Ultraprecision Form Control of Aspheric Mirror with ELID Grinding

Sei MORIYASU1), Hitoshi OHMORI1), Jun-ichi KATO2), Hajime KOGA3)and Masaru OHMAE3)

1)The Institute of Physical and Chemical Research (RIKEN), Itabashi, Tokyo 173, Japan
2)The Institute of Physical and Chemical Research (RIKEN), Wako, Saitama 351-01, Japan
3)Nippon Pillar Packing Co., Ltd., Production Technical Center, Sanda, Hyougo 669-13, Japan

1. Introduction

Soft X-ray optics has rapidly been advanced and applied to many fields. Soft X-ray mirrors could be one of the most important devices which gives a great influence on the performance of a whole system. Soft X-ray mirrors might require for higher surface quality and form accuracy than any other parts. But it involves considerable difficulty to achieve these demands. Especially it is the most difficult to produce aspheric mirrors precisely. In this report a new aspherical form control method is proposed to realize a high form accuracy regularly and efficiently by using ELID grinding technique[1], which is widely known as a method which produces high precision ground surfaces in a short period of time. Experimental data of ground SiC ceramics which is a material of the basement of a soft X-ray mirror is shown below.

2. Aspherical Form Control System

To achieve high form accuracy it is necessary to establish a system in which; the form of the workpiece after grinding is measured, from this data the form error deviated from the planned form data is calculated, and then the next NC data is generated by the feedback of the calculated form error data.

Figure 1 and Figure 2 show the outline of the form control system proposed in this paper. After an axis-symmetrical form is ground by ELID grinding, the form is measured with a measuring instrument. A digital contracer measured with a stylus which comes in contacts with the surface of the workpiece was used to measure the profile of the workpiece. The form error data after calculating the measured data is then filtered, the compensated NC data is generated, and according to these new NC data, the new form is ground. Form error is decreased by the repetition of these procedures.

2.1 Data Compensation

The following shows the method for generating new compensated data from the old NC data and the measured data.

First, the workpiece is ground according to a given NC data to create the form. After that, form error from the planned form is calculated. The measured data after proper filtering is newly registered as form error data for compensation. The pair consisting of the NC data and the form error data is made for all NC data points. The NC data and the form error data on the NC point x in the ith grinding are defined as $zx^{(i)}$ and $ex^{(i)}$ respectively. The *(i+1)*th NC data, $z_x^{(i+1)}$, is expressed generally by formula (1) where the coefficient is constant or determined by the NC point x, the number of grinding times, the work rotation speed, feedrate, grinding wheel velocity, the ith NC data $z_x^{(i)}$, etc.

$$z_x^{(i+1)}=z_x^{(i)}-K\cdot e_x^{(i)} \qquad (1)$$

Here the algorithm which gives the average of the past data as the new NC data is considered. The (i+1)th NC data can be expressed as the next formula.

$$z_x^{(i+1)}=\sum_i (z_x^{(i)} - e_x^{(i)}) / n \qquad (2)$$

(n: Number of reference data)

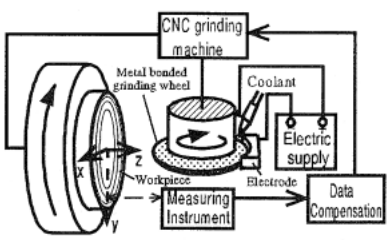

Fig.1.Aspherical Form Control system

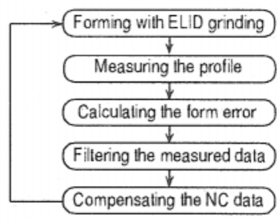

Fig.2 Form Control Sysetm Flow

For example when the past two pairs of data are referred to, (i+1)th NC data can be expressed as formula (3).

$$z_x^{(i+1)} = \{(z_x^{(i)} - e_x^{(i)}) + (z_x^{(i-1)} - e_x^{(i-1)})\}/2 \qquad (3)$$

The more pairs of past data are referred to, the less the influence of the ith measured data of the next NC data, thus realizing robust control of errors. But the referring to more pairs of past data requires more numbers of compensations, which leads to reduced convergent efficiency. The number of past data referred to should thus be decided properly from the degree of the scattering of data and the speed of the convergence of the form error.

2.2 Data Filtration

Measured data contains some noises in addition to the real signal from the measured object. The main causes of the noises are the change of the sensor sensitivity caused by the disturbance of the measuring environment, electrical drift by the temperature, etc. Consequently, it is extremely important to remove these unwanted noises from the measured data to improve the precision of reforming. The high frequency component of the signal, which means the roughness of the surface processed by rough grinding, is also unnecessary for generating the compensated data. In this sense, filtering of the measured data was performed by frequency domain filtering using FFT. The cut-off frequency of the filtering was decided from the repeatability of the data and the possibility of the grinding tool to follow the form of the workpiece.

3 Experimental Procedures and Results

3.1 Experimental Procedures

The metal bonded grinding wheel to be used was trued mechanically and pre-dressed using the electrical method. After initial dressing, an experiment was conducted. In the experiment, SiC ceramics was used as the workpiece, and the #1000 cast iron bonded diamond wheel was used as the grinding wheel. The planned form was concave spherical surface with a curvature of 2m. After grinding, the form was measured with the digital contracer. The form data was fitted to the planned data with the least squares method, and the form error was calculated. These form error data was filtered with FFT. From the filtered data the compensated data was generated by the computer. According to the compensated data, a new form was ground. These procedures were repeated several times to decrease the form error.

3.2 Experimental results

The form error of 2.6μm before compensations gradually decreased up to 0.38μm after five compensations as shown Figure 3, confirming that the form control system proposed in this paper functioned effectively. Table 1 shows the repeatability of this system. Judging from the repeatability of this system, the achieved data is considerably accurate. To achieve smaller form error, it is necessary to further improve the accuracy of the measuring instrument, and to use a measuring method that does not require the workpiece to be removed from the machine but measures the form on the machine.

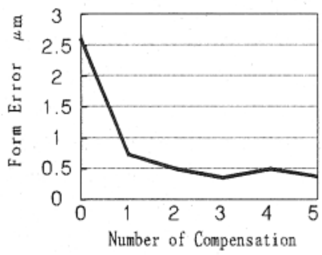

Fig.3.Change of Form Error

Table 1 Repeatability

	Standard deviation σ (3σ) μm
Repeatability of measurement	0. 03 (0. 10)
Form data scattering in a workpiece	0. 08 (0. 24)
Repeatability of grinding	0. 10 (0. 30)

4. Summary

To make aspheric mirrors for soft X-ray with high form accuracy, a new aspherical form control system by using ELID grinding was proposed. In the experiment of rough grinding, a SiC ceramics mirror with a diameter of 100mm was ground to concave spherical surface with 2m curvature, and a form accuracy of 0.38 μm was achieved after five compensations. Taking the repeatabilities of grinding and measurement into consideration, this achieved form accuracy is considerably accurate.

References

[1] H.Ohmori, Electrolytic In-process Dressing (ELID) Grinding Technique for Ultraprecision Mirror Surface Machining, JSPE, **26-4**, 273 (1992).