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Reprint of "The original concept of description of the coke optical texture"

M. Piechaczek *, A. Mianowski, A. Sobolewski

Institute for Chemical Processing of Coal, 1 Zamkowa St., 41-803 Zabrze, Poland

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ABSTRACT

The aim of the present study was to prove that the image analysis is a useful tool in coke texture characterization. The authors proposed the method of measurement of the gray color gradient vector in the prepared microscopic images with visible anisotropic effects. The research was performed for totally different samples of chars and cokes. The total texture fibrosity index for each sample was determined. The results show a strong positive correlation between proposed fibrosity index and technological parameters according to NSC test (CRI, CSR). The new parameter characterizes with universal character resistant to changes in conditions of coking process and coked coal properties.

1. Introduction

Metallurgical coke serves a very important role in the steel industry, and its quality is strictly controlled and described by several properties both physical and chemical. There is a detailed description of the sets of parametric properties, which are rigorously enforced in commercial contracts (Alvarez et al., 2007; Chatterjee et al., 2001; Diez et al., 2002; Gainieva, 2008; Gray, 1989; Guerrero et al., 2013; Hermann, 2002; Loison et al., 1989).

Development of an analytical study on the coke optical texture was caused by the need of composing the blends of coking coals from many coal components, often with unknown properties (Koszorek et al., 2009; Krzesińska et al., 2009; Patrick et al., 1983; Sakurovs, 2003). This unique optical nature of coke can be related to basic properties of coal blend and its different density when charged. As well, some additives to coal blend have the influence on coke optical morphology (Alvarez et al., 1998; Dobrowolski and Gostkowska, 1957; Pusz et al., 2010).

Morphology means study of shape and refers to the form and construction of observed particles. In case of coke microscopic images, the morphology means the set of anisotropic features, themes that can be observed in the flat image. The themes which can be observed in the coke microphotography are for example: porosity and its distribution, isotropic and anisotropic textures and their distribution, size and shape of optical textures etc. This study is focused on the coke optical texture and problem with its automatic identification.

Coke microtexture is an unique feature of any coke and is a result of many physical and chemical transformations (Gray, 1989; Reifenstein, 1997). Development of the microtexture depends on coal properties (rank, plastic properties, petrographic composition, ash content and its chemical composition, etc.), technical conditions (final coking temperature, heating rate, total coking time, etc.) and coking technology (charging system, additives). Microtexture refers to the nature of the carbon in the coke, its crystalline ordering, degree of the optical anisotropy etc. (Coin, 1987). It is also reflected by coke bireflectance. The higher value of bireflectance, the higher degree of anisotropy (Duber and Rouzaud, 1999; Duber et al., 2000). The influence of the coal properties and technology conditions on the microtexture have been already studied (Patrick et al., 1973; Piechaczek et al., 2010; Pis et al., 2002; Pusz et al., 2003, 2009, 2010; Singh et al., 2007; Smędowski et al., 2011).

Many scientists were also studying the consequences of changes of the anisotropy effect on the coke quality and technological parameters. They investigated that the reactivity of coke has a tendency to grow with decreasing degree of anisotropy (Menendez et al., 1999; Pusz and Buszko, 2012).

Gray (1989) established that coke texture can be divided into two phases: binder phase and filler phase. This nomenclature bases on size, shape and origin of texture elements. The binder phase is formed from plastifying, reactive macerals and carbon materials. It is characterized with various microtexture types with different sizes and shapes. The filler phase consists of coked inert parts (macerals and minerals), mostly with isotropic character.

It is well known that in recent years, a lot of microtextural terminologies and classifications were developed (Coin, 1987). Most of these classifications are suited for concrete laboratory, but always depends on the skills and experience of the person who performs the analysis. In this paper the ASTM Standard (D5061-07) for texture analysis was chosen. Manual methods of point counting are very laborious and

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* Corresponding author. Tel.: +48 32 271 0041-241; fax: +48 32 271 0809.
E-mail address: mpiechaczek@ichpw.zabrze.pl (M. Piechaczek).

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biased, that is why some scientists (Eilertsen et al., 1996; Pearson et al. 2012) developed automatic computer analysis to free it from human factor and make it faster to perform.

No matter which method is chosen, qualitative and quantitative analysis of the coke textures, provides a large number of results. Results in the form of percentage values (sometimes over 20 texture types) are difficult to use in the algorithms of the coke quality characterization. One solution is using the image analysis to distinguish the texture type. It was decided to exploit the difference in the distribution of color within the selected texture type (Eilertsen et al., 1996; Kolowca, 1995).

2. Theory of the new concept

Colorful microscopic image as a view of coke optical morphology in polarized light and phase retarder plate is full of themes/details that make the image analysis difficult to perform. To perform the analysis just on selected detail of interest, it must be isolated from the background. In the beginning of studies some assumptions must be established. The most important is to decrease the amount of themes on the pictures which do not take a part in texture analysis, like pores. Although, the presence of the pores has a significant impact on the gasification process, the authors focused on the chemical not physical nature of coke structure. Mechanism of determination of a gray color gradient vector is created to rate the size and shape of anisotropic particles within a certain texture type. Pores which are contained within the evaluation image will falsify the results of the evaluation. To exclude the pores from the image the segmentation process must be performed. Image segmentation is the process of partitioning an image into multiple segments that are called texture samples. The aim of segmentation process is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries in images. In this study, segmentation involves on cutting off the single optical texture type (eg. circular fine, lenticular medium, etc.) from the entire microscopic image (Fig. 1). This solution helps to skip the problem of the lack of precise shapes and borders of optical textures that are often connected and winding. Here, the operator shows to the computer what the isolated region of interest is. There are some difficulties in preparing a proper segmented images of organic inert part due to its very often, natural inertinite-like, oblong structure. After separation the organic inert parts from the pores, the obtained isolated area exhibit the isotropic texture characteristics and can be treated similarly. Both the organic inerts and inorganic inerts after the segmentation process will be treated as optical isotropic, even though their influence on coke strength and reactivity has a different character. The research is mostly focused only on the textures from binder phase.

Prepared texture samples, containing isolated texture types are analyzed with the application which converts the images to gray scale, then texture samples are divided into sections with dimensions 25×25 pixels (gradient measurement areas). For every section the vector of gray color gradient (value and direction) is analyzed, by measuring the gray color for each pixel and establishing the mean direction of changes. After the experiments aimed at obtaining the most satisfactory resolution of the results such a size of gradient measurement area was chosen. Too small or too big size of mesh of gradient measurement area results in the decrease of resolution of the method. All determined vectors from each section form the random circular histogram. Fig. 2 presents the example of final histograms generated for optical isotropic texture (Fig. 2-a), and histogram for high ordered anisotropic optical texture (Fig. 2-b). The shape of the histogram is the feature that will describe the character of the performed texture sample. To describe the shape of a histogram ellipse approximation is used (Fitzgibbon et al., 1999). The application plots the ellipse on the ends of vectors in the histogram. Then, the axis of ellipse is measured and the values of ellipse axis are used for calculating the fibrosity index (W_i) according to the equation (Kolowca, 1995):

$$W_i = (a-b)/a \quad ; \quad 0 \le W_i \le 1 \tag{1}$$

where:

W_i fibrosity index of texture type,
a longer axis of an ellipse, $a \ge b$ and
b shorter axis of an ellipse.

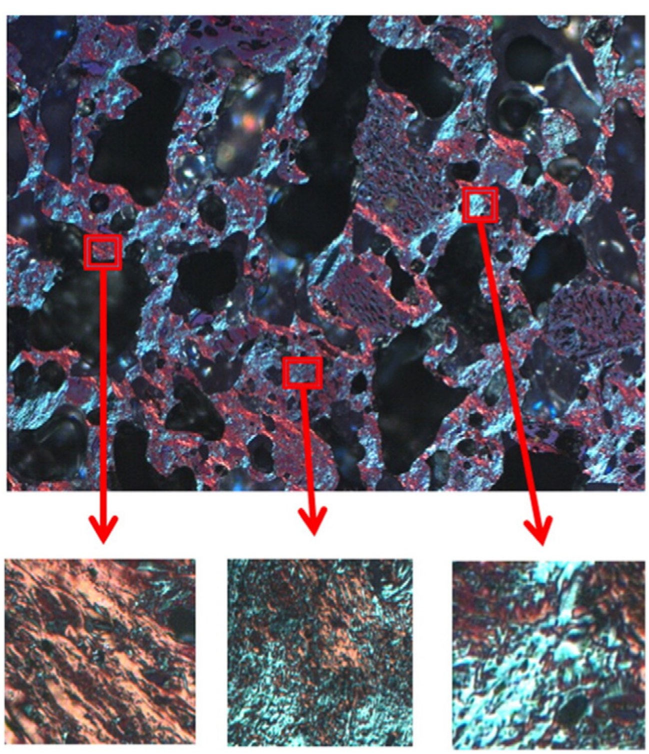

Fig. 1. Example of segmentation process and image samples of individual texture types.

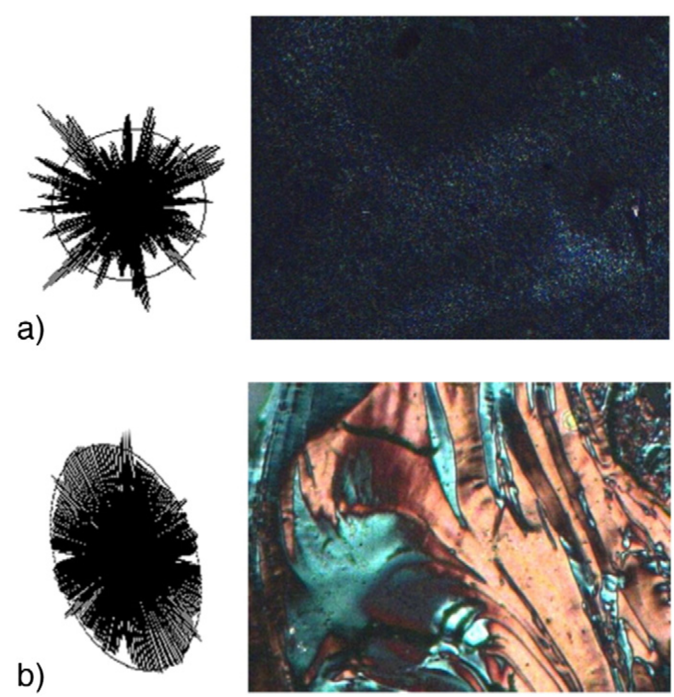

Fig. 2. Example of histogram shapes of iso- (a) and anisotropic (b) textures.