Finishing of Micro Aspheric Molds by Vibration Assisted Polishing Using Magnetostrictive Material

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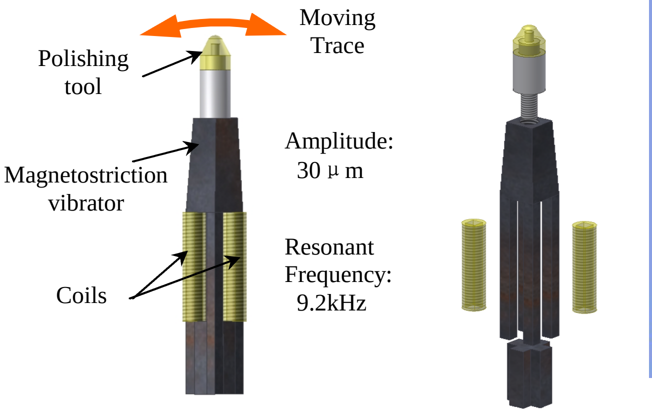
Abstract

Demands of micro aspheric glass lenses have been increased in digital optical devices such as digital cameras and blue ray pick-up devices. The glass lenses are molded by press molding with micro ceramics molds made of ceramics. In this report, in order to improve the efficiency and stability of aspheric mold furthermore, vibration assisted polishing system by using magnetostrictuve material is proposed and polishing set-up is developed. In this new polishing system, the vibration frequency is 9.2 kHz and the amplitude is 30 μm. In the experiments, the vibration characteristics are evaluated with simulated one and polishing characteristics are tested. The workpiece made of tungsten carbide is polished with new developed setup and the surface roughness and the polishing efficiency is evaluated. From the polishing experiments of tungsten carbide, shape of removal function was improved and surface roughness was improved to 10 nm *Rz* (2 nm *Ra*).

1 Magnetostriction vibration assisted polishing system

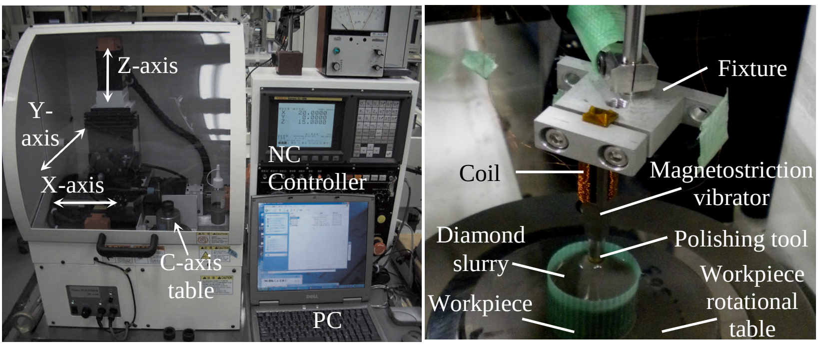
The concrete structure and the shape of the magnetostriction vibrator were designed by using finite element analysis. Figure 1 shows the design and actuation principle of the magnetostriction vibrator made of permendur. A small polishing tool is mounted on the head of the magnetostriction vibrator. The vibrator has four legs where the coils are rolled, and by controlling the input current of the coils the legs can be pushed (expansion) and pulled (contraction) separately. Permendur with strain exceeding 70 ppm and Young's modulus of 200 GPa can generate sufficient force for actuation Its high permeability enables a magnetic circuit to be constructed from this material and driven with a low voltage power supply. A pair of opposing legs has been used to generate the traverse vibration. When currents of 180 phase difference with the same bias flow in pairs of opposing coils, the vibration is generated on the polishing tool by pushing and pulling of the legs. By analysing the vibration mode, as shown in Figure 2, the 4th mode is selected as the axial vibration. The resonant frequency was 9.2 kHz and amplitude was 30μm. Figure 3 shows a view of the vibration assisted polishing system. The magnetostriction vibrator where polishing tool is attached is mounted on X-Y-Z table.



(a) Assembly view (b) Exploded view

Figure 1: Design and actuation principle of magnetostriction vibrator

Figure 2: Finite element vibration simulation



(a) Whole view of the machine (b) Polishing head

Figure 3: View of vibration assisted polishing system

2 Principle of vibration assisted polishing

In the case of vibration polishing, the relative average velocity between the polisher and workpiece V is given by:

$$V=4\lambda\cdot\nu \quad (1)$$

Where λ is the amplitude and v is the frequency of vibration respectively. When the polishing tool scans zigzag , as shown in Figure 4, the dwell time, or the polishing time t at a position of the workpiece is given by: $t=A/(C\cdot S)$ (2)

Where S is the scanning speed of polishing tool and A is the area of the polishing removal function. c is the pitch size of the scanning. From equations (1), (2), and according to Preston's equation, the desired scanning speed of the polishing tool is given by: $s= k\cdot W\cdot V\,/\,(c\cdot\delta)$ (3)

Where k is the constant value, W is the polishing load, and δ is the form deviation.

3 Polishing experiment

Major polishing conditions are summarized and shown in Table 1. As a polisher, a polyurethane tool with radius of curvature of 1mm was adopted.

Workpiece Rotational speed	Binderless tungsten carbide w=160 min^{-1}
Polisher head Radius Hardness	Polyurethane 1mm IRHD 90
Polishing load	W=0.98 mN
Vibrating mode Frequency Amplitude	Traverse γ=9.2 kHz λ=30 μm
Abrasive Grain size Density	Diamond slurry 0.5 μm 1 wt%

Table 1: Major polishing conditions.

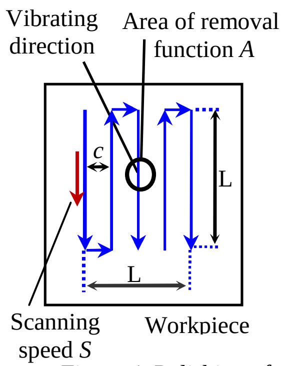


Figure 4: Polishing of free form surface.

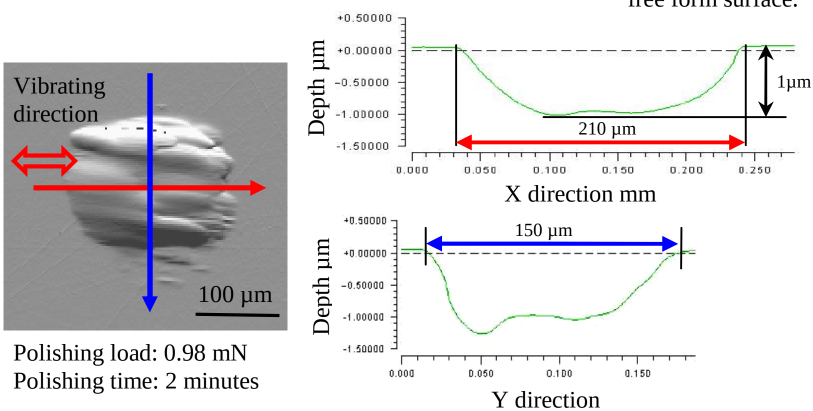


Figure 5: Shape of removal function.

3.1 Polishing conditions and removal function

In order to study basic polishing performances, the tungsten carbide workpiece was polished at a fixed position for 2 minutes under a polishing load of 0.98 mN. Figure 5 shows the polished surface and the profiles of the polished part, or the removal function. The shapes of the removal function are convex in both the polishing direction or X direction, and the cross direction or Y direction, which means that the present polishing method is suitable for aspheric generation polishing.

3.2 Basic polishing characteristics

The flat tungsten carbide workpiece was polished by varying the polishing pressure *P* from 0.98 mN to 4.9 mN. Figure 6 shows the changes in the removal depth with the polishing time. The removal depth is almost proportional to the polishing time. The change in the removal rate with the polishing pressure was calculated and shown in Figure 7. When the polishing pressure is high, the number of acting polishing abrasives decreases with an increase of the polishing pressure. The surface roughness of about 10 nm *Rz* was obtaind.

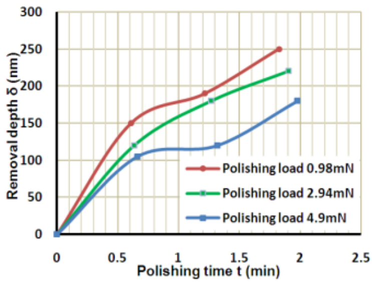


Figure 6: Change in removal depth with polishing time.

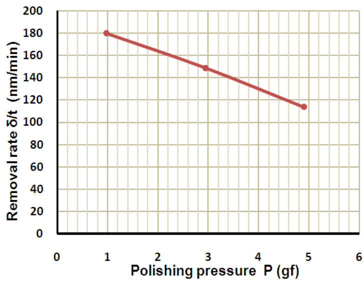


Figure 7: Relation between polishing pressure and removal rate.

4. Conclusions

In this study, vibration assisted polishing system using magnetostrictuve material was proposed and developed. From the experiments, it is clear that high performance and high accuracy polishing was carried out by using the magnetostrictuve material.

References:

[1] H.Suzuki, S.Hamada, T.Okino, M.Kondo, Y.Yamagata, T.Higuchi, Ultraprecision finishing of micro-asphric surface by ultrasonic two-axis vibration assisted polishing, CIRP Annals –Manufacturing Technology 59 (2010) 347-350.