METABK 53(3) 365-367 (2014)
UDC – UDK 669.052:546.72:66.014.438=111

CHEMICAL COMPOSITION ANALYSIS OF RAW MATERIALS USED IN IRON ORE SINTER PLANTS IN POLAND

Received – Prispjelo: 2013-10-04
Accepted – Prihvaćeno: 2014-02-20
Preliminary Note – Prethodno priopćenje

The main goal of the study was the analysis of the chemical compositions of raw materials used in iron ore sinter plants in Poland. The iron ore sintering process is the largest source of emissions of dust and gas pollution in the iron and steel industry. Hematite ores, magnetite concentrates, admixtures (dolomite, limestone and burnt lime), fuels (coke breeze, anthracite) and by-products are used in Poland to produce the sinter mixture.

Key words: iron ore sintering process; chemical composition; raw materials, Poland

INTRODUCTION

The iron ore sintering process is the largest source of pollutants generated by integrated steelworks in Poland. With regard to chemical composition, the most important factors are concentrations of iron, compounds of calcium, silicon, magnesium, aluminum and harmful compounds, mainly alkaline, sulphur, phosphor, zinc and lead [1]. The ore mixture used in Polish sinter plants is based on hematite ores and magnetite concentrates [2,3]. All these raw materials differ significantly in terms of their chemical properties and grain size distribution which may lead to deterioration of the mixture sintering conditions at the sinter belt grate and cause negative environmental impact. The decision support system and management of production orders for iron ore sinter process could quick calculate of costs and time of order realization and efficiently prepare of iron ore production for sinter process [4,5]. Chemical composition of raw materials determines the environmental impact of the process. Hg was tested in several metallurgical processes, including iron ore sintering process [6]. Mass balance for zinc and alkalis in the blast furnace process was also examined [7]. In Poland basic chemical composition of the raw materials (P_2O_5, Na_2O, K_2O, Zn, S, C, Pb, volatiles and ash) are performed in the sintering process. Inventory of input/output data for national sinter plant was published in [8]. However, there is lack of studies of all parameters contained in the raw materials in iron ore sinter plants.

Up to now the laboratory tests of raw materials were focused on the preparation of raw materials for sintering process and development of new methods for their homogenization and granulation to improve sinter mixture preparation [9]. For this purpose Intensive Mixer manufacture by Maschinenfabrik Gustav Eirich (Germany) was used. The intensive mixer enables to realize the mixture homogenization and granulation process during one technological operation. Granulation is a new method of preparation raw materials like: powders, sludges and other for other processing. This technology is widely uses in various industry like: recycling, metallurgy, polymer, composites, ceramic, mining, chemical and other [10].

MATERIALS AND METHODS

In our study the analysis of 30 parameters (C, S, Cl, Al, Fe, Ca, Mg, Na, K, Ti, P, Ag, As, Ba, Br, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Rb, Sb, Sn, Sr, V, Zn) in the raw materials used to prepare the mixture for iron ore sintering process were presented. Our study included measurements of the parameters in the raw materials:

- iron ores: hematite ore - Krivbasruda, magnetite concentrate 1 - Yuzhnyi GOK (Gorno-obogatitelj-ni kombinat) - Mining and Processing Works), magnetite concentrate 2 - Lebedinsky GOK,
- fuels: coke breeze, anthracite,
- by-product: mill scale,
- admixtures: limestone, dolomite and burnt lime.

Technological conditions, sinter parameters and basic chemical composition of raw materials were used as a main criteria in the selection of raw materials. The raw materials for our study were obtained from Polish integrated steelworks.

The raw materials were analysed in the accredited Laboratory of Solid Waste Analysis of the Central Mining Institute. The laboratory analysis included:

- determination of C content by high-temperature combustion method featuring infrared detection,
- determination of S content by high-temperature combustion method featuring infrared detection,
- determination of Cl content by weighting method in accordance with an internal testing procedure,

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- determination of Hg content by high-temperature combustion method combined with the cold vapour atomic absorption spectrometry (CVAAS),
- determination of basic chemical composition for SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, SO_3, TiO_2 and P_2O_5 by application of X-ray fluorescence spectrometry (XRF),
- determination of the content of BaO, Cr_2O_3, Mn_3O_4, PbO_2, SrO and ZnO by application of X-ray fluorescence spectrometry (XRF),
- determination of the content of trace elements: Ag, As, Ba, Br, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Rb, Sb, Sn, Sr, V and Zn by application of X-ray fluorescence spectrometry (XRF).

RESULTS AND DISCUSSION

The studies of raw materials were conducted to explore the environmental aspects of iron ore sinter process in terms of chemical composition tests. The results of the chemical analysis (30 parameters) of the raw materials used in the sinter mixture and the main parameters content in the raw materials used in the study were presented in Tables 1 - 6 respectively.

Table 1 **Chemical analyses of the iron ores used in the study**

Parameters	Unit	Hematite ore	Magnetite 1	Magnetite 2
C	wt. %	0,208	0,200	0,083
S	wt. %	0,007	0,016	0,031
Cl	wt. %	0,049	0,063	0,035
SiO2	wt. %	12,99	8,3	6,75
Al2O3	wt. %	1,67	0,005	0,005
Fe2O3	wt. %	81,96	90,7	92,04
CaO	wt. %	0,76	0,005	0,005
MgO	wt. %	0,39	0,36	0,4
Na2O	wt. %	0,03	0,01	0,04
K2O	wt. %	0,09	0,01	0,02
SO3	wt. %	0,41	0,07	0,11
TiO2	wt. %	0,14	0,1	0,12
P2O5	wt. %	0,25	0,005	0,005
Ag	ppm	1	1	1
As	ppm	1	22	1
Ba	ppm	36	6	6
Br	ppm	3	1	2
Cd	ppm	1	1	1
Co	ppm	1,5	1,5	1,5
Cr	ppm	443	496	530
Cu	ppm	37	31	32
Hg	ppm	0,0096	0,0045	0,0041
Mn	ppm	315	111	186
Mo	ppm	20	20	18
Ni	ppm	14	11	9
Pb	ppm	9	1	1
Rb	ppm	16	16	16
Sb	ppm	1	5	1
Sn	ppm	1	4	1
Sr	ppm	59	21	27
V	ppm	54	54	95
Zn	ppm	172	9	5

Table 2 **The main parameters content in the iron ores used in the study / wt.%**

Parameters	Hematite ore	Magnetite 1	Magnetite 2
Si	6,073	3,881	3,156
Al	0,884	0,003	0,003
Fe	57,323	63,435	64,373
Ca	0,543	0,004	0,004
Mg	0,235	0,217	0,241
Na	0,022	0,007	0,030
K	0,075	0,008	0,017
S	0,164	0,028	0,044
Ti	0,084	0,060	0,072
P	0,109	0,002	0,002

Table 3 **Chemical analyses of fuels and mill scale used in the study**

Parameters	Unit	Coke breeze	Anthracite	Mill scale
C	wt. %	84,548	80,248	0,101
S	wt. %	0,278	1,023	0,004
Cl	wt. %	0,077	0,063	0,049
SiO2	wt. %	7,43	4,35	0,37
Al2O3	wt. %	2,67	1,6	0,005
Fe2O3	wt. %	1,31	4,08	98,08
CaO	wt. %	0,65	0,69	0,005
MgO	wt. %	0,27	0,3	0,005
Na2O	wt. %	0,21	0,08	0,01
K2O	wt. %	0,34	0,2	0,005
SO3	wt. %	0,55	0,83	0,07
TiO2	wt. %	0,19	0,07	0,08
P2O5	wt. %	0,17	0,04	0,005
Ag	ppm	0,5	0,5	1
As	ppm	7	23	1
Ba	ppm	223	132	6
Br	ppm	0,5	0,5	4
Cd	ppm	0,5	1	4
Co	ppm	13	1,5	1,5
Cr	ppm	22	29	1117
Cu	ppm	24	28	185
Hg	ppm	0,0124	0,6395	0,0082
Mn	ppm	74	113	5722
Mo	ppm	2	3	33
Ni	ppm	20	16	81
Pb	ppm	10	13	15
Rb	ppm	18	12	12
Sb	ppm	0,5	2	3
Sn	ppm	0,5	0,5	20
Sr	ppm	144	112	21
V	ppm	49	65	108
Zn	ppm	33	36	88

Based on chemical composition analysis of raw materials it was found that the tested fuels were characterized by higher Cl, C, S, Na, K and Ba content than other raw materials. Anthracite has the highest amount of S and Hg. Coke breeze has the highest Cl, C, Na, K, Ti and Ba content. The tested iron-bearing materials were characterized by the higher Fe than other. Hematite ores had the highest Si, Al and P content. Mill scale was characterized by the highest amount of Fe, Cr, Cu, Mn, Mo and Ni. Magnetite

Table 4 **The main parameters content in fuels and mill scale used in the study / wt.%**

Parameters	Coke breeze	Anthracite	Mill scale
Si	3,474	2,034	0,173
Al	1,413	0,847	0,003
Fe	0,916	2,854	68,597
Ca	0,465	0,493	0,004
Mg	0,163	0,181	0,003
Na	0,156	0,059	0,007
K	0,282	0,166	0,004
S	0,220	0,333	0,028
Ti	0,114	0,042	0,048
P	0,074	0,017	0,002

Table 5 **Chemical analyses of admixtures used in the study**

Parameters	Unit	Lime stone	Dolomite	Burnt lime
C	wt. %	11,96	12,745	1,483
S	wt. %	0,005	0,00037	0,0001
Cl	wt. %	0,049	0,049	0,035
SiO2	wt. %	1,61	0,47	1,75
Al2O3	wt. %	0,27	0,07	0,61
Fe2O3	wt. %	0,73	1,18	0,61
CaO	wt. %	55,95	34,95	73,25
MgO	wt. %	1,46	18,8	5,74
Na2O	wt. %	0,005	0,005	0,02
K2O	wt. %	0,02	0,03	0,12
SO3	wt. %	0,41	0,48	0,62
TiO2	wt. %	0,005	0,005	0,02
P2O5	wt. %	0,03	0,005	0,005
Ag	ppm	1	1	1
As	ppm	1	1	1
Ba	ppm	6	9	6
Br	ppm	9	9	8
Cd	ppm	1	15	1
Co	ppm	1,5	1,5	1,5
Cr	ppm	3	4	3
Cu	ppm	19	18	27
Hg	ppm	0,014	0,0045	0,0145
Mn	ppm	65	500	157
Mo	ppm	1	1	1
Ni	ppm	4	1	3
Pb	ppm	23	271	106
Rb	ppm	10	9	17
Sb	ppm	1	1	1
Sn	ppm	1	1	1
Sr	ppm	180	58	243
V	ppm	1	1	1
Zn	ppm	108	1487	421

concentrates had lower content of analysed parameters than other iron-bearing materials.

CONCLUSIONS

Chemical composition of raw materials used in iron ore sinter plants in Poland was determined based on laboratory tests. Results of chemical analysis of 30 parameters in raw materials (iron-ore bearing materials – iron ores and mill scale, admixtures and fuels) were presented.

Coke breeze was characterized by the highest total amount of Cl and alkalis. Anthracite contained the highest amount of S and Hg. Mill scale had the highest amounts of Cu. Dolomite was characterized by the highest contents of Zn and Pb.

Hematite ores contained higher amount of harmful admixtures than magnetite concentrates.

Performed laboratory tests were used to establish of sinter mixtures composition used in sinter plants in Poland. Contents of harmful admixtures were examined according to chosen kinds of environmental impacts.

Table 6 **The main parameters content in admixtures used in the study / wt.%**

Parameters	Lime stone	Dolomite	Burnt lime
Si	0,753	0,220	0,818
Al	0,143	0,037	0,323
Fe	0,511	0,825	0,427
Ca	39,987	24,979	52,351
Mg	0,881	11,339	3,462
Na	0,004	0,004	0,015
K	0,017	0,025	0,100
S	0,164	0,192	0,248
Ti	0,003	0,003	0,012
P	0,013	0,002	0,002

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Note: I. Golczyk is Responsible for English language, Katowice, Poland