Analysis of Selected Factors in the Diagnostic Testing of Optically Transparent Polymeric Foils

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Abstract. *The contribution treats the topic of selected factors, that influence the quality of imaging of optically transparent polymeric foil by the schlieren visualization methods. One of the ways how to influence the resulting quality of the image gained by the visualization methods is the correction of brightness inhomogeneity of the image. Quality of images is a very important assumption when to use the quantitative methods of evaluation of foils images.*

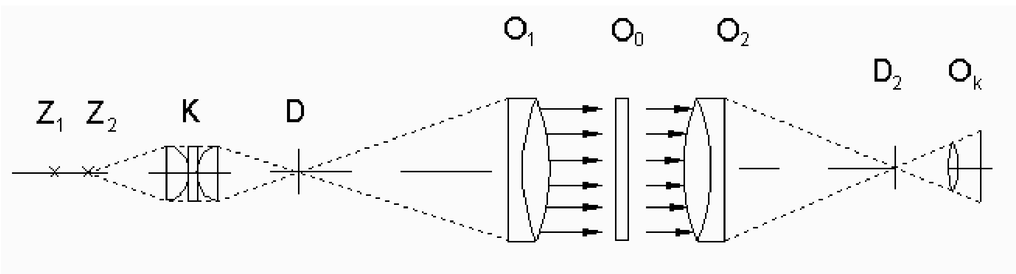
Keywords: schlieren, optical visualization, polymeric foil, of brightness

1. Introduction

Optical visualization methods offer numerous advantages in studies of hydrodynamic properties of fluids [1], but they can provide useful information on the visually inaccessible objects such as optically transparent polymers and, especially, polymeric foils as well. They use changes in the absorption of photons during their transmission through mechanically loaded regions. The main advantage of these methods is that they provide information that can be used for further processing after photographic or digital recording.

From many optical visualization methods we have chosen the schlieren method. In the fundamental arrangement, mostly referred to as the Toepler system [2], a parallel light beam traverses the test object and is focused thereafter by means of a lens or spherical mirror, named the schlieren head. A knife edge is placed in the plane of the light source image to cutoff part of the transmitted light. This Toepler schlieren system has found a great variety of modifications. An optical apparatus constructed after J. Bolf utilizes a modified schlieren head in form of the small circular diaphragm. Light is deviated along the optical path from its nominal course in the absence of refractive - index variations. The amount of light deflection generated by a transparent optical phase is measured. [3].

In fig.1 is the fundamental optical arrangement of the schlieren system.



Obr.1 The optical arrangement of the schlieren system,

The apparatus consists of the light source located at the focal point of the condenser lens K. Beyond this lens there is on the optical axis focal point D as the common point of the lens K and the objective O_1. The collimated light passes through the test object O_o (polymeric foil) and enters the objective O_2 , that focuses the light to form an image of the light source. The diaphragm D_2 (a knife edge in the original arrangement, mostly referred to as the Toepler system) is located at the focal point of the second objective. A camera lens is positioned beyond the diaphragm and located to form an image of the light source. The camera objective focuses the test object onto the recording plane, where a reduced intensity of light, depending on the amount of light cut off by the carefully adjusted diaphragm, can be observed. Without any disturbances in the optical path, the original light source will have uniform reduction in intensity due to the light cut-off by the diaphragm. When there is a disturbance in the optical path, the light rays will be deflected.

Results of papers [4],[5],[6] refer to possibilities of the use of schlieren visualization method in the field of the diagnostics of optically transparent polymeric foils. These papers showed possibilities of the use of statistical methods in the field of defectoscopy and application of co-occurrence matrix to the classification of optically transparent polymeric foils on the basis of visualized images.

2. Recording and image processing of visualized polymeric foils

For image processing it is necessary to correct influence of light source inhomogeneity, influence of the optical string and the sensing device for evaluation of images gained by the optical visualization of polymeric foils. One of the possibilities is to use reference image picked up without presence of test object. The reference image can be taken as an image of errors of the whole optical system on the assumption that we have used a virtual light source [6]. Correction of brightness errors is necessary for the further image processing by the statistical methods. The brightness correction can be evaluated from [7]

$$g(i,j) = \frac{c}{f_c(i,j)} . f(i,j) ,$$

where f(i,j) are values of brightness of a test foil , $f_c(i,j)$ are values of reference image brightness in the same point , c is a suitable chosen constant and g(i,j) is the grey level of resulting image.

Successfulness of the brightness correction based on the use of reference image depends on the stability of the light source and on the magnitude of the brightness deformations in the recorded image. In fig. 2 is illustrated time dependences of the mean grey level of the reference image. The first dependence (source 1) is measured using the halogenous light source controlled by autotransformer. The second dependence (source 2) is measured using the halogenous light source controlled by electronic controller. There is a substantial dependence in the brightness stability. Using the first source are the differences in the mean brightness in short time periods near to the step of quantization of the grey level. The relative error of brightness correction increases with the decreasing value of the grey level of pixel of reference image.

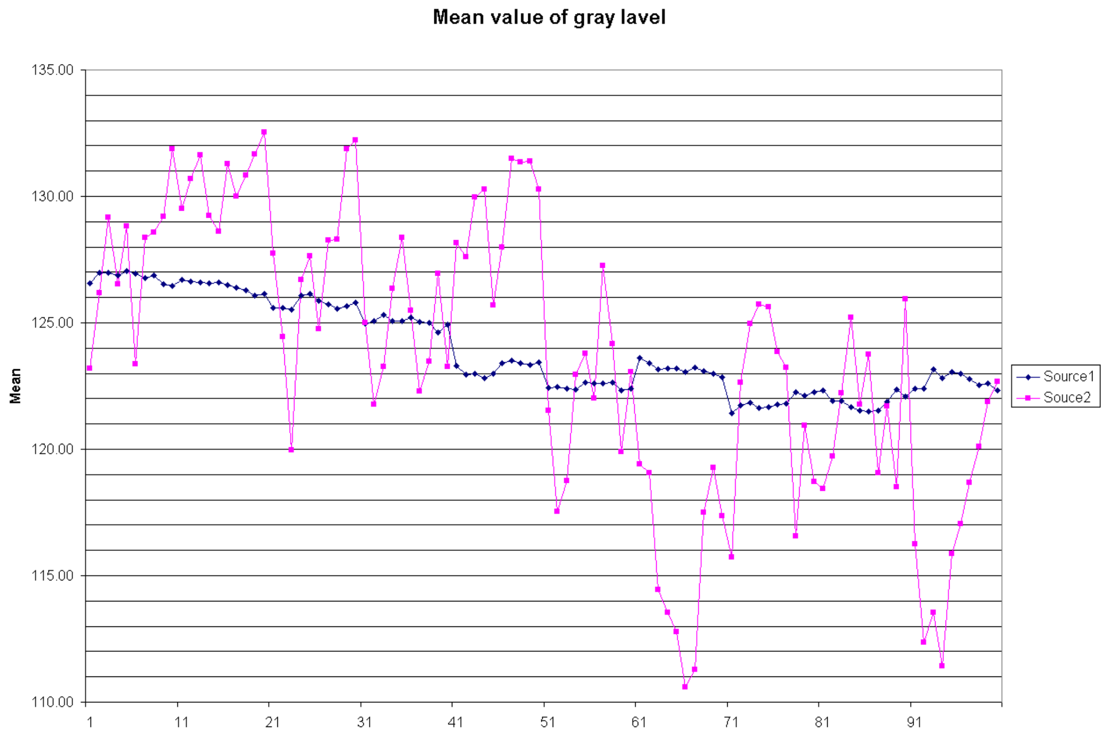
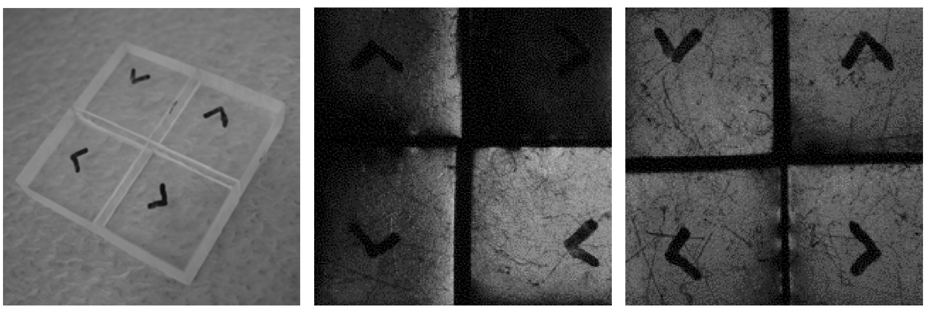


Fig. 2 Time dependence of the mean grey level of the reference image

When to process images limited extent of grey levels is used (usually from 0 to 255). Therefore it is an attempt to get such recording conditions, that changes of the brightness in the reference image were minimal. The brightness disturbances can be caused by the nonhomogeneity of the light source, by impurities in the optical path and by the noncollinearity of optical axes of objectives O_1 and O_2 (fig.1). Experiments showed, that the last factor has the substantial influence on the homogeneity of the image obtained by the schlieren apparatus.



a. b. c.

Fig. 3 a/ Image of a helpful tool
b/ Image of visualized tool in the case of inaccurate adjustment of optical axis
c/ Image of visualized tool in the case of an accurate adjustment of optical axis

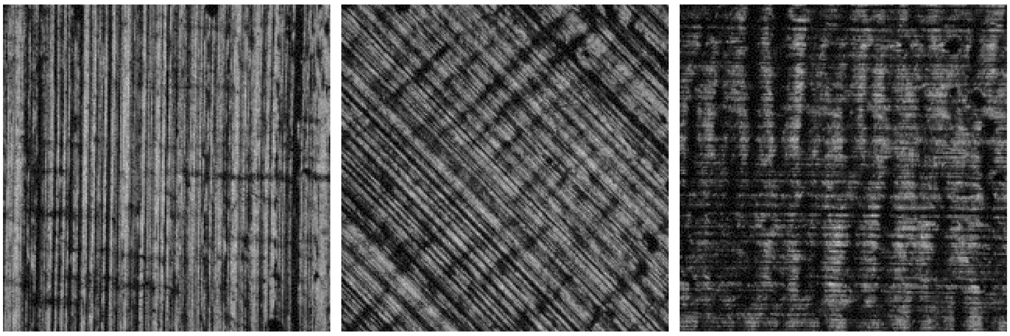


Fig. 4 Image of the visualized rotated foil in case of inaccurate adjusted optical axis.
a/ angle of rotation 0°, b/ 45°, c/ 90°

In order to rectify this error a useful tool consisting of four square areas one another 90° turned round was produced. Areas were carved out of the suitable choice perspex. Sense of areas direction is such adjusted, that the change of brightness of respective area marks direction of adjustment of optical axis of the objective O_2 in the schlieren apparatus. In fig. 3 is an image of a helpful tool with the effects of different adjustment of the optical axis.

In addition to this effect the experiments showed, that just in the process of visualization of optically transparent polymeric foils causes this factor substantial deformations in the character of visualized structures that can be revealed by the rotating the foil sample. In fig. 4 is illustrated the effect of turning the transparent foil sample on the image obtained by the schlieren apparatus in case of inaccurate adjustment of the optical axis of the objective of apparatus. In fig. 5 are images of the same sample corresponding to the different turning in the case of properly adjustment of the schlieren apparatus.

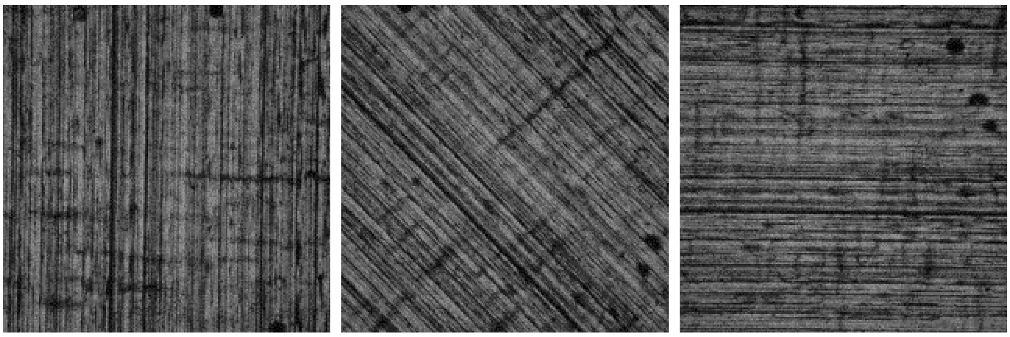


Fig. 5 Image of the visualized foil from fig. 4 in case of accurate adjusted optical axis
a/ angle of rotation 0°, b/ 45°, c/ 90°

3. Conclusion

Above mentioned results refer to the importance of the accurate adjustment of optical axes of the objectives and of the stability of the light source in the schlieren apparatus. Errors caused by these factors in the images of polymeric foils can't be rectified by the methods of image processing. Effects of such errors influence substantially statistical characteristics calculated from the images of test foils in the field of foils classification on the basis of their visualized images. In the field of defectoscopy there is a less influence of these factors because the brightness anomalies caused by the defect predominate over the changes of grey level caused by the natural anomalies of the test foil.

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