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ANALYSIS OF COAL CONCENTRATE QUALITY INDEX EFFECT ON STRENGTH POWER OF COAL COKE

Qualitative effect of coal charge indicators on the properties of final coke is analyzed. In order to determine quantitative regularities the statistical analysis of the coking process by using a passive experiment is conducted. Magnitude of the effect (in percentage) of changes in the number of components of coal charge on the quality of coal coke at various technologies of its densification is obtained.

Key words: *coal coke, charge coal, reactive capacity, coke strength reactivity after reaction with CO_2, statistical analysis.*

Operational experience of modern blast furnaces shows that in terms of frequent use of pulverized coal fuel (PCF) a coke must have high values of M_{10} and M_{25} (M_{40}), have a low coke reactivity index (CRI) and high coke strength reactivity (CSR) after reaction with CO_2, and also contain a small amount of sulfur.

Most scholars among properties of coals and charge coals, which greatly affect quality of the resulting coke, define volatile content, densification of charge coal, petrographic characteristics, ash content, sulfur content, as well as technological regime of coal preparation [1, 2].

To compare the quality of source material Table 1 shows the indicators of coal washing products of coal K and coal charge from leading foreign manufacturers (according to UKHINa) [3].

As it has been stated above, the quality of coke mainly depends on the properties of coals and charge coals in terms of average vitrinite reflectance. Currently it is known that the hardest coke is obtained usually from coals of Donbass and charge coals based on those coals, which have the value of reflectance approximately 1-1.2%. According to this indicator domestic coals are not inferior to imported ones (Table 1).

A significant effect on coal densification has a plastometric analysis and foremost on the thickness of the plastic layer y in mm. It is known [4] that the individual coals G and K, and the charge coal on their basis, having the thickest plastic layer, give hard coke. The value of this indicator of coals "K" on average corresponds to the same value of charge coals from the leading foreign manufacturers (Table 1).

Indicator of volatiles on dry ash free fuel basis (V^{daf}) is one of the main characteristics when the coals are shipped for coking and when developing coal charge composition. Numerous studies have demonstrated the interaction of this parameter with an output of coke and chemical products [5]. However volatile content can be close or even the same in coals and their mixtures, having quite different technological properties. According to Table 1 considerable differences in V^{daf} of imported and domestic charge coals are not observed.

Thus, a preliminary analysis has shown that the main indicators, characterizing the properties of charge coal to densification are the thickness of the plastic layer, the average vitrinite reflectance and volatile content.

Also of special importance is the influence of coal concentrates humidity on the strength of coke produced, since this indicator, as well as densification, is one of the important technological and economic indicators of their quality and value.

Table 1 — Average indices of coal K benefication products and coal charge from the leading foreign manufacturers

Index	Parameters of coals «K» *	Leading Foreign Manufacturers	
		coal charge	coke
Ash-content A^d, %	6.6-9.8	<8.5	<11
Sulphur S_t^d, %	0.5-2.8	<1.0	<0.8
Volatile content V^{daf}, %	22-28.7	23-27	<1.0
Index of vitrinite reflectance R_0, %	1.05-1.43	>1.1	-
Basicity index of coal charge ash $i_{b.ch.}$	8-16	<2.5	-
Thickness of plastic layer y, mm	10-23	>16	-
Physical strength of coke, %: M_{25} M_{10}	-	-	 88-89 6.5-7.0
Reactivity index CRI, %	-	-	20-30
Strength reactivity CSR, %	-	-	55-65

* According to the indicators from: Washhouse (WH) Branch of JSC “Donetskstal” MP SWH “Samsonovskaya”, OJSC “KDU”, PJSC CWH “Kalinin” PJSC CWH “Uzlovskaya” SE “Artyomugol”, PJSC “Mine management “Donbass”, mine “Shcheglovskaya-Hlubokaia”

Due to increased humidity of coal charge its pour density decreases and, consequently, the value of a single load of coke ovens, which is accompanied by deterioration of its density uniformity in the coke drum. Heat rate on coking because of additional moisture evaporation also increases [6].

This implies that the moisture of the coal charge is also a very important indicator affecting the coking process and thus the quality of the product.

Along with all the above mentioned for the production of coke coal charge is generated, which in its turn, according to technological functions, is conditionally divided into three groups: sintering charge coal basis, less metamorphized filler components and high-grade components. They make a mixture of specific technical strength, which depends on the correlative amounts of each component.

For example, to form a charge coal there is a method [7], which allows to find the optimal ratio of incoming coal concentrates (using any set) to obtain the highest possible quality of coke for blast furnace production, while taking into account the characteristics and needs of coke production technology. This method, according to the claims of the authors, enables to precisely calculate the qualitative characteristics of coke on the basis of chemical and petrographic parameters of the coal charge.

Thus, from the given analysis it is evident that there are quite many methods to optimize the composition of the coal charge and obtain the coke of the highest quality. Along with it may be noted, that currently only qualitative parameters of coal charge dependences on the strength properties of coke are described. It does not allow to assess to the full extent the impact of quantitative changes in the contents of a particular starting material component on physical and chemical properties of the final product.

Technologists and coke chemists, making the mixture of coal charge, tend to stick to specific components of its composition, based on existing methods or manufacturing experience. At the same time it is important to know how much indicators of coke strength will change in case if optimal composition of the initial charge coal deviates.

To identify the quantitative impact of coal concentrate indicators on the quality of the coke a passive experiment has been carried out. The used coke production technology has a significant impact on its physical and chemical characteristics, so the analyzed data are divided into three nominal groups by types of coke produced: dry-quenched, wet - quenched and compressed coal charge coke.

This paper investigates performance indicators of the local coke-chemical plant according to the following parameters: moisture content, ash, sulfur, volatile substances, volume weight of the coal charge, plastometric analysis (x, y). 60 days of coke-oven batteries work have been analyzed.

The analysis has been conducted by means of mathematical statistics. To use pair correlation is not appropriate here, because it does not take into account the influence of other variables on the investigated value. In this regard, the module of multiple regression is chosen for research.

Reliability of achieved results has been evaluated by the coefficient of determination, which takes into account the influence of other variables (Adjusted R^2), the values of significance point (p-value) and Student t-test. Parameter Adjusted R^2 shows correlation ratio, and the closer it to 1, the more considerable ratio is between the values researched. The statistical unreliability between investigated parameters is determined by the values of p-value and Student t-test coefficients.

At the first stage of the analysis as the affecting variables are taken all indicators of coal charge on which the corresponding correlation is based.

During the second stage of the research coal charge parameters, with p-value exceeding Student t-test (evidence of poor correlation) have been eliminated, and that enabled to improve the value of Adjusted R^2.

Analysis has been stopped at the maximum coefficient of determination, which takes into account the influence of other variables.

As a result the character of influence of coal charge components on the quality of coke has been determined (Table 2).

Average coefficient of determination, which takes into account the influence of other variables for all results, amounted 0.611, the value, which suggests a high correlation ratio.

In general, it is clear, that the nature of influence of coal charge components on the quality of coke, revealed in the course of study, corresponds to the existing concepts, which proves sufficient reliability of the analysis. Despite this there are some insignificant contradictions in the work, which are mostly manifested in the impact of plastometric x and y indicators on various coke production technologies. The increase of x in wet-quenched coke production reduces the CSR value, while production of dry-quenched coke increases the CSR value, and in charge coal compressing has no impact at all.

The second serious contradiction is manifested in correlation of volatile content and qualitative characteristics of coke produced by different methods. As it is seen from Table 2, physico-chemical properties of the coke made of compressed charge coal, are not influenced by volatiles.

According to regression equations made up by the analysis results, the effect of changes in the number of coal charge components on the quality of coke conventional unit (average for all indicators) at various technologies of its sintering is assessed (Figure 1).

Figure 1 shows that the greatest influence on the quality of the coke produced has charge coal volume weight. At wet and dry quenching those values have been 45 and 42% respectively and for compressed charge coal it is 25%. This variation may be explained by increased packaging density of the source material in the coke oven battery at compressing, which results in altering the degree of charge coal volume weight influence on the quality of coke obtained.

Dry and wet quenching coke manufacturing requires greater attention to the content of ash, volatiles and plastometric shrinkage. Sintering of compressed charge coal is focused on the control over plastometric analysis indicators and the amount of ash.

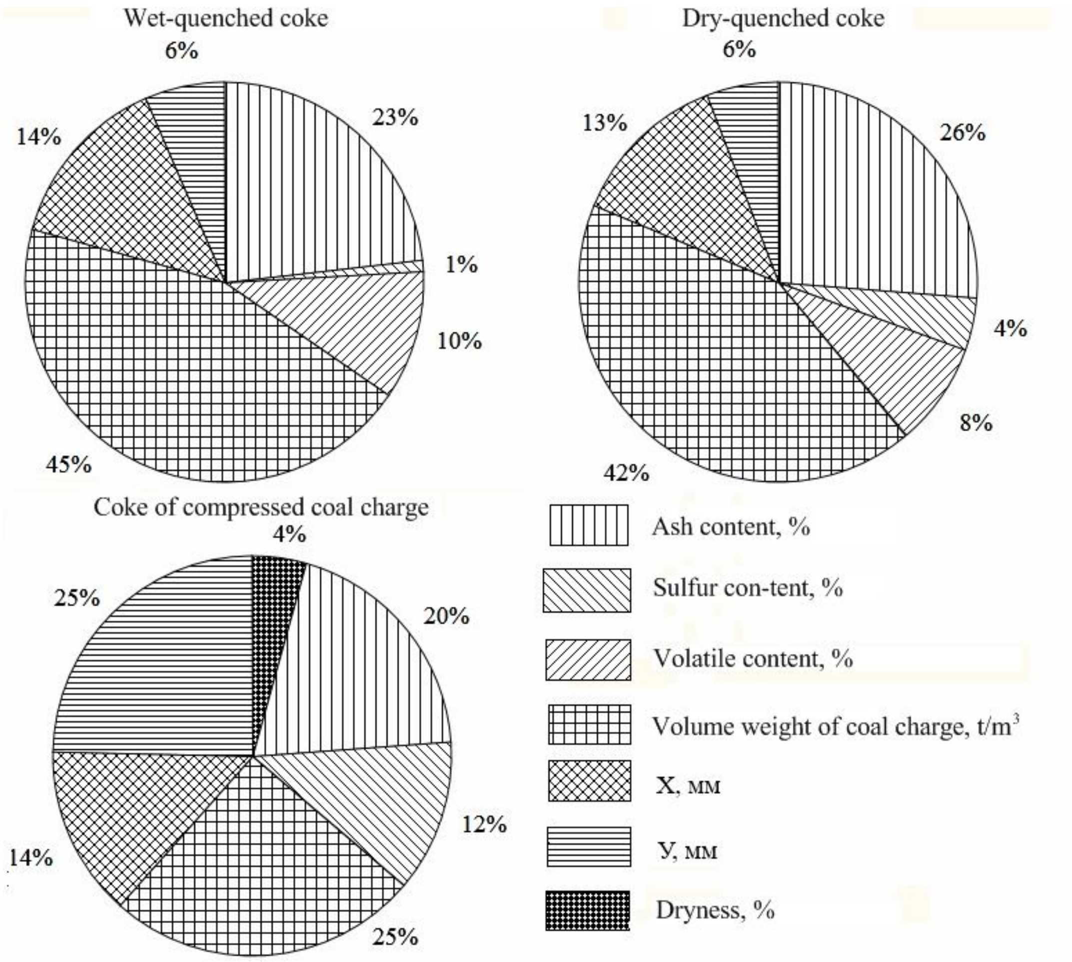

Figure1 — Magnitude of the effect (in percentage) of changes in the number of components of coal charge on the quality of coal coke at various technologies of its densification

Table 2 — The nature of the effect of coal charge components on the quality of coke at various technologies of its densification

Coke-quality index	Indices of coal charge						
	Dryness, %	Ash con-tent, %	Sulfur con-tent, %	Volatile con-tent, %	Volume weight of coal charge, t/m^3	X, mm	У, mm
Wet-quenched coke							
CSR	x	–	x	+	+	–	–
CRI	x	+	x	–	x	+	+
M_{10}	x	+	–	–	–	+	x
M_{25}	x	–	+	+	+	–	x
Dry-quenched coke							
CSR	x	–	x	+	+	+	–
CRI	x	+	+	–	x	+	x
M_{10}	x	+	+	–	–	+	–
M_{25}	x	–	+	+	+	–	x
Coke of compressed coal charge							
CSR	–	x	–	x	+	x	+
CRI	x	–	+	x	x	–	+
M_{10}	+	+	–	x	x	+	+

x — means non-adhesion; + — positive effect; – — negative effect.

Table 3 — Variability of CSR and CRI in terms of coal charge indices decline

Coke-quality index	Indices of coal charge						
	Dryness (alteration 1 %), %	Ash content (alteration 1 %), %	Sulfur content (alteration 0.1 %), %	Volatile content (alteration 1 %), %	Volume weight (alteration 0.01 t/m^3), %	X (alteration 1 mm), %	У (alteration 1 mm), %
Wet-quenched coke							
CSR, %	0	5.11	0	-0.57	-1.54	0.89	1.26
CRI, %	0	-2.61	0	0.62	0	-0.70	-1.10
Dry-quenched coke							
CSR, %	0	6.10	0	-0.40	-1.10	0.85	0.00
CRI, %	0	-2.64	-0.37	0.34	0	-0.53	0
Coke of compressed coal charge							
CSR, %	1,30	0	1.06	0	-1.88	0	-1.37
CRI, %	0	1.75	-1.06	0	0	-0.27	1.09

Conducted researches have allowed to determine the quantitative change in the quality of coke under varying conditions. Magnitude of deviation of CSR and CRI values at alteration of charge coal indicators is displayed in Table 3. Represented numbers correspond to reducing of moisture, ash, an volatiles content by 1%, and sulfur and bulk weight to 0.1%, 0.01 t/m^3.

Table 3 shows that the value of the post-reaction strength index, when pressed charge coal in coke production is used, varies within the range from 1.06 to 1.88. The decrease in volume weight by 0.01 t/m^3 reduces the value of CSR to 1.88%. For the coke, produced without pressed charge coal, this value is 1.54%. The greatest difference in quality of the final product between various technologies of its production can be observed under ash content rejecting. So, under 1% reduction of its amount for coke made by dry and wet-quenching technologies, a post-reaction strength increases by 5.11% and 6.1%, respectively.

The data obtained allow to evaluate operatively the change in the CSR and CRI under fluctuating parameters of the charge coal.

Thus, this paper investigates the indicators of the local coke plant operation on the following parameters: moisture, ash, sulfur, volatile content, volume weight of charge coal, plastometric (x,y) analysis with the help of mathematical statistics.

The nature of influence of coal charge components on the quality of coke is introduced.

By regression equations, made up after analysis, the effect of the coal charge components on changes in quality of obtained standard unit coke (average at all parameters) at various technologies of its densification is evaluated.

The data of CSR and CRI deviation value considering alteration of coal charge parameters are obtained.

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АНАЛИЗ ВЛИЯНИЯ ПОКАЗАТЕЛЕЙ КАЧЕСТВА УГОЛЬНОГО КОНЦЕНТРА НА ПРОЧНОСТЬ ПОЛУЧАЕМОГО КОКСА

Проанализировано качественное влияние показателей угольной шиситы на свойства получаемого кокса. С целью определения количественных закономерностей проведен статистический анализ процесса коксования при помощи пассивного эксперимента. Получена величина влияния (в процентах) изменения количества компонентов угольной шихты на качество получаемого кокса при различных технологиях ее спекания.

Ключевые слова: *кокс, угольная шихта, реакционная способность, прочность после реакции с CO_2, статистический анализ.*

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АНАЛІЗ ВПЛИВУ ПОКАЗНИКІВ ЯКОСТІ ВУГІЛЬНОГО КОНЦЕНТРАТУ НА МІЦНІСТЬ ВИГОТОВЛЕНОГО КОКСУ

Проаналізовано якісний вплив показників вугільної шиїти на властивості виготовленого коксу. З метою визначення кількісних закономірностей проведено статистичний аналіз процесу коксування за допомогою пасивного експерименту. Отримано величину впливу (у відсотках) зміни вмісту компонентів вугільної шихти на якість одержуваного коксу при різних технологіях її спікання.

Ключові слова: *кокс, вугільна шихта, реакційна здатність, міцність після реакції з CO_2, статистичний аналіз.*