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Abstract

A typical optical fabrication process involves a series of basic process steps including: 1) shaping, 2) grinding, 3) polishing, and sometimes 4) sub-aperture tool finishing. With significant innovation and development over the years in both the front end (shaping using CNC machines) and the back end (sup-aperture tool polishing), these processes have become much more deterministic. However, the intermediate stages (full aperture grinding / polishing) in the process, which can be very time consuming, still have much reliance on the optician's insight to get to the desired surface figure. Such processes are not presently very deterministic (i.e. require multiple iterations to get desired figure). The ability to deterministically finish an optical surface using a full aperture grinding/polishing will aid optical glass fabricators to achieve desired figure in a more repeatable, less iterative, and more economical manner. Developing a scientific understanding of the material removal rate is a critical step in accomplishing this.

In the present study, the surface figure and material removal rate of a fused silica workpiece is measured as a function of polishing time using Ceria based slurry on a polyurethane pad or pitch lap under a variety of kinematic conditions (motion of the workpiece and lap) and loading configurations. The measured results have been applied to expand the Preston model of material removal (utilizing chemical, mechanical and tribological effects). The results show that under uniform loading, the surface figure is dominated by kinematics which can be predicted by calculating the relative velocity (between the workpiece and the lap) with time and position on the workpiece. However, in the case where the kinematics predict a time-averaged removal function over the workpiece that is uniform, we find experimentally that the surface deviates significantly from uniform removal. We show that this non-uniform removal is caused by the non-uniform stress distribution resulting from the viscoelastic nature of the lap. The viscoelastic lap results in a strain difference across the part due to a time dependent deformation of the lap as it travels pass the workpiece. A quantitative viscoelastic model has been developed to explain this effect. The effects of the viscoelastic lap on the removal function can be removed by pre-straining the lap before it contacts the workpiece which have shown better than $\lambda/4$ surfaces being maintained with continuous removal.

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