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Using Coal-Dust Fuel in Ukrainian and Russian Blast Furnaces

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Over the past 25 years, 130 blast furnaces, producing around 300 million t/yr of hot metal, have successfully introduced coal-dust fuel, along with improvements in coke quality and other compensatory measures. As of 2007, smelting with coal-dust injection at the rate of 200–260 kg/t of hot metal was being introduced worldwide, with the replacement of up to 40–50% of the coke employed and reduction in coke consumption by 250–300 kg/t. This is only the beginning, as indicated by theoretical analysis and the change in coal-dust and coke consumption in the developed nations over the last 10–15 years [1–3].

Unfortunately, Ukrainian and Russian blast-furnace production falls short of the best global practices. It is no secret that, having switched to oxygen and natural gas in the 1960s, our blast-furnace industries have improved the batch and technological conditions and have attained a productivity of 2.5 and even 3 t/(m^3 day), but have not been able to reduce coke consumption below 400 kg/t, which was the industry standard 40 years ago. The situation is particularly bad in Ukraine: in 2007, furnace productivity was 1.5–2 t/m^3, with a coke consumption of 432–530 kg/t [4].

Theoretical considerations and industrial experience over the last 20 years show that the large-scale introduction of coal-dust fuel, with simultaneous improvement in coke quality and in batch and technological conditions, is the only immediately available means of reducing coke consumption considerably (by 20–40%). By this means, natural-gas consumption is reduced or eliminated, and the efficiency of blast-furnace production and ferrous metallurgy as a whole is increased.

BASIC PRINCIPLES OF COMPENSATION IN REPLACING COKE BY COAL-DUST FUEL

Since the consequences of injecting additional fuel may be calculated, it is obvious that increase in fuel consumption must be accompanied by compensatory measures to neutralize the negative impact of the coal dust on the technological conditions. The technological disruptions due to coal-dust fuel may be determined by the methods of [5–7].

To estimate the effectiveness of the compensatory measures, we introduce the total coefficient ΣK_r characterizing the replacement of coke by other fuel [8, 9]

$$\Sigma K_r = (\Delta Q_{cot} + \Delta Q_{ccm})/\Delta Q_{ot}, \tag{1}$$

where ΔQ_{cot} is the decrease in coke consumption due to increased consumption of the other fuel, kg/t of hot metal; ΔQ_{ccm} is the decrease in coke consumption due to the compensatory measures, kg/t of hot metal; ΔQ_{ot} is the additional consumption of the other fuel, kg/t of hot metal.

Calculations based on Eq. (1) and experience with coal-dust fuel at Donetsk Metallurgical Plant (now OAO DMZ) and elsewhere show that, if the replacement coefficient ΣK_r is 1 or more, increased coal-dust consumption in the blast furnace will not be accompanied by changes impairing its efficiency. Hence, in this case, the compensation of the negative impact of the additional fuels on smelting is complete.

One of the basic compensatory measures is to reduce the natural-gas flow rate, as is evident from the combustion of carbon and methane in the tuyere region

$$C + 0.5O_2 = CO + 117.845 \text{ MJ}; \tag{2}$$

$$CH_4 + 0.5O_2 = CO + 2H_2 + 36.016 \text{ MJ}. \tag{3}$$

In Eq. (3), the heat per unit of reducing gas obtained is nine times less than in Eq. (2), while the yield of reducing gas is three times higher. Correspondingly, the decrease in theoretical combustion temperature per unit fuel injection is 2.5–3 times greater than in Eq. (2). Consequently, the coefficient ΣK_r ensuring complete compensation of the negative consequences is 2–3 times higher for natural gas than for coal dust. Hence, in Ukrainian and Russian blast-furnace shops, coal-dust injection itself may serve as a compensatory factor that increases the total consumption of additional fuel (natural gas + coal dust) and reduces coke consumption, by reducing the natural-gas consumption.

To evaluate how well the technological conditions are calculated, we propose limiting parameter values that cannot be exceeded in current conditions. To estimate the limiting values, we analyze annual mean data from 57 European blast furnaces in 2002 and 2004 and from 116 Soviet furnaces in 1989 [9]. It is found that, with the attainable quality of the coke and iron ore and for furnace temperature and blast conditions corresponding to coke consumption of 250–600 kg/t of hot metal, the limiting values are as follows: for the gas velocity in the bosh, 25 m/s; for the ore load, 6 t/t of coke; for the furnace-gas yield, 4700 m^3/t of coke; for the content of fines (5–0 mm) in the iron-ore batch, 475 kg/t of coke; and for the slag yield, 1100 kg/t of coke.

The limiting parameters give regions of feasible and unlikely smelting conditions in blast furnaces with coal-dust injection. The technological conditions with coal-dust fuel are calculated by the method of [5].

INDUSTRIAL EXPERIENCE WITH COAL-DUST FUEL

Russian and Ukrainian Experience

In Ukraine, at the initiative of N. I. Krasevtsev, the director of the Donetsk Scientific-Research Institute of Ferrous Metallurgy, work on coal-dust injection began in 1963 at Donetsk Metallurgical Plant.[1] This technology completed the stage of experimental operation and industrial trials (1968–1978) and in 1980, on the basis of the first industrial unit of its type in Europe, combined natural-gas and coal-dust injection in the hearth was introduced, with an oxygen-enriched blast; as a result, the replacement of coke by other fuels was increased from 10–15% to 30–35% (Table 1) [8–10].[2]

The results obtained in 2005 and 2006 at OAO DMZ blast furnace 2, after switching off the natural-gas supply, are comparable with values obtained elsewhere in the world: in the first nine months of 2006, the mean coke consumption in this furnace was 403.6 kg/t of hot metal, in the absence of natural gas, with coal-dust injection at a rate of 167.5 kg/t. In the same period, in Ukrainian blast furnaces, the coke consumption was 496.5 kg/t and the natural-gas consumption was more

Table 1. Operational parameters of OAO DMZ blast furnace 2 (V = 1033 m^3)

Characteristic	December 21, 2002 to January 1, 2003	January 2 to March 30, 2003	December 31, 2004 to February 7, 2005	February 8 to March 8, 2005
Hot-metal output, t/day	2046	2022	2178	2124
Coke consumption (dry), kg/t	566	470	395	381
Batch consumption, kg/t:				
YuGOK sinter	487	634	709	718
LebGOK pellets	989	909	891	893
limestone and other fluxes	192	188	151	112
Blast:				
flow rate, m^3/min	2295	2152	1993	1978
pressure, kPa	240	245	245	239
temperature, °C	1085	1096	1094	1085
Consumption (per t of hot metal):				
oxygen, m^3	37	41	80	81
coal dust, kg	0	96	131	138
natural gas, m^3	99	62	69	65
conventional fuel, kg	701	661	620	608
Theoretical combustion temperature, °C	2036	2041	2031	2018
Blast-furnace gas:				
pressure, kPa	116	125	121	118
temperature, °C	263	272	238	265
Degree of CO utilization	0.374	0.390	0.461	0.457
Slag yield, kg/t	371	389	351	326
Content in slag, %:				
Al_2O_3	6.78	6.40	5.85	5.86
MgO	3.42	3.34	7.11	6.27
S	1.78	1.78	1.69	1.71
Slag basicity CaO/SiO_2	1.29	1.27	1.20	1.21
Content in hot metal, %:				
Mn	0.24	0.3	0.13	0.12
S	0.035	0.036	0.032	0.035

Table 2. Operational parameters of OAO DMZ blast furnace 2 and other Ukrainian blast-furnace shops in the first nine months of 2006 [4]

Blast-furnace shops	Output, 10^3 t	Consumption, kg/t and m^3/t of hot metal				Total conventional-fuel consumption, kg/t
		coke	natural gas	coal dust	coal	
OAO DMZ	571.7	403.6	0	167.5	0	582.9
Ukraine (without OAO DMZ)	2438.0	496.6	81.6	0	26.5	641.6
Difference		–93.0	–81.6	+167.5	–26.5	–58.7

[1] The Giprostal Research and Design Institute and Ukrenergochermet Production Facility provided the working designs and supervision for the prototype and industrial systems used in coal-dust preparation and injection.

[2] Those who participated in introducing the coal-dust technology included V. V. Nozdrachev, V. E. Popov, V. V. Braga, S. A. Ivanov, A. I. Pavlichev, E. N. Skladanovskii, the supervisor and gas specialists for blast furnaces 1 and 2 (OAO DMZ), P. D. Davidenko, N. G. Shapovalova (Giprostal), V. V. Kochura, Z. K., Afanas'eva, and T. A. Ivleva (Donetsk National Technical University).

Table 3. Operational parameters of European and Chinese blast furnaces with coal-dust fuel

Characteristic	France		Belgium, Sidmar Gent no. A, 1997	Netherlands, Corus Ijmuiden		Germany, Thyssen Krupp, Hamborn, no. 9, 2005	China, Baosteel, no. 3, 2003
	ARCELOR Dunkerque, no. 4, 2005	ARCELOR Dunkerque, no. 6, 2005		no. 6, 2005	no. 7, 2005		
Furnace's working volume, m^3	3940	1335	1754	2328	3790	1833	4350
Productivity, t/(m^3 day)	2.34	2.39	2.14	3.17	2.75	2.89	2.09
Fuel consumption, kg/t of hot metal:							
skip coke + coke nuts	289.2	306.0	294.0	274.3	289.7	311.0	273.0
coal dust	195.8	177.0	193.0	233.2	233.0	178.2	219.0
Blast:							
pressure, MPa	455	307	386	426	475	366	406
O_2 content, %	24.4	23.2	24.5	32.9	30.6	26.6	23.7
temperature, °C	1181	1165	1204	1146	1236	1079	1248
Theoretical combustion temperature, °C	2083	2122	2189	2187	2193	2155	2092
Degree of CO utilization	0.496	0.515	0.501	0.493	0.471	0.481	0.503
Slag yield, kg/t of hot metal	274	297	207	219	236	273	258
Content in slag, %:							
MgO	7.44	8.09	9.90	10.50	10.20	7.00	8.30
Al_2O_3	11.91	11.80	11.50	15.70	16.40	12.00	15.00
Basicity (CaO + MgO)/SiO_2	1.37	1.41	1.44	1.47	1.47	1.37	1.46
Content in hot metal, %:							
Si	0.48	0.41	0.38	0.41	0.44	0.40	0.28
S	0.019	0.013	0.031	0.032	0.032	0.038	0.020

than 80 m^3/t of hot metal. In this period, the batch and technological conditions were worse at OAO DMZ than at other plants (Table 2) [4].

Thus, the effectiveness of the new technology at OAO DMZ is more than double that at other Ukrainian enterprises. The data show that the introduction of the first stage of coal-dust technology has been successfully completed on an industrial scale: the coal-dust consumption is 100–150 kg/t of hot metal, while the coke consumption has been reduced to 350–400 kg/t of hot metal.

Experience Elsewhere

Globally, very high efficiency has been attained in using coal-dust fuel, with the replacement of 35–46% of the coke (Table 3). It follows from Table 3 and literature data that such technology permits decrease in the yield of blast-furnace and reducing gases to 1400–1600 and 650–700 m^3/t of hot metal, respectively [9]. The slurry yield is reduced to 220–300 kg/t of hot metal (Table 3) [1, 9]. The content of fines in the iron-ore batch is reduced to 5% [1–3]. The hot strength *CSR* of the coke is increased to 60–70% [1–3]. The theoretical combustion temperature is increased to 2083–2193°C (Table 3) [9]. Coal dust of high quality is used (A^c = 7.5–8.5%; S = 0.3–0.7%) [1–3].

In the conditions corresponding to Table 3, all the relevant parameters are below the limiting values; this indicates stable and optimal furnace operation. The large coal-dust combustion and its efficient use in these

Table 4. Efficiency of coal-dust technology for the blast-furnace shop at OAO EMZ (Enakievka Metallurgical Plant)

Characteristic	Baseline period	Period 1		Period 2	
		T coal	AS coal	T coal	70% AS coal + 30% G coal
Productivity of furnace, %	0	110.2	111.3	135.6	136.9
Consumption per 1 t of hot metal:					
coke, kg	501.7	383.0	382.4	319.1	319.3
natural gas, m^3	91.1	39.5	51.1	0	0
coal dust, kg	0	120	100	180	180
conventional fuel, kg	631.24	563.1	557.2	505.8	506
Reduction in cost per 1 t of hot metal, hryvna	0	73.5	75	100	96.8
Reduction in coke consumption, 10^3 t/yr	0	363.2	365.1	558.8	558.1
Reduction in natural-gas consumption, 10^6 m^3/yr	0	157.9	122.4	278.8	278.8
Coal consumption for coal-dust production, 10^3 t/yr	0	312.1	345.8	1089.4	1129.1
Reduction in hot-metal cost due to coal-dust technology, 10^6 hryvna/yr	0	224.9	229.5	306	296.2

conditions may be attributed to the high batch and fuel quality and to the better smelting conditions, so that complete compensation is possible despite the considerable decrease in coke consumption.

EFFICIENCY OF COAL-DUST USE FOR UKRAINIAN AND RUSSIAN BLAST-FURNACE SHOPS

Ukraine

For the injection of natural gas and coal dust in amounts of 100–250 kg/t of hot metal, the following compensatory measures are proposed, taking account of the actual capabilities of OAO EMZ (Enakievka Metallurgical Plant) and design data for furnace 5, which went into operation in 2007: increase in blast temperature to 1200°C, in the oxygen content in the blast to 38%, and in the gas pressure in the charge hole to 180 kPa; decrease in natural-gas consumption and is subsequent elimination from the blast; increase in iron content in the sinter to 57%, with increase in the basicity CaO/SiO_2 to 1.5–2; decrease in the content of fines (5–0 mm) to 8% in the sinter and to 2% in the pellets; increase in pellet content in the batch to 60–80%; improvement in coke preparation for smelting; charging of skip coke containing 90% or more of the 40–80 mm fraction in the furnace, as well as coke nuts (40–60 kg/t of hot metal); and stabilization and optimization of the technological conditions on the basis of statistical analysis of the primary information.

The coal considered for preparation of the coal-dust fuel includes coal with up to 12% ash and up to 1.5% sulfur; regular T coal (Donetsk); AS anthracite (Lugansk); G gas coal (Kuznetsk Basin, Russia); and a mixture of AS (70%) and G (30%) coal. In accordance with the set of compensatory measures, two periods with different conditions are considered: injection of coal dust in amounts of 60–160 and 160–240 kg/t of hot metal.[3]

The compensatory measures for period 1 permit decrease in the baseline coke consumption by 31–35.3 kg/t of hot metal (6.2–7.1%) and increase in the furnace productivity by 10–15.6%. The parameter values are improved here. Taking account of the overall conditions, batch based on SevGOK pellets is mainly used in period 1. In this period, the use of coal dust based on T coal (120 kg/t of hot metal) and AS coal (100 kg/t of hot metal) ensures the best efficiency, with satisfactory parameter values (Table 4). In that case, the coke consumption is reduced by 118.7–119.3 kg/t of hot metal (23.8%), the natural-gas consumption by 40–51.6 m^3 (43.9–56.6%), the conventional-fuel combustion by 68.1–74 kg (10.8–11.7%), and the cost per 1 t of hot metal by 73.5–75 hryvna; the productivity increases by 10.2–11.3% (Table 4).

In period 2, SevGOK pellets are not considered, since the slag yield per 1 t of coke and the gas velocity in the bosh exceed the limiting values in that case. In period 2, pellets from the Central Enrichment Facility

[3] The calculations used in selecting these figures were completed with the participation of A. M. Kuznetsov and V. P. Padalka OAO EMZ (Enakievka Metallurgical Plant).

reduce the coke consumption by 73.1 kg/t of hot metal (14.6%) and the conventional-fuel consumption by 77.4 kg/t (12.3%); the productivity increases by 34.3%.

Satisfactory parameter values are obtained on injecting coal dust prepared from T and AS + G coal in amounts of 180 kg/t of hot metal. In that case, the coke consumption is reduced by 182.4–182.6 kg/t of hot metal (36.6%), the natural-gas consumption by 91.1 m^3, the conventional-fuel consumption by 125.2–125.4 kg (19.9%), and the cost of 1 t of hot metal by 96.8–100 hryvna; the productivity increases by 35.6–36.9% (Table 4).

Calculations show that the use of coal dust with compensatory measures increases the replacement of coke by other fuels at OAO EMZ to 23.8–36.6%, which is higher than for the injection of natural gas + O_2 by a factor of 1.9–2.6.

Russia

In comparison with Ukrainian shops, Russian blast-furnace shops are better adapted to coal-dust fuel on account of the lower sulfur content of the batch, the lower slag yield, and the lower slag basicity. These factors permit the introduction of coal-dust technology with minimal compensatory measures.

At OAO ZSMK (West-Siberian Metallurgical Plant), compensation simply by reducing the natural-gas consumption permits the injection of coal-dust fuel prepared from Bachatsk coal (Kuznetsk Basin) in amounts of 150 kg/t of hot metal, with the optimal compensation coefficient $K_c = 0.5$ m^3/kg of coal dust; 82 kg of the coke (18.9%) is replaced by the coal dust, with decrease in the consumption of conventional fuel by 27 kg (4.8%); the coefficient of coke replacement by coal dust is then 0.55 kg/kg. The baseline productivity and hot-metal quality are unchanged here, as seen in the figure.

Thus, the injection of coal dust and natural gas in the hearth considerably increases the efficiency of the blast in comparison with natural-gas injection. In particular, the decrease in coke consumption grows from 81 to 166 kg/t of hot metal, i.e., by more than double.

The efficiency of introducing the first stage of coal-dust technology has been calculated for the basic metallurgical enterprises in Ukraine (OAO DMZ, OOO MMK im. Il'icha, OAO EMZ, OAO MK im. Dzerzhinskogo, Kramatorsk Metallurgical Plant, OAO MK Azovstal, OAO AlchMK, and OAO MK Zaporozhstal) and Russia (OAO Severstal, OAO MMK, OAO NKMK, OAO ZSMK, OAO Mechel, OAO NTMK, OAO OKhMK, OAO NLMK, and OAO Tulachermet).

ESTIMATING THE EFFICIENCY OF LARGE-SCALE INTRODUCTION OF COAL-DUST TECHNOLOGY IN UKRAINE AND RUSSIA

On the basis of the calculations, the following mean characteristics of coal-dust technology are obtained for Ukraine and Russia:

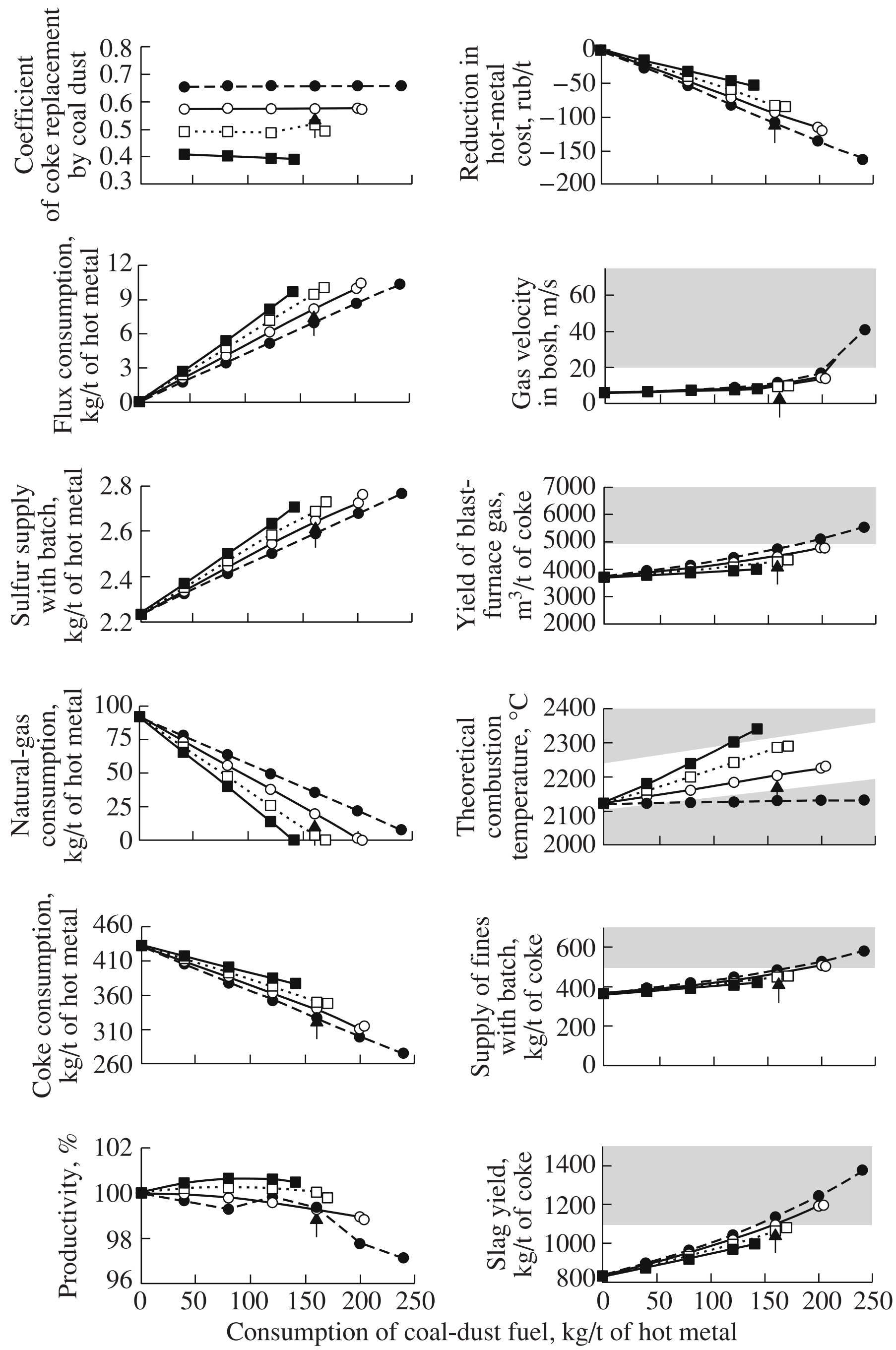
	Ukraine	Russia
Coal-dust consumption (first stage of technology)	120	140
Coal (coal-mixture) consumption in producing 1 t of coal dust, t	1.1	1.1
Coefficient of coke replacement by coal dust, kg/kg	0.60	0.60
Coefficient of coal dust/natural gas compensation, m^3/kg	0.5	0.5
Change in furnace productivity, %	0	0
Decrease in hot-iron cost on introducing coal-dust technology, hryvna/t, rub/t	60	95
Expected hot-metal output using coal dust (2011–2012), 10^6 t	30.3	56.1
Coal consumption for coal-dust preparation, 10^6 t/yr	4.06	8.64
Expected annual decrease:		
coke consumption, 10^6 t	2.48	5.11
natural-gas consumption, 10^9 m^3	1.90	3.93
cost of hot metal, 10^9 hryvna, 10^9 rub	1.81	5.33

The capital expenditures for the construction of coal-dust systems (first stage) and for the compensatory measures should be recouped within 2–3 yr.

The second stage in the introduction of coal-dust technology in Ukraine and Russia (150–200 kg/t of hot metal) is also promising, but expensive compensatory measures are required, such as reduction in slag yield to 300 kg/t; increase in blast temperature to 1150–1200°C; decrease in the content of fines (5–0 mm) in the blast-furnace batch to 5–8%; and considerable improvement in coke quality. These measures call for capital expenditures comparable with the cost of the coal-dust systems.

PROSPECTS FOR INTRODUCING COAL-DUST TECHNOLOGY IN UKRAINIAN AND RUSSIAN BLAST FURNACES

On the basis of 27 years of experience with coal-dust technology at OAO DMZ and experience around the world, some Ukrainian metallurgical enterprises have signed contracts with foreign firms for turn-key supply of systems for coal-dust production and injection. The suppliers of the equipment guarantee coal-dust consumption of up to 150 kg/t of hot metal. These guarantees imply, in fact, that the equipment will reliably, without interruption, supply coal dust to the tuyere in the amount specified by the contract. Whether the



Efficiency of injection of coal dust prepared from Bachatsk T coal in OAO ZSMK blast furnace 3, with variation in the coefficient K_c of coal-dust compensation by natural gas: *1*, 0.35; *2*, 0.45; *3*, 0.55; *4*, 0.65. Operation in the shaded region is unlikely, on account of the high parameter values.

blast furnaces will accept the 150 kg/t of hot metal is a separate issue.

It is true that some imported systems reduce the coke consumption to 250–300 kg/t of hot metal with the injection of coal dust in amounts of 180–260 kg/t (data for Belgium, the Netherlands, France, Japan, and China). However, we also know that such equipment is assembled within months under the terms of turn-key contracts. Experience shows that it takes 10–20 years to create highly efficient technologies, both abroad and at OAO DMZ. That time is required to develop compensatory measures that ensure high productivity and hot-metal quality in blast-furnace operation with reduced coke consumption. Hence, the organization of the technological process is more important than the type of equipment selected.

On the basis of the theory of complete compensation developed on the basis of extensive experience of coal-dust technology at OAO DMZ, the traditional trial-and-error approach may be replaced by a method that takes account of the influence of the reduced coke content in the batch and of coal-dust combustion on the gas-dynamic conditions, the conditions of batch combustion, the batch heating, and other factors and that also permits the calculation and adoption of the necessary compensatory measures. Such quantitative calculations facilitate the faster adoption of efficient and optimal conditions with coal-dust injection (in months, rather than years).

In comparison with foreign furnaces, the technological conditions at Ukrainian blast furnaces are considerably different, as characterized by factors such as a greater supply of fines (5–0 mm) with the iron-ore batch, greater slag yield, higher sulfur and alkali content in the batch, and lower-quality coke [1–4, 9]:

	Ukraine	Europe
Hot strength *CSR* of coke, %	35–45	55–73
Reactivity *CSI* of coke, %	25–35	18–25
Content of fines (5–0 mm) in iron-ore batch, %	10–20	1–5
Slag yield, kg/t of hot metal	350–600	150–300
Slag basicity CaO/SiO_2	1.15–1.25	1.0–1.2
Sulfur supply with batch, kg/t of hot metal	7–10	2–4
Supply of alkali ($K_2O + Na_2O$), kg/t of hot metal	6–10	1.6–3

Nevertheless, the technology created at OAO DMZ permits the replacement of 30–35% of the coke by other fuels (natural gas + coal dust), which matches the figure for most modern foreign plants with coal-dust injection in amounts of 100–150 kg/t of hot metal, where 20–30% of the coke is replaced by coal dust (Turkey, Rumania, Poland, Slovakia).

It follows from the foregoing that contracts for the construction of coal-dust systems should specify the final result: the development of a stable and efficient technology with high fuel consumption. Accordingly, along with the construction of the systems, work must begin promptly on the calculation and optimization of the blast-furnace technology with coke replacement by coal dust and on the selection and implementation of the appropriate compensatory measures. This must be undertaken before the coal-dust systems go into operation.

Ukraine has scientific and industrial experience relevant to this task: the theoretical principles of complete compensation and the highly efficient coal-dust technology created by OAO DMZ technologists and the specialist laboratory at Donetsk Technical University between 1980 and 2005. At the same time, the coal-dust systems proposed by foreign firms have already been built in 25 countries and operate efficiently.

The Donetsk coal-dust system, which was one of the first in the world, operates just as efficiently; it was modernized by Giprostal in 2002 and 2007. This system is based on Ukrainian equipment and is designed for the available resources and staff at OAO DMZ. Experience shows that the OAO DMZ equipment matches the requirement of fourth-generation systems, such as fine grinding and uniform supply of the coal-dust fuel over time and over the tuyeres; complete coal-dust combustion; and reduced atmospheric emissions. This system is considerably less expensive than its foreign counterparts. The technology developed in Ukraine takes complete account of local circumstances.

Most Ukrainian and Russian metallurgical enterprises have yet to make a decision regarding the construction of coal-dust systems. However, the development of blast-furnace technology over the past 25 years shows that coal-dust technology is the most promising option currently available. Accordingly, in the design and reconstruction of blast furnaces in the Ukraine, Giprostal makes provision for the construction of coal-dust systems, taking account of the characteristics of blast furnaces with coal-dust injection. Obviously, it is time to make a choice, as most metallurgical enterprises around the world have done.

Accordingly, we recommend careful study of experience with coal-dust technology at OAO DMZ, comparison of the efficiency obtained and the associated costs, study of the operational experience with furnaces 1 and 2 in the period 2005–2007, when natural gas was completely replaced by coal-dust fuel in typical Ukrainian conditions, and comparison of the information obtained with the conditions in which imported units operate. This analysis is likely to support the OAO DMZ system. Moreover, it has been operating successfully in new conditions for around five years. Coal-dust technology permits optimal furnace operation and efficient smelting. The same effect could be obtained, with lower cost, at any Ukrainian or Russian plant.

CONCLUSIONS

(1) Today, blast-furnace smelting with natural-gas injection in the hearth, which consumes 2.5×10^9 m^3/yr of natural gas in Ukraine, is less efficient than coal-dust technology. In particular, the amount of coke that may be replaced by coal dust is 2–3 times as much as for natural gas.

(2) In Ukraine today, on the basis of local and global experience, conditions exist for the rapid and effective introduction of coal-mixture injection in the hearth: the corresponding equipment has been developed and introduced industrially, and smelting with the injection of coal dust in the hearth (in amounts of 100–170 kg/t of hot metal) has been adopted, confirming the economic benefits of this approach and the possibility of

considerably reducing or eliminating the natural-gas consumption.

(3) Experience at OAO DMZ shows that the first stage in introducing coal-dust technology, with coal-dust consumption of 100–150 kg/t of hot metal and decrease in the coke consumption to 350–400 kg/t, poses no problems for Ukrainian blast furnaces. All that is necessary is to calculate the smelting conditions with coal-dust injection that are best suited to the available or readily created compensatory resources in the shop, on the basis of local and global experience and the theory of complete compensation. This technology may be based on Ukrainian or imported equipment.

(4) Conditions at Russian blast-furnace shops are more favorable for the introduction of coal-dust technology. To compensate coal-dust injection in amounts of 140 kg/t of hot metal, the natural-gas consumption must be reduced, with corresponding decrease in coke consumption by 91 kg/t, in natural-gas consumption by 70 m^3/t, and in cost by 95 rub; the basic furnace productivity and the quality of the hot metal remain unchanged.

(5) In Ukrainian and Russian blast-furnace shops, the use of coal dust in blast-furnace smelting is ineffective without appropriate measures to compensate the negative impact of increased coal-dust consumption.

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