Andrzej Szwedowski *

An Investigation of the Accurate Smoothing of Spherical Surfaces Processed with a Grinder of Forced Movement of Both the Tool and Workpiece

The purpose of the investigation was to determine experimentally the influence of some kinematic parameters of a special grinding machine designed in the Dept. of Optical Instruments, Technical University of Warsaw, Poland upon the results of trueing and smoothing the lens blocks performed with the finest abrasives.

As a result of the examination the dependence of the shape variation in the workpiece surface upon unclination angle α of the head as well as the angular position β of the upper drive spindle with respect to the head axis has been established. Also, the corresponding changes in the treated surface, occurring in the course of continuous supply of the grinding suspention in a closed cycle, have been examined for the case of constant initial form of the workpiece as well as the constant pressure and speed.

Grinder

The grinding machine being under study is designated for the treatment of spherical optical elements, the radii of which range from 15 to up 40 mm. In accordance with the requirements accepted during construction the exploitation features qualify the grinder to be applied in mass production of elements of relatively high thickness accuracy, medium tolerances of shape and surface purity. An essential feature of the kinematic system is the forced rotation of both the cutting tool the workpiece around the central point of the kinematic system; the point being defined as an intersection point of the head axis with those of the upper and lower spindle respectively. Simoultaneously this point happens to coincide with the center of the processed surface curvature.

The lower drive spindle unit (on which a lower tool, for instance, a convex inlay tool has to be mounted) is similar to those used in traditional types of grinding-polishing machines. The grinder head, around which the spindle driving the upper tool (for instance, a concave tool) rotates by planetary motion, may be tilted with respect to the lower spindle axis by an optional angle α ranging from 0° to 20°; the chosen angle being kept constant during the processing period. Also, the angle β between the head axis and the lower spindle axis may be regulated within the angle range $14^{\circ}-20^{\circ}$. Thanks to the concentricity of both the rotations a high smoothness of the relative movement of the tool and the workpiece was gained as well as some relative stability achieved, resulting from the

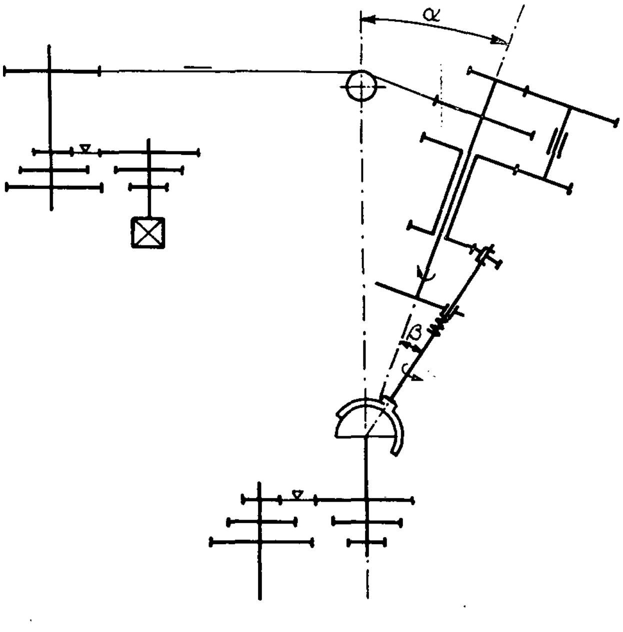

Fig. 1. Kinematic diagram of the grinder

---

*) Instytut Konstrukcji Przyrządów Precyzyjnych i Optycznych, Politechnika Warszawska, ul. Koszykowa 75, Poland.

fact that the stress produced by the telescope spindle is also directed toward the curvature center. In this way the damaging influence of the sudden "veerings rounds" of the driver during its movement on the required constancy of the friction couple, existing between the tool and workpiece surfaces, is minimized. The enforced movement of the upper convex tool is a result of superposing the rotational motion of the spindle round its axis and a rotation-translatory movement of the same spindle around the axis of the sloped head.

Results of the Investigation

The testing was performed on some convex lenses fixed on the lower spindle as well as on some concave lenses fastened to either the lower spindle or to the upper one always after having roughed the lenses in a routine way. In the both cases the tools to be applied have been modified in such a way that the suspention could flow around more freely. The examination of the workpiece shape variation dependence on the form of the cutting tool, when changing the head slope angle α and the angular spindle position β, has confirmed the well-known fact that the influence of the kinematic parameters is minor when compared to that of the cutting tool form, however, it is observable while trueing or finer trueing. The quantitative estimation shows the shape variations to be of order of few interference fringes.

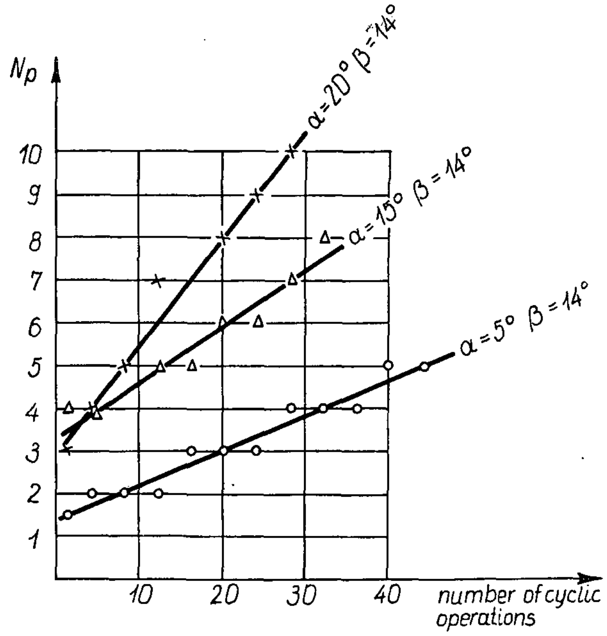

Fig. 2. Changes in a convex surface shape due to processing in a lower-positioned workpiece variant ($N_P = 1$ coresponds to $\frac{\Delta R}{R} = 1.6\cdot 10^{-4}$)

For the convex surfaces an increase of the deflection angle of the tool position results in diminishing the curvature radius of the surface being processed in a way indicating greater influence of the angle β than that of α. For instance, for $r = 24.5$ and ⌀ 18 mm an increment of α by amount of 5° results in increase of $\frac{\Delta r}{r}$ by $0.8\cdot 10^{-4}$ while the same change in β causes growth of $\frac{\Delta r}{r}$ by the factor 2.5 in comparison to the previous value. Finally, the difference in shape of the cutting tool and the workpiece surface is also changing and tends to lessen with the increment of the said angles. Note that the increase mentioned is equivalent to enlarging the workpiece area uncovered by the tool.

Trueing the lenses of concave surfaces was performed by means of two kinematic systems: a) when the tool is fixed on the lower spindle and b) when the workpiece in fastened on the lower spindle. The measurement results prove that the surface shape may be changed by altering the lathe adjustment within the similar range of values $\frac{\Delta r}{r}$. Knowledge of this dependence reders possible to correct the shape of the processed surface also when producing in a mass scale.

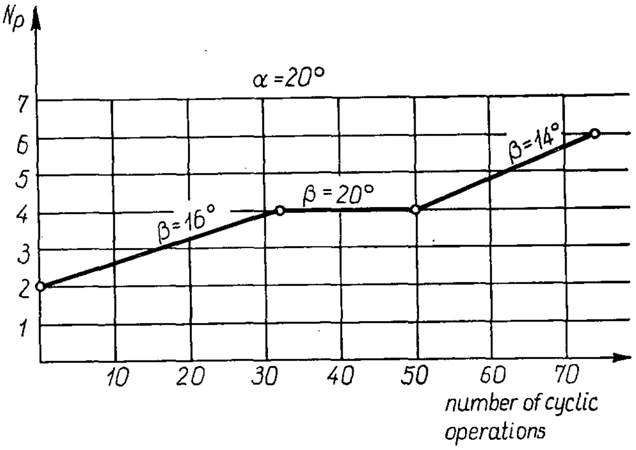

Fig. 3. Changes in concave surface shape due to the processing in a upper-positioned workpiece variant ($N_P = 1$ corresponding to $\frac{\Delta R}{R} = 1.6\cdot 10^{-4}$)

So far as the tool shape is concerned the testing of its constancy in the course of serial treatment performed under unchanged conditions seems to be much more interesting. The results of the manifold processing of concave surfaces are various, depending on the mutual positioning of the tool and workpiece. For instance, in the upper position of the workpiece the shape of its surface changes by amount of

$\frac{\Delta r}{r} = 5\cdot 10^{-4}$ after 40 operation cycles in the case of the optimal angular position of the head. The lower workpiece position variant happens to be more profitable because the change $\frac{\Delta r}{r} = 6.4\cdot 10^{-4}$ occurs first after 74 cycles, provided the same optimal adjustment is being kept. Another feature was that in the lower workpiece position the abrasive suspention concentration had to be considerably higher than that used for the upper-positioned workpiece (the corresponding relations being 1 : 1 for the first case while 1 : 6 in the second). This makes a continuous supply of the abrasive more difficult under the closed cycle condition. For the case of convex surface processing the tool shape proved to be constant within the tolerance region $\frac{\Delta r}{r} = 3\cdot 10^{-4}$ in the course of the 154 operations performed for various positioning of the head.

A long time check of the workpiece surface for a significant increase of the treatment period pointed out that the shape remains practically unchanged. For instance a prolongation of the processing time from 5 min. up to 90 min. coused a shape deformation of $\frac{\Delta R}{R} = 1.5\cdot 10^{-4}$.

The graphs illustrate the changes in both tool and workpiece shape registered during the examination.

Zygmunt Bodnar, Waldemar Kowalik *

Measurement of Optical Heterogeneity in Glass Blocks by Means of Interference and Autocollimation Method

The index of refraction in glass blocks is not a constant value. It differs in different parts of the glass blocks, depending on the local chemical composition. Thus the refractive index is a function of the spatial coordinates. The changes may be conveniently described by means of its gradient, which is also a space coordinate function. By heterogeneity we understand continuous changes of the refractive index within greater regions. These are not to be confused with the rapid changes of the stria or jump types.

Principle of Measurement

A block is illuminated by a parallel light beam. The run of the light ray is influenced by all the nonuniformities met along its path. Thus the measured value of the gradient is only an average value with respect to the unit block thickness, and we will describe it in this way. The ray deflection is caused by the following effects: geometric wedge of the block (when considering the refractive index to be constant and equal to the average value of its true distribution) and the gradient component perpendicular to the ray direction. The optical wedge φ_0 is here defined as a wedge-like operation of the optical block resulting in optical ray deflection independently of whether it is caused by a geometrical wedge or the particular type of the heterogeneity or both. This will be calculated as a geometrical wedge made of material of refractive index equal to the average index of the true material. Thus the optical wedge represents the deflecting properties of the glass block both due to true geometrical wedge

---

*) Instytut Fizyki Technicznej Politechniki Wrocławskiej, Wrocław, Wybrzeże S. Wyspiańskiego 27, Poland.