ANALYSIS OF SEM IMAGES OF MAGNETICALLY THREATED CERAMIC MATERIALS

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***Abstract*:** The report is a study on application of image processing techniques to SEM digital images in the evaluation of quality of the thermally processed and magnetically threated ceramic materials. In evaluation of the images by histograms a significant difference in intensity is observed in the images of ceramics treated with varying strength of the magnetic field but have not obtained good results in images of ceramics processed at different temperatures. Analogous results were obtained using discriminant analysis by feature „orientation". The application of texture features indicate visually that there are significant differences in the data for features contrast and energy, which is a prerequisite for the realization of further research on rapid and objective assessment of magnetically treated ceramics.

Keywords: Magnetic treatment, Ceramics, SEM images, Image analysis, Texture features

1. Introduction

SEM (Scanning Electron Microscope) is used in examination of the surface of the object through scanning with the electron beam, i.e. iterate to the surface point by

point in horizontal and vertical direction. The scanning electron microscope has a resolution that can reach 5мm and a large depth of field. This means that it can be examine the structure as a planar surface and a three-dimensional surface [9].

The method has been applied successfully in many areas such as in food science, materials research, medicine, food analysis, electrical protection equipment, also for educational purposes [1,5,6,8,10,14]. The results of magnetic and thermal treatment of ceramic materials also are present in the form of SEM images [6,13,14] which visually represent the orientation of the crystals in the structure of the material after this procedure.

Research can be made on objective presentation of these data by applying the techniques of image processing [4].

The aim of this report is to assess the possibility of application of techniques for image processing of SEM of ceramic materials obtained after electromagnetic treatment.

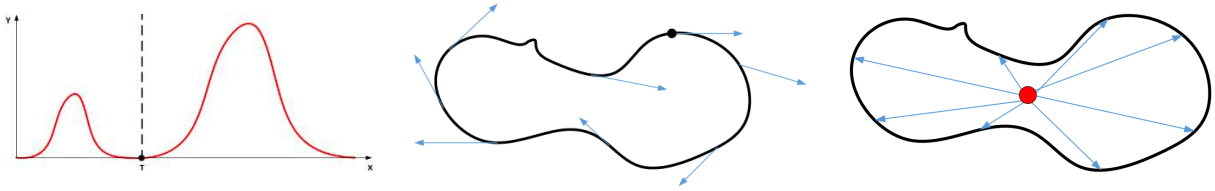
2. Exposure

The methods for the separation of objects in the image by using the features of the pixels. As a feature is mainly used gray tone or intensity of the pixels in the individual channels. In the image can be defined and used a number of other features. These features can be divided into the following categories [2,7]:

- Geometrical descriptions. Obtained from the shape of the objects. They can be an area of the object perimeter coefficient of compactness, center of gravity, relation to radii moments;
- Texture descriptions. The texture features characterize the surface structure of objects. As they are most commonly expressed by repeating the image elements of its description using dimensions associated with the neighborhood of pixels. Main feature of texture is the size of its fragments. It is therefore necessary processing to correctly determine this size. Another feature is the frequency of the structure, which allows the use of periodic functions for its modeling. A third feature is an element of randomness, which requires the use of sets of statistical analysis;
- Topological descriptions. These are related to the position and orientation of the object. They are bonded to the skeleton of the objects as well as their shape. For topological description of the objects can be used as the number of cavities number of visible surfaces, number of peaks.

Image processing operations include improving image quality in order to eliminate defects like geometric deviations, wrong focus, noise, heterogeneous movement of the camera. Analysis of the images is a process of pattern recognition of the background of the image and extract quantitative information used by management systems for decision. Processing and analysis of images can be divided into three levels – low, intermediate and high level.

The processing of low level involves removing noise from image correction levels of gray. The aim is to improve the image quality by removing redundant information. In this process using various filters such as Gaussian or Butterworth to eliminate noise.



a) by threshold b) by angle c) by regions

Figure.1. Methods for image segmentation

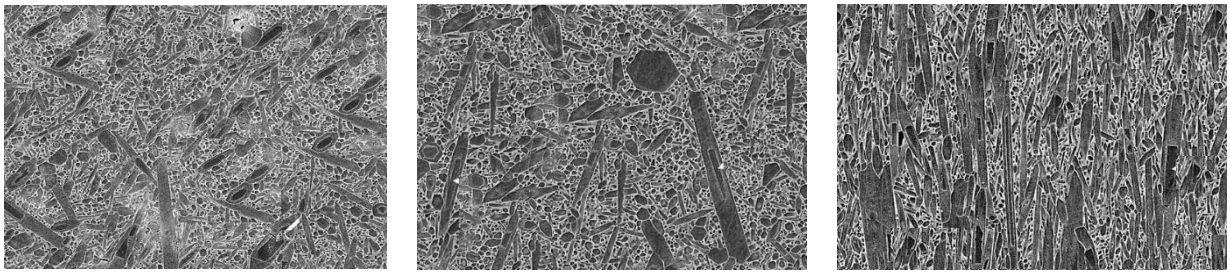
The intermediate level includes segmentation and description of the image. Segmentation (Figure 1) is an important step because the results in subsequent treatments are highly dependent on the accuracy of this treatment. The main objective is to separate areas of the image that have a strong correlation with areas of interest or areas. Segmentation can be performed in three different ways – by threshold, by angle, by regions.

The processing in high level is a recognition and interpretation usually based on statistical processing or multilayer neural networks. These level provide information necessary for the management of machines and processes.

3. Material and methods

Images used in the study. Used are SEM images obtained after processing of the ceramic material with a different value of the intensity of the magnetic field – without treatment, 1T and 12T. All images are converted into levels of gray and filtered with a filter with the same settings in order to align the output condition and clear of noise in them.

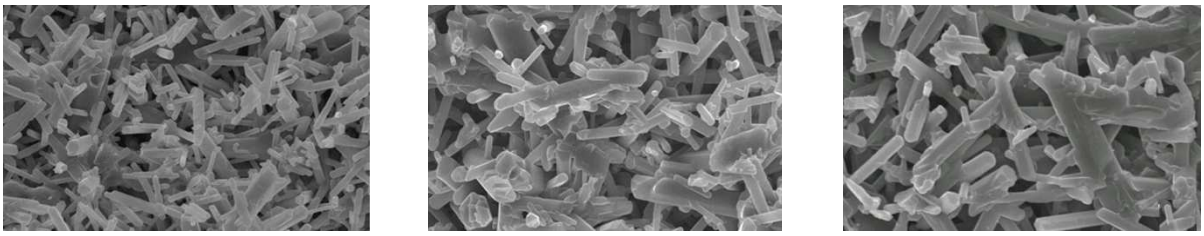
Figure 2 shows the SEM images of the original ceramics at processing while rotating the sample in the magnetic field with 5 min-1 for 2h. The magnetic field is directed parallel to the sample. The zoom is 2500. Used are images presented in [6].



a) without threatment b) 1T c) 12T

Figure.2. Original SEM images of ceramics threated in magnetic fields with different strength

Figure 3 shows SEM pictures of ceramics compiled at different temperatures. The magnetic field is directed perpendicularly to the sample. The processing time is 2h. Rotation of the sample in the magnetic field of 5 min-1. The zoom is 2500. Used are images presented in [13,14].



a) without threatment b) 1700°C c) 1800°C

Figure.3. Original SEM images of ceramics threated in different temperatures

Separation of texture characteristics. Methods for segmenting individual objects in an image use features of the pixels. Until now as feature is mainly used gray tone or intensity of the pixels in the individual channels. In the image can be defined and used a number of other features. The texture features characterize the structure and surface of objects. As they are expressed through repetitive image elements to describe them are used values associated with the surroundings of pixels.

The preparation of the values of the statistical texture features is performed using the matrix P (I, j, d, θ), where i is the level of gray of a point (x, y), j-levels of gray per pixel, located a distance d and angle θ from the coordinates (x, y). The main statistical texture features used in the study contrast, energy, correlation and homogeneity in the four directions of the angle θ are obtained by mathematical relationships presented in Table 1.

Table 1.

Main texture features

Feature	Mathematical formulation	Description
Energy	$\sum_{i,j=0}^{N-1} \left(P_{ij}\right)^2$	P_{ij} – element I,j from normalized symmetrical matrix of GLCM; N – number of grey levels in image as values; μ – mean value of the GLCM matrix.
Contrast	$\sum_{i,j=0}^{N-1} P_{ij}(i-j)^2$	
Homogeneity	$\sum_{i,j=0}^{N-1} \frac{P_{ij}}{1+(i-j)^2}$	
Correlation	$\sum_{i,j=0}^{N-1} P_{ij} \frac{(i-\mu)(j-\mu)}{\sigma^2}$	
Dispersion	$\sigma^2 = \sum_{i,j=0}^{N-1} P_{ij}(i-\mu)^2$	
Mean value	$\mu = \sum_{i,j=0}^{N-1} iP_{ij}$	

From preliminary experiments was determined direction θ, which are calculated statistical texture features to obtain the coefficients of the approximation and detailing of the image. The features are evaluated and disaggregated into informative and the size of the test sample is determined.

Calculated is the statistical description of the properties of adjacency matrix of gray level GLCM (Gray level co-occurrence matrix). This matrix is an array of mxn xp

dimension. If adjacency matrix GLCM is part of another array GLCM, then the result is a random set of statistics for each adjacency matrix GLCM [11].

The feature “contrast“ is a contrast between the intensities of each two pixels of the entire image and is 0 in uniform image.

The feature „correlation“ shows how correlate any two pixels of the entire image. This feature is 1 or -1 when there is strong positive or negative correlation between pixels in an image and has value NaN in uniform image.

Energy returns the sum of the squares of the elements in the matrix GLCM and is 1 in uniform image.

The “homogeneity” characterize the density distribution of the elements in the matrix GLCM on its diagonal and is 1 in a diagonal matrix.

Assessment of the informative features. Presented in Table 2 dependencies have the following physical meaning: The larger the variation of a typical values Mi, the wider the range of fluctuation in characteristic specification of various objects, therefore, the higher the value of this attribute is easier to distinguish them.

The less distraction values Di, the less characteristic variation of the same object. If limiting the value of F tends to zero.

Table 2.

Assessment of the informative features

$M_m = \frac{\sum_{i=1}^{k} M_i}{k}$	$M_d = \frac{\sum_{i=1}^{k} D_i}{k}$	$D_m = \sqrt{\frac{\sum_{i=1}^{k} (M_m - M_i)^2}{k-1}}$	$D_d = \sqrt{\frac{\sum_{i=1}^{k} (M_d - D_i)^2}{k-1}}$
$F = \frac{D_d}{D_m}$			

The features that occur in magnetic processing of ceramics and glass are close by characteristics. This impedes their identification and therefore requires the use of more parameters of the objects in image. The magnetic treatment changes the structure of the material, which in turn leads to an alteration of the surface. This change can be assessed using the texture features.

Due to the complex assessment, which is required for the evaluation of magnetically treated ceramic and glass electrical and dielectric materials makes it necessary to develop an information model that includes an analysis of informativeness of the characteristics, classification procedures and others.

Histogram analysis. A histogram is a universal characteristic of an image. It shows the number of pixels with the same intensity. Regarded as an integral feature of the image [12].

Through “imhist” function from Image processing toolbox of Matlab program system is obtained histogram of the image. The diagram shows the distribution of pixel values by the color bar. Following are n-number set sections, each of which represents a range of intensity values. Calculated is the number of pixels in each of these intervals. These parameters provide information about the variety of intensities that form the image.

Description of crystal structures in SEM images by morphological features. A review of published studies concerning the analysis of the shape of the elements of crystal structures to assess their quality gives rise to claims that the main signs of the

shape of an object viewed in a plane directly related to its geometric dimensions and characteristics: large axis, minor axis, area, perimeter of contour. On their base are defined sets of relationships often used for unambiguous description of the objects themselves for the purposes of their recognition or classification. In these cases, the use of such ratios is often equivalent to, and sometimes more effective than the use of more sophisticated methods.

For obtaining information on parameters of the object in the image can become a function “regionprops” from Matlab program system [2]. Table 3 describes the parameters of the objects of the image, which are obtained by this feature.

Table 3.

Statistical parameters of object in image determined with a function Regionprops

Parameter	Description	Parameter	Description	Parameter	Description
'Area'	Area of the object	*'EquivDiameter'*	Diameter of bounding circle around object	*'MajorAxisLength'*	Length of the long axis of the object
'BoundingBox'	Minimal rectangle around object	*'EulerNumber'*	Number of objects in image	*'MinorAxisLength'*	Length of the short axis of the object
'Centroid'	Center of mass	*'Extent'*	Respect of areas	*'Orientation'*	Orientation of the object in image
'ConvexArea'	Convex area of the object	*'Extrema'*	Extremes in the area	*'PixelIdxList'*	No description
'ConvexHull'	Convexity of the object	*'FilledArea'*	Active pixels in image	*'PixelList'*	Number of pixels in the object
'ConvexImage'	Convexity of all objects in image	*'FilledImage'*	Image with filled holes	*'Solidity'*	Camber of the object
'Eccentricity'	Eccentricity of the object	*'Image'*	No description	*'Perimeter'*	Perimeter of the object in image

Categorization (classification) of objects in an image. Discriminant analysis [3,7,12] is a multidimensional data analysis, which is used when there is need for "predicting" the values of the grouping variable. The main objective of the discriminative analysis is the prediction the membership of a case based on the function of continuous variables to one of several naturally formed groups. The majority of the results of the discriminative analysis is obtained by presuming normal distribution. It works with both quantitative and qualitative characteristics.

4. Results and discussion

Presentation of data from SEM images through histogram analysis. Figure 4 shows histograms of these images as a decrease in the intensity of the pixels in the image and the orientation of the crystals.

As the crystals adopt the same angle of orientation, so the intensity of the pixels is reduced. Without magnetic processing the intensity of pixels in images reaches 7000; upon application of a magnetic field with strength 1T intensity of the pixels reaches 6000; for 12T of a magnetic field the intensity of the pixels is 4000.

This significant difference in the intensity of the pixels in the use of histograms for analyzing SEM images appropriate method for objective representation of the results

of studies relating to the change of orientation of crystals in the structure of the ceramic materials at magnetic treatment with amending the value of the strength of the magnetic field.

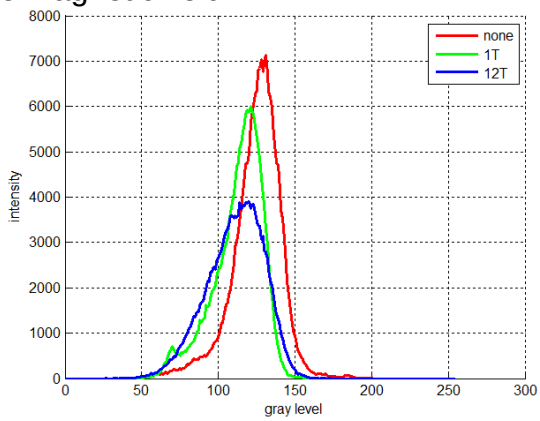


Figure.4. Histograms of SEM images of ceramics at different strengths of the magnetic field

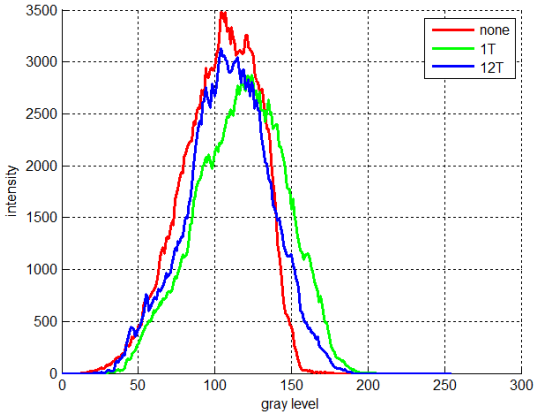


Figure.5. Histograms of SEM images of ceramics processed at different temperatures

Experimentally it is found that the method "histogram analysis" is not appropriate for objective representation of the results in the evaluation of the images obtained by increasing the size of the crystals after thermal treatment of the source material in the manufacture of ceramics, processed in a magnetic field.

As can be seen of the Figure 5, the histograms of the images obtained in the crystal growth in the structure of the material is close in values – the intensity of the pixels is in the range of 2500÷3500 for the various images.

Presentation of data from SEM images using discriminant analysis. Figure 6 presents the results of non-linear discriminant analysis, by which it is analyzed the orientation of the crystals in SEM images of ceramics according to the intensity of the magnetic field. Without treatment in a magnetic field (none) shows that the crystals are disorderly arranged in the image. When processing with 1T has a grouping, but still have some particles heterogeneous orientation. When processing with 12T particles have a strictly vertical orientation and are strongly clustered and are oriented at equal angles.

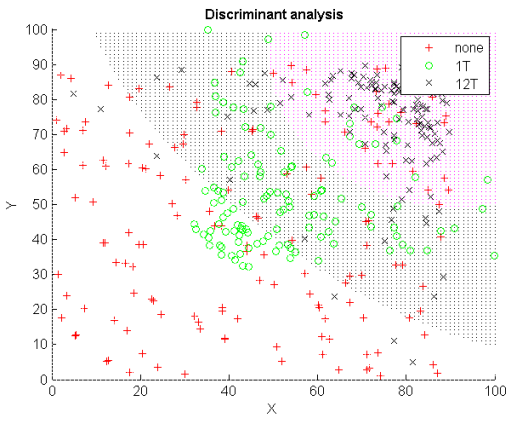


Figure.6. Grouping of the data for crystals at different strengths of the magnetic field

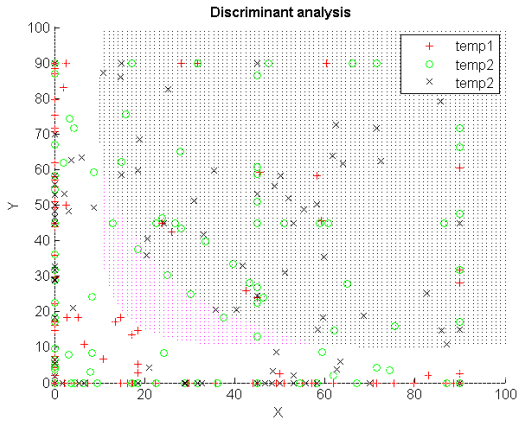
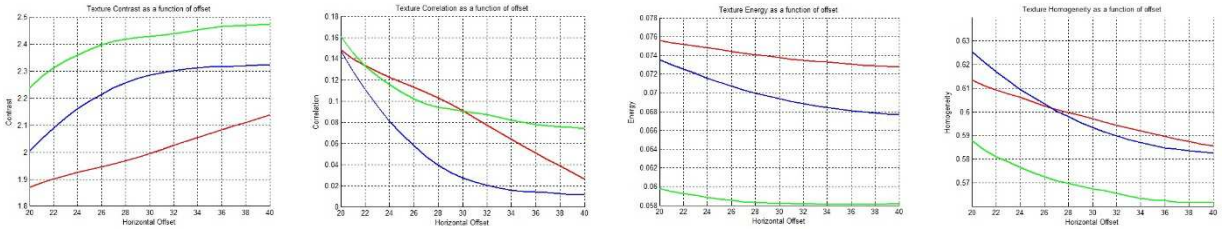


Figure.7. Grouping of the data for crystals processed at different temperatures

Figure 7 presents the results of non-linear discriminant analysis, by which it is analyzed the orientation of the crystals in SEM images of ceramics depending on the treatment temperature. This process, as can be seen from the figure does not affect the orientation of the crystals.



a) contrast b) correlation c) energy d) homogeneity

Figure 8. Presentation of SEM images of magnetically threated ceramics by texture features

Presentation of data from SEM images by texture features. In Figure 8 are presented graphs of dependencies between the texture features “contrast”, “correlation”, “energy” and “homogeneity” with the adjusting parameter offset. Apparently a significant difference in the results of image data for ceramics processed with different magnetic field strength. Only by using features “homogeneity” and “correlation” was observed overlap of data. These results are a prerequisite for carrying out further studies related to the assessment of the information texture features in order to express an assessment of changes in the structure of the ceramics processed at different magnetic field strength and varying temperature.

5. Conlusions

The present report is a study on application of image processing techniques to SEM digital images in the evaluation of quality of the heat and magnetically threated ceramic materials.

In evaluating the images by histograms is shown a significant difference 1000÷2000 in intensity in the images of ceramics treated with varying strength of the magnetic field.

Not good results are obtained in images of ceramics processed at different temperatures. The intensity of histograms in this case is 500÷1000.

The results show that the use of histograms of images on ceramics, processed at different temperatures is impractical because the structure of the material is compacted, but the crystals do not have uniform orientation and this significantly impedes the automatic processing of images.

Analogous results are obtained using discriminant analysis. Using the feature „orientation“ the common error is up to 15% of ceramics treated with different magnetic field strength, while in this treated with different temperatures with the same feature, the common error is up to 100%.

The use of informative texture features allows known methods of segmentation to be modified to solve specific problems for determining the orientation of the crystals in the SEM images of ceramics, which is a prerequisite for the realization of subsequent tests for rapid and objective assessment of magnetic treated ceramics.

6. Literature

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