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Research on key technology for processing high precision aluminium mirror with combined polishing method

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Abstract

Aluminium mirror occupies an important position in modern space optics system because of its excellent characters such as high index of reflection in infrared band, small density and so on. At present time, the single point diamond turning (SPDT) is a universal method to fabricate high precision aluminum mirror. But the defects of this technology are also obvious because of the unpredictable precision limitation sometimes and inherent tool marks. Although modern deterministic polishing technology with high machining precision and good surface quality is a potential way, it is recognizably difficult to implement on the mirror after turning because of its soft surface and active chemical property. In this paper, the suitable polishing fluid is developed basing on the research of material removal mechanism. As to enlarge the material removal and to protect the mirror surface, the mixed polishing powder and appropriate polishing pad are adopted in the course of chemically mechanical polishing (CMP) processing. The magnetorheological finishing (MRF) technology is applied because of its high figuring precision and convergence ratio on figure error. The optimal parameters are also researched through the actual experiments as to find the balance of material removal and surface quality. For the sake of removing the tool mark and controlling the whole space frequency figure error, the combination process associating CMP and MRF is proposed. High precision figure and smooth surface could be obtained efficiently with this composite polishing method through the research of technology transfer contact. The actual fabrication result on the plane and concave aspherical surface showed that the tool mark was removed completely, the figure error PV value could be better than λ/5(λ=632.8nm) and the surface roughness could be less than Ra 3nm with this combined polishing method.

Keywords: aluminium mirror polishing, magnetorheological finishing, chemically mechanical polishing, tool mark removal

1. Introduction

Aluminium material is always used in reflect scope system because of its excellent characters such as high index of reflection in infrared band, small density, easy to fabrication and so on[1,2]. At present, the single point diamond turning (SPDT) is a universal method to fabricate a high precision aluminium mirror include flat, sphere and aspheric surface[3-6]. But the defects are also obvious such as the unpredictable precision limitation due to turning machine and environment elements. The inherent tool mark from SPDT is also negative to performance of the optical systems. The existing research results indicate that the polishing technology is a potential way to remove the tool mark and improve the surface quality[7,8]. But it is recognizably difficult to polish the aluminum mirror with good surface shape and quality efficiently due to its soft surface and active chemical property.

In this paper, the combined polishing method associating MRF® and CMP technology is proposed. Based on controlling the surface quality, MRF technology is mainly used to remove the figure error with a high precision and convergence ratio. The CMP technology which adopts the mixed polishing powder and appropriate polishing pad is used to remove the tool marks brought by SPDT and remove the extra oxide layer which is brought by MRF.

2. MRF technology for aluminium mirror

As we known, MRF fabrication principle is based on the Preston Equation. It is considered that the material removal is equal to the convolution of removal function and dwell time. It is clear that a stable removal function (influence function) is the basis of the high precision fabrication. However, it is not sufficient just through actualizing the function in aluminum mirror fabrication with MRF. There are several technical matters must be settled.

2.1. Feasibility Analysis

Because of the existing of multiform foreign substances, it is very important to use the suitable polishing fluid for good surface quality. Aluminium can be etched both in acidic and alkalescent solution. The key point is to control the etching speed of all substances. It is the base for good surface quality. The tradition polishing MR fluid for glass is not suitable for aluminium. From the actual experiments, it is known that the alkalescent carrier liquid is more suitable for aluminum polishing. Fig.1 showed the actual polishing procedure and Fig. 2 showed the surface roughness results before and after MRF fabrication.

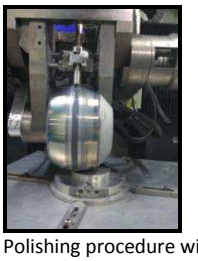
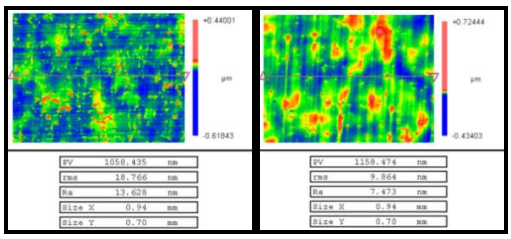


Figure 1. Polishing procedure with MRF



(a) (b)

Figure 2. Surface roughness before (a) and after MRF(b)

The removal function linear behavior and stability are also researched after confirming the polishing fluid. The experiment results indicate that it is tenable for deterministic polishing.

2.2. Parameters optimization

As to seek the optimal parameters for high material removal and good surface roughness, a series of experiments for magnetic field, polishing wheel speed, impress depth are done. From the results, the parameters are decided. Fig.3 shows that the surface roughness has been improved after MRF.

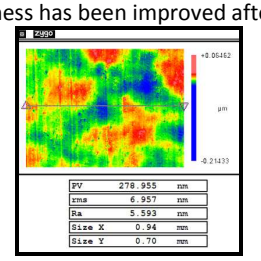


Figure 3. Surface roughness with parameters optimization after MRF

3. CMP technology for aluminum mirror

CMP technology is mainly used for removing the tool marks from the SPDT and ulteriorly improving the surface roughness after MRF. In this technology we mainly use the mix abrasive to improve the removal efficiency and surface roughness at the same time. As to keep the surface figure fabricated by the MRF technology, polishing cloth pad and appropriate parameters are researched.Fig.4 has shown the actual CMP polishing procedure and Fig.5 has shown the mirror surface before and after CMP. From the figure, we can find that the tool marks have been removed.

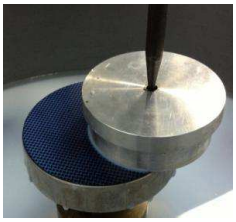
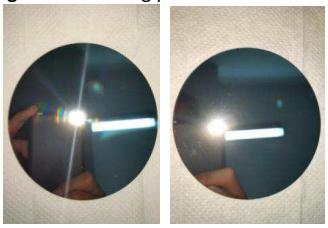


Figure 4. Polishing procedure with CMP



(a) (b)

Figure 5. Mirror surface before (a) and after CMP(b)

4. Experiment certification

An experiment on a circular aspherical mirror adopting this combined method is accomplished on the MRF machine and CCOS machine developed by ourselves. The workpiece is a paraboloid mirror and diameter is 90mm. Radius of curvature is 400mm. Fig.6 has shown the result of the surface figure error correction. From the result, it is improved to the final λ/5 (PV value) just through one iteration less than 60 min.

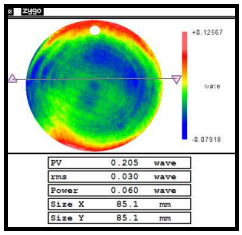


Figure 6. Figure error after fabrication

Fig.7 has shown the result of the surface roughness correction with this method. From the result, we can know that the surface roughness is improved to the final Ra 2.775nm.

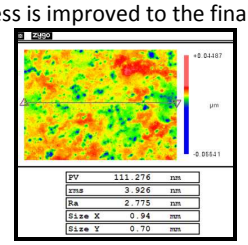


Figure 7. Surface roughness after fabrication

5. Summary

From the work, we can know that the aluminum mirror can be fabricated with the MRF technology adopting the suitable polishing fluid. The figure error can be improved to below than λ/5 quickly. As to remove the tool mark from SPDT, CMP technology is used after MRF fabrication, the surface figure can be kept and surface roughness can be improved to below than Ra 3nm adopting the mix abrasive and new style polishing pad. It is an effective method to fabricating high precision aluminum mirror by combining MRF and CMP technology. It is expected that the better surface roughness less than Ra 1nm can be acquired if the densification aluminum material is adopted.

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