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# Online monitoring of Grinding Aspherical Surface by Acoustic Emission Signal

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**Abstract**
To monitor the grinding process and improve efficiency of aspherical surfaces production, on-line monitoring of the grinding process by acoustic emission (AE) was studied. Firstly the material removal rate and average material removal rate in cross grinding for aspherical surface was derived. Secondly, the grinding and monitoring experiments were conducted. The experimental results showed that the surface quality and amplitude of AE signal at different position on aspherical surfaces was different because of different material removal rate at different position on aspherical surfaces. Therefore, the surface quality of aspherical surfaces could be monitored or predicted by AE sensor. At last, the fitting curve was indicated that the AErms of grinding process could be used to predict the surface quality of aspherical surface preliminarily.

aspherical surface, monitor; acoustic emission; surface quality

## 1. Introduction

For aspherical optical component could be used to achieve new functions, such as integration of optical refraction, reflection and transmission, wave conversion, and so on, which is inaccessible to be realized by spherical optical component, therefore, scientific value and promising applications of aspherical component is increased considerably [1]. However, aspherical surfaces are difficult to process, many key technologies of important products and equipment are difficult to break through because of its low processing accuracy and efficiency [2]. So far, fixed AE sensor was mostly only used for monitoring plane grinding process, which could not be used for monitoring aspherical surface grinding process with two rotary spindle. In this paper, rotary AE sensor was used to monitor aspherical surface grinding process. Material removal rate of grinding aspherical surface was analyzed to establish bridge between surface quality and AE signal firstly. AE monitoring experimental system was established secondly. And then, grinding experiments of aspherical surfaces were carried out to explore the AE characteristic of aspherical surfaces grinding process, relationship among material removal rate, AE signal and surface quality.

## 2. Material removal rate

In the grinding process of aspherical surfaces, the material removal rate in cross grinding for aspherical surface is expressed as [3]：

$$MRR' = \pi x_i n a_p F \qquad (2)$$

In Eq.(2), $x_i$ is changed from 0 to the max maximum following the interpolation curve motion from center to edge in grinding process, $n$ is the workpiece rotary speed, $a_p$ is the depth of cut, $F$ is the feed rate. Therefore, with fixed grinding parameters, the material removal rate is different at different position on the aspherical surface, which at the edge of workpiece is much more than that at the center.

The average material removal rate is used to evaluate the efficiency of the ground aspherical surface, and it is described as [3]:

$$MRR_{av} = V_w/T_g = (S_w \cdot a_p)/(L/F) \qquad (3)$$

where $V_w$ is the removal volume of the ground aspherical surface, $T_g$ is the time of finishing one whole aspherical surface, $S_w$ is the acreage of aspherical surface, $L$ is the arc length of aspherical surface.

## 3. AE monitoring technical solution

Fig. 1 shows the flow chart of AE signal transmission. The rotary AE sensor was installed on the bolt which used to fix the wheel, and the stator AE sensor was installed on the displacement vernier device in vertical direction, which can keep the space is below 1mm between the end faces of two sensors. Besides, when grinding, the AE signal is tansmitted from ① to ② through abrasive layer and metallized substrate of wheel, and arrived at rotary AE sensor ③ through the grinding spindle and the bolt, then the AE signal is tansmitted from the sending end of rotary sensor to the receiving end of stator sensor through air by wireless transmission, hereafter, it is tansmitted to the computer through controller and data acquisition card by cable transmissions [4]

## 4. Grinding experiments and results

The trued D64 diamond wheel was used for grinding aspherical surface. Here, the grinding experiments were carried out to investigate characteristic of AE signal in grinding aspherical surface, the relations between and among material removal rate, surface quality and AE signal.

According to the Eq.(3), the average material removal rate are only related to the depth of cut and feed rate, and irrelevant to the workpiece rotary speed and wheel speed. Hence the grinding parameters with various depth of cut and feed rate are tabulated in Table 1.

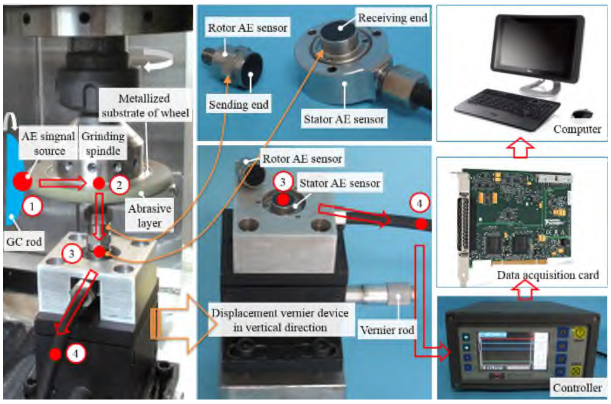


**Figure.1** The flow chart of AE signal transmission[4]

**Table. 1** Grinding parameters

| No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| $a_p$( μ m) | 100 | 100 | 100 | 150 | 150 | 150 | 200 | 200 | 200 |
| $F$(mm/min) | 45 | 30 | 15 | 45 | 30 | 15 | 45 | 30 | 15 |
| $N_s$(rpm) | 6045 | | | | | | | | |
| $n$(rpm) | 385 | | | | | | | | |
| $MRR_{av}$(mm³/min) | $4.5\times S_w/L$ | $3\times S_w/L$ | $1.5\times S_w/L$ | $6.75\times S_w/L$ | $4.5\times S_w/L$ | $2.25\times S_w/L$ | $9\times S_w/L$ | $6\times S_w/L$ | $3\times S_w/L$ |

Fig.2 shows SEM photo and roughness at different position of an aspherical surface (Exp. No.4). As shown in Fig.2 (a), The grinding traces at center was more uniform and finer than at edge of aspherical surface. The roughness Ra and Rz measured by profilometer was both decrease from center to edge as shown in Fig.2(b). The results demonstrated that surface quality decreased from center to edge of aspherical surface, and one of the most important reasons is that the material removal rate at the edge of aspherical surface was much more than that at the center.

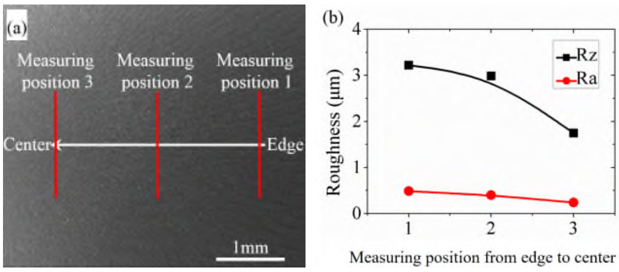


**Figure 2** SEM photo and Roughness from edge to center of one aspherical surface (a) SEM photo and arrangement of measuring positions (b) Roughness

Fig.3 shows $AE_{rms}$ in grinding process of all aspherical surfaces in Tab.1. As shown in Fig.3, $AE_{rms}$ was increased with rising average material removal rate in general. The reason is that collision between material of workpiece and wheel was enhanced with increasing average material removal rate. Besides, though the average material removal rate of No.2 (No.5) and No.9 (No.1) was equal, the $AE_{rms}$ from grinding process of No.2 (No.5) was stronger than No.9 (No.1). Meanwhile, the average material removal rate of No.8 was more than No.1, but the $AE_{rms}$ from grinding process of No.8 was similar as No.1. The reason is that the effect of equal average material removal rate with different combination of depth of cut and feed rate on $AE_{rms}$ was different. This indicated that $AE_{rms}$ with more depth of cut and slower feed rate was less than which with less depth of cut and faster feed rate when average material removal rate was equal.

Fig.4 shows effect of $AE_{rms}$ maximum value on roughness of aspherical surface. As shown in Fig.4, roughness of Rz was increased with rising maximum value of $AE_{rms}$ in general. Besides, though maximum value of $AE_{rms}$ of No.1 and No.8 was equal, the roughness of Rz from grinding process of No.1 was more than No.8. The reason is that the effect of equal $AE_{rms}$ maximum value with different combination of depth of cut and feed rate on roughness of Rz was different. This indicated that roughness of Rz with more depth of cut and slower feed rate was less than which with less depth of cut and faster feed rate when maximum value of $AE_{rms}$ was equal.

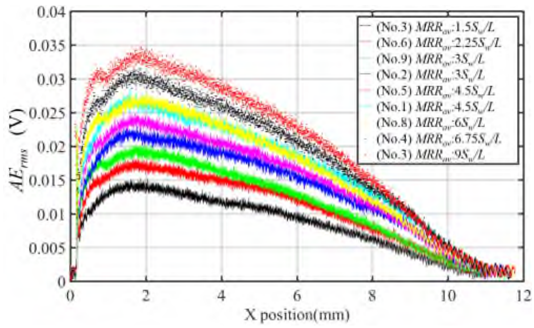


**Figure.3** AErms in grinding process of all aspherical surfaces

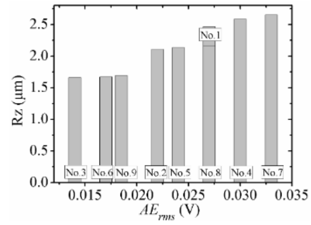


**Figure 4** Effect of AErms on roughness of aspherical surface

Fig.5 shows the fitting line between maximum value of $AE_{rms}$ and roughness of Rz based on the original maximum value of $AE_{rms}$. The fitting line was:

$$y=57.7538\cdot x+0.7427 \quad (5)$$

where $y$ is roughness of Rz, $x$ is maximum value of $AE_{rms}$. As shown in Fig.5, the original data well surround the fitting line. Therefore, maximum value of $AE_{rms}$ could be used to predict the roughness of Rz in grinding aspherical surfaces within limits.

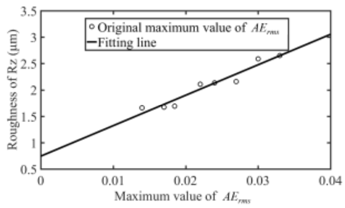


**Figure 5** Fitting line between AErms and roughness of Rz

## 6. Conclusion

Different from the equal AE signal strength in a plane interpolation grinding process, the AE signal decreased from maximum to 0. Aspherical surface quality decreased from center to edge of aspherical surface. $AE_{rms}$ was increased with rising material removal rate in general. The effect of equal average material removal rate with different combination of depth of cut and feed rate on AErms was different. The effect of equal AErms maximum value with different combination of depth of cut and feed rate on roughness of Rz was also different.

### References


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