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Ultra-precision diamond grinding of large sized infrared aspherical lens

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Abstract
Infrared aspherical lens are widely applied in automobile, civil aviation, and space industries. The normal processing method for infrared aspherical lens is traditional polishing with low efficiency, or diamond cutting with intense wear of tools when processing large sized lens. Therefore, the ultra-precision diamond grinding technology of large sized infrared aspherical lens was researched to improve processing efficiency and surface quality. In this paper, the key technologies of grinding large sized infrared aspherical lens was investigated, including on-machine precision truing of arc-shaped diamond wheels technology, errors analysis and compensation technology for high form accuracy, and grinding parameters optimization technology for homogeneous and well surface morphology. With these technologies, multispectral CVD zinc sulphide for aspherical lens with diameter of 93.5 mm was ground with form error PV≤0.8 µm and roughness Ra <5 nm. This research gives an indication of the strategy to follow to achieve high efficiency and quality ground aspheric surfaces on brittle infrared materials.

Keywords: Ultra-precision diamond grinding, large sized infrared aspherical lens, processing efficiency, surface quality

1. Introduction

Aspheric lens have many advantages in terms of optical system optimization, spherical aberration and optical aberrations reduction of spherical lens in the collimating and refocusing optics system, quantity of optical components decreasing, weight decreasing, size reducing and integration realization[1]. Therefore, aspheric infrared lens have important and extensive application perspectives in aerospace, electrical, building, medicine, automotive, and so on. At present, the main method for mass production of aspheric infrared lens is by means of traditional abrasive polishing with low efficiency and poor product uniformity. While the ultra-precision grinding with high efficiency and technological stabilization, good product uniformity is the novel key technologies for hard and brittle materials[2].

In this paper, the key technologies of grinding large sized infrared aspherical lens was investigated, including on-machine precision truing of arc-shaped diamond wheels technology, errors analysis and compensation technology for high form accuracy, and grinding parameters optimization technology for homogeneous and well surface morphology. Finally, with these technologies, multispectral CVD zinc sulphide for aspherical lens with diameter of 93.5 mm was ground.

2. On-machine precision truing of arc-shaped diamond wheels technology

Arc-shaped diamond wheels with precision profile were usually adopted for ultra-precision grinding of aspherical surfaces[2]. A novel on-machine precision form truing of resin and metal bonded arc-shaped diamond wheels is proposed utilizing rotary green silicon carbon (GC) rod.

Fig.1 shows the ORGCR mutual-wear truing principle of arc-shaped diamond wheel. In ORGCR mutual-wear truing, the GC rod is driven by the workpiece spindle on the machine with the wheel speed n to true diamond wheel with the wheel speed N along the circular interpolation paths circularly with the feed rate v in CNC grinding system as shown in Fig.1 (a). Besides, the motion paths was designed to utilize more cylinder of GC rod to true the arc profile of diamond wheel as shown in Fig.1 (b)

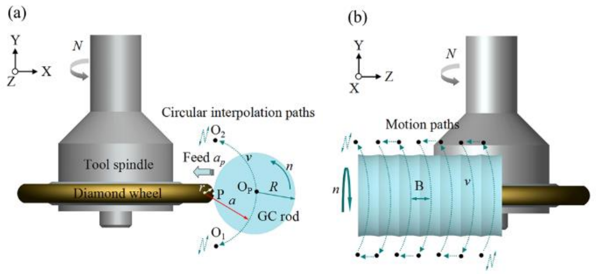

Fig.1. ORGCR mutual-wear truing mode of arc-shaped diamond wheel (a)truing mode (b)truing motion paths.

As shown in Table 1, the D3 wheel form error of 2.5µm after truing contrast of 35µm before truing. The similar truing performance also could be presented on the D7 and D15 wheels, and the optimal results of these three wheels in the experiment were displayed in Table 1.

Fig.2 shows the LSDLM photos of three wheels arc profile topography. Before truing, the arc profile topography transited wavily, and existed a lot of raised and foveate stripe on the wheel surface, as shown in Fig.2(b), (e) and (h), which certainly reduced the form accuracy of the wheel profile. After truing, the formed arc profile topography was uniform and smooth. Besides, the truing traces could be observed clearly on the metal bonded wheel surface, as shown in Fig.2(c), (f) and (i).

Table 1. Truing performance.

Wheel	Expected r	r before truing	r after truing	e_s before truing	e_s after truing
D3	6 mm	3.093 mm	5.765 mm	35 µm	2.5 µm
D7	4 mm	3.096 mm	3.867 mm	26 µm	2.8 µm
D15	4 mm	3.818 mm	4.007 mm	33 µm	3.2 µm

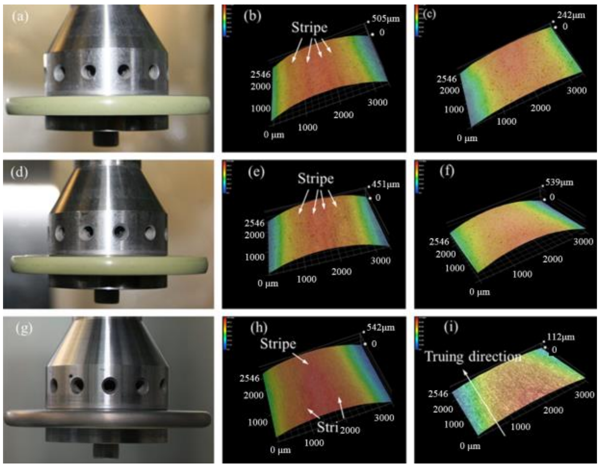

Fig.2. LSDLM photos (a) D3 wheel (b) D3 before truing (c) D3 after truing (d) D7 wheel (e) D7 before truing (f) D7 after truing (g) D15 wheel (h) D15 before truing (i) D15 after truing.

3. Errors analysis and compensation technology

Tool setting error of wheel affect form accuracy seriously, as shown in Fig.3. And tool setting error in X direction can be compensated through grinding workpiece test, on-machine measuring form error profile, calculating error and compensating grinding. Tool setting error in Y direction can be revised through truing of wheel as shown in Fig.1.

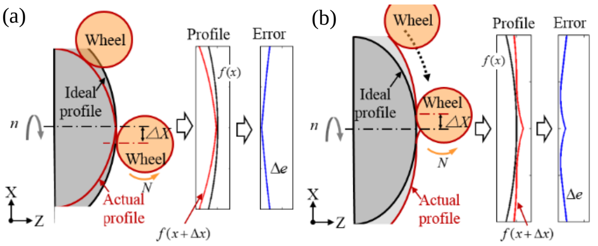

Fig.3. Tool setting error in X direction (a) not to center (b) past center.

Radius error and wear error of wheel may affect form profile as shown in Fig.4, and radius error also can be compensated as tool setting error in X direction, wheel wear error need compensated based on relationship between radius of wheel and grinding ratio in grinding process.

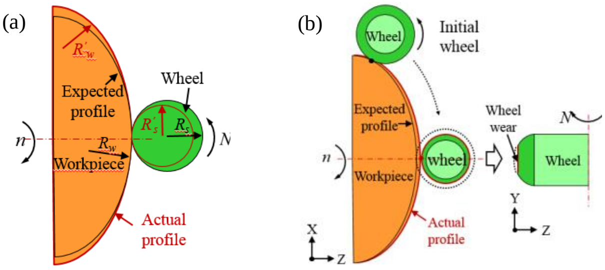

Fig.4 Wheel error (a) radius error (b) wear error

4. Grinding parameters optimization technology

Two classic kinds of grinding points distribution appear on the ground surface because of different parameters, as shown in Fig.5. One kind is remarkable grinding marks with patterned grinding points distribution as shown in Fig.5(a), another kind is the weak grinding marks with homogeneous distribution of grinding points as shown in Fig.5(b).

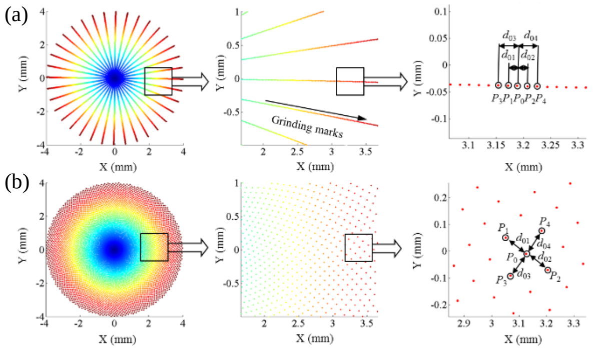

Fig.5. Simulation of grinding points (a) remarkable (b)homogeneous.

An arbitrary grinding point is chosen as research object, the distance between it and the nearest grinding point is defined as d_{01}, the distance between it and the second nearest grinding point is defined as d_{02}, and the distance between it and the third nearest grinding point is defined as d_{03}. Therefore, the discriminating standard of grinding marks can be expressed as:

$$\triangle d= (d_{03}- d_{01}) / d_{01} \tag{1}$$

The grinding marks are remarkable when Δd is close to 1, while the distribution of grinding points is homogeneous when Δd is close to 0. The grinding parameters can be optimized for homogenizing the grinding points distribution by the discriminating standard, in order to reducing the grinding marks in actual grinding process.

5. Results

With the errors compensation and optimal grinding parameters, the homogeneous ground surfaces with roughness of Ra<5 nm and high form accuracy of PV≤0.8 μm were finished by the truing wheel, as shown in Fig.6.

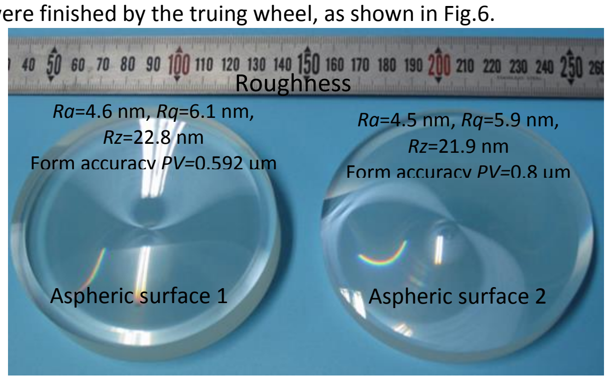

Fig.6 Ground surfaces and results

6. Conclusion

Through the three key technologies, the ultra-precision large aspheric surfaces can be obtained. This research gives an indication of the strategy to follow to achieve high quality ground aspheric surfaces on brittle materials.

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