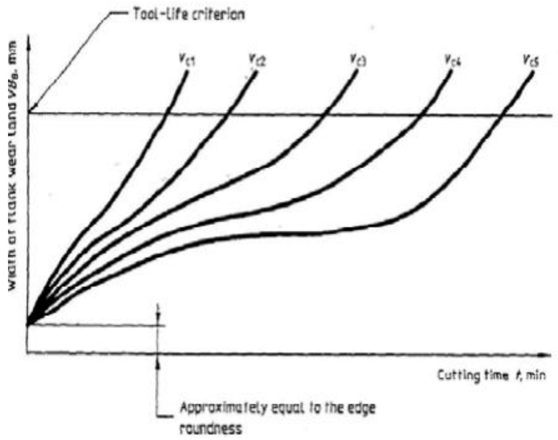

Figure 2 Flank wear progress as a function of time

The effects of cutting speed can be seen from Figure 2. The Cutting speed is usually expressed in meters per minute and can range up to 500 m/min.

The standard gives a limit to the cutting speeds by limiting the minimum tool life to 5 minutes or to 2 minutes when using a ceramic tool.

The cutting feed is expressed as millimeters per revolution, ranging from 0.1 to 0.9 mm/rev Standard has defined the maximum feed to 0.8 times the corner radius of the tool. The corner radius can be seen in Figure 3. To be able to measure the wear, especially flank wear, a few variables must be known.

Most important variables are corner radius (r_c) and depth of cut (b). These are represented in Figure 3. This figure is depicting the tip or nose of the tool viewing it from the top. The arrow in the figure represents the cutting direction.

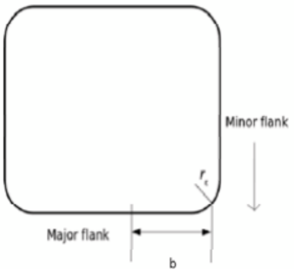

Figure 3 Nose of the tool

The variable r_c tells the corner radius, i.e. how round the tip of the tool is. b on the other hand tells the depth of the cut used to cut the work-piece. These are used in measuring the flank wear. The measurements defined for flank wear in the standard are shown in Figure 4. The figure depicts the major flank of the tool from the side and the tip of the tool lies at the top.

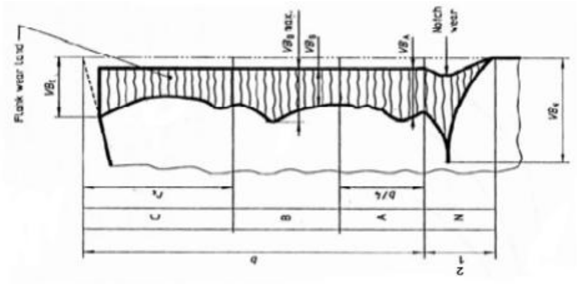

Figure 4 Measurement of flank wear

In Figure 4 two measures are the most important, as they are designated in the standard to be tool-life criterions.

These measures are VB_B and VB_B max. Besides these most important measures, also VB_C is measured, which is considered to be the maximum wear width in zone C. VB_B and VB_B max. Govern the tool-life by following criteria:

a) The maximum width of the flank wear land VB_B max. = 0.6 mm if the flank wear land is not regularly worn in zone B.

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a) The maximum width of the flank wear land VB_B 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 VB_B = 0.3 mm if the flank wear land is Considered regularly worn in zone B.

III. EXPERIMENTAL SETUP

The machining tests were carried out on CNC lathe machine under dry cutting condition and the cutting insert used was carbide tool. The coated tool chosen for machining test was titanium nitride (TiN). The main characteristics of titanium coated insert are high strength, hardness and high corrosion resistance to acid, alkali and chlorine. For capturing tool images RAPID-I machine vision system was utilized.

The vision system has work table movement in X axis-200mm, Y axis-150mm, Zaxis-90mm which is controlled by joy stick. The resolution of vision inspection system is 1micron (min) and the maximum weight of job placed on table limited to 5kg (max). The system has magnification in the order of 18X, 67Xand120X with a variable zoom objective piece and up to 240x with 2x objective lens. The lighting of the system was solid state 4 quadrant lighting with provisions for enhancement of surface feature/ sharpening profile. The image was captured by digital camera with 1280 x 1024 pixel resolution.

IV. METHODOLOGY

Before starting the machining operation the tool insert image was captured and it is to be taken as reference image. The tool was fitted in the tool holder of the machine and the machining processes had been done. The parameters speed, feed & depth of cut of machining operation were noted. After every one hour machining interval the insert was removed and the image was captured. The wear depth had been calculated using the focus meter by setting Z1 and Z2 in the vision system. The RGB image taken from the vision had been converted into gray scale image and the gray scale values are calculated using MAT Lab.

The methodology of flow chart is listed below.

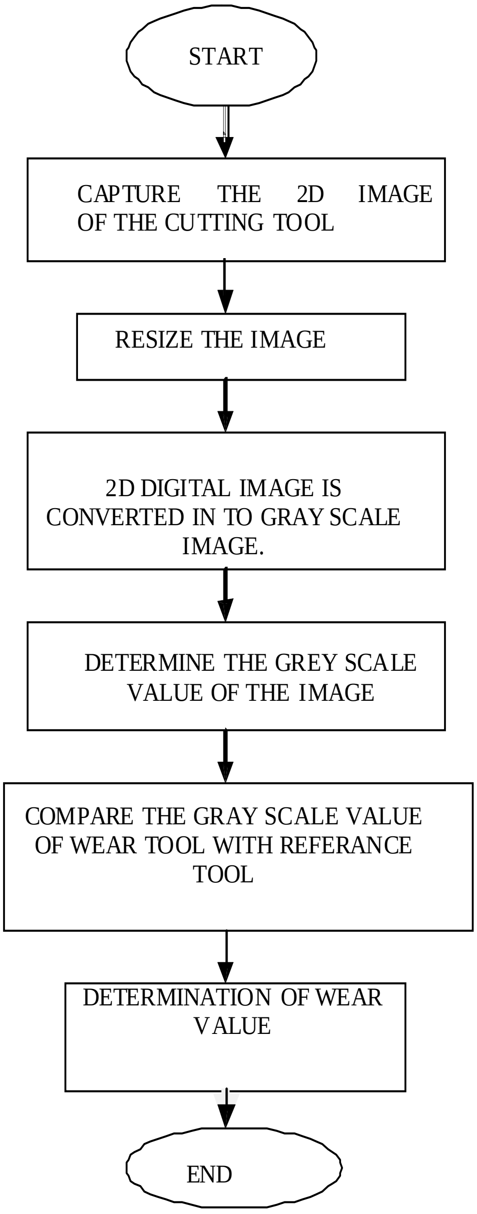

Figure 5 Flow chart

To estimate the wear tool gray value and estimate the wear value of one pixel in simple C program listed below.

a.Program

The simple program used for conversion of RGB image and the estimation for wear value of one pixel is given below.

```
clc; clearall;
closeall;
a=imread('E:\D\Images\Tung\TUN8.TIFF');
a1=imresize(a,[100 100]); figure,imshow(a1)
a2=rgb2gray(a1); figure,imview(a2)
K=xlswrite('E:\D\Images\Tung\\Tung-
81.xls',a2);
K1=sum(a101,cw101)/10000;
Wear = K1/wear avg value
```

S.l no.	Tool no	Reference image gray value	Wear tool gray value	Wear measurement	Wear value for one pixel
1	TN 4015	79.67	75.54	0.05	82.6
2	TN 4015	79.67	74.71	0.06	82.67
3	TN 4015	79.67	73.11	0.09	72.88
4	TN 4015	79.67	72.32	0.11	66.81
5	TN 4015	79.67	72.03	0.115	66.43
6	TN 4015	79.67	71.63	0.125	64.32

Wear value for one pixel= (Reference image gray value –wear tool gray value) / (Wear measurement)

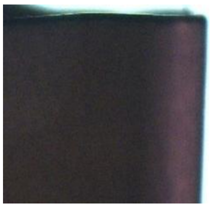

Figure 6 Reference image

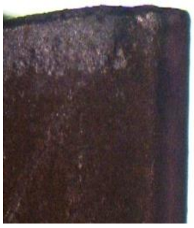

Figure 7 Wear image at 0.06mm

Figure 8 Wear image at 0.09mm

V.CONCLUSION

The off line tool wear by gray scale analysis was established for the generalized machining condition. Tool wear can be easily established 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.

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