Development of a Measuring Instrument for Grinding Wheel Peripheral Shapes

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Abstract

In the present paper, a precise measuring method of contours of rotating grinding wheel is proposed, in which a wire is used as a contact probe and wire touch signals to rotating wheel are detected by an acoustic emission sensor. Utilizing a wire as a probe, new wire part can be provided as a probe in every touching to wheel surface by reeling it. In this study, a driving system feeding the probe in the direction parallel to the wheel axis is developed, and wheel peripheral shapes are measured in a surface grinding machine. As the test results, it is clarified that rotating wheel peripheral shapes can be measured with the resolution in micron order. Furthermore, it is confirmed that this measuring method can be applied to monitor protruding abrasive grains causing scratches in grinding operations.

Key words: Grinding Wheel Peripheral Shape, AE sensor, Wire, Measuring Instrument.

1. Introduction

Since geometrical shape of grinding wheel periphery is directly copied to workpiece surface in grinding operation, it is very important to confirm that wheel periphery is generated as required. From such a viewpoint, authors have proposed a precise measuring method of wheel peripheral shape [1]. In this method, a wire is used as a contact probe to rotating wheel. Although the wire surface is ground by direct contact to rotating wheel, new part of wire as a touching probe is supplied by reeling wire before every contact. And then, probe geometry is not affected by contact to wheel. Their contact signals are monitored by an Acoustic Emission i.e. AE sensor. In reference [1], a measuring system of wheel peripheral shape is developed, in which coordinate system of numerical control machine is applied to obtain the wheel geometry for NC machines. In this study, a new measuring equipment for ordinary grinding machines without NC control is developed and its performance is clarified.

2. Measuring equipment and system

Figure 1 shows a newly designed measuring equipment. It consists of monitoring part for detecting wheel periphery and driving part feeding the monitoring part to wheel radius and rotating axis directions. The monitoring part consists of an AE sensor, a spool reeling wire, a wire guide and a stepping motor. Since this part is designed compact i.e. 220 mm high, 380 mm width and the weight is 50N, it can be located on tables of ordinary surface grinding machines.

Figure 2 shows a setup of the measuring system. An X-Y stage and a stepping motor are controlled by a personal computer in this system.
Measurement of wheel shape is carried out in the following procedure. The wire is fed upward by Y stage and approaching to wheel surface. A touching signal emitted by AE sensor due to their contact is rectified and transferred to a discriminator. In the discriminator, contact signal is evaluated whether on or not based on previously determined threshold signal level. In case of that contact signal is detected, upward feeding of Y stage is stopped. Simultaneously, the coordinate of X and Y at contact point are transferred from the feed controller to the personal computer. After that, Y stage is fed downward and the wire is reeled by stepping motor in order to supply a new part to contact point as a new probe.

On the other hand, X stage is feed to the previously determined next monitoring point in the wheel rotating axis direction, where Y stage is fed upward. Repeating this procedure, a series of contact coordinates are obtained. Finery, compensating the wire radius, the wheel shape can be obtained.

3. Comparison with conventional copy method

In order to evaluate the measuring performance of the proposed method, measured results are compared with the results of conventional copy method. Conventional one is a method in which grinding an easy to grinding material, the surface of ground workpiece is measured with a contour measuring device. Since this method is easy and reliable, it is applied in this study.

On the other hand, a precise monitoring method of the distribution of abrasive grains height in rotating wheel surface is developed and their monitoring results are compared with the measuring results in the proposed wire method. Figure 3 shows a schematic diagram of monitoring the distribution of abrasive grains. In this method, a flat workpiece is ground under the depth of cut $D$. A grinding mark depending on the surface geometry of wheel is made in the ground surface as shown in below in Figure 3. In this method, the surface roughness of wheel is expanded in the mark remained in the surface of ground workpiece.

The relation between actual roughness height of wheel $\Delta$ and copied height on workpiece $X$
can be easily calculated by geometrical relations as follows.

\[ R^2 = (X + B)^2 + (R - D)^2 \] ………… 1

\[ (R - \Delta)^2 = B^2 + (R - D)^2 \] 

\[ X^2 + 2\sqrt{(R - \Delta)^2 - (R - D)^2} X + \Delta^2 - 2R\Delta = 0 \] ………… 2

Where, \( R \) is a wheel radius, \( D \) is a depth of cut and \( B \) is a distance from center to point \( b \) in Figure 3. From Equation (2), the expanding ratio, \( X/\Delta \), can be obtained as a function of \( \Delta \) as shown in Figure 4. This is a calculated example when \( 2R \) is 200 mm. According to this calculation, it is easy to monitor the geometric shape of wheel surface in 20 magnification.

4. Measurement of wheel peripheral shape

Measured examples of a wheel peripheral shape by the proposed wire method and the copy method are shown in Figure 5(a). These measurements are carried out under the machining conditions as shown in Table 1. In these curves, two groves can be seen. They are previously made by a dresser in order to compare two measuring results. It can be confirmed that these two curves coincide each other well.

Figure 5(b) shows the deviation of these two curves. Dotted two lines in both side show the level of \( \pm 10.0 \) \( \mu \) m. Deviation curves are less than \( \pm 10.0 \) \( \mu \) m, it means that the proposed wire method can measure the detail of wheel surfaces as precise as the copy method.

5. Measurement of abrasive grain height of wheel surfaces

The precise monitoring method of the distribution of abrasive grains height described above is applied to a wheel after grinding, and the microscope photograph is shown in Figure 6(a). In this figure, grinding marks of each abrasive grain can be monitored clearly. In this experiment, since wheel diameter \( 2R \) is 200 mm and wheel depth of cut \( D \) is 120 \( \mu \) m, the magnification rate is 20 from the calculation result shown in Figure 4. As shown in this figure, it can be seen that the height of abrasive grains are not average, and some of them are protruding about 20 \( \mu \) m. Since these
protruding grains cause scratching of ground surfaces in grinding, they must be monitored carefully.

Figure 6(b) shows the measuring results of the same part by the proposed wire method. This result shows that the proposed wire method can measure the wheel surface geometrical shape precisely. As these experimental results, it is clarified that the method proposed in this study can be applied to precise monitoring of abrasive grains in rotating wheel surface.

6. Conclusions

A measuring instrument for rotating wheel peripheral shapes using a wire touching probe is developed for ordinary surface grinding machine. Its measuring performance is evaluated experimentally. The results as follows are obtained.

1) This equipment can be applied to an ordinary surface machine which is not numerically controlled, and it may be used other type of grinding machines.

2) Using this equipment, protruding abrasive grains in rotating wheel surfaces can be monitored clearly. It means that it may be apply to analyze the generating algorithm of workpiece surface topography in grinding operations.

Reference