Monitoring of Grinding Wheel Wear in Surface Grinding Process by Using Laser Scanning Micrometer

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ABSTRACT

This paper deals with the monitoring of grinding wheel wear in surface grinding process. A monitoring system, which makes use of a laser scanning micrometer, is developed to measure the circumferential shape as well as the axial profile of grinding wheel. The monitoring system is applied to surface grinding processes. The experimental results show that the developed monitoring system is useful not only for monitoring the amount of wear in grinding wheel but also for evaluating the quality of ground surface and determining proper dressing time for the grinding wheel.

Keywords: Grinding Wheel Wear, Surface Grinding, Plunge Grinding, Traverse Grinding, Laser Scanning Micrometer(LSM),

1. Introduction

Grinding is acknowledged as one of the most important machining processes to guarantee the surface quality of workpiece. It is well known that grinding is essentially performed by the interaction between the grinding wheel and workpiece In consequence, the grinding process is significantly affected by the grinding wheel condition. Among others, grinding wheel wear is very important because it gives rise to a certain amount of machining errors by causing the difference between the apparent depth-of-cut and the actual depth-of-cut[1]. On the other hand, on-machine measurements for grinding wheel have been often made [2-9]. On-machine measurements of grinding wheel condition not only increase the grinding efficiency but also enhance the grinding accuracy by helping to compensate the positioning error due to wear. In addition, monitoring of grinding wheel wear makes it possible to indirectly evaluate the quality of ground surface and determine the dressing time for grinding wheels

This paper proposes a monitoring method for grinding wheel wear by using a laser scanning micrometer (LSM). A monitoring system is developed and applied to estimate the grinding wheel wear by measuring the circumferential shape and the axial profile of grinding wheel in two surface grinding processes. The experimental results show that the monitoring system is useful in surface grinding processes. The surface roughness of ground surface is also measured along with the grinding wheel wear to investigate the relation between the grinding wheel wear and the surface roughness of workpiece. The experimental investigation shows that the grinding wheel wear is closely tied with the surface roughness of workpiece. It is also illustrated that a proper dressing time can be revealed by statistical evaluation of measured grinding wheel wear.

2. Grinding Wheel Wear Measurement System

Fig. 1 shows a conceptual diagram for the LSM, which is used through the entire experiment. Various types of commercial LSM's are available. The specifications of the LSM used in this paper are described in Table 1. The LSM has a long service life and it is simple and accurate enough to measure the grinding wheel wear on the machine.

In the LSM, the laser beam emitted from a diode laser is scanned by a polygon mirror, which is rotating at a constant rotational speed. Then the plane mirror and collimation lens make the scanned beam to be a parallel beam. The parallel beam arrives at a convex lens, which focuses the beam into a photodetector. The coordinates of edges of an object are measured by detecting the instant when the scanned laser beam is protected by the object. There are three kinds of optional interface systems to communicate with other devices, e.g. RS232C, BCD, analog output channels.

Fig. 2 shows the experimental set-up for monitoring of grinding wheel wear, in which the measured analog output signal from the LSM is converted into digital data by using an ADC board. Then, statistical evaluation for the digital data is made to provide information for the grinding wheel condition. It should be noted here that a measured signal is a height averaged over the axial length equivalent to the width of the laser beam (approximately 0.1~0.2 mm).

3. Monitoring of Grinding Wheel Wear

3.1 Measurement of surface profile in profiled grinding wheel

As a preliminary test, the developed system is applied for measuring the profile of a profiled grinding wheel, which is used for grinding of linear motion guide rails. Fig. 3 shows the profile of the grinding wheel measured along the axial direction of the grinding wheel. Each point on the profile is obtained by taking average over 1,000 samples measured along the circumference of the grinding wheel at every 100㎛ position in the axial direction.

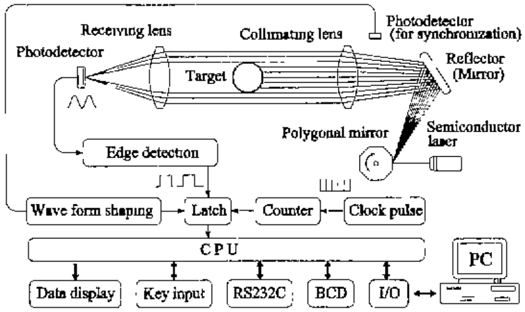

Fig. 1 Schematic for the LSM(Controller : LS-5500, Laser head : LS-5040)

Table 1 Specifications of LSM

Range of measurement	0.2～40㎜
Instantaneous accuracy	±2㎛
Mean accuracy	±0.3㎛
Laser scanning rate	1200 scans/s
Lase scanning speed	121㎧
Range of laser scanning	46㎜
Distance between source and receiver	160±40㎜
Laser source	0.8㎽, 670㎚

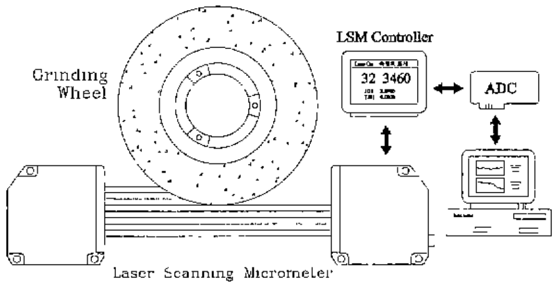

Fig. 2 Schematic diagram for measurement of grinding wheel wear using laser scanning micrometer

3.2 Monitoring of grinding wheel wear in surface grinding process

The developed system is applied to monitoring of grinding wheel wear for two kinds of grinding processes: plunge grinding and traverse grinding.

3.2.1 Experimental set-up

Fig. 4 illustrates an experimental set-up for

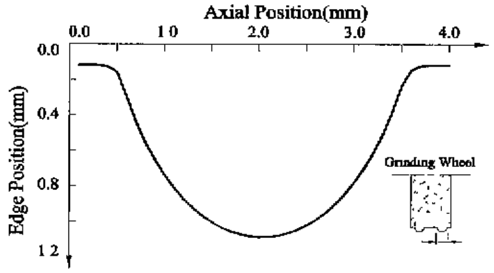

Fig. 3 Measured cross section of profiled grinding wheel

measuring grinding wheel wear by using the LSM. Care should be given to maintain a good alignment between the table and the LSM to avoid the possible measurement error. The rotational speed of the spindle remains constant at 1700rpm during grinding. In order to measure the circumferential profile more accurately, an auxiliary motor is implemented to be able to run the spindle at 30 rpm. In this case, the sampling rate can be retained to be 1000 samples/rev. The circumferential profile is measured repeatedly at every 100㎛ movement in the axial direction. Table 2 describes the basic experimental conditions.

3.2.2 Compensation of table feeding errors

The measured surface profile of the grinding wheel has an apparent slope. This is believed to occur due to the angular positioning error taking place in the table movement. To identify and compensate the slope error, a laser interferometer (HP5529A) is used to measure the angular errors associated with table motion. Fig. 5 shows the angular errors for the table movement. It is found that the pitch error is significant and influencing the measurement. The identified pitch error at the sensor location is used to remove the slope error out of the measured axial profile for the grinding wheel. The yaw error is not so significant and does not affect the measured profile.

3.3 Grinding wheel wear monitoring in plunge grindng

Although the LSM is able to measure absolute coordinates of an object, it is convenient to make use of a reference to measure the amount of wear in grinding wheel. In plunge grinding, the width of workpieces is kept to be 26㎜, small enough for a part of the grinding wheel surface not to participate in grinding. The average height of the part of grinding wheel surface not engaged in grinding is used as the reference to identify the wear by comparison with the other part of the grinding wheel surface. The first measurement begins after dressing is done on the test grinding wheel. Then, measurement is repeated every 10 times grinding by 10㎛ depth-of-cut, i.e. a set of measurement is made after every 100㎛ depth-of-cut grinding is done.

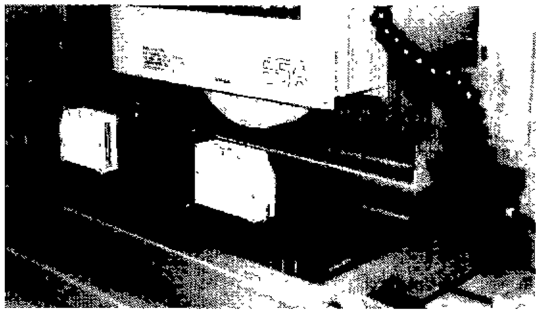

Fig. 4 Experimental setup for monitoring of grinding wheel wear in surface grinding machine

Table 2 Basic grinding conditions

Grinding wheel	WA90JmV
Width of wheel	38㎜
Cutting speed	Φ240㎜ × 1700rpm
Table feeding speed	0.154㎧
Grinding method	Up-Grinding
Workpiece	SCM4

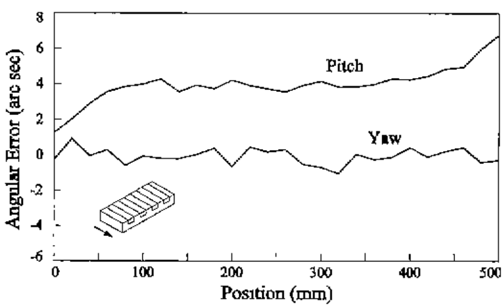

Fig. 5 Angular motion errors of feeding table for the grinding machine

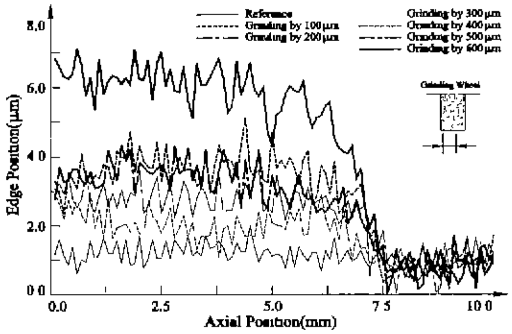

Fig. 6 Wear of grinding wheel in plunge grinding process

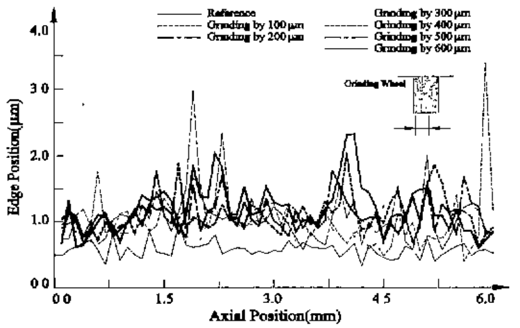

Fig. 7 Standard deviation of grinding wheel prominence in plunge grinding process

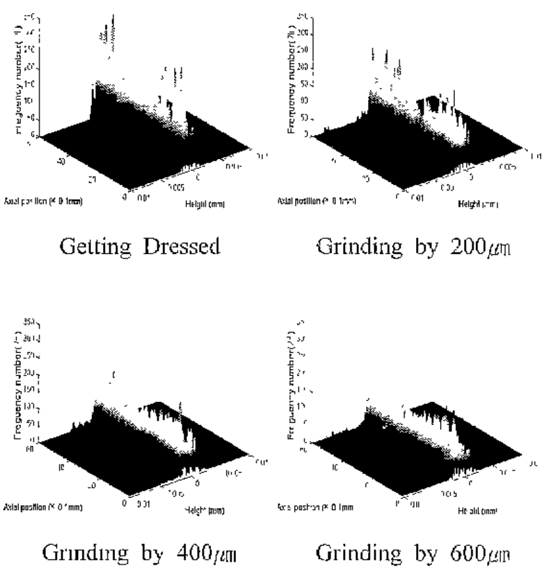

Fig. 8 Change in histogram of grinding wheel prominence along the axial direction due to grinding wheel wear in plunge grinding process

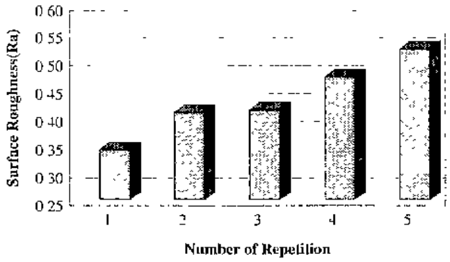

Fig. 9 Change of surface roughness in plunge grinding process

Fig. 6 shows the axial surface profile that is obtained by taking average over 1,000 samples acquired along the circumference of the grinding wheel at every 0.1 mm in the axial direction. The slope error residing in the measured profile is eliminated. In Fig. 6, the horizontal axis beyond 7.5 ㎜ indicates the reference part of grinding wheel, which does not take part in grinding. Fig. 6 clearly shows that the grinding wheel wear is getting large with the grinding progressed. Thus, if the predetermined depth-of-cut is given to the machine without any knowledge about actual dimensions of the grinding wheel, the grinding wheel wear surely introduces a certain amount of machining error into the grinding process.

It is also observed in Fig. 6 that the grinding wheel wear increases abruptly at a specific condition. In the beginning, most of the grinding wheel wear occurs due to the fracture or wear in abrasives. However, the abrupt wear in the final stage of experiment implies that the grinding wheel wear is depending mostly upon fall-out's of abrasives due to either loading or the increase of the grinding force by wear[9-11]. This phenomenon seems to be useful to detect the appropriate dressing time as discussed in the reference[1].

Fig. 7 shows the standard deviation of the circumferential profiles. As the grinding process progresses and the grinding wheel wear increases, the standard deviation also increases. Fig. 8 show the variation of grinding wheel prominence histogram with the grinding progressed. In the beginning of grinding, the prominence histogram looks concentrated around the mean value, while the histogram is getting scattered as the grinding progresses. It can be deduced from Figs. 7 and 8 that the grinding accuracy and surface roughness get worse with the increase in the standard deviation of grinding wheel prominences. On the other hand, the surface roughness for the workpiece is measured by a hand-carry stylus, along with the measurement of grinding wheel wear. Surface roughness values measured on six different locations are averaged to provide representative values for the surface roughness. Fig. 9 shows the measured surface roughness in plunge grinding. The surface roughness increases as the grinding wheel gets worn.

3.4 Grinding wheel wear monitoring in traverse grinding

There are various grinding methods that are chosen based upon the shape and target accuracy of the workpiece. Here, traverse grinding is performed and monitored on the grinding wheel wear. The dimensions of the workpiece are 500㎜× 50㎜ and the cross feed and depth-of-cut are 2.5㎜ and 10㎛, respectively. Measurement is made everytime 10㎛ depth-of-cut is ground. Unlike plunge grinding, all part of the grinding wheel is engaged in the current grinding process. To use as the reference, a step is made along the circumferential surface of the grinding wheel. In traverse grinding, leading abrasives grind the workpiece roughly and the consecutively following abrasives successively grind the workpiece like fine grinding. Consequently, the leading part of the grinding wheel undergoes more significant wear than the other part.

Fig. 10 shows the grinding wheel wear measured everytime 10㎛ depth-of-cut is ground. The leading part of the grinding wheel has far more significant wear than the other part as already discussed. As the grinding progresses, the amount of wear definitely increases and the grinding wheel surface profile gets biased.

Fig. 11 shows the standard deviation of the circumferential profile data, which appears to be proportional to wear. Fig. 12 shows histograms for the grinding wheel prominences. The progress of grinding makes the histogram diverse as in the case of plunge grinding.

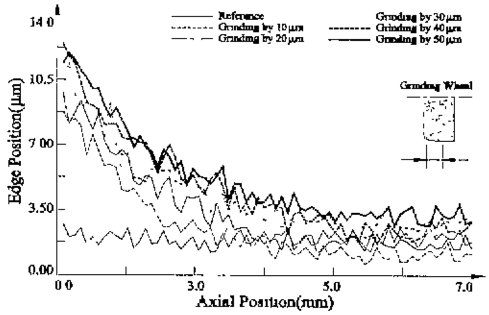

Fig. 10 Wear of grinding wheel in traverse grinding process

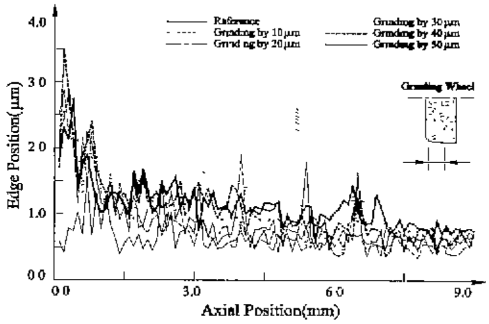

Fig. 11 Standard deviation of grinding wheel prominence in traverse grinding process

From Figs. 11 and 12, it can be deduced that the wear in the leading part of the grinding wheel is mostly due to fall-outs of the grinding wheel abrasives.

Fig. 13 shows the surface roughness measured during the traverse grinding in the same manner as in the plunge grinding process. Unlike the plunge grinding process, the surface roughness is getting better and seemingly converges to a certain value as the grinding is repeated. This is due to the fact that the rear part of the grinding wheel plays a role in finishing the surface.

4. Conclusions

In this paper, a monitoring system for grinding wheel wear is developed and applied to surface grinding processes. A laser scanning micrometer (LSM) is used as the sensor. The developed system is applied to two surface grinding processes: plunge grinding and traverse grinding.

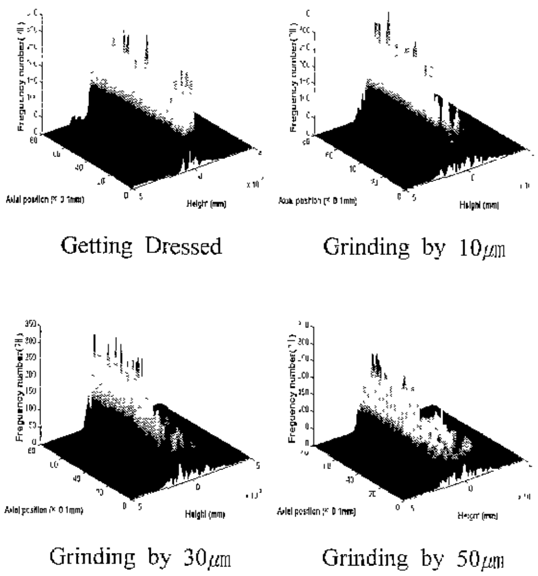

Fig. 12 Change in histograms of grinding wheel prominence along the axial direction due to grinding wheel wear in traverse grinding process

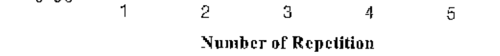

Fig. 13 Change of surface roughness in traverse grinding process

Through the experiments, the monitoring system is proved to be useful for measuring the grinding wheel wear in surface grinding. It is also proved that the statistical evaluation on the measured data provide some useful information on the surface quality and the dressing time

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