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ASSESSMENT OF FORECAST ACCURACY DANGEROUS PROPERTIES OF COAL LAYERS BY THE DEGREE OF METAMORPHISM OF SOLID FOSSIL COALS

Antoshchenko Mykola
Volodymyr Dahl East Ukrainian National University,
Doctor of Engineering Sciences, Professor,
Head of the department of Mining, Ukraine

Rudniev Yevhen
Volodymyr Dahl East Ukrainian National University,
PhD, Associate Professor, Head of the Department
of Electrical Engineering, Ukraine

Filatiev Mykhailo
Volodymyr Dahl East Ukrainian National University,
Doctor of Engineering Sciences, Associate Professor Department of
Town Planning, Municipal Facilities and Materials Science, Ukraine

Filatieva Elvira
Volodymyr Dahl East Ukrainian National University, Senior
Lecturer Department of Chemical Engineering and Ecology, Ukraine

Brozhko Rostyslav
Volodymyr Dahl East Ukrainian National University,
PhD, Associate Professor, Associate Professor of the Department
of Electrical Engineering, Ukraine

Abstract

In the normative base of Ukraine for the safe mining of coal seams, only five indicators of the degree of metamorphism are used to predict the manifestation of their hazardous properties during mining operations: mass release of volatile substances during thermal decomposition of coal without air (V^{daf}) access to characterize coal; volumetric yield of volatile substances V_V^{daf} to establish the distinctive properties of anthracites; logarithm of electrical resistivity ($\lg\rho$); the thickness of the plastic layer (y) and the grade of coal (M) for predicting the outburst hazard of seams. When developing regulatory documents, it was assumed that these criteria for assessing the degree of coal metamorphism remain constant within one mine field. Their values, as mining operations show, are influenced by the location of the coal sampling site in relation to the distance from relatively large geological

disturbances or the boundaries of the gas weathering zone.

In most cases, the boundaries of mine fields are usually relatively large geological faults. The proximity of the locations of coal sampling points to them influences the obtained results of evaluating the properties of mine layers.

Adjusting indicators (V^{daf}, V_V^{daf} , lgρ, y ,M) for individual mines on the possible impact of geological disturbances, the depth of the mining robot and the distance from the zone of gas weathering, according to the requirements of regulatory documents. For this reason, it is of scientific and practical interest to establish the possible ranges of change in the indicators of the degree of metamorphism of coal within the same mine layer. The results of research in this direction are relevant, as they are necessary to improve the regulatory framework for the safe mining of coal mines.

A possible change within a separate mine field was considered using the example of the indicator V^{daf} as the most studied at present. According to a specially developed methodology, the analysis involved data on 2193 mines from different coal basins. Most of them belong to the mines of the Donetsk basin (1773). The rest of the basins account for information on 460 mine layers, including data on 46 mine layers for the Lvov-Volyn basin.

Introduction

It has been established that within the boundaries of a separate mine formation, V^{daf} remains relatively constant. Along with this, it was found that, in addition to the location of the coal sampling site, the accuracy of determining the indicator is significantly affected by the absolute value V^{daf}. Absolute standard deviation (σ_i) from the averaging straight line in separate intervals the values were 2.29-5.33%, and the relative ($\Delta\sigma$) - were in the range of 8.50-213.01%. Maximum values $\Delta\sigma$ (more than 20%) corresponds to the values In the regulatory documents, the degree of coal metamorphism is assessed, including for the range of variation V^{daf} within 2-8%, which can lead to even greater relative deviations $\Delta\sigma$ (more than 100%) and errors in predicting the hazardous properties of mine layers. Such an accuracy of V^{daf} determination V^{daf} and other indicators of thermal destruction of coal casts doubt on their use for predicting the hazardous properties of mine layers.

In essence, thermal decomposition is another artificial stage in the transformation of coals outside the Earth's interior at a higher temperature than the process of metamorphism. It does not directly reflect changes in the chemical composition, internal structure and properties of coals that have occurred in the past geological periods

of time.

To improve the regulatory documents on the safe conduct of mining operations to characterize the degree of coal metamorphism when predicting the hazardous properties of mine layers, it is necessary to use classification indicators that directly reflect the change in the composition and properties of coals in the process of geological transformations.

Main Body. During mining, in many cases, accidents occur, accompanied by the processes of gas release, gas-dynamic phenomena, spontaneous combustion of coal, increased dust formation with its tendency to explosiveness. These and some other dangerous phenomena accompanying accidents with serious consequences in mines, according to many scientists [1-5], due to the genetic properties of fossil coals. They appeared as a result of metamorphic processes of transformation of the original organic matter under the influence of increased temperature and pressure within the Earth in the past geological periods of time. In the generally recognized case, metamorphism means a variety of endogenous processes, which are associated with changes in the structure, mineral and chemical composition of coals [6].

The degree of metamorphic transformations in accordance with the requirements of the modern regulatory framework of Ukraine for the safe conduct of mining operations [7-10] is predicted, in most cases, by one indicator - a massive release volatiles during thermal decomposition of coal without air access (V^{daf}).

When developing regulatory documents, it was assumed that the indicator and some other criteria for assessing the degree of coal metamorphism are relatively constant within the same mine field. The accuracy of the prediction of the manifestation of hazardous properties of each mine layer largely depends on the reliability of the assumption. In most cases, the boundaries of mine fields are usually relatively large geological faults [11]. The proximity of coal sampling sites to them undoubtedly affects the results obtained for assessing the properties of mine layers. For example, the degassing effect of the Karlovsky and Sofievsky discharges spread over a distance of up to 680 m [12]. In close proximity to geological disturbances, the coal gas content did not exceed 10 $м^3$/tons of ash-free rock, and outside the zone of their influence, it stabilized at the

level of 30 м^3/tons of ash-free rock. The gas content of the anthracite layer also changed depending on the distance to the upper boundary of the methane zone. The methane content of coal-bearing deposits is mainly determined by the depth of the seams, the degree of coal metamorphism, the presence of cover deposits and other factors [13].

The information provided indicates a possible change in gas content depending on the location of coal sampling at different values of depth and distance to a geological fault or a zone of gas weathering. In turn, in the regulatory documents [7-10] empirical dependences of gas content and other hazardous properties of the manifestation of mine layers during mining operations on the degree of coal metamorphism are used without taking into account the influence of this factor. In almost all cases, predicting the manifestation of hazardous properties and the likelihood of emergencies is established [7-10] in relation to a separate mine layer. An individual assessment of the manifestation of the hazardous properties of each mine layer is made, in general, using five indicators of the degree of coal metamorphism. In addition to the indicator V^{daf} in some cases, in addition to characterizing the properties of anthracites, the volumetric yield of volatile substances is use (V_V^{daf}) and logarithm electrical resistivity (lgρ). In other cases, to establish the hazardous properties of mine layers, sometimes the thickness of the plasticity layer is also considered (y) and coal brands (M). They are not corrected for the possible influence of geological disturbances, the depth of mining operations and the distance from the gas weathering zone. For this reason, it is of scientific and practical interest to establish the possible boundaries of the ranges of variation of the indicators of the degree of metamorphism of coal within the same mine formation. In a number of cases, it is also necessary to substantiate the possibility of using indicators of the degree of coal metamorphism without adjusting them to establish the manifestation of the hazardous properties of mine layers in different coal basins. The research results in this direction are necessary to improve the requirements of the regulatory framework for the safe mining of coal mines, which indicates their relevance.

The idea is to use experimental data on the quantitative value of one of the main indicators of the degree of coal metamorphism,

determined by different researchers for a specific mine formation at different periods of time of its development. This allows you to analyze randomly generated databases on the current ranges of change in the classification indicator in the aggregate of the considered layers of the mine.

The goal is to establish possible absolute and relative individual errors in determining one of the main indicators of the degree of metamorphism V^{daf} within the boundaries of a separate mine formation at a random place of coal sampling.

Methodology. One of the main and most studied indicator of the degree of coal metamorphism is the release of volatile substances (V^{daf}). To predict the manifestation of hazardous properties of mine layers during mining, this indicator is used in all regulatory documents [7-10]. Sufficiently voluminous information about the values of the indicator V^{daf} contained in the "Catalog of mine plastics of the USSR on the dust factor" [10]. It provides data for 2,193 mines from different coal basins. The bulk of the data relates to the mines of the Donetsk basin (1773). The rest of the basins account for information on 460 mine layers, including data on 46 mine layers for the Lvov-Volyn basin. In parallel with the data [10], the analysis involved information on the release of volatile substances for 206 mines according to other sources [1-4, 14, 15].

To exclude possible errors in establishing the correspondence between the considered mine layers according to different sources of information, their belonging was checked by the name of the mines (mine departments), the local name of the layers and their geological symbols.

Results of statistical studies. Processing of data pairs of weight yield of volatile substances V_1^{daf} и V_2^{daf}, borrowed, respectively, from the "Catalog of Mine Plastics of the USSR on the Dust Factor" [10] and others [1-4, 14, 15] sources have shown a close correlation between them (fig. 1). The correlation coefficient (r) for the considered sample of 206 data pairs was quite high $(0{,}935)$.

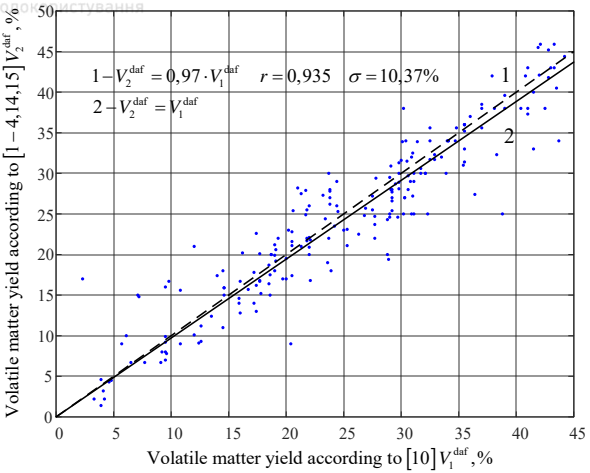

Fig. 1. Correspondence of the yield of volatile substances during thermal decomposition of coals of different coal deposits between data $\left(V_1^{daf}\right)$, catalog [10] and given in others [1–4, 14, 15] sources $\left(V_2^{daf}\right)$

1 - straight line obtained from processing results experimental data by the least squares method; *2* - bisector of the coordinate grid;

• - points defining the relationship between V_1^{daf} and V_2^{1daf};

r, *σ* - respectively the correlation coefficient and standard deviation

This indicates that within the boundaries of an individual mine formation, the value of the mass yield of volatiles during the thermal decomposition of coal remains relatively constant. Ideally, the experimental points of interdependence of the function $V_2^{daf} = f\left(V_1^{daf}\right)$ must be located on a segment of the bisector line (2) of the coordinate grid.

The resulting averaging regression line (1) slightly differs from the bisector (2). On the other hand, experimental data from different sources in a significant part of cases deviates significantly from the considered straight lines (1,2). One of the reasons for this situation may be coal sampling in different parts of the mine field and at different distances from the zones of influence of geological disturbances and gas weathering. In addition to the place of sampling of coal in the mine field for significant deviations σ=10.37%

experimental data from averaging straight lines (1, 2) could provide the accuracy of determining the yield of volatiles during thermal decomposition of coal without air access. To assess the influence of this factor, the absolute standard deviations were considered $(\bar{\sigma}_i)$ in separate ranges V^{daf} (tab. 1).

Table 1

Information about the values of standard deviations (RMS) $(\bar{\sigma}_i)$ from the averaging straight line 1 (Fig. 1) in separate ranges of variation V_i^{daf}

Ranges of change V_i^{daf}, %	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45
Average value in the range V_i^{daf}, %	2,5	7,5	12,5	17,5	22,5	27,5	32,5	37,5	42,5
Absolute RMS in the range $\bar{\sigma}_i$,%	5,33	4,23	3,62	2,29	4,22	3,08	3,17	4,38	3,61
Relative RMS,% $\Delta\bar{\sigma}_i = \frac{\bar{\sigma}_i}{\bar{V}_i^{daf}} \cdot 100$	213,01	56,4	28,95	13,07	18,74	11,19	9,76	11,7	8,50

Absolute standard deviations (σ_i) were in the interval 2,29-5,33 % with correlation dependence (r=1) от $\bar{V}_i^{daf}$ (fig. 2*a*). Its average value (line 1) is 3,8 %.

Relative standard deviations ($\Delta\sigma_i$) defined by dependency

$$\Delta\sigma_i = \frac{\bar{\sigma}_i}{V_i^{daf}} \cdot 100, \%. \quad (1)$$

For the considered sampling possible values output volatiles V_i^{daf} were in the range 1-50%, and the absolute standard deviations $(\bar{\sigma}_i)$ in separate ranges V_i^{daf} were 2,29-5,33%. Based on possible values V_i^{daf} and $\bar{\sigma}_i$, calculated according to equation (1) the minimum expected ($\Delta\sigma_{min}$), maximum ($\Delta\sigma_{max}$) and middle ($\Delta\sigma_{cp}$) relative standard deviations.

Minimum value $\Delta\sigma_{min}$ will be observed at the maximum value

V_i^{daf} $(\approx 50\%)$ and minimal $\bar{\sigma}_i$ $(\approx 2{,}29\%)$. For this case

$$\Delta\sigma_{\min} = \frac{2{,}29 \cdot 100}{50} = 4{,}58\% .$$

Maximum value $\Delta\sigma_{\max}$ will be observed at $V_i^{\text{daf}} = 1\%$ and $\bar{\sigma}_i = 5{,}33\%$:

$$\Delta\sigma_{\max} = \frac{5{,}33 \cdot 100}{1{,}0} = 533\% .$$

Based on similar reasoning, the average value $\Delta\sigma_{\text{ср}}$ for the considered sample is determined by the average possible values $\bar{V}_i^{\text{daf}} \approx 25\%$ и $\bar{\sigma}_i = 3{,}8\%$

$$\Delta\sigma_{\text{ср}} = \frac{3{,}8 \cdot 100}{25} = 15{,}2\% .$$

Based on the above calculations and the schedule of changes $\Delta\bar{\sigma}_i$ (fig. 2) should, what $\bar{V}_i^{\text{daf}}$ more or less reliably determined when its values are higher 25%. The relative standard deviation in this case is about 15%, which is quite acceptable for technical calculations.

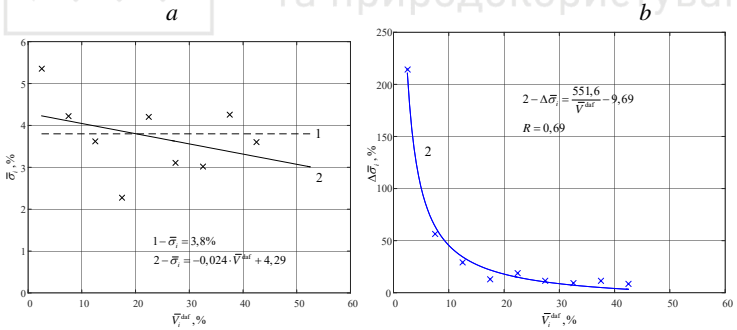

Fig. 2. Dependence of changes in absolute (a) and relative (b) $(\Delta\sigma_i)$ root-mean-square deviations from the value of the release of volatile substances in separate intervals $\bar{V}_i^{\text{daf}}$: 1(*a*) - direct dependence of the mean absolute value $\bar{\sigma}_i$; 2(*b*)- relative value curve $\Delta\bar{\sigma}_i$;

× - average values $\bar{\sigma}_i$ and $\Delta\bar{\sigma}_i$ in the respective ranges $\bar{V}_i^{\text{daf}}$;

r, *R* - correlation coefficient and correlation ratio

At values of the yield of volatile substances in the range of 25-

8%, the determination accuracy $\overline{V}_i^{daf}$, since the relative standard deviations can exceed 50%. This casts doubt on the use of the yield of volatile substances in the considered range of its change as a reliable classification indicator of the degree of metamorphism of coals when establishing the hazardous properties of mine layers.

The accuracy of determining the mass yield of volatile substances decreases even more when its values are less than 8%.

In this case, the relative standard deviations can exceed 500%. Such an accuracy in determining any parameter is unacceptable for its use in engineering calculations.

The features of the accuracy of determining the mass yield of volatile substances were taken into account when developing GOSTs for the classification of coals according to their genetic and technological parameters.

According to [16] V^{daf} used as a classification indicator for dividing fossil coal into fuels. When V^{daf}=8% and more coals are classified as stone, and when V^{daf}<8% - to anthracites. In the range and more, using this indicator, coals are divided into 21 types according to their consumer properties. The high determination error in the range of 8-25% when establishing consumer properties according to industrial classifications was compensated for by considering additional indicators characterizing the technological properties of coals. The final selection of a set of classification indicators for the coals under consideration was established empirically with subsequent verification in production conditions. Thanks to this approach, a modern industrial classification has been created [16].

It is not possible to predict the hazardous properties of coal layers in this way, due to the lack of conditions for carrying out appropriate experiments in mine conditions. For this reason, in the regulatory documents [7-10], the release of volatile substances during the thermal decomposition of coals without air access remains practically the only classification indicator of the degree of metamorphism. When establishing certain types of hazardous properties of coal layers, meaning V^{daf}≥4% [3-5], which does not exclude a relative error of up to 100% in determining this indicator. In the regulatory documents [7-8], the assessment of the degree of

metamorphism of coals is performed for the range of variation within 2-8%, which can also lead to significant errors. The above facts testify that the modern regulatory framework of Ukraine for the safe mining of coal deposits requires its improvement in terms of predicting the hazardous properties of coal layers using other indicators of the degree of coal metamorphism V^{daf}.

In addition to the place of sampling of coal in the mine field and the absolute value V^{daf} ash content also affects the error of its determination [17,18]: the higher it is, the more the value is distorted V^{daf}. With an increase in ash content, the proportion of volatile substances from mineral components increases and the proportion of organic matter decreases, which includes the total value of volatiles from the organic and mineral parts of coal, calculated on a dry ashless mass. Due to the lack of methods for complete demineralization of the sample, to obtain an accurate value laboratory is impossible, and recalculation of volatile substances per organic mass leads to an overestimation of the indicator V^{daf}. Currently the indicator only approximately characterizes the behavior of the organic mass of coals during thermal destruction and is completely unacceptable for calculations at high ash content of samples V^{daf}. In accordance with the current situation, when establishing the consumer properties of coal, their ash content should not exceed 10% [19]. Samples with a higher ash content are preliminarily enriched in organic or inorganic liquids in accordance with the developed GOSTs. Such an artificial decrease in the indicator of the content of mineral impurities in coal samples when determining does not correspond to the natural state of mine layers, which undoubtedly affects the accuracy of predicting their hazardous properties V^{daf}.

The presence of a stable connection between V_2^{daf} and V_1^{daf} (r=0,935, fig. 1) when sampling coal at different distances from the zones of gas weathering and geological disturbances, it indicates that the release of volatiles during the thermal decomposition of coal is a fairly stable indicator for separately considered mine formation regardless of the coal deposit. This is, to a degree, due to the weak correlation dependence of volatiles on the depth of the gas weathering zone (r=0.51) and its practical absence (r=0.05) and

angle of the abundance coal seam [20].

The studies carried out have confirmed some constancy of the volatile matter yield for coal of a particular mine formation, regardless of the sampling location. Along with this, taking into account the ambiguous change in the relative RMS depending on the absolute values of the indicator, it cannot be considered scientifically justified to establish the degree of metamorphic transformations of coals with the release of volatile substances less than 25%.

As it was established earlier, the relative RMS for such cases can exceed 100%, which obviously indicates the possibility of obtaining unreliable results when predicting the manifestation of hazardous properties for a significant number of mines.

The use of the volatile matter yield indicator for predicting the hazardous properties of mine layers [7-10] is borrowed, without proper scientific justification, by analogy with its application in the industrial classification [16]. To establish consumer properties, coal samples are prepared for dry or dry ashless mass [19], which does not correspond to the state of coal in mine layers during mining operations. When predicting the tendency of coal mines to manifest their hazardous properties, it is necessary to take into account the existing differences between the laboratory determination of indicators and the conditions for finding coal in production conditions. They are primarily distinguished by the presence of natural moisture and ash content during mining operations.

Also, without proper scientific substantiation in the regulatory documents [7-10], the release of volatile substances during thermal decomposition of coals is accepted as a classification indicator of the degree of coal metamorphism. The generally accepted concept of metamorphism is the transformation of brown coal sequentially into coal and anthracite as a result of changes in the chemical composition, structure and physical properties of coal in the bowels, mainly under the influence of increased temperature and pressure [6]. Volatile products during the thermal decomposition of coals cannot directly characterize changes in the chemical composition, structure and physical properties of coals, occurring in past geological periods of time. In essence, the processes of thermal decomposition are the next artificial stage in the transformation of coals at higher temperatures [21]. The processes of coal metamorphism in natural

conditions reached a certain degree of transformation of organic matter at a temperature of no more than 650 °C. Thermal decomposition, according to the requirements of chemical and technical analysis, is carried out at 900 °C or 850 °C [19].

Conclusions. The studies carried out allow us to make the following conclusion, important for improving the regulatory framework for the safe mining of coal seams:

1. The release of volatile substances during the thermal decomposition of coal is a relatively constant indicator for individual mine layers in different coal basins, which is confirmed by a high mutual correlation dependence between the results of laboratory tests of coal samples taken in different parts of the mine fields.

2. The relative error in determining the weight yield of volatile substances for all considered coal basins depends on the absolute value of the indicator. The maximum relative standard deviations of more than 100% are observed when the release of volatile substances is less than 8%, and when the release of volatile substances is more than 25%, they stabilize at the level.

3. When developing normative documents for the safe mining of coal mines, the indicator of the weight yield of volatile substances to characterize the degree of metamorphism was borrowed from industrial classifications characterizing the consumer properties of coal without sufficient scientific justification.

4. The value of the weight yield of volatile substances according to the methods for establishing consumer properties is determined in laboratory conditions with an artificial decrease in ash content of less than 10% and removal of external moisture, which does not correspond to the production conditions of the manifestation of hazardous properties of mine layers during mining.

5. In essence, thermal decomposition is another artificial stage in the transformation of coals outside the bowels of the Earth at a higher temperature compared to the processes of metamorphism. Decomposition products do not directly reflect changes in the chemical composition, internal structure and properties of coals that have occurred in the past geological periods of time.

6. To improve the regulatory documents on the safe conduct of mining operations to characterize the degree of coal metamorphism

when predicting the hazardous properties of mine layers, it is necessary to use classification indicators that directly reflect the change in the composition and properties of coals in the process of geological transformations.

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RESULTS OF PHYSICO-CHEMICAL STUDIES OF ORE ROCKS AND ELEBARATION THEWAY OF EXTRACT USEFUL COMPONENTS FROM THEM

Toktosunova B.
Kyrgyz State University of Geology, Mining and Natural Resources Exploitation named after Academician U.Asanaliev (KGGU), Doctor of Chemistry, Professor, Head of the "Natural Sciences", Kyrgyzstan

Sultankulova A.
Kyrgyz-Russian Slavic University named after B. N. Yeltsin (KRSU), Candidate of Chemical Sciences, Associate Professor, Leading Researcher, Kyrgyzstan

Kushnazarova S.Z.
Kyrgyz Institute of Mineral Resources (KIMR), Researcher, Kyrgyzstan

Aitkulov B.T.
Kyrgyz Institute of Mineral Resources (KIMR), Researcher, Kyrgyzstan

Toktosunov N.M.
Kyrgyz Institute of Mineral Resources (KIMR), Researcher, Kyrgyzstan

Annotation

This paper work determinesthe results of research on the physico-chemical properties of ore minerals from the deposits of the Sarijaz Ore Area of the Berkutsk Group of the Kyrgyz Republic.Mechanical processing of test minerals according to known method was carried out.The influence of particle dispersion in test samples on the expression of some metals in ore minerals has been studied.The effect of the