Precision grinding and polishing of large aspheric glass lenses for digital single lens reflex cameras

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Abstract

Needs of digital single lens reflex (SLR) cameras are increasing rapidly in recent years, and the demands of large aspheric glass lenses are increasing. The small glass lenses for the compact digital cameras are molded effectively by the glass press molding process with micro ceramics molds as shown in Figure 1(a) [1, 2]. On the other hand, in the case of manufacturing large aspheric lenses made of glass such as the digital SLR camera, a series of grinding and polishing process, as shown in Figure 1(b) is more effective and more precise than the molding process. Precision grinding and polishing technologies for the complex shape of the aspheric lenses are required furthermore. In this study, a new effective and precision grinding method is proposed and developed for the aspheric convex lens. The disk type of resinoid bonded diamond wheel which edge is trued to flat shape on the machine by a metal alloy, is scanned and controlled in 3-axis (X, Y, Z) and a contact point on the grinding wheel to the workpiece is changed in order to reduce the tool local wear. As a finish process, uniform polishing method of the ground lenses by using a balloon type of polisher

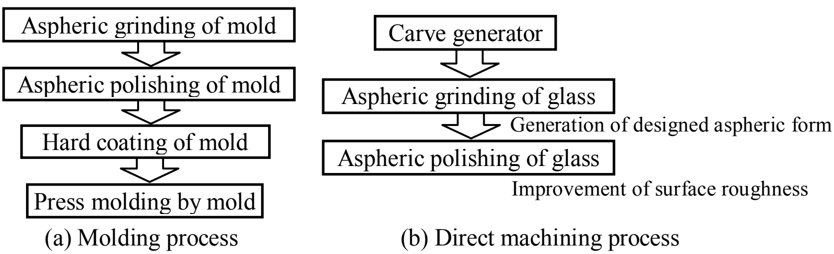
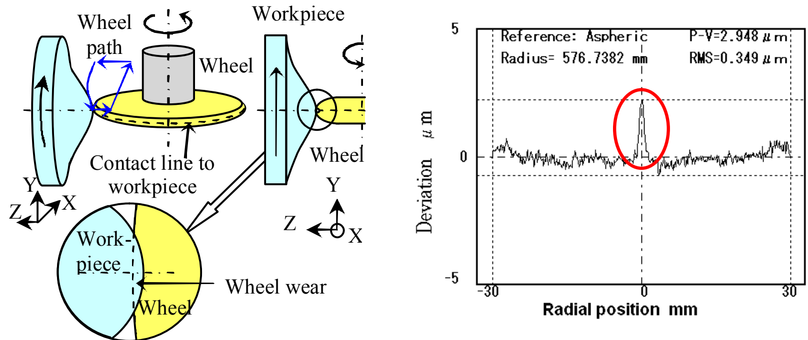


Figure 1: Mass-production process of aspheric glass lens

with high pressed air is also proposed and developed in order to increase polishing efficiency and reduce the surface roughness. By developing of the proposed grinding/polishing process, form accuracy of less than 1 µm P-V and surface roughness of 10 nm Rz (2 nm Ra) were obtained, and the total manufacturing efficiency was increased.

1 Proposed aspheric grinding method

At first the glass material is pre-ground to an approximate radius curvature by the curve generator. In the conventional finish aspheric grinding process, the designed aspheric shape is generated by the CNC aspheric grinding machine with a disk type of the diamond wheel having a round edge as shown Figure 2(a). The wheel scans in 2 axis (X, Z) and after several decades of grinding pass, the wheel will wear at the top of the wheel. Then the workpiece form error will occur in the center area of workpiece by the local wear of the wheel as shown in Figure 2(b).



(a) Conventional aspheric grinding method (b) Form error by the wheel wear

Figre 2: Conventional aspheric grinding

In this paper, a new aspheric grinding method of 3-axis control is proposed as shown in Figure 3. A flat disk shape of the wheel is used, the wheel scans in 2-axis (X, Z), and after the pass, the wheel moves in Y-axis and the grinding point on the wheel changes every grinding path in order to reduce the wheel wear.

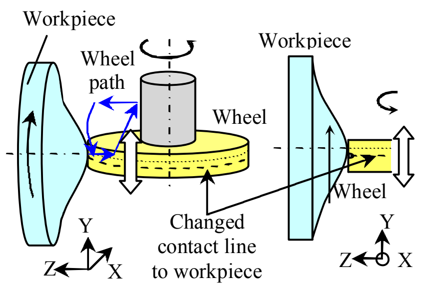


Figure 3: Proposed aspheric grinding method

2 Aspheric grinding results

Figure 4 shows the grinding set-up. The machine having air bearings and roller type slide table was 4-axis (X,Y,Z,C) controled. Table 1 shows grinding conditions. The workpiece was an optical glass and the wheel was resinoid bonded diamond. Figure 5 shows a form deviation profile and figure 6 shows a change of form deviation in grinding workpiece. Very fine form deviation was kept after 70 pass of grinding.

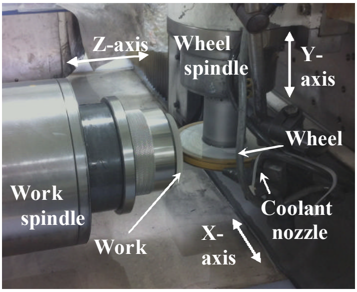


Figure 4: Grinding machine

Table 1: Grinding conditions

Workpiece	Glass
Diameter	φ60 mm
Approximate radius	550 mm, Convex
Rotational speed	500 min^{-1}
Wheel	Resinoid bonded diamond
Grain size	1200
Diameter	φ100mm×5t
Rotational speed	15000 min^{-1}
Depth of cut	3 μm
Feed rate	5 mm/min
Coolant	Solution type

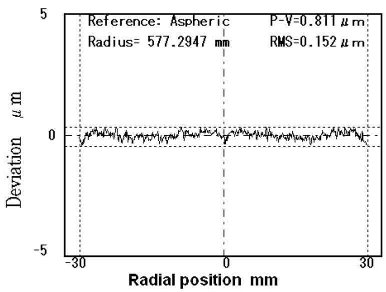


Figure 5: Form deviation of proposed grinding

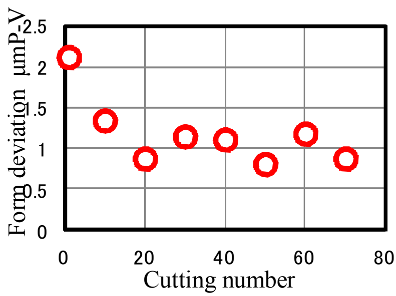


Figure 6: Change of formdeviation

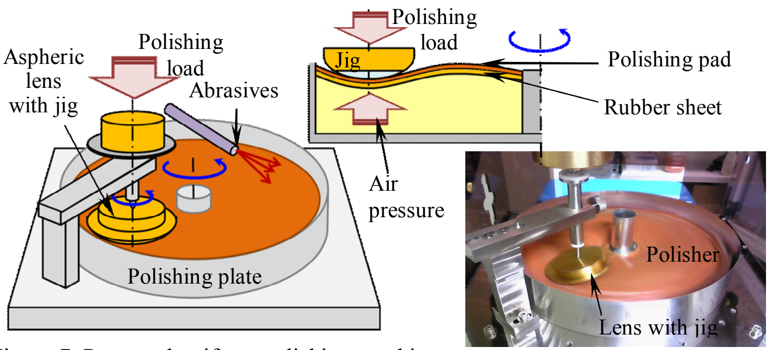


Figure 7: Proposed uniform polishing machine

3 Proposed uniform polishing method

Figure 7 shows a proposed uniform polishing method. Polishing plate is covered with a rubber sheet and air is injected into the cavity. The workpiece is put on the balloon type of polisher by the jig. The polishing disk is rotated and the workpiece is also rotated, and the lens surface will be polished by the abrasives. The pressure distribution is uniform, and then the removal distribution also becomes uniform.

4 Uniform polishing results

In this experiment, ground lenses made of BK7 were polished. Table 2 shows polishing conditions. As an abrasive, CeO_2 was used. Figure 8 shows a change of deviation profiles before and after 30 min polishing. Uniform polishing was carried out. Figure 9 shows changes of removal and surface roughness. Smooth surface of 10nmRz was obtained.

Table 2: Polishing comditions

Lens Diameter Approximate radius	BK7 Φ80 mm R280 mm
Polisher	Urethane (t=0.8 mm)
Abrasive Density	CeO_2 10 wt%
Polishing pressure	10.2 kPa (104.1 gf/cm^2)
Rotational speed Speed	30 min^{-1} 20.7 m/min (r=110 mm)

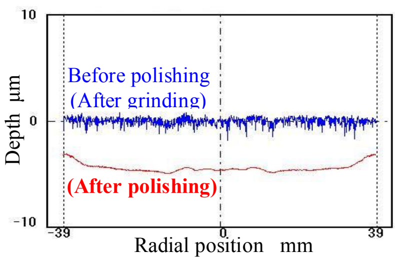


Figure 8: A change of deviation profiles

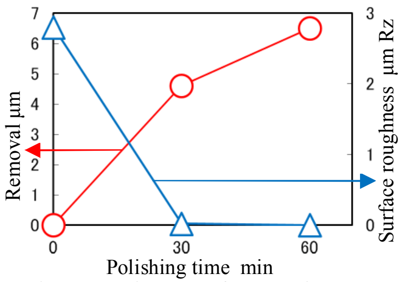


Figure 9: Changes of removal and surface roughness

4 Conclusions

In this study, a new effective and precision grinding / polishing method is proposed and developed for the aspheric glass lens. From the experiments, it was cleared that the proposed grinding and polishing methods are useful.

References:

[1] Suzuki, et al.: Precision Grinding of Aspherical CVD-SiC Molding Die, International Journal of JSPE, 32,1(1998) pp.25-30.
[2] Suzuki, et al.: Ultraprecision Finishing of Micro-Aspheric Surface by Ultrasonic Two-Axis Vibration Assisted Polishing, Annals of the CIRP, 59,1(2010) pp.347-350.