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Estimation of the Efficiency of Use of Sizing Out of Small Classes before Final Grinding of Coals

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Abstract
The coal raw material base of coking at the AZOVSTAL metallurgical plant is characterized by the presence of coals of varying degrees of metamorphism, caking capacity, size and grindability, which predetermines the use of progressive coal preparation schemes. Laboratory coking has shown that screening out fine grades (<6 mm) before the final grinding of the coal blend will improve the mechanical strength of the resulting coke in terms of M25 by 0.4–1.0%, and M10 by 0.1–1.0%, and the more low-caking coals (in the range from 15 to 35%), the greater the effect of screening out of fine grades on the quality of coke. The use of preliminary crushing of low-sintering coals, followed by screening of fine grades and final grinding of the coal blend does not improve the quality of the resulting coke.

Keywords: *Coal concentrates; Coal blend; Particle size distribution; Preliminary grinding; Preparation scheme.*

1. Introduction

The choice of the technological scheme of coal preparation is decided depending on the peculiarities of the coal raw material base for coking. For example, at the cokemaking plants of Ukraine, working mainly with the use of coals of the Donetsk basin, the preparation of the coal blend is carried out mainly according to the schemes of crushing components (CC), group (GCC) and differentiated (DCC) crushing of components, which makes it possible to increase the density of the charge by 2–2.5% and improve coke strength indicators. For petrographically heterogeneous coals (the raw material base of Russia), the process of selective crushing of the coal blend with separation is preferable; at the same time, the quality indicators of metallurgical coke are significantly improved, and the coal raw material base is expanding.

Grinding the coal blend makes it possible to improve its coking properties by increasing the homogeneity of the dispersed mass, which leads to an improvement in the quality of coke. However, significant grinding of the charge can lead to negative results. Since the bulk density of the coal blend depends on the degree of its grinding, which determines the economic performance of the coal preparation and coke shops, the optimal degree of grinding is found for charges of different composition [1–7].

With the same fineness, characterized by a content of grades <3 mm, different methods of preparing the charge can give different dust contents in the final product (fineness grade <0.5 mm).

When preparing coals for coking, it is necessary to achieve an optimal ratio of size grades in the coal blend to ensure a higher bulk density; avoid the formation of a large number of fine grades that reduce the caking capacity of coals. Large classes of the prepared coal blend in terms of sintering capacity, ash content and petrographic composition should not differ sharply from other classes.

This article presents the results of studies devoted to assessing the effect of screening out fine grades of coals before their final grinding in the conditions of the AZOVSTAL metallurgical enterprise.

2. Experimental part

2.1. Raw materials

For the research, samples of coal components were taken from the raw material base of the metallurgical enterprise AZOVSTAL. The selected ones were analyzed by a set of standardized methods with the determination of proximate (A^d, S^d_t, V^{daf}), petrographic (R_0, Vt, Sv, I, L, ∑FC, vitrinite reflectogram), plastometric (x, y) and particle size (> 50; 25 –50; 13–25; 6–13; 3–6; 1–3; 0.5–1.0; <0.5 mm) analyzes. In addition, for coal concentrates the caking capacity by Roga and the Hardgrove grindability index are determined. The research results are shown in Table 1–3.

Table 1. Technological properties of coals

Provider	Proximate analysis, %			Plastometric indicators, mm		Roga Index, units	Hardgrove grindability index, units
	A^d	S^d_t	V^{daf}	x	y	RI	HGI
Promugolservice, Russia	8.3	0.65	39.5	38	10	32	59
Wellmore, USA	7.7	1.17	33.8	22	18	77	69
Oaky North, Australia	10.0	0.66	26.4	12	19	79	81
Svyato-Varvarinskaya, Ukraine	8.1	0.82	28.1	11	13	65	84
Teck Premium, Canada	8.9	0.62	27.5	16	15	67	86
Berezovskaya, Russia	11.0	0.47	27.5	26	13	46	79
Pocahontas, USA	8.3	0.92	18.8	6	12	41	89
Promugolservice, Russia	8.3	0.65	39.5	38	10	32	59

Table 2. Petrographic characteristics of coals

Provider	Petrographic composition, %					Ref* %	Stages of vitrinite metamorphism, %					
	Vt	Sv	I	L	∑FC	R_0	0.50–0.64	0.65–0.89	0.90–1.19	1.20–1.39	1.40–1.69	1.70–2.59
Promugolservice, Russia	73	0	26	1	26	0.66	48	52	0	0	0	0
Wellmore, USA	74	0	21	5	21	0.94	0	39	61	0	0	0
Oaky North, Australia	84	0	16	0	16	1.20	0	0	48	52	0	0
Svyato-Varvarinskaya, Ukraine	85	0	13	2	13	1.11	0	2	85	13	0	0
Teck Premium, Canada	69	2	27	2	29	1.09	0	4	79	15	2	0
Berezovskaya, Russia	61	3	35	1	37	1.13	0	7	73	13	8	0
Pocahontas, USA	77	0	23	0	23	1.52	0	0	7	5	78	10
Promugolservice, Russia	73	0	26	1	26	0.66	48	52	0	0	0	0

**Average coefficient of reflectance of vitrinite, %*

Table 3. Granulometric composition of coals

Provider	Granulometric composition (mm),%									d_{av}, mm*
	>50	25–50	13–25	6–13	3–6	1–3	0.5–1.0	<0.5	<3	
Promugolservice, Russia	0.0	11.5	22.3	22.5	15.4	16.3	4.0	4.7	3.3	28.3
Wellmore, USA	0.0	8.2	11.8	17.4	15.7	22.6	7.2	10.0	7.1	46.9
Oaky North, Australia	0.0	2.7	7.4	9.9	11.8	28.5	13.2	17.5	9.0	68.2
Svyato-Varvarinskaya, Ukraine	0.0	9.7	7.7	15.6	13.4	20.0	8.7	13.9	11.0	53.6
Teck Premium, Canada	0.0	0.0	3.7	9.4	12.1	24.9	9.8	18.8	21.3	74.8
Berezovskaya, Russia	2.8	23.0	7.9	12.6	11.0	17.1	6.3	10.6	8.7	42.7
Pocahontas, USA	0.0	0.7	3.9	8.8	11.7	27.1	11.7	23.9	12.2	74.9
Promugolservice, Russia	0.0	11.5	22.3	22.5	15.4	16.3	4.0	4.7	3.3	28.3

** Average diameter of particles, mm*

Analyzing the data Table 3, it can be stated that the raw material base of the AZOVSTAL metallurgical plant contains coals that differ significantly in sieve composition.

Thus, in coals Oaky, Teck Premium and Pocahontas, the content of the class 0–3 mm is more than 60%, as a result of which it becomes expedient to use devices for screening out small classes in order to prevent their additional crushing and "self-reduction". Coals of Promugolservice, Berezovskaya, on the other hand, are characterized by a content of this class at the level of 28.3–42.7%, which predetermines their thorough grinding when bringing the total blend grinding to 80±2%. The rest of the coals are intermediate values.

2.2. Experimental equipments

The coal preparation scheme is shown in Fig. 1. The coal preparation department of the coke plant of the coke and chemical production AZOVSTAL operates according to the following coal preparation scheme. About 30% of hard low-metamorphosed and inertinite coals are crushed to a grade of 3–0 mm, equal to 75–80%. After that, the crushed product is mixed with the remaining 70% of soft coals and fed to the final grinding, where it is crushed to a level of 80–82% of the class less than 3mm in the finished blend.

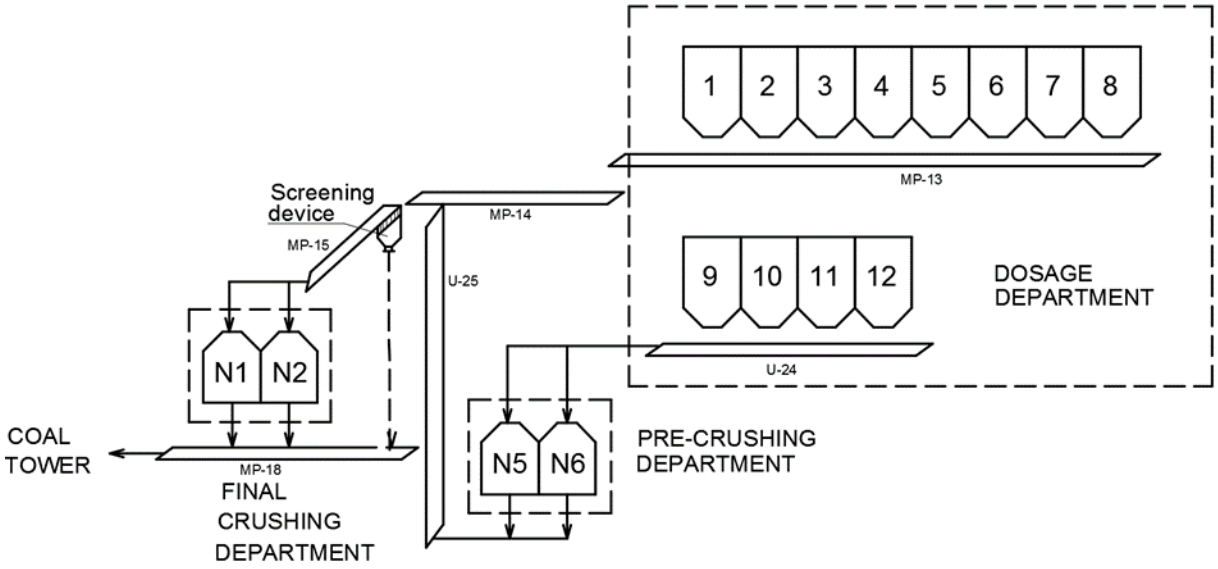

Fig. 1. Coal preparation scheme at AZOVSTAL

3. Results and discussion

The efficiency of using progressive coal preparation schemes was tested at 2 levels of coal blend quality:

1. Reduced content of low-caking coals in the blend (10% of Promugolservis and 5% of the Berezovskaya).
2. Increased content of low-caking coals in the charge (20% of Promugolservis and 15% of Berezovskaya).

The influence of the screening out of small grades on the quality of coke was tested by coking the following options for coal blends:

- The hard group of coals is crushed to ~ 80% of the grade of <3 mm, after which it is mixed with coals of the soft group and jointly crushed to ~ 80% of the grade of <3 mm.
- ~ 24% of coal (class <6 mm) is screened out from the total blend. Most of the coal blend is crushed to such a state content that, after combining with the screened part, the total grind of the charge is ~ 80%.
- The hard group of coals is crushed to ~ 80% of the <3 mm class, after which it is combined with the soft group of coals. ~ 24% of coal (class <6 mm) is screened out from the

total blend. Most of the coal blend is crushed to such a state content that, after combining with the screened part, the total grind of the blend is ~ 80%.

The dropout value of 24% was adopted based on the results of the work of the screening device of small classes before the final grinding of the coal blend in the coal preparation department of ZAPOROZHKOKS [8].

Table 4 shows the component and grade compositions of the experimental coal blends, characterized by a low (option 1.1–1.3) and increased (option 2.1–2.3) content of low-caking coals used to determine the effect of screening out of small classes on the quality of coke.

Table 4. Component compositions

Provider	Share, %	
	1.1–1.3	2.1–2.3
Promugolservice, Russia	10	20
Wellmore, USA	25	25
Oaky North, Australia	30	25
Svyato-Varvarinskaya, Ukraine	15	0
Teck Premium, Canada	5	15
Berezovskaya, Russia	15	15
Total	100	100
Promugolservice, Russia	10	20
Wellmore, USA	25	25

The results of determining the technological properties (Table 5) and petrographic characteristics (Table 6) of coal blends indicate that in terms of ash content, total sulfur content, plastic layer thickness and petrographic characteristics, coal blends within the same grade and component composition are similar, which excludes the possibility significant errors in their compilation.

Table 5. Technological properties

Option	Proximate analysis, %				Plastometric indicators, mm	
	A^d	S^d_t	V^d	V^{daf}	x	y
1.1	8.9	0.77	26.1	28.6	17	16
1.2	8.2	0.77	25.9	28.2	23	16
1.3	8.3	0.80	26.0	28.4	20	17
2.1	8.4	0.75	26.8	29.2	27	15
2.2	7.9	0.74	27.9	30.3	27	15
2.3	8.5	0.75	27.3	29.8	28	15

Table 6. Petrographic characteristics

Sample	Petrographic composition,%					$R_{o,av*}$	Stages of vitrinite metamorphism,%					
	Vt	Sv	I	L	∑FC	R_0	0.50–0.64	0.65–0.89	0.90–1.19	1.20–1.39	1.40–1.69	1.70–2.59
1.1	78	1	20	1	21	1.14	0	7	10	46	22	13
1.2	79	0	19	2	19	1.12	0	5	14	48	23	10
1.3	76	0	22	2	22	1.09	0	5	22	41	18	15
2.1	74	1	23	2	24	1.04	1	11	15	46	12	15
2.2	72	1	24	3	25	1.03	2	10	23	35	19	11
2.3	73	1	25	1	26	1.05	1	11	16	40	19	13

**Average coefficient of reflectance of vitrinite, %*

As for the preparation of coal blends (Table 7), it can be stated that almost the same specified level of grinding was maintained (79.6–81.6%).

Table 7. Granulometric composition

Option	Granulometric composition (mm), %					d_{av*}
	3–6	1–3	0.5–1.0	<0.5	<3.0	d_{av}
1.1	20.2	24.7	13.5	41.6	79.7	1.60
1.2	19.6	29.2	12.2	39.0	80.5	1.64
1.3	20.4	26.5	14.1	39.0	79.6	1.64
2.1	20.1	33.6	13.3	33,0	79.9	1.79
2.2	18.4	32.9	12.6	36,1	81.6	1.71
2.3	20.1	34.4	13.5	32,0	79.9	1.81

**Average diameter of particles, mm*

The results of determining the technological properties (Table 8) of the coke obtained in a 5-kg laboratory furnace indicate that the use of fine grades screening before the final grinding of the coal blend improves the mechanical strength in terms of M25 by 0.4–0.9% and M10 by 0.1% with a reduced content of low-caking coals (option 1.2), and at an increased content (option 2.2), respectively, by 1.0% and 1.0%.

Table 8. Coke yield and quality indicators

Variant	Proximate analysis, %			Yield of coke, %	Mechanical strength, %	
	A^d	S^d_t	V^{daf}	B^d,	M25	M10
1.1	11.7	0.68	0.3	76.2	92.1	6.1
1.2	10.9	0.74	0.4	76.3	92.5	6.0
1.3	11.0	0.72	0.3	76.4	91.5	6.4
2.1	11.2	0.67	0.6	75.7	92.1	6.7
2.2	10.5	0.59	0.4	75.3	93.1	5.7
2.3	11.3	0.61	0.5	75.5	90.5	7.1

The use of preliminary grinding with subsequent screening of fine grades (options 1.3, 2.3) leads to some deterioration in the quality of coke. With a reduced content of low-caking coals, the M25 index decreases by 0.1–0.6%, and M10 increases by 0.1–0.4%; at increased – M25 by 1.6%, and M10 by 0.4%.

4. Conclusions

The coal raw material base of coking at the AZOVSTAL metallurgical plant is characterized by the presence of coals of varying degrees of metamorphism, caking capacity, size and grindability, which predetermines the use of progressive coal preparation schemes.

Laboratory coking has shown that screening out fine grades (<6 mm) before the final grinding of the coal blend will improve the mechanical strength of the resulting coke in terms of M25 by 0.4–1.0%, and M10 by 0.1–1.0%, and the more low-caking coals (in the range from 15 to 35%), the greater the effect of screening out of fine grades on the quality of coke.

The use of preliminary crushing of low-sintering coals, followed by screening of fine grades and final grinding of the coal blend does not improve the quality of the resulting coke.

Symbols

M25	*crushing strength of coke, %;*	*Vt*	*vitrinite, %;*
M10	*abrasion of coke, %;*	*Sv*	*semivitrinite, %;*
A^d	*ash, %;*	*I*	*inertinite, %;*
S^d_t	*content of sulfur, %;*	*L*	*liptinite, %;*
V^{daf}	*volatile matter, %*	*∑FC*	*sum of fusinized components, %;*
x	*plastometric shrinkage, mm;*	R_0	*average coefficient of reflectance of vitrinite, %;*
y	*thickness of plastic layer, mm;*	d_{av}	*average diameter of particles, mm;*
RI	*Roga Index, units;*	B^d	*yield of coke, %;*
HGI	*Hardgrove grindability index, units;*		

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