The Use of Brightness Correction Improvement in Defectoscopy of Transparent Polymeric Foils

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Abstract. *The contribution treats the topic of analysis of deformations sources of visualized transparent polymeric foils images by the schlieren method and by methods of image processing. The brightness deformations caused by the in-homogeneity and imperfection of tested material are visualized by schlieren system and by methods of image processing. A new method of correction of brightness distortion is presented. The method is completed by the image correction of foil based on the equalizing local mean values of greyscale to the global mean value of the image excluding pixels with outlying brightness. The described correction is applied on the detection of polymeric foils defects.*

Keywords: Schlieren, Optical Visualization, Polymeric Foil, Brightness Correction, Defectoscopy

1. Introduction

Optical visualization methods utilize changes in the absorption of photons during their transmission through mechanically loaded regions. With regard to the equipment of our optical laboratory we have chosen schlieren visualization method. Schlieren system serves to measure the amount of light deflection generated by an optical transparent phase object. A parallel light beam traverses the test object and is focused thereafter by means of a lens of spherical mirror, named the schlieren head. Optical apparatus constructed after J. Bolf [1] consists of the light source. Light beam traversing the test object is deviated along the optical path from the nominal course corresponding to the absence of variations of refractive index. 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. The biggest advantage of Schlieren method is that it provides an illustrative and comprehensive picture of the nature of the flow, it provides useful information on the visually inaccessible objects such as optically transparent materials, especially, polymeric foils [2], [3]. Digital recording can be further processed by means of image processing methods enabling defectoscopy and classification of tested polymeric foils.

2. Brightness correction

In order to evaluate images gained by the optical visualization of polymeric foils by image processing it is necessary to correct influence of non-homogeneity of light source, influence of the optical string and the sensing device [4]. 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 provided that we have used a virtual light source [5]. Correction of brightness errors is necessary for the further image processing. The brightness disturbances can be caused by non-colinearity of optical axes of the condenser lens and the objective lens [4], non-homogeneity of the light source and impurities in the optical path. When we scan the image by the schlieren apparatus without presence of the tested foil brightness distortions of the obtained image represent image of distortions of the optical path and non-homogeneity of light source. Formula for corrected foil image $f_C(i,j)$

$$f_C(i,j) = \frac{c}{f_e(i,j)}.f(i,j) \tag{1}$$

where f(i,j) is distorted foil image, $f_e(i,j)$ is an image of distortions from virtual ideal homogenous light source whose image in ideal case is the image with the constant brightness c. The value c is chosen in order to have brightness value of corrected image in boundaries of display access. Correction [5] is based on the fact that in case of the foil without defects each area of image of visualized foil structure of sufficient size should have the same mean value. Image of foil I(i,j) of size NxN has been divided into square disjunctive areas J(m,n) of size KxK, where K=N/k. Coefficient of correction of radial deformation for the area centre is described by

$$C\left((m-1)K + \frac{K}{2}, (n-1)K + \frac{K}{2}\right) = \frac{\frac{1}{N^2}\sum_{i=1}^{N}\sum_{j=1}^{N} I(i,j)}{\frac{1}{K^2}\sum_{i=(m-1)K}^{mK}\sum_{j=(n-1)K}^{nK} I(i,j)} \tag{2}$$

When to put $m_K = (m-1)K + \frac{K}{2}$ $n_K = (n-1)K + \frac{K}{2}$ then the coefficient (5) can be expressed by $C_{m,n} = C(m_K, n_K)$. We shall calculate value of correction for the arbitrary point of the image by the bilinear transformation of coefficients (3) of four nearest areas centres to the given point. When for i, j $i \in \langle r_K, (r+1)_K \rangle$, $j \in \langle s_K, (s+1)_K \rangle$ and when to mark A, B as

$$A = C_{r,s} + \frac{C_{r+1,s} - C_{r,s}}{K}(i - r_K) \qquad B = C_{r,s+1} + \frac{C_{r+1,s+1} - C_{r,s+1}}{K}(i - r_K)$$

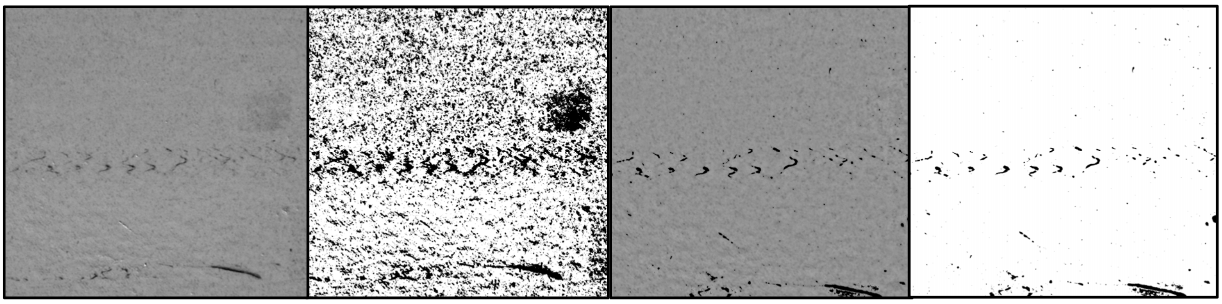
Brightness values of corrected image are calculated from

$$f_{CR}(i,j) = f_C(i,j).C(i,j) \tag{3}$$

where $C(i,j) = A + \frac{B-A}{K}(j - s_K)$.

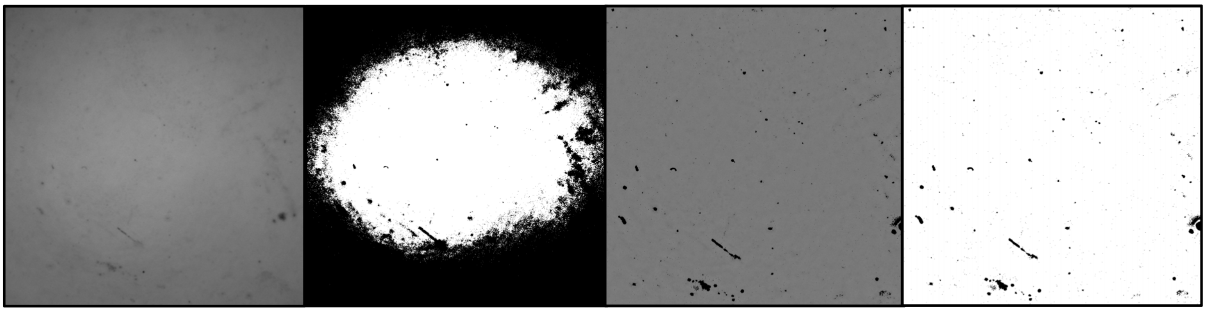
3. Experimental results

Images of visualized foils have been captured by a color still camera because of higher resolution (5 megapixels). Quantization error of brightness level with 256 levels of brightness using equation (1) causes that distortion correction towards lower values are characterized by higher relative error. This effect gives rise to the fact that greater brightness distortions are not sufficiently corrected. It can be seen that image brightness distortion are caused by the global tendency of decrement in brightness with increasing distance from the optical axis of the schlieren apparatus. Fig. 1 demonstrates the difference between results of brightness correction according to (1) and (3) on the images of foil sample KXE20.



a/ b/ c/ d/

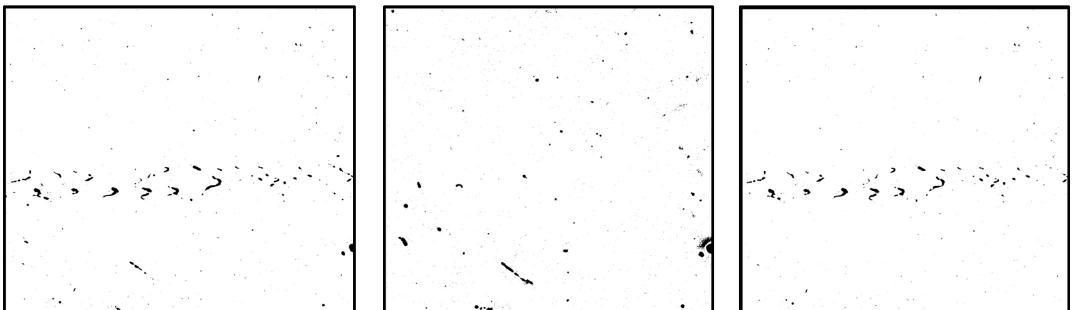
Fig. 1. Images of foil KXE20 a/ after correction according (1), b/ thresholded image corrected according (1), c/after correction according (3), d/ thresholded image corrected according (3)



a/ b/ c/ d/

Fig. 2. Reference image a/ without foil corrected according (1), b/ thresholded image according (1), c/ after correction according (3), d/ thresholded image corrected according (3)

Imperfection of the correction is visible in Fig. 1.b created by the thresholding by the optimal global threshold (Otzu) of corrected image (Fig. 1. a) by the method (1). Good properties of correction of the image 1.c according (3) demonstrates Fig. 1.d obtained by the thresholding of the image 1.c by the same method as the image 1.b was.



a/ b/ c/

Fig. 3. Thresholding of corrected images by method (3) a/ foil KXE20 with defects and with anomalies of optical path, b/ reference image, c/foil KXE20 with defects but without anomalies caused by the optical path.

The ability of method (3) to correct the inhomogeneity of the light source caused by the tendency of image intensity reduction with increasing distance from the optical axis demonstrates Fig. 2 for image gained by the schlieren system without foil sample. Method (3) demonstrates good properties in Fig. 2.c presenting corrected image Fig.2.a. Correction quality proves thresholded image Fig. 2.d of the image Fig. 2.c. From Fig. 1.d and Fig. 2.d it is evident that correction (3) doesn’t suppress nor deform local anomalies of the image brightness level. As the significant anomalies we shall consider such areas whose brightness level after correction exceeds k.σ (k multiple of the standard deviation from mean brightness level of all image). During the foil recognition from their images these areas are excluded from the calculation. In the case of defectoscopy marked areas in Fig. 2.d detect local anomalies of the optical path of the schlieren system that logically are areas where it is not possible to localize defects of the tested foil. In the case of foil images mentioned anomalies in the image can be caused by the foil defect. The fact enables to visualize only defects of the foil without anomalies caused by the optical path. Correction (3) gives a relatively simple representation of anomalies in the image of distorted foil. In Fig. 1.d we can see not only deformation caused by the defects of the foil but also anomalies caused by the optical path. There are only anomalies of the optical path in Fig. 2. Detection of defects is based on the extraction of optical path anomalies from images of tested foils. Described procedure demonstrates Fig. 3. There are visualized anomalies caused only by the defects of tested foil in Fig. 3.c.

4. Conclusions

The contribution presents application of a new approach concerning correction of brightness levels of visualized polymeric foils images in defectoscopy. In contrast with method [6] that was able to detect only areas with extensive defects described method localizes and distinguishes significantly smaller defects. As a result the method enables to analyse shape, frequency and distribution of defects in the image.

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