

THE USING OF COAL BLENDS WITH AN INCREASED CONTENT OF COALS OF THE MIDDLE STAGE OF METAMORPHISM FOR THE PRODUCTION OF THE BLAST-FURNACE COKE. MESSAGE 2. ASSESSMENT OF COKE QUALITY

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

¹ Kryvyi Rig Metallurgical Institute, Ukraine National Metallurgical Academy, 50006, Kryvyi Rig, Ukraine

² National Technical University "Kharkiv Polytechnic Institute", 61002, Kharkiv, Ukraine

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Abstract

Industrial tests show that the enrichment of coal blends containing more than 70% bituminous coals with high level of fluidity (HFC) must be increased in order to improve coke strength. However, it makes more sense to replace some of the HFC in the blend with an optimal quantity of low-metamorphic coal, and to reduce the degree of crushing, so as to ensure coke quality consistent with blast-furnace requirements (minimum strength $M_{25} = 90\%$, $M_{10} = 6\%$).

Keywords: oal batch; bituminous coal; crushing; clinkering properties; coke strength.

1. Results and discussions

The table presents the characteristics of the coke, which was produced at the ArcelorMittal Kryvyi Rig.

Table. Coke characteristics (2005–2011)

Year	Characteristics, %								
	W_t	A^d	S^d_t	M_{25}	M_{10}	>80 mm	<25 mm	CSR	CRI
2005	2.7	11.6	1.38	87.4	7.6	8.5	3.8	30.9	45.1
2006	2.9	12.3	1.08	88.4	7.5	9.1	3.1	42.0	37.1
2007	3.2	12.6	0.86	87.5	7.9	8.8	4.0	47.6	36.0
2008	3.5	13.1	0.80	85.0	9.3	12.4	5.8	41.2	40.4
2009	3.9	12.9	0.84	84.5	9.0	10.9	5.9	41.9	41.5
2010	4.4	12.9	0.88	83.4	8.6	7.3	6.8	41.2	41.5
2011	3.8	12.4	0.88	86.6	7.6	10.6	5.1	47.4	42.1

Analysis shows that the indices of resistance of coke abrasion (M_{10}) and crushability (M_{25}) deteriorated markedly from 2006 to 2010 and improved in 2011 insufficiently to meet blast-furnace requirements [1–5].

Analysis of the decline in coke quality at ArcelorMittal Kryvyi Rig has identified factors such as the following [6–13]: the large number of coal suppliers; the instability of concentrate supplies (with 60–80 reconfigurations of the blend in some months); imprecise selection of the optimal degree of blend crushing (the content of the ≤ 3 mm class), such that the blend density and content of the lean class (<0.5 mm) fluctuated impermissibly with the varying rank com-

position; poor blending of the blend after crushing (very poor blending in terms of some characteristics, such as the content of the <0.5 mm class); increased moisture and ash content of the coking blend; and extreme fluctuation in the coal and blend characteristics.

Insufficient attention has been paid to the selection of the optimal degree of blend crushing with a very high content of HFC. In the coking blend at ArcelorMittal Kryvyi Rig, the content of HFC fluctuated from 56 to 89% in 2011, according to petrographic data.

Semantic analysis (content analysis) of the information sources, which assesses the intensity of research in coke chemistry, clearly shows that very fine crushing of HFC is regarded as inexpedient in most publications (such as [14–22]). For example, with a considerable proportion of HFC in the blend, only the large concentrate need be crushed, with an overall level of crushing of 75–80% (that is, with 75–80% of the ≤ 3 mm class), according to [14]. To obtain coke of optimal quality, 75% crushing of HFC, 80% crushing of low metamorphic coal, and 85% crushing of high metamorphic coal is recommended in [15].

Industrial coking of blend with uncrushed concentrate consisting of blended HFC and low-metamorphic coal shows the possibility of using larger blend, with reduction in the content of the ≤ 3 mm class from 78 to 74.5%. Such preparation of the batch does not reduce coke strength, and blast-furnace operation is satisfactory [16].

At Kryvyi Rig coke plant, the crushing of low-metamorphic coal and a binary low-metamorphic + HFC blend corresponded to at least 80% of the ≤ 3 mm class; for high-metamorphic coals, the corresponding figure was 90%; and HFC coal, which contained 76–77% of the ≤ 3 mm class, were introduced in the blend without further crushing, according to [17]. Subsequently, at Kryvyi Rig coke plant, as a result of research with blend containing 65–95% of the ≤ 3 mm class, the following levels were adopted: 75% for the blend as a whole; 75–76% for low-metamorphic coal; 90–92% for lean coal; and 60–70% for HFC [18].

At Zaporozhe coke plant, with a large proportion of low-metamorphic and HFC in the blend, the overall degree of crushing was reduced so as to improve coke quality by increasing the batch density: from 88.4 to 84.7% of the ≤ 3 mm class. The content of the lean class (≤ 0.5 mm) was reduced from 46 to 38.1%, with gains in coke quality [19].

Excessive crushing of coal with good clinkering properties should be avoided according to [20]. Such crushing reduces the yield of liquid thermostable products, which bind the other components of the blend.

In studying the mutual penetration of the thermal-destruction products of different coals, it was established in [21] that, in all cases, decrease in grain size sharply reduces the motion of the destruction products of HFC, which is most fully converted to a liquid like plastic state. That explains why coke quality deteriorates as a result of fine crushing of HFC coal and the inclusion of a high content of such coal in the blend.

Large classes of HFC and high metamorphic coal obtained with cautious crushing are very similar in composition to grains of the same coal in the ≤ 3 mm class and have better properties in coking, according to the experiments in [22]. Consequently, there is no need for fine crushing of such coal [22].

Note that the foregoing applies to standard blend recommended for the production of blast-furnace coke of satisfactory quality. On average, standard blend consisting of coal from different basins contains no more than 30–55% HFC and 35–20% low-metamorphic coal (from the Donets and Karaganda basins, respectively) [23].

The opposite opinion was advanced in [24]. According to that argument, since coking is based on the interaction of coal particles with different properties, the preparation of each component must take account of the properties of all the other components and their proportion in the blend. If the lean coal is very finely crushed, say, its clinkering properties may be further reduced on account of the higher content of the <0.5 mm class and, equally importantly, its specific surface may be increased so much that satisfactory coke cannot be obtained even from a blend of such coal with highly coking coal. Therefore, the optimal balanced degree of crushing must ensure the required contact between grains, without reducing the coking properties of the components (without increasing the content of the <0.5 mm class).

On that basis, it was concluded in [24] that relatively fine crushing of HFC (in particular, of blend with moderate or poor coking properties) may improve the overall coking of the blend and increase the coke strength. In other words, additional crushing of HFC does not impair the coking properties and increases the contact area of the most valuable component in the blend with the other components, thereby resulting in greater coking. In a 2-kg furnace, coke of higher strength was obtained from blend containing 60% HFC with greater crushing in [24].

We know that, with excessive HFC in the blend, the coke cracks, and small pieces predominate. The basic property of HFC is to hold together a considerable quantity of lean additives. Without sufficient additives, blend with a large content of HFC must be thoroughly crushed in order to prevent excessive coking properties.

As already demonstrated, the content of HFC in the coking blend at ArcelorMittal Kryvyi Rig may be as much as 89%. The blend is crushed in the coal preparation shop without any possibility of separate crushing of the HFC so as to reduce its coking properties. Since the degree of crushing in the coal preparation shop was increased from 76 to 89% in 2011, while the content of HFC rose from 56 to 89%, the influence of these two factors on the coke quality may be analyzed.

In Fig. 1, we show the coke strength M_{25} as a function of the content of HFC in the blend, in the range 56–89% (on the basis of petrographic analysis in 2011). We conclude that, with variation in the degree of blend crushing in the range 76–89%, increasing the content of HFC above 60–70% reduces M_{25} .

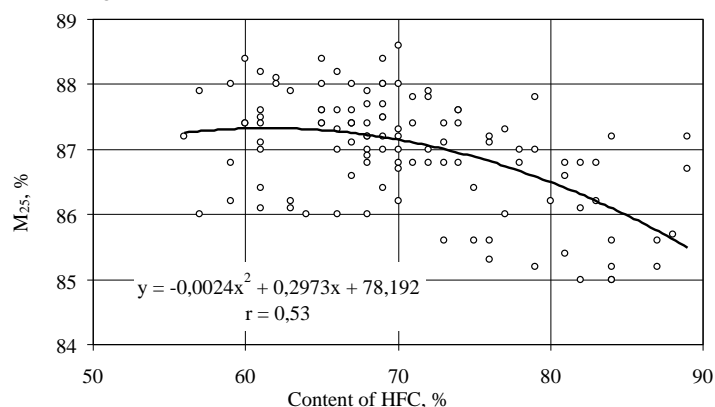


Fig. 1. Dependence of the coke strength M_{25} on the blend's content of HFC

At the same time, if we analyze the dependence of the coke strength M_{25} on the degree of blend crushing within the given range, when the blend contains 70–89% HFC (Fig. 2), we see that the strength increases with increase in the degree of crushing. This increase in coke strength is due to the blend's loss of coking properties.

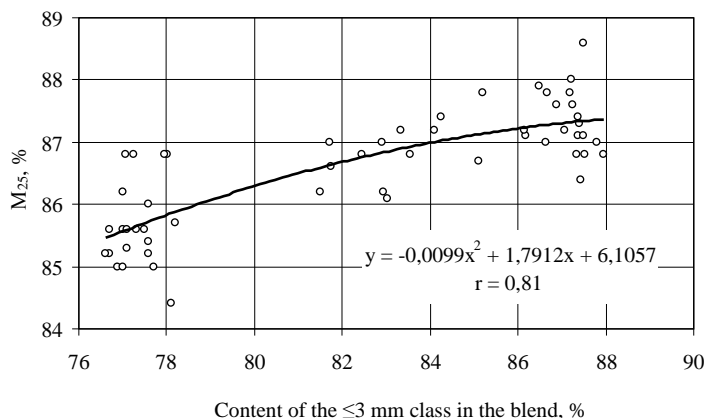


Fig. 2. Dependence of the coke strength M_{25} on the degree of blend crushing with 70–89% HFC

In Fig. 3, we see the variation in content of the lean class (<0.5 mm) with increase in the degree of crushing of blend containing 70–89% HFC. It follows from Fig. 4 that, in production conditions, increase in content of the <0.5 mm class in blend with a high content of HFC boosts coke strength. Thus, increasing the content of the <0.5 mm class from 37 to 47% raises M_{25} from 85.6 to 87.3%, on average.

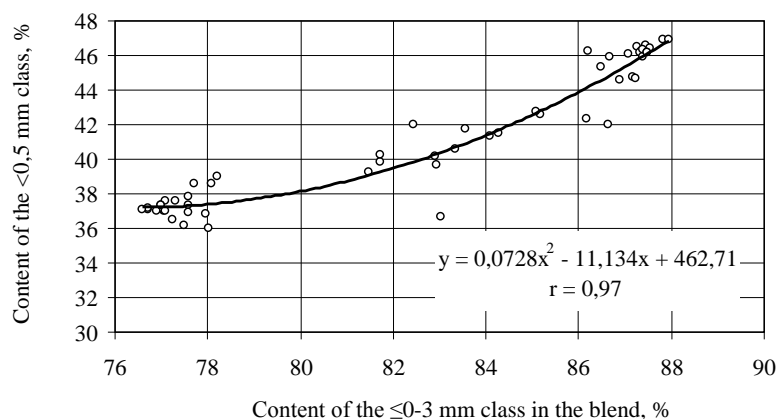


Fig. 3. Dependence of the content of the <0.5 mm class on the degree of batch crushing (the content of the ≤3 mm class), with 70–89% HFC

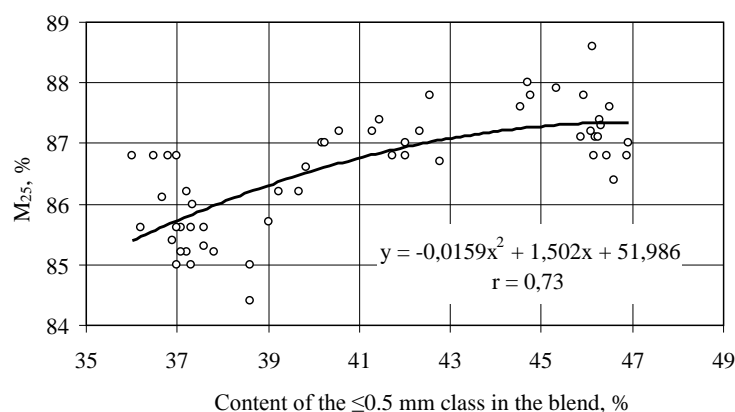


Fig. 4. Dependence of the coke strength M_{25} on the content of the <0.5 mm class, with 70–89% HFC

Note that, whereas reducing the coking properties of HFC (by increasing the content of the <0.5 mm class) is necessary in order to boost the quality of coke produced from blend with an excess of HFC, this is not recommended as a rational approach to the preparation of coking blend. If the coking properties of the blend are excessive, that may be addressed by introducing lean additives and petrographically no uniform coal. As we know, it is expedient to combine HFC with low metamorphic coal. In addition, given the current shortage of high metamorphic coal, it is expedient to increase the proportion of low metamorphic coal in the blend.

In coal blend, we must maintain an optimal HFC content of no more than 40–50% and also introduce up to 30% low metamorphic coal [25].

As an example, we note the experience of Bagleisk coke plant, where the coking blend was of variable composition and contained up to 70% coal with limited coking properties. The quantity of low metamorphic coal was increased from 29.5 to 56%, with decrease in the content of HFC from 39 to 21% and in the content of coal with $V_{daf} \sim 18$ –22 % from 17 to 9%. The content of high-metamorphic coal varied in the range 13–18%. The degree of blend crushing was 78.2–80.0% in terms of the content of the ≤3 mm class. With increase in the content of coal with limited coking properties, the coke quality deteriorated, but timely correction of the degree of blend crushing permitted the maintenance of relatively high coke quality. Thus, with

29.5% low-metamorphic coal in the blend, $M_{25} = 88.7\%$ and $M_{10} = 5.5\%$. With 56% low-metamorphic coal, the coke quality deteriorated: $M_{25} = 85.3\%$; $M_{10} = 7.3\%$ [26].

In 2011, according to petrographic analysis, the low metamorphic coal content in coking blend at ArcelorMittal Krivoi Rog fluctuated basically in the range 0–22%. As follows from Fig. 5, increase in the low-metamorphical coal content to 15% was accompanied by increase in M_{25} , with reduction in the HFC content of the blend.

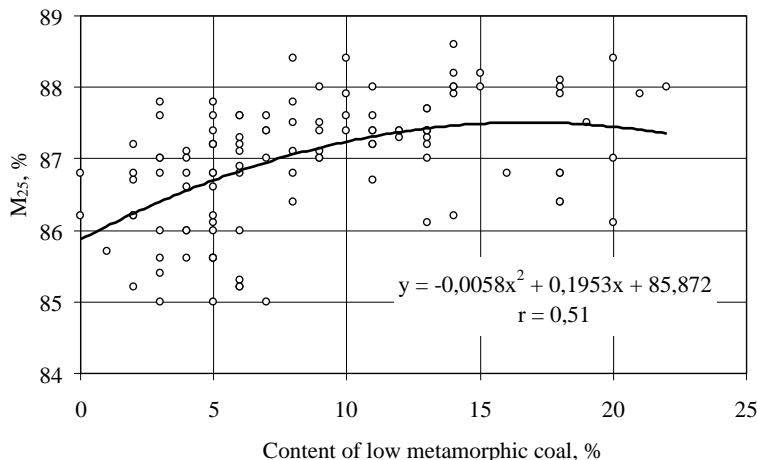


Fig. 5. Dependence of the coke strength M_{25} on the blend's content of low metamorphic coal

2. Conclusions

In industrial conditions, if the content of HFC in the blend is too high (>70%), the coke strength may be increased by crushing the blend until it contains 88% of the ≤ 3 mm class, on account of the increase in content of the lean (<0.5 mm) class.

However, this means of boosting coke strength is not recommended, because the properties of valuable HFC are wasted, along with the power required for crushing. A better approach is to introduce the optimal proportions of low metamorphic coal and HFC in the blend, with appropriate crushing, so as to ensure coke quality consistent with blast-furnace requirements (minimum strength $M_{25} = 90\%$, $M_{10} = 6\%$).

Symbols

W^r_t – water content of coke, %;

A^d – ash content of coke in the dry state, %;

S^d – sulphur of coke in the dry state, %;

M_{10} , M_{25} – indices of resistance of coke abrasion and crushability, respectively, %;

>80, <25 – content of particles more and less 80 and 25 mm in coke accordingly, %.

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

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To whom correspondence should be addressed: Dr. E. O. Shmeltser, Kryvyi Rig Metallurgical Institute, Ukraine National Metallurgical Academy, 50006, Kryvyi Rig, Ukraine