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Precision grinding of structured tungsten carbide mold

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Abstract. Demands of glass Fresnel lens is increasing in solar panel in order to increase power efficiency. Glass lens is usually molded by glass molding method with tungsten carbide molds. In this study, large Fresnel lens molds made of tungsten carbide are tested to be ground by simultaneous 2-axis (*Y, Z*) controlled grinding method. The resinoid bonded diamond wheel was trued with a rare metal truer to improve the sharpness of the wheel edge. In the grinding test of the tungsten carbide mold, a form accuracy of less than 0.8 μm P-V and surface roughness of 18 nm Rz were obtained, and it is clarified that the proposed grinding method is useful for the Fresnel grinding.

Introduction

Fresnel glass lenses are useful in order to increase the generating efficiency of solar power system by irradiating the sun light efficiently, as shows in Fig.1. The Fresnel lenses made of glass must be press molded in high temperature by using the precision molds made of stainless steel or tungsten carbide. In the conventional optical system, plastic lenses are usually used. The plastic lenses are molded at low temperature by using the injection molding with the aspheric molds made of soft metals such as electroless Ni. The soft metal can be machined precisely by the cutting tools made of a single crystal. Structured surface can be also machined by the sharp tool. On the other hands, the ceramics molds such as tungsten carbide cannot be machined by the single crystal diamond tool and must be ground precisely by a diamond wheel.

In this study, large Fresnel lens molds made of tungsten carbide are tested to be ground by our developed simultaneous 2-axis (*Y, Z*) controlled grinding method [1]. In the grinding test, the resinoid bonded diamond wheel was trued with a rare metal truer to improve the sharpness of the wheel edge. In the grinding experiments, the large Fresnel molds made of tungsten carbide mold was tested to be ground. The ground structured surface was measured our developed laser probe measurement system.

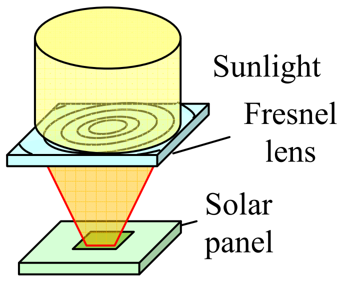


Fig. 1 Fresnel glass lens for solar panel

Precision grinding of structured surface

In this study, the grinding method with simultaneous 2-axis(*Y, Z*) controlled machine was proposed, as shown in Fig.2. As a wheel, a disk shape of diamond grinding wheel, whose edge is trued as a sharp knife-edge, is used and the wheel scans vertically along the workpiece radial position. The wheel air spindle rotates vertically and the workpiece air spindle rotates horizontally. The feature of this grinding method is that the wheel rotates in the parallel with the workpiece rotational direction at the grinding point. The axis-symmetric Fresnel shape of the mold will be generated by the grinding wheel with sharp edge. Therefore the sharpness of the wheel is important in order to generate the structured surface precisely.

The tool path is calculated by the following formulae:

$$\left.\begin{aligned} Y_0 &= Yw - R\,\sin\theta \\ Z_0 &= Zw - R\,(\cos\theta - 1) \end{aligned}\right\} \quad (1)$$

Where R is a radius curvature of the grinding wheel tip, θ is a tangential angle of the grinding point, (Y_0, Z_0) is a center position of the grinding wheel tip and (Y_w, Z_w) is a grinding point on the workpiece surface.

The axis-symmetric Fresnel shape (Fig. 3) is given by:

$$Z = f(Y) = \mathrm{mode}(g(Y), b) \quad (2)$$

$$g(Y) = \frac{Cv \cdot Y^2}{1 + \sqrt{1 - (K+1) \cdot Cv^2 \cdot Y^2}} + \sum_{i=1}^{n} C_i \cdot Y^i \quad (3)$$

Where Y is a radial position of the mold, Z is a rotation axis position, K, Cv, C_i(i=1 - n) are aspheric constants, and b is a height of Fresnel lens.

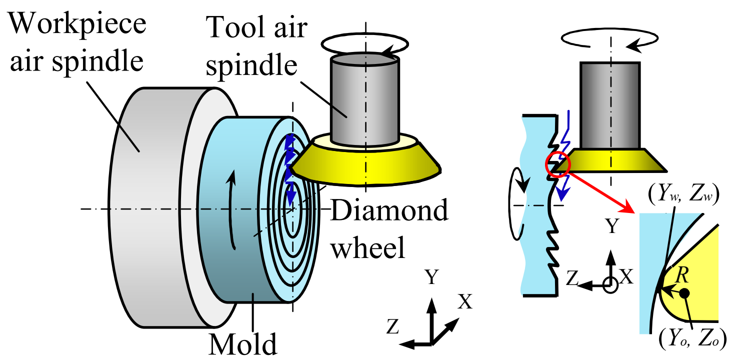


Fig. 2 Fresnel shape grinding of 2-axis control using diamond wheel

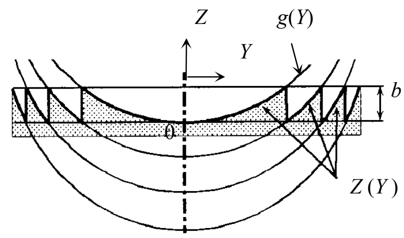


Fig. 3 Definitions of Frenel shape.

High precision and high performance truing / dressing of diamond wheel by rare metal

In the grinding, grinding wheels must be formed on the truing process to reduce the run-out of the wheel and improve the workpiece form accuracy. Usually in the truing/dressing process of the resinoid bonded diamond wheel, the wheel is trued by a single crystalline diamond truer and the trued diamond wheel is dressed by a green silicon carbide (GC) dresser. However, in the conventional truing process, the diamond abrasives on the wheel surface will be dropped off by the diamond truer and the acting abrasive number on the wheel surface will be decreased. In the conventional dressing process of the resinoid bonded diamond wheel, the abrasive on the wheel surface will be sharpened and the acting abrasive number will increase on the wheel surface by rubbing by the GC dresser. However, it is difficult to sharpen the wheel edge, because the GC dresser is not so hard compared with the diamond wheel [2].

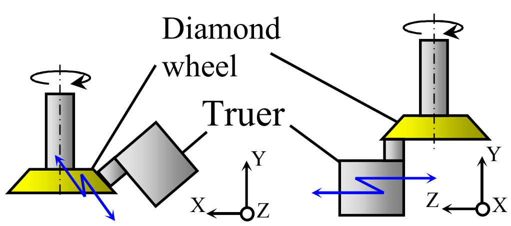


Fig. 4 Truing/dressing process of the resinoid bonded diamond wheel for the grinding of the Fresnel lens mold.

In this paper, Nb was used as a truer/dresser, because it seems to be active to the carbon atom of diamond. For the diamond wheel of the Fresnel lens molds, the grinding wheel is rubbed and formed for truing and dressing on both the outer side surface and the bottom side surface of it, as shown in Fig. 4.

Experimental set-up and method

The grinding wheel was attached to a 4-axis (*X, Y, Z, C*) ultra-precision machine, ULG-100D(SH^3) as shown in Fig. 5. The wheel was actuated in *X, Y* and *Z*-axis by the linear scale feedback system with 1 nm positioning resolution. The wheel air spindle and the workpiece air spindle were an air-bearing spindle. Their maxim rotation speeds are respectively 40,000 min^{-1} and 1,500min^{-1}. The structured workpiece was vacuum chucked onto the workpiece air spindle (*C*-axis table).

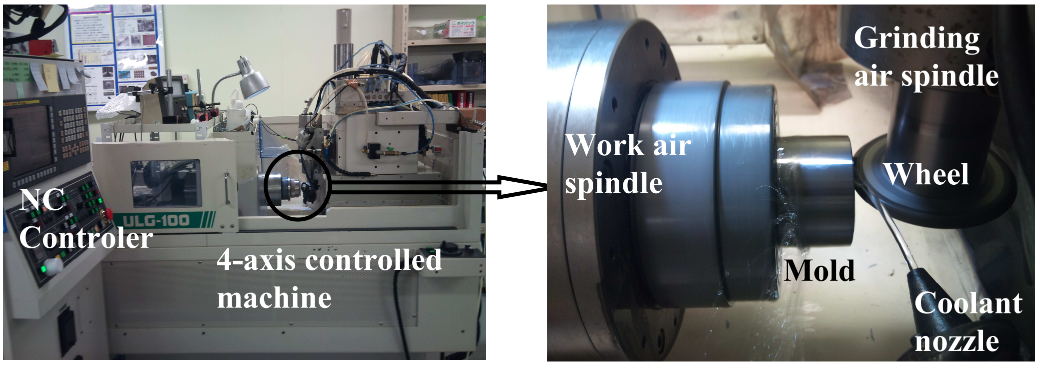


Fig. 5 View of Fresnel grinding experiment.

Experimental results

In order to evaluate the grinding performances of the Fresnel mold, a tungsten carbide workpiece of 50 mm diameter was ground to the shape, as shown in Fig. 6. And it was ground under the grinding conditions as shown in Table 1. Fig. 7(a) shows a measured sharpness wheel edge of the diamond wheel before truing. Fig. 7(b) shows a measured sharpness wheel edge of the diamond wheel which was trued on the machine with sharp edge of 45 degrees by rare metal (Nb). The shape of the diamond wheel edge was measured by the non-contact laser probe scanner. The shape of the diamond wheel edge could be trued sharply.

Table 1 Grinding conditions

Wheel	Resinoid bonded diamond wheel
Grain size	SDC1200
Diameter	Φ70 mm
Rotational speed	12,000 min^{-1}
Work piece	Binderless tungsten carbide
Rotational speed	500 min^{-1}
Depth of cut	0.5 μm/pass
Feed rate	0.5 mm/min
Coolant	Solution type

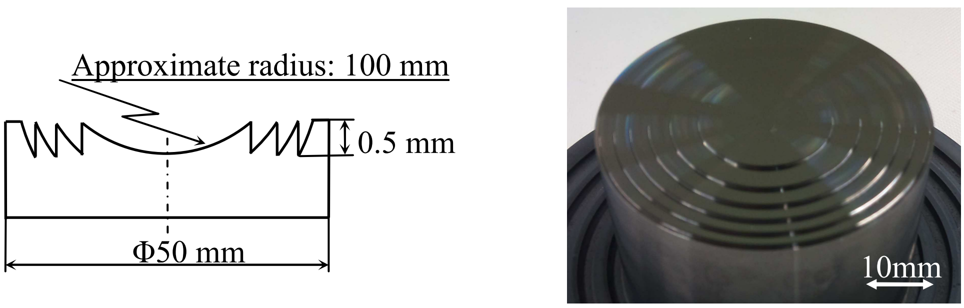


Fig. 6 Geometry and view of Fresnel lens mold for structured grinding.

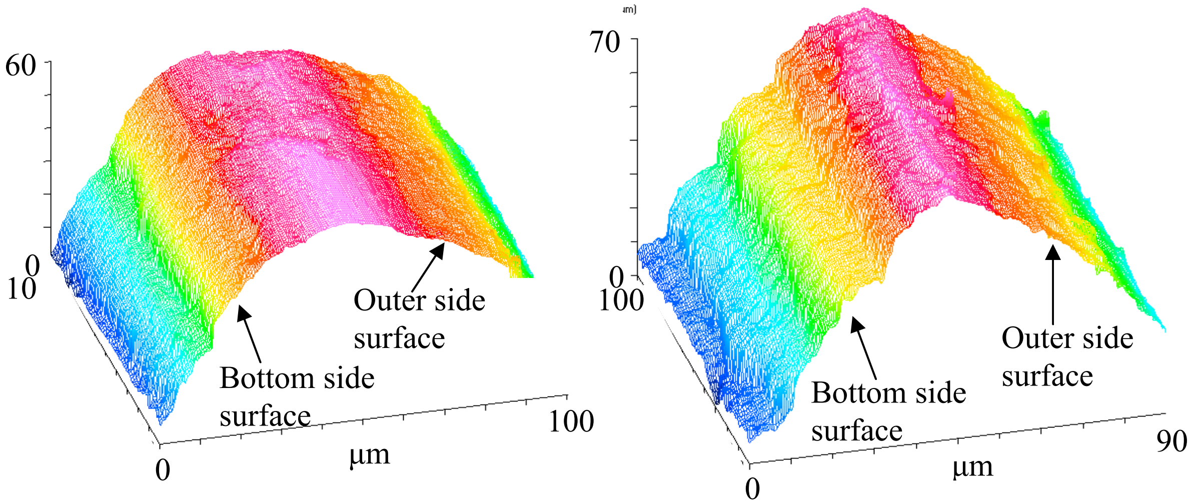
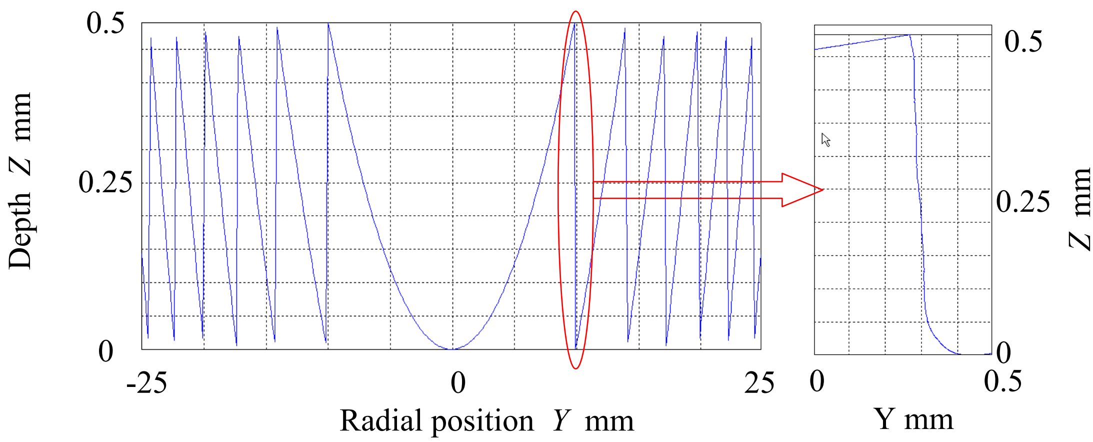


Fig. 7 Compare the diamond wheel edge of before truing and after truing.

Fig. 8(a) shows a measured profile of the ground Fresnel mold. Fig. 8(b) shows a detail of the mold edge. These were measured by the non-contact laser probe scanner. It was found that structured surface with sharp edges was generated. Fig. 9 shows a deviation profile of the ground Fresnel mold, which was calculated from the measured profile in Fig. 8 (a). It was found that the form accuracy was improved to 0.8 µm P-V. Fig. 10 shows surface roughness profiles of the ground surface, measured in the center region by a non-contact measuring instrument. Surface roughness of 18 nm Rz was obtained.



(a) A cross section in the radial position (b) A detail of the edge

Fig. 8 Measured profiles of the ground fresnel mold.

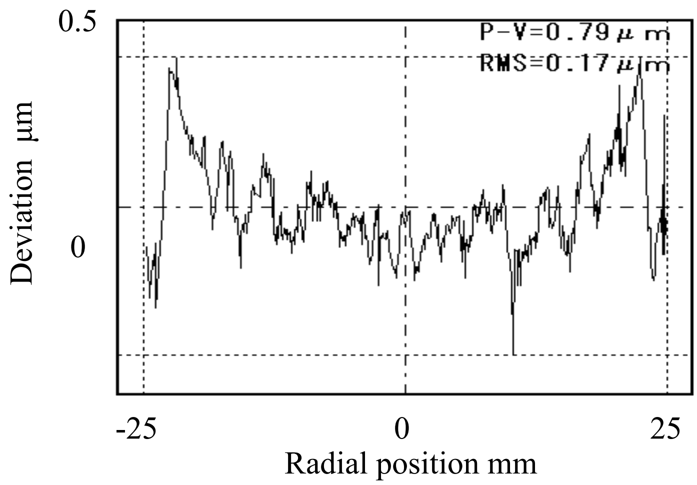


Fig. 9 Form deviation profile of the ground Fresnel mold.

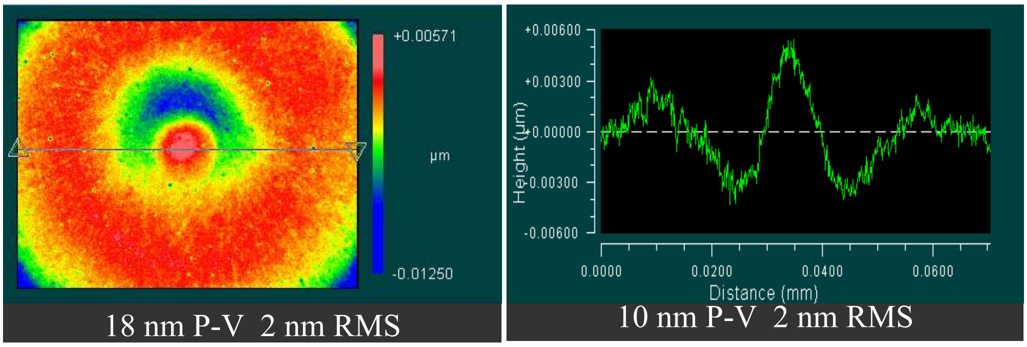


Fig. 10 Surface roughness of ground tungsten carbide workpiece.

Summary

In order to machine large Fresnel lens mold for solar panel, tungsten carbide by the diamond wheel trued with rare metal was ground. From the experimental results, the following results were obtained:

(1) Diamond wheel was trued by rare metal (Nb). Consequently, the shape of the diamond wheel edge was trued sharply.

(2) In consequence of the Fresnel lens mold for solar panel that was ground precisely with diamond wheel, the form accuracy of 0.8 µm P-V and the surface roughness of 18 nm Rz were obtained.

Consequently, it was found that the grinding method with simultaneous 2-axis(*Y, Z*) controlled machine and the truing with rare metal are effective.

References

[1] Suzuki. H, Kamano. T, et al., Study on micro aspherical optical component with glass molding - Improvement of form accuracy by deformation correction in Solidification shrinkage process - Proc. JSPE autumn meeting, (1999)266.

[2]Yamamoto. Y, Suzuki. H, et al., Study on grinding of micro Fresnel lens mold (2nd report) - precision truing of grinding wheel that having sharp edge with truer is made of Mo, and high precision grinding of Fresnel shape- , Japan Society for Precision Engineering, 73, 6, (2006)84.