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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

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Abstract

The basic requirements of the granulometric composition of blast furnace coke were considered. The change in granulometric composition for the same coke plant at different times was analyzed: specifically, for the example of Krivyi Rig coke plant between 1980 and 1988 and the same facility (by then the coke plant at ArcelorMittal Krivyi Rig) between 2006 and 2012. The comparison shows that the content of different size classes in the gross coke has been significantly redistributed. Thus, the coke's content of the >80 mm, <25 mm, and 80–60 mm classes are greater in the later period; correspondingly, the values of the strength M_{25} and susceptibility to wear M_{10} are worse. It was shown that a high content of fractions> 80 mm and significant fluctuations in the granulometric composition of coke of the coke plant of PJSC ArcelorMittal Kryvyi Rig necessitate the stabilization of coke by means of its mechanical processing.

Keywords: *Coke; Granulometric composition; Strength M_{25}; Susceptibility to wear M_{10}; Stabilization; Mechanical processing of coke.*

1. Introduction

The most important means of improving blast-furnace performance is to supply high-quality batch—in particular, high-quality coke. Coke quality is key to satisfactory furnace operation and may be assessed in terms of physical characteristics, (indices of resistance of coke abrasion and crushability, granulometric composition), chemical composition, coke reactivity index and coke strength after the reaction. In terms of chemical composition, we require coke with maximum carbon content and minimum ash and sulfur content. In terms of granulometric (fractional) composition, the coke must be of uniform size, with a minimum content of the smallest (<25 mm) and the largest (>80 mm) classes.

Since coke is the most expensive component of the batch for hot-metal production, it is a priority to minimize its consumption. Two approaches are possible:1) decrease in the heat consumption during smelting by improved batch preparation and organization of the process; 2) replacement of coke by a less expensive fuel. The effectiveness of the second method depends on the properties and cost of the substitute employed. It is always used as a supplement to the first method [1].

In the blast furnace, coke plays a complex role. Its transformation at the tuyeres provides most of the heat required for smelting and also forms most of the reducing gas, to which gas from direct reduction is added at higher levels. Besides these functions, the coke serves as solid packing in the zone characterized by softening and melting of the iron-bearing materials: in so doing, it ensures a counter flow of batch and gas in the furnace. The coke also regulates the gas distribution over the furnace cross section. Accordingly, coke must satisfy strict requirements.

Analysis of the blast-furnace process yields the minimum possible coke consumption, which may be 180–200 kg/t of hot metal. Given that the technology employed is already at a high level, traditional methods may not permit the attainment of this value. However, the scope for improvement in blast-furnace technology is far from being exhausted [2-3].

At present, many plants employ the injection of natural gas and pulverized coal in the blast-furnace tuyeres. Pulverized-coal injection ensures high blast furnace performance.

The use of new technologies requires, first of all, the anticipatory improvement in the quality of coke, characterized by a number of indicators.

Typical requirements were laid out at the Fifth International Congress of Blast-Furnace Specialists [4]: crushability M_{25} no less than 90%; resistance of coke abrasion M_{10} no more than 6%; content of the >80 mm class no more than 5%; content of the <25 mm class no more than 5%; fluctuations of the moisture content no more than ±0.5%; coke reactivity index *CRI* = 23–26%; and coke strength after reaction *CSR* = 70%.

The granulometric composition of coke is also one of the essential characteristics of its quality for blast furnace smelting.

Regarding the optimal size of blast furnace coke, experts expressed different points of view: "... to ensure optimal gas-dynamic conditions, the size of coke should correspond to the lumpiness of the agglomerate…" [5-6]; to establish the lower limit of coke size by the average sinter size "is an unreasonable and not confirmed by practice; ...for blast furnace smelting coke of class 40–80 mm is required"[7]; "... the question of the optimal size of coke should not be complicated by linking with the existing sieve composition of the charge materials; ... in blast furnace, coke plays a leading, largely independent role, independent on the state of the charge..."[8].

At present, the blast furnace expert's countries of the European Union restrict content skip coke product: content class <40 mm – no more than 15–25%, and class <20 mm should not exceed 3%. Firm Rautaruukki (Finland) priority value gives the content of class 80–40 mm in skip coke. Maintaining the exit of this class at the level of 60–68%, it is most favorable for conditions in the furnace of the furnace and for furnace productivity. At the same time, an increase in class output> 80 mm negatively affects performance furnaces; therefore, a strict restriction of content in this class is considered one of the preliminary conditions of high-performance operation of blast furnaces. In Germany, a yield of class> 80 mm is limited to a maximum of 10%, and coke> 100 mm should be excluded. General practice for EU countries is also used in blast furnace batch of fine coke class 10–35 mm in the amount of up to 100 kg/t of cast iron. The high reactivity coke nut mixed with iron ore batch and loaded to the peripheral part of the blast furnace. The large coke with lower reactive ability loaded in the central part furnaces for guaranteed maintenance of gas reduced to the level of the tuyere zone of the hearth [9].

The study of raw and technological factors that determine the quality indicators and the distribution of coke by size classes, as well as the study of the possibility of influencing the granulometric composition of coke during its production, make it possible to increase the uniformity and uniformity of its sieve composition.

2. Results and discussions

In recent years, significant changes have taken place in the coking raw material base. Thus, the coal raw material base of the coke production of PJSC ArcelorMittal Kryvyi Rig, 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, Kazakhstan, and the United States, Canada) is associated both with a shortage of Ukrainian coal of suitable quality (low sulfur content, I_0≤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. The petrographic and technological characteristics of raw materials and aspects of the technology of preparing coal for the production of blast-furnace coke under the conditions of the multi-basin raw material base were analyzed in detail in [10-12].

In the period 1980-1988 years in the conditions of the Krivorozhsky coke plant, the quality of coke was characterized by the following particle size distribution: the yield of a class> 80 mm was in the range from 4.0 to 8.45%, of a class of 80-60 mm - from 24.81 to 28.7%, of a class 60-40 mm, which forms the basis of blast furnace coke and characterized by uniformity of properties, finely porous dense structure, relatively low fracture and low tendency to abrasion - from 45.8 to 49.84%, class 40-25 mm - from 13.73 to 16.6%, class 0-25 mm - from 2.3 to 3.18%. At the same time, the cold strength of coke according to the M_{25} index was at the level of 87.9-88.88%, the abrasion resistance, according to the M_{10} indicator, was 6.3-6.54%.

In 2005-2012 there was a redistribution of the content of size classes in the gross coke of coke plant PJSC ArcelorMittal Kryvyi Rig. The quality of coke, according to the indices of crushability M_{25} and resistance of coke abrasion $M_{10,}$ has noticeably worsened and does not meet the requirements of modern blast furnace smelting, according to which it should be at least M_{25} = 90%, M_{10} = 6%.

Comparing the change in the granulometric composition of coke in previous years and at present, attention should be paid, first of all, to an increase in the yield of classes >80 mm, <25 mm (Fig. 1, 2), which was reflected, respectively, in a decrease in the yield of the most valuable classes 60-40 mm and 40-25 mm.

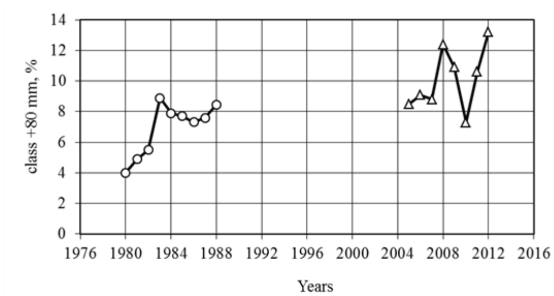

Fig. 1. Changing the content class> 80 mm

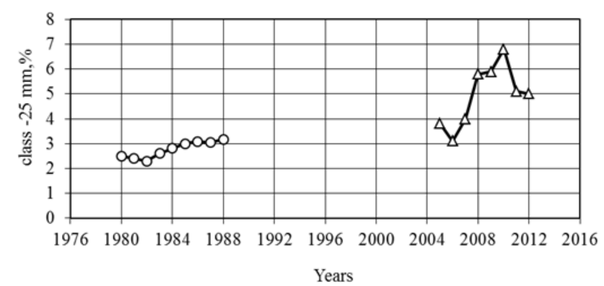

Fig.2. Changing the content class< 25 mm

Comparing the quality of coke in previous years and now, one should pay attention to the deterioration of the quality of coke in terms of strength M_{25} and abrasion resistance M_{10} (Fig. 3, 4).

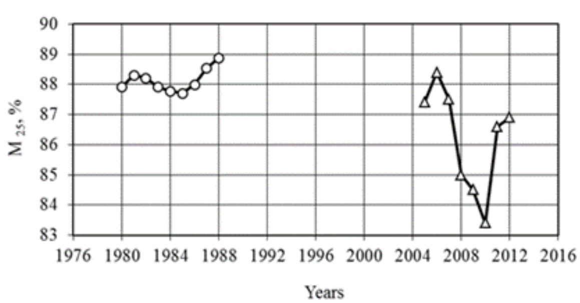

Fig.3. Changing the coke strength M_{25}

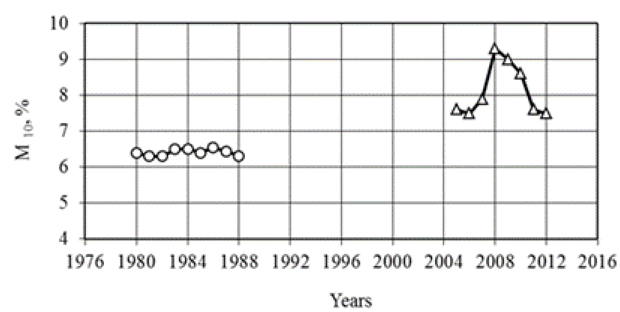

Fig.4. Changing the coke abrasion resistance M_{10}

Indices of the blast furnace process, such as coke burning intensity and blast intensity (Fig. 5, 6), also decreased markedly. This cannot be said that this is fully due to the deterioration in the quality of coke, but this factor undoubtedly has an effect.

For the study period 2006-2012 years under the conditions of PJSC ArcelorMittal Kryvyi Rig, there is also a high variability in the yield of various classes of coke size. The fluctuation was evaluated by the standard deviation σ and the coefficient of variation v.

From the data in Figure 7 shows that significant fluctuations are characteristic of all classes of coke fineness in the period 2006–2012: class> 80 mm (σ = 1.37-4.09; v = 11.21-31.27 %), class 80-60 mm (σ = 0.8-4.53; v = 3.43-14.59 %), 60-40 mm (σ = 1.11-2.89; v = 2.65-11.24 %), 40-25 mm (σ=0.81-3.63; v=3.9-25.19 %), <25 mm (σ=0.08-0.67; v =3.3-12.93 %).

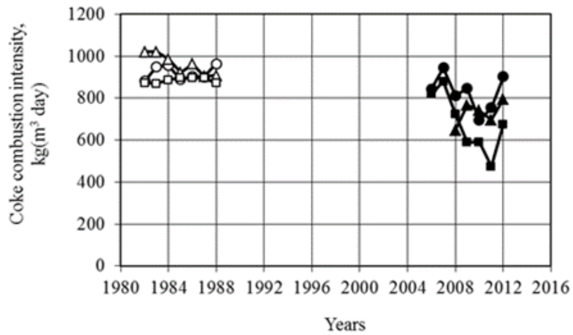

Fig.5. Changing the intensity of combustion of coke:
−o− blast furnace №7 volume 2000 м^3, −Δ− blast furnace №8 volume 2700 м^3,
−□−blast furnace №9 volume 5000 м^3 for the period 1980-1988 years;
−•− blast furnace №7 volume 2000 м^3, −▲− blast furnace №8 volume 2700 м^3,
−■−blast furnace №9 volume 5000 м^3 for the period 2006-2012 years

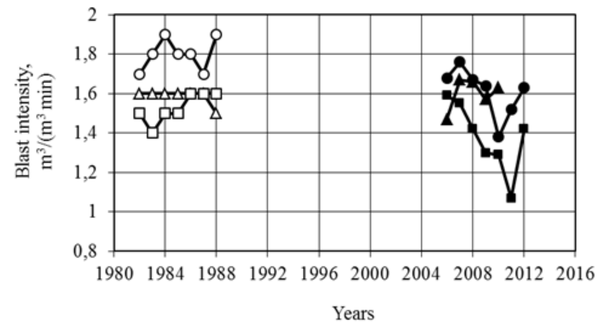

Fig.6. Changing blast intensity: −o− blast furnace №7 volume 2000 м^3,
−Δ− blast furnace №8 volume 2700 м^3, −□−blast furnace №9
volume 5000 м^3 for the period 1980-1988 years;
−•− blast furnace №7 volume 2000 м^3, −▲− blast furnace №8 volume 2700 м^3,
−■−blast furnace №9 volume 5000 м^3 for the period 2006-2012 years

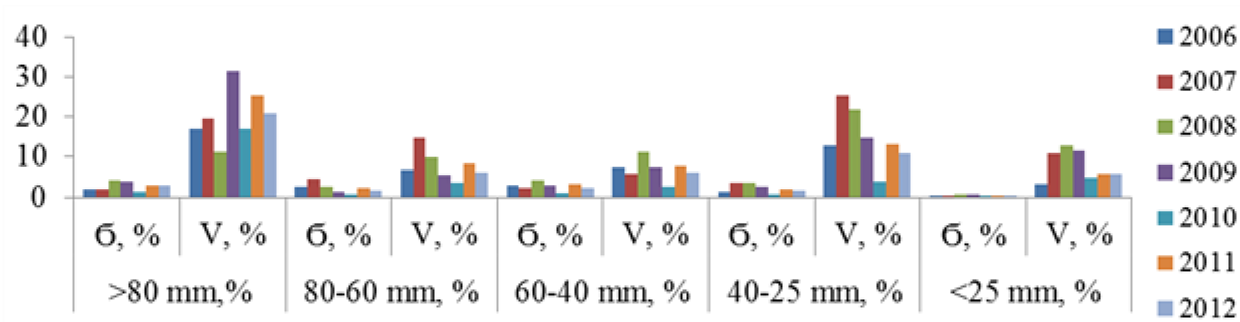

Fig.7. Fluctuations of distribution of the classes coke in 2006-2012

D. Muchnik and V. Babanin in [8] indicate the advisability of using controlled mechanical influences that significantly affect the grain size and mechanical strength of the bulk density of coke. This makes it possible to maintain the constancy of the main characteristics of its quality regardless of possible fluctuations in the properties of raw materials and coking technology.

3. Conclusions

Thus, the high fraction content> 80 mm and significant fluctuations in the granulometric composition coke of coke plant PJSC ArcelorMittal Kryvyi Rig necessitate the stabilization of coke by means of its mechanical processing.

The most suitable for the classification and quality management of coke under the conditions of the coke plant is the unit for obtaining the specified properties of coke. This unit is a drum, the cylindrical surface of which is made in the form of profile rods with distances between them, depending on the set size of the oversize part of the coke, or in the form of replaceable cards with holes of a given size and shape. The control of the unit for obtaining the specified properties of coke to improve the quality of coke, both to stabilize the properties of the bulk density and to achieve one of the selected fineness indicators, is carried out by changing the angle of the unit. The design characteristics and parameters of the drum are selected in accordance with the coke sorting scheme to provide the required destructive effects, which together with a certain intensity, allow you to change the specific characteristic of the physico-mechanical properties of coke to the desired value. Stabilization of coke in the process of its preparation not only improves the quality indicators of coke but also reduces the variability of its properties.

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, %;
CRI, CSR – coke reactivity index and coke strength after reaction, %

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