

Development of Effective Measurement Method for Burr Geometry

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ABSTRACT

Triangulation method, conoscopic holography method and interferometry method are analyzed for effective measurement of micro burr geometry, which is formed in micro drilling. To select proper sensor, cylinder with 0.5mm diameter is measured and the result shows that conoscopic holography method is effective for measuring highly inclined surface. Burr with 1.0mm height and 30 μ m height are measured by all methods. As a result, the conoscopic holography method is proved to be most proper method for measuring micro burr. A program for 3D display of measured burr is developed. A system for automatic burr measurement is developed. Burr measurement system is composed of laser sensor, X-Y table, controller and 3D measurement program.

Key Words : Burr Measurement, Triangulation method, Conoscopic holography, Interferometry method

1. Introduction

Burr is formed as a result of plastic deformation in metal cutting and blanking operation, which is undesirable in manufacturing and has great influence on the accuracy of the parts. To remove or prevent these burrs effectively, burr must be measured with

accuracy. For the burrs formed in machining are irregular and very sharp in shape, it is usually very difficult to measure burr accurately. If the geometry of burr is measured properly, the proper deburring method or processes can be recommended.

Burr measurement method can be classified into contact and non contact method. In contact method, some difficulties are confronted due to the irregular and sharp shape of burr. When height gage is used for measuring burr height, plastic deformation at the tip of burr reduced the height due to the spring force in ductile materials. When stylus is used, the probe is liable to be broken due to the sharp edge of burr. In this research, non contact measurement methods are applied[1].

Among non contact measurement method, triangulation method and conoscopic holography method use laser as light source. White light is used as source in interferometry method. In the case of micro burr formed in micro drilling or in fine blanking, not all the non contact method can be used for measurement due to the very thin and sharp edge of burr[2]. In interferometry method, the distance between interference patterns becomes too small to be measured when measuring sharp edge. In measurement using laser, laser beam spot size and the diffuse reflection at the edge of burr determines the measuring performance. Therefore it is necessary to determine proper laser sensor according to the size and shape of burr.

In this paper, drilling burrs are measured using triangulation method by laser, conoscopic holography method and interferometry method. After comparing the characteristics of each method, it turns out that conoscopic holography method is most properly applied for small burr measurement. To visualize and quantify the burr geometry from the measured raw data, a program is developed using Visual C++. Specific burr measurement system is composed of the XY table with the sensor for position control and the developed program.

2. Characteristics of Optic Sensors

Laser triangulation, interferometry method using white light source and conoscopic holography method is used for burr measurement experiment. According to the size and geometry, proper specification of sensors must be determined.

2.1 Laser triangulation method

The triangulation method using laser as light source is applied with sensor LK031 produced by Keyence. The beam spot size is $30\ \mu\text{m}$ and measurement range is $\pm 5\text{mm}$ as represented in Table 1. The light emitted from laser diode is collected on CCD through transmitted lens as shown in Fig.1 According to the change of the height of the object, the reflection angle changes and the peak point of light intensity of beam on CCD also changes. The CCD detects the movement of the peak point of beam spot and calculates the displacement, which is recognized as the burr height respect to reference surface

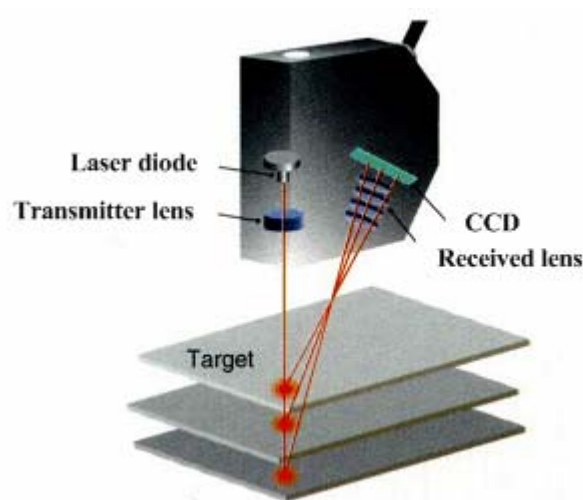


Fig. 1 The principle of laser triangulation method ^[3]

2.2 Interferometry method using white light

As light source, white light is used in interferometry method. Scanning for interference is conducted along the normal direction to the surface. The light from the source is splitted into two ways. One is reflected on the mirror which is fixed and another is reflected on the surface of object. By moving the object precisely with nanometer scale, the interference pattern appears over the specified area for measurement. The intensity of the pattern becomes largest when the difference of the phases of two lights along two paths becomes zero. This position will be the relative height to mirror surface[4,5]. Fig.2 shows the schematic representation of measurement principle of interferometry method, Accura, which is produced by Intekplus[4].

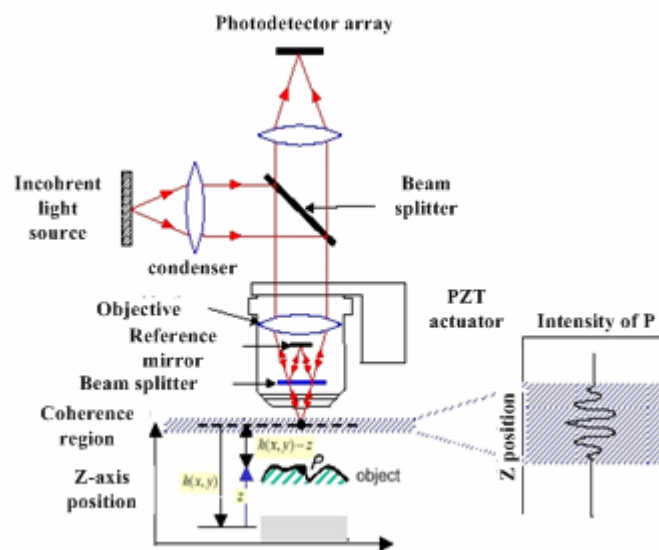


Fig. 2 The principle of white-light scanning interferometry method [4]

2.3 Conoscopic holography method using laser

In classical holography an interference pattern is formed between an object beam and a reference beam using a coherent light source. The object beam and the reference beam propagate with the same velocity but follow different geometrical paths.

However in conoscopic holography the separate coherent beams are replaced by the ordinary and extraordinary components of a single beam traversing a uni-axial crystal. This produces holograms, even with incoherent light, with fringe period that can be measured precisely to determine the exact distance to the point[6,7].

Conoscopic module is composed of two discs type polarizer, uni-axial crystal between discs and CCD as shown in Fig.3. The first polarizer disc splits the reflected beam into two orthogonal beams. Each beam passes through the birefringent medium with different velocity due to the different refraction behavior. The second polarizer merges the ordinary beam and extraordinary beam. Phase difference is caused by the difference of velocity due to the different refraction, which produces interference pattern and recorded in CCD. The height of the object can be calculated by measuring the diameter of the concentric circle of the interference pattern.[7]

In conoscopic holography, the objective lens can be changed according to the size of object. For this experiment, two kinds of lenses with 16mm and 25mm focus length are used. For the conoscopic holography method, Conoprobe sensor made by Optimet is used as specified in Table 1.

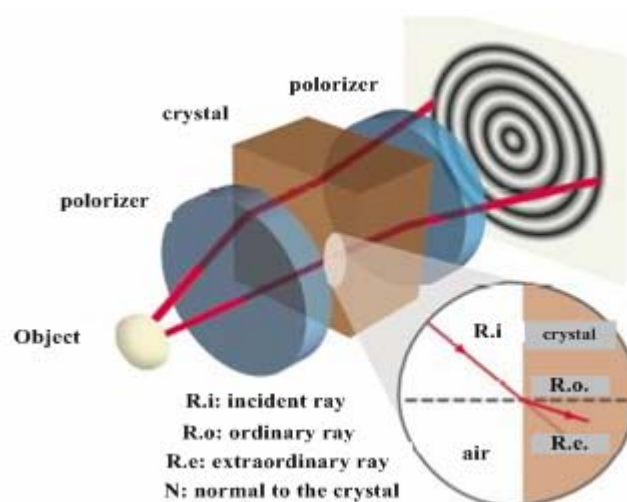


Fig. 3 Schematic illustration of conoscopic module [7]

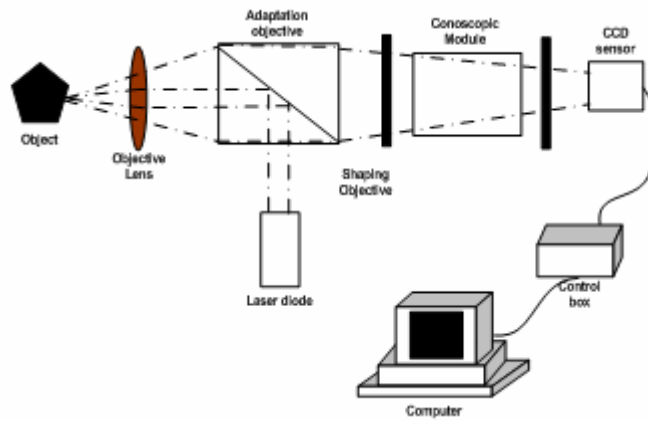


Fig. 4 Measurement system of conoscopic holography

Table 1 Specifications of Sensors

Sensor	Spot size	Range
Keyence LK031 (Triangulation method)	30 μ m	+/- 5mm
Accura (Interferometry method)	-	Tens of μ m
Conoprobe 25mm (Conoscopic holography)	22 μ m	1.8mm
Conoprobe 16mm (Conoscopic holography)	8 μ m	0.5mm

3. Measuring Experiment and Analysis

3.1 Comparison of measurement performance using cylinder with 0.5mm diameter

To evaluate the performance of each method in measuring burr geometry, a cylinder with 0.5mm diameter is used to observe the characteristics of the measured data. The effect of the change of surface slope on the measurement performance is evaluated. In Fig.5, measurement results are represented. By comparing the results with the original circular shape, the performance can be evaluated. In the case of Keyence sensor by laser

triangulation method, the signal from the side of cylinder cannot arrive to CCD because the slope is very high. When Keyence sensor is used for measuring the surface with high slope, the reflected light is scattered due to diffuse reflections as shown in Fig.6. It is predicted that the reflected beam from the surface with high slope cannot return to the CCD receiver that the signal at this part is lost or unstable as shown in Fig.5. In contrary, Conoprobe sensor by conoscopic holography method can measure the shape of the cylinder very accurately. Two kinds of objective lenses are used, 16mm and 25mm focus length. Even the 16mm case shows more high resolution and reduced measuring ranges, there is no big differences between them in both cases. Accura sensor by inteferometry method cannot measure properly due to the limited measuring ranges, 0.25mm.

From this simple experiment, it is proved that conoscopic holography sensor can be used for measuring the burr geometry with high slope. And this comparison method can be used for selecting proper sensors by changing the size of diameter considering the burr size.

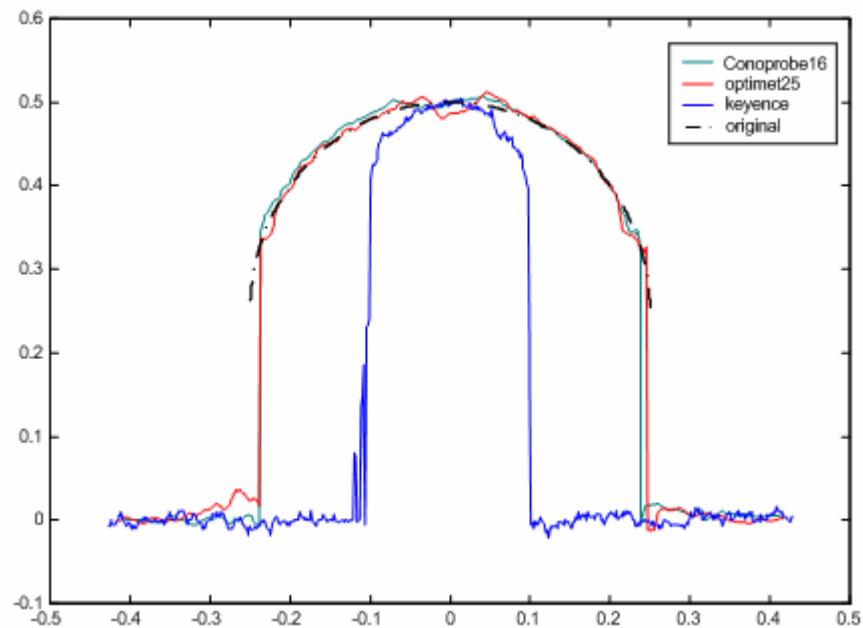


Fig. 5 Comparison of the measurement results for the cylinder with 0.5mm diameter

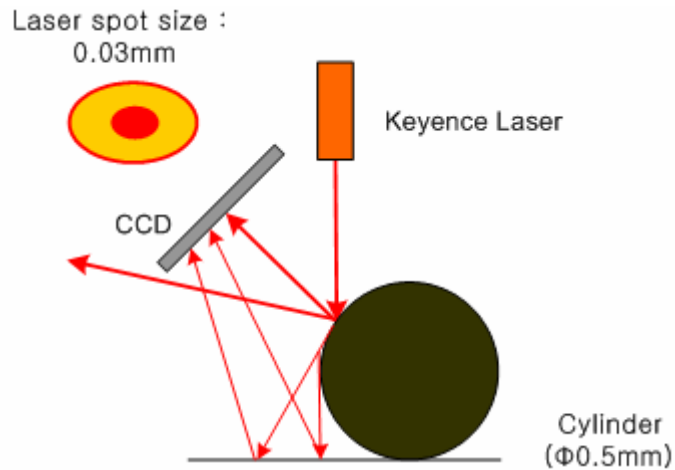


Fig. 6 Schematic illustration of measurement principle for the cylinder using triangulation method

3.2 2D representation of drilling burr

According to the measurement range, several kinds of drilling burrs are classified and measured. For the burr more than 1mm in height, Conoprobe sensor with 25mm objective lens and Keyence sensor are used. In Fig.7 the data from Keyence sensor in measuring the large burr are unstable at the surface with high slope of burr, which represent the fact that this sensor is not proper for measuring the surface with high slope. The data from Conoprobe sensor shows very stable and accurate geometry of burr.

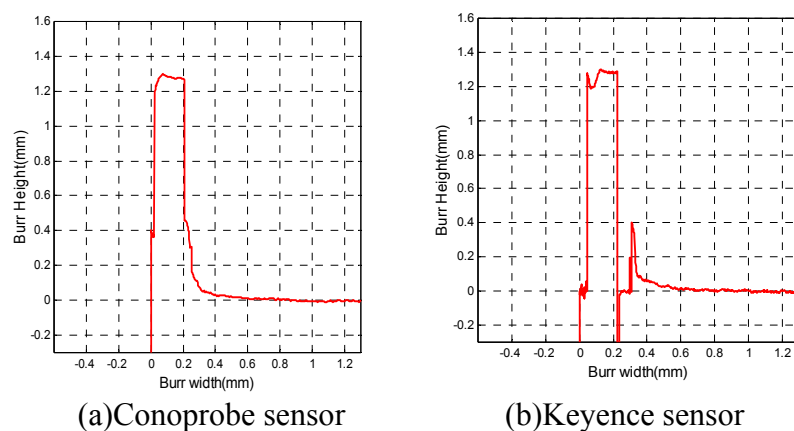


Fig. 7 Measurement of drilling burr larger than 1mm by Conoprobe and Keyence sensor

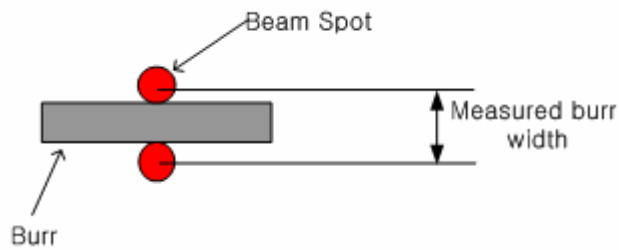


Fig. 8 Schematic illustration of widening effect of burr width according to the beam spot size

In measuring micro burr which is less than $30\mu\text{m}$ in this experiment, the size of beam spot affects on the width of burr rather than burr height. Because the location is detected by the peak point of the reflected beam on CCD, this peak point is affected by the beam spot size as shown in Fig.8. When the beam spot size increases, the width of burr becomes larger. In Fig.9(a), width of burr is detected as 0.2mm using Keyence sensor, which is larger than 0.1mm by Conoprobe sensor in Fig.10. The widened value may include also the effect by the unstable signal at the surface with high slope as mentioned before. The measured burr height is about $25\mu\text{m}$. When the burr is very thin and sharp in geometry, the sensor with larger beam spot size than burr width cannot catch the sharp edge precisely. For more accurate measurement of micro burr geometry, the beam spot size must be small as much as possible.

Accura sensor by interferometry method using white light loses the data at the end of edge because it cannot produce the interference pattern properly due to the high slope at edge of burr as shown in Fig.9(b). Conoprobe sensor by conoscopic holography shows the measurement result in Fig.10. The height of burr is about $20\mu\text{m}$, which is similar to the result from Keyence and the width of burr is 0.1mm in both cases with 16mm and 25mm focus length. It can be realized from the measurement result that Conoprobe sensor is proper for measuring small scale burr.

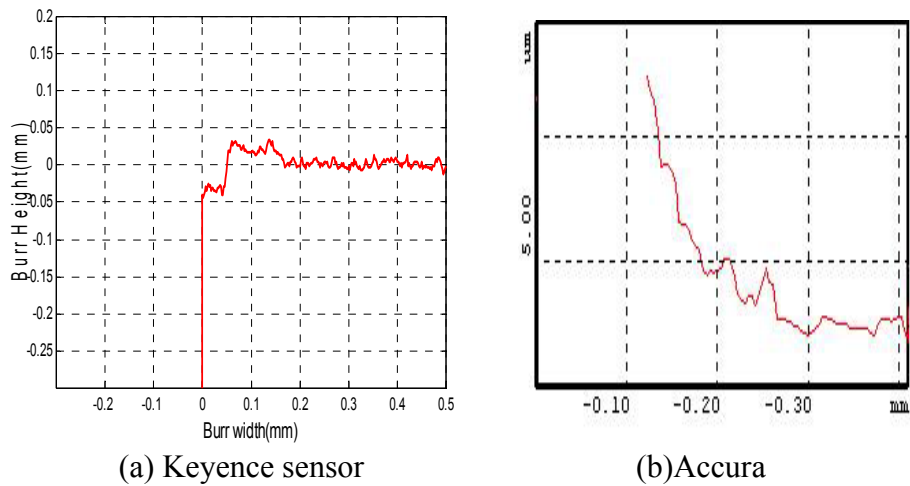


Fig. 9 Measurement by Keyence and Accura for small drilling burr

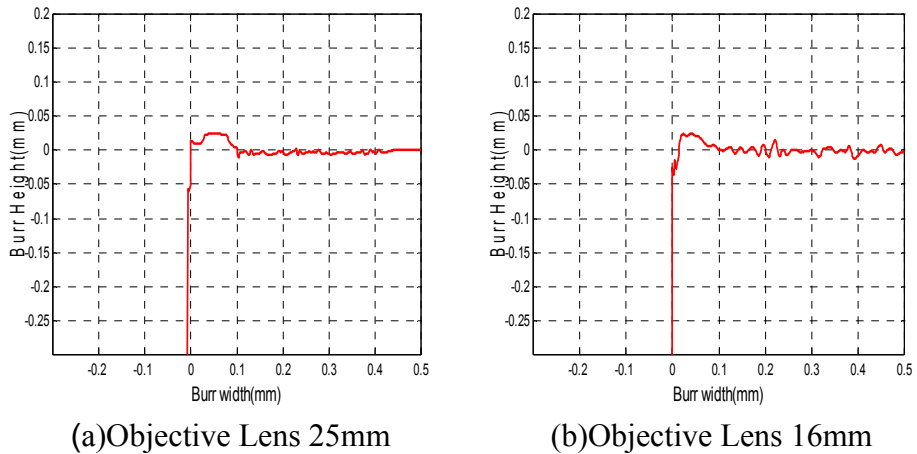


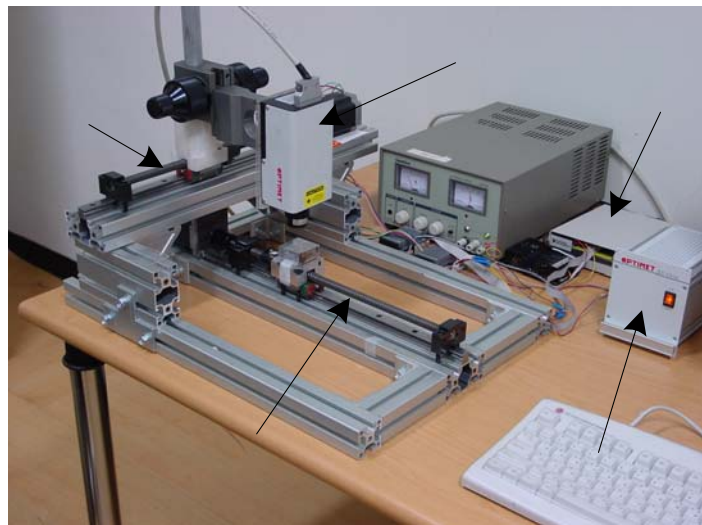
Fig. 10 Measurement by Conoprobe for small drilling burr

4. Development of Burr Measurement System

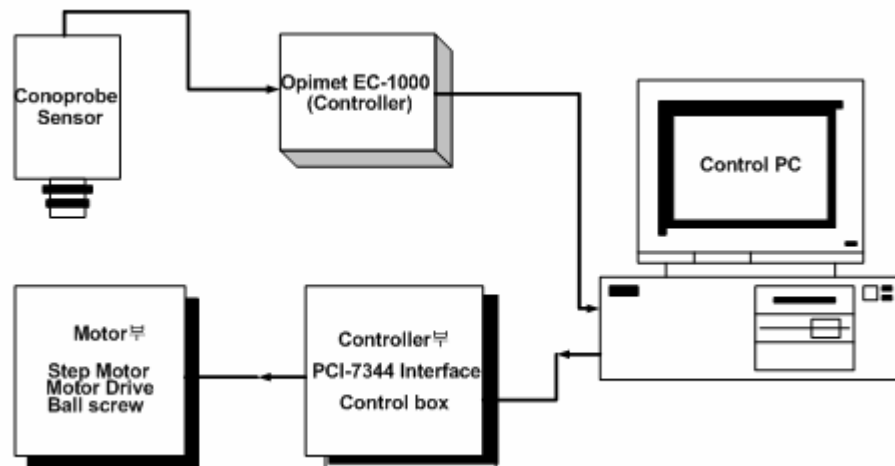
4.1 Specification of 3D burr measurement system

Burr measurement system is composed of Conoprobe sensor and controller, X-Y precision table, controller for motor control and burr measurement program as shown in Fig.11. A Conoprobe sensor by conscopic holography method is used , which is proper for burr measurement as mentioned before. The raw data are acquired by scanning the XY

table in X and Y directions. A program is developed to represent the burr shape into 2D and 3D. For motion control of step motor and control of Conoprobe in specified program, Visual C++ is used. A program for displaying burr geometry is developed using Measurement Studio based on MFC. NI-7344 made from NI company is used for controller of step motor.



(a) Over view of burr measurement system



(b) Layout of measurement system

Fig. 11 Photograph and layout of burr measurement system

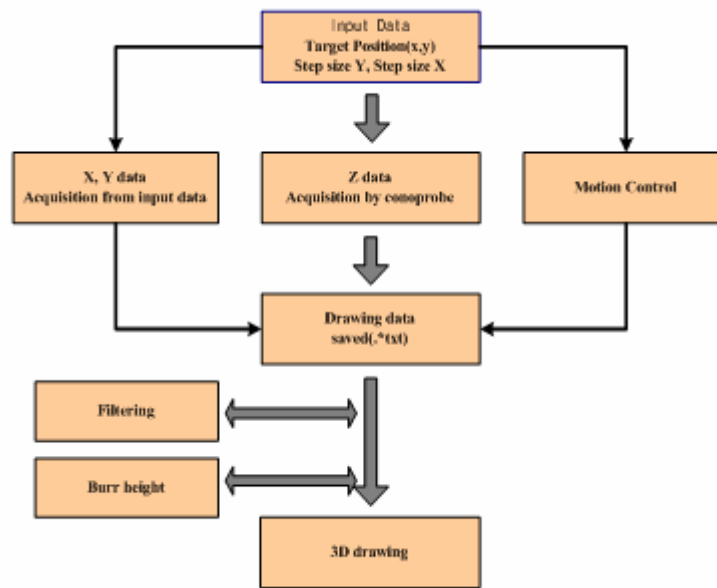


Fig. 12 Structure of burr measurement program

Conoprobe sensor generates the pulses for measurement according to the signal from encoder in motion controller. According to the pulses for measurement, the sensor measures the height, which is the Z-value of position data of surface. The position of each motor at the moment of measurement is used for X and Y value of surface. Using the measured raw data, the surface is represented in 3D. The data from outside of the measurement range are deleted by filtering in program. To check the reliability of the measured data, a signal/noise ratio is always evaluated. If the ratio is less than 45%, the signal is considered as error due to diffuse reflection on surface. The structure of the program is represented in Fig.12. As input, the measurement range and step sizes in X and Y direction is given. According to the step sizes, measuring positions are decided. The motor controller controls the step motor to measure at the decided position. At each point the burr height is measured as Z value. The position data of X and Y step motor are used as X and Y value of 3D surface. With the 3D measured data, filtering and checking of the signal/noise ratio are necessary for 3D representation.

4.2 Experiment for measuring drilling burr

For 3D measurement of drilling burr, measurement ranges are decided. In Fig.13 sensor moves along scan area 1 for measuring and returns along scan area 2 and moves along scan area 3 for next measurement. 8mm is input as ranges for X and Y direction measurement. As step sizes in each direction, 0.002mm and 0.05mm are used respectively. These values are determined by predetermined feed velocity and sampling rate.

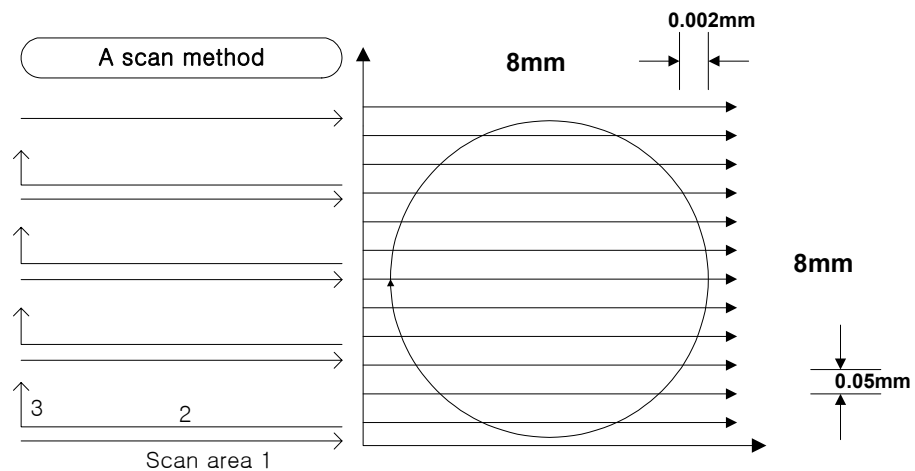


Fig.13 Schematic diagram of scanning track for automatic burr measurement

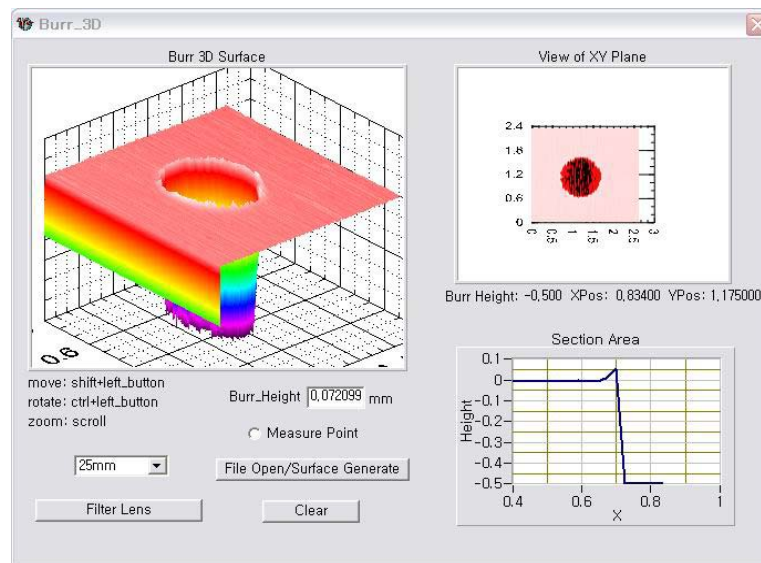


Fig. 14 3D display of drilling burr measured by burr measurement system

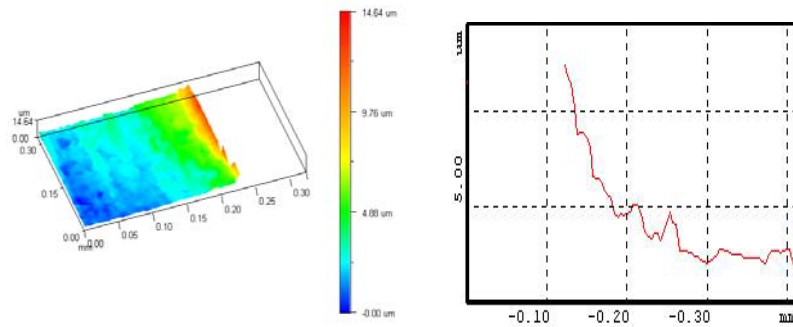


Fig. 15 3D display of drilling burr measured by Accura

Conoprobe sensor with 25mm objective lens is used. X-Y table with 1 μ m resolution is used. Using the developed program, the measured data are displayed in Fig.14. Among the measured burr height, the maximum value is displayed and the average burr height is also can be calculated. From the X-Y plane representation of the measured data, it is possible to specify the interested location of burr. Along the specified line, the cross section of the burr geometry is displayed at the left side of bottom in Fig.14. The maximum size of measured burr is 0.07mm and the burr height at specified location is about 0.05mm as shown in Fig.14. In Fig.15, 3D representation of burr measured by Accura interferometry sensor is displayed. Due to the limited measuring range, only a part of burr can be measured. It cannot measure the edge of sharp burr because the interference pattern cannot be produced properly as mentioned before.

5. Conclusions

For measuring the sharp edges of burr, Conoprobe sensor by conoscopic holography method is recommended by comparing the measurement performance with other non contact measurement methods. Laser triangulation method produces unstable signal in measuring the surface with high slope. Interferometry method also fails in producing

proper interference pattern at sharp edge near the top of burr. Smaller beam spot size must be guaranteed for precision measurement. In the case of Conoprobe sensor, beam spot size changes according to the focus length of objective lens. As a first step of development of burr measurement system, proper sensor must be determined considering measuring range and accuracy.

Specific burr measurement system is developed. It consists of Conoprobe sensor and sensor controller, XY table and motion controller and burr measurement program. A program for automatic measurement system is developed. The measuring ranges and step sizes are input. 3D and 2D display of the measured data and quantitative representation of burr size are available. Statistical management of burr data is possible using data base system.

Acknowledgement

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