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INVESTIGATION OF POSSIBLE LOSSES OF COAL RAW MATERIALS DURING ITS TECHNOLOGICAL PREPARATION FOR COKING
MESSAGE 2.THE ACTUAL MASS VARIATION OF COAL IN THE PROCESS OF ITS STORAGE AND CRUSHING

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Abstract

The authors of the article conducted a comprehensive study aimed at determining the actual mass loss of coal concentrates during their preparation and the coal charge during its transportation to the coal tower. As a result of carrying out the actual definitions of moisture changes of incoming coal on the path of a car dumper – a silo of a closed warehouse, coal, and coal charge on the crusher path - coal tower of coke oven batteries in the summer, it was established that the loss of moisture in coal concentrates during transportation significantly depends on the ambient temperature: the higher the temperature, the more moisture is lost, and vice versa.
It was determined that the unloading and transportation of coal to a silo of a closed coal warehouse is accompanied by a loss of ~ 0.9% moisture at an ambient temperature of 23.5° C and ~ 0.2% at a temperature of +4°C. When crushing and transporting the coal batch to the coal tower of the coke oven battery, the variation its actual weight is ~ 0.1% at an ambient temperature of +4° C and ~ 0.7% at an ambient temperature of 23.5–25.5° C

***Keywords**: coal concentrates; temperature condition; coal transportation scheme; mass variation; moisture.*

1. Introduction

The coal raw material base of the coke production of PrJSC Avdeevskii coke plant, like the majority of the coke enterprises of Ukraine, has a multi-basin character, and the share of domestic raw materials is about 20%. The increase in the share of imported coal (coal concentrates in Russia, and the United States) is associated both with a shortage of Ukrainian coal of suitable quality (low sulfur content, $I_0 \leq 2.5$ basicity index), and with an increase in the quality requirements for coke to reduce its consumption in blast smelting, as well as in connection with the introduction of pulverized coal injection technology in blast furnace production [1].

Under the conditions of the formed multi-basin raw material base of coking, it is necessary to improve the basic technological methods of preparation for their use in coal mixtures. Achieving optimal characteristics of coke for blast furnace smelting conditions is possible with a comprehensive, scientifically based approach to improving the technology of preparing coal for coking, which consists in developing methods and technological measures aimed at optimizing the composition, properties and degree of grinding of the batch, taking into account its petrographic characteristics [2-3].

The supply of foreign coal due to the considerable distance of suppliers takes quite a long time, including long-term transportation by water transport, during which they undergo an oxidation process, which leads to changes in their technological properties [4-5] and requires compliance with the developed recommendations on the use of oxidized coal for the production of blast-furnace coke [6].

It should be noted that during transportation and technological operations for the preparation of coal raw materials for coking (storage, crushing) its humidity changes. Thus, Ukrainian suppliers supply coal concentrates with the moisture of more than 10%. When the ambient temperature rises, the moisture evaporates intensively, which leads to the loss of the total mass of coal concentrates.

In general, the above circumstances lead to a discrepancy in the balance of the coal preparation workshop in part of the mass of incoming coal concentrates and the mass of the finished coal batch to the tower. Based on the above, it became necessary to determine the actual mass loss of coal concentrates during their preparation and the coal batch during its transportation to the coal tower.

2. Results and discussions

Currently, in the raw materials base of the coal preparation department PJSC Avdeevskii coke plant ("AKHZ"), there are coals of both the neighbor (Uskovskaya mine, Shchedrukhinskaya Central Processing Plant, Section Bochatsky, Berezovskaya) and long-distance (Carter Roag, Goonyella, Toms Creek) abroad. Coal concentrates of the above suppliers in the process of transportation over long distances can lose moisture, which entails the actual loss of their mass.

The analysis showed that coal moisture loss can occur when coal is unloaded from coal cars on wagon tipplers, when coal is pumped into a silo of a closed coal storage, during storage in silos of a closed coal storage, during their dosing and transportation to the coal batch crushing department, as well as further transportation of the coal batch to the coal towers.

Studies have been performed to determine changes in the moisture content of coal concentrates during their transportation from the car dumper to the top of the coal preparation warehouse silos as well as during the crushing of coal in the coal preparation shop.

For the study, 8 coal concentrates of various degrees of metamorphism were selected, which were part of the raw materials base of the coal preparation department PJSC Avdeevskii coke plant, namely:
- Shchedrukhinskaya coal, Russia, coal rank "G";
- Uskovskaya coal, Russia, coal rank "GZh";
- Carter Roag coal, USA, coal rank "Zh";
- Toms Creek coal, USA, coal rank "Zh";
- Svjato-Varvarinskaya coal, Ukraine, coal rank "K";
- Goonyella coal, USA, coal rank "K";
- Berezovskaya coal, Russia, coal rank "KO";
- Section Bochatsky, Russia, coal rank "KO."

The quality indicators of technical, plastometric, petrographic, and granulometric analysis of the investigated coal concentrates are given in Tables 1–3.

Coal concentrates Shchedrukhinskaya and Uskovskaya are characterized by an increased volatile matter (37.5% and 38.3%) with a low value of the content of total sulfur – 0.54% and 0.43%. The components of vitrinite mainly (91.0% and 88.0%) correspond to the stages of metamorphism of DG and GZh coal. This coal can be attributed to the hard group, as the coefficient of Hardgrove grindability index (HGI) is 55 units and 54 units. The mean particle diameter (d_{me}) is 9.67 and 5.33 mm.

Coals rank "Zh" Toms Creek and Carter Roag are characterized by an average total sulfur content of 0.98 and 0.96%, and the vitrinite components are mainly located in the stages of metamorphism of the "DG," "GZhO" and "Zh" ranks.

The petrographic analysis showed that the content of vitrinite is 70.0 and 66.0%, and the sum of the fusinized components is 25.0 and 26.0%, respectively. The mean particle diameter, respectively, is 8.48 mm and 4.89 mm. The values of the Hardgrove grindability index are 68 and 67 units, which classifies these coals as transitional from soft to hard in terms of hardness.

Table 1. Technological properties of coal concentrates Avdeevskii coke plant

Component; country	Coal rank	Proximate analysis, %			Thickness of plastometric layer, mm	Hardgrove grindability index (HGI), units
		A^d	S^d_t	V^{daf}	y	
April						
Shchedrukhinskaya coal, Russia	G	7.5	0.54	37.5	12	55
Toms Creek coal, USA	Zh	7.6	0.98	35.5	18	68
Svyato-Varvarinskaya coal, Ukraine	K	8.7	0.77	27.8	16	82
Section Bochatsky coal, Russia	KO	7.0	0.45	24.8	10	67
August						
Uskovskaya coal, Russia	GZh	7.3	0.43	38.3	17	54
Carter Roag coal, USA	Zh	8.1	0.96	33.7	21	67
Goonyella coal, USA	K	9.1	0.50	26.1	18	72
Berezovskaya coal, Russia	KO	7.7	0.52	25.3	12	62

Table 2. Petrographic characteristics of coal concentrates Avdeevskii coke plant

Component; country	Coal rank	Petrographic composition (without mineral impurities), %					Mean vitrinite reflection coefficient, %	Distribution of vitrinite reflection coefficient, %						
								<0,50	0,50-0,79	0,80-0,89	0,90-1,19	1,20-1,49	1,50-1,69	1,70-2,59
April														
		Vt	Sv	I	L	∑FC	R_o							
Shchedrukhinskaya coal, Russia	G	69	1	29	1	30	0.68	3	91	6	0	0	0	0
Toms Creek coal, USA	Zh	70	0	25	5	25	0.93	0	25	27	41	7	0	0
Svyato-Varvarinskaya coal, Ukraine	K	88	1	8	3	9	1.16	0	0	0	68	32	0	0
Section Bochatsky coal, Russia	KO	42	2	55	1	57	1.06	0	0	9	82	9	0	0
August														
Uskovskaya coal, Russia	GZh	94	0	5	1	5	0.73	0	88	12	0	0	0	0
Carter Roag coal, USA	Zh	66	0	26	8	26	0.93	0	0	36	64	0	0	0
Goonyella coal, USA	K	79	0	21	0	21	1.13	0	0	0	84	16	0	0
Berezovskaya coal, Russia	KO	45	2	51	2	53	1.04	0	0	3	93	5	0	0

Table 3. Granulometric composition of coal concentrates Avdeevskii coke plant

Component; country	Coal rank	Granulometric composition (%) by class (mm)									Mean particle diameter, mm
		>50	50–25	13–25	6–13	3–6	1–3	0,5–1	<0,5	<3	d_{me}
April											
Shchedrukhinskaya coal, Russia	G	1.9	8.6	11.6	21.6	18.6	17.2	6.7	13.8	37.7	9.67
Toms Creek coal, USA	Zh	0.7	7.8	14.1	18.2	14.5	17.1	8.6	19.0	44.7	8.48
Svyato-Varvarinskaya coal, Ukraine	K	0.0	4.8	11.3	19.0	15.8	17.9	8.1	23.1	49.1	6.49
Section Bochatsky coal, Russia	KO	5.0	18.4	17.0	14.5	12.1	12.8	6.4	13.8	33.0	15.67
August											
Uskovskaya coal, Russia	GZh	0.0	0.0	10.6	28.9	15.5	18.6	6.3	20.1	45.0	5.33
Carter Roag coal, USA	Zh	0.0	3.1	6.5	14.4	18.8	23.1	9.2	24.9	57.2	4.89
Goonyella coal, USA	K	0.0	3.2	7.0	15.3	15.7	18.5	9.3	31.0	58.8	5.21
Berezovskaya coal, Russia	KO	10.0	6.0	10.0	15.1	13.0	14.6	7.8	23.5	45.9	13.7

Table 4. The variation of moisture content of coal concentrates in the process of transportation in condition the raw material base Avdeevskii coke plant

Component; country	Coal rank	Moisture W^r_t, %		ΔW^r_t, %
		After car dumper	Top silo	
April				
Shchedrukhinskaya coal, Russia	G	10.3	10.1	0.2
Toms Creek coal, USA	Zh	7.4	7.1	0.3
Svyato-Varvarinskaya coal, Ukraine	K	9.8	9.6	0.2
Section Bochatsky coal, Russia	KO	8.9	8.7	0.2
Mean loss of moisture	–	–	–	0.2
August				
Uskovskaya coal, Russia	GZh	10.0	9.1	0.9
Carter Roag coal, USA	Zh	7.8	7.0	0.8
Goonyella coal, USA	K	7.8	7.3	0.5
Berezovskaya coal, Russia	KO	10.1	8.7	1.4
Mean loss of moisture	–	–	–	0.9

Coal rank "K" Svyato-Varvarinskaya and Goonyella are petrographically homogeneous: the content of vitrinite is 88.0 and 79.0%, and the sum of fusinized components is 9.0 and 21.0%, respectively. The components of vitrinite mainly correspond to the stages of the metamorphism of "Zh" and "K" coal rank. Coals can be attributed to the soft group since their coefficient of Hardgrove grindability index is 82 and 72 units; the mean particle diameter coals are 6.49 and 5.21 mm.

Coals rank "KO" Bochatsky and Berezovskaya are characterized by a low value of the volatile matter (24.8–25.3%) and a low content of total sulfur (0.45–0.52%). The coals studied are petrographically heterogeneous: the content of vitrinite is (42.0–45.0%), and the content of fusinized components (57.0–53.0%). The components of vitrinite are predominantly concentrated in the middle stage of metamorphism. These coals, along with bituminous coal with a high level of fluidity coal of Toms Creek, are characterized by a transitional level of hardness — the Hardgrove grindability index is 62–67 units. The mean particle diameter coal is 13.70–15.67 mm.

The study to determine the variation in moisture content during the transportation of the above coals was carried out as follows: the conveyor stopped, the coal concentrates from the car dumper to the top of the silo of the closed coal store, and at the same time coal samples (80–100 kg) were taken directly from conveyors.

It should be noted that the weather conditions during the sampling of coal samples differed significantly. In April 2017, the ambient temperature was +4°C, and in August 2017 it rose to +23.5°C. Table 4 shows data of changes moisture content in coal concentrates. Analyzing the data, we can conclude that the loss of moisture in the coal concentrates in the process of their transportation in April amounted to a mean of 0.2%, and in August – 0.9%.

Based on the foregoing, it can be concluded that moisture loss in coal concentrates substantially depends on the ambient temperature: the higher the temperature, the more moisture is lost during transportation of coal concentrates and vice versa. This circumstance must be taken into account when removing the remnants of coal raw materials in the coal preparation department of the coke plant.

Taking into account the present level of coal processing in the coal preparation department (~ 265,000 t/month), the variation in the actual weight of the coal can be in winter time ~530 t/month; in summertime ~2 385 t/month.

To assess the change in humidity during the crushing of coal batch (entering the coke battery 9), samples were taken to determine the working moisture, before crushing, after crushing, and before the coal towers of coke oven batteries. After the selection, coal concentrates were delivered to the control department of the Quality Control Department and immediately disassembled according to the accepted method and transferred to the Central Laboratory of the Plant to determine the moisture in them.

Table 5 shows the variation of moisture content in coal blends (entering the coke battery 9) the coal preparation department PJSC "AKHZ," in the process of their transportation from the silo of closed coal storage to the coal tower of the coke oven battery.

Table 5. The variation of moisture content of coal batches entering the coke battery 9 Avdeevskii coke plant in process its preparation

Battery	Date	Moisture W^r_t, %					ΔW^r_t, %
		Line, load, t/hour		Calculated before crushing	After crushing	Before coal tower	
		A	B				
9	19.04	8.9/234	8.7/366	8.8/600	8.8	8.8	0.00
9	20.04	8.8/264	8.6/336	8.7/600	8.8	8.7	0.10
mean							0.1
9	28.06	8.5/240	8.3/360	8.38	8.2	7.7	0.68
9	09.08	7.5/228	8.8/372	8.31	8.1	7.6	0.71
mean							0.7

The study was conducted as follows: the conveyor stopped, feeding the coal concentrates from the silos of the closed coal storage to the crushing, and then, taking into account the load on the belt, the mean dynamic moisture value of the entire coal batch was calculated, along with them the conveyor after the crusher and the conveyor also stopped. The coal tower was used to collect coal samples (1 meter) weighing 80–100 kg directly from the conveyors mentioned above.

After the delivery of coal concentrates to the control center of the Quality Control Department, they were promptly disassembled according to the accepted method and transferred to the Central Laboratory of the Plant to determine the working moisture in them.

The results of determining the moisture content of coal batch samples, made in April (ambient temperature + 4°C) showed that the moisture content of the coal batch in the process of its preparation does not change (ΔW^r_t = 0.1%).

The results of determining the humidity of coal batch samples in the summer showed that the loss of moisture was ~ 0.7%: 0.68% in June and 0.71% in August. The experiment was carried out at mean daily temperatures of 25.5°C and 23.5°C, respectively.

Taking into account the present level of coal processing in the coal preparation department, the variation in the actual weight of the batch can be in winter ~ 265 t/month; in the summer ~ 1 855 t/month.

3. Conclusions

As a result of the actual measurements of the moisture change of incoming coal in the path of the car dumper - silo of the closed coal and coal batch in the path of the crusher - coal tower of coke oven batteries in different temperature conditions, we formulated the following conclusions:

1. Moisture loss in coal concentrates during their transportation significantly depends on the ambient temperature: the higher the temperature, the more moisture is lost, and vice versa. It was established that unloading and transportation of coal to the silo of a closed coal warehouse is accompanied by a loss of ~ 0.9% moisture at an ambient temperature of 23.5°C and ~ 0.2% at a temperature of +4°C.
2. When crushing and transporting the coal batch to the coal tower of a coke oven battery, the variation in its actual weight is ~ 0.1% at an ambient temperature of +4°C and 0.7% at an ambient temperature of 23.5–25.5°C.
3. The results of research should be taken into account when measuring residues of raw materials, materials, and products in warehouses in coal preparation department of coke plants.

Symbols

W^r_t	*moisture content of coal, %;*
A^d	*ash content of coal in the dry state, %;*
S_t^d	*sulphur of coal in the dry state, %;*
V^{daf}	*volatile matter in the dry ash-free state, %;*
y	*thickness of the plastic layer, mm;*
HGI	*hardgrove grindability index, units;*
Vt	*vitrinite, %;*
Sv	*semivitrinite, %;*
I	*inetinite, %;*
L	*liptinite, %;*
R_0	*mean vitrinite reflection coefficient, %;*
∑FC	*sum of fusinized components, %;*
d_{me}	*mean diameter of coals particles, mm.*

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