Development of an Industrial Robot Based Polishing Platform for Large Optical Components

X. Tonnellier[1], P. Comley[1], X.Q. Peng[2] and P. Shore[1]

[1] Cranfield University Precision Engineering Institute, Cranfield University, MK43 0AL, England, UK

[2] National University of Defence, Changsha, Hunan, China

email: x.p.tonnellier@cranfield.ac.uk

Summary

The implementation of a new robot based polishing system is presented. Fused silica parts with a ground surface were polished then evaluated for surface roughness and form. A surface roughness of less than 2 nm S_a was produced on 100 mm parts in 2.6 hours.

Introduction

The demand for higher precision large optics has increased with major science and commercial projects running within the astronomy, fusion energy, and lithography sectors. The affordability of such projects necessitates reductions in cycle times and costs of the current optical process chains [1]. Recent developments in grinding and figure correction, using the BoX grinding machine and Reactive Atom Plasma (RAP) machine [2, 3] have demonstrated significant reduced processing times in the process chain. However, there remains scope for additional cost reduction within the polishing stage. To address this, a new industrial robot based polishing platform has been developed at Cranfield University. The platform offers an economic solution for processing ground surfaces for subsequent RAP processing and the application of a final neutral polishing to reduce surface roughness. This paper presents an analysis of polished fused silica surfaces; a material selected because of its use in lithography optics and fusion energy laser systems. The target surface roughness (R_a) was <10 nm while maintaining the surface form accuracy obtained from grinding.

Experimental approach

The robot platform uses a standard commercial Fanuc M710ic/50 six axis robot equipped with a high precision air bearing spindle and a commercial lapping slurry system (Fig 1). The system has a working envelope of 1.5 metres with a positional repeatability of 70 microns. The polishing tool is a flexible solid rubber base with a polyurethane pad. A water based slurry with 1-5 microns cerium oxide particle size is employed.

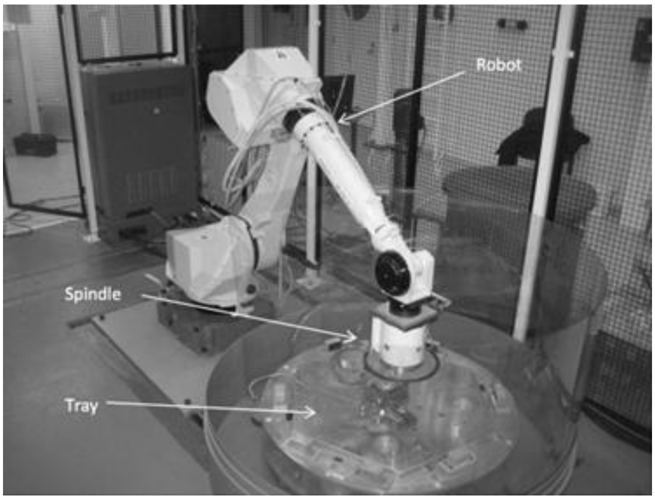

Fig 1. : Industrial robot based polishing system

Fused silica samples of size 100 mm square by 20 mm thick have been processed. The surfaces were prepared by a BoX finish grinding machine using a D46 grinding wheel [4]. For the polished surfaces, the surface texture and profile were measured using a profilometer with a 2 µm radius diamond stylus, and the surface roughness using a Rank Taylor CCI.

Results

The material removal rate of 1.5 mm^3/min ensured that 15 microns of material was removed after five runs of 52 minutes duration. After the third polishing iteration, the surface roughness (R_t and R_a) measurements were reduced from 3 µm and 120 nm to the target roughness of 66 nm and 8 nm respectively. At this stage the total polishing cycle times was 2.6 hours. The final two polishing runs removed any grinding “cusps” residue and remaining subsurface damage. Surface profile (P_t) measurements demonstrated the general surface form error was maintained to within one micron after the five runs. The final surface roughness was < 2 nm S_a and < 10 nm S_t, and the total polishing cycle time was 4.4 hours.

Conclusions

This paper demonstrates an efficient industrial robot based polishing process on fused silica material. A significant reduction in mid-spatial frequency error is observed without additional high frequency errors being induced, with the target surface roughness of <10 nm attained in 2.6 hours. This economic platform in combination with existing BoX and RAP processes has the potential to reduce overall manufacturing process cycle times for large optical components. Further work is on-going to demonstrate on metre-scale optics.

Acknowledgements

The authors gratefully acknowledge funding from the McKeown Precision Engineering and Nanotechnology Foundation at Cranfield and project funding through the UK’s Joint Research Councils’ - Basic Technologies programme and EPSRC funded UPS2 Integrated Knowledge Centre.

References

[1] P. Shore et al., Precision engineering of astronomy and gravity research (keynote), *CIRP Annals*, **59/2**, p.694, 2010.
[2] P. Comley et al., Grinding Metre-Scale Mirror Segments for the E-ELT Ground Based Telescope, *CIRP Annals*, **60/1**, p.379, 2011.
[3] R. Jourdain et al., Plasma surface, figuring of large optical components, *SPIE Proceedings*, **8430**, p.843011, 2012.
[4] X. Tonnellier, Precision Grinding for Rapid Manufacturing of Large Optics, PhD thesis, Cranfield University, 2009.