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Study of the Granulometric and Morphological Composition of Coal Powders

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Abstract

The granulometric and morphological composition of fine coal powders prepared according to a special technique for the size classes −0.2 +0.1, −0.1 +0.063, −0.063 +0.04, −0.04 mm from ten different grades of coal (B, D, G, Zh, K, KS, OS, SS, T, A) of the Kuznetsk coal basin was investigated. Technical and elemental analysis, petrographic studies were carried out with the coal samples using standard methods. The set of values of the reflectivity of vitrinite, the sum of the fusenized components, the thickness of the plastic layer and the yield of volatile substances allowed us to establish the grade identity of the studied samples in accordance with the unified classification of coals on the basis of genetic and technological parameters. According to the results obtained by SEM, changes in the structure of coals and the relief of the fracture surface pattern are observed in the series of metamorphism of the studied coal samples from brown coal to anthracite. The granulometric composition of coal powders was determined by laser diffraction when the samples were dispersed in an aqueous medium with the addition of a surfactant. The particle size distribution in coal powders of the fraction −0.04 mm for all grades of coal is characterized as monomodal, in the fractions −0.063 +0.04 mm − as monomodal asymmetric, in fractions −0.1 +0.063 and −0.2 +0.1 mm − as bimodal. These fractions contain irregularly shaped particles (needle-shaped, oval), as determined by means of SEM. According to the results of the studies of KS grade coal by means of NMR spectroscopy, it is established that the content of aliphatic carbon (CH_3) in the samples increases insignificantly with a decrease in the size of the coal powder fraction − from 3.05 % for the fraction −0.2 +0.1 mm to 3.73 % for the fraction −0.04 mm. The values of the aromaticity index f_a for all fractions remain constant.

Keywords: coal powder, granulometric composition, morphological composition, sieve analysis, laser granulometry, scanning electron microscopy

INTRODUCTION

Coal powders are widely used in many branches of industry. The major characteristics of the powders are granulometric composition, concentrations of mineral inclusions, humidity, *etc*. Depending on the grade composition of coal and the purpose of the use of coal powders, the major quality parameters may vary substantially. However, one of the main indicators of coal power quality is the particle size distribution. A broad range of methods used to determine the particle size distribution include the sieve and sedimentation analysis, conductometry (Coulter method), microscopy, laser diffraction [1]. All these methods have their own advantages and shortcomings and limitations for use. Previously we demonstrated that laser granulometry might be effi-

ciently used to study particle size distribution in coal powder [2].

Fine coal powders are used in many technological processes. Combustion of dust-like coal fuel in the boilers of different capacities for obtaining heat and electric energy is becoming more and more widespread. Numerous research works deal with the studies of this aspect [3–7]. The effect of the granulometric composition of coal dust on the parameters of gasification aimed at obtaining chemical products and hydrogen was considered in [8–12]. Coal enrichment processes in which the granulometric composition of coal fractions is significant have been studied by the authors of [13–17]. Special attention in coal mining, transportation and processing is paid to an increase in the level of dust explosion safety of technological processes [18–24]. The size of coal particles formed in these processes defines the measures that are to be taken to neutralize the explosive properties of the dust. The authors of [25–30] studied the explosion danger of coal dust and reported the results of the determination of its granulometric composition.

Another essential aspect of the investigation of the granulometric composition of coal powder and dust is the necessity of this information for ecological and sanitary-hygienic control at the enterprises engaged in coal mining, processing and transportation. For instance, in 2018, the list of substances subjected to the state ecological control in the Russian Federation was supplemented with black coal dust, and a regulatory document for the determination of this parameter in the atmospheric air of residential areas was developed [31]. The standards for the concentrations of suspended matter with particle size 2.5 μm (PM2.5) and 10 μm (PM10), and black coal dust in atmospheric air were adopted [32]. These parameters were included in the list of pollutants with respect to which the measures of state regulation in environmental protection are taken [33]. There also is the necessity to take inventory of the industrial sources of atmospheric emissions of suspended particles with the size less than 10 μm (PM10) and less than 2.5 μm (PM2.5). This problem is especially urgent for the coal industry. In addition, black coal dust is the source of polycyclic aromatic hydrocarbons (PAHs) [34] and toxic elements in the objects of the environment [35].

So, investigation of the granulometric and morphological composition of coal powders and industrial carbon-containing dust holds a methodical and technological significance.

The goal of the work was to determine the granulometric and morphological composition of coal powders of different size ranges (−0.2 +0.1, −0.1 +0.063, −0.063 +0.04, −0.04 mm) for subsequent methodical substantiation of the choice of coal powder particle size for extracting the compounds of PAHs class from them.

EXPERIMENTAL

The objects of investigation and their characterization

The Kuznetsk coal basin possesses great resources of black coal of all grades, from long-flame to lean. In the work, we consider a series of natural coal samples of different maturity from the Kuznets coal basin. For the investigation, we chose 10 samples of the Kuznetsk coal of different grades (B, D, G, Zh, K, KS, OS, SS, T, A) from the Coal Bank of the Federal Research Centre of Coal and Coal Chemistry of the Siberian Branch of the Russian Academy of Sciences (FRC CCC SB RAS, Kemerovo). Each coal sample was kept in a plastic vessel with inert gas, which provided reliable conservation of each sample without any loss of initial properties and qualities. The data on the origin of coal samples chosen for investigation are listed in Table 1.

The standard procedures were used to determine the following characteristics:

– ash content according to GOST R 55661–2013 (calculated in per cent from the mass of residue after annealing);

– analytical moisture content according to GOST 33503–2015 (calculated as a mass loss by coal portion during heating in a drying box at 105–110 °C to the constant mass);

– the yield of volatiles according to GOST 6382–2001 (calculated as the mass loss by coal portion during heating without air access subtracting the mass loss due to sample moisture, calculated for the dry ash-free state of the fuel);

– plastic layer characteristics according to GOST 1186–2014;

– carbon content according to GOST 32979–2014 and hydrogen content according to GOST 2408.1–95 (calculated using Liebig method);

– sulphur content according to GOST 32465–2013 (determined with the help of a CHS-580 analyzer (ELTRA, Germany)).

The data of proximate and elemental analysis of coal samples are presented in Table 2. The ash content of coal samples varies from 5.5 to 16.4 %;

TABLE 1

Data on the origin of coal samples under investigation

Sample No.	Coal grade	Explanation of coal grade	Deposit (enterprise)
1	B	Brown	Tisul (Kaychakskiy open pit)
2	D	Long-flame	Taldinskoye
3	G	Gas	Leninskoye (S. M. Kirov mine)
4	Zh	Fat	Nikitinskoye Kostromovskaya mine)
5	K	Coking	Kiselevskoye (LLC Koksoviy region)
6	KS	Low-coking	The same
7	OS	Lean caking	Tomskoye (Tomusinskiy open pit)
8	SS	Low-caking	Bachatskoye (Bachatskiy open pit)
9	T	Lean	Bungurskoye (Bungurskiy open pit)
10	A	Anthracite	The same

TABLE 2

Technical and elemental analysis of coal samples

Coal grade	Technical analysis, %				Elemental analysis, % per daf			Atomic ratio	
	W^a	A^a	V^{daf}	$S^d_{t\ tot}$	C	H	(O + N + S)	H/C	O/C
B	10.3	10.6	48.5	0.3	–	–	–	–	–
D	5.4	14.0	38.2	0.6	80.1	5.5	14.4	0.82	0.13
G	3.3	16.4	41.2	0.3	83.0	5.8	11.2	0.84	0.10
Zh	1.8	12.6	40.1	0.7	85.3	6.1	8.6	0.86	0.08
K	1.0	4.7	20.8	0.4	89.3	5.0	5.7	0.67	0.05
KS	1.4	5.5	18.7	0.4	88.8	4.6	6.6	0.62	0.06
OS	0.7	15.2	22.6	0.9	90.3	5.2	4.5	0.69	0.04
SS	1.9	6.0	19.5	0.6	87.5	4.5	8.0	0.62	0.07
T	1.6	10.5	9.6	0.3	90.7	3.2	6.1	0.42	0.05
A	0.5	15.0	8.0	0.2	–	–	–	–	–

Note. 1. daf is the dry ash-free state of the sample. 2. Dash means that a parameter was not determined for a given coal grade.

analytical moisture varies from 0.5 to 10.0 %; the yield of volatiles changes from 8.0 to 48.5 %. All the coal samples under investigation are low-sulphur (sulphur content is less than 1.0 %); in the metamorphism series from brown coal to anthracite, carbon content increases from.1 to 90.3 %, while hydrogen content regularly decreases from 5.5 to 3.2 %.

Petrographic analysis of ten samples under investigation was carried out to confirm coal grading. Measurement of the reflectivity of vitrinite ($R_{o,r}$) of coal samples was carried out using the SIAMS 620 integrated measuring equipment to determine the grade composition of coal and coal mixtures (LLC SIAMS, Russia). Results of the petrographic analysis are presented in Table 3.

According to the data of petrographic analysis of coal samples, the values of vitrinite reflectivity $R_{o,r}$, which characterizes the degree of carbonization of coal matter, increases from 0.39 to 2.25 % in the sequence of coal samples under study, which is in agreement with a decrease in the yield of volatiles (V^{daf}) (see Table 2). The content of the sum of fusenized components (ΣFC) increases from 10 to 94 % with an increase in the maturity of coal samples under investigation.

The main petrographic components of the studied coal samples are:

– vitrinite, Vt (from 5 % for A coal grade to 90 % for Zh grade);

– semivitrinite, Sv (from 1 % for Zh grade to 19 % for SS grade);

– inertinite, I (from 9 % for Zh grade to 92 % for T and A grades).

The set of characteristics, namely vitrinite reflectivity, the sum of fusenized components, the thickness of the plastic layer, and the yield of volatiles, allows determining the grades of coal

TABLE 3

Petrographic composition of coal samples of different grades

Parameter	Coal grade									
	B	D	G	Zh	K	KS	OS	SS	T	A
Maceral composition of coal, %:										
vitrinite (Vt)	–	69	76	90	65	38	56	45	6	5
semivitrinite (Sv)	–	6	3	1	11	15	13	19	2	3
inertinite (I)	–	25	21	9	24	47	31	36	92	92
Sum of fusinite components (ΣFC), %	–	29	23	10	32	57	40	49	93	94
Vitrinite reflectivity ($R_{o,r}$), %	0.39	0.60	0.78	0.83	1.37	1.31	1.39	1.25	2.11	2.25

Note. Dash means that a parameter was not determined for a given coal grade.

samples under study according to the unified coal classification over the genetic and technological parameters.

Coal samples were used to prepare coal samples of the following size classes, mm: −0.2 +0.1, −0.1 +0.063, −0.063 +0.04, −0.04.

The procedure of coal powder preparation

Ten samples of fossil coal of different genetic kinds characterized by technological parameters were chosen for tests. Each sample was separated into two parts, and each of them was ground to obtain the necessary size class. For mixing, a sample weighted preliminarily was put into an even smooth surface, excluding fuel contamination. The material was mixed and shaped like a cone by placing each portion on the surface of the previous one. Thorough mixing of the particles of different sizes was achieved in the case if the fuel was dusted down from all sides of the cone and distributed in a random manner. The process was repeated not less than 5 times, spattering from the cone base to its vertex in the anticlockwise direction. The cone was flattened, and point samples were taken in a random order using the access method with the help of a trowel immersing it to the very bottom of the layer. These taken point samples were united into an "initial" sample, which was again placed in the corresponding tight vessel. The average mass of 'initial' samples was 53 g. The rest material was thoroughly mixed once more using the cone method. Then the sample was divided into four parts with the help of a cross-piece, and each part was ground to the particle size, mm: −0.2 +0.1; −0.1 +0.063; −0.063 +0.04; −0.04.

Preparation of the fraction −0.2 +0.1 mm. A portion of the fuel in the initial state was placed onto a sieve with mesh size 0.1 mm and sieved by tapping. The material with a particle size of less than 0.1 mm was rejected. Non-sieved material was placed onto a 0.2 mm sieve and again sieved by tapping. The residue on the sieve was once crushed in a DGShCh 150 × 80 laboratory jaw crusher (Russia) to a particle size of less than 3.0 mm and sieved once more. Then the material with particle size larger than 0.2 mm was additionally crushed in a porcelain mortar until it passed completely through a 0.2 mm sieve.

At the second stage of sample preparation, the obtained −0.2 mm fraction was again sieved through a 0.1 mm mesh by tapping. The material with a particle size of less than 0.1 mm was rejected. Sieving was continued until no visible fuel particles could be seen on a white paper sheet under the sieve with the sample portion. The product obtained on the sieve was the −0.2 +0.1 mm fraction.

Preparation of the fraction −0.1 +0.063 mm. The weighted portion of the fuel in the initial state was placed onto a sieve with mesh size 0.063 mm and carefully sieved by tapping. The material with a particle size of less than 0.063 mm was rejected. Non-sieved material was put on a sieve with mesh size 0.1 mm and again sieved by tapping. The residue of the product in the sieve was twice crushed in a DGShCh 150 × 80 laboratory jaw crusher to particle size less than 3.0 mm and again sieved. Then the material with a particle size of more than 0.1 mm was additionally crushed manually in a porcelain mortar till it could completely pass through a 0.1 mm sieve.

At the second stage of sample preparation, the obtained fraction −0.1 mm was again sieved through a 0.063 mm mesh size by tapping and with the help of a soft brush. The material with a par-

TABLE 4

Main parameters of laboratory sieves, made of square-mesh wire grid, used to prepare the fractions of coal powders

Mesh size, mm	Admissible deviation from the maximal size of one mesh, mm	Regulatory document for grid material, the accuracy of manufacture
0.2	0.106	GOST 6613–86, grid of normal accuracy
0.1	0.034	GOST R 51568–99, grid of normal accuracy
0.063	0.028	GOST 6613–86, grid of high accuracy
0.04	0.021	GOST R 51568–99, grid of normal accuracy

ticle size of less than 0.063 mm was rejected. Sieving proceeded until no visible fuel particles could be seen on a white paper sheet under the sieve with the sample portion. The product obtained on the sieve was the −0.1 +0.063 mm fraction.

Preparation of the fraction −0.063 +0.04 mm. The weighted portion of the fuel in the initial state was crushed in a DGShCh 150 × 80 laboratory jaw crusher to a particle size of less than 3.0 mm, placed in the sieve with 0.063 mm mesh size, and carefully sieved with the help of a soft brush. Non-sieved material was again consecutively ground in the laboratory jaw crushed to a particle size of less than 2.0 mm, and then to less than 1.0 mm. After each crushing stage, the ground sample was placed into the sieve with mesh size 0.063 mm and carefully sieved with the help of a soft brush. Then the material with particles larger than 0.063 mm was additionally ground manually in a porcelain mortar till the material could be completely sieved through the 0.063 mm mesh.

At the second stage of sample preparation, the obtained fraction −0.063 mm was sieved through 0.04 mm mesh with the help of a soft brush. The material with particles smaller than 0.04 mm was rejected. Sieving was continued until no visible fuel particles could be seen on a white paper sheet under the sieve with the sample portion. The product obtained on the sieve was the −0.063 +0.04 mm fraction.

Preparation of the fraction −0.04 mm. The weighted portion of the fuel in the initial state was ground in the laboratory jaw crusher DGShCh 150 × 80 to particle size less than 2.0 mm, placed onto a 0.04 mm mesh sieve, and carefully sieved with a soft brush. Non-sieved material was again ground in the laboratory jaw crusher to particle size less than 1.0 mm, placed on a 0.04 mm mesh sieve, and sieved carefully with the help of a soft brush. Then the material with particles larger than 0.04 mm was stage by stage ground in an IVP-micro vibratory attritor (Russia). Each grinding stage lasted from 1 min to 30 s. After each stage, the material was sieved again. When the mass of the residue on the sieve reached 7–10 g, grinding was continued manually in a porcelain mortar until the material could completely pass through a 0.04 mm sieve.

To separate coal powders on the basis of particle size, round laboratory sieves 200 mm in diameter made of wire grid with square meshes (LLC RNPO RusPribor, Russia) were used. The main parameters of the laboratory sieves and their admissible deviations are listed in Table 4. Particle conglutination was observed during sieving the material with particle size from 0.063 to 0.04 mm through the corresponding sieves.

Methods of coal powder investigation

The images of the powders were taken by means of scanning electron microscopy (SEM) with the help of a JSM-6390LA electron microscope (JEOL, Japan).

The granulometric composition of coal powders was determined by means of laser diffraction using an Analysette 22 MicroTec plus particle size analyzer (Fritsch, Germany). The measuring unit of the analyzer includes two semiconductor lasers: green (λ = 532 nm, 7 mW) and infrared (λ = 850 nm, 9 mW), which allow measurement within the range 0.08–2000 μm. The detector records 108 particle size classes. The dispersing unit contains a liquid in the amount of 300–500 mL, is equipped with a centrifugal pump with adjustable productivity and an ultrasonic radiator with adjustable power (its maximal power is 60 W, its frequency is 40 kHz). The materials used in the sample contour are stainless steel, Teflon, VK7 glass, Viton Extreme, tubes made of Norprene A-60-G. The working liquid in the dispersing unit is tap water purified additionally in a system of cartridge filters. Surfactant PAV-901 – Dusazin 901 (Fritsch,

Germany) is used for making the dispersion medium. Measurement conditions have been described in detail in [2].

High-resolution NMR spectra in solids on ^{13}C nuclei were recorded with the help of an Avance III 300 WB spectrometer (Bruker, Germany) using the standard procedure of cross-polarization with magic angle spinning (CPMAS) with decoupling from protons, at the frequency of 75 mHz. Contact time was 1500 μs, with the accumulation of 4096 scans, delay between the scans was 2 s, the frequency of sample spinning was 5 kHz. To obtain the quantitative data, the spectra were simulated with the help of Dmfit software. The ranges of chemical shifts of ^{13}C NMR signals corresponding to the resonance absorption by the following groups of carbon atoms were distinguished, ppm: 187–171 – carbon atoms of carboxyl groups and their derivatives (COO–); 171–148 – carbon atoms of aromatic systems bound with an oxygen atom ($C_{ar}O$); 148–93 – carbon atoms of aromatic systems with substituted and unsubstituted hydrogen atom ($C_{ar} + CH_{ar}$); 67–51 – carbon atoms of methoxy groups (OCH_3); 51–0 – carbon atoms of alkyl fragments (C_{alk}) [36]. The degree of aromaticity (f_a) was calculated according to equation: $f_a = (C_{ar} + CH_{ar})/(C_{ar} + CH_{ar} + C_{alk})$.

RESULTS AND DISCUSSION

Scanning electron microscopy

Coal samples were studied by means of SEM to establish the characteristic features of the structure formed during coal generation and metamorphism.

SEM is used to measure many characteristics of samples: composition, surface topography, crystallographic orientation, and to observe structural patterns directly. Detailed investigation of the supramolecular organization of fossil coal by means of SEM allows us to describe the dynamics of the structural transformations of coal during metamorphism.

Comparing the images of different types of coal, one may reveal differences in their structures. A 100–200fold magnification is the most informative one to characterize the relief of fissure and sample surface. The fissure is commonly understood as surface type depending on the petrographic composition of coal and its maturity.

The micrographs of coal samples of D, Zh, KS and T grades most significantly differing from each other in the petrographic composition are shown in Fig. 1. Thus, grade Zh is characterized by the highest vitrinite content and the lowest sum of fusinized components, while grade T, quite contrary, – by the high content of fusinized components and low vitrinite content. The D and KS grades occupy an intermediate position with respect to these parameters between Zh and T grades. However, vitrinite content in grade D is more than two times higher than fusinite content, while KS grade is distinguished by the higher content of fusinized components in comparison with vitrinite.

It should be stressed that for the comparative analysis of coal particle morphology, we chose the fraction −0.2 +0.1 mm, which better depicts the features of particle fissure pattern, surface relief and the electrophysical properties of the particle surface; thus this fraction may be considered to be representative. One can see in Fig. 1 that there are qualitative differences between the particles of Zh and T grades. For example, the particles of grade Zh coal with the highest vitrinite content are characterized by sharp even fissure edges, smooth surface, and surface charging effects (overexposed regions in the micrograph).

According to SEM data, changes in coal structure and in fissure surface relief are observed in the metamorphism series of coal samples under investigation, from brown coal to anthracite. For instance, coal samples of B grade are characterized by smoothed edges of fissure surface, and the particles with rounded, oval shapes dominate. The angulated fissure surface and irregular shapes of particles are observed for coal of D grade. Asymmetric particles of plate-like flat shape dominate in the structure of coal of G and Zh grades, which is the distinguishing feature of these grades in particle shapes. Angulated particles with the shape close to isomorphic one are typical for coal of K and KS grades, however, the fissure surface for KS coal grade has sharper edges. In the structure of OS grade coal, we observe asymmetrical particles with splintered edges; elongated planked particles are present in the structures of coal of grades SS and T. The particles of isometric shapes with even edges of fissure surface are characteristic of the coal of A grade.

Microphotographs of different fractions of the coal of OS grade are shown in Fig. 2. The presence of asymmetric particles with sizes exceeding the nominal mesh size of the corresponding sieve is detected. The oval or plate-like shape of asymmetric particles allows them to pass through the sieve mesh. In addition, the admissible deviation of the

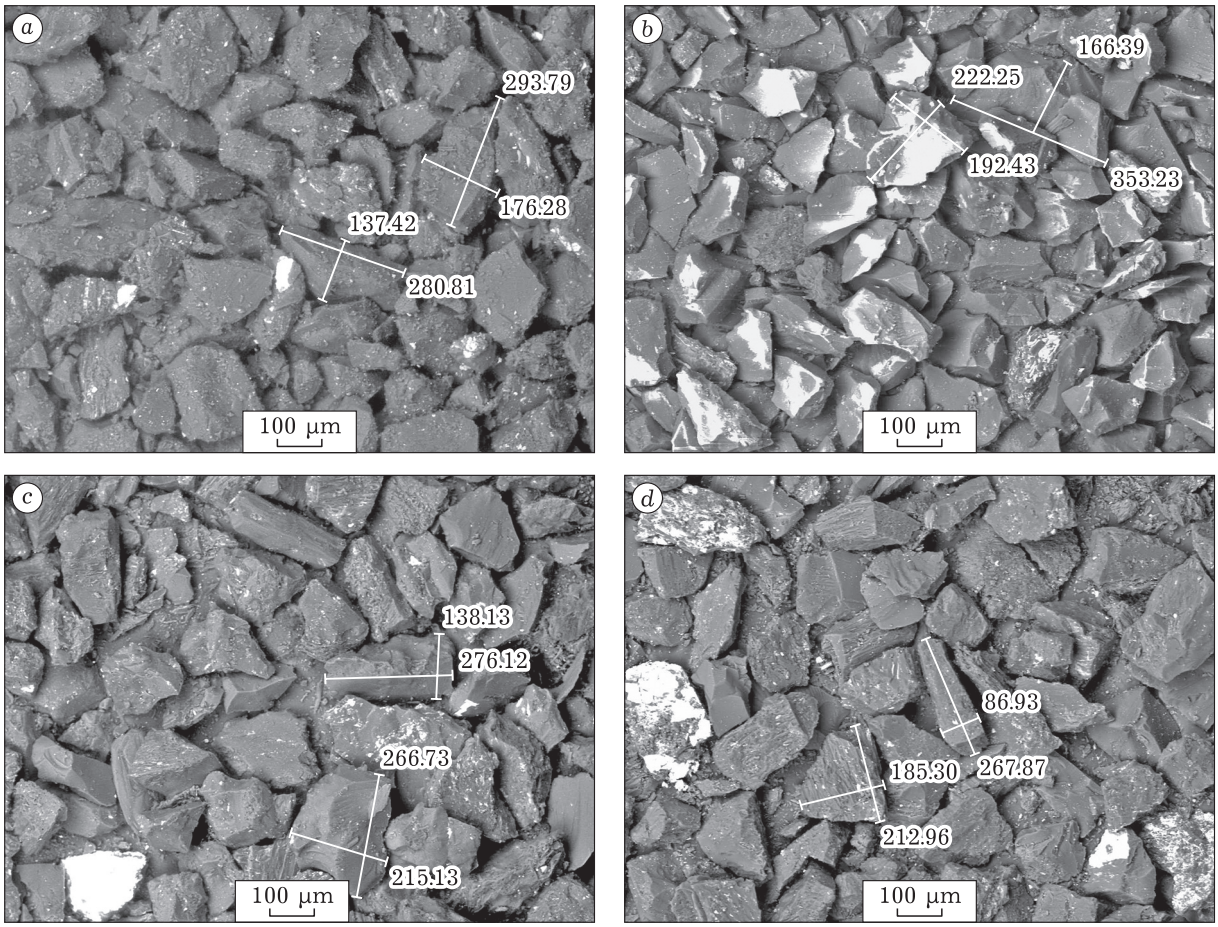

Fig. 1. SEM microphotographs of coal samples of the −0.2 +0.1 mm fraction, coal grades: D (*a*), Zh (*b*), KS (*c*), T (*d*).

maximal size of one mesh (see Table 4) is a substantial value; for instance, it reaches 0.106 mm for a sieve with mesh size 0.2 mm (the percentage of these meshes being not more than 8 %).

Laser diffraction

The granulometric composition of coal samples was determined by means of laser diffraction.

The size distribution of particles in the coal powders of size classes −0.2 +0.1, −0.1 +0.063, −0.063 +0.04, −0.04 mm is presented in Table 5; the histograms of the particle size distribution for OS grade coal are shown in Fig. 3.

It follows from the obtained results that the particle size distribution in coal powders of the −0.04 mm fraction is characterized as monomodal for all coal grades. In this situation, 90 % of the particles are 16.37 to 23.90 μm in size. The size distribution of the particles in coal powders of the fraction −0.063 +0.04 mm for all grades is characterized as monomodal asymmetric. At the same time, these samples contain particles with sizes exceeding the mesh size of a corresponding sieve: from 75.37 μm (for coal of grade D) to 101.16 μm (for coal of grade G). The particle size distribution in coal powders of −0.1 +0.063 and −0.2 +0.1 mm fractions is characterized as bimodal. These fractions also contain the particles with the size exceeding the mesh size of a corresponding sieve: for the −0.1 +0.063 mm fraction − from 124.42 μm (for coal of grade Zh) to 173.76 μm (for coal of grade B); for the −0.2 +0.1 mm fraction − from 224.77 μm (for coal of grade A) to 308.68 μm (for coal of grade Zh).

^{13}C NMR spectroscopy

Due to the application of ^{13}C NMR spectroscopy, as a quantitative method of analysis, it is possible not only to identify the signals from separate carbon nuclei depending on their environment but also to provide a strict evaluation of their absolute or relative content [37]. This allows one to reveal the features of chemical structure with high selectivity, and to determine the quantitative ratios of fragments in the multicomponent systems of natural and synthetic origin.

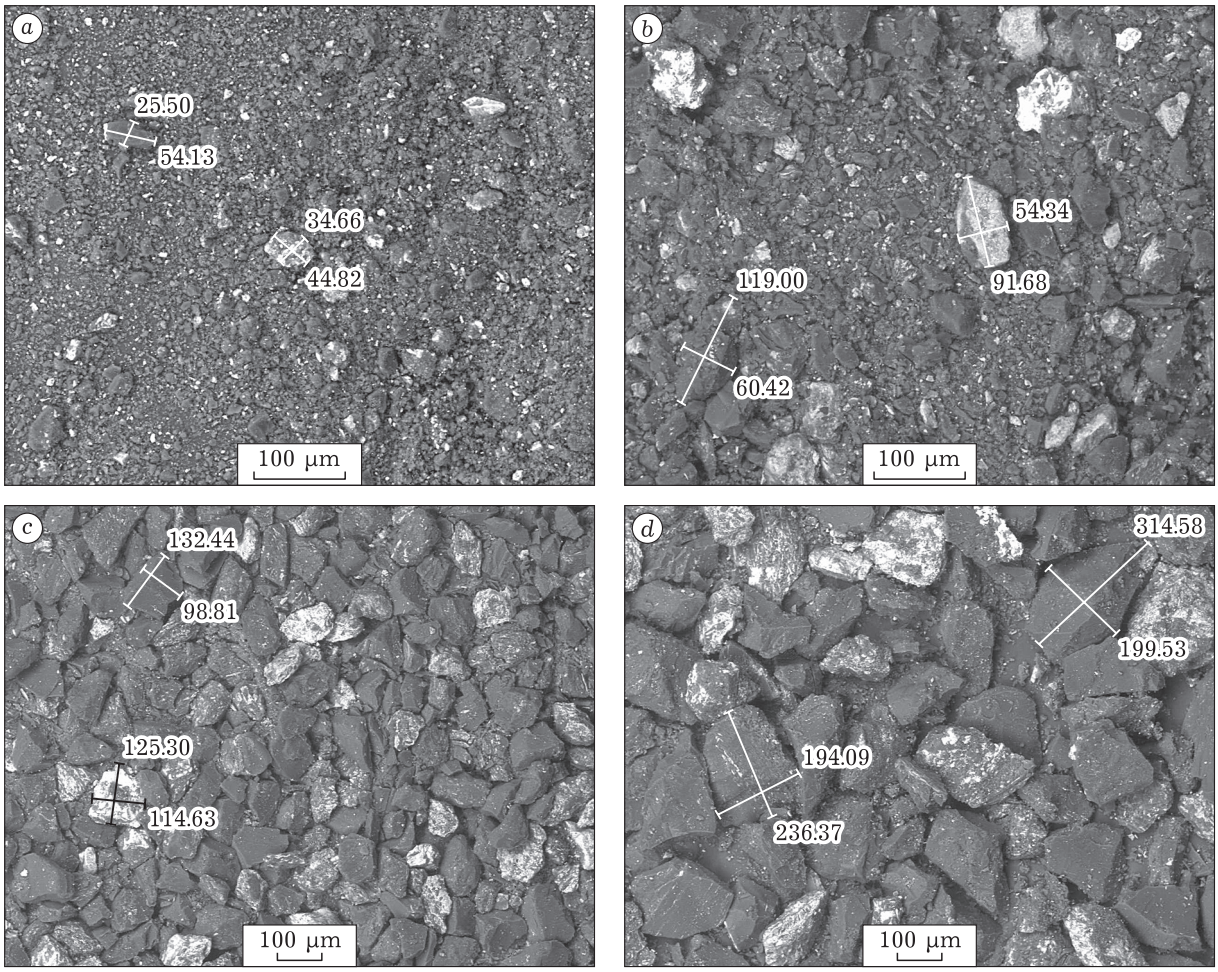

Fig. 2. SEM microphotographs of the samples of OS coal grade, fractions, mm: −0.04 (*a*); −0.063 +0.04 (*b*); −0.1 +0.063 (*c*); −0.2 +0.1 (*d*).

One can see in Table 6, showing the results of the studies of KS grade coal by means of NMR spectroscopy, that the content of aliphatic carbon (CH_3−) in the samples increases insignificantly with a decrease in the size fraction of coal powder − from 3.05 % for the −0.2 +0.1 mm fraction to 3.73 % for the −0.04 mm fraction. Also, a slight increase in the amount of oxygenated functional groups is observed, which is explained by an increase in the surface area of smaller particles and their oxidation with oxygen. Aromaticity factor f_a remains constant for all fractions.

CONCLUSION

Integrated studies of the granulometric and morphological composition of the fine coal powders prepared using a special procedure of separation into particle size classes −0.2 +0.1, −0.1 +0.063, −0.063 +0.04, −0.04 mm from ten different coal grades (B, D, G, Zh, K, KS, OS, SS, T, A) of the Kuznetsk coal basin were carried out.

The particle size distribution in coal powders of the −0.04 mm fraction for all coal grades is characterized as monomodal; for the −0.063 +0.04 mm fraction it is monomodal asymmetric; for the −0.1 +0.063 and −0.2 +0.1 mm fractions it is bimodal. It is demonstrated by means of SEM that the particles of irregular shapes (needle-like, oval) are present in these fractions.

Results of the investigation of KS grade coal by means of ^{13}C NMR spectroscopy show that the content of aliphatic carbon (CH_3−) increases only slightly with a decrease in particle size in coal powder fractions, and aromaticity factor f_a remains constant for all fractions.

The data obtained in the investigation allow us to suppose that the applied procedure of the preparation of coal powder fractions does not have an essential effect on the chemistry of the surface of carbon material. Investigation of the

TABLE 5

Particle size distribution in coal powders of different size classes

Coal grade	Fraction size, mm	Particle size, μm*		
		Fraction content, %		
		0–10	0–50	0–90
B	−0.04	3.05	10.68	22.99
	−0.063 +0.04	7.87	47.73	93.89
	−0.1 +0.063	18.54	106.88	173.76
	−0.2 +0.1	6.21	144.74	266.64
D	−0.04	3.09	10.91	23.78
	−0.063 +0.04	9.06	41.03	75.37
	−0.1 +0.063	8.45	88.57	152.23
	−0.2 +0.1	4.82	60.77	249.15
G	−0.04	1.45	9.00	23.29
	−0.063 +0.04	9.50	58.25	101.16
	−0.1 +0.063	8.38	96.41	165.81
	−0.2 +0.1	4.64	185.90	305.10
Zh	−0.04	2.21	8.60	18.90
	−0.063 +0.04	8.99	38.53	83.47
	−0.1 +0.063	8.82	72.48	124.42
	−0.2 +0.1	9.88	149.32	308.68
K	−0.04	2.98	11.64	23.90
	−0.063 +0.04	16.69	61.65	90.21
	−0.1 +0.063	14.61	87.64	152.80
	−0.2 +0.1	12.18	138.81	248.77
KS	−0.04	2.41	8.91	19.56
	−0.063 +0.04	8.47	44.23	95.08
	−0.1 +0.063	9.76	83.04	147.20
	−0.2 +0.1	6.85	142.91	265.53
OS	−0.04	1.74	7.16	16.37
	−0.063 +0.04	4.73	27.52	76.25
	−0.1 +0.063	10.67	88.43	150.59
	−0.2 +0.1	6.50	126.23	231.82
SS	−0.04	2.38	8.83	19.60
	−0.063 +0.04	13.23	52.04	97.03
	−0.1 +0.063	7.75	82.42	144.93
	−0.2 +0.1	7.91	145.83	268.55
T	−0.04	3.22	10.83	22.91
	−0.063 +0.04	15.16	60.49	92.74
	−0.1 +0.063	8.31	88.52	144.33
	−0.2 +0.1	7.34	149.02	244.94
A	−0.04	2.95	10.54	23.25
	−0.063 +0.04	11.86	50.61	91.22
	−0.1 +0.063	8.49	78.53	135.26
	−0.2 +0.1	4.89	116.15	224.77

* The maximal size of particles within the indicated range of fraction content is given.

granulometric and morphological composition of coal particles is one of the stages of the integrated studies for subsequent methodical substantiation of the choice of coal particle sizes for the extraction of polycyclic aromatic hydrocarbons from coal.

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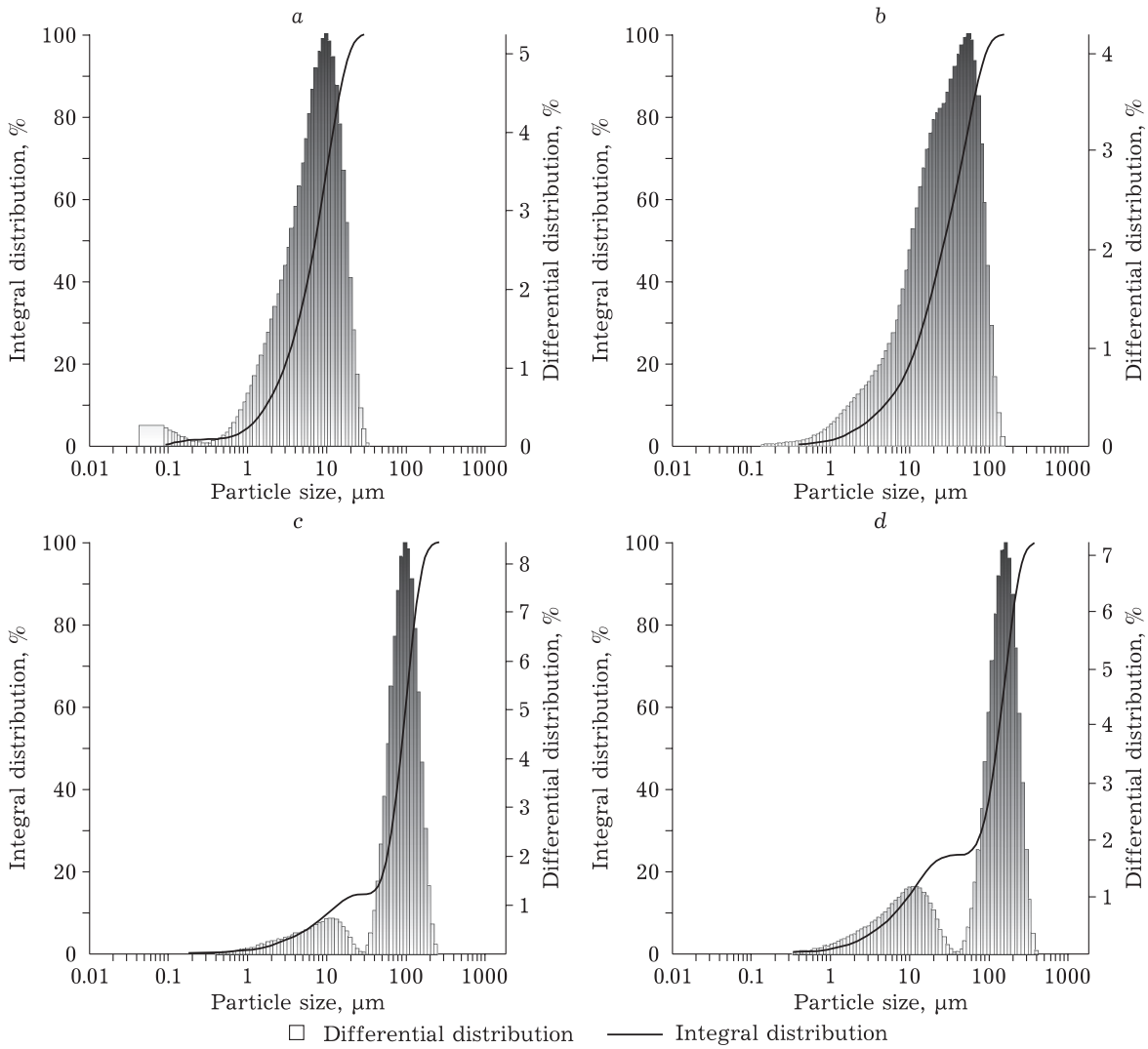

Fig. 3. Histograms of the size distribution of coal particles of OS grade, fractions, mm: −0.04 (*a*); −0.063 +0.04 (*b*); −0.1 +0.063 (*c*); −0.2 +0.1 (*d*).

TABLE 6

Carbon distribution over structural fragments in different granulometric fractions of KS grade coal according to the data of ^{13}C NMR spectroscopy

Structural fragment	The region of absorption maximum, ppm	Fragment content, rel. %			
		Fraction, mm			
		−0.04	−0.063 +0.04	−0.1 +0.063	−0.2 +0.1
CH_3−	0−25	3.73	3.61	3.36	3.05
CH_2=	25−51	11.59	11.90	11.45	11.77
CH_3−O−	51−67	0.31	0.36	0.29	0.20
C−O−C	67−93	0.61	0.73	0.69	0.54
C_{ar}−H	93−125	61.32	63.40	64.02	62.83
C_{ar}−C	125−148	17.49	16.22	16.36	17.29
C_{ar}−O	148−171	3.95	2.90	2.95	3.41
COOH	171−187	1.00	0.86	0.89	0.90
C=O	187−235	–	–	–	–
f_a		0.83	0.83	0.83	0.84

Note. Dash means that structural fragments containing carbon were not detected.

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