Jurnal
Teknologi

Full Paper

APPLYING IMAGE PROCESSING TOOLS TO ANALYZE THE SURFACE CHARACTERISTICS OF NANO ALUMINA (NANOAL$_2$O$_3$) AND NANO TITANIUM (NANOTIO2)

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Article history
Received
10 September 2017
Received in revised form
13 December 2017
Accepted
15 February 2018
Published online
3 June 2018

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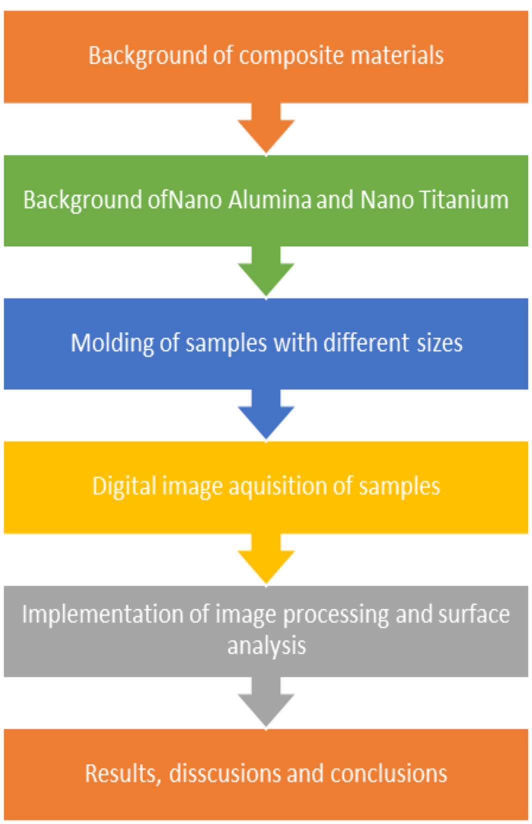
Graphical abstract



Abstract

Composite material is a material constructed of two or more materials that leads with different physical or chemical characteristics. Nano Alumina (NANO AL2O3) and Nano Titanium (NANO TIO2) are normally used to construct the composite material. The fundamental of texture analysis seeks to derive a general efficient and compact quantitative description of textures so that various mathematical operations can be used to achieve, compare and transform of texture characteristics. Many mechanical and physical methods are used to measure the surface characteristics. Some of these methods suffered from accurate description of material surface. In addition, the details of material surface are not clear via applying the traditional methods for surface analyzing. This work is concentrated on combining many functions and steps of image processing method to understand and analyze the surface characteristics of the composite material (Nano Alumina and Nano Titanium). The implemented approach including many steps: image enhancement, texture analysis, edge detection and contour analysis. This approach leads to explain, extract, analyze and evaluate the characteristics of surface texture of the composite material via measuring of mean values for original gray image, adjusted gray image, equalized gray image and adapted gray image. The average mean values of Nano Alumina are 103, 110, 128 and 134 for the applied method respectively. The average mean values of Nano titanium are 120, 123, 125 and 129 respectively. As a conclusion the implemented approach of surface texture analysis indicated that there is a significant improvement at the surface characteristics for both equalization and adaptive methods compared with the adjustment method.

Keywords: Surface Analysis, Composite Materials, Image Analysis, reinforcing particle materials, Nano Alumina (NanoAl$_2$O$_3$) Analysis and Nano Titanium (NanoTiO$_2$) Analysis

1.0 INTRODUCTION

Today, several domains are very important part of because it is shown in numerous applications. The use of an image processing field for the extraction of the surface characteristics of composite materials leads to a benefit in the treatment and analysis. The material used as a template for preparing a resin composite type epoxy (EP Polyprime from Hankl Company) that having a density of 1.03 g of the viscosity / cm 3 and low. This makes the basic blend of business processes easier with the particles and epoxy resin in liquid state, as it has high adhesion property and high chemical resistance and low creep speed. Polymerization and solid state processing may have occurred by addition of the hardener to the same type of resin hardener, characterized by a low viscosity liquid and a light density. The hardener relative to the resin is (1: 2) with a resin curable for 48 hours at room temperature and then two weeks to complete the treatment (complete cure) and then cut the samples with the standard size to be used by the test procedures [1,2]. These Nano composite materials are especially important due to their bridging role between the world of conducting polymers and that of inorganic materials. Different nature and size of Inorganic nanoparticles can be combined with the conducting polymers, giving rise to a host of nanocomposites with specific physical properties and important application potential. Inorganic materials used for this purpose are usually of two types: nanoparticles and some nanostructured materials or templates. Depending on the nature of relationship between the inorganic and organic components, nanocomposites are classified into two categories: first in which the inorganic particle is embedded in organic matrix and the second where organic polymer is confined into inorganic template [13,14]. Texture is another feature that can help segment the image in regions of interest and classify these regions. In some circumstances, it may be the characteristics and regions critical to the correct analysis. Texture gives us information about the color of the spatial arrangement or the intensity of an image. The texture is usually found in natural scenes, especially in outdoor scenes containing natural and artificial objects. Sand, stones, leaves, grass, bricks and other objects create an appearance of textures [15, 16].
Part of the problem in texture analysis is defining exactly what texture is. There are two main approaches:

- **Structural approach**: Texture is a set of primitive Texel's in some regular or repeated relationship**.**
- **Statistical approach:** Texture is a quantitative measure of the arrangement of intensities in a region.

While the first approach is appealing and can work well for man-made, regular patterns, the second approach is more general and easier to compute and is used more often in practice [17, 18].

The fields of composite materials and texture analysis are introduced in many applications and so many related works are published concerned of this work. The following researches are considered as related works of this paper:

G. N. Srinivasan, and Shobha G. (2008), studied Methods and algorithms by statistical analysis of the texture of 2D images. Basic statistical approaches lead to characterizations of surface texture extraction, smoothness, roughness, etc. One of the most common ways that are used to explain texture moments is to use the histogram of a grayscale image. Spectral analysis methods are also used in texture analysis techniques based on increasing the Fourier spectrum and the properties of the base wavelet transform. These techniques are used effectively to detect the frequency of the image by identifying high energy narrow peaks in the spectrum [19].

Izabela Jasińska (2009), developed a new method of evaluating knitted surfaces. The proposed methods are developed by the analysis of a spot surface after the ball formation process using RGB color digital images. The RGB color model is used to differentiate changes more efficiently and more accurately and to form stuffed balls. Numerical analysis of color images of spongy tissue carries a degree of pilling value of the standard. Analytical results are used to evaluate the ball formation process to improve the precise effects [20].

Arun Ross and Manisha Sam Sunder (2010), analyzed the texture of the surface of the iris and implement the assigned class action quantitatively. This approach applied for 68 extracted and 68 statistical characteristics of the texture of the iris. These characteristics in terms of high frequency information in relation to the anatomical structures in the iris. The statistical characteristics extracted passed the function stage and the performance of the decision. The experimental results indicate a good efficacy of the proposed approach in the grouping of textures. A partial iris set was used to obtain the partial iris matching [21].

WANG Shu-yong, *et al*. (2012), implemented a method that began to acquire composite section images using the ICT technique. The section images are then used for composite images of internal meso structure. Finally, the meso structure images are converted to vector input format to construct the finite element model for ANSYS analysis to generate the mechanical properties of the samples tested. The results show that this method is an effective method for the finished model to extract the properties of the composite elements [22].

Abdul Adeem Zaily Hameed, *et al*. (2015), developed an approach that focuses on image enhancement improvement to detect small obstacles on the surface of the sample. This approach allows the characteristics and details of the sample to appear and make it more visible.

Evaluation of the results of this approach is implemented by many statistical measures. The results lead to high performance with sufficient signal to noise [23].

Abdul Adeem Zaily Hameed *et al*. (2015), presented the effects presented alumina Nano by the analysis of the superficial texture. The proposed treatment approach texture image focused on improving the image of the earth and detecting small obstacles on the surface. Many algorithms and mathematical models were applied to compare the surface of many images. The results indicate a good correlation occurring in the Nano alumina composite [24].

2.0 METHODOLOGY

2.1 Implemented Samples

In this approach, two types of reinforcing particle materials and nanoparticles are used, these materials being aluminum oxide powder (Al2O3) and titanium dioxide powder (TiO2) which were mixed separately with epoxy resin with percentages in Weight of (0.02, 0.04, 0.06 and 0.08% by weight). Then mix the grind together (1: 1) with epoxy and the same amount for the hybrid composite. Two types of materials are used in this research as reinforced materials for the matrix material, they are: aluminum dioxide powder (alumina) and titanium dioxide powder [3,4].
Two kinds of aluminum dioxide powder (Al2O3) with different particles sizes are used in this research.

First Type: Micro Aluminum Dioxide powder England origin, prepared from a company (RIEDEL-DE HAEN AG), of the micro alumina powder and the specifications as show in Table 1 [5, 6].

Table 1 specifications of micro alumina by the manufacturer

Density	Purity	Particle Size	Type	Type Color
3.38 (g/m³)	99.5	3 (μm)	α	White

Second Type: Nano Aluminum Dioxide powder China origin, prepared by (MTI) company. Powder and the specifications as shown in the Table 2 [7, 8].
Two types of Titanium dioxide Powder (TiO2) with different particle sizes are used in this research.

First Type: Micro Titanium dioxide powder England origin, prepared by a (AVOCHEM limited) company of the micro Titanium powder and the specifications as shown in Table 3 [9, 10].

Table 2 specifications of nano alumina

Density	Purity	Particle Size	Product
3.97 (g/m³)	> 99 %	20-30 (nm)	Al2O3 (white powder, alpha type, Crystalline Structure)

Table 3 specifications of micro Titania by the manufacturer

Density	Molecular mass	Purity	Particle Size	Color
4.23 (g/m³)	79.866(g/mol)	99.5	30 (μm)	TiO2 (white powder, alpha type, Crystalline Structure)

Second Type: Nano Titanium dioxide powder of china origin, and the product NanoTiO_2 (anatase) and their specifications as shown in Table 4 [11, 12].

Table 4 specifications of nano Titania by the manufacturer

Density	Purity	Particle Size	Product
4.2 (g/m³)	99.8%	<50 nm)	TiO2 (white powder, alpha type, Crystalline Structure)

2.2 Preparing the Samples

Hand lay-up method was used in the process of preparing the samples this method includes the following steps as shown in Figure 1.

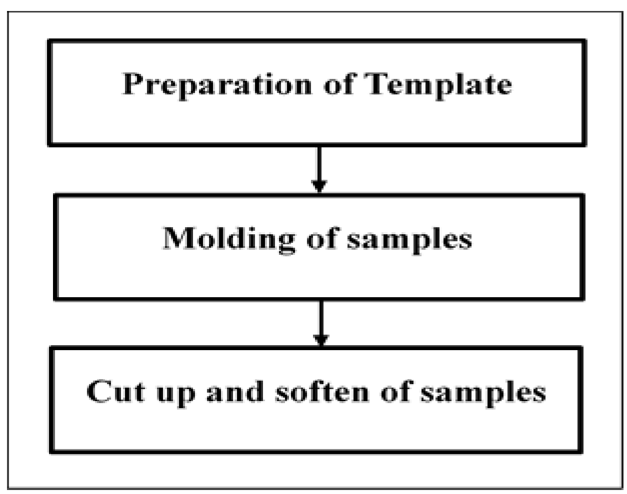


Figure 1 Preparation of samples

First step: Preparation of Template

Three private templates include the casting process is the base of each glass plates coated with thermal paper template (so as to prevent the adhesion of the resin on plate of glass and easily manufactured by cutting output) with a high degree of subject plates Equator (ensure flush surface mediated settlement balance) aspects of the three templates consist of different thickness glass rulers (10mm, 6mm, 3mm) with different lengths and laminated material.

Second step: molding of samples

The main method of preparation and casting of samples consist of the following steps (Figure 2):

- Preparing the weighted amount of required epoxy proportion and hardener that added by (2:1).
- Preparing the weighted amount of material reinforcement (aluminum oxide minutes and titanium dioxide minutes) nanoparticles and natural hybrids according to weight are added.
- Mixing reinforcement material and matrix at room temperature. Where mixing the weighted ratios of reinforcement and matrix together in a special pot mixing happened and confused by the electric mixer to a maximum of (1 – 10) minutes. However, this method does not give a homogeneous mixture well so noticing deposition of a large amount of material reinforcement at the bottom of the mixture.
- Pour liquid mixture to form a torrent in the middle of the template so that the flow take place to all areas of ongoing and regular template that the template is filled to the desired level.
- Leave the pressed into the template for (48) hours to hard definitively and graduating her image is captured by a digital camera and then put in oven with temperature (50°C) for (5) hours to complete the formability and graduating to take another picture.

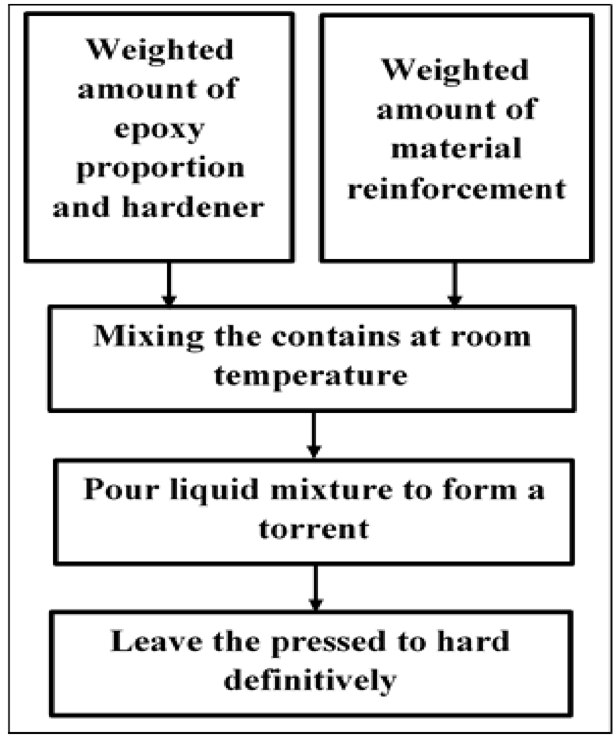


Figure 2 molding of samples

Third step: cut up and soften of samples

Standard dimensions are chopping samples according to specifications and global measurements for each test set out in previous Table 1 using soft-toothed band so that it was manufactured in the lab to ensure no vibration during cutting samples and it also saw teeth smoothness to avoid distortions that may occur during cutting. Then the process of refinement with smooth sheets (silicon carbide) and different degrees of softness.

2.3 Implemented Processing Approach

The acquisition of pictures are arranged in two steps: First set of images are done after the prepared mixtures (for both Nano Alumina and Nano Titanium) are definitively hard. Second set of images are done after curing and cutting the sample into parts.

The proposed approach deals with the surface texture analysis in which image processing is applied to extract the features of the composite materials. This approach including many components as shown in Figure 3, and that illustrated below:

Acquisition: in this step a high resolution camera (Cannon EOS 600D – 18 Megapixel CMOS sensors) is used to take pictures of the sample surface. These pictures are passed to the computer to be processed via the implemented algorithm.

Preprocessing: it is an important step because it is the principle step the all other steps depend on it. In this step all images are prepared to be at the same size, converted image into gray scale and then filtered to remove the effects of noise.

Feature Extraction: in this step both discrete Fourier transform and discrete wavelet transform are applied in order to extract the special characteristics of the image surface.

Enhancement: in this step many procedures such as noise removal and filtering are applied to display the efficient characteristics of the tested sample.

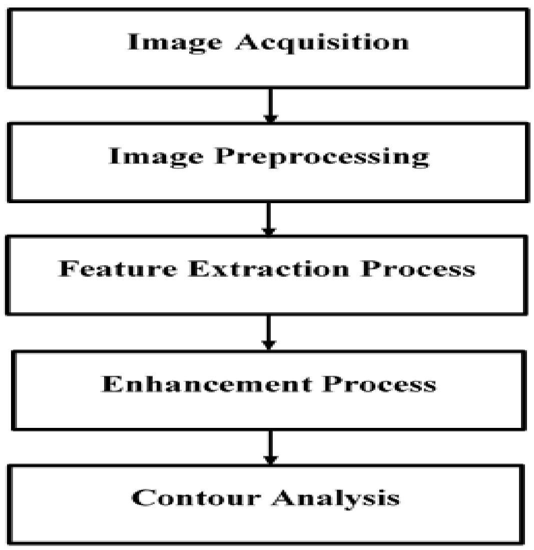


Figure 3 proposed texture analysis approach

3.0 RESULTS AND DISCUSSION

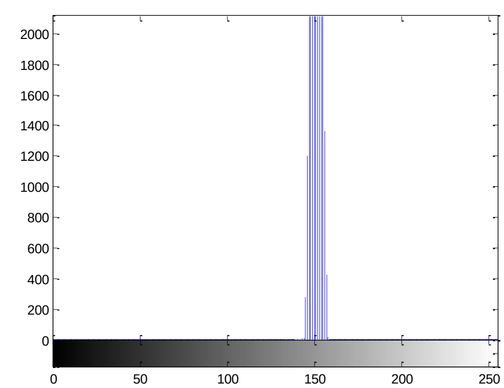
According to the implementation of this approach an adequate results are obtained in which are demonstrated in below. The implemented procedure including preprocessing, enhancement, equalized histogram, normal contour and filled contour for both Nano Alumina and Nano Titanium. The following results are concentrated on the texture surface analysis with the supporting of Matlab package.

3.1 Nano Alumina Molding Case

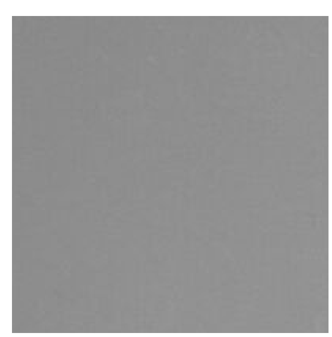
Figure 4 to Figure 6 illustrate the implemented procedures of the image surface of the molding using Nano Alumina. These figures show the effect of each process on the surface image and the related histogram of that surface. Figure 4 shows the preprocessing operation on the image surface and their histogram. This surface image then it will be enhanced to give better details and that is clear in Figure 5. In Figure 6 the histogram equalization is applied to give better distribution of pixels over the processed surface. Then contouring process is applied to classify the surface into areas with distinct colors (Figure 7).

The obtained results for Nano Alumina indicated that there are some missing in the surface smoothing and particles distribution on the overall surface. These defects are very clear in the contour plot and filled contour plot, in which the cluster of the image is indicated.

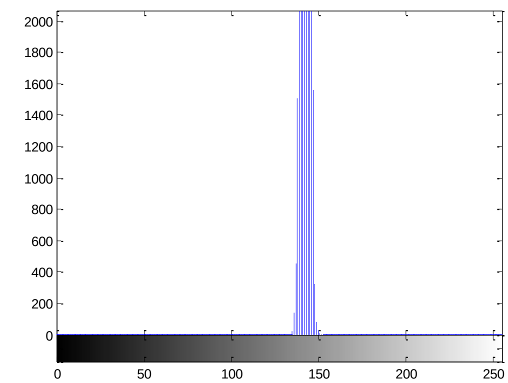
(a) Original image before curing



(b) Histogram of original image before curing

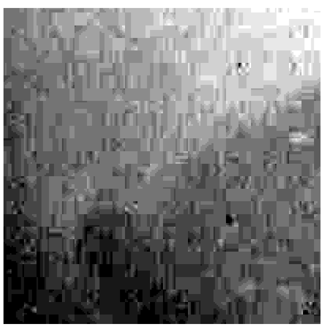


(c) Original image after curing

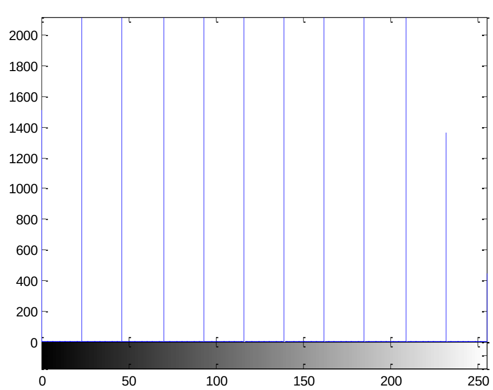


(d) Histogram of original image after curing

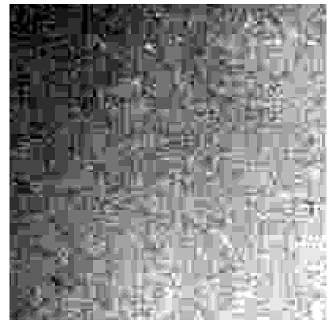
Figure 4 preprocessed images of Nano Alumina and histogram (before and after curing)



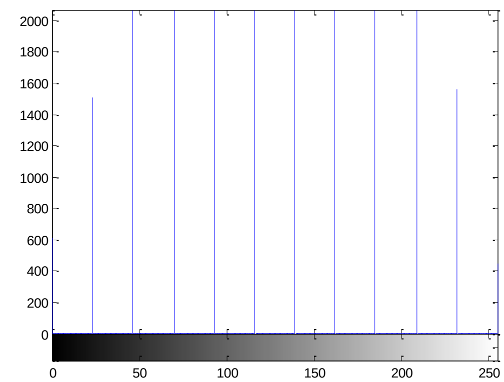
(a) Adjusted image before curing



(b) Histogram of adjusted image before curing

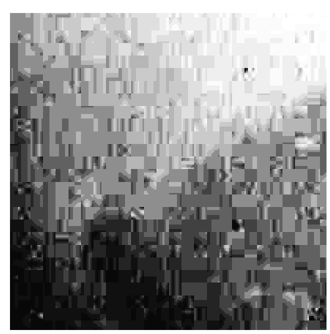


(c) Adjusted image after curing

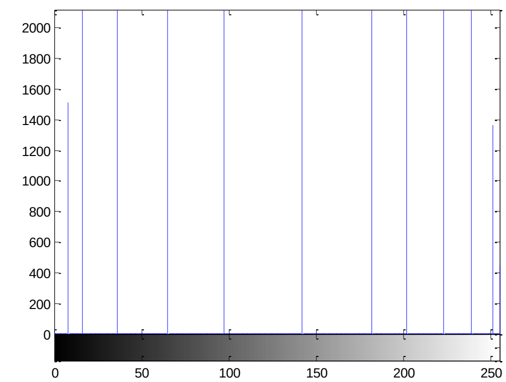


(d) Histogram of adjusted image after curing

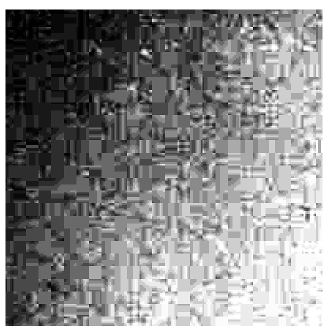
Figure 5 adjusted images of Nano Alumina and histogram (before and after curing)



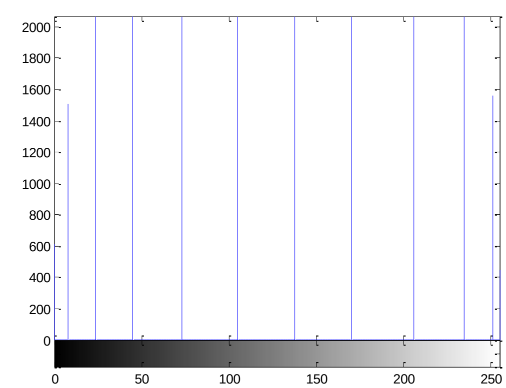
(a) Equalized image before curing



(b) Histogram of equalized image before curing

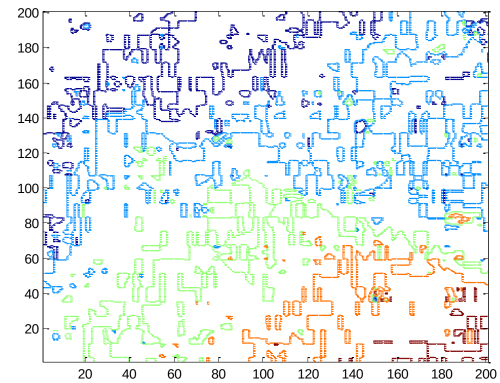


(c) Equalized image after curing

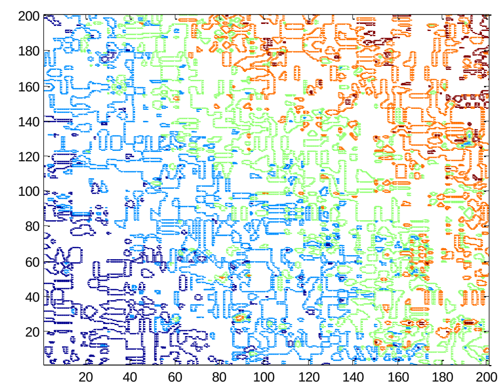


(d) Histogram of equalized image after curing

Figure 6 equalized images of Nano Alumina (before and after curing) with their histogram



(a) Contour of image before curing



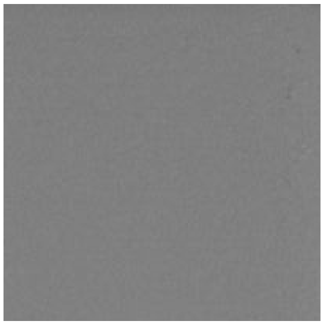
(b) Contour of image after curing

Figure 7 contour of Nano Alumina (before and after curing)

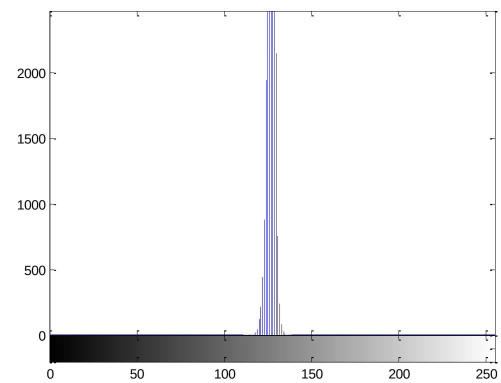
3.2 Nano Titanium Molding Case

Figure 8 to Figure 10 illustrate the implemented procedures of the image surface of the molding using Nano Titanium (NanoTiO2). The same procedures are implemented for Nano Titanium molding. The obtained results for Nano Titanium image surface indicated that there are no missing in the image surface so it is clear and smooth surface, and there are good particles distribution on the overall surface. On the other hand there are no defects on the image surface that are very clear in the contour plot and filled contour plot, in which you can indicate the group of clusters of the image surface (Figure 11).

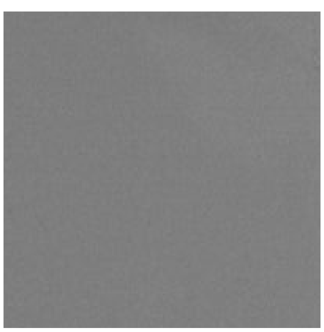
On the other hand the texture analysis of the curing process of Nano Titanium composite material show that there are significant improvement of this surface which is clear from countering.



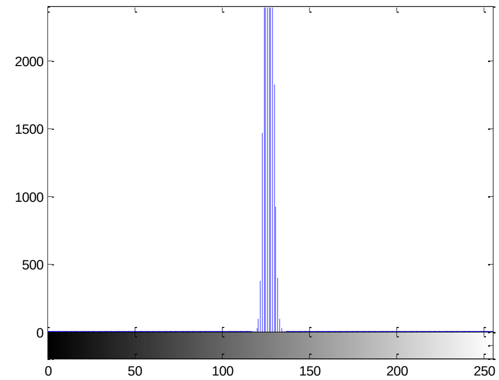
(a) Original image before curing



(b) Histogram of original image before curing

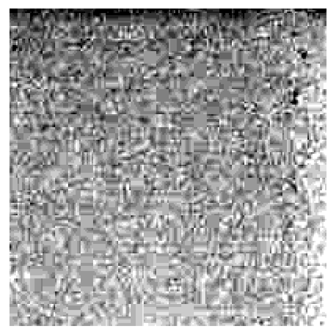


(c) Original image after curing

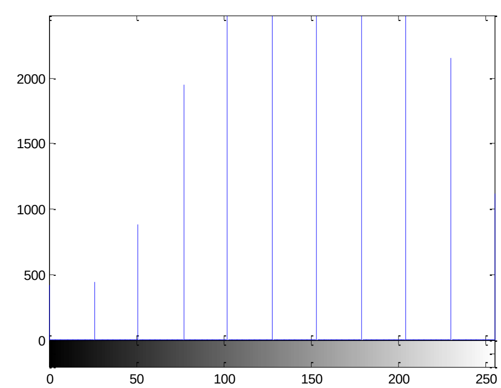


(d) Histogram of original image after curing

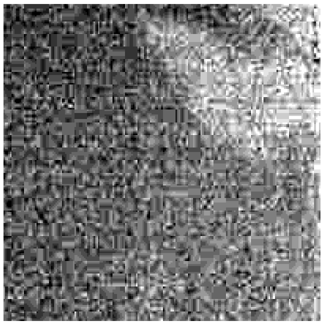
Figure 8 preprocessed images of Nano Titanium and histogram (before and after curing)



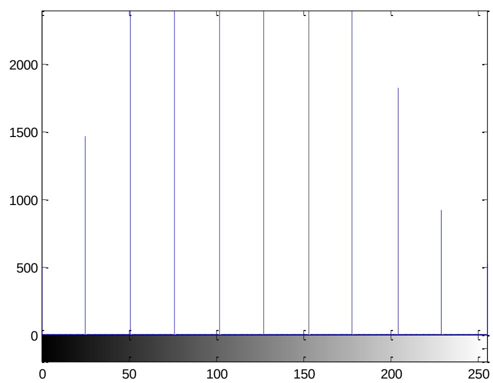
(a) Adjusted image before curing



(b) Histogram of adjusted image before curing

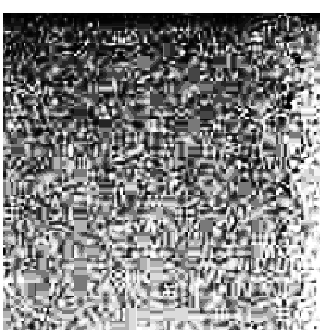


(c) Adjusted image after curing

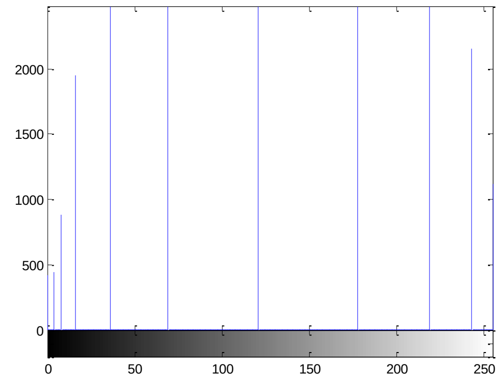


(d) Histogram of adjusted image after curing

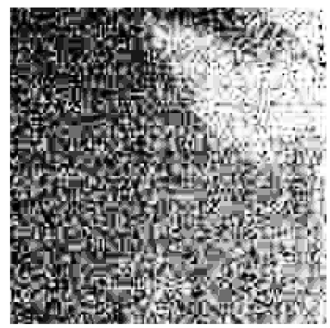
Figure 9 adjusted images of Nano Titanium (before and after curing) with their histogram



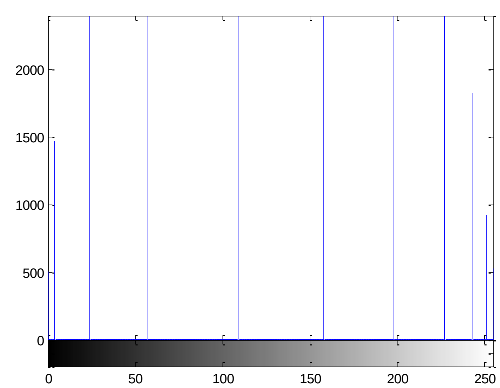
(a) Equalized image before curing



(b) Histogram of equalized image before curing

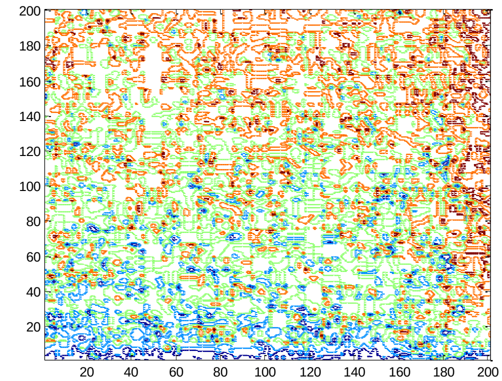


(c) Equalized image after curing

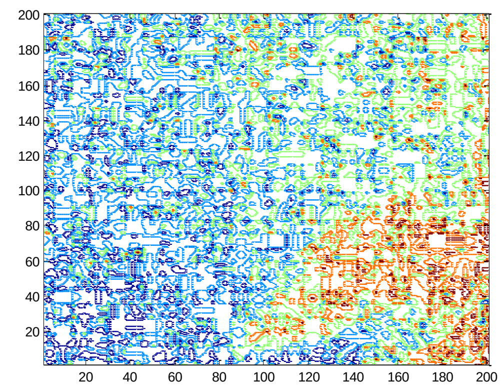


(d) Histogram of equalized image after curing

Figure 10 equalized images of Nano Titanium (before and after curing) with their histogram



(a) Contour of image before curing



(b) Contour of image after curing

Figure 11 contour of images of Nano Titanium (before and after curing)

3.3 Comparing Alumina and Titanium

Figure 12 shows the mean value results of the four implemented methods: gray image or original image, adjust image, histogram equalization method and histogram adaptive method. Comparing these four applied enhancing methods for Nano Alumina Molding Case (Figure 12) in which achieved the first finding that for all four methods give minimum mean values for after curing sample. It is clear from this figure that the difference is so small between the two first methods. But the difference is significant in the methods of equalization and adaptive.

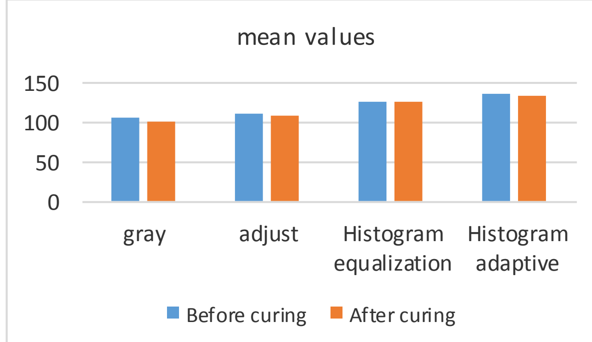


Figure 12 mean values of Nano Alumina (before and after curing) with different methods

Figure 13 shows the mean value results of the above four methods applied on Nano Titanium. Comparing the four enhancing method for Nano Titanium Molding Case (Figure 13) in which achieved that these methods give minimum mean values in case of after curing sample. In this case there is a significant difference between the two cases before and after curing. The difference is about 10% between the two cases.

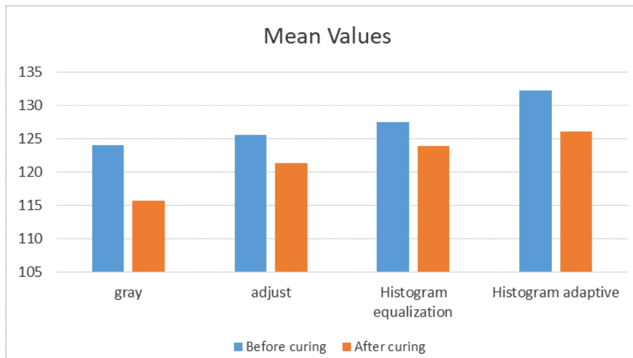


Figure 13 mean values of Nano Titanium (before and after curing) with different methods

4.0 CONCLUSIONS

The main objective of this paper is to design and implement an efficient approach for applying image processing tools to analysis the surface of composite material of Nano Alumina and Nano Titanium. The implemented approach is divided into many steps: preprocessing, enhancement, then using contour plot to display the clusters in each image. This procedure is applied effectively on the image surface to enhance and analyze the characteristics of the surface. The obtained results indicated that an effective approach is implemented to demonstrate and illustrate all the features and characteristics of the tested surface. A good surface enhancement is observed via applying this approach. According to these results it is clear that Nano Titanium surface leading to better characteristics comparing with Nano Alumina (NanoAl_2O_3). In addition that the curing samples give better characteristics of the surface texture distribution compared with the samples before curing.

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