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Fuzzy Logic Analysis of Parameters of Dimples of Ductile Tearing on the Digital Image of Fracture Surface

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Abstract

An automated method for analyzing shapes and sizes of dimples resulting from fracture of titanium alloy VT 23, which can be used in technical diagnostics systems, is proposed. The developed approaches to the analysis of images of fracture surfaces obtained from scanning microscope allow highlighting the components of the objects under study, performing their morphological analysis, and evaluating the mutual relationship between them. The proposed algorithm has a self-processing feature for the identification of the objects sought in the images of fracture surfaces, because it does not need to be adapted to images of different types, and does not require any individual adjustment of parameters.

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1. Introduction

Fractographic analysis is one of the most informative methods for interpreting the mechanisms of failure [1, 2]. Therefore, it is widely used in the study of damages of various transportation systems to determine the reasons for their breakdown or unpredictable failure.

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The analysis of physical and mechanical regularities in the failure of materials and structures is impossible without a quantitative description of morphology of their fracture, shape and dimensions of the micro-relief elements. Using such approaches allows automating the process of fractographic analysis, which will increase the accuracy and reliability of the results obtained.

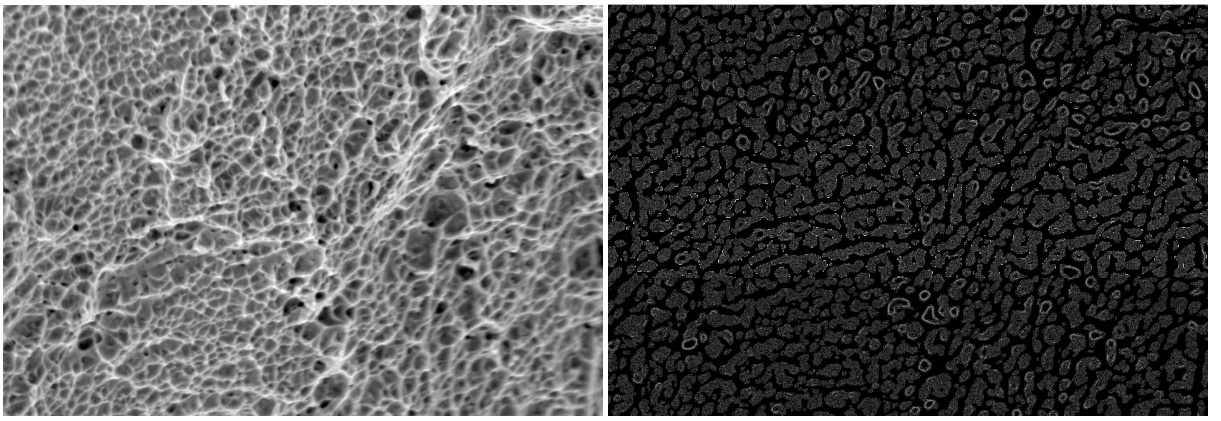
To identify and analyze dimples of ductile tearing on the fracture surface of the material, a number of techniques are developed based on the analysis of the surface image [2–4]. In this case, a combination of various known algorithms for image analysis is used (including the analysis of the image histogram, watershed transformation, filtering, wavelets, texture analysis).

As shown in [2, 4], the quantitative evaluation of the informative fractographic signs of fractures and structural components of the metal allows finding correlations between them and the mechanical properties of structural materials, which is especially important for the damage analysis.

The objective of this paper is to develop and test the numerical analysis method of shapes and sizes of dimples of ductile tearing on the fracture surface of titanium alloy using the analysis of digital images of the surface.

2. The algorithm for image analysis

The initial image for the proposed algorithm is the grayscale image of the fracture surface of titanium alloy VT 23 obtained with an electron microscope REM 106-I (Fig. 1a). The algorithm includes two parts: the basic part and the analytical part. The basic part of the algorithm is intended for the division of the image into two segments: the background and objects. The analytical part of the algorithm is designed to evaluate the ambiguous recognition of edges of the objects found. The basic algorithm for calculating the parameters of objects (dimples) using their images consists of the operations of filtering and watershed transformation [5].



a) b)

Fig. 1. The initial image (a) and the result of recognizing the edges of dimples (b).

The basic part of the algorithm. The basic part of the algorithm consists of the operations of filtering and segmentation. Filtering with the Gaussian filter allows smoothing out of gradients between different parts of an image and reducing the fragmentation of recognized objects. An important parameter in filtering is the size of the filter kernel, because it affects the processes of “screening” of background pixels and combining separated fragments of the object of recognition. Therefore, changing the size of the filter kernel has a significant impact on the final result of recognition.

Filtering was followed by segmentation, which consists in highlighting pixels that correspond to the damaged areas. The adaptive boundary transformation (Bradley’s conversion) based on the integral image was used for segmentation [6]. Each pixel is considered as the one that belongs to the object, provided its brightness is to a specified percentage lower than the average brightness of surrounding pixels in the window of specified size. The integral image is calculated prior to the thresholding, and allows to significantly reduce the number of calculations