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OPTICAL CONSTANTS OF THE SUBSTANCE COMPOSING THE PARTICLES OF CONVERTER DUST

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Using the Shimon method, the optical constants of dust particles from an OKG-100-3B boiler are determined.

Theoretical methods of calculating the attenuation factors of the fluxes of dust particles in power-generating-technological apparatuses require data on the optical constants of the substance of the dust particles, i.e., on the refraction index n and the absorption index κ.

The scientific and reference literature contains results of investigations of the optical constants of pure chemical compounds and the ash of power-generating fuels [1-4]. But the literature lacks data on the optical constants for the chemical composition of dust from apparatuses of converter processes.

The present work reports results of an investigation of the optical constants of the substance of dust particles taken from the heating surfaces of the convective part of an OKG-100-3B converter-process waste-heat boiler. The chemical composition of the substance of the dust particles investigated was the following (wt.%): Fe_2O_3 73.2; CaO 8.5; FeO 7.2; SiO_2 2.3; ZnO 1.5; MnO 0.9.

To determine the optical constants, use is made of the Shimon method [5, 6], based on measurement of the coefficients of specular reflection of polarized radiation at angles of incidence of the beam on the surface of the sample investigated $\varphi = 20$ and 70°. A state of polarization in which the electric vector oscillates parallel to the plane of incidence of the beam is used. To implement the chosen method of measurement the optical scheme of a Specord M80 spectrophotometer was adopted [7]. Frequency-modulated (12.5 Hz) infrared flux is passed through a polarizer and then is directed alternately by a rocking mirror to the measurement and comparison channels of the cuvette chamber.

In conducting experiments, first a standard aluminum-coated mirror and then the investigated sample with an optically smooth surface is positioned in the measurement channel. The reflected beam from the cuvette chamber enters a monochromator, in which it is directed by a system of plane and spherical mirrors through an optical inlet slit onto a diffraction grating and is then brought out through light filters onto a vacuum thermoelement with a lens made of cesium iodide.

The signal from the thermoelement is recorded by a digital storage. The coefficient of reflection of the sample investigated is determined by the formula

$$R = R_{st} (I/I_{st}) ,$$

where R_{st} is the coefficient of reflection of the standard aluminum coating, equal to 97%.

The values of the reflection coefficients are brought out onto a digital printer with a step $\Delta R = 4$ cm^{-1}.

The samples were tablets of diameter 15 mm or dimensions 15 × 15 mm and thickness from 2 to 3 mm that were pressed by the method of [8]. The difference between the roughness parameters of the reflecting surfaces of the standard aluminum-coated mirror and the samples investigated did not exceed 0.5%.

The technique by which the samples were prepared dictated the choice of the method for determining the optical constants.

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TABLE 1. Reflection Coefficients R (%) and Indices of Refraction n and Absorption κ of the Substance of Dust Particles from the Convection Part of an OKG-100-3B Waste-Heat Boiler

Wavelength, μm	Reflection at angles φ		n	κ
	20°	70°		
2.50	9.81	21.00	0.940	0.789
2.56	7.81	18.89	0.968	0.618
2.63	9.58	17.87	1.032	0.740
2.70	8.68	18.22	1.009	0.673
2.78	8.38	18.52	0.997	0.669
2.86	8.59	17.34	1.027	0.678
2.94	6.42	17.60	0.998	0.583
3.03	7.15	18.05	0.991	0.605
3.13	6.40	17.14	0.998	0.585
3.23	6.89	16.88	1.026	0.590
3.33	7.09	18.33	0.953	0.535
3.45	6.53	16.08	1.026	0.590
3.57	7.46	15.53	1.060	0.605
3.70	5.97	17.00	0.990	0.558
3.85	6.45	13.95	1.106	0.602
4.00	6.51	13.57	1.124	0.603
4.17	5.22	14.60	1.058	0.521
4.35	5.08	13.30	1.091	0.524
4.55	6.76	20.42	0.923	0.559
4.76	6.81	18.53	0.953	0.535
5.00	6.59	16.85	1.026	0.590
5.26	6.42	17.35	0.998	0.583
5.56	4.96	17.18	0.975	0.506
5.88	6.50	17.40	1.027	0.678
6.25	8.54	14.18	1.148	0.699
6.67	6.20	15.19	1.063	0.573
7.14	6.33	11.02	1.227	0.599
7.70	3.95	9.74	1.215	0.449
8.33	4.23	7.82	1.289	0.422
9.09	4.00	7.61	1.268	0.391
10.00	4.30	8.65	1.284	0.462
11.11	4.33	10.30	1.212	0.483

In the Kravets method, which can also be used, the reflection coefficient is measured for normal beam incidence: once from the sample surface in air; a second time in a specially selected immersion liquid. The basic requirement of the method consists in the presence of optical contact between the surface of the sample and a liquid that is neutral with respect to the sample and transparent over the entire range of wavelengths in the measurements. But since the pressed samples are hygroscopic, it was impossible to apply the Kravets method.

The determination of the indices of refraction n and absorption κ from the measured reflection coefficients R for the two angles φ was carried out using the Fresnel formulas [5, 6].

As already noted, a state of polarization of the incident radiation in which the electric vector oscillates parallel to the plane of incidence is used, and the problem of determining the optical constants is reduced to the use of two equations.

For convenience in working with the Fresnel formulas, the values of the indices of refraction n and absorption κ are calculated on a computer for reflection coefficients changing with a step $\Delta R = 0.005\%$. Tabulation of values with this step ΔR made it possible to increase the accuracy of the determination of n and κ.

The obtained experimental values of the coefficients of reflection of the samples at angles of incidence of the beam $\varphi = 20$ and 70° and the corresponding values of the indices of refraction n and absorption k as functions of the wavelength are given in Table 1.

It is evident from an analysis of the data in the table that within the spectral range 2–15 μm the substance investigated belongs to an intermediate class: between metals, for which the absorption index $k > 10$, and semiconductors, for which $0.01 < \kappa < 0.1$.

A comparison of the results obtained with data of [1-3] shows that the dispersion of the optical constants depends strongly on the proportion of the content of the basic chemical components entering into the composition of the substance of the dust particles. Furthermore, the dispersion is associated with the microstructure of the substance of the particles. In [3], the values of the optical constants for crystalline and amorphous hematite differ rather markedly.

NOTATION

n, refraction index; κ, absorption index; R, R_{st}, coefficients of reflection of the sample and the standard; φ, angle between the normal to the sample surface and the beam direction; I, I_{st}, intensities of the reflected radiation from the sample and the standard.

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