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Wavelet Analysis as a Learning Tool a Polymer Composites

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ABSTRACT: *The image processing analysis is one of the most powerful tool in various research fields, especially in material/polymer science. But the image processing is very much. Each method can analyze a specific point in the image. We reviewed the methodology for wavelet analysis of image processing in the study of polymer compositions. This allows you to improve the study of the properties of fiber as a reinforcing agent in polymer compositions. In this paper experiments had been held. The results presented here were found satisfactory and also are in good agreement with our earlier work and some other worker in the same field.*

Keywords: *wavelet analysis, polymer composites, median filter, noise suppression, image processing.*

I. INTRODUCTION

The volume and number of applications of polymer composites have grown steadily, penetrating and conquering new markets relentlessly. Modern polymer composites constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications.

Composites are used because polymeric materials reinforced with synthetic or natural fibres provide advantages of high stiffness and strength to weight ratio as compared to conventional construction materials. Also, unlike conventional materials (e.g., steel), the properties of the composite material can be designed considering the structural aspects. Careful selection of reinforcement type enables finished product characteristics to be tailored to almost any specific engineering requirement. The design of a structural component using composites involves both material and structural design. Due to this, it is essential to illustrate and record the properties of these composites and investigate new source of applications of fibres in composites.

Various properties of the natural or synthetic fibre composites are influenced by many factors such as fibre loading, dispersion and fibre to matrix adhesion [1], [2], [3], [4], [5]. Also it has been illustrated that there are many factors that can change the properties of natural fibre reinforced polymer composites [4], [6], [7]. Yet, till date, example, the performance of coir fibre as a replacement in polymer composites has not proved satisfactory and comparable to other fibres [2], [3], [5]. It is known that investigators have done chemical modification of natural fibres in order to improve them with a polymer composite [3], [8]. Due to this, it is essential to illustrate and record the properties of these fibres and investigate new source of applications of fibres in composites. But a property of the fiber depends on its structure, changes in the morphology of fibre before and after treatment [1], [9], [10]. Therefore it is important to have high-quality images composites, which are made under a microscope. In order to address these issues in detail is necessary to use the image processing procedure for the investigation of the fiber [9, 10, 11]. One of the promising methods for image processing is wavelet analysis.

II. MATERIALS AND METHODS

2.1 Methodology of Image Processing and Wavelet Analysis in Study the Polymer Composites

Methodology of image processing is one the areas of data mining and method for extracting additional information about processes under study. One can talk about the variety of methods that form the basis of image processing. In particular, there are methods of preliminary image processing, methods of the preliminary analysis, cognitive processing recognition methods of the received information and methods of the formalized representation of the received visual patterns for their subsequent processing. For image analysis the polymer composites, we will use the methods of the preliminary analysis – segmentation (allocation of objects, detect image edges). Despite the ability of using various methods processing and analysis of received visual image, one should consider both the specifics of how these images are displayed, as well as key tasks, which need to be addressed. To segmentation image can be used the ideology of the wavelet analysis [12].

Wavelet analysis based on wavelet transform – this is a image decomposition by the system of wavelets where the wavelets are obtained by shifting and scaling a single function – parent wavelet [13]. Wavelet in this case is a function rapidly decreasing to infinity with average value equals to zero. If the signal is discontinuous, only those wavelets will have high amplitudes, where the maximum value will appear near the discontinuity point, which will allow detecting image contour. At the same time, discontinuity point is a sharp intermittent transition during some process. Quantitatively, it can be estimated by the value of the first derivative of such process, taking into consideration that the first derivative of intermittent transitions is very high. If the transition is in the form of discontinuity point, then the first derivative tends to infinity. The sharper the transition, the higher the derivative value is. Smooth transitions will have small derivative values. This allows us to determine the presence of special characteristics of the analyzed image, as well as the point where these characteristics may arise. Thus methodology of wavelet analysis allows taking into consideration the particular characteristics of the images under study by decomposing source data into a plurality of approximate and detailed coefficients.

Behind the formalization of the continuous wavelet transform (CWT) there's the use of two continuous and integrable along the whole axis t functions [13], [14]:

– wavelet – function $\phi(t)$ with zero integral value

$$\int_{-\infty}^{\infty} \phi(t)dt = 0, \qquad (1)$$

determining the details of the signal and generating extended fractions;

– scaling function $\varphi(t)$ with a unit value of integral

$$\int_{-\infty}^{\infty} \varphi(t)dt = 1, \qquad (2)$$

determining a rough approximation of signal and generating approximation coefficients.

However, CWT function can be applied only for one-dimensional signals, and image is a two-dimensional signal. Therefore, in order to be able to apply CWT to detect image edges it is suggested to consider the following analysis and edge detection procedure [15]:

- let's perform calculation for horizontal discontinuities of the original image F (we are building a matrix of horizontal discontinuities), represented by matrix defined by its readings $f_{ij} \in \{0,1,\ldots,P\}, i = 1,2,\ldots,N, j = 1,2,\ldots,M$ on a square lattice $N \times M$. To do this, we use the following formula to get the so-called matrix of wavelet spectrogram W (based on the sequential processing of each line of the original image F):

$$W[f_{ij}] = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} f_{ij} \phi(\frac{t-b}{a})dt, \qquad (3)$$

where $\phi(\frac{t-b}{a})$ is a mother wavelet that meets the condition (1),

a, b – scale and center of temporary localization which determine the scale and bias function $\phi(t)$ in accordance with the terms of scaling (2);

$\lfloor f_{ij} \rfloor$ indicates the number of the processed string of the original image F to get a plurality of values of its wavelet spectrogram.

Parameters a, b are chosen so that the corresponding linear dimensions of the matrix of wavelet spectrogram W correlate with linear dimensions of the original image F, and at the same time possible parameter of wavelet transform are taken into account.

Then, based on the analysis of the obtained spectrogram (W for each raw of the original image F) we select its certain line NN based on the condition:

$$NN = \max_m (\frac{1}{M} \sum_{d=1}^{M} w_{md}) \qquad (4)$$

where w_{md} is the element of wavelet spectrogram of the analyzed row (line) of the original image F ($m = \overline{1,a}$, $d = \overline{1,b}$, $b = M$).

This selection is determined by the fact that we select that part of spectrum of the original image row (line), which corresponds to the largest discontinuity area of the original signal between its readings (see comments above).

The selected in such a way line (row), will correspond to the line (row) in matrix F_g which characterized the matrix of horizontal discontinuities of the original image F.

Processing of all lines of the original image F allows obtaining the matrix of horizontal discontinuities F_g through the following sequence of transformations:

$$F \xrightarrow{\text{CWT lines}} W \xrightarrow{\text{selection line}} F_g ,$$

- in a similar way we calculate the vertical discontinuities of the original image F for each column (we are building a matrix of vertical discontinuities). For this purpose, use formula (3) and the formula similar to formula (4) to select certain line from the obtained wavelet spectrograms of each column of the original image F: $MM = \max_{m}(\frac{1}{N}\sum_{d=1}^{N} w_{md})$, (5)

where w_{md} is the element of wavelet spectrogram of the analyzed column of the original image F ($m = \overline{1, a}$, $d = \overline{1, b}$, $b = N$).

Processing of all columns of the original image F allows as a result obtaining the matrix of vertical discontinuities F_v, due to the following sequence of transformations:

$$F \xrightarrow{\text{CWT column}} W \xrightarrow{\text{selection column}} F_v .$$

- add matrixes of vertical and horizontal discontinuities into one matrix that displays the edge of the original image based on CWT methods. For visual clarity, matrixes are horizontal, vertical discontinuities, as well as generalized matrix showing the edge of the original image can be inverted.

The general algorithm of wavelet transform is shown in **Fig. 1**.

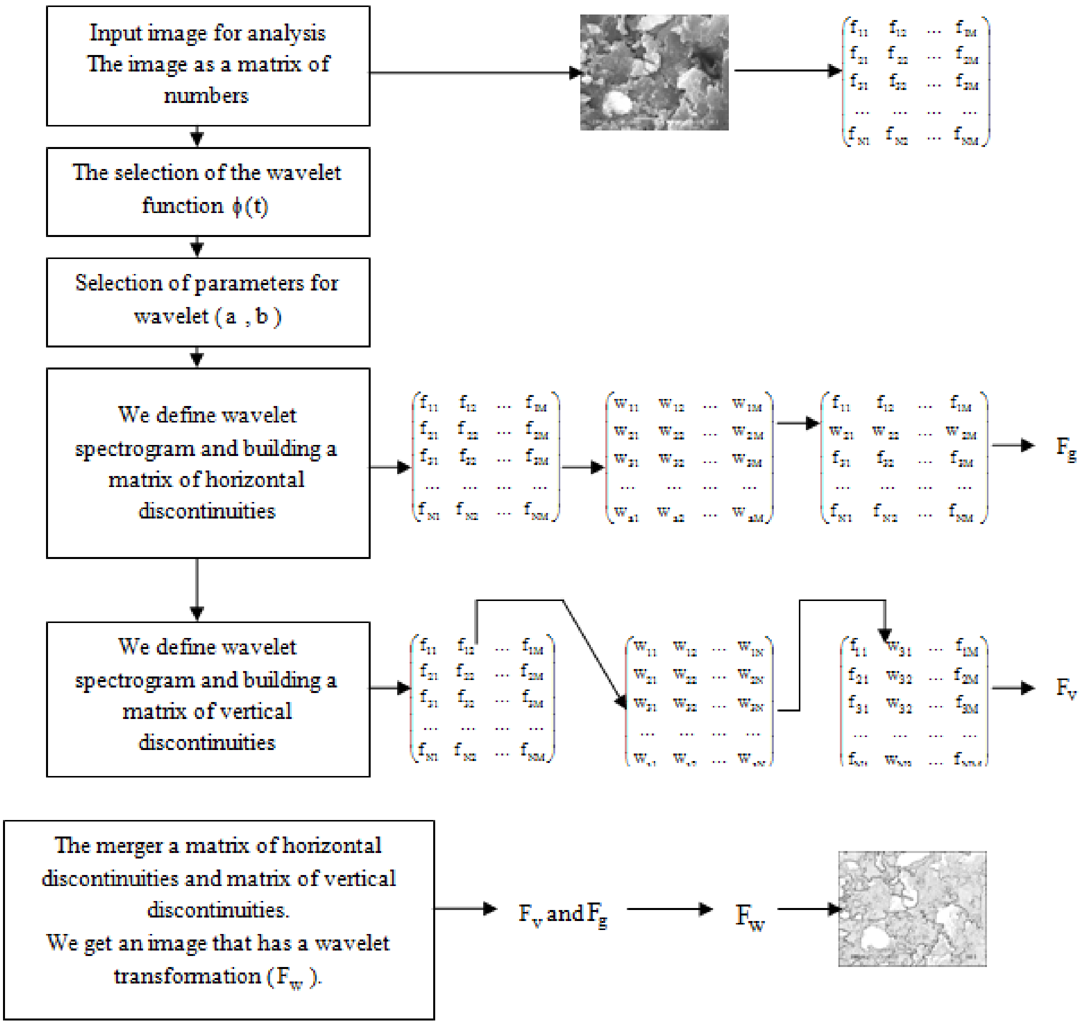


Figure 1: The general algorithm of wavelet transform for the image analyzing

It should be noted that the construction wavelet transform is largely depends on parameter a and parameter b when conducting wavelet transform of the image under study. By changing the value of the parameter a and parameter b we can get a result for image segmentation.

2.2 Data for Analysis

For analysis, we use images that are obtained by means of scanning electron microscopy. The scanning electron microscopy of the test samples were done by JSM 6390A (JEOL Japan).

Fig. 2 shows the SEM (Scanning Electron Microscope) micrograph of polymer coir – aluminum nitrate composite sample. From the SEM it is observed that, the surface of polymer matrix is smooth and homogeneous with aluminum nitrate particles are uniformly distributed throughout the polymer matrix. These distributed aluminum nitrate particle forms the clusters micro-grains in the polymer matrix adding higher mechanical texture to the host matrix.

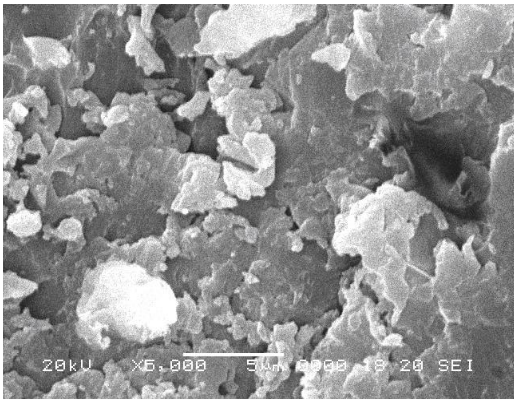


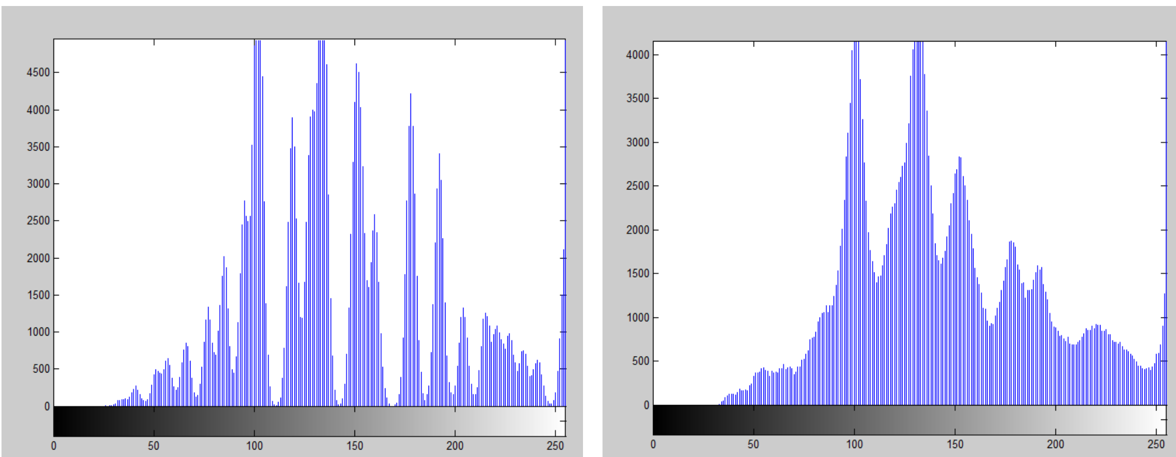
Figure 2: Image of polymer composite

But one can notice from the above image that there is change in the morphology of composite sample. We can see, that clusters micro-grains of composite sample is the inhomogeneous and deformed at microscopic level and therefore can be, for example, the reason for resistive ac conduction.

In particular the bright areas observed in the SEM micrograph are due to the strong reflections from aluminum nitrate particles embedded in the host matrix. Therefore, important highlight these plots and assess their area. In [9, 11] is shown that it is difficult to make an assessment for the area, which is analyzed. We will apply the method of wavelet transform for analyzing input image.

III. RESULT OF IMAGE PROCESSING

We see that the input image has a noise (see **Fig. 2**). Noise - fine grains in the image. This noise will affect the results of the processing. We will remove the noise. We use the median filter. The results of application of median filtering can be clearly seen on **Fig. 3**, which shows the histogram of the original and processed images.



a) the histogram of the original image b) the histogram of the image after filtering

Figure 3: Histogram of the original image and the image after filtering

Now we will do the wavelet transform to the image, which is processed by the median filter. For this we use the general algorithm of wavelet transform for the image analyzing (see **Fig. 1**). The result of building a matrix of horizontal discontinuities can be seen in **Fig. 4**. In **Fig. 4** we see bright spots that are allocated and have a white light. But these areas of do not have clear boundaries.

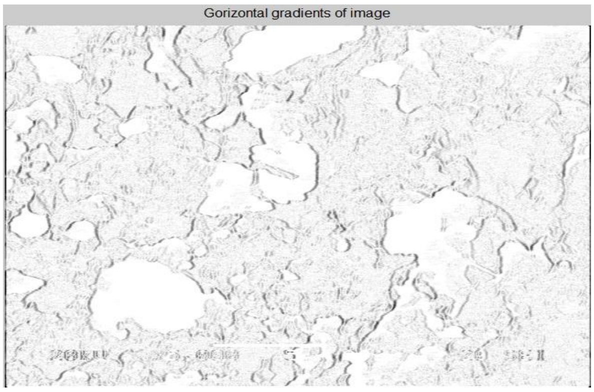


Figure 4: Showing a matrix of horizontal discontinuities

The result of building a matrix of vertical discontinuities can be seen in **Fig. 5**. We also see that there is no a clear allocating the bright areas.

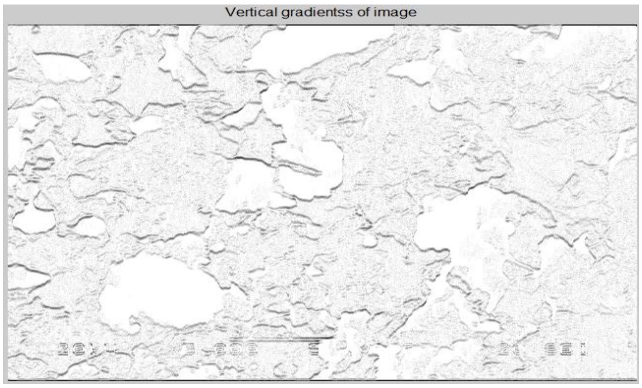
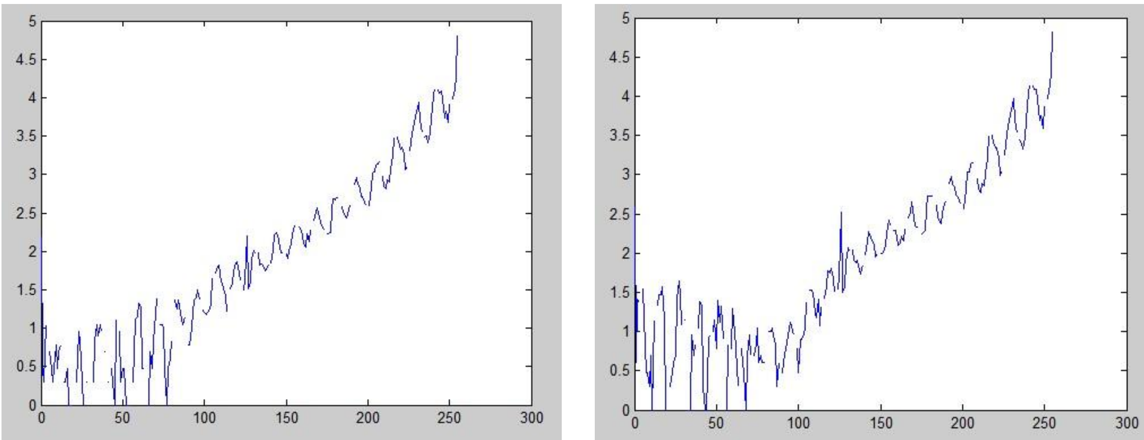


Figure 5: Showing a matrix of vertical discontinuities

But we see that the areas in the matrix of vertical and of horizontal discontinuities are allocated differently. This can be seen on the histograms, which are shown in **Fig. 6**.



a) matrix of horizontal discontinuities b) matrix of vertical discontinuities

Figure 6: The logarithmic histogram of the matrix of horizontal and of vertical discontinuities

In **Fig. 7** can see the result of combining of the matrix of horizontal and of vertical discontinuities. This is the result of wavelet transformation for the original image in **Fig. 2**. Bright areas are highlighted in blue.

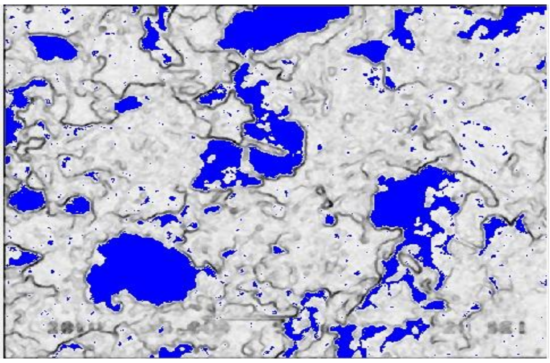


Figure 7: Result of wavelet transformation for the original image in **Fig. 2**.

At the same time we can see the smallest bright areas. The total area of the bright regions is equal to 16% of the area of the entire image. If we take the the original image (see **Fig. 2**), the total area of the bright areas is within the range 12-21%. This an error related to the fact that it is difficult to identify all the bright area on the original image. The wavelet transform allows accurately determine the most bright areas of the image that is analyzed.

IV. CONCLUSION

In summary, this paper discussed the possibility and feasibility of applying wavelet analysis as a separate procedure for processing image of the polymer composites. This is done by allocating specific features on the image of the polymer composites with a special emphasis on the impact of scale value when constructing wavelet spectrogram, in order to allocate separate areas.

The present study also shows that the wavelet transform allows you to select areas that are analyzed. This selection is the accurate. This allows to someone for the better perceive the differences between uneven and cracked surface in polymer compositions. And this approach is not only enough for the contemporary need of engineering judgment but also requires a rigorous mathematical model to obtain optimal process settings. In this paper different experiments had been held. These experiments allow you to build accurate models.

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