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Abstract

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THE ROLE OF THE GASEOUS MEDIUM IN THE PROCESSES OF COAL DESTRUCTION

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The question of the influence of the gaseous medium in which the coal of most coal seams is found on its strength properties is of great practical interest. This consideration led to the undertaking of work to determine the role of the gaseous medium in the processes of coal destruction. The method adopted in the work was described in a previous communication ([1]). In the present work we studied the relationship between the effect of the action of the gaseous medium on the strength of fossil coals and the natural disturbance of their structure, the degree of their metamorphism, and also the effect of the action of various gases.

The strength properties of solids are appreciably affected by various defects concentrated at the weak points of solids. These defects may have the most diverse dimensions—from defects in the crystal lattice to visible cleavages or cracks. Of special importance for such a highly porous body as coal are surface defects, since coal in a seam is in a gas medium capable of being well adsorbed on its surface.

As shown by the work of P. A. Rebinder and co-workers ([2,3]), adsorbed molecules penetrate, by two-dimensional migration, into the interior of a solid along places of weakened bonds, along fine, not fully developed cleavages. As a result of the lowering of the surface tension, the adsorbed molecules facilitate the development of new surface defects—microcleavages—and hinder their reverse closing. These concepts, developed for the solid-liquid system, may be extended to the coal-gas system. In the process of deformation of coal, new separation surfaces are formed, penetrating the coal in the form of wedge-shaped cracks. Under conditions of a medium of a well-adsorbing gas, the newly arisen surfaces become covered with adsorption layers. The penetration of such layers is limited by a steric factor in those cases where the width of the cracks is smaller than the dimensions of the adsorbed molecules.

The defects that participate in lowering the strength of fossil coals in a seam as a result of the presence of gas adsorption processes are natural microcracks. The primary conditions of formation of coal seams and the subsequent tectonic processes lead to the formation in the seams of individual bands with a high degree of structural disturbance ([1,4]). As the degree of disturbance of coals

Fig. 1. Relationship between the crushability of coal in the systems coal—air and coal—CO_2

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increases, the network of microcracks increases and the average distance between them decreases.

We investigated the friability of coal for a group of coals (more than 100 samples) of five types of structural disturbance. The friability of coal was determined in air, CO_2, and CH_4 at a pressure of 40 atm. For carbon dioxide, as for methane, the presence of physical adsorption is characteristic. In the air medium the coal samples were tested after they had been degassed of methane following extraction from the seam.

In Fig. 1 the abscissa gives the amount of dust formed during the crushing of coal in an air medium (as a percentage of the sample taken).

of coal), and along the ordinate axis—the amount of dust formed when coal is crushed in a CO_2 medium.

In the absence of an effect of carbon dioxide on coal, the amount of dust in both experiments should be the same; i.e., the points corresponding to individual samples should lie, with a certain scatter, around straight line I. However, the points lie above this straight line, and, as the dust yield in the air medium increases, they move farther away from it. The physical meaning of this phenomenon is that strong coals with a low degree of fracturing do not possess those hidden defects (microcracks) along which the gaseous medium could act so as to reduce their strength. Coals with a high degree of fracturing, which are easily pulverized even without the action of a gaseous medium, are characterized by a large number of microcracks through which gas from the external medium penetrates. As a result of such penetration, the strength of weak coals is reduced still further, sometimes by a factor of two in comparison with the strength of coal in air.

Fig. 1. Relationship between the crushability of coal in the systems coal—air and coal—CO_2

The experimental points showing the relationship between the dust yields in the air medium (Q_a) and in the carbon dioxide medium (Q_{CO2}) are located near straight line II. By the method of least squares one can find the value of the coefficient k in the equation of this straight line

$$Q_{CO2} = kQ_a \tag{1}$$

This gives $k = 1.34$.

Fig. 2. Relationship between the natural fracturing of coal and its crushability in the coal–CO_2 system

Figure 2: Fig. 2. Relationship between the natural fracturing of coal and its crushability in the coal–CO_2 system

In Fig. 2, in semilogarithmic coordinates, the average distance between cracks (as an index of coal fracturing) and the dust yield in a CO_2 atmosphere are plotted. The relationship between coal fracturing and dust yield is quite evident here.

As a result of the decrease in free surface energy during gas adsorption, the gas penetrates into incipient microcracks of tectonic and endogenic origin and produces additional deformation there through the wedging action of the adsorption layers. Therefore, during mechanical action on coal occurring in a gaseous medium, in addition to the large planes along which the destruction of coal takes place, microcracks also participate. In cases where such pre-fracturing is absent in the coal, the gas itself is incapable of causing the appearance of new fracture surfaces.

Fig. 2. Relationship between the natural fracturing of coal and its crushability in the coal–CO_2 system

coal–gas system and thereby facilitate the destruction of coal along new planes. In analogous experiments carried out in the coal–methane system, the same effect was observed as in the coal–CO_2 system, but to a lesser degree. The average increase in dust yield in a methane medium, as compared with air, was 1.25.

In a coal seam, where under natural conditions the coal is saturated with gas, the influence of the gaseous medium on the strength properties of coal manifests itself as follows: the described cases of coal softening when the working face becomes gassy are reduced not to softening of the coal, but to the fact that it does not harden. At the edge of the coal seam a very thin film is formed, consisting almost of 100% methane. With active ventilation this film is continually, as it were, stripped away. Gas emission from the layers of coal nearest the face is thereby noticeably intensified, while the rate of gas diffusion from the depth of the coal seam toward the edge of the face lags behind the rate of gas emission into the working. The gas pressure in the near-face zone of the seam then falls somewhat, the wedging action of the gas adsorbed in the microcracks decreases, and the miner subjectively senses the effect of coal hardening. When ventilation is switched off, however, its stripping action ceases, and the coal stops hardening.

Fig. 3. Influence of the degree of metamorphism on the crushability of disturbed coals (types IV and V of disturbance) in a CO_2 medium

Of interest is the question of whether, in a laboratory test, closure of microcracks

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Fig. 4

Figure 4: Fig. 4

can be achieved under all-sided compression of coal. The elimination of microcracks should reduce the effect of the gaseous medium. The experiments were carried out in a high-pressure apparatus; the coal was placed in an oil medium. To prevent the oil from penetrating into the coal, the specimens were wrapped in layers of thin rubber. All-sided compression of the specimens was carried out at pressures of 1000, 2000, 3000, and 4000 kg/cm^2. However, no differences in the action of the gaseous medium on compressed and uncompressed specimens were noted. The difference in the results of their crushing lies within the limits of the usual scatter of the data. Evidently, the adsorbed gas layers remaining in the microcracks do not allow them to close under all-sided compression.

Within the limits of a single petrographic type, the least strong coals are those of an intermediate degree of metamorphism (K and PS). Younger and more mature coals possess greater resistance to mechanical action ([5]).

In order to trace the relationship between the effect of the gaseous medium on the strength properties of coals and their degree of metamorphism, coals of the same degree of disturbance but with different yields of volatile matter were compared.

In Fig. 3 (coals of types IV and V of disturbance), the greatest dust yield was observed for coals of an intermediate degree of metamorphism, which agrees with the results of other authors. The natural disturbance of fossil coals is the principal factor in the softening action of gas on coal. The degree of metamorphism, at the same degree of disturbance, affects ⋯

strength properties of coals equally in the coal—air system and in the coal—well-adsorbed gas system.

Adsorption layers spread over the surface of a solid by two-dimensional migration of surface-active molecules. When a gas approaches the mouths of microcracks, the molecules most strongly adsorbed on the coal surface will outstrip all other molecules and provide the greatest effect of the gaseous medium. In such a case, the gas that is best sorbed should have the greatest effect. If the adsorption effect were absent, then the greatest effect would be exerted by the gas with the smallest molecular size.

Fig. 4. Decrease in the strength of hard coals when saturated with various gases. Experiments: *a* —with carbon dioxide, *b* —with methane, *v* —with hydrogen.

Fig. 4 shows the result of the lowering of the strength properties of fossil coals under the action of different gases. Carbon dioxide had the greatest effect, followed by methane, while hydrogen had practically no effect, although the effective diameter of the molecules is $H_2 = 2.74$ Å, $CH_4 = 4.14$ Å, and $CO_2 = 4.59$ Å. The sorption capacity of coal with respect to these gases decreases in the series CO_2—CH_4—H_2. This confirms that the picture obtained of the sorption action of gases on the strength properties of coals is correct.

In conclusion, we consider it our pleasant duty to express gratitude to L. E. Shterenberg for assistance in selecting coal samples and classifying them, and to V. S. Voblikov for assistance in carrying out the experiments on the triaxial compression of coals.

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Note: Figure translations are in progress. See original paper for figures.