Comparison of Manual and Image Processing Methods of End-Milling Burr Measurement

R.V. Sharan and G.C. Onwubolu

Abstract

This paper compares the results for manual method of burr height measurement with the image-processing technique for end-milled work-pieces under various conditions. The manual method refers to the traditional way where a few readings are taken at random locations using a microscope and the burr height is approximated with an average value. In contrast, the image processing technique analyzes the whole burr profile as seen through the lens of the microscope and captured using a digital camera. With the results obtained using the image processing method as reference, the results show a significant difference between the two average readings in most cases and generally the percentage error is greater for work-pieces with irregular burrs.

Keywords

End-milling • Burr height • Image processing

Introduction

Burr formation during machining processes, such as an end-milling operation, are unwanted and often require deburring operations which has been made possible with continuous developments in computer-aided manufacturing (CAM). However, before deburring can be carried out, determining the size of the burr and its location would be required [1].

Various research work also focus on predicting the best milling conditions that would produce minimum burr. One such work is presented in [2] which utilizes the hybrid group method for data handling (GMDH) network to predict burr formation under different conditions in an end-milling operation. An integral phase of such work is carrying out burr height measurement under various milling conditions and then using this data to train the network based on which it makes predictions.

While microscopes of very high resolution have been developed over the years, the often irregular burr profile implies that the few readings normally taken using the manual method of burr height measurement would not give a correct impression of the burr profile or its average value. As such, no matter how sound the prediction technique is, the predicted data may not be totally correct primarily because of the imprecise data with which the network was trained.

This paper takes an advanced approach to end-milling burr height measurement by employing the image processing technique, similar to the work of [1, 3–5] and [6] and as presented in [7], and compares the results against the manual measurement method, which is presented in [2]. While there are many similar off-the-shelf products which can be used for this purpose, the image processing method employed in this work is simple, economical, and task specific.

R.V. Sharan (✉)
School of Engineering and Physics, University of the South Pacific, Suva, Fiji
e-mail: sharan_r@usp.ac.fj

G.C. Onwubolu
Knowledge Management and Mining, Toronto, Canada
e-mail: onwubolu@gmail.com

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Experimental Overview

During experimentation, exactly the same work-pieces were used for both the methods with end-milling operations performed on the work-pieces under varying conditions. The steps taken in burr height measurement using the image processing technique are image acquisition and image processing, which involves image pre-processing and burr profile measurement, as outlined in [7]. The image acquisition hardware includes a high resolution digital camera (3,072 × 2,304 pixels) mounted on the viewing lens of the Mitutoyo Toolmaker's microscope as shown in Fig. 1. The microscope is also equipped with a dial gauge and a high intensity light focused on the section of the burr under analysis.

A sample end-milled work-piece for burr height measurement is shown in Fig. 2 and a sample captured image is shown in Fig. 3.

The captured image is transformed into grayscale format for further analysis. To calibrate the system, burr height measurement is firstly performed using the dial gauge along the cross-hair reference of the microscope and the same is then done manually on the image to get the relationship in micrometers per pixel. Based on this, the resolution of the system was determined to be approximately 2.2 μm. Next the edge of the work-piece is automatically determined and used as a reference for making the measurements. The developed vision system also caters for the disorientation of this reference line during image capture. That is, it determines the inclination of the reference line and aligns it to the horizontal axis before taking measurements.

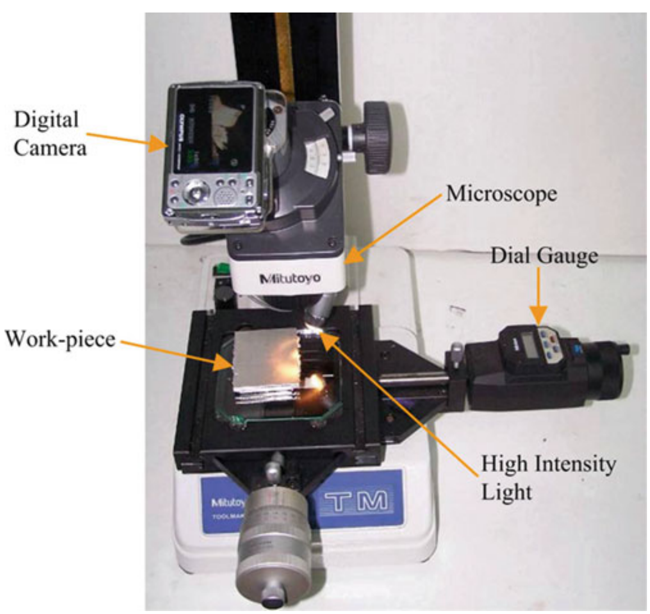

Fig. 1 Image acquisition setup [7]

Fig. 2 Sample work-piece [7]

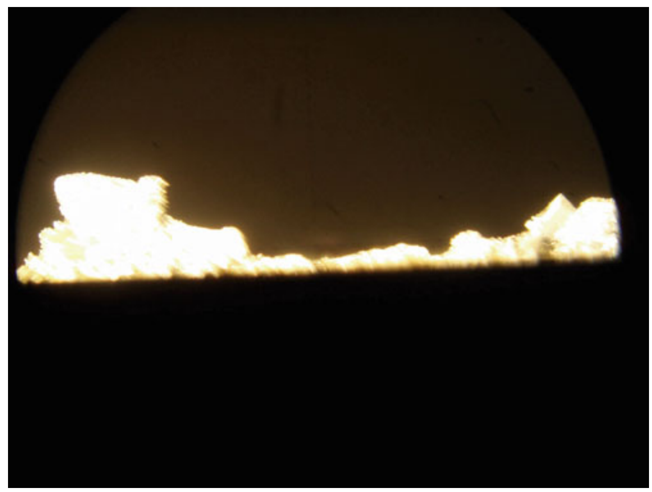

Fig. 3 Sample image [7]

The distance between the horizontal reference line and the burr edge is then measured and multiplied by the calibration value to get the burr height. This is done for the entire length of the burr to obtain the whole burr profile, as shown in Fig. 4 for the sample image of Fig. 3, and the average burr height is then given as

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

where B_{yn} is the burr height, in pixels, at the nth pixel along the reference line, R_y is the height of the reference line in pixels, N is the number of pixels along the reference line and C is the calibration constant. The horizontal line in Fig. 4 indicates the average burr height.

Three such images were taken and analyzed along a single edge, two on the ends and one in the middle, to carry out the analysis using the image processing method.

The manual measurement setup is similar to that shown in Fig. 1 except that the digital camera is not utilized. Instead, ten readings were taken at random locations using the dial gauge and an average value is determined [2].

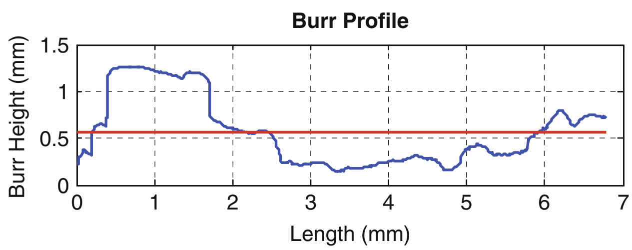

Fig. 4 Measured burr profile [7]

Results

The average burr height measurement values obtained using the image processing and manual methods are given in Table 1 along with the absolute percentage error between the two values with the value obtained using the image processing technique as basis. The results are for a range of 32 work-pieces end-milled under varying conditions of tool angle, depth, feed rate, and speed.

Discussion

The average value was seen as one way to compare the two readings and the comparisons would be different if some other readings were compared. There is a significant percentage error in almost all readings which in some cases

Table 1 Average burr height measurement values for the image processing and manual methods

	Milling conditions				Average burr height (mm)		
Test	Tool angle (°)	Depth (mm)	Feed rate (rev/min)	Speed (rpm)	Manual	Image processing	Absolute error (%)
1	19	0.5	65	320	0.162	0.214	24.2
2	19	0.5	65	410	0.178	0.194	8.3
3	19	0.5	127	600	0.116	0.203	42.7
4	19	0.5	127	865	0.223	0.344	35.2
5	19	1	264	320	0.409	0.549	25.5
6	19	1	264	410	0.329	0.326	1.0
7	19	1	500	600	0.176	0.183	3.6
8	19	1	500	865	0.492	0.553	11.0
9	38	1.5	65	320	0.119	0.536	77.8
10	38	1.5	65	410	0.447	0.331	35.1
11	38	1.5	127	600	2.254	1.527	47.6
12	38	1.5	127	865	2.119	2.058	3.0
13	38	2	264	320	1.399	0.870	60.9
14	38	2	264	410	1.893	1.294	46.3
15	38	2	500	600	3.678	1.561	135.7
16	38	2	500	865	3.629	3.156	15.0
17	55	0.5	65	320	0.815	0.649	25.5
18	55	0.5	65	410	0.435	0.449	3.0
19	55	0.5	127	600	0.335	0.953	64.9
20	55	0.5	127	865	1.178	1.328	11.3
21	55	1	264	320	1.046	0.444	135.5
22	55	1	264	410	1.164	0.505	130.3
23	55	1	500	600	0.633	0.378	67.3
24	55	1	500	865	0.345	0.494	30.1
25	47	1.5	65	320	0.274	0.137	100.7
26	47	1.5	65	410	0.192	0.179	7.4
27	47	1.5	127	600	0.603	0.520	15.9
28	47	1.5	127	865	0.605	0.888	31.9
29	47	2	264	320	0.855	0.427	100.1
30	47	2	264	410	0.737	0.671	9.9
31	47	2	500	600	4.946	2.380	107.8
32	47	2	500	865	1.251	1.423	12.1

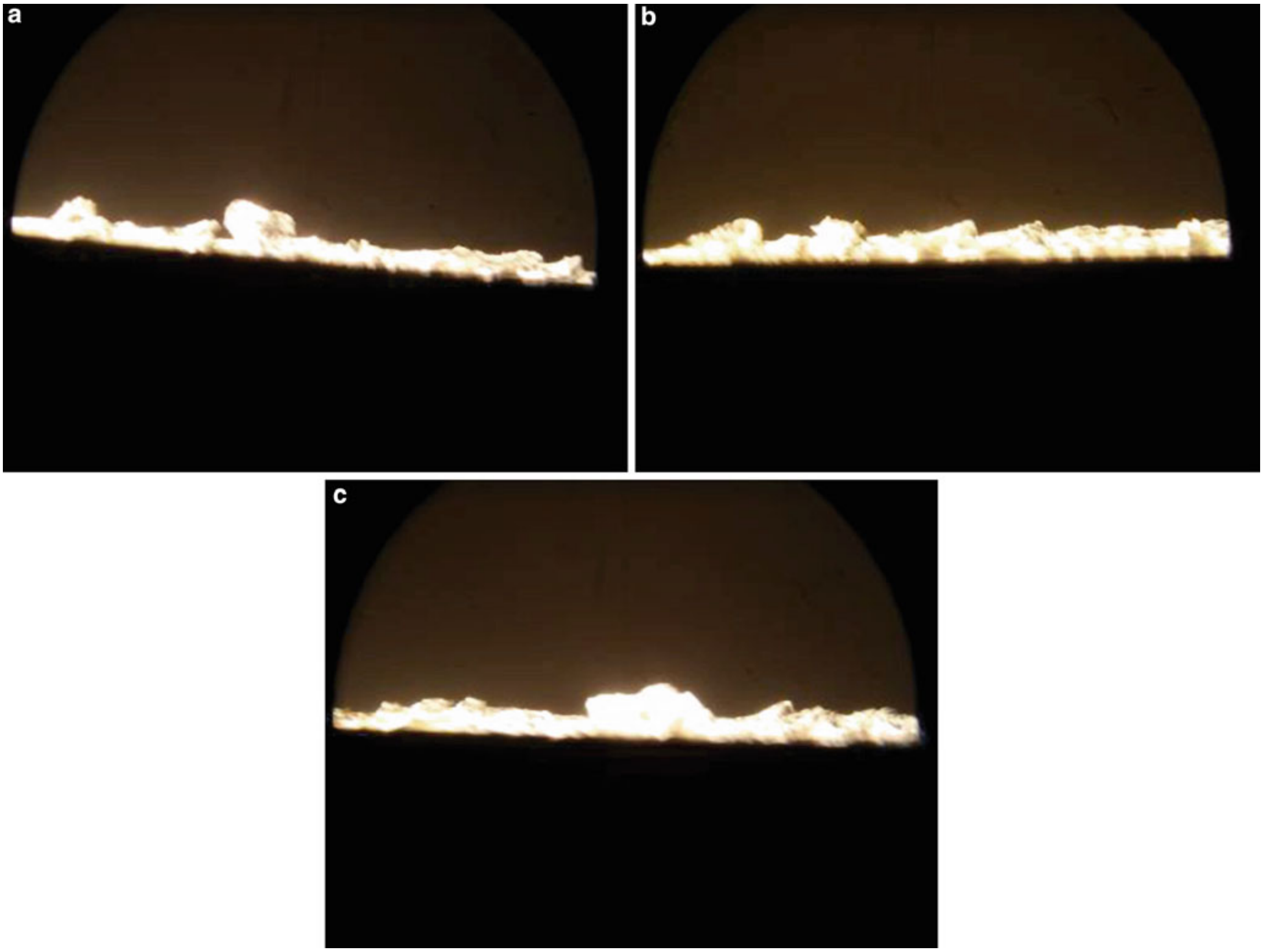

Fig. 5 Images for test 6

exceeds 100 % with an average absolute percentage error of 44.6 %. The values obtained using the image processing method is seen as more accurate since it covers approximately 33 % of the length of the work-piece when compared to the limited number of readings taken using the manual method.

It was also found that generally the error was higher when the burr profile under analysis was irregular. This is evident when looking at the images analyzed for tests 6 and 15 which produce the least and most difference respectively. The three images used for burr height measurement using the image processing technique for test 6 are shown in Fig. 5 and the burr profile is quite uniform with a percentage error of 1.0 %. However, the burr profile is very irregular for the three images shown in Fig. 6 which were used for burr height measurement using the image processing technique for test 15 with a percentage error of 135.7 %.

Although the average burr height is considerably larger for test 15 than test 6, the increase in the difference between the two measurements is difficult to attribute to the increase in burr height. Tests 12 and 16, for example, have greater burr height, using the image processing based results, when compared to test 15 but the error is significantly lower. Similarly, the average burr height for test 25 is lower than that for test 6 but the error is much greater.

Conclusion

While it is obvious that the image processing measurement method will produce more accurate readings of the two methods, the main aim of this work was to compare the results with those obtained using the manual measurement method. It is generally observed that approximating the burr height using the manual method is more inaccurate when the burr profile is irregular. Also, the high error rate with the manual method shows the advantages of the image processing technique which does automatic analysis to a greater extent in a significantly lower time than the traditional method.

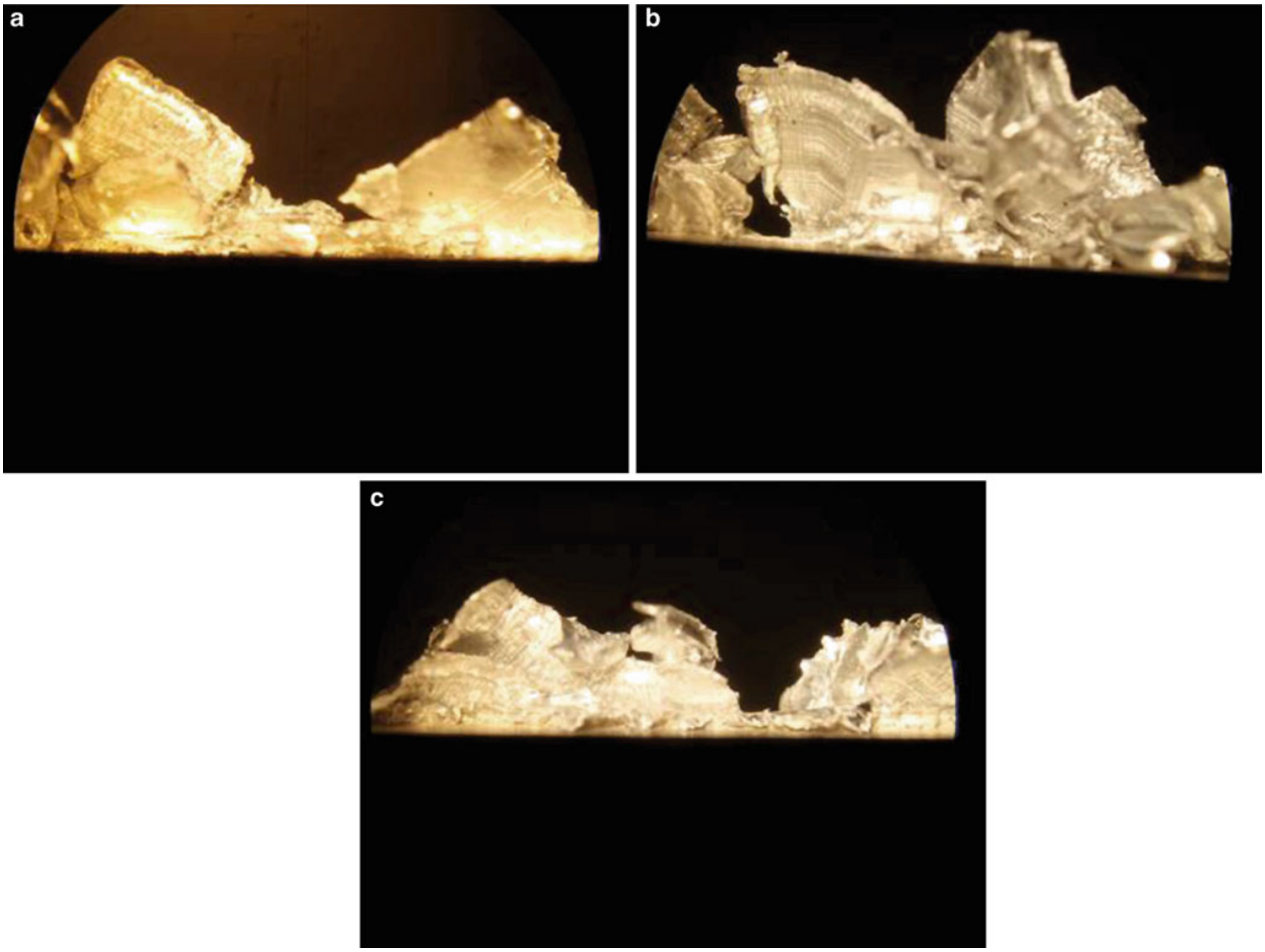

Fig. 6 Images for test 15

The image processing technique utilized here is task specific, low cost and can be implemented quite easily. It could also be adapted for burr measurement in a CAM setup for deburring purposes rather than resorting to costly off-the-shelf products. In addition, a higher resolution digital camera can be utilized to increase the resolution of the image processing technique.

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