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METHOD OF CALCULATING AND ANALYZING THE FACTORS THAT AFFECT THE COKE CONSUMPTION AND PRODUCTIVITY OF BLAST FURNACES AT THE CHELYABINSK METALLURGICAL COMBINE

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Statistical analysis is used to examine the effect of the main raw-material and process factors on coke rate and productivity for the blast furnaces at the Chelyabinsk Metallurgical Combine during the period from 2007 to July 2012. A method is developed for calculating and predicting coke rate and daily pig-iron output in the blast-furnace shop, and a combination of parameters is found to reduce coke rate and increase the productivity of the shop. The factors table which is used throughout the industry is refined for the conditions that exist in the blast-furnace shop at the ChMK.

Keywords: *sinter, blast-furnace coke, iron, abradability M_{10}, oxygen, correlation, design procedure, consumption, basicity, productivity, strength, natural gas.*

The factors which affect the coke use and productivity of blast furnaces at metallurgical plants are accounted for by using a factors table [1] that includes characteristics of the quality of the coke (mechanical strength M_{25} and abradability M_{10}, the content of the +80-mm fraction, and the contents of ash and sulfur), the content of the 5–0-mm fraction in the sinter, furnace operating parameters and downtime, and the chemical composition of the pig iron. However, the raw materials, operating conditions, and design characteristics of blast furnaces differ significantly from one plant to the next. The table also does not include such important characteristics as sinter basicity, the sinter's cold strength (X_{+5}), its content of FeO, or the ratio of the content of sinter to the content of pellets in the furnace charge.

Taking the above into account, we developed a new method and computational program to analyze and predict coke rate and productivity on the blast furnaces at the Chelyabinsk Metallurgical Combine (ChMK). We also refined the values of the coefficients in the factors table and obtained values for the missing coefficients.

The blast-furnace shop at the ChMK includes three operating blast furnaces with a combined useful volume of 5143 m^3: BF-1, with a volume of 2038 m^3; BF-4, 1386 m^3; BF-5, 1719 m^3. The sinter production facility includes sinter plant No. 2 (SP-2), which began operation in 2005. The plant has four 240-m^2 sintering machines, each with a sintering zone of 138 m^3 and a cooling zone of 102 m^2 (SP-1 was closed in 2008).

The computational method was based on a statistical analysis of average monthly data on the performance of the blast-furnace shop and SP-2 during the period 2007 – July 2012.

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TABLE 1. Average and Limiting Values of the Performance Indices of the Blast-Furnace Shop in the Sample (45 months)

Indices	Minimum	Maximum	Average
Pig-iron output, tons/day	10570	12168	11292
Coke rate (dry), kg/ton pig	434.6	488.3	463.28
Smelting rate, tons/(m^3·day)	2.055	2.366	2.196
Iron content of the furnace charge,%	55.07	58.62	56.92
Mechanical strength of the coke M_{25}, %	82.7	87.1	84.79
Abradability of the coke M_{10}, %	8.05	10.70	9.12
Content of the 5–0-mm fraction in the sinter, %	13.99	25.6	18.09
Sinter content of the iron-ore-bearing part of the charge, %	56	87.71	72.11
Mechanical strength of the sinter X_{+5}, %	70.03	78.10	75.25
Basicity of the sinter	0.96	1.62	1.30
FeO content of the sinter, %	6.93	14.64	9.92
Blast temperature, °C	1029	1145	1097
Consumption, m^3/ton pig			
natural gas	108.2	122.70	115.07
oxygen	77.2	109.6	91.93
Oxygen content of the blast, %	24.94	27.00	25.77
Top-gas pressure, kPa	98.1	120.8	104.5
Downtime, %	0.51	3.65	1.55
Content in the pig iron, %:			
Si	0.5	0.81	0.64
Mn	0.09	0.52	0.32
P	0.116	0.140	0.129
S	0.021	0.0322	0.0257
Moisture content of the coke, % (of the dry state)	4.60	5.77	5.25
Wind rate, m^3/ton	1143	1273	1208
Ash content of the coke, %	10.95	12.726	11.583

The average monthly data used in the analysis were tentatively divided into “base” data and “supplementary” data. The base data from the above-indicated period characterize the factors at the “inlet” of the blast furnaces. The supplementary data (the contents of Si, Mn, S, and P in the pig iron) were used with correction factors that were found for them and with certain coefficients in the existing factors table (the contents of ash and sulfur in the coke).

We performed a preliminary analysis of the performance of the furnaces over a period of 70 months. This period was chosen based on the following considerations: it does not include performance data from the crisis period or data from periods when the furnaces were operating under emergency conditions; it makes it possible to obtain a range of data that can be used to reliably evaluate the effect of the different factors on the performance of the blast-furnace shop. The choice of the 70-month period for the preliminary analysis left 45 other months of furnace operation in the above-indicated sample. During the 45-month period, the amount of furnace downtime and slow-speed operation did not account for more than 4% of the entire sample and pig-iron output did not dip below 10500 tons/day. The average for the sample was 11300 tons/day (Table 1).

The technical reports generated by the blast-furnace shop at the ChMK are organized in such a way that the statistical data they contain characterize the performance of the shop as a whole, rather than individual furnaces. The largest differences between the furnaces' average monthly performance indices and the corresponding indices for the shop as a whole are relatively small and are 0.21 tons/(m^3·day) for smelting rate, 9.7 kg/ton for coke rate, 2.7 m^3/ton for natural-gas consumption, and 2.6% for blast temperature. Also, the same raw materials are used in the charges of all of the furnaces and the ratio of sinter content to pellet content is almost the same in each case. These similarities made it possible to employ shop-wide data to develop the methods that were used to perform the calculations and analyze shop performance.

The multiple regression equation that was used to calculate coke consumption includes eight variables: the iron content of the iron-ore-bearing part of the furnace charge; the coke abradability index M_{10}; blast temperature; natural-gas consumption; sinter basicity (CaO/SiO_2); the FeO content of the sinter; the sinter content of the sinter-pellets mixture; sinter strength index X_{+5}. Collectively, the operating data for BF-2 showed that the strength X_{+5} of the sinter cooled on the sintering machines is highly stable and depends little on the conditions under which the samples are obtained or even on the length of time the sinter is stored. The given strength index correlates well with coke rate. The data on the content of the 5–0-mm fraction of sinter depend appreciably on the condition of the equipment used to mechanically process the sinter cake, the method used to obtain samples of sinter from the sinter cars and the hoppers in the stockhouse of the blast furnace, and subjective factors in the sampling process. There is no correlation between the content of the indicated sinter fraction and coke rate. There is also almost no correlation between sinter strength and the yield of the 5–0-mm fraction, which shows that the latter index is primarily affected by the conditions under which the sinter cake is mechanically processed and the subjective factors in the sampling operation.

The following equation was obtained to calculate *coke rate*:

$$\mathrm{R_c} = K_1 \cdot \mathrm{FeO} + K_2 \cdot \mathrm{Bsc.} + K_3 \cdot \mathrm{Bf_{snt}} + K_4 \cdot \delta_{\mathrm{snt}} + K_5 \cdot M_{10} + K_6 \cdot T_{\mathrm{b}} + K_7 \cdot V_{\mathrm{nt.g}} + K_8 \cdot \mathrm{Fe} + A, \tag{1}$$

where FeO is the ferrous oxide content of the sinter, %; Bsc. is the basicity of the sinter; $\mathrm{Bf_{snt}}$ is the sinter content of the iron-ore-bearing part of the blast-furnace charge, fractional units; δ_{snt} is the cold strength of the sinter, %; M_{10} is the abradability index of the coke, %; T_{b} is the temperature of the blast, °C; $V_{\mathrm{nt.g}}$ is the unit consumption of natural gas, m^3/ton; Fe is the iron content of the iron-ore-bearing part of the blast-furnace charge (IBC), %; $A = 1098$ is a random variable; $K_1 = -0.159$; $K_2 = -33.693$; $K_3 = -0.459$; $K_4 = -1.438$; $K_5 = 7.119$; $K_6 = -0.141$; $K_7 = -1.159$; $K_8 = -3.960$.

The correlation coefficient of Eq. (1) $R = 0.873$.

The multiple regression coefficient used to calculate the *productivity of the blast-furnace shop* contains 10 variables. Compared to Eq. (1), this equation also includes the unit consumption of oxygen, the mechanical strength of the coke M_{25}, and shop downtime. Unlike Eq. (1), it does not include natural-gas consumption, and the cold strength of the sinter is replaced by its content of the 5–0-mm fraction. The content of that fraction is a more important variable for this case. The equation has the form

$$\mathrm{P_{bfs}} = K_1 \cdot \mathrm{FeO} + K_2 \cdot \mathrm{Bsc.} + K_3 \cdot \mathrm{Bf_{snt}} + K_4 \cdot (5\text{–}0) + K_5 \cdot M_{10} + K_6 \cdot M_{25} + K_7 \cdot T_{\mathrm{b}} + K_8 \cdot V_{\mathrm{O_2}} + K_9 \cdot \mathrm{Fe} + K_{10} \cdot \mathrm{Ng} + A, \tag{2}$$

where (5–0) is the content of the 5–0-mm fraction in the sinter, %; M_{25} is the mechanical strength of the coke, %; $V_{\mathrm{O_2}}$ is unit oxygen consumption, m^3/ton; Fe is the iron content of the IBC, %; $A = 10565$ is a random variable; $K_1 = 102.45$; $K_2 = 188.4$; $K_3 = 21.85$; $K_4 = -45.89$; $K_5 = -623.91$; $K_6 = 2.80$; $K_7 = 6.32$; $K_8 = 10.37$; $K_9 = 269.45$; $K_{10} = -67.06$.

The correlation coefficient of Eq. (2) is also very high: $R = 0.892$.

As new data are added to the sample, the average values of the parameters in the sample and the coefficients of the terms in the equations are automatically corrected – as is the quantitative effect of the factors on coke rate and blast-furnace productivity.

TABLE 2. Relative Effect of the Factors on Coke Rate and Daily Pig-Iron Production in the Blast-Furnace Shop (BFS) at the ChMK

Factor	Effect of the factor, %			
	according to the factors table		for the BFS at the ChMK	
	coke rate	productivity	coke rate	productivity
Base factors				
1% increase in Fe content	–1.0	1.7–2.0	–0.86	2.39
1% decrease in the content of the 5–0-mm fraction in the IBC	–0.50	1.0	–	0.41
1% increase in coke strength based on the index M_{25}	–0.60	0.60	–0.30	0.02
1% decrease in coke abradability based on the index M_{10}	–2.80	2.80	–1.54	5.54
10°C increase in blast temperature within the range 1000–1150°C with 25–35% O_2 in the blast	–(0.22–0.25)	0.22–0.25	–0.31	0.56
Increase in natural-gas consumption, m^3/ton	–(0.7–0.8)	–	–0.25	–
1% increase the oxygen content of the blast	0.3	2.1	–	1.2
9.81 kPa increase in top-gas pressure	–0.2	1.0	–0.67	0.83
1% decrease in furnace downtime and slow-speed operation	–0.5	1.0–1.5	–0.66	0.60
0.1 increase in sinter basicity	N.d.	N.d.	–0.74	1.67
1% decrease in the FeO content of the sinter	N.d.	N.d.	–0.03/–0.70[**]	–0.91
1% increase in sinter strength X_{+5}	N.d.	N.d.	–0.31	–
1% increase in the sinter content of the charge	N.d.	N.d.	–0.10	0.20
Supplementary factors				
0.1% decrease in the pig iron's content of:				
Si	–1.20	1.20	–1.37	1.34
Mn	–0.20	0.20	–0.73	0.17
P	–0.6	0.6	–0.15	–
0.01% increase in the S content of the pig	–1.0	1.0	–1.49	3.49
Decrease in the coke's content of:[*]				
ash by 1%	–1.3	1.3	–1.3	1.3
sulfur by 0.1%	–0.3	0.3	–0.3	0.3
the +80-mm fraction by 1%	–0.2	0.2	–0.2	0.2

[*] From the factors table. [**] With a decrease from 12.5 to 8.3%.

The pairwise relationships between the terms of Eqs. (1) and (2) are analyzed with the use of linear equations. Here, not all of the terms of the equations are independent. In addition, certain pairwise relations are more accurately described by polynomial equations and thus require a more refined analysis.

Table 2 shows the results obtained from evaluation of the effect of the "base" factors on coke rate and blast-furnace productivity in accordance with Eqs. (1) and (2). The table also shows the effect of the "supplementary" factors, and it compares these results with data from the factors table. Table 3 shows data on the effect of the "base" factors on the performance of the blast-furnace shop in absolute quantities.

TABLE 3. Absolute Effect of the Base Factors on Coke Rate and Daily Pig-Iron Production

Effect of the factors	Increase in the factor by 1%								T_b, by 10°C	$V_{nr.g}$ by 1 m^3/ton	Basicity, by 0.1	V_{O_2} by 1 m^3/ton
	Fe	X_{+5}	5–0 mm	Bf_{snt}	FeO	M_{10}	M_{25}	δ_{snt}				
On coke rate, kg/ton	–3.96	–1.44		–0.46	–0.16	7.12		–1.44	–1.41	–1.16	–3.37	
On pig-iron output, tons/day	269		–45	22	102	–624	2.8	68	63		188.4	10.4

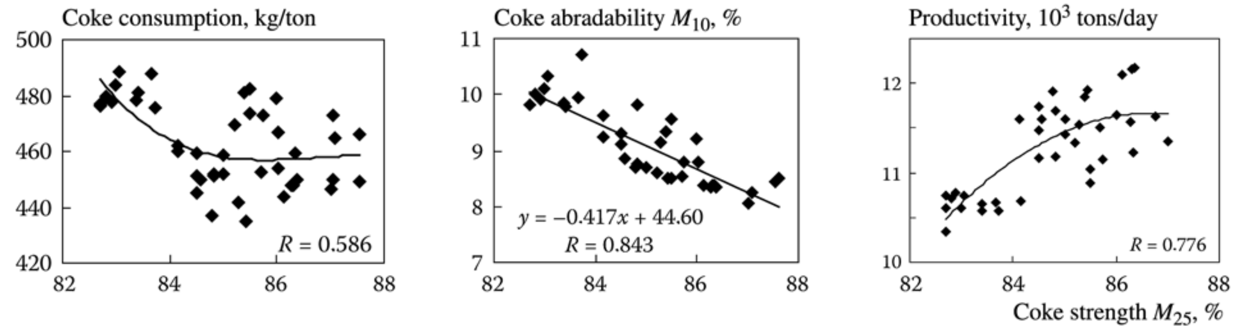
TABLE 4. Average Indices for the 12 Most Efficient Months of BFS Operation

Index	For coke rate	For BFS productivity
Average daily pig output, tons/day	11538/11712*	11883/12051*
Coke rate, kg/ton	445.2/438.6*	451.4/445.1*
Mechanical strength of coke M_{25}, %	86.1	85.9
Coke abradability M_{10}	8.56	8.70
Fe content of charge, %	56.7	57.3
Sinter content of charge, %	68.9	72.0
Sinter basicity	1.426	1.374
Fe content of sinter, %	8.34	8.86
Mechanical strength of sinter X_{+5}, %	77.4	76.6
Content of 5–0-mm fraction in sinter, %	19.0	18.8
Temperature of hot blast, °C	1124	1112
Natural-gas consumption, m^3/ton pig	115	114
Oxygen consumption, m^3/ton pig	89.0	90.5
Shop downtime, %	2.9	2.3
*Indices without downtime.		

Table 4 shows the indices that correspond to the most efficient periods of shop operation based on the results obtained for coke rate and furnace productivity. We took the months in which coke rate was below 445 kg/ton pig, assuming that this figure can serve as a point of reference for the operating conditions which presently exist in the shop. There turned out to be 12 such months in the sample. We then chose the 12 months in which the daily output of pig iron was highest. We therefore obtained the ranges of values of the shop performance indices for which – in the absence of shop downtime – coke rate will be 439–445 kg/ton and pig-iron production will be 11.7–12.05 thousands of tons/day. This does not mean that the improvements made in the given characteristics are at best moderate; it means only that the indicated ranges of values are sufficient to achieve the targets for coke rate and daily pig-iron production.

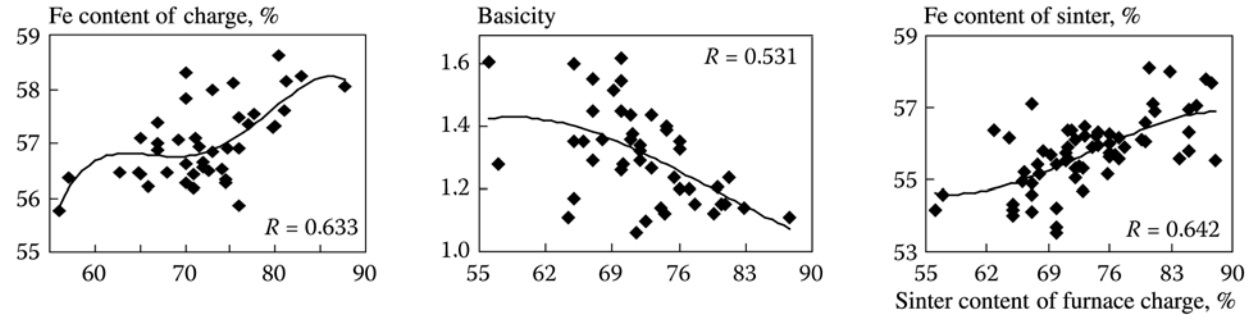
The signs in Tables 2 and 3 which indicate the effect that the parameters in the sample have on coke rate and shop productivity are consistent with the data in the factors table. Thus, they are also in agreement with the theory and practice of blast-furnace smelting. At the same time, as might be expected, the quantitative values of the parameters may be different from the data in that table.

The parameters which have the greatest effect on coke rate and shop productivity are the coke abradability index M_{10}, the iron content of the furnace charge, blast temperature, and sinter basicity.



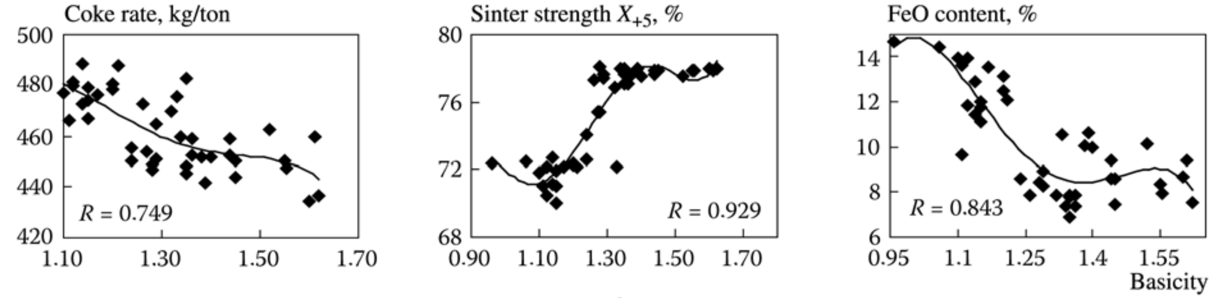
a *b* *c*

Fig. 1. Dependence of coke rate (*a*), coke abradability M1$_0$ (*b*), and BFS productivity (*c*) on coke strength M_{25}.



a *b* *c*

Fig. 2. Dependence of the iron content of the furnace charge (*a*), sinter basicity (*b*), and the iron content of the sinter (*c*) on the sinter content of the furnace charge.



a *b* *c*

Fig. 3. Dependence of coke rate (*a*), sinter strength (*b*), and FeO content (*c*) on sinter basicity.

For example, a 1% decrease in the abradability index decreases coke rate by 7.12 kg/ton pig (see Table 3). Substitution of the average monthly data on the index M_{25} into Eq. (1) showed that this parameter has almost no effect on the coke rate. The reason for this can be discerned from Fig. 1*a*, where a polynomial equation was used to analyze the data. It can be seen that the relationship between the index M_{25} and coke rate R_c ends when $M_{25} > 84.5\%$, which corresponds to the working range. At the same time, there is a close relationship between M_{25} and M_{10} (Fig. 1*b*). Finally, it is known that the yield of the +80-mm fraction (for which data are lacking) increases with an increase in the strength of the coke. As can be seen

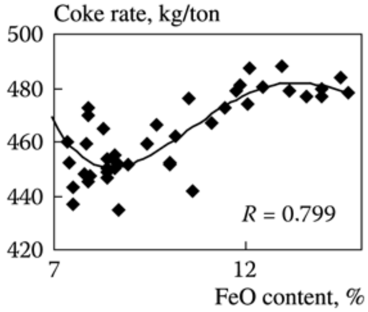


Fig. 4. Character of the dependence of coke rate on the FeO content of the sinter.

from the factors table, this linkage has an adverse effect on coke consumption and furnace productivity. An increase in the strength of the coke is accompanied by an increase in its volumetric density and, thus, a decrease in porosity – which slows the reaction $C + CO_2 = 2CO$.

The index M_{10} has a significantly greater effect on shop productivity than is indicated by the factors table (Table 2). The fact is that coke strength has a substantial effect both on shop productivity and on coke rate up to $M_{25} < 84.5\%$ (Fig. 1*c*). Thus, the entire set of properties of the coke is probably best represented by its abradability index M_{10}.

It can be seen from the data in Table 4 that economical coke use and high shop productivity are both achieved when $M_{25} = 85.9–86.1$ and $M_{10} = 8.56–8.70$.

The effect of the iron content of the furnace charge on coke rate and shop productivity is close to that indicated by the factors table (Table 2).

The iron content of the furnace charge increases, albeit nonlinearly, with an increase in the charge's sinter content (Fig. 2*a*), i.e., with a decrease in the charge's content of pellets – which contain more iron than the sinter. This contradictory finding can be explained by the fact that the basicity of the sinter decreases with an increase in the amount of sinter in the charge (Fig. 2*b*) and, accordingly, an increase in the charge's iron content (Fig. 2*c*). However, when sinter basicity is 1.1 or less, the pellets begin to have the greatest positive effect on the iron content of the charge. The pellet content of the charge is fairly high in this case.

In accordance with the data in Table 3, an increase in sinter basicity by 0.1 is accompanied by a 3.37 kg/ton reduction in coke rate and a 188 ton/day increase in pig-iron output despite the decrease in the iron content of the furnace charge. The character of the dependence of coke rate on sinter basicity is illustrated by Fig. 3*a*. The positive effect that an increase in the basicity of the sinter has on the smelting indices is manifest in particular through an increase in the sinter's strength (Fig. 3*b*) and a decrease in its content of FeO (Fig 3*c*). These characteristics in turn have a positive effect on coke rate and the productivity of the blast-furnace shop (see Tables 2 and 3).

In accordance with the data in Table 4, an economical coke rate and high shop productivity are realized when the iron content of the charge is within the range 56.7–57.3%, sinter basicity is 1.374–1.426, sinter strength is 76.6–77.4%, and the sinter content of the charge is 69–72%.

As is known, the FeO content of sinter is an indirect indicator of its reducibility, and an increase in the degree of indirect reduction that sinter undergoes in a blast furnace saves coke. At first glance, the savings in coke which is obtained as a result of a decrease in the FeO content of the sinter is small according to Eq. (1) – 0.16 kg/ton, or 1%. However, it can be seen from the data in Fig. 4 – which shows these two quantities as having a polynomial relationship with one another – that the curve has an extremum (FeO content ~8.3%) which corresponds to the minimum coke rate. Coke rate even increases to some extent with a decrease in FeO content to the left of the extremum, this increase in rate being due to the decrease in the strength of the sinter. An increase in the FeO content of the sinter within the range 8.3–12.5% is accompanied by a substantial rise in coke rate. According to Table 4, the optimum range of values for the FeO content of the sinter is 8.34–8.86%. These values correspond to a bed height of 550 mm on the sintering machine.

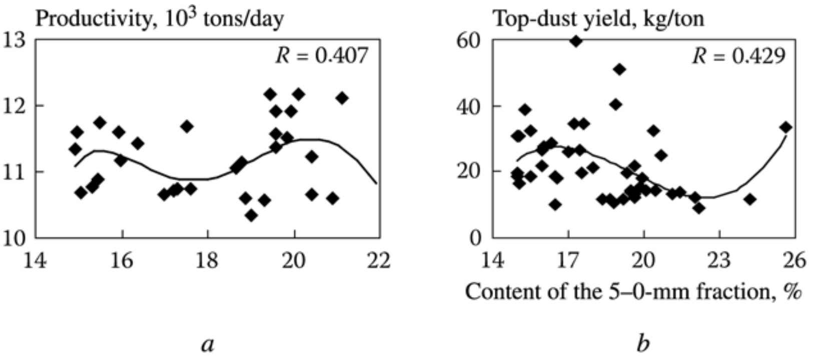


Fig. 5. Character of the dependence of BFS productivity (*a*) and top-dust yield (*b*) on the content of the 5–0-mm fraction in the sinter.

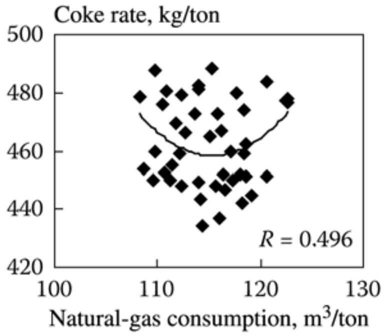


Fig. 6. Dependence of coke rate on natural-gas consumption.

The sinter-strength index X_{+5} has a very strong effect on coke rate. The data in Table 3 show that a 1% increase in X_{+5} results in a decrease in coke consumption by 1.41 kg/ton pig iron.

The effect of the content of the 5–0-mm fraction in the “hopper” sinter on blast-furnace productivity is significantly smaller than indicated by the data in the factors table (0.4% versus 1.0%, respectively). This difference may (as noted above) be partially connected with subjective factors involved in the sampling of the sinter. Here, a sharp reduction in pig-iron output is seen only when the content of the 5–0-mm fraction exceeds 20% (Fig. 5*a*). This phenomenon can be explained by the improvement in the distribution of the charge’s granulometric composition over the diameter of the blast furnace and the corresponding improvement in the distribution of the gas flow, as well as by the suitability of this fraction for the sintering of deep beds of charge materials, the fact that the sinter undergoes cooling while on the sintering machine, and the use of efficient jaw crushers for its comminution.

The explanation just given – which runs counter to existing representations – was substantiated by data obtained on the yield of top dust (Fig. 5*b*). Top-dust yield even decreases somewhat as the content of the 5–0-mm fraction in the sinter is increased to 22%, and it begins to increase rapidly only after that percentage is reached. Top-dust yield was not found to have any correlation with the cold strength of the sinter or its abradability.

If the undersized 5–3-mm fraction of sinter were not needed for balling sintering-machine charges composed of 80% fine concentrates, it could probably be used in blast-furnace smelting – as is being done at a number of metallurgical plants in Japan.

The data in Table 2 suggest that an increase in blast temperature has more of an effect than is indicated by the factors tables, especially in regard to the productivity of the blast-furnace shop. The substantial savings in coke that is seen is

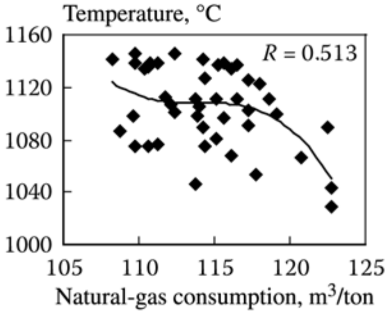


Fig 7. Relationship between natural-gas consumption and blast temperature.

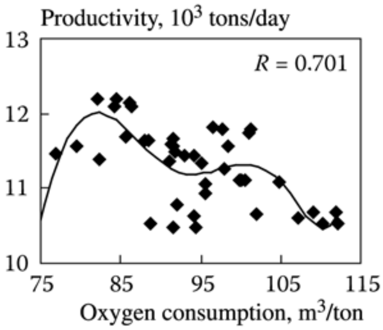


Fig. 8. Relationship between oxygen consumption and BFS productivity.

greater than the theoretical value calculated on the basis of the amount of heat introduced into the furnace by the heated blast air. This fact was first explained by J. Edelman in 1839 [2] and has been observed at other metallurgical plants [2]. The essence of the explanation for this apparent contradiction is that an increase in blast temperature is accompanied by broadening of the moderate-temperature range in the furnace and a corresponding increase in the amount of indirect reduction of iron oxides which takes place in it. The greater amount of indirect reduction saves coke.

Although blast temperature is an independent variable in Eqs. (1) and (2), the effectiveness of its use depends on the extent to which the chosen blast temperature is appropriate for the amounts of natural gas and oxygen injected into the furnace and the quality of the coke used in the charge. The relationship between natural-gas consumption and coke rate is described well by a polynomial curve with an extremum (Fig. 6).

V. N. Andronov argues that cold natural gas, undergoing conversion in the oxygen of the hot blast, not only does not heat the hearth but inevitably cools it. This causes part of the hot blast to be shifted toward the upper part of the furnace, where there is already excess heat. The end result is an increase in the temperature of the top gas [3].

He also concludes that an increase in natural-gas consumption should necessarily be accompanied by an increase in the temperature of the blast. However, under the current conditions of operation of the blast-furnace shop, an increase in the amount of natural gas used is not always accompanied by an increase in blast temperature (Fig. 7). Thus, the descending branch of the curve in Fig. 6 represents the favorable conditions created by increasing natural-gas use and compensating for this through the blast temperature, while the ascending branch represents the corresponding conditions created by increasing natural-gas use and lowering the blast temperature. As a result, the efficiency of using natural gas on the blast furnaces at the ChMK is only one-third as great as indicated by the factors table.

Introducing oxygen content into Eq. (1) as a variable decreased the equation’s correlation coefficient but did not affect coke rate. It was thus excluded from the equation.

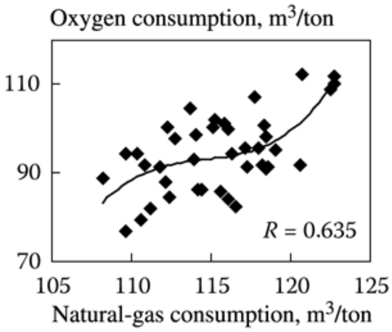


Fig. 9. Relationship between oxygen consumption and natural-gas consumption.

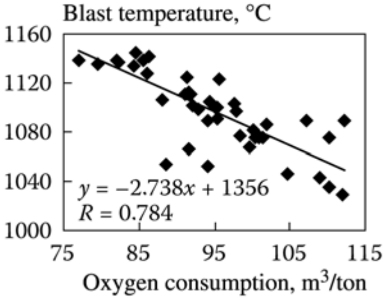


Fig. 10. Relationship between oxygen consumption and blast temperature.

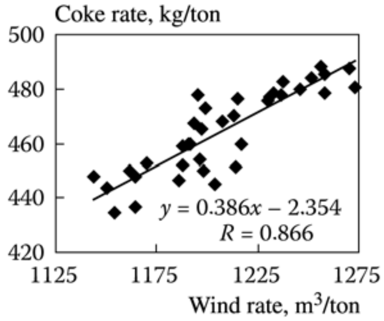


Fig. 11. Relationship between wind rate and coke rate.

The factors table indicates that a 1% increase in the oxygen content of the blast should be accompanied by a 2.1% increase in furnace productivity, while this increase is just 1.2% when determined on the basis of Eq. (2). In accordance with the data in Fig. 8, effects of opposite sign are obtained in different ranges of oxygen consumption. The explanation for this is as follows. The consumption of oxygen is determined by the consumption of natural gas (Fig. 9) and, as follows from the data in Fig. 10, an increase in oxygen consumption is accompanied by a decrease in blast temperature. Nevertheless, "...the addition of process oxygen to the blast is not an independent parameter of blast-furnace smelting technology; rather, it is only a means of increasing the consumption of natural gas" [3].

The wind rate that corresponds to the lowest coke rate is about 1150 m^3/ton pig (Fig. 11).

Figure 12 shows the relationship between smelting rate and coke rate. It can be seen that coke rate begins to increase

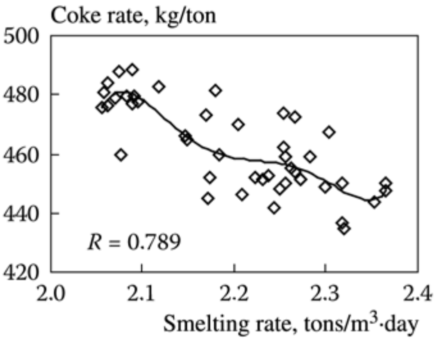


Fig. 12. Relationship between smelting rate and coke rate.

when the smelting rate exceeds a certain limit (~2.35 tons/(m^3·day). This value of this limit needs to be refined after new data are obtained for the operation of the blast-furnace shop.

For the most part, characteristics that are close to or are not critically different from the data in the factors table were obtained from an evaluation of the effect of gas pressure and "supplementary" factors on the indices of blast-furnace smelting. We used linear equations to perform this evaluation, the results of which are shown in Table 2.

Conclusions

1. The existing table of factors that affect the coke rate and productivity of blast furnaces correctly reflects the sign and relative importance of these factors. However, the table cannot cover the entire range of raw materials that are used or the range of operating conditions encountered in different blast-furnace shops. It needs to be corrected for the specific operating conditions that exist in each case.
2. A method was devised to calculate and predict the coke rate and productivity of blast-furnace shops for the conditions which exist at the Chelyabinsk Metallurgical Combine.
3. Data were obtained that characterizes the effect of the main raw-material and processing factors on coke rate and the productivity of a blast-furnace shop.
4. It was shown that the most important raw-material factor is the coke abradability index M_{10}.
5. Features of the effect of the content of the 5–0-mm fraction of sinter on the performance of blast furnaces at the ChMK and the yield of top dust were established for the case when the sinter is cooled on the sintering machines and crushed in jaw crushers.
6. It was shown that the use of natural gas and oxygen is ineffective if it is not done together with appropriate regulation of blast temperature.

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