

MEASUREMENT OF DRILLING BURR BY IMAGE PROCESSING TECHNIQUE

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1. Introduction

Drilling operations are used as the most common machining processes for making circular holes to parts. Because of plastic deformation of the workpiece during drilling, drilling burrs are generated at both sides of the entrance and exit of machined workpieces. In particular, the burr size at the exit side tends to be large, which requires deburring processes to finish the parts. The deburring processes are additional machining operations, consequently it results in an increase of machining costs. Therefore, the drilling technique that requires few or no deburrings must be a key for reductions of machining costs. It is important to study the mechanism of the burr formations to develop the effective drilling technique. Many experimental and theoretical studies on drilling burr formations have therefore been conducted [1]-[4].

Measurements of size and profile of every drilling burr created in the experimental studies are vital to evaluate the experimental results. Two measurement methods for the burr size have been mainly used in these studies. Direct burr measurements have been conducted with universal profile projectors. In another method, resin mold of the burr have been cut and then used for indirect burr measurements by universal profile projectors. These methods require inconvenient processes and much time to measure.

The purpose of this work is to develop an effective measurement technique for drilling burr profiles; a burr thickness and height. The present paper describes simple and convenient measurement technique of the drilling burr profiles and a developed drilling burr measurement system based on image processing techniques. Measurement tests using the developed system have then been conducted. An outline of the technique and the developed system will be described with measurement results in the following sections.

2. Measurement Method

Figure 1 shows a schematic of the setup consisting of a measured burr specimen and four mirrors. An image of the measured burr specimen is taken with a CCD camera located right above the burr specimen. A feature of the present measurement method is in the method for taking side images of the burr specimen. A key idea of the measurement method is to take image of the side surfaces of the burr by means of the set of four mirrors, in which the angle between mirror surface and setup base is 45 degrees, located around the measured burr. In this case, images of four side surfaces of the burr are projected to upper direction by the mirrors. Consequently, both images of top and side surfaces of the burr can be taken by CCD camera, simultaneously. An original three-dimensional burr image can be therefore transformed to a two-dimensional image, which is effective to avoid complicated calculations of three-dimensional image data. A rod with circular cross section is inserted into the drilled hole of the specimen in order to shut out the

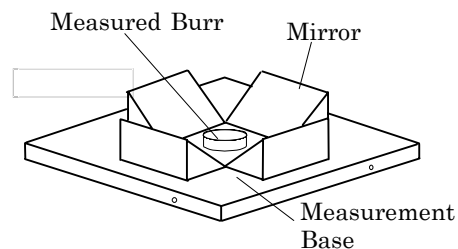


Fig.1 Burr Setup for Measurement

opposite side surface of the burr for convenience in the following calculations.

3. Calculation of Burr Thickness and Height

Figure 2 shows a flowchart of a series of calculations for burr profile measurements. In advance of an analysis of the burr profile at a last step of the calculations, conventional image processing techniques such as the binary image processing, the noise reduction and the labeling are applied for measured image data. Top surface and four-side surface images of the burr profile are obtained as shown in Fig. 3(a). The binary image processing is applied for the measured image data. Examples of binary imaged burr profiles are shown in Fig. 3(b). Here, each image as shown in Fig. 4 is then named as I, II, III, IV and V, respectively. After the noise reduction and the labeling process, the labeled images of the burr; I, II, III, IV and V; are analyzed at the final step.

A two-dimensional coordinate system in Fig. 4 is then defined for the analysis of the binary imaged and labeled burr profiles. Burr height and thickness are calculated based on the defined coordinate system. By the image processing techniques, the pixels corresponding to the burr areas become 'black', whereas all other pixels become 'white'. Analyzing the area I, the burr thickness can be given by the length between point A and B. Burr heights are obtained from the analysis of the pixel of each area labeled as II, III, IV and V. In this case, the burr thickness is given by length between point C and D in the case of the area II, for example.

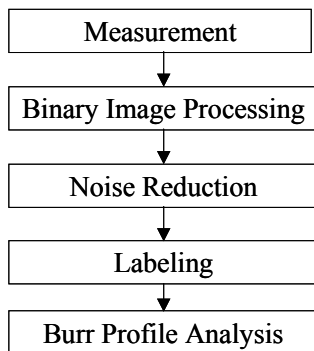
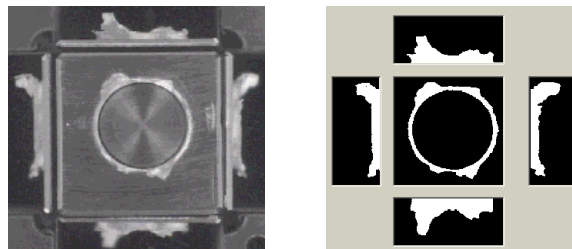


Fig. 2 Flowchart



(a) Original Burr Image (b) Binary Imaged Burr

Fig. 3 Sampled Burr Image

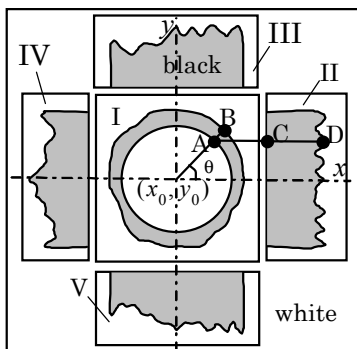


Fig.4 Coordinate System for Analysis

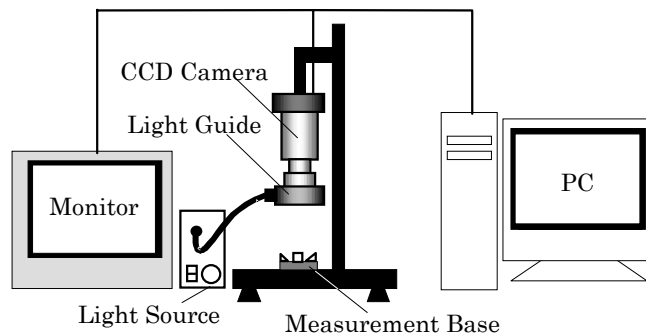


Fig.5 Schematic of Measurement System

4. Measurement System

4.1 Measurement Instrument

Figure 5 shows a schematic of the developed measurement system. A measured specimen is set on a designed base in which four mirrors are fixed at particular positions. Consequently, whole side surface images of the burr specimen on the base are projected to upper direction. Controlled light is supplied to the measured burr through optical fiber cables from a light source device. A CCD camera is fixed right above the measured burr. A taken burr image is recorded in a computer memory and then analyzed by the developed software. A resolution of measured burr image using the system is approximately 40 μm .

4.2 Measurement Accuracy

Total measurement accuracy of the system depends on the accuracy of both the measurement process using developed instrument and the analyzing processes using developed software. The accuracy of each process has been examined. Simple objects have been measured and analyzed instead of actual drilling burrs in these tests.

Accuracy of the analyzing processes has first been examined using a simple image data. For the test, precise image data was made as a model of actual drilling burr. The modeled burr image is an ideal uniform burr with 1.81mm burr thickness and height. Calculated results are given in Fig. 6 (a) and (b), respectively. Average values of the analyzed burr thickness and height are 1.84 mm and 1.81 mm. Each calculation error is 30 μm and 0 μm in average.

Similarly, accuracy of the measurement processes has been examined using a specimen as a model of an actual drilling burr with ideal uniform burr. A thickness and a height of the model are 1.93 mm and 2.0 mm, respectively. Calculated results are shown in Fig. 7(a) and (b). Average values of calculated burr thickness and height are 1.875 mm and 2.037 mm. Each calculation error is 55 μm and 37 μm .

5. Measurement of Drilling Burr

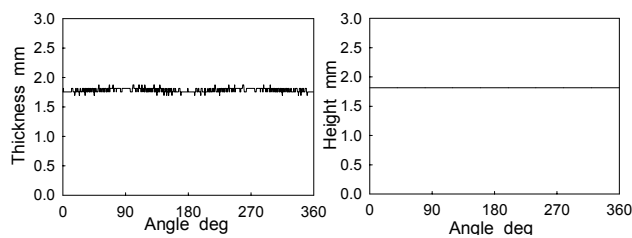
Figure 8(a) shows an example of a measured drilling burr. Using the developed instrument, both a top surface image and four side surface images have been obtained as shown in Fig. 8(b) and then have been analyzed by the developed software. Calculated burr thickness and height are given in Fig. 9(a) and (b), respectively. The standard deviations of the calculated burr thickness and height are 0.254 mm, 0.258 mm, respectively. In contrast, another burr as shown in Fig. 10 has been also measured and the result is given in Fig. 11(a) and (b). In this case, the standard deviations of the calculated burr thickness and height are 0.071 mm, 0.057 mm, respectively. It is considered that uniformity or other features of the burr profiles can be represented by these standard deviations or other statistical values. Using these values, for example, it is possible to investigate repeatability of the drilling burr formation by same machining condition and classify types of created burrs such as “uniform-type burr” and “crown-type burr”, in more objective ways.

6. Summary

A measurement method for drilling burr profile was presented and a measurement system was developed. The measurement method is based on image processing techniques. In particular, a set of mirrors is used to take side surface images of measured burrs. Measurement accuracies of the measurement system and results of actual drilling burr measurement tests are presented. Developed system will be a useful tool for studies on drilling burr.

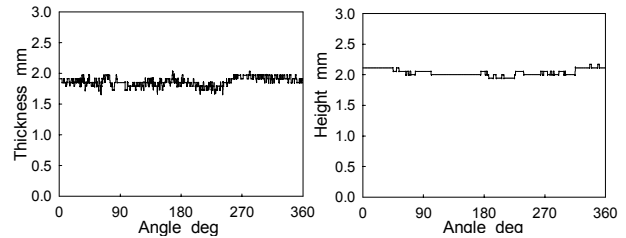
References

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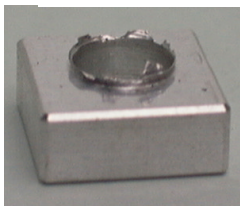
(a) Burr Thickness (b) Burr Height

Fig. 6 Calculated Profile
(Measured Object: Image Data)

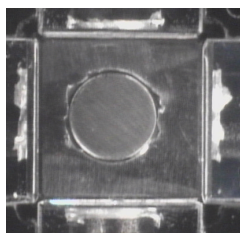


(a) Burr Thickness (b) Burr Height

Fig. 7 Calculated Profile
(Measured Object: Burr Model)



(a) Burr Sample



(a) Projected Burr Image

Fig. 8 Measured Burr

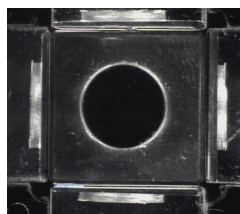
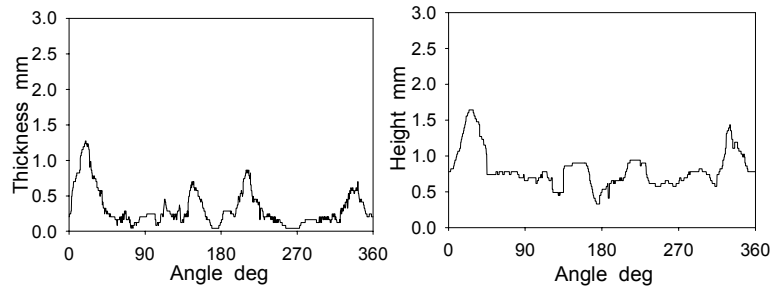
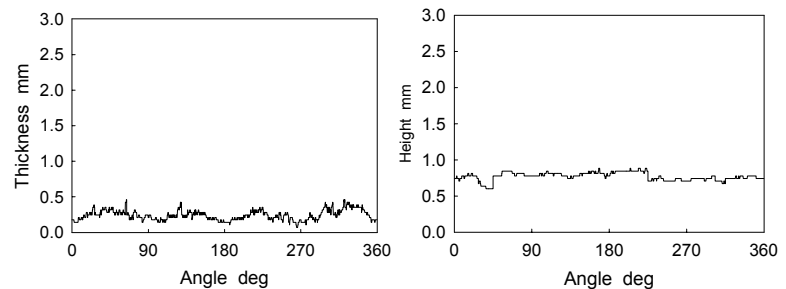


Fig. 10 Projected Burr Image



(a) Burr Thickness (b) Burr Height

Fig. 9 Calculated Burr Profile
(Measured Object: Actual Burr)



(a) Burr Thickness (b) Burr Height

Fig. 11 Calculated Burr Profile
(Measured Object: Actual Burr)