RECENT PROGRESS ON MAGNETIC AIDED OPTICAL POLISHING OF CIOMP

Zheng Ligong[1,2]
[1]*Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP), Chinese Academy of Sciences, Changchun, Jilin, China*
[2]*Key Laboratory of Optical system advanced Manufacture Technologies Chinese Academy of Sciences, Changchun, Jilin, China*

Abstract: Sub-aperture polishing technologies, including CCOS (Computer controlled Optical Surfacing), CCP (Computer controlled Polishing), MRF (Magnetorheological Finishing), IBF (Ion Beam Figuring) etc., are widely used for aspheric optical surface polishing. Because magnetic aided optical polishing could reach both high accuracy and low sub-surface damage, CIOMP cooperated with Belarusian National Technical University (BNTU) and A.V. Luikov Heat and Mass Transfer Institute of the National Academy of Sciences of Belarus (HMTI) respectively to develop magnetic aided polishing technologies for aspheric optics since 2008.

Key words: Magnetic Aided Polishing, Magnetorheological Finishing, Magnetic-Medium Assistant Polishing, aspheric optics

1. Introduction

MRF technology was invented by Mr. William Kordonski, A.V. Luikov Heat and Mass Transfer Institute of the National Academy of Sciences of Belarus in 1980s. Mr. Kordonski joined the Center of Optical Manufacture (COM), University of Rochester and started to develop computer numeric controlled MRF machines in 1990s. After that, QED company was established in 1996 and developed commercial MRF CNC machine successfully, and MRF technologies played an important role in high precision aspheric and freeform optical manufacturing[1,2].

Prof. Mikalai Khomich, Belarusian national technical university, studied the MAM(Magnetic-Medium Assistant) polishing technology from 1960s, and developed prototype machine tools for metal grinding and polishing[3,4]. The property of its removal spot is similar to that of MRF, so CIOMP decided to cooperate with BNTU and studied whether MAM could be applied to optical polishing.

2. Progress on MAM technology

MAM polishes the optical parts with abrasive slurry applying to the joint area between the magnetic medium brush and optical surface. By carefully designing, the magnetic wheel could generate magnetic field as shown in Fig-1. Under the magnetic field, the magnetic medium forms a brush that could contain the slurry and act on optical surface as flexible polishing tool.

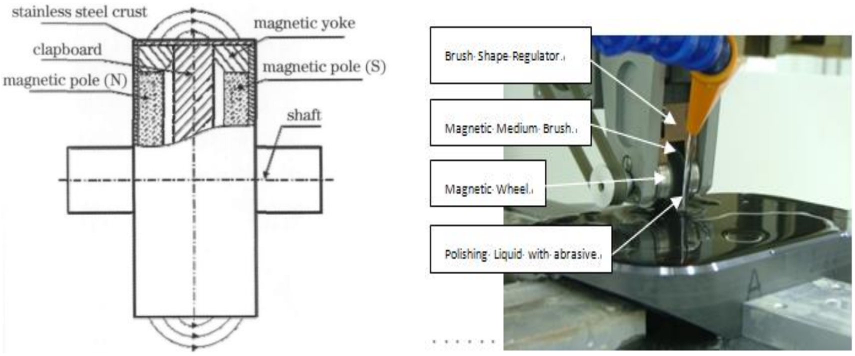


Fig 1. MAM polishing device

The MAM removal function which is not circular symmetry was tested as shown in Fig-2 and testing conditions in Table 1.

Table 1. Removal function testing conditions

Optical material:	Fused silica
Magnetic wheel:	Φ60mm
Magnetic medium:	PF40/0
Slurry:	CeO_2

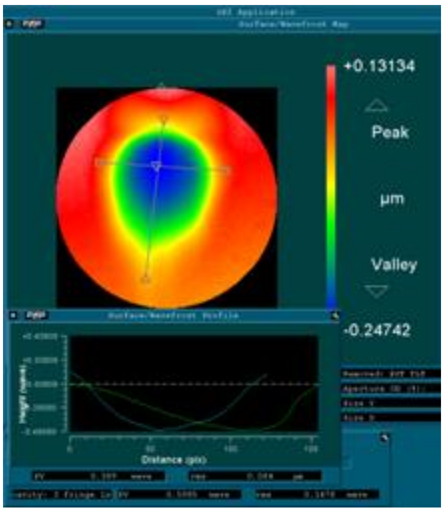


Fig 2. MAM Remove Function

As a deterministic fabrication, the stability of the MAM removal function is very important for polishing, and it highly depends on the stability of the polishing conditions including the slurry level, shape magnetic medium, magnetic wheel rotating speed, and so on. The testing shows the stability of MAM removal function is better than 90 % within 1 hour (See fig-3).

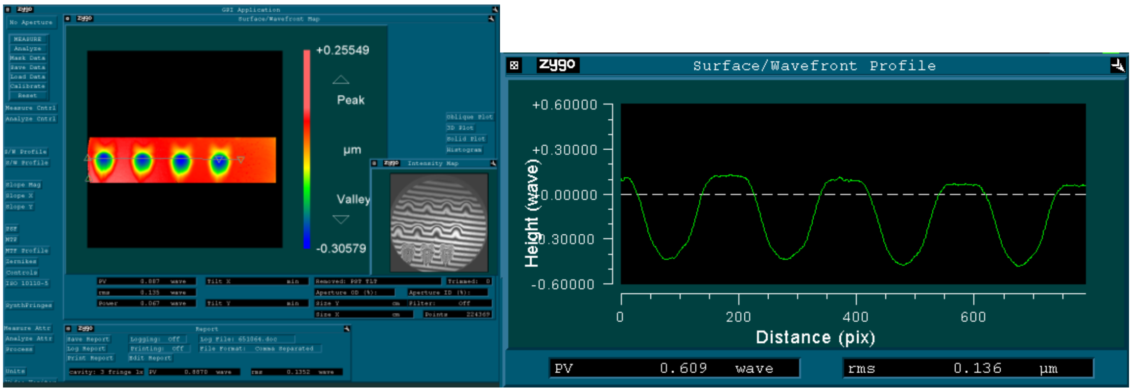
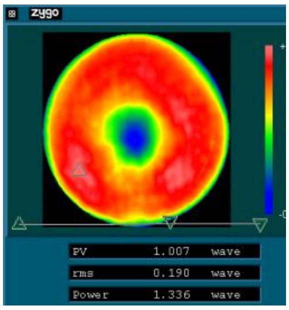


Fig 3. Stability of MAM Remove Function

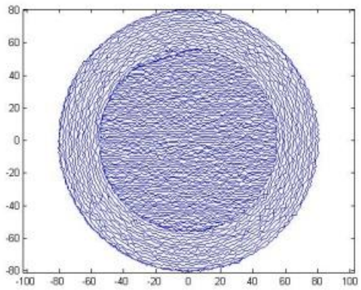
In order to verify the determination of MAM polishing, a flat part was polished by MAM, the conditions and results are below.

Table 2. Polishing Testing Conditions

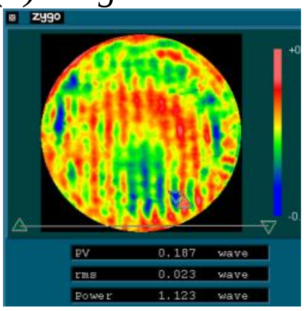
Optical material:	K7
Aperture of the part:	Φ150mm
Thickness of the part:	5mm
Magnetic wheel:	Φ60mm
Magnetic medium:	PF40/0
Slurry:	CeO_2



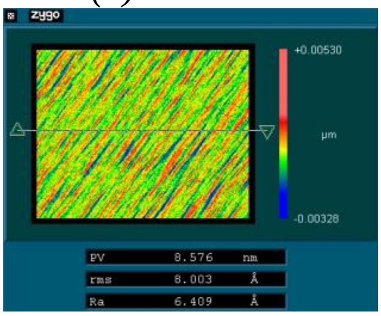
(a) Original Flatness



(b) Tool Path



(c)Flatness



(d)Roughness

Fig 4. MAM Computer Controlled Polishing test

After three circling, the flatness error converged from RMS 0.190λ to RMS 0.023λ, and the roughness of the part was RMS 0.8nm, the result showed that MAM technology is suitable for optical polishing.

3. Progress on MRF technology

MRF has been proved an effective method for optical finishing by QED. It works by the magnetorheological property of the magnetic fluid under magnetic field as shown in Fig-5.

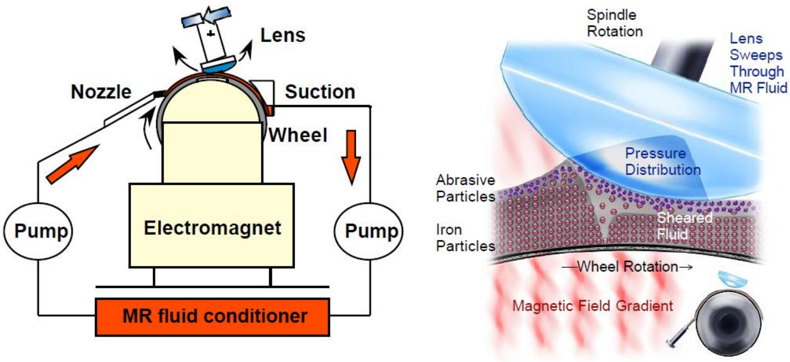
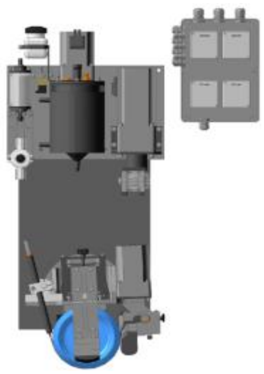


Fig 5. The principle of MRF

Cooperating with HMTI, CIOMP developed the MRF machine and tested the MRF removal function in Fig-6. In order to polishing large optics, the MRF is vertical which ensures that the optical part is under the polishing wheel.



(a)MRF device

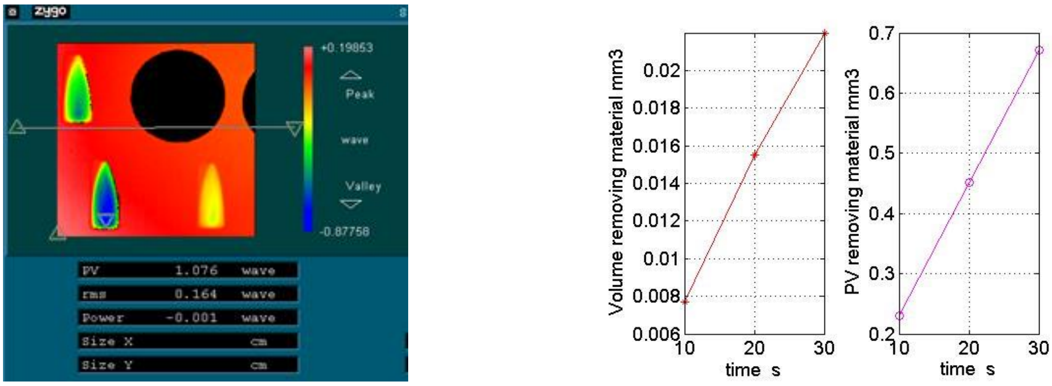
(b)1m MRF CNC machine

Fig 6. MRF machine

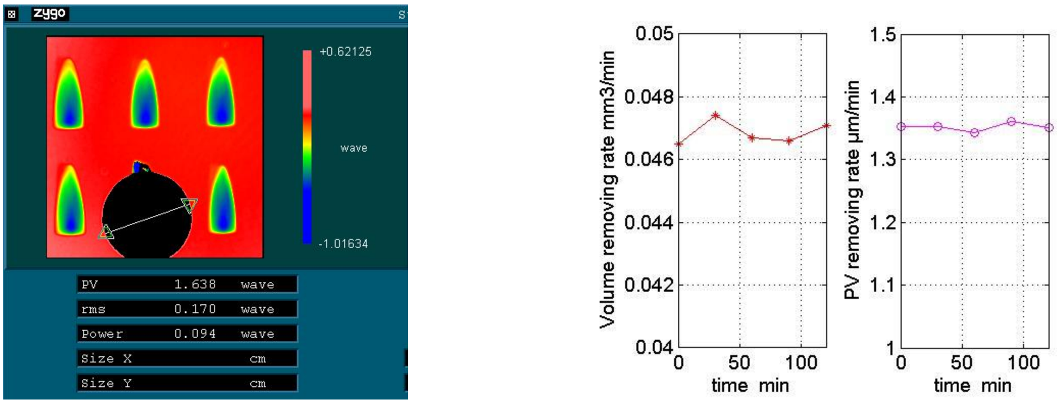
The linearity and stability were tested as shown in Fig-7 and its testing conditions in Table 3. The results show that the stability of its removal function is better than 95 % within 2 hours, and the volume and PV of material removed is almost linear to dwell time when rotating speed of the magnetic wheel is fixed. These results ensure that the MRF machine and MR fluid developed by HMTI and CIOMP are qualified for 1m level optical polishing.

Table 3. Polishing Testing Conditions

Optical material:	Si
Magnetic wheel:	Φ160mm
Wheel speed:	120 r/min
MRF fluid:	Diamond



(a) Linearity of MRF removal function



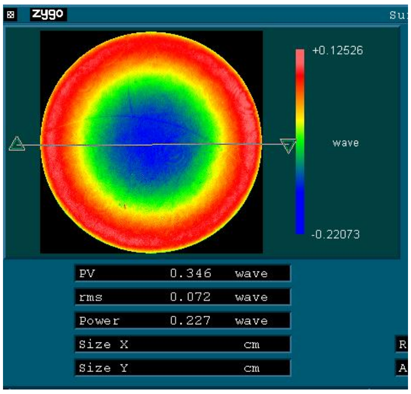
(b)Stability of MRF removal function

Fig 7. MRF removal function

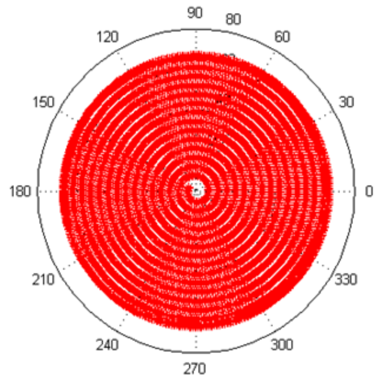
In order to verify the determination of MRF polishing of our machine, a flat Si part was polished by MRF, the conditions and results are below.

Table 4. Polishing Test Conditions

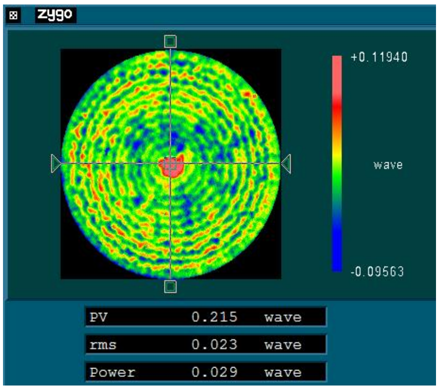
Optical material:	Silicon
Aperture of the part:	Φ120mm
Magnetic wheel:	Φ160mm
Wheel speed:	120r/min
MRF fluid:	Diamond



(a) Original Flatness



(b) Tool Path



(c)Flatness

Fig 8. MRF Computer Controlled Polishing test

In fig 8, just after one circling with spiral path, the flatness error converged from RMS 0.072λ to RMS 0.023λ, and the convergence rate is above 60 % which is almost the same value obtained by simulation. Also the roughness of the part was RMS (<1nm). These results showed that MRF is a high determined polishing method which is more suitable for optical polishing.

4. Conclusions

a) Both MAM and MRF are qualified for optical polishing.

b) Because the testing shows that the stability of MAM removal function decrease sharply after 1 hour, the diameter of optical parts have to be limited within 300mm. For the MRF technologies, the stability of its removal function is better than 95 % within 2 hour and 90 % within 4 hour respectively, the diameter of optical parts could be more than 1m level, but larger area of the removal function is needed.

c) It is not easy to control the mid-spacial-frequency error when polish the optical parts by MAM and MRF. The other methods have to be introduced into polishing process to achieve better accuracy.

Acknowledgements

Prof. Mikalai Khomich and his team form Belarusian National Technical University developed the MAM device, and worked with CIOMP on the MAM technologies, Dr. Evgeniya Korobko and her team form A.V. Luikov Heat and Mass Transfer Institute of the National Academy of Sciences of Belarus developed the MRF devices and worked with CIOMP on MRF technologies. Thanks for their excellent works. Also thanks Mr. Oleg Penyazkov and Mr. Yury Aliakseyeu for their well organization and smart leadership for the teams.

References

1. Daniel C. Harris.History of Magnetorheological Finishing[C]. SPIE, 2011, 8016: 1~22
2. S. D. Jacobs, D. Golini, Y. Hsu, B. E. Puchebner et al. . Magnetorheological finishing: a deterministic process for optics manufacturing[C]. SPIE, 1995, 2576:372~382.
3. Zhang Feng, Deng Weijie. Magnetic- medium assistant polishing of silicon modification layer on silicon carbide surface [J]. Acta Optica Sinica, 2012, 32(11): 1116001.
4. Zhang Feng, Zhang Binzhi. Surface roughness of optical elements fabricated by magnetic fluid-assistant polishing[J].Optics & Precision Engineering, 2005, 13(1): 34~39
5. Marc Tricard1, Paul Dumas, and Greg Forbes. Sub-aperture approaches for asphere polishing and metrology[C].SPIE. 2005, 5638:284~299.