Petroleum and Coal

Article **Open Access**

Influence of the Properties Raw Coal Materials and Coking Technology on the Granulometric Composition of Coke
Message 3. Method of Machining Blast Furnace Coke

*V. P. Lyalyuk, E. O. Shmeltser *, D. A. Kassim, I. A. Lyakhova*

Kryvyi Rig Metallurgical Institute, Ukraine National Metallurgical Academy, 50006, Kryvyi Rig, Ukraine

Received October 23, 2019; Accepted February 9, 2020

Abstract

The method of mechanical treatment of blast furnace coke is proposed, which includes the improvement of the initial indexes of its quality M_{25}, M_{10} and class >80 mm in continuous or periodically working open or closed industrial cylindrical oblique stabilizer drum. The advantage and difference of the method is that the angle of inclination of the drum-stabilizer to the horizon and the number of its revolutions is chosen from the optimum number of revolutions of the test drum Mikum on the dynamics of improving the initial indicators of coke quality for every 1-2 revolutions of the drum, taking into account the sums of the products of the coefficients of indices each indicator and the amount of specific consumption of coke in the blast furnace, and the number of revolutions of the drum-stabilizer limit the loss of blast furnace coke not more than 3.0-3.5% of the original value.

***Keywords**: Technological properties of coal batch, Coking technology, Coke, Granulometric composition, Indices of resistance of coke abrasion and crushability, Drum-stabilizer.*

1. Introduction

We analyzed the basic requirements for particle size distribution of coke, studied the influence of raw materials and technological factors on the distribution of coke by size classes and recommended the use of machining to stabilize the physical and mechanical characteristics [1-2]. In the process of coke production by layer coking, pieces of coke of various sizes are formed: from <10 mm to> 150 mm. At the same time, depending on the carbon content of the coal charge, the coking rate, the number of pieces of coke of various sizes can vary within wide enough limits, in particular pieces of size> 80mm (from 1 to 40%).

Analysis of the results indicates that, with no changes in the coking conditions, the granulometric composition depends significantly on the ash content and packing density of the coal batch. The packing density, in turn, depends on the moisture content and the degree of crushing (the content of the ≤3 mm class). Optimal crushing of the coal batch may ensure more uniform granulometric composition of the coke [3].

Currently, the only direction to improve the quality of blast furnace coke at virtually all coke plants were and remain the factors provided by the properties of coal raw materials and coke production technology.

However, this process is not completely controllable. In addition, the attraction of coal concentrates with optimal caking and a favorable chemical composition of the mineral part is associated with a shortage of resources and is limited by economic feasibility.

The high yield of coke fraction >80mm usually requires after furnace treatment: the crushing of the entire ramp coke during transportation on the coke feeder path or the separation of the class> 80mm and its grinding (usually in crushers). The process of grinding all of the ramp coke or grade 80mm roller screen is accompanied by the loss of commercial coke (class

>25mm or class >40mm) due to the difficulty of adjusting the distance between the rollers stars.

Practically the only way to ensure the management of properties, up to obtaining the required strength and composition indicators of coke obtained in the layer process and traditional coke ovens, is the mechanical processing (stabilization) of coke.

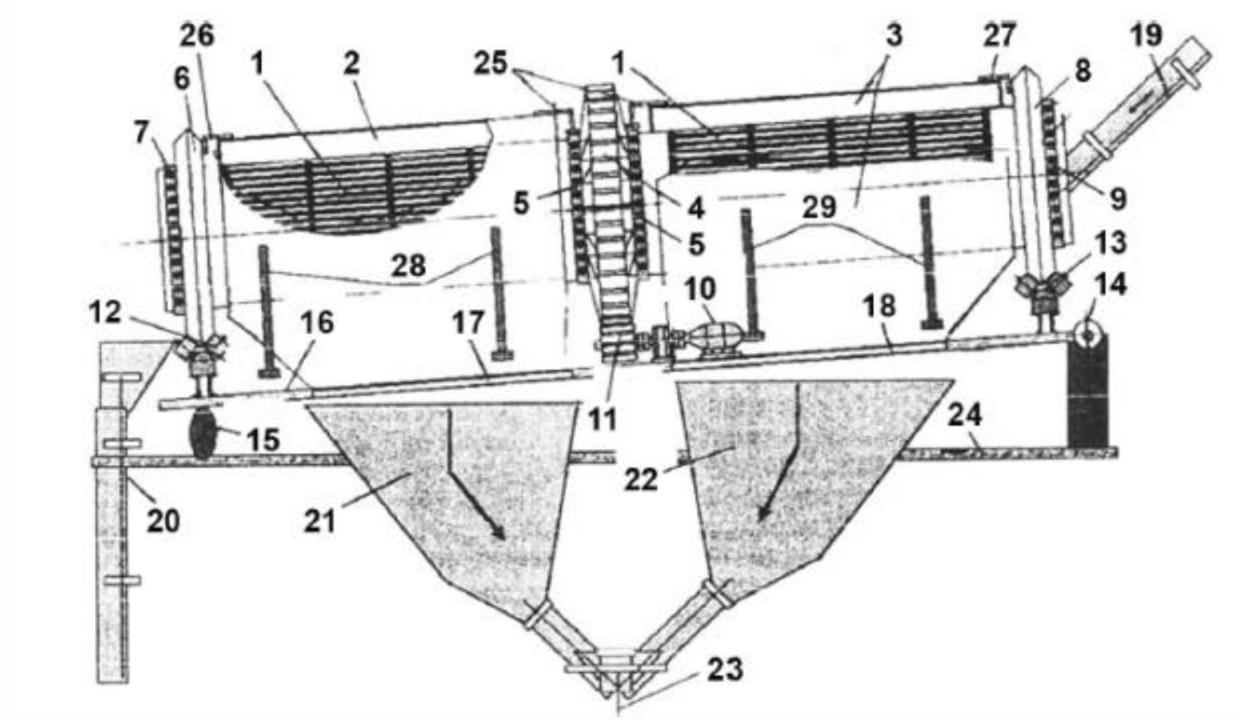

Fig.1.Unit for obtaining the specified properties of coke

1 - classification drum; 2,3 - front and back cover;4, 5, 25 - known main drive gear, its drum attachment and retainer; 6, 8, 26, 27 - front and rear support ring of the drum and their fastening; 7, 9 - mounting the support rims to the drum; 10 - electric drive; 11 - known drive gear; 12, 13 - roller supports; 14, 16 - system of change of angle of inclination; 15 - the location of the drum; 17, 18 - front and rear openings for drum failure;19 - a coke chute that is loaded; 20 - unloading chute of the drum;21, 22, 23 - gutter unloading troughs; 24 - construction site for the placement of the unit for obtaining the specified properties of coke; 28, 29 - support of front and back cover

2. Results and discussions

The theory of control of the granary and strength of coke is based on a mathematical description of the process of its destruction, depending on the magnitude and nature of mechanical loading, as well as the initial properties of coke and their changes. However, since the destruction occurs in different devices in different ways, the named constants depend on the type in the apparatus. Comparison of different units that can exert mechanical influence on coke if its intensity is changed has shown that the most promising is the drum [4].

The most suitable for the classification and quality management of coke is the unit of obtaining the specified properties of coke, which performs the function of stabilizing coke, classifying and improving its quality by the selected indicator to the required level. It is suggested to install the specified unit instead of roller screen.

The presented unit is a drum, the cylindrical surface of which is made in the form of profile rods with a distance between them, depending on the size of the lattice part of the coke that is given, or in the form of replaceable cards with holes of a given size and shape.

The material inside the rotating drum, depending on the speed of rotation may be in cascade or waterfall, or centrifugal modes. A centrifuge drum with a diameter D is created at a rotational speed equal to the critical one. Under these conditions, centrifugal force is applied to the material against the wall of the drum. The rotation of the material occurs together with the drum without moving each other [4].

Managing the unit of obtaining the specified properties of coke, through the method of maintaining the capacity of the coke, is in the plan of stable stability of the bulk of the power, so as to reach one of the two indicators of the given value, to save a good deal for the aggregate.

Thus, if necessary, the granulometric composition of the coke is improved, in particular reducing the content of the fraction> 80 mm from 11 to 3%, find the number of revolutions of the test drum that is required to change the amount of the specified fraction. To do this, we solve the equation [4] with respect to:

$$C_n = C_0 e^{-m_1 n^{t_1}} \tag{1}$$

where at C_n= 3, n_M= 22,5 rotate

compute

$$n = \frac{\sqrt{\pi^2 n_M{}^2 - L^2}}{\pi D} = \frac{\sqrt{3{,}14^2 \cdot 22{,}5^2 - 14^2}}{3{,}14 \cdot 2} = 11{,}0 \tag{2}$$

find

$$sin\,\alpha = \frac{L}{n \cdot \sqrt{\left(\frac{L}{n}\right)^2 + \pi^2 D^2}} = \frac{14}{11 \cdot \sqrt{\left(\frac{14}{11}\right)^2 + 9{,}86 \cdot 4}} = 0{,}202, \tag{3}$$

α ≈11,5 degrees

Installing the stabilizer drum at an angle of 11.5 degrees, processing the coke, we improve its quality in terms of particle size.

The disadvantage of this method of machining blast furnace coke, including the improvement of the output indicators of its quality M_{25} (M_{40}), M_{10} and class > 80 mm in continuous or periodically operating open or closed cylindrical oblique drum stabilizer [4], is that the improvement output cold indicators of its quality, increase of M_{25} (M_{40}) indicators and decrease of M_{10} index and content of class > 80 mm, do not limit the amount of blast furnace coke losses, which results in decrease (deficiency) of the amount of coke supplied in the blast furnace, and causes the coke to be consumed in the blast furnace and increase the specific cost of pig iron production.

To improve the quality of coke while limiting the transfer of blast furnace coke into the screenings (reducing blast furnace coke loss), it is necessary to select and set the optimum inclination angle for continuously or intermittently working open or closed industrial cylindrical oblique stabilizer drum that provides the required rotation speed.

We suggest [4] to determining and installing the stabilizer drum at a certain angle of its inclination to improve the physical and mechanical properties of coke (increase M_{25} to 88-90% and decrease M_{10} to 5-6%, and class> 80 mm 3-4%). In order to improve these indicators of coke quality, it is necessary to determine and install the stabilizer drum at a certain angle of inclination to the horizon (α) and choose the required number of revolutions (n), which on the one hand will allow to improve the performance, and on the other - to prevent the transfer of pieces of coke to the screenings, that is to achieve a reduction in the output of class <25 mm and increase the number of suitable coke fraction 25 -80 mm, which is loaded into the blast furnace.

To determine the optimal *α* and *n* for the processing of pieces of coke in a stationary drum-stabilizer, first test coke, determining changes from the original M_{25}, M_{10} and class >80 mm, in the Mikum drum after 1-2 rotations.

On the basis of these tests the optimum number of revolutions (n_m) is determined, for which the dynamics of improving the output indicators of coke quality for each 1-2 turns of the drum determines the sum of the outputs of indicators of quality of coke on the coefficients of influence of each indicator on the reduction of the specific consumption of coke (M_{25} +1% - – 0.6%; M_{10} – 1% - – 2.8% and >80 mm – 1% - – 0.2%) and the amount of specific consumption of coke in a blast furnace, to which this batch of stabilized coke is fed.

The obtained amount of coke savings in the blast furnace due to its stabilization is compared with the amount of blast furnace coke losses, that is, they constantly monitor the output of the class <25 mm.

In this regard, we propose to limit the number of revolutions of the drum-stabilizer the amount of blast furnace coke, preventing the increase yield of class <25 mm more than 3.0-3.5% of the original value.Choosing the optimum number of revolutions nm determine the optimal *α* and *n* for the drum-stabilizer by the formulas:

$\alpha = \arcsin L/\pi n_m$, (4)

where: α – angle of inclination of the drum, degrees; L – length of the drum, m; n_m –optimum speed of the Mikum drum, and

$n = n_m/D$, (5)

where D – diameter of the drum-stabilizer.

Thus, in a blast furnace, for example, with a volume of 5000 m^3, which melts 9390 tons of iron per day, at a specific consumption of coke – 450 kg/t, the quality of the coke is stabilized by its stabilization in a continuously or intermittently open cylindrical roller drum which is open or closed. Possible use is to install a stabilizer drum instead of roller screen for coking in a coke shop.

The difference (Δ) of indicators M_{25}, M_{10} and the amount of coke fraction >80 mm resulting from machining were multiplied by the coefficients of influence of each indicator and the amount of specific consumption of coke in the blast furnace. All results of the calculations are shown in Table 1.

Table 1. Modification of coke properties and reduction of its specific consumption as a result of machining

n_m	Changing metrics			Reduction of specific consumption of coke, kg/t				Waste
	Δ (>80)	ΔM_{25}	ΔM_{10}	Δ (>80)·0,2·4,5	ΔM_{25}·0,6·4,5	ΔM_{10}·2,8·4,5	Δ	<25,%
0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2	3,92	0,82	0,44	3,53	2,22	5,55	11,30	0,84
4	4,97	1,13	0,65	4,47	3,05	8,15	15,68	1,37
6	5,66	1,37	0,80	5,10	3,70	10,14	18,93	1,82
8	6,19	1,57	0,94	5,57	4,24	11,79	21,60	2,22
10	6,61	1,75	1,05	5,95	4,72	13,21	23,88	2,60
12	6,96	1,91	1,15	6,26	5,15	14,47	25,89	2,95
14	**7,26**	**2,05**	**1,24**	**6,53**	**5,54**	**15,61**	**27,68**	**3,28**
16	7,52	2,19	1,32	6,77	5,90	16,64	29,31	3,60
18	7,75	2,31	1,40	6,98	6,24	17,59	30,80	3,90
20	7,96	2,43	1,47	7,16	6,55	18,47	32,18	4,19
22	8,15	2,53	1,53	7,33	6,84	19,29	33,46	4,48
24	8,32	2,63	1,59	7,48	7,11	20,06	34,66	4,75
25	8,40	2,68	1,62	7,56	7,25	20,43	35,23	4,89

Table 1 shows that the total reduction in the specific consumption of coke first changes by 2 turns by 11.3 kg/t of iron, and then decreases. After 22 revolutions, the effect decreased to 1.2 kg in 2 revolutions. In total, if we estimate the effect of reducing the consumption of coke per ton of pig iron, which is a direct reduction in the cost of cast iron, at a processing of 14 revolutions and the conventional cost of a ton of coke3600 $/t, the cost decrease will be 3600·0.02768≈ 99.6 $/t. In this case, the loss of blast furnace coke will be only 3.28%.

The stabilizer drum for coke machining can be 5-8 m long and 1.75 to 2.5 m in diameter, depending on the performance of the drum and the limits of its adjustable speed.

On a blast furnace with a volume of 5000 m^3, taking into account its productivity, it is possible to use a stabilizer drum with length 8.5 m and diameter 2 m, then set the angle of inclination to the horizon equal to:

$\alpha = \arcsin L/\pi n_m = \arcsin 8{,}5/3{,}14 \cdot 14 = 11$ degrees, (6)

and the number of its revolutions will be equal:

$n = n_m/D = 14/2 = 7.$ (7)

3. Conclusions

Thus, the choice of rational parameters of the technology of stabilization of coke quality indices in an industrial cylindrical oblique stabilizer drum, taking into account the high losses of blast furnace coke, can significantly reduce the cost of cast iron in blast furnace.

Thus, the use of the process of machining pieces of coke can not only stabilize the properties of coke, but also significantly improve them until you get the set, desired performance particle size, strength and resistance to friction.

Symbols

M_{10}, M_{25} – indices of resistance of coke abrasion and crushability, respectively, %;
>80 mm, 80-60 mm, 60-40 mm, 40-25 mm, <25 mm – content of particles in coke accordingly, %;
D – diameter of the drum-stabilizer;
α – angle of inclination of the drum, degrees;
L – length of the drum, m;
n_m –optimum speed of the Mikum drum.

[1] Lyalyuk VP, Shmeltser KO, Kassim DA, Lyakhova IA. Influence of the properties raw coal materials and coking technology on the granulometric composition of coke. Message 1. Analysis of changes in particle size distribution of coke on the example of the coke plant in Krivyi Rig. Petroleum and coal, 2019; 62(1): 173-177.

[2] Lyalyuk VP, Shmeltser KO, Kassim DA, Lyakhova IA. Influence of the properties raw coal materials and coking technology on the granulometric composition of coke. Message 2. Granulometric composition of the coke as a function of the coal batch properties. Petroleum and coal, 2019; 62(1) 178-184.

[3] Lyalyuk VP, Shmeltser KO, Lyakhova IA, and Kassim DA. Changes in granulometric composition of blastfurnace coke. Coke Chem., 2013; 56(12): 456–460.

[4] Muchnik DA, Babanin VI. Vozmozhnosti uluchsheniya kachestva koksa posle vydachi iz pechey (Opportunities Improving the quality of coke after dispensing from ovens) Yekaterinburg, 2011.

[5] Muchnyk DA, Tovarovs'kyy IH, Lyalyuk VP, Shmeltser EO. UA Patent 127112, Byull. Izobret., 2018, no. 13.

To whom correspondence should be addressed: Dr. E. O. Shmeltser, Kryvyi Rig Metallurgical Institute, Ukraine National Metallurgical Academy, 50006, Kryvyi Rig, Ukraine, E-mail shmelka0402@gmail.com