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The Analysis of Properties of Schlieren Color Images

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Abstract

Contribution treats the topic of experimental analysis of statistical properties of intensity images of red, green, blue component and grey-scale representation of color image of visualized optically transparent polymeric foil by means of schlieren method. As the subject of the analysis were corrected intensity images of RGB components and grayscale representation of color image of visualized foil. Properties of mean value and standard deviation of color components intensity levels and grayscale images for selected samples of 5 types of polymeric foils were studied. The analysis shows effect of the choice of color component. Characteristics calculated from the intensity image of blue component color image proved the best properties. Such a fact can be used in the case of defectoscopy and the foil recognition by the use of methodology of processing and statistical analysis of images visualized optical transparent polymeric foils captured by the color cameras.

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Keywords: schlieren; color images; polymeric foil; statistical analysis

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1. Introduction

The schlieren method as one of optical visualization methods is based on use changes in the absorption of photons transmitting through optically transparent material. When there are mechanically loaded regions as deformation or non-homogeneity in material the intensity of absorption of photon changes and such a change represents also change of refractive index that can be visualized. The schlieren method enables to measure amount of light deflection caused by transparent phase object [1,2,3]. The camera objective focuses the test object onto the recording plane, where one receives image corresponding to the amount of reduced intensity of light and therefore

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by the schlieren method it is possible to visualize refractive behavior of transparent material, e.g. visual investigation of several phenomena occurring in the region of flow that can be related to its velocity but enable visualization of optically transparent polymeric foils as well [4]. The image created by the schlieren apparatus reflects several properties of polymeric foil. Measure of absorption of photons transmitting material depends on its type (structure) and thickness revealing average intensity of image. Deflection of light rays leaving visualized transparent foil from the direction parallel with the optical system axis reflects local changes of the intensity of the image. The main factors influencing character of local changes of the image intensity are distribution of material density influencing refractive index changes and variable thickness of foil material caused during the foil technology. Surface of the foil can be distorted by the anomalies in the technology of production and also by damages caused as a consequence of manipulation, foils storage and further processing. Mentioned anomalies also can be shown in their visualized images, their character is random and their presence is not regular as the presence of anomalies caused by the technologic process under standard conditions. Mentioned anomalies are observable in the foils visualized images enabling to use such a method for the defectoscopy of polymeric foils [5].

2. Subject and methods

The used modified schlieren apparatus constructed after J. Bolf [4] is described in detail in [6]. We can consider images of visualized polymeric foils taken by schlieren method as textures consisting of texture primitives or texture elements. Image texture can be described by the number and types of primitives and by their spatial relationship. Weak textures can be weak, when texture primitives or pixels in the image are small, the differences between neighboring primitives are large and spatial interactions between primitives are small. Such textures can be adequately described by frequencies of primitive types appearing in some neighborhood and therefore many statistical properties of textures [7,8] can be evaluated in the description of weak textures. The fact, that visualized images of polymeric foils can be taken to be weak textures are illustrated in the following images of chosen polymeric foils.

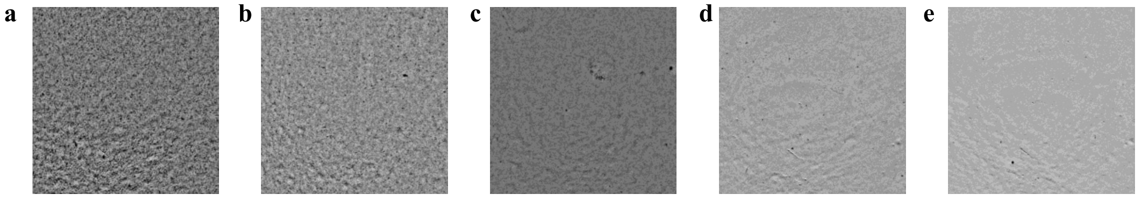

Fig. 1. Modified images of visualized foils samples (a) KXE20, (b) KXE30, (c) KXT21, (d) ON25 and (e) ONE12 by the schlieren method.

The image characteristics can be calculated by different methods only from the grayscale images (statistical and frequency methods). Properties of the image characterized by the statistical methods of description are relative more influenced by the non-homogeneity of light beam transmitted through the tested material and by the presence of stochastic defects of the foil material surface. There is a question whether numerical characteristics calculated for the individual color components would have significant different properties (values) to the characteristics of grayscale image. It can be of course expected that properties wouldn't be the same as the schlieren method is based on the visualization of anomalies due to changes of light beam deflection caused by the change of refractive index in tested material and in the case of polymeric foils visualization by the change of thickness. The angle of deflection depends on the value of refractive index and wavelength of light beam. Statistical characteristics were calculated for corrected intensity images $f_C(i,j)$ of individual color components by the use of reference images [9] (fig. 3) according to

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

where f(i,j) is the intensity function of tested foil image, $f_R(i,j)$ is the intensity function of reference image and c is suitable chosen constant value. In fig. 2 color reference image (image from the schlieren apparatus without the foil sample) and the color image of tested foil sample are presented. From captured images square sections of 1400x1400 pixels are selected. From the color trimmed images intensity images for the color components R, G, B are generated. For each color component corrected intensity image according to (1) is created. The use of such correction is advantageous because it allows holding the intensity of individual color components of the virtual light source to the same value. This enables to compare quantitatively the effect of individual color components of the light source on the properties of corrected image. It is possible to compare differences in the intensities distribution in the images for color components in the histograms (fig. 4).

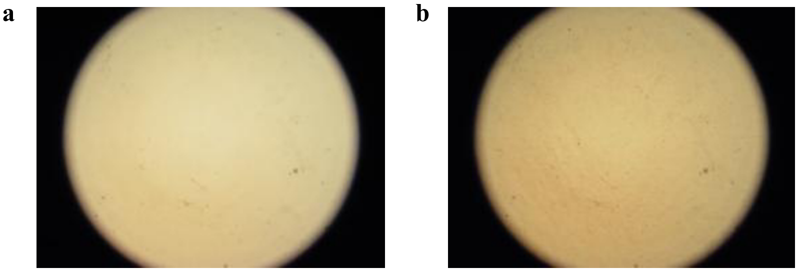

Fig. 2. (a) color reference image, (b) color image of tested foil (KXT21).

In Fig. 3 are presented corrected intensity images of visualized polymeric foil and its histograms of color components are in fig. 4.

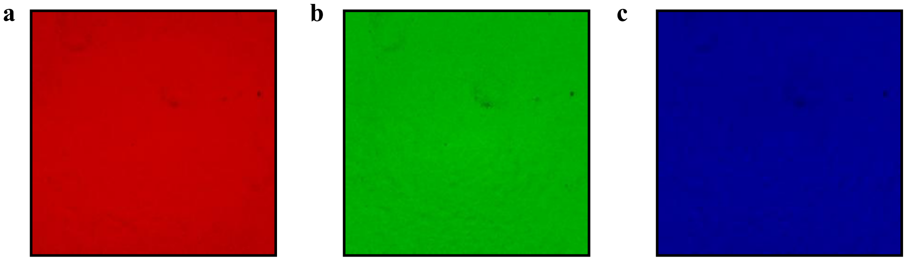

Fig. 3. Intensity images of (a) red, (b) green and (c) blue components of corrected image from fig. 2.

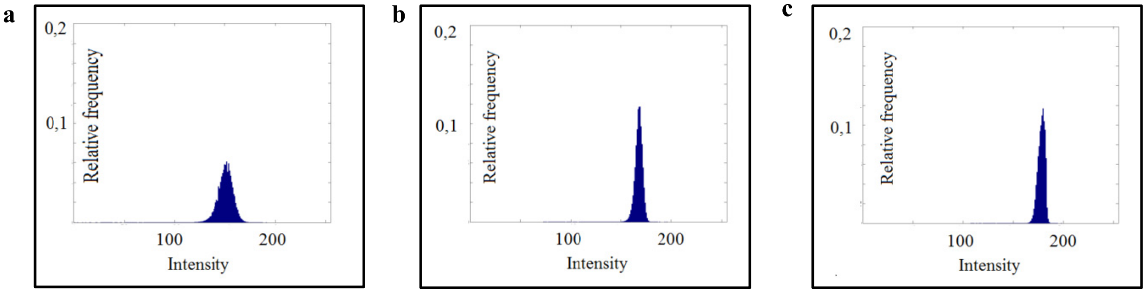

Fig. 4. Histograms of intensity of (a) blue, (b) green and (c) red component of corrected images of visualized polymeric foil from fig. 3.

3. Results

To the analysis of the properties color images visualized by the schlieren method we have used samples of foils whose modified grayscale images are in fig. 1. Six types of selected optical transparent polymeric foils were used. The types of foil differ in material, technology of production and in their thickness. 16 foils samples of 14 foil sample KXE20, 6 samples KXE30, 15 samples KXT21, 15 samples ON25 and 11 samples ONE12 were selected. Foils with large defects were excluded from the choice in order the presence of defects wouldn't influence the results of analysis. We used a color digital camera with resolution 5 mega-pixels. The properties of the simplest statistical moments of images as the mean

$$m = \sum_{i=0}^{255} ip\ (\mathrm{i}) \qquad (2)$$

and the standard deviation

$$\sigma = \sqrt{\sum_{i=0}^{255} (i-m)^2 p(i)} \qquad (3)$$

for the images of color components R, G, B, where p(i) is the probability (relative frequency) of intensity i in the image. As the color images have bit depth 24 bits value of the intensity of color component is in the range <0,255>.

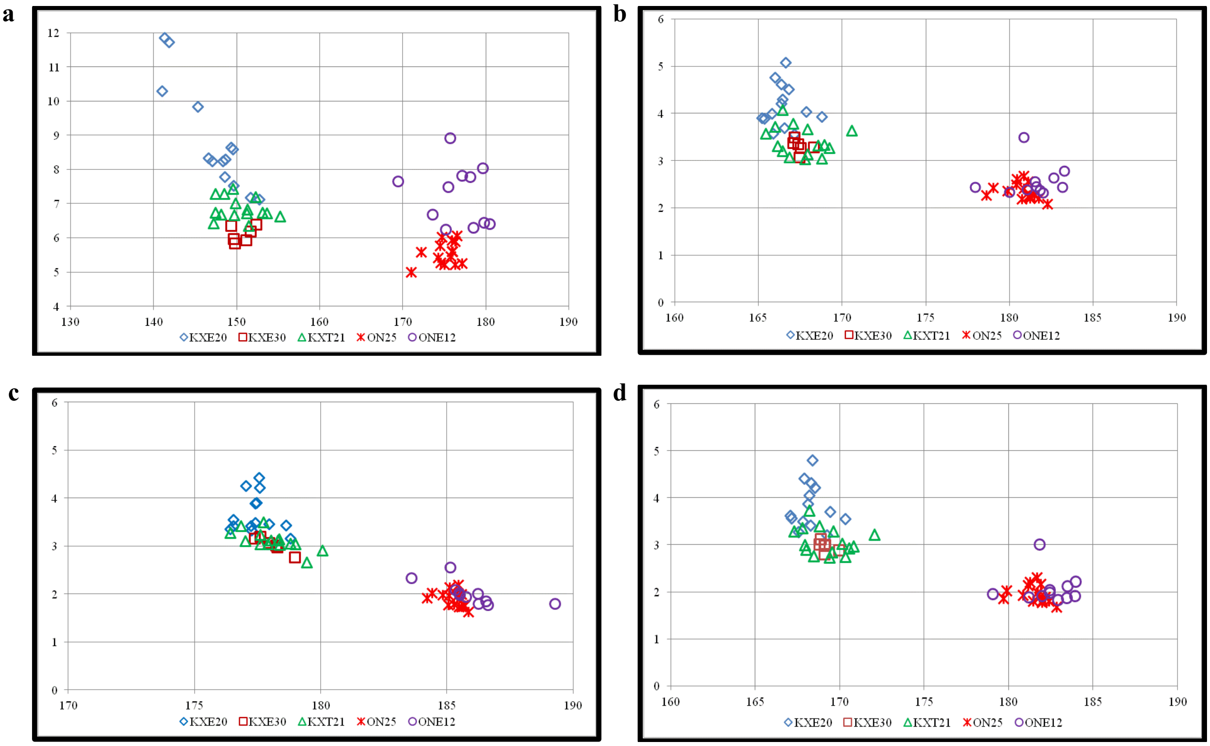

Fig. 5. Patterns (m x σ) of foils calculated from intensity images of (a) blue, (b) green, (c) red components of color image and (d) grayscale image.

Into the analysis also the grayscale image of the foil sample calculated as the Y-component of color space XYZ was included. Y-component was calculated by the use of transform relation between XYZ space and RGB space [9].

We have used grayscale images at the analysis of properties of the visualized foils images published in the previous papers [10,11]. In fig. 5 patterns of all selected foils samples are presented. Correspondence of patterns to the corresponding types of foil is defined by the symbol in legend. Position of patterns is defined by the couple of characteristics mean and standard deviation of intensity images (blue, green and red) and grayscale image of all selected foils samples. It is evident that the positions of patterns depend on the color component of the image from that they were calculated. For better appreciation average value of mean and standard deviation calculated for each type of foil and color component of grayscale image were used.

$$\overline{m_{t,c}} = \frac{1}{n_t}\sum_{j=1}^{n_t} m_{t,c,j} \tag{4}$$

$$\overline{\sigma_{t,c}} = \frac{1}{n_t}\sum_{j=1}^{n_t} \sigma_{t,c,j} \tag{5}$$

where t is the index of the foil type, c is color component from that the characteristics is calculated, j is index of foil sample of given type and n_t is the number of foil samples of given type.

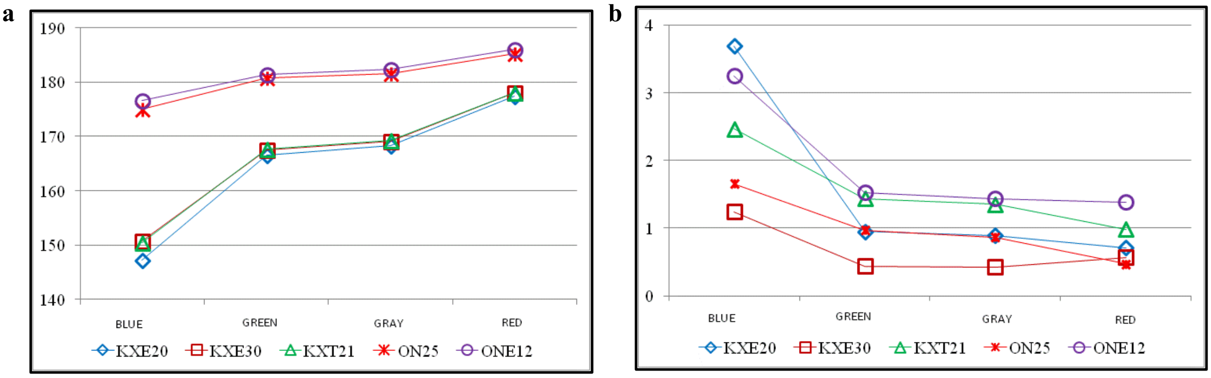

Fig. 6. Dependency of (a) average of mean and (b) average of standard deviation of types foils on components of color image.

In fig. 6(a) are the dependences of the average mean value and in fig. 6(b) average standard deviation (5) of the intensity of color component used at the calculation for all type of foils. Dependence in 6(a) verified assumption that the mean of the intensity of color component image increases with the wave-length of dominant component of color spectrum in the order blue, green and red. The value of grayscale corresponds to the fact, that grayscale image is calculated as the weighted sum of components R, G, B. Dependence in 6(b) verifies that with the increasing wave-length the light ray of the homogenous light source is less deflected. Deflection of light ray at the presence of anomalies of tested foil results in the change of light intensity and thereafter in the change of brightness of intensity images. Character of the dependence shows evidence of the fact that the value of brightness changes in the image of foil is evidently larger in the case of blue color when to compare to the green, red eventually grayscale ones. Similar are dependences for the foils samples KXT21 an ON 25. It is interesting character of the dependence for KXE20 (big drop between blue and green component) and character for KXE30 (slight increase of the red component when to compare to the green one) what is probably caused by the thickness of the foil. This foil type was the thickest.

4. Conclusion

Presented results show that the use of color cameras during the visualization of optical transparent polymeric foils images is advantageous. By the processing of intensity images of blue component of color image it is possible to gain better information on the brightness changes in the image that reflect local changes of polymeric foils properties. It is possible to use image processing in two areas: in the defectoscopy of polymeric foils and in the recognition of foils based on the visualization by the schlieren method. Higher sensitivity to the anomalies of the brightness levels in the foil image in the case of defectoscopy enables to detect smaller defects when to compare to the grayscale image processing. From presented dependences it is possible to observe that the higher sensitivity to the anomalies detection in the foil image causes the variance increase of statistical characteristics of foil images within the framework of one type of foil but also the variance increase of average values of statistical characteristics among different types of foils. It shows that variance of average values of characteristics increase towards the blue color more slowly as the variance of characteristics for images of concrete type of foil. Such effect is illustrated in fig. 5(a) to 5(d), where the tendency to the patterns clustering according to the type of foil is the best just for patterns from the image of blue color component suggesting that the use of patterns for the image of blue component should give better results in the case of foil recognition as well. In future it should pay more attention to this problem namely to the research of properties of other characteristics, to the methodology of capturing and image processing of color foil images.

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