$\frac{\Delta r}{r} = 5 \cdot 10^{-4}$ 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 non-uniformities 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.

operation and the gradient component perpendicular to the viewing direction. The perpendicular gradient component happens to be proportional to the difference of the optical and geometrical wedges

$$\mathrm{grad}_z n = \frac{n}{z}(\varphi_0 - \varphi),$$

where n is an average index of refraction in the block, z denotes the block thickness in the viewing direction, φ_0 is the optical wedge, while φ denotes a geometrical one.

The measurement is reduced to measuring the geometrical and optical wedges. The method proposed hereafter allows to determine the measuremental sense of the grad n. Namely, it will be understood as an average value for that part of the light beam cross-section for which the geometrical and optical wedges have been determined. This will be true for both the telescope method and the interference method, the latter being formulated in terms of averaged distances between the fringes. When using the interference method (Fringes of equal thickness) a more accurate analysis of the cross-section is possible by increasing the number of points to be analysed (congestion of the interference fringes) and changing their directions. Practically, it is possible to determine the gradient for arbitrary chosen point region of the cross-section of the light beam passing through the block. Generally the perpendicular gradient component is a nonlinear function of the cross-section coordinates. By some convention it is possible to introduce a distinction between linear and nonlinear changes.

Determination of Linear Changes

AN AUTOCOLLIMATION METHOD has been proposed by Z. Bodnar [1] and then improved by Z. Bodnar and F. Ratajczyk [2,3]. The glass block ot be examined is placed between two autocollimating telescopes positioned each in front of the other. The angular distances of the autocollimation hair-crosses reflected from both the block sides are to be measured. Then the block is turned round by about 180° about the vertical axis and the measurements are repeated. In this way after some calculations we obtain simultaneously the horizontal components of the geometric and optical wedges both being perpendicular to the viewing direction. Different positioning of the glass block results in obtaining each time two gradient components for the same coordinate and different viewing direction.

THE INTERFERENCE METHOD allows also to find both the geometrical and optical wedges. The geometrical wedge may be conveniently found by means of the Dowell interferometer. Naturally, the surface of the block to be examined is then deposited with metal films so that they reflect totally the light. The optical wedge may be determined in the Fizeau interferometer by realizing an interference between the block sides. The laser light is then most conveniently to be applied, because considerable path differences occur in the region. The same results may be obtained by placing the glass block in one branch of the Twyman-Green interferometer. An interference through glass block is then realized. The grad n may be determined without the geometrical wedge measurement as well.

Then the block has to be cut into two parts and one of them is to be turned with respect to the other by 180° about the axis perpendicular to the cut plane. In this mutual position they should be glued together, while the surfaces perpendicular to the cut plane have to be polished. In this case the geometrical wedge between the respective sides of the modified block will be the same. The gradient components parallel to the cut plane in both the parts will be reversely directed. For the viewing direction parallel to the division plane the differences of the optical wedges for both the block parts may be easily measured. The differences are proportional to the grad n. The greatest disadvantages of the last method lies in cutting the block.

Determination of the Nonlinear Heterogeneity

When performing the measurements zone after zone for both the telescopes we may determine the values of the nonlinear changes. They are defined by the gradient differences in the particular zones. In the interference method a general dependence may be found, i. e. the linear changes modified by the nonlinear changes (if we resign of the averaging of the fringe distances). The only nonlinear changes are much easier to determine by measuring the rise of arch of the interference fringes.

Preliminary Measurements

All the above considerations are correct when ignoring some additional errors. The errors are introduced first of all by deviations of the block surfaces from perfect flatness as well as by the surfaces of interference mirrors and so on. These additional influences may be taken into consideration but the respective analysis becomes much more complex. The elimination of the errors is possible by requiring high quality flat surfaces for both the glass block and the interferometer mirrors.

In our case all the surfaces were flat up to 0.1λ. The checking measurements were carried out for several glass blocks with the methods described above. The linear changes for different blocks ranged from $5\cdot10^{-6}$ cm^{-1} to $25\cdot10^{-6}$ cm^{-1}. The maximal scatter of the results between the particular methods amounted up to 10%. The nonlinear changes amounted up to $1.5\cdot10^{-6}$. In the majority of blocks they were not measurable.

The further work is being done to improve the accuracy of the measurements.

References

[1] Bodnar, Z. *Autokolimacyjna metoda badania niejednorodności szkła optycznego*, Pom. Aut. i Kontr. rok II, 1963, No. 1, p. 35.

[2] Bodnar Z., Ratajczyk F., *On an Autocollimation Method of Optical Glass Heterogeneity Measurement*, Appl. Opt. No. 2 (1965), p. 181.

[3] Rau K., *Die Homogenität des Quarzglases*, Sonderdruck aus „60 Jahre Quarzglass — 25 Jahre Hochvakuumtechnik", herausgegeben von der W. C. Heraeus GmbH, Hanau 1961.

[4] Bodnar Z., Ratajczyk F., *Some Remarks Concerning Optical Glass Heterogeneity Measurements with the Help of the Autocollimation Methods*, Appl. Opt., No. 3 (1965), p. 351.

[5] Rosberry F. W., *The Measurement of Homogeneity of Optical Materials in the Visible and Near Infrared*, Appl. Opt., No. 6 (1966), p. 961.

[6] Roberts F. E., Langenbeck P., *Homogeneity Evaluation of Very Large Discs*, Appl. Opt., No. 11 (1969), p. 2311.

Halina Płokarz, Florian Ratajczyk, Barbara Lisowska *

An Attempt of Numerical Estimation of the Stria Measurement due to GOST-Method

The striae are regions inside glass volume differing distinctly by the refractive index from the surrounding glass mass. These regions may be differently spread and have various forms. Any light beam is deflected by them (being refracted, reflected or difracted) by an angle α. This fact enables to observe a shadow "map" of the striae on a screen positioned perpendicularly to the beam pass direction. The procedure described above determines the essence of the so called shadow projection. The striae intensity in the method is defined by the measurement condition, for instance, the light source diameter, the distance of the glass block from the screen and so on, by which the shadow becomes invisible on the screen.

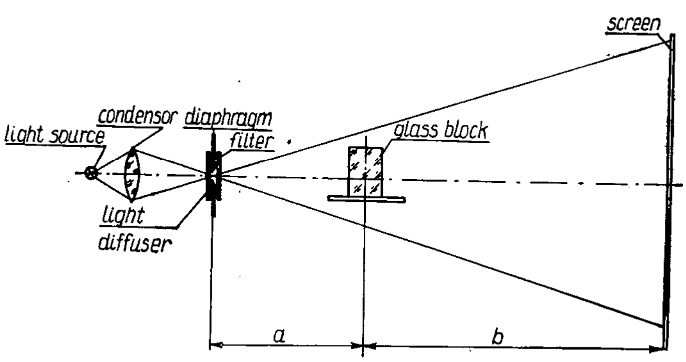

Fig. 1

Another seldomly applied method of the striae detection is due to Topler. The measurement arrangements based on the method are called striascopes (Schlierengärate in German). They allow for an immediate measurement of the angle α of the light beam deflection by a stria. In this sense it is a numerical (objective) method. The purpose of the work is to establish if there exists any connection between the two methods.

Among the shadow projection methods the one similar to that described in the Soviet Standard GOST 3521—57 has been chosen for considerations. A setup for the observation with the help of the said

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