ISSN 2226-3780

UDC 622.82:54-3
DOI: 10.15587/2312-8372.2019.191902

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ANALYSIS OF METAMORPHISM AND TENDENCY OF BLACK COALS TO SPONTANEOUS COMBUSTION

Об'єктом дослідження є кам'яне вугілля різних стадій метаморфізму і летючі продукти їх термічного розкладання. В даний час, на основі базових генетичних ознак метаморфізму, відсутня достовірна нормативна база визначення небезпечних властивостей шахтопластів, в тому числі схильності вугілля до самозаймання. Труднощі в систематизації полягають у відсутності хоча б одного класифікаційного параметра, що визначає необхідність додаткового аналізу фізико-хімічних властивостей кам'яного вугілля різних стадій метаморфізму і летючих продуктів їх термічного розкладання, як об'єкту дослідження.

Завдяки отриманим функціональним залежностям, які характеризують елементний склад кам'яного вугілля в усьому діапазоні ряду метаморфізму, забезпечується можливість оцінити його класифікаційні показники. Отриманий результат показав зміну властивостей вугілля, які в результаті перетворення внутрішньої структури можуть приймати максимальні або мінімальні значення. За монотонного і одностороннього характеру зміни вмісту компонентів C^0, O^0, і N^0 неможливо робити висновки щодо залежності властивостей вугілля від елементного вмісту цих компонентів. Характер залежності H^0 від V^{daf} і питомої ваги (K_∂) дає підставу передбачити набуття нових властивостей вугіллям після зниження V^{daf} менш 30–25 %, а питомої ваги при K_∂>1,3.

Відзначено, що вугілля з однаковими властивостями в одних випадках характеризуються різними величинами класифікаційних показників (V^{daf}, $V^{daf}_{об}$, C^{daf}, K_∂), в інших випадках – вугілля з різними значеннями класифікаційних показників можуть мати однакові властивості. Складний і неоднозначний характер носять зміни фізико-механічних і теплотворних властивостей вугілля від V^{daf} і C^{daf}. Це є непрямим доказом зміни внутрішньої структури вугілля в процесі геологічного перетворення. Перебудова внутрішньої структури вугілля змінює значення електромагнітних характеристик. Пропонується при встановленні схильності вугілля до самозаймання за генетичними і технологічними параметрами використовувати сучасні знання в галузі геології, історичної геології та палеонтології, фізики, хімії, термодинаміки, а також досвід промислового застосування вугілля.

Ключові слова: *метаморфізм, ендогенна пожежа, самозаймання кам'яного вугілля, геолого-генетичні чинники, елементний склад.*

Received date: 31.10.2019
Accepted date: 19.11.2019
Published date: 30.12.2019

1. Introduction

Coals of all stages of metamorphism are subject to spontaneous combustion to varying degrees [1]. In general, this term refers to the totality of endogenous processes associated with changes in the structure, mineral and chemical composition of rocks (coals) under conditions different from their initial state. The formation of metamorphic rocks in general [2] and fossil coals in particular [3, 4] practically do not differ from each other. Conditionally, it is possible to assume that the processes of metamorphism occurred at temperatures of 200–650 °C at a depth of 10–40 km [5]. The main factors of metamorphism are temperature, pressure, composition and chemical activity of solutions and fluids. Metamorphic processes are diverse in form and nature of the transformation of rocks, which are classified taking into account individual factors (thermodynamic, physicochemical, etc.) and geological conditions. Many classifications of metamorphic processes have been proposed [6], based on various principles and reduced to numerous names of types and species.

A special place among these classifications is occupied by coal metamorphism. That is, an irreversible carbonization process, which is characterized by a change in the chemical composition, physical properties and internal structure of fossil coals under the influence of temperature and pressure [2–4].

A variety of geological and genetic factors caused the formation of coals with various physicochemical, technological and other properties [4].

The classification parameters that exist in the whole range of coal metamorphism include:

- content of the main components of the organic mass [4, 7];
- weight and volumetric yields of thermal decomposition products of coal without air access [8, 9];
- presence of moisture [10–12];
- calorific value [13];
- mechanical strength [3, 14] and others.

Along with the above, there are parameters that are characteristic only for individual ranges of a number of degrees of metamorphism. These include resin yield, plastic layer thickness, expansion index, etc.

Practical experience has shown that all existing classifications (chemical, genetic, industrial) are aimed at identifying the consumer properties of fossil coal [15].

A fairly accurate industrial classification [16] is developed thanks to research in geology, historical geology and paleontology, physics, chemistry, thermodynamics, statistics, as well as extensive practical experience in the industrial use of coal.

The features established by this classification of changes in the elemental composition and properties of coals under the influence of geological transformations are, to date, not sufficiently used in resolving issues related to the safe mining operations in mines. In particular, many parameters characterizing the degree of coal metamorphism are ignored. It has become a practice when for these purposes, in most cases, one indicator is used – the mass yield of volatile substances (V^{daf}) during thermal decomposition of fossil fuels.

In order to characterize anthracites in parallel with V^{daf}, a volumetric yield of volatile substances V_v^{daf} and a logarithm of electrical resistivity *lg*. are used. These indicators can't be used to highlight any properties of coal at the lower stages of metamorphism. At such stages, coals can be compared with dielectrics, and at high (anthracites), with conductors [11, 12, 17].

The use of a limited number of parameters characterizing the degree of coal metamorphism led to the attribution of all mine plasts of Donbass (Ukraine), except anthracites, according to the regulatory document [18], prone to spontaneous combustion. With all the variety of elemental composition of coals and their properties in a series of metamorphism, indicators are classified by the degree of endogenous fire hazard into only three groups. Clear boundaries between the groups according to endogenous fire hazard on the basis of genetic signs have not been established, since there is no normative base for their determination.

This situation is confirmed by studies [3, 6, 10] on the establishment of coal groups according to the degree of coalification using three indicators – V^{daf}, coal grade (M) and carbonization (C_n). The carbonization index characterizes the elemental composition, which is defined as the quantitative ratio of the carbon content to the sum of oxygen and hydrogen, calculated on dry and ashless mass. It should be noted that the selected indicators (V^{daf}, M and C_n) partially correlate with each other and each of them does not fully reflect the transformation of coal in the process of metamorphism. In addition to these parameters, the content of sulfur and iron disulfides (pyrite and marcasite), the thickness of the developed formations, their structure and dip angles, and tectonic disturbance are considered. According to these indicators, eight characteristic zones of the relative distribution of the number of mine plastics of spontaneously combusting coal are identified depending on the degree of manifestation of the main factors at 560 sites [19]. Under different other conditions, coals of grades *D*, *Zh*, *K*, *OS*, and T had an increased endogenous fire hazard. It is also established that when mining seams containing the same coal grades, there is no endogenous fire hazard [10, 19].

The above facts testify to the shortcomings of the regulatory document [18] regarding the establishment of only three groups of mine plastics by their endogenous fire hazard. The results of literature analysis indicate the relevance of studying the influence of the degree of metamorphism of coal on their spontaneous combustion with the involvement of more genetic and technological factors that directly affect the occurrence of endogenous fires in coal mines. Solving this problem will help to improve the regulatory framework for creating safe conditions in coal mines.

Thus, *the object of research* is the coals of different stages of metamorphism.

The aim of research is determination of general methodological approaches to the selection of classification parameters for assessing the degree of coal metamorphism when establishing their propensity for spontaneous combustion.

2. Methods of research

Using the classical definition of metamorphism [3], based on the well-known classifications of industrial use of coal [16], it is possible to establish a set of indicators that most fully determine the propensity of fossil coals for spontaneous combustion.

The methodology provides for the establishment of changes in the classification parameters of the degree of metamorphism, characteristic of the whole series of coalification. In parallel, identify indicators that exist only in some ranges of a number of degrees of metamorphism. Comparison of changes in indicators in individual intervals will allow for a more detailed gradation of the properties of coals by their tendency to spontaneous combustion.

3. Research results and discussion

Studies of the elemental composition, as one of the main indicators of the degree of conversion, fossil coals under the influence of geological processes. The main components of organic mass are carbon (C^0), oxygen (O^0), hydrogen (H^0) and nitrogen (N^0). In insignificant amounts (0.001–0.243 %) phosphorus (P^0) may be contained in the form of various compounds. Scattered and rare elements are found in coals of various stages in the form of salts included in the organic and mineral parts of coal [9, 11].

In the transition from brown coal to anthracite, the carbon content increases from 50 to 97 %. In parallel with this process, there is a decrease in oxygen from 20–28 to 1 % and hydrogen from 4.4–6.3 to 1 %. The nitrogen content at the beginning and end of a series of metamorphism is up to 1 %, and in its middle part up to 2 % [20]. The change in the ratio between the main organic components of fossil coals under the influence of metamorphic processes is confirmed by the graph (Fig. 1).

Unambiguously, practically functionally, there is an increase in the carbon content and a decrease in the sum of other elements (O^0, H^0, N^0). It should be noted the different nature of the reduction of the individual components of the sum of the components. Oxygen decreases in the entire range of a series of metamorphism. The hydrogen content remains almost constant during the transition from brown coal to stone. A noticeable decrease in the hydrogen content is observed in fossil fuels with a high degree of metamorphism (C^0>87 %) and anthracites (Fig. 1, *c*).

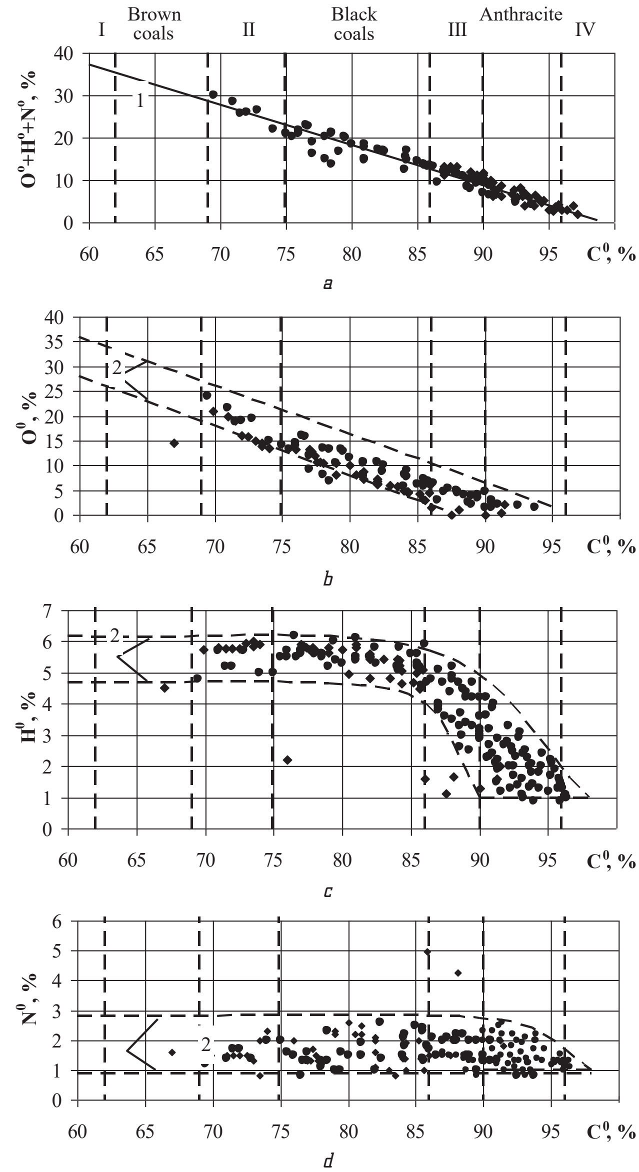


Fig. 1. Dependence of changes in the ratio of elements of coal in organic mass [19–26]: *a* – the ratio between the carbon content and a mixture of other components (O^0, H^0, N^0); *b* – the ratio between the content of carbon and oxygen; *c* – the ratio between the content of carbon and hydrogen; *d* – the ratio between the carbon content and nitrogen; I, II, III, IV – ranges of changes in the properties of coal; 1 – linear interpolation of experimental data; 2 – the boundaries of the change in components; • – experimental data

Confirmation of this nature of changes in the hydrogen content in the process of coalification is a graph of its relationship with oxygen (Fig. 2).

A noticeable decrease in hydrogen begins to occur when the oxygen content is less than 5 %. Obviously, this dependence is due to the introduction of hydrogen at this stage of metamorphism into compounds that are carried out or not taken into account in the organic (combustible) mass.

The nitrogen content remained almost constant (as a rule, not exceeding 2–3 %), and only at the stage of anthracite with a high degree of metamorphism (C^0>95 %) did its significant decrease (Fig. 1, *d*).

Considering the ratios of organic components from the position of the propensity of coals for spontaneous combustion, it is worth noting the different nature of the changes in O^0 and H^0 with a carbon content of up to 87 % and above this value.

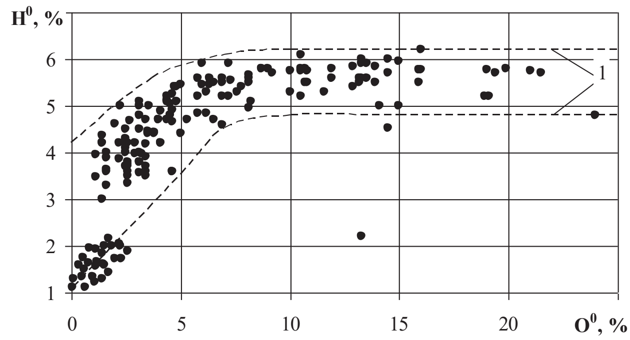


Fig. 2. The interdependence of the content of hydrogen (H^0) and oxygen (O^0) in the organic (combustible) mass of coal according to [19–26]: 1 – the boundaries of the change in the considered parameters; • – experimental data

When the carbon content is in the range of 70–87 %, the oxygen content decreases with approximately the same intensity, and the hydrogen content remained constant and amounted to 4–6 %. These data indicate that with a carbon content of about 87 %, qualitative changes occur in the internal structure of coals.

Moisture is not taken into account in organic matter, but significantly affects the spontaneous combustion of coal. The results of processing the data [19] indicate that during the transition from brown coal to stone, the moisture content decreases to 1–3 %, and then increases in anthracite to 4–5 %, sometimes reaching 7–8 %. Similar results (Fig. 3) are obtained by processing other experimental data [19–26].

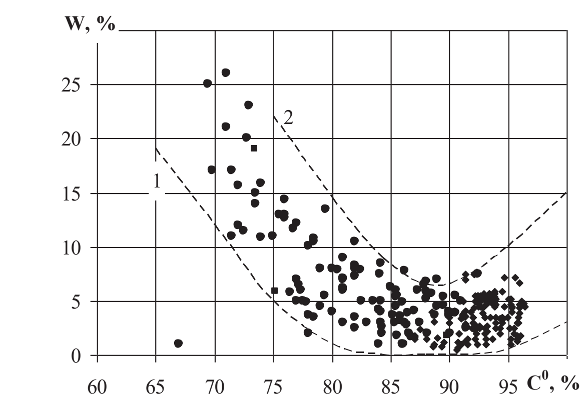


Fig. 3. The dependence of the working moisture of coals (*W*) on the carbon content (C^0) according to [19–26]: 1, 2 – the boundaries of the changes in the considered parameters; • – experimental data

This indicates a different transformative effect of pressure, temperature, and time factors at individual stages of metamorphism. In the transition from peat to brown coals and with an equal carbon content (Fig. 1, range I), the main distinguishing features are only the moisture and oxygen content. The moisture content in peat is 75 %, in brown coals 60 % or less, oxygen, 31–40 % and 18–26 %, respectively [20]. At this stage, the degree of conversion of coal is determined by the amount of moisture and oxygen removed from the brown coal under the influence of external conditions.

When brown coal loses up to 90 % moisture, the properties inherent in bituminous coals appear (sintering ability, coking ability, resin yield, etc.). This stage roughly corresponds to range II of carbon change (up to 75 %) in the organic (combustible) mass of coal (Fig. 1).

At the stage of black coal, along with the transformation of the internal structure of the organic mass and the change in its elemental composition, there is a further removal of bound and free moisture. This explains the reduced humidity of the coals. Upon transition from black coals to anthracites, the acquired properties are lost, but new ones appear that indicate a significant structural and molecular transformation of the constituent coal components. These include a change in mechanical strength, density, electrical properties, etc. The acquisition of new properties was due not only to a change in the composition of the organic mass. The increase in the percentage of carbon occurred mainly due to a decrease (from 6 to 1 %) of hydrogen in the organic (combustible) mass (Fig. 1, range III). The removal of hydrogen at this stage could occur after its entry, under the influence of pressure and temperature, into compounds that are carried out or not taken into account in the organic (combustible) mass.

The decisive influence of a certain combination of parameters (pressure, temperature, time) is evidenced by the fact of an increase in moisture in anthracites. As a result of a deep internal change in the structure of coal at this stage of metamorphism, not only the removal of free moisture occurred, but also the additional release of pyrogenetic and hydrated moisture.

An increase in the moisture content in anthracites does not contradict the general tendency of metamorphism processes to an increase in carbon content and a decrease in other components. The increase in the humidity of anthracites is not caused by the cessation of processes for its removal, but is the result of an internal reorganization of the substance at this stage of coal formation. A proof of this is a significant decrease in moisture compared with anthracites in graphite and natural coke [10].

In the technical analysis of fossil fuels and anthracites, bound and free moisture is completely removed when heated to 105–110 °C. This process, obviously, is more associated with the properties of water than with the properties of coals and the degree of their metamorphism.

Pyrogenetic and hydrated moisture can be removed from coal only at a temperature of 300–550 °C and more [27]. This process largely depends on the internal structure of coals, associated with their degree of metamorphism.

The above facts indicate that knowing the ratio between the types of moisture, one can judge the degree of metamorphism of coals and their properties.

The factors of pressure, temperature and time at a late stage of coal formation are decisive. For example, the elemental composition of anthracites with a high degree of metamorphism (C^0>97 %) is close to the composition of graphite and natural coke [2–4]. But these substances have completely different properties, due to a change in their internal structure under the influence of a certain combination of these factors.

Analysis of changes in the elemental composition of fossil coals shows that according to this factor they can be divided into only two groups – black coal and anthracite. The boundary of this separation is determined by the carbon content of 87 %. This indicator roughly corresponds to an oxygen content of less than 5 % and hydrogen less than 4 %, and the content of working moisture increases from 1–3 % to 7–8 %. It is not possible to establish other boundaries of the ranges of changes in the properties of coals by their elemental composition, including determining the degree of propensity for spontaneous combustion.

In the process of metamorphic transformation, a change in the composition of the main components of the organic matter depends to some extent on the release of volatile substances (V^{daf}) during the thermal decomposition of coal without access to air (Fig. 4).

V^{daf} indicator is the main criterion, according to all regulatory documents currently in force, for determining the hazardous properties of mine plastics that have appeared in the process of metamorphic transformations. In this case, an equal sign is put between the value of one parameter V^{daf} and the value of the physicomechanical, electromagnetic, plastometric, chemical and other properties of coal under the influence of metamorphic processes.

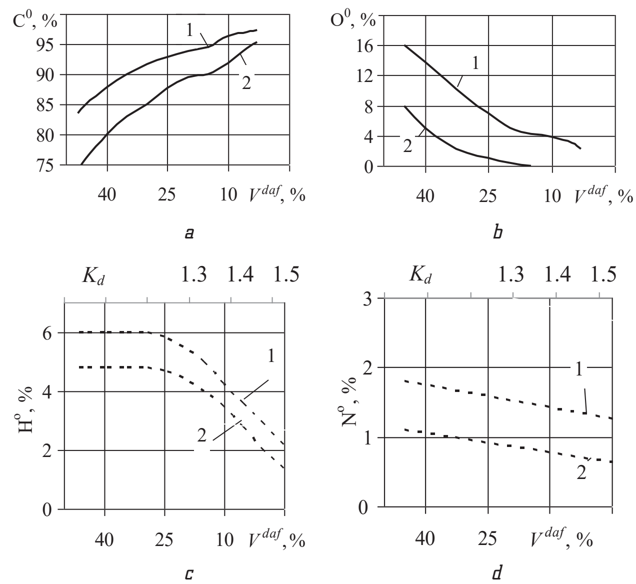


Fig. 4. Change in the composition of the main organic mass of Donbass coals (C^0, O^0, H^0, N^0) from the release of volatile substances (V^{daf}) and specific gravity (K_d) according to [28]: *a* – dependence of carbon content on the yield of volatiles; *b* – dependence of the oxygen content on the yield of volatiles; *c* – dependence of the hydrogen content on the yield of volatiles and specific gravity; *d* – dependence of the nitrogen content on the yield of volatiles and specific gravity; 1, 2 – upper and lower boundaries of the change of parameters

The propensity of coal for spontaneous combustion is one of the most dangerous properties, which is manifested in the process of mining. The degree of conversion of the organic mass of coal in this case is estimated ambiguously by the V^{daf} index. A different percentage may correspond to one of its values, rather in a wide (up to 8 %) range of changes in the main components of the organic mass.

To characterize anthracites, the volumetric yield of volatile substances V_v^{daf} and the logarithm of electrical resistivity *lgc* are currently used. In [17], these indicators were replaced by the application of specific gravity (K_d) of organic mass (Fig. 4).

The introduction of additional classification indicators was due to the fact that, when passing from low-sintering

ISSN 2226-3780

grades of coal to anthracites, within a relatively narrow range of V^{daf} changes, the properties of coal undergo drastic changes. The use of these indicators of the degree of metamorphism limits the entire characterization of the properties of coal in solving the problems of safe mining of coal mine layers.

The predominant use of the total weight output of volatiles during thermal decomposition is not justified from the standpoint of the classical definition of the concept of «coal metamorphism». The indicator implies changes in the internal structure, chemical composition and physical properties under the influence of temperature and pressure during geological processes.

Volatile substances are considered vapor- and gaseous decomposition products of organic matter and some mineral impurities that are not directly related to the previous process of metamorphism. In the case under consideration, V^{daf} is only an indirect indicator of changes in the composition of organic matter occurring in coals, which does not uniquely determine the content of the main components (C^0, O^0, H^0, N^0).

In the case of thermal decomposition of fossil fuels and anthracites without access to air, the V^{daf} value decreases from 47 to 5 %. In this case, the carbon content increases from 75 to 97 %, and one value of V^{daf} corresponds to the fluctuation of C^0 to 8 %. The content of the remaining main components (O^0, H^0, N^0) decreases with increasing C^0. The oxygen content decreases from 16 to 0 %, a single value of V^{daf} can correspond to values of the content of O^0 in the range up to 8 %. In a smaller range, the content of H^0 and N^0 changes. One value of V^{daf} corresponds (Fig. 4, *c*, *d*) to the range of variation of H^0 and H^0 of one percent [28]. The content of H^0 in 5–6 % remains constant with a decrease in V^{daf} to 25 %, and then its content decreases to 1–2 % with subsequent stabilization at this level (Fig. 4, *c*). The nitrogen content in the range of 1–2 % decreases monotonously (Fig. 4, *d*). The above facts indicate a different nature of changes in the content of the main components in the organic mass (C^0, O^0, H^0, N^0) depending on V^{daf}.

By the monotonous and one-sided change in the components C^0, O^0 and N^0 (Fig. 4, *a*, *b*, *d*) it is impossible to judge the change in the properties of the coals from the elemental content of these components. The nature of the dependence of H^0 on V^{daf} and specific gravity (K_d) suggests that coals acquire new properties after V^{daf} decreases by less than 30–25 %, and the specific gravity at K_d>1.3 (Fig. 4, *c*).

Using two parameters (V^{daf} and K_d) as a criterion for assessing the degree of coal metamorphism, the whole process of coal formation can be divided into three stages. The first with V^{daf}>30–25 %, the second with V^{daf}<30–25 %, and the third with K_d>1.3. Such a division does not give an idea of a change in the properties of coal at these stages.

Additional information is provided by the analysis of changes in the content of specific gases of thermal decomposition of coals (H_2, CH_4, CO, CO_2) in their total volume from V^{daf} or V_v^{daf} (Fig. 5).

The hydrogen (H_2) content in the products of thermal decomposition with a decrease in V^{daf} increases proportionally, and at V_v^{daf}<150 cm^3/g there is a slight decrease (Fig. 5, *a*).

A sequential increase, and then a decrease in the products of coal decomposition, the methane content (CH_4) can also be noted, but the nature of this dependence differs significantly from the change in hydrogen content (Fig. 5, *b*). An increase in the content of CH_4 occurs at V^{daf}<30 %, and at V^{daf}>30 %, a decrease.

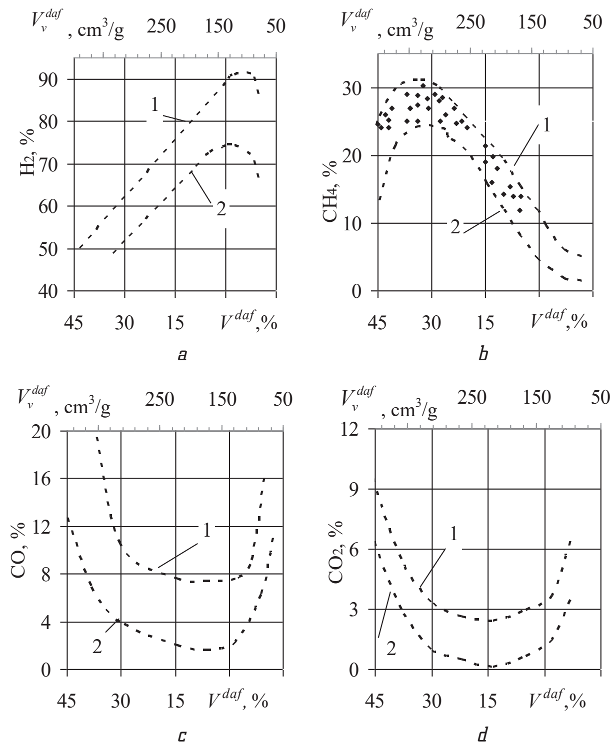


Fig. 5. Dependence of the gas content of thermal decomposition of coal on the weight (V^{daf}) and volumetric (V_v^{daf}) yield of volatile substances according to [28]: *a* – hydrogen; *b* – methane; *c* – carbon monoxide (II); *d* – carbon monoxide (IV); 1, 2 – upper and lower boundaries of the change in parameters; • – experimental data [19, 29]

The dependences of the content of CO and CO_2 have a slightly different form. At V^{daf}<30 %, the content decreases in a certain range, and at V^{daf}>30 %, their stabilization occurs, and at V_v^{daf}<150 cm^3/g – an increase (Fig. 5, *c*, *d*).

Comparison of the graphs of changes in the chemical composition of coals and their thermal decomposition products without air access (Fig. 4, 5) show that coals with the same elemental composition can relate to different degrees of conversion under the influence of metamorphic processes. And, conversely, coals of varying degrees of metamorphism can have the same chemical composition.

The changes in the physicomechanical and calorific value of coal from V^{daf} and C^{daf} are complex and ambiguous (Fig. 6).

This is indirect evidence of changes in the internal structure of coals in the process of their geological transformation. The restructuring of the internal structure of coal led to a change in their electromagnetic characteristics (Fig. 7).

A change in the properties of coals (Fig. 6, 7) shows that coals as a result of transformations of the internal structure can take maximum or minimum values. Based on the type of curves, coals with the same properties can in some cases be characterized by different values of classification indicators (V^{daf}, V_v^{daf}, C^{daf}, *M*), in others – coals with different values of classification indicators have the same properties.

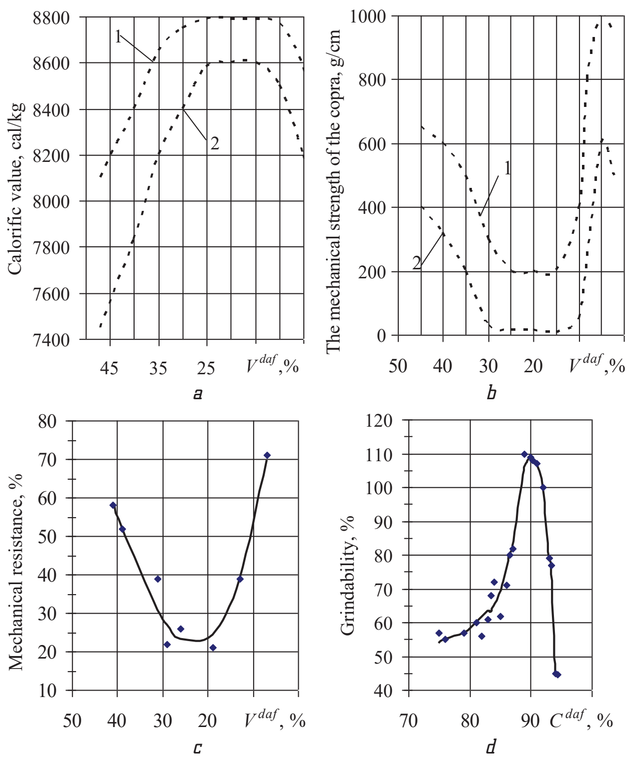


Fig. 6. Change in the physico-mechanical properties of coals [10, 14, 28]: *a* – dependence of the calorific value on the release of volatile substances; *b* – dependence of the mechanical strength of the copra on the yield of volatile substances; *c* – dependence of mechanical resistance on the release of volatile substances; *d* – dependence of grindability on the carbon content on a dry ashless state; 1, 2 – upper and lower boundaries of the change of parameters

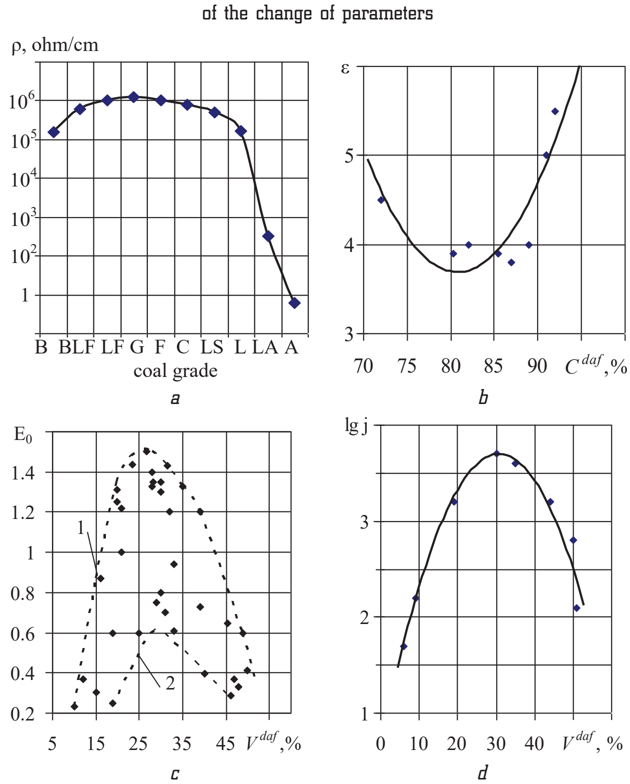


Fig. 7. The dependence of electromagnetic parameters from influencing factors [7, 10–12, 17]: *a* – electrical resistivity from the brand of coal; *b* – dielectric constant from the carbon content to a dry ashless state; *c* – specific electric field of the dust stream from the exit of volatile substances; *d* – logarithm of the intensity of the emission of high-energy electrons from the release of volatile substances; 1, 2 – upper and lower boundaries of the change of parameters

In the current regulatory framework, the classification parameter V^{daf} is the most used for characterizing the hazardous properties of coal that appeared during metamorphic transformations. The volatility yield index is not universal, since in the range of its possible change (≈48–1 %) there are no some indicators that characterize the specific properties of coal. An example of such indicators (Fig. 8) is the thickness of the plastic layer (*y*) and the yield of naphthalene extract (*e*). The presence of such indicators indicates the possibility of the existence of separate ranges of a certain degree of coal metamorphism with only characteristic hazardous properties.

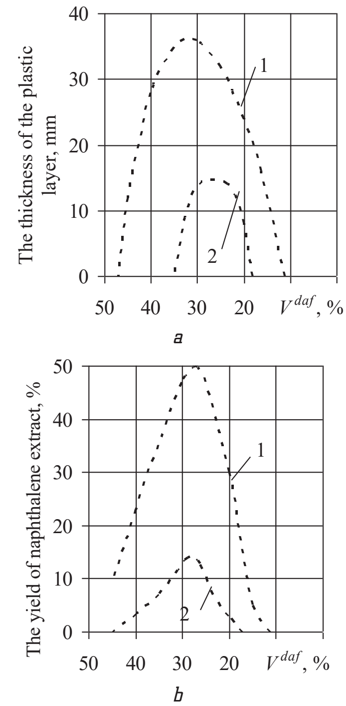


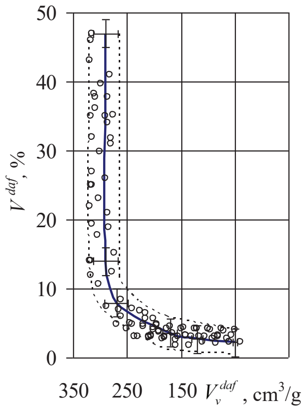
Fig. 8. The dependence of the technological properties of coal on influencing factors: *a* – dependence of the thickness of the plastic layer on the release of volatile substances; *b* – dependence of the yield of naphthalene extract on the yield of volatiles; 1, 2 – upper and lower boundaries of the change of parameters

Difficulties in the systematization of coal for any purpose, including the determination of their propensity for spontaneous combustion, lie in the absence of at least one classification parameter that meets the following requirements:

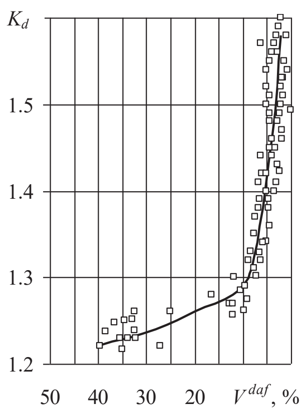
– existed in the entire range of a series of metamorphism;
– changed in one direction without reaching lows and highs;
– had a minimum scatter of experimental data near the averaging lines and was within the error range of their change.

None of the considered parameters complies with these requirements (Fig. 4–8). These graphs show that at certain stages of coal formation, indicators can remain almost constant, therefore their values are lost as classification ones. For example, with a weighted yield of volatiles (V^{daf}) of less than 9 %, this indicator remains almost constant, although others (and V_v^{daf}, K_d) vary over a wide range (Fig. 9).

The main components of the volatile products of thermal decomposition of coal (V^{daf} and V_v^{daf}) are H_2, CH_4, CO and CO_2. Considering the total weight or volume of these gases, it is impossible to unambiguously judge the chemical composition of the initial coal material and their properties, since the proportion of each of the components formed is not constant.



a



b

Fig. 9. The relationship of some classification parameters of the degree of coal metamorphism [28]: *a* – dependence of the yield of volatiles on the volumetric yield of volatiles; *b* – dependence of the specific gravity on the yield of volatile substances; 1, 2 – upper and lower boundaries of the change in parameters; • – experimental data

For the coals of the Donetsk basin, the proportion of hydrogen is 45–86 %, methane 1.5–32.5 %, carbon oxides (II) and (IV), respectively 2.0–19.5 % and 0.5–9.0 % [28]. Given the different physical and chemical properties of these gases and the inconsistency of their relationships, the V^{daf} and V_v^{daf} parameters can't fully characterize the properties of the combination of gases generated during the thermal decomposition of coals and, especially, the source material (coals).

4. Conclusions

1. The research results show that at present, based on the basic genetic signs of metamorphism, there is no reliable regulatory framework for determining the hazardous properties of mine plastics, including the tendency of coal to spontaneously ignite. It is shown that more than two dozen classification indicators characterizing the processes of metamorphism are used to establish a possible direction for the use of fossil coal in industry, but no more than three indicators are used to establish all the hazardous properties of mines in the modern regulatory framework. This does not allow scientifically substantiated gradation of mine plastics by the degree of their propensity for spontaneous combustion according to genetic characteristics.

2. It is proposed to use modern knowledge in the field of geology, historical geology and paleontology, physics, chemistry, thermodynamics, as well as experience in the industrial use of coal when establishing the propensity of coal for spontaneous combustion by genetic characteristics. It is shown that the most suitable basis for establishing a set of classification indicators for coal spontaneous combustion by genetic characteristics is the industrial classification, which uses ten initial parameters: moisture capacity, heat of combustion for a wet ashless state, the yield of volatile substances and semi-coking resins, the thickness of the plastic layer, the Roga index, the content of fusenized components on pure coal, the anisotropy of vitrinite reflection, the reflection index of vitrinite and free expansion.

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