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EMPLOYMENT OF COMPUTERIZED IMAGE ANALYSIS METHODS TO ANALYZE MICROSTRUCTURES

WYKORZYSTANIE METOD KOMPUTEROWEJ ANALIZY OBRAZU DO ANALIZY MIKROSTRUKTUR

Abstract

Microstructures have a very big influence on the physical properties of materials and hence on its practical application, therefore, are the subject of intense research. The article discusses the use of computer image analysis methods for the analysis of microstructures on the example of the problem alpha phase detection for aluminum alloy AK64 ($AlSi6Cu^4$). In the analyzed images can be identified alpha and beta phases, silicon and warp. Basing on the observed properties distinguishing the alpha phase of the remaining parts of the image, to designate alpha phase the different mechanisms of computer image analysis were used, for example: filters, Binarization, Segmentation and shape factors.

Keywords: *image analysis, noise removal, objects detection, microstructure*

Streszczenie

Mikrostruktury mają bardzo duży wpływ na własności fizyczne materiałów, a co za tym idzie – na ich praktyczne zastosowanie, dlatego są przedmiotem intensywnych badań. Artykuł omawia użycie metod komputerowej analizy obrazu do analizy mikrostruktur na przykładzie problemu detekcji fazy alfa dla stopu aluminium AK64 ($AlSi6Cu^4$). Na analizowanych obrazach wyróżnić można fazy alfa i beta, krzem oraz osnowę. Bazując na zaobserwowanych własnościach wyróżniających fazę alfa spośród pozostałych elementów obrazu, do wyznaczenia jej użyte zostały różne mechanizmy komputerowej analizy obrazu, między innymi: filtry, binaryzacja, segmentacja oraz współczynniki kształtu.

Słowa kluczowe: *analiza obrazu, usuwanie szumów z obrazu, detekcja obiektów, mikrostruktura*

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1. Introduction

Computer science is taken advantage in each domain of science. Computer science, but especially image analysis is used also in a materials engineering. Image analysis is a valuable tool, which allows to extricate from image details at a given moment interesting. Eyesight is most perfect human sense, but computer image analysis is better than traditional analysis, because of speed receiving and precision of results. Computer systems don't tire therefore work efficiently. Otherwise, computer systems enable to obtainment results, which are practically impossible for evaluation.

In a materials engineering the term microstructure is defined inner structure of materials, and thus the spatial distribution of phases and defects in the crystal structure. The phases have different shapes and phase boundaries between them. Microstructures have a very big influence on the physical properties of materials and hence on its practical application, therefore, are the subject of intense research.

The purpose of the research is to create a tool that would automatically find elements fitting a previously set pattern on images. The tool will be utilised as a means of detecting specific phases on the images of various microstructures, that is why an analysis and quality enhancement of the images, as well as an attempt to the best possible separation of particular phases were necessary, what will be presented in the example of alpha phase detection. The following stage is to create and implement an algorithm for detection of elements of microstructures based on their phases on user-selected images of microstructures. Ultimately, the tool is supposed to work on any images and patterns provided by the user.

2. Methodology and discussion about algorithm

This section will discuss the mechanisms used to analyze the microstructures of images to detect the alpha phase. Structural description of the image presented of the microstructure contains several levels.

In considering the image as a whole is distinguished by its characteristics such as size, average degree of clarity whether the dominant colour.

At the next level of analyzing, the image can be divided into background and major regions, which have different characteristics.

The next level allows for separation of components of objects, differing in certain characteristics, such as shape, and within subregions – morphological features, which include the parameters of objects and geometrical shape factors, allowing the obtain image elements of a specific shape.

Between objects belonging to the same level – excluding level description of the image as a whole - there are geometrical, topological, metrological relationships and relationships of objects similarities. Understanding these relationships will help to distinguish the individual picture elements.

2.1. Improving image quality

In order to improve quality images of microstructures are subjected to filtration. The idea of filtration is the removal of noise, the value is too large or too small. Removal of

noise from an image is very important due to the fact that they can cause an erroneous identification of objects in the picture. The activity of filters is based on algebraic operations on numbers that describe the colour or gray level points in the vicinity of the point currently analyzed. Using a filter establishes to a contextual operation realization- to determine the value of one pixel of the resulting image, you need to perform calculations on the many of pixels of the source image in the vicinity of the analyzed point.

The filter is so really a multi-argument mathematics function, which transforms one image into another method of "pixel by pixel". Filter properties result from the analytical properties of functions realizing it, so there are linear and nonlinear filters – depending on whether they are based on linear or nonlinear combination of the source image pixels. Nonlinear filters have the advantage that practically do not interfere with useful information.

To remove noise from images of microstructures have been used the nonlinear filtering, namely filter based on the median, which rejects the extreme values, and – in contrast to the linear filter based on the average - does not introduce new values to the image, so it don't deprive details of image (Fig. 1). Filtration is realized by moving a window measuring 5 by 5 pixels along the image and the replacing value of the element at the center of the window (Table 1) at the median value of all elements of the window (Table 2). Points of the mask are set in a monotone sequence according to their brightness, then is selected the middle point of this sequence. Outliers are rejected and the current pixel is replaced by the received middle pixel. The operation is repeated for each point.

Table 1

Examples of pixels values of neighborhood of the analyzed point

1	17	15	31	27
16	12	17	43	7
14	5	**13**	18	11
9	7	9	13	6
7	5	8	8	10

Ordered values of pixels contained in the window are as follow: 1, 5, 5, 6, 7, 7, 7, 8, 8, 9, 9, 10, **11**, 12, 13, 13, 14, 15, 16, 17, 17, 18, 27, 31, 43

Table 2

The pixels values after replacing the central pixel value with the median value

1	17	15	31	27
16	12	17	43	7
14	5	**11**	18	11
9	7	9	13	6
7	5	8	8	10

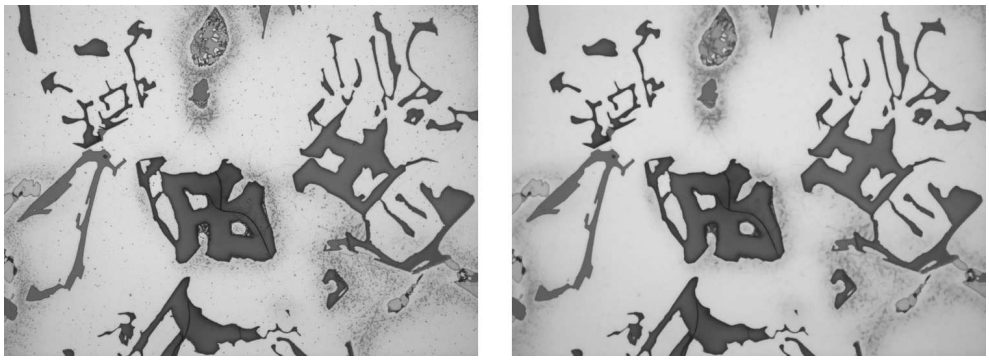


Fig. 1. An image of a microstructure and the same image subject to median filtration
Rys. 1. Obraz mikrostruktury oraz ten sam obraz po zastosowaniu filtracji medianowej

Description of the filters in the literature: [1], [3], [6].

2.2. Binarization

Binarization is a operation that converts a gray image into a binary form. The aim of binarization is radical reduction the amount of information contained in the image. The proposed algorithm implements automatic binarization procedure, which uses a global, point method proposed by Kapur, Sahoo and Wong. Automatic binarization is realized by thresholding. The brightness value of each picture element is compared with the threshold value computed automatically, next step is to assign the element to one of two categories: with the exceeded or not exceeded threshold value. Description of binarization in the literature: [1].

2.3. Segmentation

The aim of Image segmentation is to isolate disjoint areas having a common characteristic, which not found in the vicinity of the area.

Segmentation was also used to split overlapping regions. The implementation relies on a distance function computation, followed by a filtering step and a segmentation using the watershed line. The description in the literature: [2], [6].

2.4. Close

Closing serves to fill the narrow notches, small holes and gulfs inside particles. The operation consists of combining objects that lie close together and clogging “holes”. Of the minimum distance between objects and the diameter of “holes” decide the dimensions of the structural element.

2.5. Shape factors

For the extraction of specific image objects, you can use the geometric shape factors. To eliminate objects that do not resemble “Chinese script”, was used elongation factor (ellipticity). In this way, the most elongated objects were removed.

$$W = \frac{L_1}{L_2}, \tag{1}$$

where:

W – elongation factor,
L_1 – minor diameter of ellipse, that is described on the object,
L_2 – major diameter of ellipse, that is described on the object.

As shown, the objects that match the alpha stage, have typically large circuits, the proposed algorithm uses Crofton dependence.

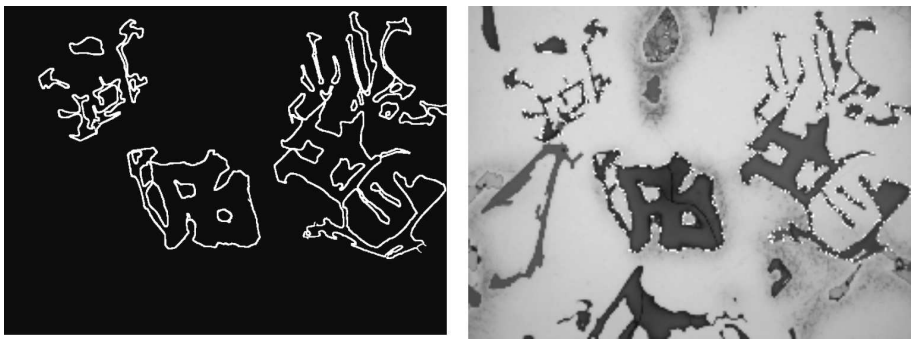
$$L = \frac{\pi}{4}[N_0 + N_{90} + \frac{a}{\sqrt{2}} \cdot (N_{45} + N_{135})], \tag{2}$$

where:

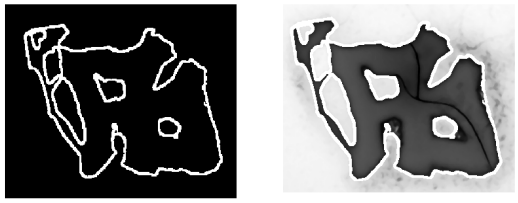
L – circuit length,
$N_0, N_{45}, N_{90}, N_{145}$ – the numbers of pixels crossed by secants leading at an angles: 0, 45, 90 and 135 degrees.

3. Results of detection

Analysis results are binary images (Fig. 2) and images after visualization – initial images with alpha phase boundary (Fig. 2). Figure 3 shows the pattern of the alpha phase (Fig. 3).



Rys. 2. Binarny wynik analizy oraz wynik po wizualizacji
Fig. 2. Result image and image after visualization



Rys.3. Przykład wzorca fazy alfa
Fig. 3. Example of the alpha phase pattern

The developed method produces correct results in most cases, however further tests on a large batch of images are required. Detection of specific phases will allow for easy pattern creation for the automatic detection of predefined elements on any microstructure image.

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