

An Effective Drilling Wear Measurement based on Visual Inspection Technique

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Abstract

The purpose of this research is to use the visual inspection technique for the automatic tool wear measurement of different coated drills. The tool wear images with the different coated drilling are captured using a machine vision system incorporating with an effective vertex detection algorithm based on subpixel edge detector and Gaussian filter is presented. The results show that the proposed algorithm is an effective method for the different coated drilling factor is recognized to make the most significant contribution to the over all performance. All drilling tests were carried out under dry cutting conditions without any coolant being used, The TiAlN-coated drilling has the least wear rate amongst these coated drilling cutters and has the longest tool life in this experiment

Keywords: Visual Inspection, Different Coated Drilling, Tool Wear, Machine Vision, dry cutting.

1. Introduction

In machining processes, drilling operation is material removal processes that have been widely used in manufacturing since the industrial revolution. It was also estimated that drilling accounts for nearly 40% of all metal removal operations in the industry [1]. TiN-coated high speed steel tools [2-4] are currently used in metal cutting operations and increasingly replace uncoated drills, Whereas Ti-Base coated drilling operation has moved to the stage of automation in recent years, there are still two unsolved problems in drilling, like in many other machining processes: tool wear and tool breakage. Therefore, Monitoring of tool wear condition for drilling is a very important economical consideration in automated manufacturing, and to achieve an optimal use of resources. Most of the on-line identification techniques of tool wear based on the measurement of cutting forces and power signals [5-10]. These techniques can be broadly

classified as direct methods and indirect methods based on the type of sensor measurements.

The research of vertex detection techniques have been developed in recent years. High curvature points are commonly called vertices. Vertices play an important role in object recognition. In order to achieve high recognition rate, it is critical to extract vertices from the profile of a drilling tools completely and precisely. Consequently, an effective vertex detection represents an important research area in machine vision. Although some researchers use k -curvature [11], chain-code [12], vector method [13], or cosine value [14], as alternatives to estimate curvature, the results are still unsatisfactory. The objective of this research was to develop an effective and reliable vertex detection algorithm so as to extract all the desired drilling wear images vertices successfully. In addition, we investigated the influence of edge detection method as well as smoothing technique on the overall performance of vertex detection techniques.

Therefore, the purpose of this research is to monitor the flank wear of different coated drilling based on the image data of cutters tool in the drilling operation. The tool wear images of the cutters are captured and processed using a machine vision system incorporating with the vertex detection and Visual Inspection technique.

2. Experimental Method

In order to observe the effects of coating layer, spindle speed and feed rate on the tool wear of the drilling operation, three types of different coated cutters were used in the drilling of JIS S45C carbon steel. All drilling tests were carried out under dry cutting conditions without any coolant being used and drilling continuously 50, 60, 70 holes. The drilling conditions are recommended by the manufacturers. Each at three levels, are considered. The drilling experimental is designed by using Taguchi's method, as shown in Table 1.

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Table 1. Drilling experimental factors

Control Factor	Level 1	Level 2	Level 3
A Coating Layer	TiN	TiCN	TiAlN
B Spindle Speed [rpm]	764	955	1050
C Feed Rate [mm/rev]	0.12	0.18	0.21
D number of times	50	60	70

2.1. Wear Measurement System

The machine vision system for tool wear monitoring consists of a CCD camera, a macro lens, a circular light, a PC for image processing, and suitable software. The experimental system for tool wear measurement is shown in Fig. 1.

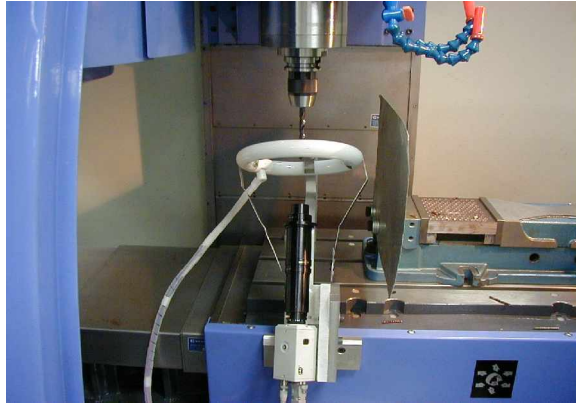


Fig. 1: Drilling experimental system

The drilling experimental were carried out a CNC machining center. The image of cutting edge was captured by a CCD camera via a back-lighted source. Then, the image was registered using self-developed software in order to find out an optimal tools image.

2.2. Image Analysis

2.2.1. Vertex Detection and Procedure

The vertex detection procedure developed for the study consists of the following steps:

1. Select a suitable threshold value automatically to segment object from the background.
2. Apply subpixel accuracy edge detector to collect edges.
3. Rearrange edges in an ordered clockwise manner.
4. Smooth the ordered edges using B-spline approximation technique.
5. Calculate the curvature of every point along the profile of an object.

6. Smooth the curvature curve using Gaussian low-pass filter such that location of each vertex on the smoothed curve becomes conspicuous.

7. Select a suitable threshold value using statistical process control (SPC) technique such that vertexes can be automatically detected.

The flowchart for the proposed algorithm is depicted in Fig. 2. Each step will be described in more detail in the following sections.

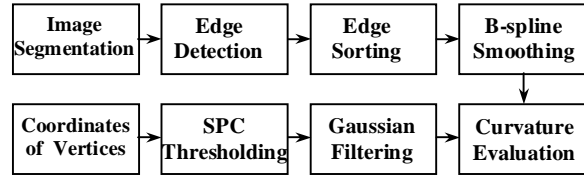


Fig. 2: Flowchart of the proposed edge detection algorithm.

2.2.2. The optimization image processing

To automate vertex detection process, a threshold value should be selected automatically. In this research, five automatic thresholding methods have been investigated, including Tri-Level thresholding method [15], Mode method, Iterative threshold selection method, Otsu method and Moment-preserving method. After testing with various images, the results suggest that Tri-Level thresholding method is a better choice when the multi-gray-leveled image into an optimization of the image processing.

2.2.3. Subpixel Edge Detection

After each object has been separated from the background, the next step is to collect edge points representing the profile of an object. Chain-code is a popular edge detector, which has been used by most researchers but it is limited to detect edges to pixel accuracy. On the other hand, since spatial-moment edge detector proposed by Lyvers [16] is capable of extracting edge points to subpixel accuracy, we use it as an edge detector. The 2D spatial-moment measures definition following:

$$M_{pq} = \iint x^p y^q f(x,y) dy dx \quad (1)$$

2.2.4. Curvature Computation

For a plane curve $\vec{\gamma} = x(t)\vec{i} + y(t)\vec{j}$, the curvature κ is defined as:

$$\kappa = \frac{\dot{x}\ddot{y} - \dot{y}\ddot{x}}{(\dot{x}^2 + \dot{y}^2)^{3/2}} \quad (2)$$

From Eq.2, we know that three consecutive edge points are sufficient to compute the curvature at any point on the profile of an object. The curvature curve can be obtained by drawing a continuous curve through each point in the curvature list. We use Gaussian low-pass filter to smooth the curvature curve. The advantage of our approach is that locations of the vertexes will not be changed. The zero-mean Gaussian function in one dimension is defined as:

$$G(x, \sigma) = e^{-\frac{x^2}{2\sigma^2}}, \quad x = -\left[\frac{n}{2}\right], \dots, -1, 0, 1, \dots, \left[\frac{n}{2}\right] \quad (3)$$

where n is the window size and σ is the spread parameter of the Gaussian.

2.2.5. SPC Automatic Thresholding

As mentioned, high curvature points usually represent vertices. To extract all the true vertices from the curvature curve without any specious vertex being extracted, a suitable threshold value must be chosen. The mean value of curvatures \bar{K} and the standard deviation σ are defined by:

$$\bar{K} = \frac{\sum_{i=1}^n |k_i|}{n} \quad (4)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (|k_i| - \bar{K})^2}{n}} \quad (5)$$

2.3. Tool Wear Analysis

The morphology processing was used in the image post-processing in order to obtain the optimal flank wear image. The wear of cutting edge after the image post-processing is analyzed via the aid of personal computer. The MIL (Matrox Imaging Library) software with user-friendly window interface is used to measure the crater wear width. The maximum flank wear (VB_{\max}) is definition by:

$$VB_{\max} = D - d_n \quad (6)$$

3. Experimental Results and Discussion

3.1 Experimental Results of the optimization of the image processing

Fig. 3 shows the images of segmentation before and after the drills. the results suggest that Tri-Level thresholding method is a better choice when the multi-gray-leveled image into an optimization of the image processing. Fig. 3(a)-(c) shows the images of tool segmentation before and after the image processing. The original images of drilling are shown in Fig. 3(a), Fig. 3 (b) and (c) show the binarized image and Tri-Level Thresholding image, respectively. Fig. 3(d) is the morphological operator image.

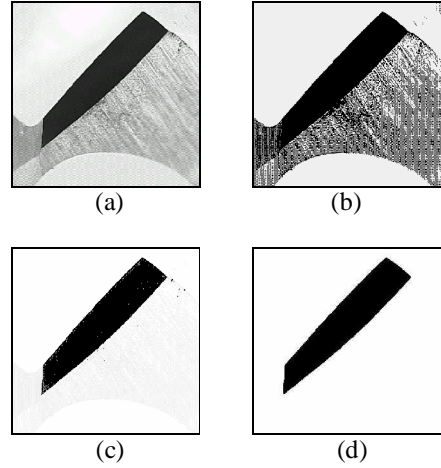


Fig. 3: Result of the different segmentation methods: (a) the original tool image; (b) the binary tool image; (c) the Tri-Level Thresholding image; (d) the morphological operator image.

3.2 Gaussian filtering and vertex detection

Effect of smoothing using Gaussian low-pass filter show the curvature curves derived from spatial-moment edge detector, Apparently, all the true vertices have been detected successfully without any false vertex being detected, as shows Fig. 4(a). Figs. 4(b) show the detected vertices by referring to the smoothed curvature curve. thus, after smoothed by Gaussian filter, the vertex detection method performs perfectly.

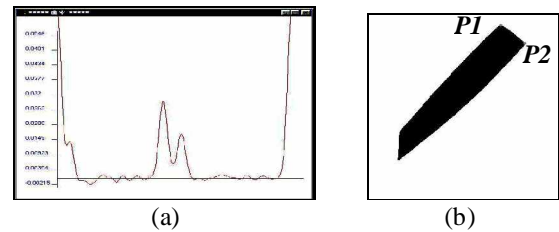


Fig. 4: Effect of smoothing using Gaussian low-pass filter. (a) smoothed by Gaussian low-pass filter; (b) Vertices detected by referring to the smoothed curvature curve .

3.2 Wear Measurement and Discussion

The maximum wear land width (VB_{\max}) is measured as a criterion for the tool wear in this study. From the Table 2, The TiAlN-multilayer coated drills have the least average flank wear and the longest tool life amongst three different coated drilling cutters. The reason may be explained by the TiAlN-multilayer coated drilling cutter has a higher anti-oxide temperature and lower thermal conductivity.

Table 2. Drilling flange wear measurement [mm]

drill	50 holes	60 holes	70 holes	Ave. [mm]	Tol. ave. [mm]
TiN	0.018	0.056	0.165	0.080	0.0956
	0.033	0.088	0.139	0.087	
	0.092	0.116	0.151	0.120	
TiCN	0.151	0.230	0.270	0.217	0.2440
	0.267	0.312	0.325	0.301	
	0.079	0.252	0.311	0.214	
TiAlN	0.050	0.075	0.125	0.083	0.0813
	0.043	0.091	0.103	0.079	
	0.055	0.083	0.107	0.082	

4. Conclusions

A real-time drill flank wear measurement method, based on visual inspection technique during drilling, is proposed. In this paper, we have presented an effective algorithm for detecting vertices of drilling wear image. After testing on a variety of objects for the performance of the proposed algorithm, the results are satisfactory. The experimental results are summarized as follows:

- (1) Drill flank wear can be on-line measurements of visual inspection technique based on the proposed method.
- (2) The effect of edge detector and smoothing on the performance of the vertex detection algorithm has been explored in detail.
- (3) The Gaussian filter should be used to smooth curvature curve instead of smoothing the profile of an object.
- (4) The TiAlN-multilayer coated drilling cutters have the least flank wear and have the better anti-wear ability.

5. References

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