Mining of Mineral Deposits
Volume 16 (2022), Issue 4, 40-46

MMD JOURNAL / MINING.IN.UA

https://doi.org/10.33271/mining16.04.040

Effect of the quality indices of coal on its grindability

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Abstract

Purpose is to determine the effect of quality indices of coal characterized by different degrees of metamorphism as well as petrographic and ultimate composition on the values of its grindability defined by the Protodyakonov and Hardgrove methods.

Methods. 14 coal samples being a part of the raw material base of coking and chemical enterprises of Ukraine were studied. In terms of the samples, the parameters of technical, petrographic, and ultimate analysis were identified. GOST 21153.1-75 Rocks. Method of determining the Protodyakonov strength coefficient and ISO 5074:2015 Bituminous coal. Determination of Hardgrove grindability index were used to identify coal grindability. Graphical and mathematical dependencies between the indices of coal quality (R_0, V^{daf}, C^{daf}, O_d^{daf}) and values of its grindability (f and HGI) were developed.

Findings. The obtained mathematical and graphic dependencies of the effect of different indices of coal quality (R_0, V^{daf}, C^{daf}, O_d^{daf}) on the values of its grindability (f and HGI) were obtained. It is shown that dependence of coal quality indices with its strength coefficient (f) is much lower (R^2 = 0.550-0.716) than with the Hardgrove grindability index (HGI): R^2 = 0.807-0.937.

Originality. For the first time, comparative measurements of coal grindability according to the Protodyakonov and Hardgrove methods have been performed. It has been identified that the value of these indices are inversely proportional and described by a second-order polynom.

Practical implications. The obtained graphical and mathematic dependencies can be used to predict the operation of crushing equipment for both individual coal and the one of different grade and ultimate composition at coking-chemical and heat-producing enterprises.

Keywords: *coal, volatile matter content, macerals, metamorphism, crushing, vitrinite, grindability*

1. Introduction

According to the data by UKRMETALLURGPROM, 12.93 mln of coking coal was used by the coking and chemical enterprises of Ukraine during 12 months of 2021 (96.9% in terms of January-December 2020); of them, 3.65 t of Ukrainian coal and 9.29 mln t of the imported one [1]. Coal consumption in the Ukrainian energetic sector in 2021 was 20.50 mln t [2]. It means that 33.43 mln t of coal were used for coking and electric energy generation in 2021.

It is known that coal preparation for burning or coking is an important link in a technological chain of an enterprise, and a coal crushing method influences greatly the product quality and output [3], [4]. In that way, coke ability to function in a blast furnace process is stipulated by the totality and level of its chemical, physicochemical, and physical properties [5]. In this context, coke quality and its stability depend considerably on the composition of coal charge, efficiency of its preparation and, in a lesser degree, on a coking mode. Due to that fact, one of the main measures aimed at improving the quality indices of coke is optimization of the coal charge quality by reaching optimal indices of moisture content, ash content, fragmentation, and high mixing degree of coal concentrates being a part of coal charge for coking. Both a degree and a method of coal crushing effect considerably the coke strength and fineness, output of coke blast furnaces, costs for coal preparation, operating conditions of coal-preparation and coking workshops. Moreover, thermal electric stations usually burn powder coal. Coal powder preparation consists of several stages; however, the most complicated and energy-capacity stage is the one dealing with fuel crushing.

It is also pointed out that changes in maximum capacity of a crusher in terms of varying coefficient of coal strength are not linear [6] while crushing intensity can result mostly in pore narrowing at simultaneous opening of new system of pores, as a result of which gas molecules are not accessible within the area of upper pores [7]. The results of study [8] have shown that current understanding of a crushing mechanism is focused only on its influence on the product fineness and distribution in terms of particle sizes while neglecting the aspect of consumed energy and physicochemical envi-

Received: 2 February 2022. Accepted: 31 October 2022. Available online: 30 December 2022

Mining of Mineral Deposits. ISSN 2415-3443 (Online) | ISSN 2415-3435 (Print)

ronment. Thus, to design and operate crushing equipment, one should know the characteristics of fuel strength; the key one here is grindability representing fuel resistance to crushing during the powder preparation. A grindability index is one of the main fuel indices while designing powder-preparation plants as well as while assessing mill output and specific electric energy consumption for coal crushing [9].

In general, coal transportation systems include belt conveyors and crushers. Basing on the energy models of a belt conveyor and a crusher, paper [10] represents a strategy of energy efficiency optimization for the coal transportation systems involving supply rate, conveyor belt velocity, and crusher rotation velocity as the optimization variables. A coal transportation system at a coal electric power station was used as the verification study. The results confirm that optimization helps reach 9.68% of energy saving.

Previous study proves that both coal grade and its maceral composition influences crushing properties; moreover, the effect of maceral and ultimate composition is more important than the coal grade one [11]. In particular, in terms of high-volatile bituminous class, the Hardgrove grindability index (HGI) grows along with the increasing coal grade; and it decreases along with the increasing leptynite content for each specific grade.

To predict HGI, both regressive and neural network methods were applied in paper [12]. It is determined that the input parameters are to be selected basing on deep knowledge in chemistry and petrology of coal avoiding any extra parameters. In case of bituminous coal with high volatile-matter content, it is better to predict HGI while using such parameters as random index of vitrinite reflectance (or index of volatile-matter), leptynite content, and ash content.

Study [13] analyzed 26 samples of bituminous coal from Zonguldak coal basin (17 from Zonguldak and 9 from Amasra) and 17 samples of low-grade coal from different places in Turkey. First, the Hardgrove grindability index was defined. Then, an alternative method, not requiring standard mill for HGI determination, was applied. For the alternative method of determining a grindability index, coal samples of −1.7 + 1.18 mm were prepared and crushed in a ring mill. The ring mill is applied as it is widely used to prepare samples, and it can be found in almost each laboratory. After grinding, the coal samples are characterized by rather nonuniform distribution of particles as for granulometric composition depending on their crushing capacity. While comparing the results of sieve analysis with the previously determined HGI values, one can state that coal grindability can be identified easily with the help of this method since the assessed HGI values in terms of the proposed method differ by ±0.05% from the identified HGI values.

Use of Random Forest (RF) with the help of variable importance measurement (VIM) and prediction is a new model of data intelligence that is not widely used in the applied science and technology. In paper [14] VIMs (proximate and ultimate analysis, petrography) processed by RF models were used to predict HGI basing on a wide range of Kentucky coal samples. With the help of different analysis, VIM in combination with Pearson correlation has shown that maximum coefficient of vitrinite reflectance (R_{max}), content of general sulphur (S^d_t), content of leptynite (L) and vitrinite (Vt) are the most important variables to predict HGI. Those parameters were used as the input data to predict HGI with the help of RF model. The results have demonstrated that RF-model can model HGI ($R^2 = 0.90$) rather sufficiently; 99% of the predicted HGI values differ by less than 4 units from the actual ones. According to the results, by representing nonlinear VIM and an accurate prediction model, RF can be used further as a reliable and accurate method to assess complex interrelations in analyzing a coal conversion process.

Study [15] identifies that the experimental data for wet and dry coal crushing are characterized by the generally applied distribution functions. It is defined that the R-R functions and Swrebec have better approximation characteristics for the cumulative size curves of the particles as compared with other analyzed functions. That is the basis for formulating the time-dependent expression to describe cumulative distribution of particles in time. Secondly, the R-R function provides much better correspondence relative to distribution of crushed product masses comparing to others per short period of crushing. Predictability of all the considered distribution functions experiences its deterioration in about 3 minutes that can be connected with changes in dominating crushing mechanisms from impact to abrasion – chipping. Along with the increasing time of cru-shing, the G-G-S function is the optimal one to characterize particle distribution in size in case of wet crushing while the G-M function provides the best approximation while using dry crushing. Besides, optimal functions of particle size distribution are connected with the difference in brea-king mechanisms between wet and dry crushing.

To specify scientifically the substantiated correlation dependencies for predicting coal grindability on the basis of their identified quality parameters, it is required to study the influence of main parameters of coal quality and indices of its mechanical strength, first of all, on the Hardgrove grindability index. Similar dependencies will make it possible to use them successfully to optimize crushing sections of coal preparation workshops being a part of coking-chemical and metallurgical enterprises, i.e. to adjust properly the crushing equipment to avoid overcrushing of the coking coal base as well as assess with high accuracy the degree of its influence on electric energy consumption.

It is also of the utmost interest to specify successful application of the alternative method that is simpler in terms of equipment (i.e. no complex facilities are required) to identify the connection with the Hardgrove grindability index.

2. Materials and methods

2.1. Raw materials

The paper represents the results of analysis of 14 coal samples characterized by different degrees of metamorphism and petrographic homogeneity. The analyzed coal forms the raw-material basis of the Ukrainian coking and chemical enterprises. The samples were selected involving a methodology and scheme of coal sampling from the transportation belt flow. Having been selected, the coal samples were averages and reduced to ~ 30 kg; then they were dried to the air-dried state for further studies.

Table 1 represents the indices of technological properties of the analyzed coal samples (proximate and ultimate analysis, petrographic composition as well as their maximum, minimum, and average values).

Table 1. Technological properties of coal

Sample No.	Grade	Proximate analysis, %			Ultimate analysis, %					Petrographic composition, %					Average index of vitrinite reflectance, %	Hardgrove grindability index, units	Protodyakonov strength coefficient, units
		A^d	S^d_t	V^{daf}	C^{daf}	H^{daf}	N^{daf}	S^d_t	O_d^{daf}	Vt	Sv	I	L	$\sum FC$	R_0	HGI	f
1	Gas	9.9	0.34	37.7	83.51	5.43	2.17	0.34	8.55	81	0	18	1	18	0.73	48	1.05
2	Fat	7.9	1.08	34.3	86.40	5.58	1.57	1.08	5.37	85	0	12	3	12	0.96	60	0.86
3	Coking	7.5	1.14	25.2	87.96	5.10	1.65	1.14	4.15	81	0	18	1	18	1.22	80	0.76
4	Lean baking	9.9	0.33	19.2	89.89	4.83	2.33	0.33	2.62	69	0	31	0	31	1.54	86	0.75
Maximum		10.8	1.32	38.6		90.51	5.84	2.97	1.32	95	2	75	11	76	1.54	1.54	1.37
Minimum		7.2	0.27	18.3		83.39	4.52	1.32	0.27	24	0	5	0	9	0.72	0.72	0.65
Average		8.5	0.64	28.2		87.18	5.18	1.99	0.65	70.7	0.5	27.7	1.7	28.9	1.10	1.10	0.82

2.2. Methods

The Protodyakonov strength coefficient is applied while determining hardness according to GOST 21153.1-75 Rocks. It is used for hard rock and determine a method of determining its strength according to Protodyakonov to classify rocks and use this method in technical documentation while calculating and designing mining operations, mining equipment as well as while carrying our scientific studies.

The method means determining a strength coefficient being proportional to the operation applied for rock crushing as well as a new surface formed after crushing that is assessed by total volume of the particles being less than 0.5 mm [16].

A device for determining a strength coefficient represented in Figure consists of a cup *1*, a tubular headframe *2* inserted into it; in the middle of the headframe, a balance weight *3* of 2.4 ± 0.01 kg is located with an attached handle *4*. The tubular headframe has openings in its upper part; pins *5* are inserted into them to limit the balance weight lifting. The device also includes a volumeter consisting of a cup *6* and a plunger *7* with a measuring scale ranging from 0 to 150 mm along its longitudinal axis.

The sampled rock (coal) is cleaved by a hammer on a hard base until the particles of 20-40 mm are obtained. The crushed material is inspected to select 20 subsamples of 40-60 g each. The number of balance weight descending per each subsample is set while crushing first five subsamples. Each subsample is crushed separately in a cup by means of balance weight falling from the height of 60 cm. The number of balance weight drops is taken depending on the expected rock (coal) hardness; generally, it is from 5 to 15 drops per each subsample.

Correctness of the selected testing mode is controlled after sieving the first five crushed subsamples until the undersize stops being produced, and its volume is measured in a volumeter. When a coal column, being 20-100 mm high in terms of plunger scale, is obtained, the number of drops per each subsample is preserved for 15 subsamples. If height of the coal column is lower or higher in the volumeter, the number of drops is corrected to be more or less, respectively.

The remained 16 subsamples are crushed in the apparatus one by one under the preset testing mode: in terms of constant number of balance weight drops and 60 cm height of the balance weight lifting.

After crushing each of the five subsamples, they are sieved, the undersize is discharged into the volumeter, height of the coal columns is measured with the plunger and recorded.

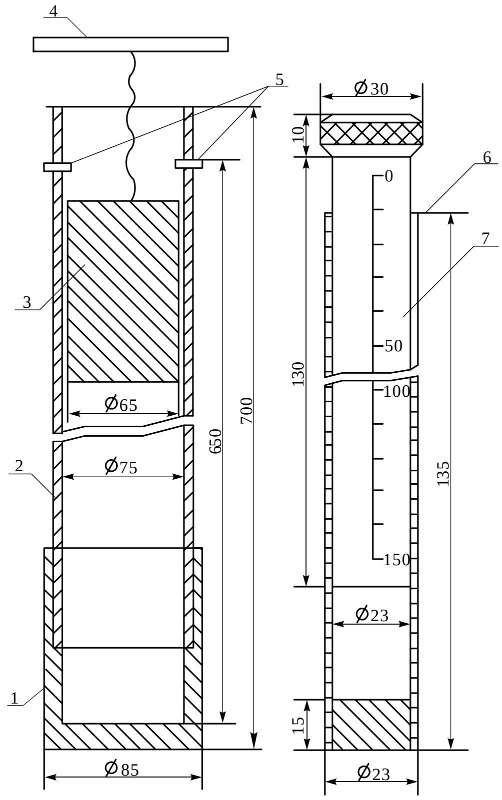

Figure 1. Protodyakonov apparatus: 1 – cup; 2 – tubular headframe; 3 – balance weight; 4 – handle; 5 – pins; 6 – measuring cup; 7 – scaled plunger

The rock strength coefficient (*f*) is calculated according to Formula 1:

$$f = \frac{20 \cdot n}{h}, \tag{1}$$

where:

20 – the empiric numerical coefficient providing generally accepted values of a strength coefficient and considering the crushing operation;

n – is number of the balance weight drops while testing one sample;

h – is height of the coal column in the volumeter after testing five samples, mm.

The arithmetic average is taken as the final test result.

ISO 5074:2015 Hard Coal – Determination of Hardgrove grindability index defines a method for specifying the Hardgrove grindability index for bituminous coal. It also determines a calibration procedure for the testing device and preparation of standard reference coal samples [17].

An air-dried coal sample prepared for testing with the present granulometric composition is crushed in a graded Hardgrove apparatus under standard conditions; then, a sieve analysis of the obtained material is performed.

To test this method, the Hardgrove apparatus represented in Figure 2 is used. The apparatus contains a fixed tempered-steel crushing cup *1* with a circular horizontal hollow in the lower part, where there are polished steel balls of (25.40 ± 0.13) mm in diameter. The balls drives the upper pressing ring *2*, rotating with the velocity of (20 ± 1) rot/m.

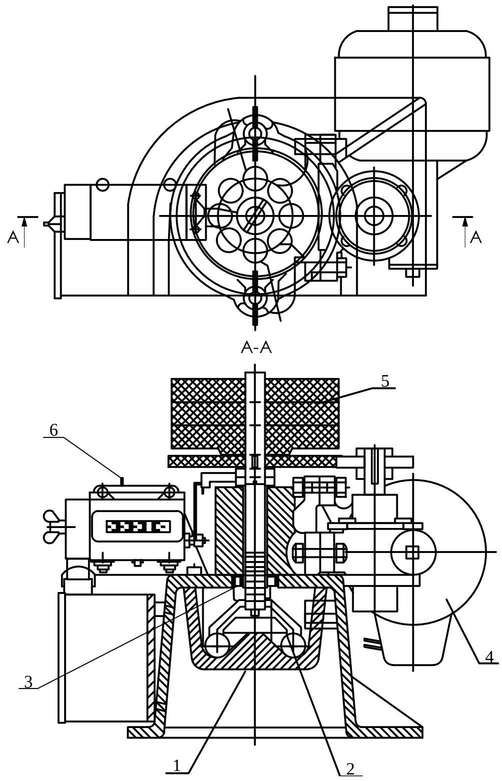

Figure 2. Hardgrove apparatus: 1 – crushing cup; 2 – pressing ring; 3 – shaft with a gasket; 4 – electric motor; 5 – loading; 6 – revolution counter

In its turn, the pressing ring is driven by a vertical shaft with a gasket *3* with the help of electric drive *4* by means of step-down gearing or, in modern models, by means of belt gearing. Additional loads *5* are applied on the vertical shaft so that the general vertical force pressing the balls and consisting of the weight of loading, shaft, upper pressing ring, and gearing mechanism, will be (29.0 ± 0.2) kg. The apparatus should be equipped with a revolution counter *6* and automatic device adjusted to stop the apparatus functioning after 60 ± 0.25 shaft rotations.

The coal sample to be used for determining the Hardgrove grindability index is crushed up to the maximum particle size of 4.75 mm (5 mm). Minimum mass of a coal sample with such crushing degree is ~ 2 kg.

An air-dried sample is screened on the sieves of 0.60-1.18 mm. Coal particles more than 1.18 mm are united and crushed until they are screened through the 1.18 mm sieve.

A sample of (50 ± 0.01) g is taken from the analyzed subsample with the particle size from 0.60 to 1.18 mm. The sample is spread uniformly in the circular hollow of a crushing cup and flattened. The upper pressing ring descends into the crushing cup and is connected with the vertical shaft. Loading is put on the upper part of the shaft; the loading mass is calculated taking into account the fact that general loading on the balls is (29.0 ± 0.2) kg. It is necessary to install a revolution meter and adjust an automatic shutdown device so that the shaft revolution stops after 60 ± 0.25 rotations. After automatic shutdown, one should remove the crushing cup and the upper pressing ring, and put the coal together with the balls into the protecting sieve inserted into the sieve with 0.075 mm openings, under which there is a closely fitting pan. Screening continues for 10 min ± 10 s.

Coal mass screened through the sieve with the opening of 0.075 mm, *m*, expressed in grams, is calculated using Formula 2:

$$m = m_1 - m_2 , \quad (2)$$

where:

m_1 – is mass of the sample selected for testing, g;

m_2 – is mass of the coal remained on the sieve with the opening of 0.075 mm, g.

HGI is determined from a calibrating curve or calculated using a calibration line equation. The final test result is calculated as the average arithmetic of the results of two determinations of HGI rounded to the nearest whole number.

Absolute difference between the results of two separate tests carried out successively in one and the same laboratory by one and the same operator involving similar equipment should not exceed the repeatability value equal to 3 un. Absolute difference between the final results of the carried out tests in different laboratories on the duplicate of one sample, obtained with the help of divider, with maximum particle size of 4.75 mm should not be more that the reproducibility value equal to 7 un.

3. Results and discussion

While analyzing the data shown in Table 1, it is possible to note that the coal used for the studies meets the stated grade belonging. The data represented in Table 1 demonstrate that the HGI values within the sampling range vary from 38 to 84 un. and crushing indices according to Protodyakonov *f* – from 0.54 to 1.37. Moreover, Table 1 shows that HGIs classify satisfactorily the coal in terms of its degree of resistance to crushing forces. Thus, it varies within the range of 38-48 un. for gas coal; 60-66 un. – for fat coal; 69-80 un. – for coking coal, and 84-86 un. – for lean baking coal.

The same can be said as for the possibility to classify adequately the coal according to its Protodyakonov grindability index *f*. For gas coal, the index is from 1.05-1.37 un.; fat coal – from 0.55 to 0.86 un.; coking coal – from 0.54 to 0.93 un.; and lean baking coal – 0.65-0.75 un.

Coefficients of pair correlation between the coal properties and values *f* and HGI are calculated for the analyzed samples (Table 2). A numerator shows values of pair correlation for *f*; a denominator demonstrates the ones for HGI.

Table 2. Coefficient of pair correlation r

Value	R_0	V^{daf}	C^{daf}	O_d^{daf}
$\lvert r \rvert$	0.693	0.586	0.771	0.798
	0.930	0.896	0.935	0.898

Basing on the indices, with which values *f* and HGI correlate, it can be concluded that the mechanical strength indices are the parameters, on which carbon content and degree of structural ordering of coal organic mass (COM) depend. An increase in its absolute value depends on the growth of general (C^{daf}) and aromatic (C_{ar}) carbon content as well as a nonsaturation degree of its structure (δ).

As Table 2 shows, values of pair correlation coefficients between the indices f and HGI as well as indices R_0, V^{daf}, C^{daf}, O_d^{daf}, characterizing coal composition and structure, are more than 0.5. Figures 3-6 demonstrates graphic dependences of indices f and HGI on the coal quality indices R_0, V^{daf}, C^{daf}, O_d^{daf}. While analyzing these graphic dependences, one can state that they are described satisfactorily by the second-order polynoms.

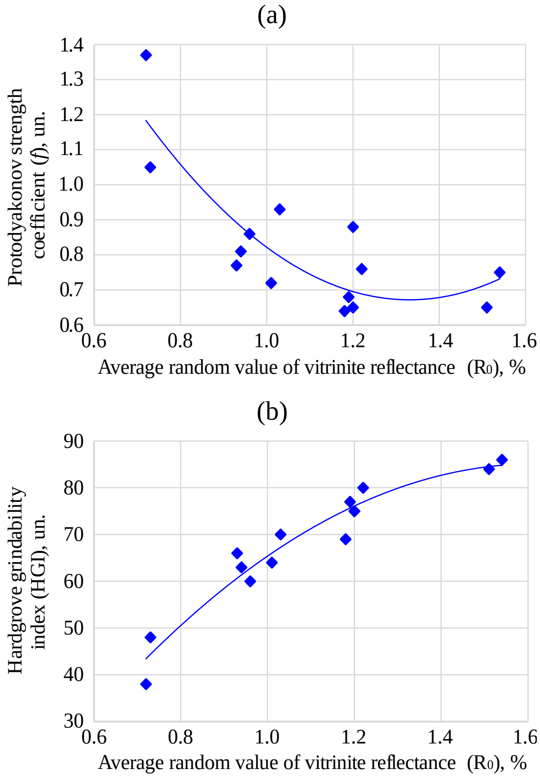

Figure 3. Effect of R_0 on coal grindability: a – f; b – HGI

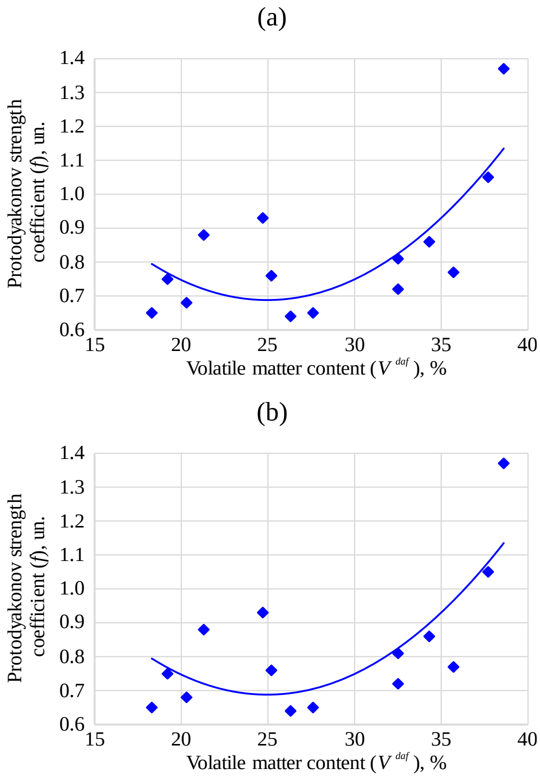

Figure 4. Effect of V^{daf} on coal grindability: a – f; b – HGI

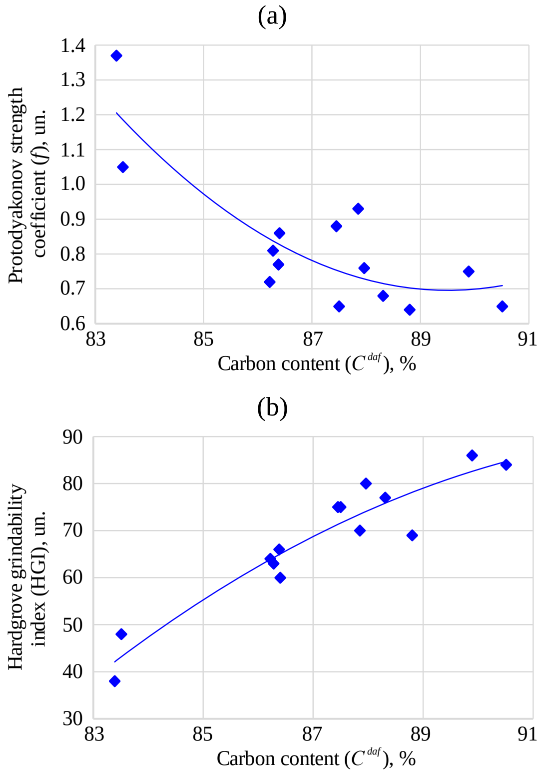

Figure 5. Effect of C^{daf} on coal grindability: a – f; b – HGI

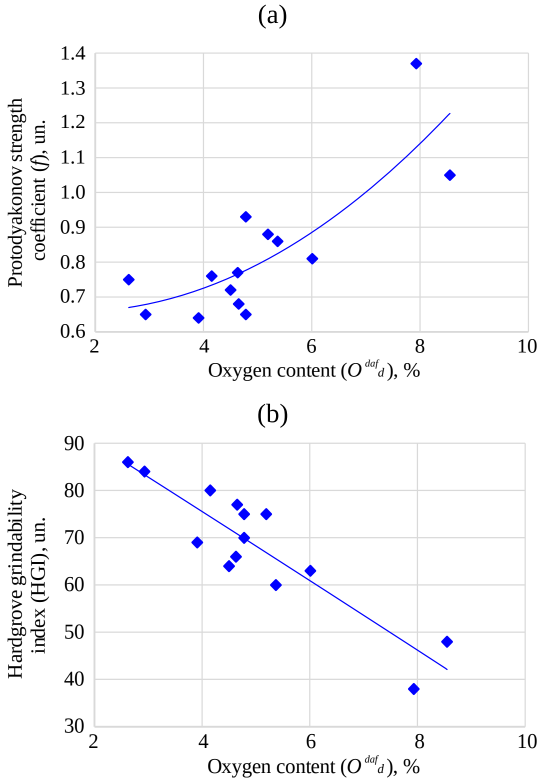

Figure 6. Effect of O_d^{daf} on coal grindability: a – f; b – HGI

Value f also decreases while HGI increases respectively to a certain degree along with the growing value of vitrinite reflectance as well as the volatile matter content of coal. It should be noted that these parameters reflect indirectly structural features of COM. Thus, a value of vitrinite reflectance is connected with the availability of one or another number of cyclic polymerized carbon in COM. The volatile matter content represents COM thermal resistance that depends on a part of aliphatic and aromatic components of its macromolecules.

Figure 7 shows a graph of dependence of strength coefficient f on the grindability index HGI, which analysis helps conclude that the two indices are interconnected, and correlation coefficient is 0.90.

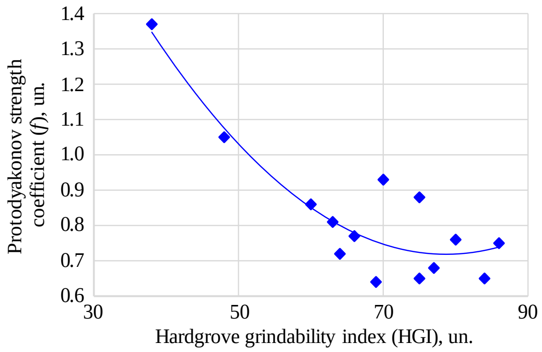

Figure 7. Effect of HGI on f

Table 3 represents mathematical Equations 1-8 and statistic evaluation of the dependences of coal properties under analysis that helps predict successfully the f and HGI indices.

Table 3. Mathematical equations and their statistic evaluation

No.	Equation type	R^2
1	$f = 1.3695 \cdot R_0^2 - 3.6455 \cdot R_0 + 3.0978$	0.711
2	$HGI = -51.754 \cdot R_0^2 + 167.42 \cdot R_0 - 50.297$	0.937
3	$f = 0.0024 \cdot \left(V^{daf}\right)^2 - 0.1199 \cdot V^{daf} + 2.1846$	0.550
4	$HGI = -0.0738 \cdot \left(V^{daf}\right)^2 + 2.487 \cdot V^{daf} + 60.081$	0.845
5	$f = 0.0136 \cdot \left(C^{daf}\right)^2 - 2.4376 \cdot C^{daf} + 109.79$	0.716
6	$HGI = -0.396 \cdot \left(C^{daf}\right)^2 + 74.843 \cdot C^{daf} - 3445.1$	0.897
7	$f = 0.0119 \cdot \left(O_d^{daf}\right)^2 - 0.0385 \cdot O_d^{daf} + 0.6895$	0.674
8	$HGI = -0.0141 \cdot \left(O_d^{daf}\right)^2 - 7.164 \cdot O_d^{daf} + 104.42$	0.807
9	$f = 0.0004 \cdot HGI^2 - 0.0599 \cdot HGI + 3.0722$	0.814

It is shown that the effect of coal quality on its Protodyakonov strength coefficient f is much lower R^2 = 0.550-0.716 than its Hardgrove grindability index HGI: R^2 = 0.807-0.937. Basing on this fact, it is better to use the Hardgrove method to predict coal grindability rather than the Protodyakonov one. The last equation presented in Table 3 shows that allows predicting coal grindability in terms of one value of the two. It is the first time when the relation between these two methods has been identified.

It should be noted that this fact proves the previously obtained conclusions [18] that all indices of coal mechanical properties are interconnected by the correlation relationships. Relying on that, strength identification may require the use of any objective method, i.e. a pounding method based on the degree of coal breaking per one breaking operation. For these purposes one can apply a headframe method (like the Protodyakonov method in our study), crushing in a cylinder or grinding (the Hardgrove method) with the evaluation of a coal grindability index that represents the ratio of energy consumption for crushing of both analyzed and reference fuels. A grindability index is used to assess productivity of crushing devices while solid fuel crushing in them.

The findings confirm also the earlier ones [19], concerning the fact that coal oxidation results in reduced HGI index due to chipping of the oxidized particles while preparing sample conditioning (Fig. 6b).

The obtained results also prove that there is certain limit of coal strength weakening expressed by f, HGI or any other indices with the increasing degree of its metamorphism. It may be that strength weakening or a growing grindability index while coal transferring to a medium metamorphism stage is connected with shortening of lateral chains of macromolecules and oxygen elimination in the form of carbon dioxide and water. That weakens the structure due to reduced chemical bonds through oxygen bridges and decreased role of hydrogen bonds. The gained strength of highly metamorphosed coal is explained by growing carbon networks with the orientation of parallel networks into packets and growing internuclear bonds formed by carbon valencies.

Minimum coal hardness of a medium metamorphism stage is explained by the fact that at this stage both opposite processes balance each other. The obtained results are confirmed in study [20] where it is defined that for 66 coal samples characterized by a range of vitrinite reflectance index changes from 0.85 to 0.90%, growth in the content of macerals of a leptynite group results in the reduced HGI parameter. Thus, it is highlighted that leptynite resists crushing while other macerals are rather crushable [21].

We consider that further it is of practical interest to identify whether the Hardgrove grindability index is an additive parameter for coal mixtures or not. That will favour the formation of basic principles of grindability determination for real industrial coal mines with the help of this method.

4. Conclusions

Qualitative parameters of 14 coal samples characterized by different metamorphism degree, technical analysis, petrographic, plastometric, and ultimate composition as well as grindability index have been defined.

It has been shown that the Hardgrove grindability index classify sufficiently the coal in terms of its resistance of crushing forces. The HGI values vary within the range of 38-48 un. for a gas coal group; 60-66 un. – for a fat coal group; 69-80 un. – for a coking coal group, and 84-86 un. – for a lean and baking coal group.

The same can be said concerning the possibility of adequate coal classification in terms of Protodyakonov grindability index f. For a gas coal group, this parameter varies within the range from 1.05 to 1.37 un.; for a fat coal group – from 0.55 to 0.86 un.; for a coking group – from 0.54 to 0.93 un.; and for a lean and baking coal group – from 0.65 to 0.75 un.

For the first time, a relation between the Protodyakonov strength coefficient and the Hardgrove grindability index has been identified. It has been shown that the influence of coal quality on its Protodyakonov hardness coefficient f is much lower (R^2 = 0.550-0.716) than on the Hardgrove grindability index HGI: R^2 = 0.807-0.937.

Graphic and mathematical dependencies have been developed making it possible to predict the Protodyakonov (f) and Hardgrove (HGI) coal grindability basing on the coal quality indices (R_0, V^{daf}, C^{daf}, O_d^{daf}).

It has been specified that the values of HGI and f are inversely proportional; a mathematical and graphical dependence of their prognosis has been developed basing on one of their value.

Acknowledgements

The authors express their gratitude to the Ukrainian State Research Institute for Carbochemistry for giving their laboratory equipment.

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Вплив показників якості вугілля на його розмолоздатність

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Мета. Визначення впливу показників якості вугілля, що характеризується різними значеннями ступеня метаморфізму, петрографічного та елементного складу, на величини його розмолоздатності, що визначаються методами Про-тод'яконова та Хардгрова

Методика. Досліджено 14 проб вугілля, що входить до сировинної бази коксохімічних підприємств України. В цих пробах були визначені показники технічного, петрографічного та елементного аналізів. Для визначення розмолоздатності вугілля використовували ГОСТ 21153.1-75 Породи гірські. Метод визначення коефіцієнта міцності згідно Протод'яконову та ISO 5074:2015 Вугілля кам'яне. Визначення коефіцієнта розмолоздатності здійснювали згідно Хардгрову. Розроблено графічні та математичні залежності між показниками якості вугілля (R_0, V^{daf}, C^{daf}, O_d^{daf}) та значеннями його розмолоздатності (f та HGI).

Результати. Отримані математичні та графічні залежності впливу різних показників якості вугілля (R_0, V^{daf}, C^{daf}, O_d^{daf}) на значення їх розмолоздатності (f та HGI). Показано, що залежність показників якості вугілля з коефіцієнтом їхньої міцності (f) значно нижча (R^2 = 0.550-0.716), ніж з коефіцієнтом розмолоздатності згідно Хардгрову (HGI): R^2 = 0.807-0.937.

Наукова новизна. Вперше проведено порівняльні виміри розмолоздатності вугілля методами Протод'яконова та Хардгрова. Встановлено, що значення цих показників обернено-пропорційні та описуються поліномом другого ступеня.

Практична значимість. Отримані графічні та математичні залежності можуть бути використані для прогнозування роботи дробильного обладнання при подрібненні як індивідуальних, так і сумішей вугілля різного марочного й компонентного складів на коксохімічних і теплогенеруючих підприємствах.

Ключові слова: *вугілля, вихід летких речовин, мацерали, метаморфізм, подрібнення, вітриніт, розмолоздатність*