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Rational Crushing of Coal Charge for Improvement of Coke Quality for Blast-Furnace Smelting

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It is possible to improve significantly mechanical strength indexes of coke and its granulometric composition due to developed preparation of coal charge.

Keywords: COAL CHARGE, GRANULOMETRIC COMPOSITION, PETROGRAPHIC ANALYSIS OF CHARGE

Introduction

Grade composition and properties of coal charge are primary factors defining physicmechanical properties of coke. Variation of charge makeup under conditions of worsening raw-material base for coking becomes ineffective, and frequent reburdening operations do not improve coke quality and lead to its quality index variations. As a result, there are unstable thermal conditions of blast furnaces and coke overconsumption since engineeres of blast-furnace shops must work with increased concentration of silicon in cast-iron in order not to allow cooling-down of furnaces.

The feature of raw-material base for coking is the fact that grade composition on the developed areas of coal deposits does not correspond to grade composition of coal charge ensuring coke with high parameters [1].

Results and Discussion

For blast-furnace smelting coke should be characterized by following: large average size, high strength (M_{40}, M_{25}) and abrasion hardness (M_{10}), short range of granulometric composition, low reactive capacity (CRI) and high strength after reaction (CSR).

Cold strength indexes (M_{40}, M_{25} and M_{10}) determine permeability of charge layer in a blast furnace up to liquid-plastic zone, and indexes CRI and CSR define mechanical strength in the bottom of furnace and under liquid-plastic zone. They are of great importance for furnaces operating with pulverized coal fuel injection.

Coke used in powerful blast furnaces at iron & steel plants of Europe such as Redkar (Great Britain), Taranto (Italy), Shvelgern (Germany), Hoogovens (Netherlands) and Dunkirk (France) is characterized by high CSR and cold strength indexes, high abrasion coke strength (**Table 1**) [2].

In Ukraine coke with high indexes of cold mechanical strength M_{25} 89-90 % and M_{10} 5-5.5 % is produced on the battery No. 10 at JSC "Alchevskkoks", at which coal charge compaction and dry coke quenching are combined. High-grade coke is produced from charge with amount of well sintered coals (at practical absence of grade K) 33.9 % at content of gaseous and weakly sintering coal 66.1 % [3].

Experience of JSC " Alchevskkoks " shows that it is possible to improve significantly mechanical strength indexes of coke and its granulometric composition due to developed preparation of coal charge. One of these areas is selection of optimum fineness number.

According to electronic version of the newsletter "Russian market of production and consumption of coked coals" (January 2009)

Table 1. Coke used in powerful blast furnaces at iron & steel plants of Europe

Index	Plant				
	Redkar	Taranto	Shvelgern	Hoogovens	Dunkirk
Average size, mm	54.7	52.2	45.9	51.4	53.2
M_{40}, %	87.1	86.2	83.3	87.8	91.2
M_{10}, %	5.8	6.2	7.2	6.2	5.5

presented on website www.metcoal.ru ("RasMin" Ltd.,), fineness number of coal charge at by-product coke plants of Russia varies from 73.6 to 79.0 % and only at Novokuznetsk Iron & Steel Integrated Works – 83.7 %. At the same time, coke quality indexes vary within the limits: M_{25} 84.4-89.1 %, M_{40} 75.6-79.8 % and M_{10} 7.2-10.3 % (**Table 2**).

Authors of paper [4] notice that large-sized differentiated grinding of coals (from 78 to 74.5 %) should be considered as a rational preparation of coal charge. This grinding ensures such size ratio at which maximum density of coal charging and high sintering ability of coal charge are reached.

There are also other opinions. Author [5] underlines that caking strength of coal particles is in the direct dependence on bulk density of coal mass. At the same time the author says that decrease of grinding level can not be considered as a universal method for bulk density increase. Preliminary selection of fine grains by mechanical method on a sizing screen and selective fine crushing of only large part are rational. In this case, increase of apparent density is reached due to more favorable ratio between large and fine (-0.5 mm) parts coming close to theoretical (68:32). Effect of coal charge fineness (0-3 mm) and content of large fractions (3-6 and +6 mm) on bulk weight of the charge was investigated in coal preparation shop of coke and by-product process at “ArselorMittal Kryvyy Rih”. Graphs constructed according to investigation results are presented in **Figures 1-4**.

Table 2. Fineness number of coal charge and coke quality at by-product coke plants of Russia

Plant	Charge grinding and coke quality			
	(0-3 mm), %	M_{25}, %	M_{40}, %	M_{10}, %
Novokuznetsk Iron & Steel Integrated Works (Novokuznetsk)	83.7	87.1		9.4
JSC “Koks” (Kemerovo)	74.2	84.5		7.9
“Severstal” (Cherepovets)	77.7		79.8	7.6
Novolipetsk Steel “NLMK” (Novolipetsk)	73.6	88.9		7.2
JSC “Moskoks” (Vidnoye)	79.0		78.5	9.0
Nizhniy Tagil Iron and Steel Works	74.7	89.1	75.6	8.6
OJSC “Magnitogorsk Iron & Steel Works”	79.0	86.3	78.3	10.3
Mechel (Chelyabinsk)	N/A	86.0		9.6
“Gubahinsk koks”	75.4	86.8		9.8
“Ural steel” (Novotroitsk)	N/A	84.4		9.9

As charge fineness increases from 71 to 92 % (**Figure 1**) at the average moisture 11.2 %, charge bulk weight decreases from 0.862 to 0.761 t/m^3, i.e. raise of charge fineness number by 1 % reduces its bulk weight by 4.8 kg/m^3 and by 3.9 kg/m^3 - at the average moisture of the charge 5.6 %.

Also it is necessary to notice that the lower moisture content in the charge, the more its bulk weight under constant fineness number.

Content of fraction -0.5 mm at theoretically optimum level 32 % (**Figure 2**) even at charge moisture 11.2 % ensures high enough value of bulk weight of the charge 0.86 t/m^3, and increase of bulk weight to 0.91 t/m^3 is possible at moisture 5.6 %. Anyway, it was determined experimentally that bulk weight of the charge was 0.885 t/m^3 at content of fraction -0.5 mm in the charge 35 %.

Charge overgrinding and increase of fraction -0.5 mm up to 54 % leads to sharp decrease of bulk weight to 0.75 t/m^3. The situation can be improved if lower batch moisture from 11.2 to 5.6 %.

Petrographic analysis of coal charge selected before and after crushing and petrographic analysis of fraction -0.5 mm in the charge before and after crushing were carried out. Fractional makeup of charge at moisture 12.4 % before crushing is presented in **Table 3**. Petrographic composition of coal charge before crushing was as follows: vitrinite (V_t) – 79.2 %, total amount of fusainized components (inert components) – 17.8 %. Vitrinite reflectance R_0 was 1.03 %. Fractional makeup of the charge at moisture 10.5 % after crushing is presented in **Table 4**.

Table 3. Fractional makeup of charge at moisture 12.4 % before crushing

Fraction	+6 mm	6-3 mm	3-0.5 mm	-0.5 mm	0-3 mm
%	12.94	14.91	43.0	29.15	72.15

Table 4. Fractional makeup of charge at moisture 10.5 % after crushing

Fraction	+6 mm	6-3 mm	3-0.5 mm	-0.5 mm	0-3 mm
%	7.39	12.81	42.54	37.26	79.8

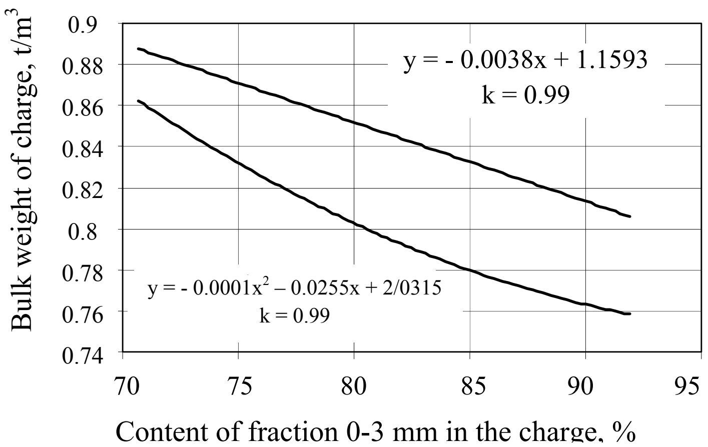

Figure 1. Dependence of coal charge bulk weight on its fineness number at the average values of moister: upper curve - 5.6 %; lower curve - 11.2 %

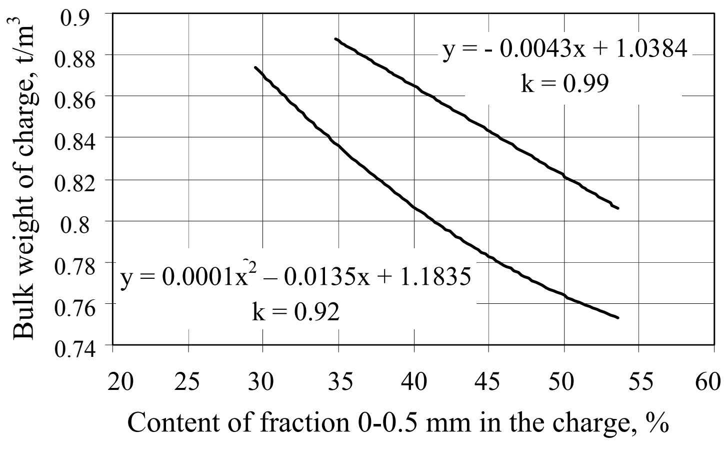

Figure 2. Dependence of coal charge bulk weight on content of fraction 0-0.5 mm at the average values of moister: upper curve - 5.6 %; lower curve - 11.2 %

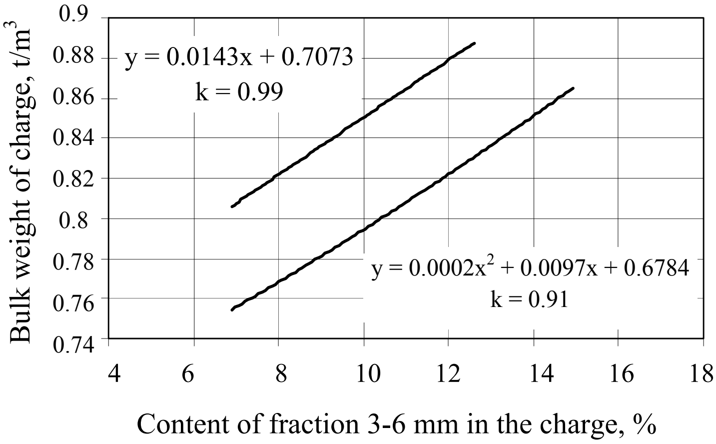

Figure 3. Dependence of coal charge bulk weight on content of fraction 3-6 mm at the average values of moister: upper curve - 5.6 %; lower curve - 11.2 %

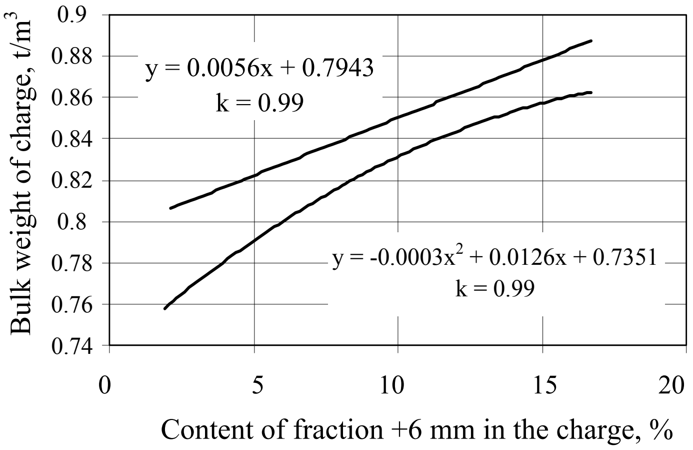

Figure 4. Dependence of coal charge bulk weight on content of fraction +6 mm at the average values of moister: upper curve - 5.6 %; lower curve - 11.2 %

Content of -0.5 mm fraction increased and was 37.26 %, and the bulk weight reduced down to 0.803 t/m^3 in the charge sample selected after crushing at fineness number 0-3 mm 79.8 %.

Petrographic analysis of coal charge after crushing was as follows: vitrinite (V_t) – 67.0 %, total amount of inert components 29.0 %. Vitrinite reflectance R_0 was 1.02 %. Increase of charge fineness number by 7.65 % in the investigated range reduces vitrinite content (V_t) by 12.2 %, and total amount of inert components drops by 11.2 %, i.e. sintering ability of the charge decreases.

Petrographic analysis of fraction -0.5 mm before and after crushing also specifies that as content of fraction -0.5 mm in coal charge grows, its sintering ability drops. So, before charge crushing vitrinite content (V_t) in class -0.5 mm is 65.7 %, and total amount of inert components - 27.4 %. Vitrinite reflectance R_0 is 1.41 %. After crushing, the vitrinite content in class -0.5 mm increased a little (V_t) to 67 % at more considerable growth of total amount of inert components 31 %. Vitrinite reflectance R_0 considerably decreased to 1.07 %.

Conducted investigations confirm that there is no necessity in overgrinding when preparing charge for carbonization. It is rational to select fraction 0-3 mm on sizing screens from initial charge and to crush only fraction +3 mm. Moreover, crushing of this charge should be accomplished so that the total content of fraction -0.5 mm in the charge for carbonization would not exceed 30-32 %.

If providing this condition is impossible, it is necessary to select fraction 0-6 mm from the charge and to crush +6 mm. As for coals with moisture ≥6 %, the ratio between large, average and fine fractions of coal is 45:40:15 [6].

Researchers from Kryvyy Rih Metallurgical Department of National Metallurgical Academy of Ukraine investigated preliminary screening of size 0-3 mm on the experimental screening machine (**Figure 5**) installed before crushing machine No. 9. Results showed that if content of fraction -0.5 mm was 18.8 % in the initial coal charge, the content of fraction -0.5 mm in the charge after preliminary screening of size -3 mm and crushing of size +3 mm increased only to 29.4 %.

Detailed investigation of coal used for batch preparation (**Table 5**) showed that most of them initially contained size -0.5 mm at the optimum level in the charge. So, it is not casual that content of fraction 0-0.5 mm is 46-49 % at charge fineness number 87.7-89.2 %, which undoubtedly affects coke quality. Interrelation between bulk weight of coal and content of fraction -0.5 mm for coals of various grades and at various moisture is shown in **Figure 6**. It follows from **Figure 6** that bulk weight of coal reduces as content of fraction -0.5 mm grows more than 25 %.

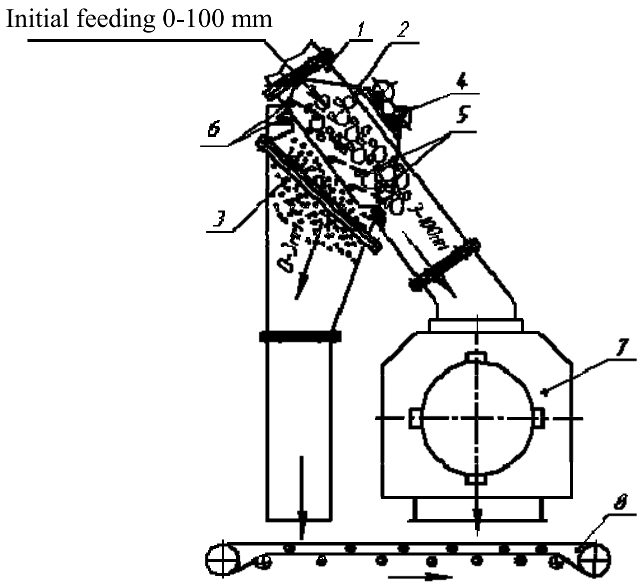

Figure 5. Experimental sizing screen before crushing machine No. 9: *1* - chute, *2* - screen, *3* - screen underflow (fraction 0-3 mm), *4* - screen vibrator, *5* - grading screen, *6* - shock reducers, *7* - hammer breaker, *8* - collecting conveyor

Table 5. Fractional makeup of coals used in the charge

Coal grade	Fractional makeup of coal, mm					Bulk weight, kg/m^3	Moister, %
	+6	6-3	3-0.5	-0.5	0-3		
К – Ukrkoks	12.15	18.60	40.08	29.17	69.25	914	19.80
Ж – Krasnolimanskiy	40.56	19.74	23.10	16.60	39.7	871	10.50
Ж – Ukrkoks	12.48	13.33	41.05	33.14	74.19	859	14.40
Ж – Kievskiy	2.86	5.98	49.81	41.35	91.16	832	12.00
2Ж – Pecherskiy	29.48	14.56	25.10	30.86	55.96	841	10.50
ГЖ – Paspadskiy	16.93	18.37	36.98	27.72	64.70	891	13.60
К – Severnyy	19.95	15.24	32.32	32.49	64.81	847	12.70
К+КО+ОС – Severnyy	14.08	12.93	34.37	38.62	72.99	927	17.20
К+КЖ – Vostochnyy	6.68	9.52	40.40	43.40	83.80	801	12.60
Poland T34 (Г)	38.29	15.99	32.69	13.03	45.72	859	9.15
USA “Alpha” (К1)	6.25	14.70	44.95	34.15	79.10	890	14.40
Canada “Eagle” (К)	14.05	12.81	34.62	38.52	73.14	831	12.10
USA “Coking Coal Pardee” (ГЖ)	42.65	13.76	22.24	21.35	43.59	870	11.00

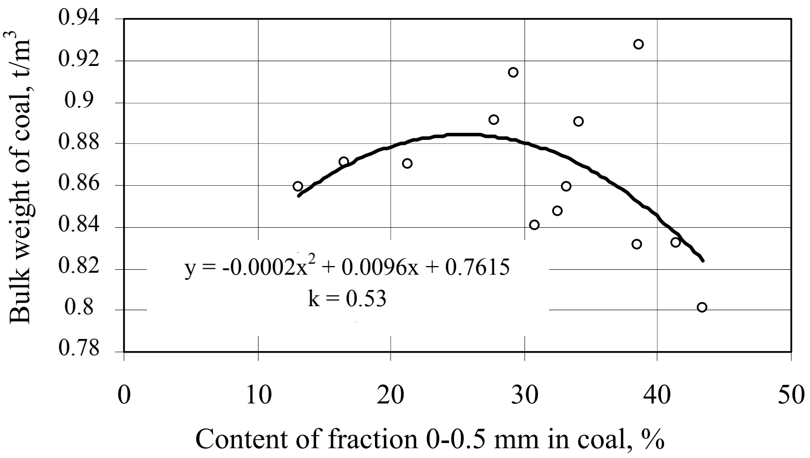

Figure 6. Dependence of coal charge bulk weight on content of fraction 0-0.5 mm

Conclusions

When preparing coal charge for carbonization it is necessary to consider grade, petrographic and also fractional makeup of coals as well as their bulk weight. It is necessary to specify (select) an optimum fineness number of coal charge which cannot be constant at the change of grade makeup or component ratio in the charge.

It is rational to separate preliminary fraction -3 …-6 mm from the initial charge, and to crush fraction +3 … +6 mm. Moreover, this charge should be crushed so that the total amount of fraction -0.5 mm would not exceed 30-32 % in the charge used for carbonization.

In case of high content of fraction -0.5 mm in the initial coals, it is necessary to apply granulating or half pelletizing of this fraction.

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Организация рационального дробления угольной шихты
путь к повышению качества кокса для доменной плавки

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При сложившейся угольной базе коксования можно существенно улучшить показатели механической прочности кокса и его гранулометрический состав за счет совершенствования подготовки угольных шихт.