Measurement of end-milling burr using image processing techniques

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Abstract: This paper presents a method that has been developed to measure the height of end-milling burr on the edges of a work-piece using techniques of image processing. This simple and economical system consists of a microscope with a digital camera mounted on the viewing lens and a personal computer for image processing. An image is captured and then processed whereby the whole burr profile is analysed and compared to traditional methods, where normally a few readings are taken at random locations. An added feature of this system is that disorientation of the reference horizontal axis, along which burr height measurements are taken, on the work-piece during image capture is catered for with relevant image processing functions. In addition, the system determines and plots the height of the burr against its location, together with the average burr height, which can be used later for deburring or further analysis.

Keywords: end-milling, burr height, image processing

1 INTRODUCTION

Burrs are always a problem during an end-milling operation and deburring operations are often required. Deburring has been made possible with continuous advancements in robotics and machining technologies but these processes normally requires the location and height of the burr that has to be removed [**1**]. Also, conditions which produce the least amount of burr are often desired so that machining costs can be reduced [**2**]. However, this requires accurate measurement and analysis of the burr profile.

Microscopes with very high resolution have been developed over the years for more accurate burr measurement. The traditional burr measurement method follows the manual process where a few readings are taken using a microscope and dial gauges at random locations on the work-piece [**2**]. However, in cases where burr profiles are not uniform, this technique would give an inaccurate interpretation of the burr profile, no matter how precise the individual readings are.

The current work looks at an advanced approach to burr height measurement which is based on image-processing-based techniques, similar to the work of Lee *et al.* [**1**], Nakao and Watanabe [**3**], Ogawa *et al.* [**4**], and Su *et al.* [**5**]. It is applied to burr height measurement on the edge of work-pieces in end-milling operations. An image of the burr as seen through the viewing lens of a microscope is captured and transferred to a computer. The image is then processed and analysed to determine the burr height through calibration. Whereas only a limited number of readings are taken using the traditional method of burr measurements, the image-processing technique analyses the burr profile throughout the length of the captured image in significantly less time.

There are already off-the-shelf packages (for example, see reference [**6**]) available for certain microscopes which would conduct such an analysis, but the current work presents a simple and task-specific alternative which can be implemented very easily and at a low cost. An outline of the technique and the developed system is given in the following sections.

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2 OVERVIEW OF THE MEASUREMENT SYSTEM

Figure 1 shows the flowchart for the proposed measurement method. Image acquisition refers to capturing an image of the burr profile and the related hardware used in image capturing. The captured image is then transferred to a computer where image processing is performed to measure the burr. Image processing is divided into two components: image pre-processing, which deals with preparing the image for burr measurement and has been performed using the image-processing toolbox in MATLAB, and the actual burr measurement. The following sections discuss the components of Fig. 1.

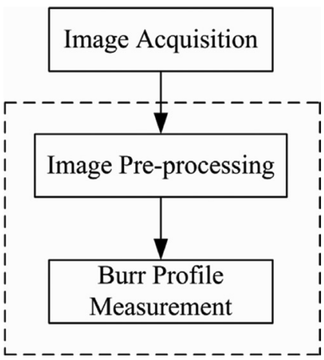

Fig. 1 Flowchart of proposed measurement method

2.1 Image acquisition

The image acquisition hardware includes the Mitutoyo Toolmaker's microscope, which includes a high-intensity light and a high-resolution digital camera, as shown in Fig. 2. The digital camera has a resolution of 3072×2304 pixels and is mounted on the viewing lens of the microscope, while the high-intensity light is focused on the burr profile of interest. In the approach taken towards the vision-based technique, the background area of the work-piece under analysis is captured as dark while the burr on the work-piece is brightly lit.

The work-piece for burr height measurement is rectangular in shape and is milled along the edges on one face of the work-piece, as shown in Fig. 3(a). Before taking an image for burr measurement, the work-piece is placed facing downwards, as shown in Fig. 3(b), so that the edge that has not been milled, which is now facing upwards, becomes the reference line for burr measurement.

The captured coloured image is then transferred to a computer. A sample image is shown in Fig. 4.

2.2 Image pre-processing

The captured image is converted to greyscale format for analysis. The greyscale image for the coloured image of Fig. 4 is shown in Fig. 5.

During image capturing, the orientation of the reference line is not given much emphasis. However, since

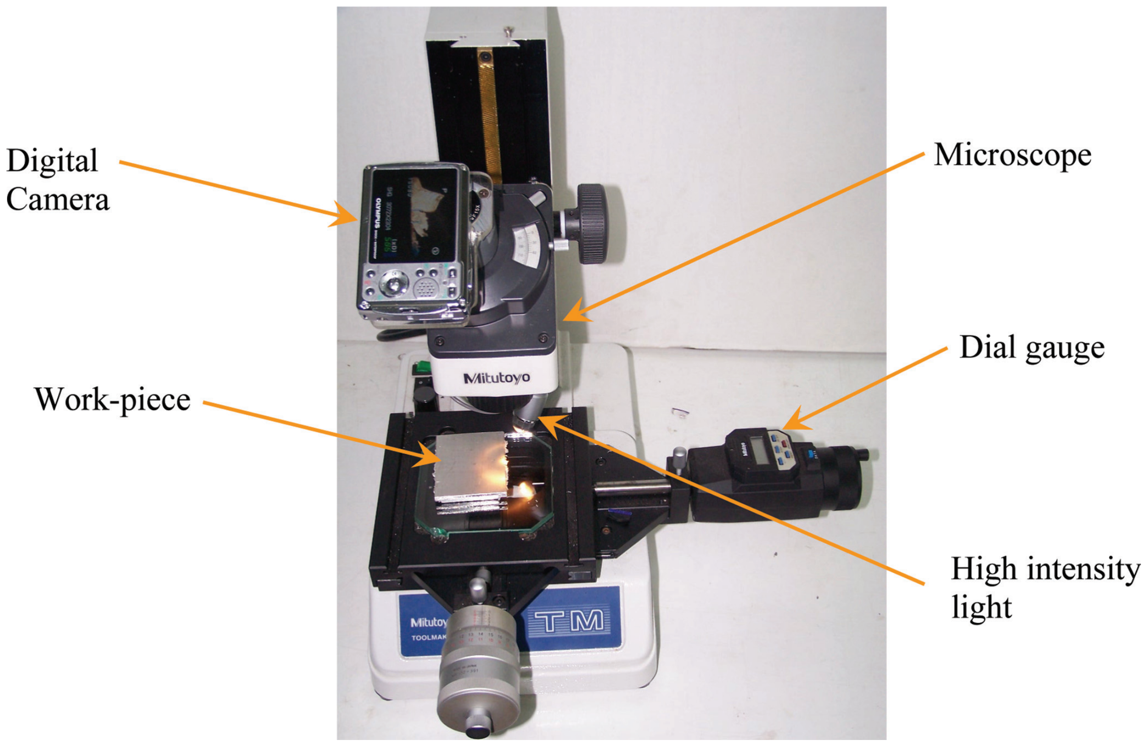

Fig. 2 Image acquisition set-up

(a) (b)

Fig. 3 The work-piece (a) milled side and (b) rear side with the reference edges

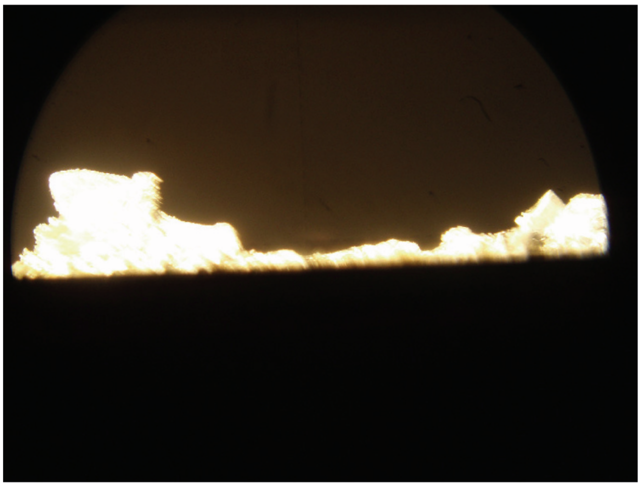

Fig. 4 Sample image

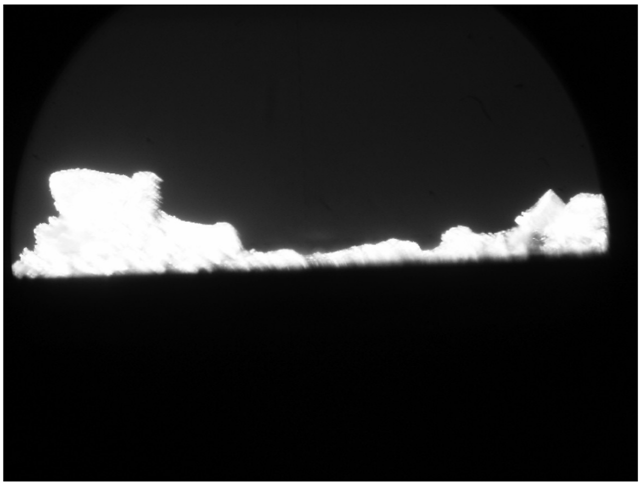

Fig. 5 Greyscale image

burr measurements need to be taken perpendicular to the reference line and the orientation of the reference line has to be consistent for all measurement, the reference line is reoriented using image processing so that it is horizontal. Hence, first the reference line is located in the image and then its orientation is determined in relation to the horizontal before rotating it to a horizontal position. The reoriented greyscale image for the greyscale image of Fig. 5 is shown in Fig. 6.

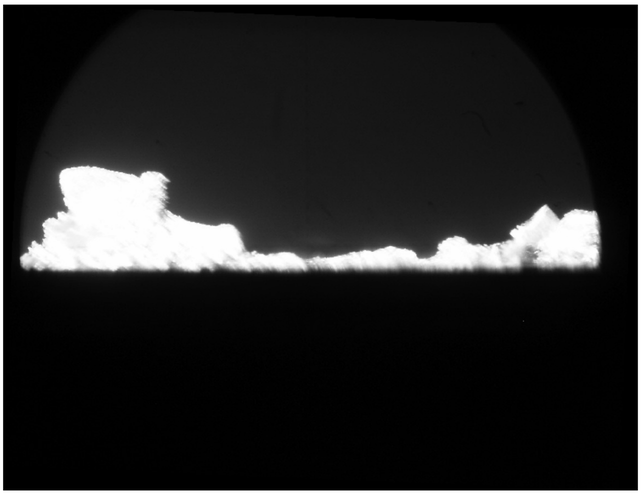

Fig. 6 Reoriented greyscale image

2.3 Burr profile measurement

The reoriented greyscale image is now utilized for burr height measurement. However, before any measurements can be taken, a calibration value is determined. For calibration, determining the actual measurement represented by a pixel, the cross-hairs on the lens of the microscope are utilized. The horizontal line of the cross-hair is made parallel with the reference line while the burr height, along the vertical line of the cross-hair, is measured using the dial gauge on the microscope. The same distance is then manually determined in pixels in the image, as illustrated in Fig. 7, and a calibration value is obtained by dividing the distance in millimetres (mm) by the distance in pixels to obtain mm per pixel, i.e.

$$C = \frac{C_{\mathrm{mm}}}{C_{\mathrm{p}}} \tag{1}$$

The calibration value is also the resolution of this system and is approximately 2.2 μm.

The average burr height is then determined as the summation of the difference between the y coordinates of the burr profile and the reference line, as illustrated in Fig. 7, divided by the number of pixels along the reference line, where the measurements are taken from. This is then converted to mm by multiplying by the calibration constant and is given as

$$\text{Average burr height} = \frac{\sum_{n=1}^{N} (B_{y_n} - R_y)}{N} \times C \tag{2}$$

The measured burr profile for the sample image of Fig. 4 is shown in Fig. 8 along with its average value, given by the horizontal line.

3 CONCLUSION

An image-processing-based technique to measure the burr height produced by end-milling operations on the edge of work-pieces has been presented. This system analyses the whole burr profile and gives the output as burr height against its location along the reference line together with the average burr height. An additional function also caters for disorientation

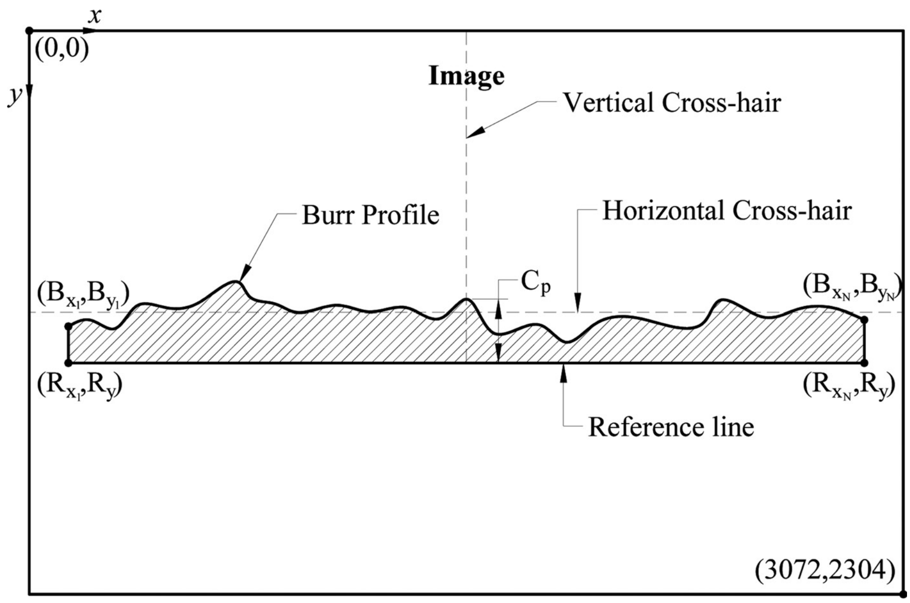

Fig. 7 Image coordinate system for burr measurement

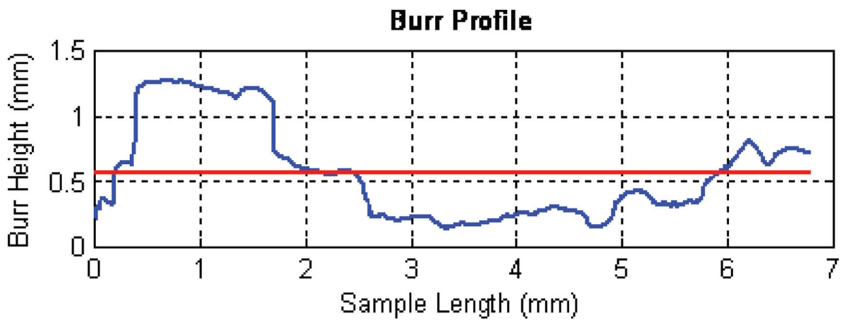

Fig. 8 Measured burr profile

of the reference line along which measurements are taken.

However, although the resolution of this system is determined as approximately 2.2 μm, further tests have to be carried out to determine the accuracy of the measurements. Also, a higher resolution digital camera can be utilized to improve both the resolution and accuracy of this system. It would then be desireable to compare the results of the traditional method and the image-processing method for a range of milling conditions.

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APPENDIX

Notation

B_{y_n}	n^{th} height of the burr
C	calibration constant
C_{mm}	calibration distance along cross-hair in millimeters
C_{p}	calibration distance along the cross-hair in pixels
N	number of pixels along the reference line
R_y	height of reference line