The Use of Frequency Properties of Image in the Classification of Transparent Polymeric Foils

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Abstract. *The contribution treats the topic of processing the experimentally gained information on the properties of optically transparent polymeric foils. Schlieren optical system was used to examine and visualize refractive index distribution. Frequency approach enables an useful classification of different types of foils into classes. Experimental results are presented as well.*

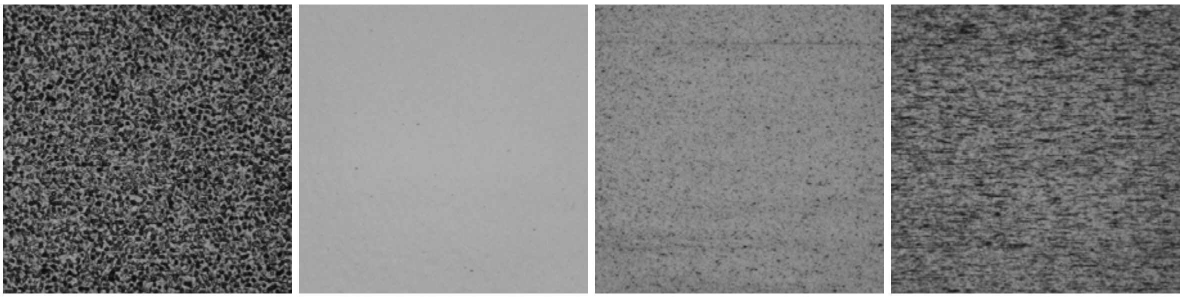
Keywords: optical visualization, polymeric foil, classification, Fourier transform.

1. Introduction

Optical visualization methods are sensitive to the changes in the absorption of photons during their transmission through mechanically loaded regions of transparent materials such as optically transparent polymers and, especially, polymeric foils. The methods use the fact that the material density is a function of the refractive index of tested foil. The intensity of photon absorption changes especially in the area of deformation, which results in a change of the refraction index. The change of the refraction index can be visualized [1]. And therefore the main advantage of all visualized methods is that they provide useful information for further processing after photographic or digital recording. Considering the available instrumental facilities and required sensitivity of measurement, we have chosen the schlieren method. An optical apparatus using a traditional photographic apparatus constructed after J.Bolf was modified and completed with a camera [2]. The schlieren system enables to measure the amount of light deflection generated by a transparent optical phase object. When there is a disturbance in the optical path the light is deviated from its nominal course in the absence of refractive index variations. Optical disturbance in the test object will produce variations of recorded light intensity that are a measure of the deflection experienced by the light in the test object. Obtained results can be processed using methods of image processing. Results of paper [3] refer to possibilities of schlieren visualization method in the field of the diagnostics of optically transparent polymeric foils using statistical methods.

2. Image Processing of Visualized Polymeric Foils

The brightness disturbances can be caused by the inhomogeneity of the light source, by impurities in the optical path and by the noncollinearity of optical axes of objectives of the schlieren apparatus. Experiments showed, that the last factor has the substantial influence on the homogeneity of the image obtained by the schlieren apparatus. 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 when there is no object under test. 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 [4]. Correction of brightness errors is necessary for the further image processing. In fig. 1 are samples of corrected images of visualized polymeric foils.



a. b. c. d.

Fig. 1. Samples of corrected images of visualized polymeric foils a/ OOL30, b/ KXE30, c/ CHSVC1. d/CHSVC2

Let us have f(x,y) as the matrix of grey level of digital image, where x is horizontal and y vertical position of a pixel, then discrete Fourier transform can be defined by [5]

$$F(u,v)=\frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}f(x,y)exp\left(-i2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)\right) \qquad (1)$$

where M, N are dimensions of an image, and u, v are spatial frequencies. The Fourier transform of a real function is a complex function

$$F(u,v)=R(u,v)+iI(u,v) \qquad (2)$$

where R(u,v) and I(u,v) are the real and imaginary components of F(u,v). The magnitude function |F(u,v)| is called the frequency spectrum of image f(x,y),

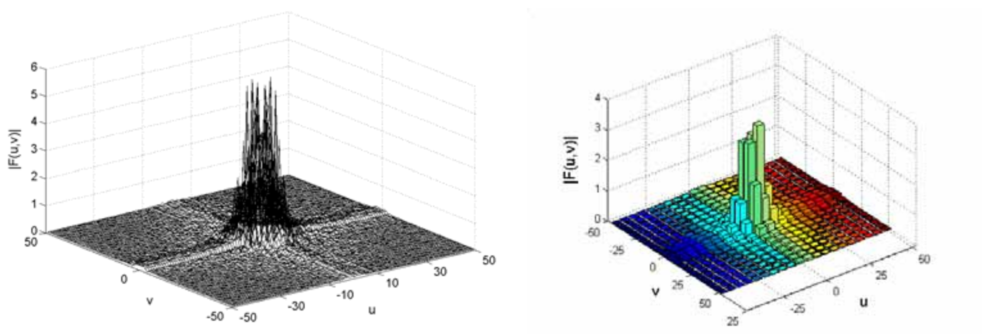
$$\left|F(u,v)\right|=\sqrt{R^2(u,v)+I^2(u,v)} \qquad (3)$$

the function φ(u,v) is called the phase spectrum

$$\phi(u,v)=arctg\left(\frac{I(u,v)}{R(u,v)}\right) \qquad (4)$$

and P(u,v) is called the power spectrum of image f(x,y)

$$P(u,v)=\left|F(u,v)^2\right| \qquad (5)$$

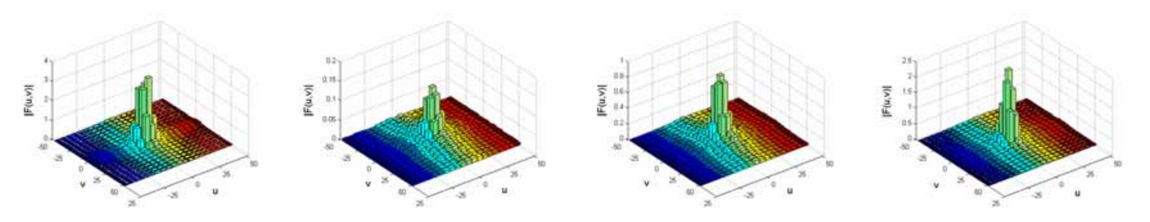


a. b.

Fig. 2. a/ Frequency spectrum, b/ modified frequency spectrum of corrected image of visualized polymeric foil OOL30

For the image analysis frequency spectra have been used from which spectral component F(0,0) corresponding to the average brightness of image was omitted. Fig. 2a shows frequency spectrum of a sample of a foil of image OOL30. Dimension of a sample is 100x100 pixels. Images of visualized foils and their frequency spectra have a stochastic character, but there are some features typical for individual type of foils. By way of illustration fig. 2.b. shows modified frequency spectrum consisting of the average values of a magnitude within the frequency bandwidth $\Delta u=5$ and $\Delta v=5$.

Fig. 3 shows a dissimilarity of modified frequency spectra for samples of foils from fig. 1. Frequency spectra differ in the shape and parameters such as are position and magnitude of a maximum.



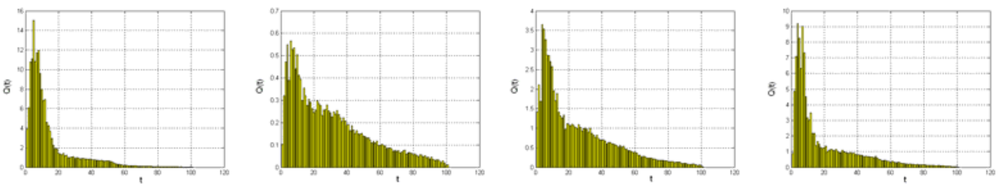
a. b. c. d.

Fig. 3. Modified frequency spectra of corrected images of foils a/ OOL30, b/ KXE30, c/ CHSVC1. d/CHSVC2

It is necessary to choose suitable characteristics of frequency spectrum for a classification and defectoscopy of foils. The signature vector consists of the characteristics. One of the possibilities is to use the scalar function

$$Q(t)=\sqrt{\sum_u \sum_v |F(u,v)|^2} \quad for \quad t \le \sqrt{u^2+v^2} < t+1 \qquad (6)$$

The curves of function Q(t) for spectrum of foil images from fig. 1 is in fig. 4.



a. b. c. d.

Fig. 4. The curve of function Q(t) for a frequency spectrum of corrected foil images a/ OOL30, b/ KXE30, c/ CHSVC1. d/CHSVC2

3. Results

The convenience of characteristics calculated from function Q(t) was experimentally verified 9 different types of foils have been used and from each type of the foil we captured 16 images. We used a digital camera with resolution 5 megapixels. The frequency spectrum was calculated from the part of images with dimensions 100x100 pixels.

In fig.5 is the tendency of clustering of signature vectors corresponding to the same types of foils and the tendency of clustering of signature vectors corresponding to the different types of foils presented. The signature vector consists of two components. They are a moment of the 1st order (7) and maximum value of function Q(t) (8).

$$f_1 = \sum_{t=0}^{t_{max}} t.Q(t) \tag{7}$$

$$f_2 = \max_t Q(t) \tag{8}$$

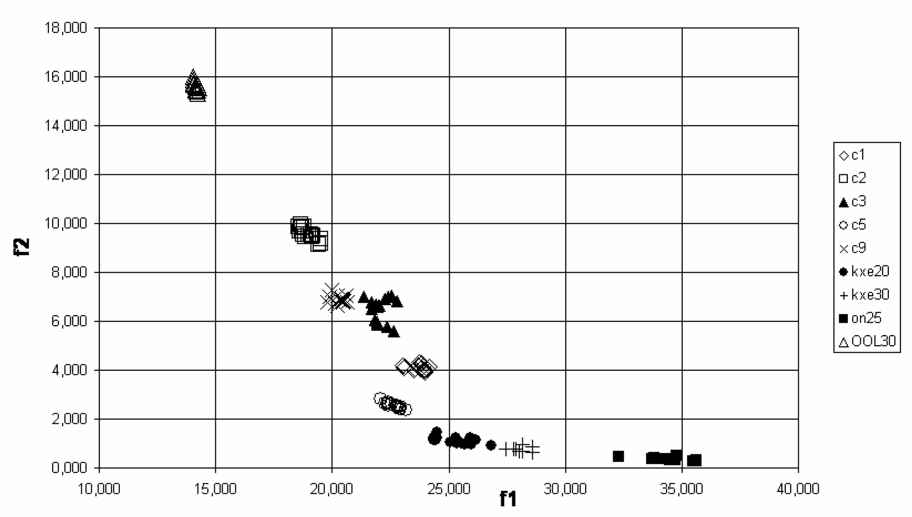


Fig. 5. Projection of patterns of tested foils images to the plane (f_1 x f_2)

4. Conclusions

Schlieren visualization method with some characteristics calculated from the frequency spectrum of the pre-processed image is a suitable tool enabling classification and identification of polymeric foils. It is possible to apply the method of identification of transparent polymeric foils to the comparison of different types of foil samples, or to the evaluation of technology parameters. Possibilities of the use of the described approach were verified in defectoscopy of polymeric foils as well. Some problems can occur during the choice of suitable dimensions of analysed image. To disadvantage of the frequency method when to compare with the statistical ones belongs large time requirements.

Acknowledgements

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