Optical Texture Characterization of Calcined Petroleum Cokes by Image Analysis

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Introduction

Optical texture indices (OTI), which are calculated from arbitrarily assigned numbers to represent different degrees of microstructural order, have been used to characterize the optical texture of petroleum cokes[1,2]. Determining OTI for calcined cokes, however, is very difficult because of the more complex heterogeneity of the calcined coke texture. Automatic image analysis or computer-aided microscopy has been used to characterize various carbon materials[3-6], but there is no report on quantitative texture characterization of calcined cokes by image analysis.

In the present study, a new method is introduced to characterize calcined needle coke texture by analyzing the change in the gray level distributions of surface images upon rotating one of the polarizing filters (analyzer) used in polarized light microscopy. The cumulative gray level changes obtained from a number of images are used to calculate an optical texture index for a coke sample.

Experimental

As a preliminary test of the proposed method, a two-level approach was taken to characterize the optical texture of coke samples: (1) classification of a large number of particles into three categories with respect to their shape and apparent reflectance by visual inspection; and (2) characterization of optical texture of randomly selected particles in each of the three categories by image analysis textures. A combination of particle shape distribution with the individual optical texture parameters was then used to obtain an overall optical texture index for a given coke sample.

Six calcined commercial needle petroleum coke samples were tested in this study. These samples were classified into three groups, *e.g.*, needle (N), intermediate (M), and isometric (I) categories, mostly according to the aspect ratio of the particles.

The optical textures of coke specimens were examined under a polarized-light microscope with a tint plate (Nikon Microphot-FXA). Image acquisition from the microscope is performed via a high resolution video camera (1000 lines) and an image analysis system (PGT, IMAGIST). For each point selected on the specimen two digital images were obtained at two different analyzer angles to give the largest change in gray level distributions[6]. Two digital images, thus obtained, were then analyzed using IMAGIST software, and a distribution of gray levels was determined for each image by the area fraction of each gray level (0 to 245, which has been divided into 7 groups, GL_1 to GL_7). The changes in each gray level between the two images (e.g., changes in area fractions of gray levels, ΔGL_j) were calculated and plotted for each gray level.

Twenty optical images were randomly taken from different particles in a sample pellet, in other words, 40 digital images for each category of particles, and a total of 120 images were analyzed for each coke sample.

Results and Discussion

Changes in Gray Level Distribution

Fig. 1 shows a typical gray level distribution in different texture images, i. e., flow domains (a), domains (b), and mosaic (c) texture at different analyzer angles (0 to $\pm 90°$). It is clear that the distribution of gray levels strongly depends on the optical texture. Flow domain and domain images (diagrams (a) and (b)), possess large proportions of bright area GL_7, constituting typically more than 60% of the area for flow domains and about 40% for domains. The images of mosaic regions, in contrast, have a small percentage (less than 10%) in this brightest level. On the other hand, the area fractions of intermediate levels (GL_3 to GL_6 are small in both flow domain and domain images, while they are rather large in images of mosaic textures. Large fractions of GL_2 are mostly observed for flow domains and, to some extent, for domain and mosaic images, depending on sample orientation. Thus, in general, different gray level distributions can be assigned to different optical textures, or to different degrees of orientation of anisotropic microstructures on cokes surfaces.

Distinguishing different images in terms of the distribution of gray levels can be achieved by rotating the analyzer to a given angle. The changes of gray level distribution in a flow domain images (Fig. 1 (a)) are much more sensitive than in the others for a wide range of rotation angles. In a flow domain image, even a slight rotation of analyzer (e.g., 15°) leads to significant change of gray level distribution. Thus, a representative account of these changes on a sample surface can be used to quantitatively characterize the optical texture of calcined cokes.

Definition and Calculation of Optical Texture Indices

An optical index was defined on the basis of the changes in the gray level distributions of imagepairs. The following equation is used to calculate a texture index for each particle category:

$$I_i = \frac{\sum^{n} \left(\sum_{j}^{7} (\Delta GL_j)\right)}{n} \qquad (1)$$

where I_i is a texture index for particle category i (i=N, M, and I); ΔGL_j (j=1, 2,...7) is the change in gray levels; and **n** is the number of images collected (n=20 in the present study).

Considering the distribution of particle categories, an overall optical texture index of a coke is determined by the following equation:

$$I_o = \sum_{i} (f_i \times I_i) \qquad (2)$$

where I_o is an overall optical texture index of a coke sample; f_i is the percentage fraction of i category or size of the particles; and I_i is a texture index of ith particle category obtained by formula (1).

Table 1 summarizes the texture indices I_i and overall indices I_o calculated using formulas (1) and (2) based on different particle categories of coke samples tested in this study. The final ranking of these samples were decided according to overall texture indices, **Io**. This ranking of the needle coke samples appears to agree very well with ranking based on field performance of these cokes, including the data on the coefficient of thermal expansion (CTE) of these needle cokes [7].

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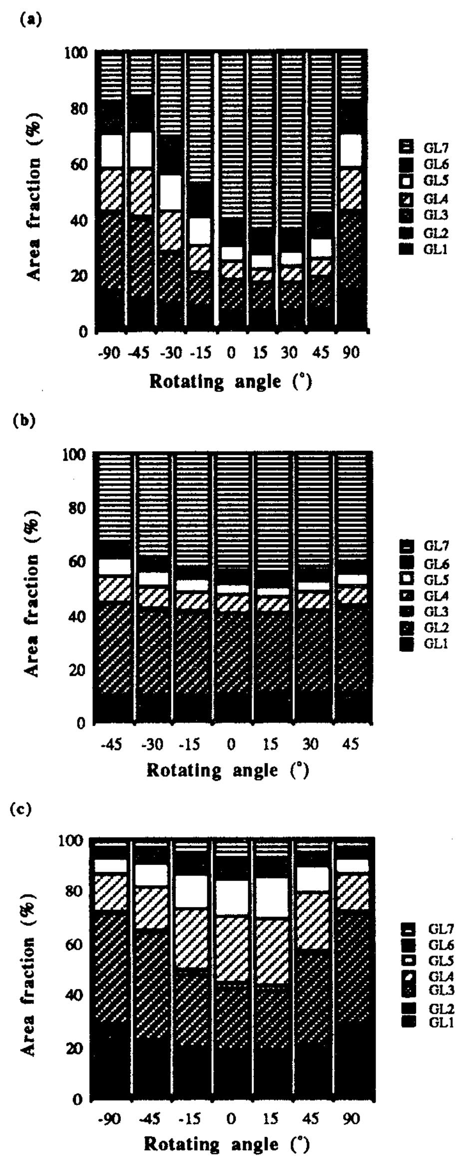

Fig. 1. Typical gray level distribution in digital images of (a) flow domain, (b) domain, and (c) mosaic optical texture.

Table 1. Optical Texture Indices by Image Analysis

Coke	I_N	F_N	I_M	F_M	I_I	F_I	Io
1	27.7	14.7	25.6	80.8	23.5	4.5	2580
2	23.3	21.2	26.5	75.7	19.5	2.8	2550
3	44.6	21.6	22.1	67.1	14.8	11.3	2610
4	32.1	20.9	24.2	67.8	11.8	11.3	2445
5	29.9	14.8	18.9	72.4	22.3	12.8	2100
6	40.5	12.8	20.5	68.2	24.7	19.1	2400

Texture indices from equation(1), I_N, I_M, and I_I for needle, intermediate, and isometric particles, respectively; F_N, F_M, and F_I: particle fractions for N, M, and I categories, %; Io: overall indices obtained by equation (2).