

# Precision Complex Machining of Glass Lens Mold with Fresnel Shape

T. Fujii<sup>1</sup>, K. Nakamoto<sup>1</sup>, T. Ishida<sup>1</sup>, Y. Takeuchi<sup>1</sup>

<sup>1</sup> *Department of mechanical Engineering, Osaka University, Japan*

[takeuchi@mech.eng.osaka-u.ac.jp](mailto:takeuchi@mech.eng.osaka-u.ac.jp)

## Abstract

The study proposes a new machining process for cemented tungsten carbide glass lens mold with Fresnel shape. The curved surfaces except for sharp edges of Fresnel shape are machined by the conventional grinding method with a disk type metal bonded diamond wheel. Then, sharp edges on curved surfaces are created by fly cutting method with knife-edged single crystal diamond tool. As a result, complex machining of Fresnel shape by proposed machining method allows sharp edges to be created on tungsten carbide mold.

## 1 Introduction

In optical devices, the demand of lenses with complicated shapes like Fresnel shape is recently growing up [1]. Fresnel shape has some sharp edges on curved surfaces. In recent years, it is strongly required to make these lenses by glass in terms of improving its optical performances. Brittle materials such as cemented tungsten carbide are used for glass molding. Thus, it is expected to develop a high precision machining method to fabricate minute structures on brittle materials, difficult to machine.

## 2 Proposed machining method

The study proposes a new machining process for the brittle material molding die with Fresnel shape shown in Figure 1, aiming at high precision machining. In the proposed process, the curved surfaces except for sharp edges are machined by the conventional grinding method with the disk type metal bonded diamond grinding wheel [2]. Then, ultra precision cutting with a very sharp single crystal diamond cutting tool is applied to create the sharp edges. The ultraprecision machining center, AHN05 by JTEKT Corporation, is used for experiments. The machine has three translational axes, X, Y,

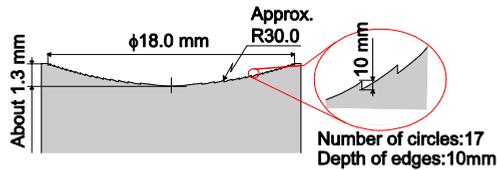


Figure 1: Target shape to be machined

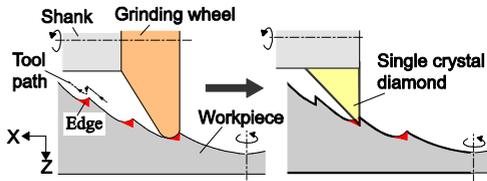


Figure 2: Complex machining

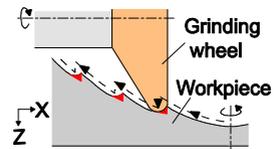


Figure 3: Grinding method

and Z and has a rotational axis, B. The resolution of translational axes is 1 nm, and rotational axis is 0.0001 degree.

The proposed machining method is shown in Figure 2. At first, the curved surfaces except for sharp edges are machined by grinding method with the disk type diamond grinding wheel. Then, fly cutting is applied to create the sharp edges.

### 3 Curved surface grinding process

The area except the edge section is machined with a knife edge grinding wheel. Fresnel shape is machined by moving a knife edge grinding wheel along the section curve in the simultaneous two axes (X and Z axis) control, while rotating the workpiece set in the main axis, as shown in Figure 3. In this research, a metal bonded grinding wheel that has high binding strength and small deformation volume is used to decrease the contact point error by the elastic deformation of the grinding wheel as much as possible.

The radius of wheel edge is about 5  $\mu\text{m}$ . Then, the NC data is made, based on this radius of the wheel edge, and the first grinding of the Fresnel shape is done.

### 4 Edge section cutting process

The tool original point alignment is necessary when the grinding wheel is changed to fly cutting tool. The tool changing process illustrated in Figure 4. The alignment is done by installing a new workpiece, called a dummy work, which is set on the machined workpiece, and by machining it.

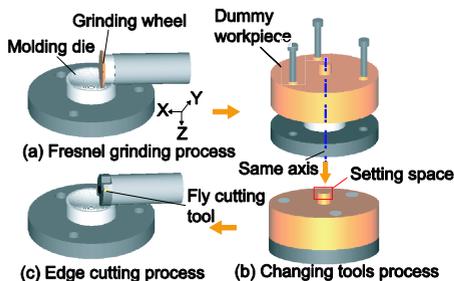


Figure 4: Proposed machining method

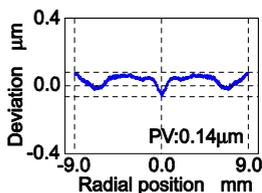


Figure 6: Shape accuracy (Reference: Base line)

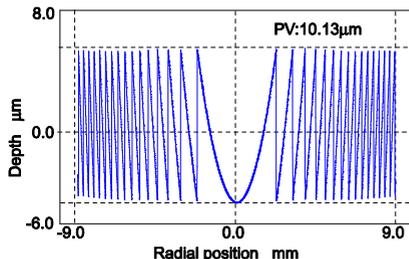


Figure 7: Profile of Fresnel shape (Reference: Aspheric)

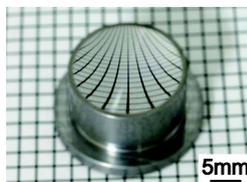


Figure 5: Whole view of workpiece

After the original point coordinates of the fly cutting tool are determined according to the tool changing process, the edge section is cut. The tool is fed in the Z direction. The most of part in the edge section is removed. The remaining part is cut two or more times along the section curve. The workpiece is cut from the center to the outside in sequence by this tool path.

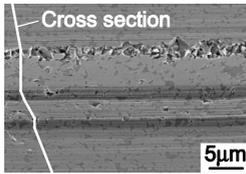
## 5 Verification of proposed method

The machining of glass molding die with Fresnel shape is conducted by using the proposed method. The cutting time of edge section is about 52 hours.

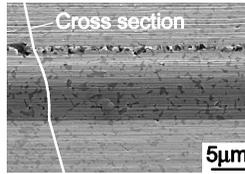
Figure 5 shows the whole view of machined molding die. The surface roughness of ground surface measured with a 3D optical profiler is about 18 nm Rz.

The profile of machined shape is observed with UA3P. Figure 6 shows the deviation of machined shape except for neighborhood of edge sections. The shape accuracy of molding die is 0.14 µm. Figure 7 shows the profile of Fresnel shape removing the aspheric shape from the whole machined shape. The measured depth of edge is 10.13 µm, approximately equal with design value 10 µm.

The edge section of the molding die machined by the proposed complex machining is compared to one of a molding die machined by only grinding process. The SEM



(a) Complex machining



(b) Grinding

Figure 8: SEM images of 1st edge

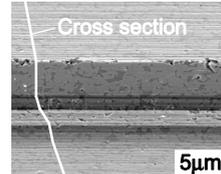


Figure 9: SEM images of 15th edge

observation result of the 1st edge from the molding die center is shown in Figure 8. Very steep edge shape is obtained in the complex process, while rounded edge shape in only grinding process. The SEM observation result of

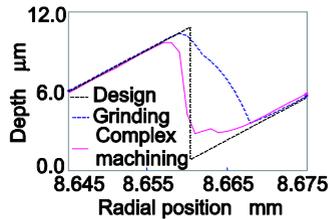


Figure 10: Profile of 15th edge (UA3P)

15th edge from the center of the workpiece is shown in Figure 9, together with the measured result shown in Figure 10. It is seen that very steep edge shape is obtained in the complex machining as well as the 1st edge, thus showing the effectiveness of the proposed method.

## 6 Conclusion

The complex machining method is proposed that uses the grinding process with a knife edge grinding wheel for the curved surface part and the fly cutting for the edge part so that the glass lens molding die with Fresnel shape can be accurately machined. Very steep edge shape can be obtained in machining a cemented tungsten carbide molding die with Fresnel shape compared with only grinding process. As the result, the usefulness of the proposed method is shown.

## References:

- [1] Y. Ono: Recent Advances in Diffractive Optical Elements: From Diffractive Optics towards Periodic Structure Optics, Japanese Journal of Optics (in Japanese) 2003; 32: 468-475
- [2] Y. Yamamoto, H. Suzuki, T. Moriwaki, T. Okino, T. Higuchi: Precision Grinding of Micro Fresnel Lens Molding Die (2nd Report), Journal of the Japan Society for Precision Engineering (in Japanese) 2007; 73: 688-692