KnE Materials Science
TECHNOGEN-2019
IV Congress "Fundamental research and applied developing of recycling and utilization processes of technogenic formations"
Volume 2020

Knowledge E
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Conference Paper

Assessment of Pyrometallurgical Scheme Options of Red Mud and Scale Co-processing

Yu. A. Chesnokov, L. A. Marshuk, I. N. Tanutrov, and M. N. Sviridova

Institute of Metallurgy of the Ural Branch of the Russian Academy of Sciences, 101, Amundsen street, Ekaterinburg, Russia 620016

Abstract

The analysis of various options for the use of alumina production wastes (red mud) and oiled scale using various methods of agglomeration to produce conditioned commercial iron is presented. Co-processing utilization of red mud and oiled scale allows to obtain raw materials with an iron content of more than 50%, which meets the modern requirements for charge materials for use in the blast furnace process. The calculation analysis carried out using a mathematical model of blast furnace process, allowed to determine the optimal proportion of the iron-containing material for the partial replacement of charge materials without reducing the technical and economic indicators of blast furnace smelting.

Keywords: Bayer process, red mud, oiled scale, mathematical model, blast furnace process, metallurgical properties, complex utilization

Corresponding Author:
Yu. A. Chesnokov
garlics@list.ru

Published: 31 December 2020

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the TECHNOGEN-2019 Conference Committee.

In the process of industrial processing of bauxite to produce alumina, waste is generated. About 1 ton of red mud is generated for each ton of alumina, produced for Bayer process, and about 2.5 tons of red mud is generated with the use of combined method, including sintering process and leaching. Only in the Russian Federation, annually about 1.5 million tons of red mud (RM) are put into the sludge storage facilities. Starting from the 1950s, numerous laboratory and semi-industrial studies of the complex processing of bauxite and the disposal of aluminum production waste were carried out at IMET UB RAS [1–4]. Nevertheless, the problem of developing and implementing an effective technology for the processing of red mud is still an actual technical and environmental problem.

The purpose of this study is the development and improvement of technological methods, allowing to solve the problem of waste disposal aluminum production and oily scale (OS), a comparative analysis of the various options of pyrometallurgical processing for receiving quality metal products. The object of the study were red muds of JSC "UAZ" RUSAL and oiled scale of Sinarsky Pipe Plant. The information system "Interactive calculations in ferrous metallurgy" developed in Institute of Metallurgy UB RAS was used for the calculation analysis [5]

For further analysis in the blast furnace process, the calculation of the options for the studied materials was made – pelletizing and briquetting with the use of lime as a binder, since other types of binders (liquid glass, lignosulfates, oil pitch, etc.) have undesirable components in their content in terms of obtaining the quality of the obtained metal products. The ratio of components in the charge was selected so that the iron content in the proposed product remained high enough while considering the fact that it is necessary to dispose the largest possible amount of red mud. Computational analysis showed that these requirements are met the ratio of 50% RM and 50% of OS with the following composition: Fe_{tot} – 51÷52%, Fe_{met} – 15÷17%, Al_2O_3 – 5÷7%, Σ(Na_2O+K_2O) – 2÷3%.

Table 1: Chemical composition raw materials

Material	Fe	Fe_2O_3 (Fe)	CaO	MgO	SiO_2	TiO_2	Al_2O_3	MnO	P_2O_5	SO_3	R_2O	ппп
Red mud	32,79	46,84	14,13	0,77	7,17	3,56	10,17	0,30	0,6	0,9	3,37	12,0
Rolled scale	70,96	(31,61)	0,67	1,00	4,34	0,03	1,76	0,76	0,68	0,10	0,92	-
Lime	1,6	0,00	91,16	2,90	2,60	0,00	0,87	0,03	0,00	0,34	-	0.0
Bentonite	5,00	7,14	3,36	3,53	58,60	0,96	20,83	0,00	0,00	0,00	-	5,6

Practical data obtained during laboratory tests of red mud and rolled scale (Table 1) were used to calculate the options for the use of pellets and briquettes in the blast furnace charge for the operating conditions of the Serov metallurgical plant (SMP). Below are the reported and specified metallurgical properties of charge materials, technological parameters for blast furnace smelting and the results of calculations on the mathematical model of the blast furnace process.

Table 2: Chemical composition of the blast furnace charge

Material	Component, %												
	Fe_{tot}	Fe_{met}	FeO	CaO	MgO	SiO_2	TiO_2	Al_2O_3	R_2O	Cr_2O_3	MnO	P_2O_5	SO_3
Sinter	52,67	0,00	14,56	12,2	1,52	9,05	0,00	2,64	0,00	0,00	0,24	0,03	0,35
Iron additives	82,70	81,41	1,70	2,00	0,20	5,00	1,01	6,30	0,00	0,61	0,56	0,03	0,50
Briquettes RM+OS	49,93	15,49	0,00	11,39	0,99	5,54	1,65	5,58	2,01	0,18	0,51	0,61	0,51
Pellets RM+OS	51,91	0,00	2,5	7,53	0,91	5,86	1,83	6,08	2,19	0,19	0,58	0,65	0,13

Preliminary analysis (Tables 2 and 3) of the raw materials shows that the metallurgical properties of the experimental briquettes and pellets mainly meet the modern requirements for charge materials used in the blast furnace process (cold and hot strength, reducibility, softening and melting intervals). Of the negative factors should be noted low iron content and high content of harmful impurities – phosphorus (0,61÷0,65 %) and sulfur (0,13÷0,51 %), respectively.

TABLE 3: Metallurgical properties of ore components, %

Material	Fine fraction M_{-5}, %	Reducibilit GOST 17212-84, %	Hot Strength, ISO 13930, %	Strength, GOST 15137-77, %	T beg, grad. C	T end, grad. C	Bulk density, t/m^3
Sinter	44,3	77,0	78,58	92,90	1130	1340	1,70
Iron additives	3,5	99,0	89,0	89,5	1030	1230	2,00
Briquettes RM+OS	1,5	92,0	41,0	99,0	1210	1270	1,80
Pellets RM+OS	3,00	92,0	85,5	92,9	1050	1150	1,70

As a basic variant, the reporting data of the blast furnace № 3 with the volume of 205 m3 of SMP for 2015 were used. In the calculations, a partial replacement sinter was made by using the proposed briquettes and pellets at a given pig iron quality ([S] = 0.028 %), as well as considering the limitations on the total arrival of alkalis in the blast furnace (no more than 5-7 kg per ton of pig iron). Alkalis have an undesirable property to accumulate in the blast furnace, circulating in its working space in the temperature range 700-1100 °C. Excessive accumulation of alkaline compounds in the blast furnace has a negative impact on its operation, reducing the hot strength of coke, destroying the fire-resistant lining, contributing to the suspension of the charge and the burnout of the lances. Changing the profile of the blast furnace violates the uniformity of the distribution of the charge and the gas flow in its working space, which ultimately leads to an increase in fuel consumption and a decrease in the productivity of the furnace.

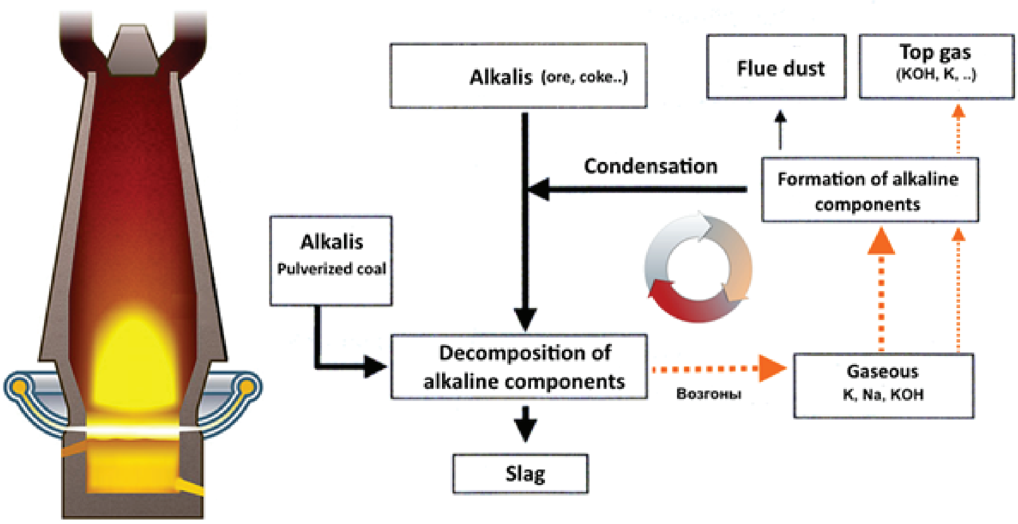

Figure 1: Scheme of the alkalis circulation in the blast furnace

TABLE 4: Calculated indicators of blast furnace smelting with the use of the briquettes and pellets of red sludge and rolled scale in the blast furnace charge

Parameter	Unit	Base version	Version 1	Version 2
Productivity	Hot pig iron per day	370	399	405
Total ore consumption	kg per ton of iron	1 823	1 837	1 827
Siter		1 686	1 528	1 520
Briquettes RM+OS		0,00	183,68	0,00
Iron additives		136,7	124,9	124,3
Pellets RM+OS		0,00	0,00	182,7
Average content of iron		54,92	54,44	54,64
Total coke rate		526,2	484,9	480,8
Anthracite		18,4	16,9	16,8
Coke		507,8	467,9	463,9
Natural gas	м^3 per ton of iron.	97	97	97
Blast				
Rate	м^3 per ton of iron.	1 622	1 523	1 499
Temperature	grad. C	1 113	1 113	1 113
Oxygen	%	21,00	21,00	21,00
Top gas				
Rate	м^3 per ton of iron.	2 285	2 137	2 107
Pressure	kPa	170	170	170
Temperature	grad. C	261	240	219
CO	%	26,06	23,99	23,67
CO_2	%	11,76	13,32	13,85
The theoretical combustion temperature	grad. C	1 959	1 941	1 937
Iron cast content:				
[Si]	%	0,65	0,65	0,65
[S]	%	0,028	0,028	0,028
[Mn]	%	0,25	0,27	0,27
[P]	%	0,043	0,087	0,087
[Fe]	%	94,45	94,36	94,37
[C]	%	4,52	4,50	4,50
Slag content:				
(CaO)	%	42,77	42,68	41,70
(MgO)	%	5,52	5,35	5,37
(SiO_2)	%	35,73	33,98	34,47
(TiO_2)	%	0,48	1,02	1,10
(Al_2O_3)	%	13,52	14,27	14,60
(MnO)	%	0,30	0,34	0,34

Parameter	Unit	Base version	Version 1	Version 2
(FeO)	%	0,61	0,60	0,61
(R_2O)	%	0,52	1,21	1,30
(S)	%	1,01	0,99	0,94
Basicity (CaO)/SiO_2	%	1,197	1,256	1,209
Slag	кг/т чуг.	480,6	485,7	477,6

Generally, in the blast furnace process, the bulk of the alkalis $R_2O=\sum(Na_2O+K_2O)$ is introduced with fuel (ash of coke and pulverized coal fuel), however, for the proposed raw materials, a sufficiently high content of alkaline components (about 2,0÷2,2%) should be considered.

The calculation analyzed the following options for using briquettes and pellets obtained from a mixture of red slurries and rolling scale in the blast furnace charge:

- Base version – calculation for conditions of SMP 2015. Total arrival of alkalis – 2.6 kg per hot ton of pig iron.
- Version 1 - with the addition of 10% briquettes in the blast furnace charge by reducing the proportion of sinter. Total arrival of alkalis -5,95 kg per hot ton of pig iron.
- Version 2 – with the addition of 10% pellets in the blast furnace charge by reducing the proportion of sinter. Total arrival of alkalis - 6,36 kg per hot ton of pig iron.

Based on the studies carried out, the following is shown:

1. Red mud and rolled scale contain a number of useful components - primarily iron and alumina oxides, i.e. co-processing of red mud and oily scale allows to solve not only environmental issues, but also to obtain a demanded product for partial replacement of iron ore raw materials.

2. The technical and economic indicators of the blast furnace smelting for the conditions of the Serov metallurgical plant showed the prospects of adding the industrial product. Replacement of 10% of sinter reduces coke consumption by 5-7% (mainly due to reduction of the amount of fine fraction 0-5 mm).

3. The results of calculations of the use of red mud in ferrous metallurgy put forward a number of necessary requirements for the recyclable product:

4. The total iron content of the processed product should be at least 50%, and the higher the iron content, the lower the production costs and energy consumption;

5. Harmful impurities present in red mud and scale degrade the quality of the obtained metal. This is especially true for phosphorus, which is twice as high as the base version (up to 0.09%);

6. The total content of alkalis (R2O) is highly desirable to have less than 1.0% in terms of how they negatively affect the lining of the furnace and limit the consumption of the recyclable product to 10% in the charge of the blast furnace;

7. It is necessary to conduct further researches of use of the recyclable products with receiving comparative settlement technical and economic indicators according to the scheme an sintering (metallization) and electric arc melting.

The work was carried out with the support of the grant of the Russian Foundation for Fundamental Research N° 18-29-24143.

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