New polishing technology for large mirrors and lenses

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Summary

The *Precessions*™ process, and the 200mm capacity 'AII' machine which embodies it, are outlined in the accompanying paper '*New method to control form and texture on industrially-sized lenses*'.

In this paper, we summarise the development of the process to address larger optical components. The first machines constructed for this application are of 600mm capacity. A conceptual design of a 1-2m class machine of bridge-configuration has also been produced. Unlike the AII machine, the work-piece on these larger machines lies in a horizontal plane i.e. with the rotation axis of the work-piece spindle vertical. This configuration is preferred because it allows the use of a hydrostatic support-system for the work-piece; important for large optics in general, and particularly so for light-weight optics. The machine can also provide a clear vertical path above the work-piece for optical testing, or for access by lifting gear.

It is interesting to consider how the *Precessions*™ process can be scaled. As an example, consider first that the type of surface-form remains the same; it might, for example, be an f/2 parabola. Consider then that the work-piece diameter, the bonnet-diameter, the polishing spot-sizes used, and the tool-path on the surface, are all stretched by a factor of two. The area of the polishing spot and that of the work-piece have both increased by a factor of 4, but the number of convolutions of the spiral tool-path remains the same. Since the spot instantaneously addresses the same fraction of the overall work-piece surface-area, the terms all cancels in relation to cycle-time. However, for the same tool-rpm, the larger bonnet delivers a proportionally higher surface-speed, because the polishing action is further from the axis of rotation. Therefore, the volumetric removal rate (proportional to contact-area times surface-speed) tends to vary as the cube rather than the square of the scale-factor. As a result, the larger bonnet working over the larger work-piece with the same polishing pressure, will remove twice the depth of material in the same time.

The Zeeko IRP600 CNC polishing machine at UCL (600mm capacity)

The above scaling could, in principle, *reduce* cycle times on larger parts. In practice, we have found that excessive removal-rates lead to impractically short dwell-times, especially near the centre of a spiral tool-path. Such scaling also demands increased traverse-speeds and accelerations from the machine, and this rapidly becomes a limitation.

Moreover, as the process converges on final form, *smaller* depths of material need to be removed. In practice, we have found it necessary to moderate the process by diluting the slurry and by moving from a polyurethane tool-surface to a material that delivers a lower-removal rate, such as Multitex. We are also developing bonnets that are compatible with operation at a reduced polishing pressure, in order to give additional control for fine-removal.

The current status of the process development is as follows. A form error of ~80nm peak-to-valley has been achieved aspherising a 100mm diameter part. This work revealed some subtle but significant limitations in the optimisation code, mostly concerned with convergence and residual ripples. Recent work has focussed on this aspect, and the revised code is now ready for polishing trials. A 150mm diameter part is currently in-process, and work is about to commence on a 300mm fused silica mirror for a space application.

For process cutting stiffnesses much greater than the critical cutting stiffness, large tool vibration is indicated by the eddy current probe and heavy chatter marks are observed at the edge of the ground surfaces, as shown in the Figure 3a. For process cutting stiffnesses smaller than the critical cutting stiffness, chatter was not observed during grinding or on the final surface.

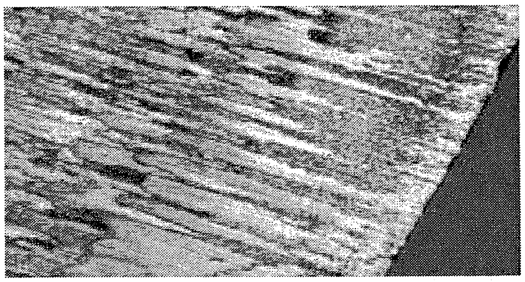

Figure 3a: Heavy chatter marks

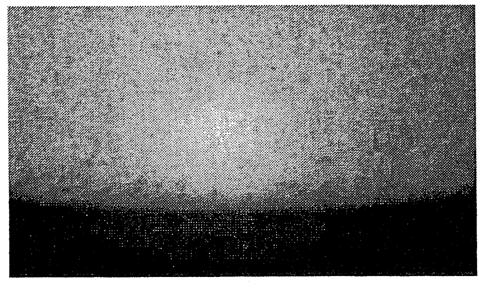

Figure 3b:No chatter marks

Experiments also showed the chatter amplitude increase with the cutting stiffness. This is illustrated in Figure 4.

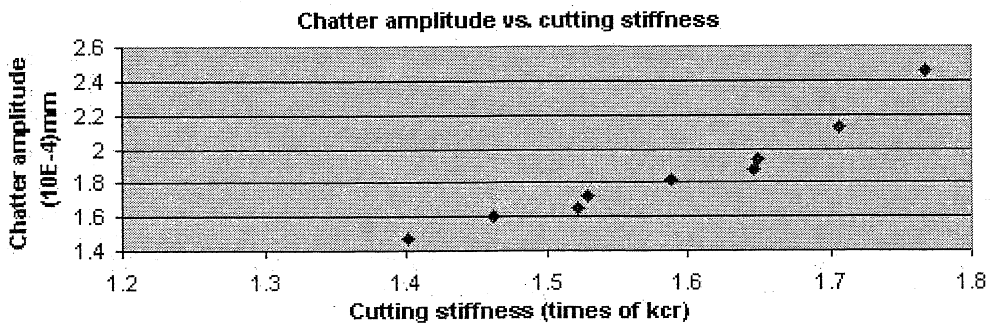

Figure 4: Chatter amplitude increases with the cutting stiffness

4. Conclusion:

Chatter can be predicted when the process cutting stiffness exceeds the critical cutting stiffness. Modeling can predict process cutting stiffness as a function of process parameters. Experimental results show chatter amplitude increases with the process cutting stiffness. Proper process parameters can be selected to limit the process cutting stiffness and avoid chatter.

5. Reference

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