Design Considerations of Polishing Lap for Computer-Controlled Cylindrical Polishing Process

Gufran S Khan*, Mikhail Gubarev*, Chet Speegle** and Brian Ramsey*

NASA / Marshall Space Flight Center

*** Jacobs, NASA / Marshall Space Flight Center*

Huntsville, AL-35805, USA

mailto:gufran_ks@yahoomail.co.in

This paper presents the development a deterministic computer-controlled polishing process to minimise the mid-spatial-frequency axial figure errors on cylindrical shaped mandrels. We discuss the design considerations of large size polishing lap and report our first experiments performed using a newly developed computer-controlled polishing machine.

1 Introduction

Replicated grazing-incidence full shell optics for hard X-ray telescopes are under development at Marshall Space Flight Center [1-2]. The angular resolution of mirror shells depends on the quality of the mandrel from which they are being replicated. Mid-spatial-frequency axial figure error arises from the mandrel fabrication process and is a dominant contributor in the error budget of the mandrel. We presented our efforts in developing a polishing process whereby a computer-controlled polishing machine and the simulation software to optimize the mandrel figuring process were developed [3].

In this paper, we present further investigations on the optimisation of the polishing process. The process variables, such as the material removal rate, and the shape and size of the tool's influence function have been determined from the actual polishing runs on a mandrel. Using the extracted information of the process variables, a large size polishing lap has been designed.

2 Determination of process variables

Experiments were designed to determine the material removal rate and the shape and size of the tool's influence function under a set of known polishing parameters as such applied weight, stroke length of the polishing lap, rotational speed of the mandrel, tool distribution on the lap, and the duration of polishing time.

2.1 Determination of material removal rate

To extract the material removal rate, one half of the specimen was polished for two hours under a set of known operational parameters. The other half remained untouched during the experiment. Diamond-shaped tools were selected in the polishing lap configuration. Figure 1 shows the difference between the measurements before and after the polishing. The amount of material removed during the polishing operation was approximately 0.5 microns which makes material removal rate 0.004 µm /min.

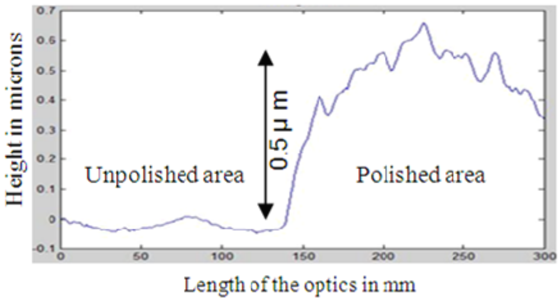

Fig. 1 *Difference between height measurements before and after the polishing (before - after).*

2.2 Determination of tool influence function

A polishing lap comprising of four square shaped tools was prepared. The tools had enough separation between them so that their polishing contour on the specimen did not overlap. The polishing was performed for two hours with a stroke length of 30 mm. Figure 2a shows the difference between the measurements before and after the polishing run. It has been compared with simulations when a step influence function is considered.

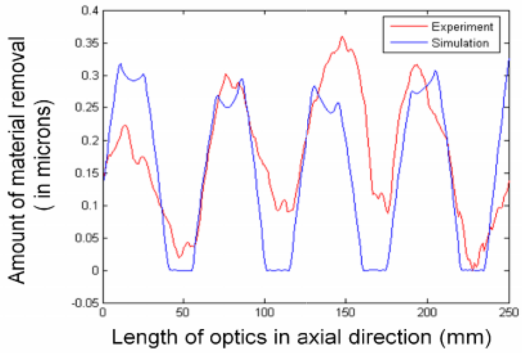

Fig. 2 *Difference between height measurements before and after polishing*

Figure 3 shows the shape of the average influence function for the selected square tools in axial and azimuthal directions qualitatively. It is observed that the influence functions are not symmetric in shape in azimuthal direction. We believe that the rotational directionality of the mandrel is the main reason for this asymmetry.

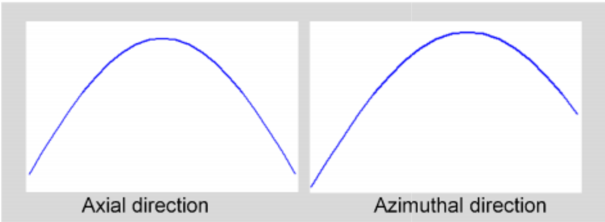

Fig. 3 *Experimental influence function in axial and azimuthal directions for the selected square tools*

3 Design considerations of large size polishing lap

The experimentally measured values have been fed in to the simulation software to get optimized design of polishing lap and machine operational parameters. It is observed that equal tool to groove ratio with two rows of shifted tool conguration (Fig.4) delivers the least residual mid-spatial-frequency deviations. The optimum stroke length is found to be as 30 mm.

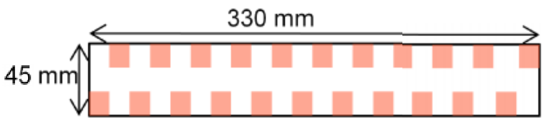

Fig. 4 *Optimum lap configuration while using square tool*

4 Results and Discussion

Using the inputs from the mathematical model, a mandrel having conical approximated Wolter-1 geometry has been polished using the computer-controlled cylindrical polishing machine recently developed at MSFC. The same polishing run is simulated using the developed mathematical model. Figure 5 compares the amount of material removal during actual polishing with that of the simulated one.

The experimental results agree with the predictions in broad terms but there are disagreements in the localised regions. At present we believe that they arise due to the non-uniformity in polishing lap compliance. Certain areas of tools are either not in contact with the surface or are not applying the same pressure on the surface. Investigations are in progress to determine the level of non-uniformity. This information will also be fed into the simulations to be able make more accurate predictions.

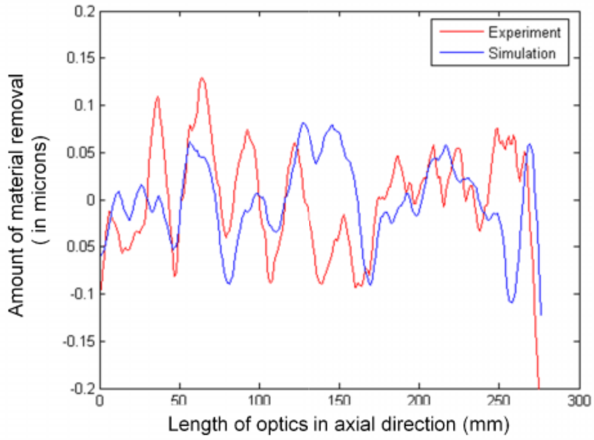

Fig. 5 *Difference between height measurements before and after polishing*

5 Conclusions

In summary, we have presented design considerations of large size polishing lap where the experimentally determined process variables have been used for optimising the lap configuration and the machine operational parameters. The first experimental results have been found in qualitative agreement with the predictions of the simulated model. Further investigations are under way to make the process quantitatively deterministic. One of the goals of developing the model is to find out the achievable limits in terms of angular resolution of the developed replicated optics at Marshall Space Flight Center, NASA. Additionally, the ability to simulate the polishing process is an important contribution to extend automation further and thus increase the cost effectiveness of mandrel production

6 References

1 Brian D. Ramsey, "Replicated nickel optics for the hard-x-ray region," Experimental Astronomy 20, 85-92 (2005).

2 Mikhail Gubarev, B. D. Ramsey, D. Engelhaupt, W. Arnold, "Technology Development for Nickel X-Ray Optics Enhancement," Proc. SPIE 7011, 7701133-7 (2008).

3 Gufran S. Khan, M. Gubarev, W. Arnold and B. Ramsey, "Development of a Computer-Controlled Polishing Process for X-Ray Optics", *Proc SPIE 7437*, (2009) 74371

Acknowledgements

This research work was supported by an appointment to NASA Postdoctoral Program at the Marshall Space Flight Center, administered by Oak Ridge Associated Universities through a contract with NASA