Development of Technology for Carbonate Removal from North Urals Bauxite at RUSAL Krasnoturyinsk

Alexey Pivovarov[1], Andrey Stepanenko[2], Artem Stepanenko[3], Sergey Ordon[4], Andrey Panov[5]
1. Director, Equipment and New Technology Department, RUSAL ETC, Saint Petersburg, Russia
2. Director, Gormashexport, Novosibirsk, Russia
3. Head of laboratory, SFU SNFMMS, Novosibirsk, Russia
4. Deputy General Director for Alumina Production and Ecology
5. Director R&D Alumina
RUSAL ETC, Saint Petersburg, Russia
Corresponding author: Aleksey.Pivovarov@rusal.com

Abstract

Currently because of high initial carbonate content in North Urals bauxites (SUBR) the concentration of carbonates in the process alkaline aluminate liquors at Bogoslovsk aluminum smelter (BAZ) has increased. High carbonate content in the liquors reduces the efficiency of evaporation trains, increases specific steam consumption and causes the excessive consumption of expensive caustic in place of cheaper sodium carbonate. All those factors lead to the decrease of the equipment utilization factor, reduction of the evaporation trains efficiency, increase of the consumption of heating steam, and loss of the service life of heat-exchange tubes. This paper presents technical, design and process solutions that provide for efficient bauxite beneficiation with the use of SEPAIR dry concentration technology. The decrease of carbonate content in the bauxites (SUBR) will facilitate the increase of evaporation and digestion throughput, reduction of caustic consumption. Also these measures will increase the alumina production efficiency in view of both technology and cost effectiveness.

Keywords: bauxites, dry beneficiation, carbonate removal.

1. Introduction

For over 70 years North Urals deposits have been the main source of raw materials for alumina production at Urals aluminum smelters. North Urals bauxites (SUBR) are diaspore-boehmite and boehmite bauxites mainly characterized by a high content of $A1_2O_3$ (52—54 %). For a long time customers were supplied with a mixture of bauxites from different deposits that allowed maintaining A/S ratio (Al_2O_3/SiO_2) > 14 and carbon dioxide content (CO_2), i.e. the most harmful impurity of alumina production < 3.8 %. All these years these bauxites have been and still remain the bauxites of the highest grade in Russia. For bauxite mining underground (mines) method is used.

With lowering of the mining level, CO_2 content in bauxites increases. CO_2 is present in bauxites in form of calcium, iron and magnesium carbonates; and as evidenced in practice with mine development quality of SUBR bauxites gradually deteriorates in terms of both alumina content and limiting impurities. Increase of carbon dioxide mass fraction in the ore is mainly attributed to increase of mechanical dilution of the ore with limestone and lime shale of overlying bauxite that is apt to capability in course of mining; and also addition of soil lime due to challenging hypsometry (variability coefficient for sub-ore patent marks can reach 72 %).

Gradual changes in bauxite quality in course of ore mining and changes of mining methods eventually led to reduction of alumina content and increase of harmful impurities in marketable bauxites. At present high content of carbonates in SUBR bauxites causes their accumulation in process liquors. High carbonate content in the liquors reduces the efficiency of evaporation trains, increases specific steam consumption and causes the excessive consumption of expensive caustic in place of cheaper sodium carbonate.

Conditioning of raw material that is fed to the process becomes more and more urgent. Currently the most critical issue is preliminary beneficiation of GB-1 and GB-2 bauxites from the North Urals bauxite mine. Bauxite moisture does not exceed 10 %. Maximum size of bauxite particles is 250 mm. The decrease of carbonate content in the bauxites (SUBR) will facilitate the increase of evaporation and digestion throughput, reduction of caustic consumption and increase of use of calcined soda which is less expensive that will reduce heat consumption and improve the sintering capacity.

There are two options to improve the quality of SUBR bauxite while maintaining their competitive ability:

- adding bauxites of higher grades from other deposits;
- preliminary beneficiation.

Earlier in the Soviet Union and later in the Russian Federation extensive study of process flowsheets for domestic bauxite beneficiation was conducted. As a result the possibility to remove sulfides, carbonates and clay minerals from bauxites by means of flotation, gravity, radiometric concentration and during the pyrometallurgical processing was determined.

2. Experimental

Work on bauxite beneficiation was executed using SEPAIR technology. This project is aimed to study the beneficiation ability of SUBR bauxites to generate the concentrate of GB-1 bauxite quality in the end product and carbon dioxide (CO_2) content to < 4.0 %. Feed sample for the tests contained 6.6 % CO_2, 48.9 % Al_2O_3.

Tests were carried out using the pilot concentration plant of "GORMAShEXPORT" laboratory (Figure 1) comprising the following equipment: belt feeder, SEPAIR-1-0.5 plant.

Figure 1. SEPAIR-1-0.5 Plant.

SEPAIR-1-0.5 pneumatic concentration plant comprises the following: vibrating feeder, mesh-belt conveyer, hopper for separated products, nozzle, DNu – 8/1500 exhaust fan, air suction system.

The principle of operation of the separator is as follows: material for separation is evenly distributed with a vibrating feeder as "monolayer" on the mesh-belt conveyer. Then the material is conveyed to under the nozzle through which the air is drawn in with the specific velocity. The air stream is generated by an exhaust blower that is connected with the nozzle via product and mud separating hopper. The frequency converter is used to set the rotation speed of exhaust blower motor that ensures the required air consumption (flowrate) through the nozzle. Particles/grains are separated due to the difference of their fall velocity/terminal velocity (terminal velocity of an object is equal to the constant speed as the object is falling in the static air. In a free fall two forces are acting on an object: weight and drag force. Weight amounts to mass multiplied by gravity acceleration, and drag force is proportional to object's cross section and the squared air velocity and density) that is defined by their physical properties: density, size, shape.

At a specified air flowrate the grains of the material with a less terminal velocity (border density) are "grabbed" by the flow and transferred to the product hopper while the material with a greater velocity remain on the conveyor and is discharged to the holding tank for separation tails/waste. In the nozzle material grains form a circulating fluidized layer ("bed"), the terminal velocity of these grains is equal to the air flowrate. This layer functions as a "filter" for "heavy" grains and prevents them from being grabbed by air flow due to irregular air flowrates passing the material on the conveyor and nozzle inlet. Heavy grains fall on from the nozzle on the conveyor and discharged to the waste tank.

To separate the material by density using such a method the material shall be preliminary divided into mechanical grades. The grade width is determined by an equal settling factor. The equal settling factor is a relation of equivalent diameters of light and heavy grains falling with equal terminal velocity in actual air environment.

In this test run ore beneficiation was carries out for the following mechanical grades: 1-3, 3-6, 6-13, 13-25, 25-50 (mm). Beneficiation of coarser grades was not tested due to limited capacity of the pilot plant. Beneficiation of < 1 mm grade was not tested as it mainly consists of bauxite dust.

The separation is aimed to separate heavy fraction of minerals, increase aluminum content and reduce CO_2 content. A weighted portion of ore mechanical grade was fed to the separator for beneficiation. The separator was adjusted as follows: the air flowrate in the nozzle was set with the frequency converter of the exhaust blower motor to the value at which the separation of the material into light and heavy grains started in the nozzle. Preliminary weighted mechanical grade of the ore sample was fed to the receiving hopper of the plant vibrating feeder. The vibrating feeder is actuated to provide a preset feeding of the material to pneumatic separation. Upon completion of the separation light fraction is discharged from the product hopper, weighted and marked as Product 1; heavy fraction is returned to the head of the process and the test is repeated at a higher upward velocity. Light fraction is again weighted and marked as Product 2 and the heavy fraction is returned to the head of the process, etc. As a result of the separation about 6 – 8 products are generated for each mechanical grade. Upon completion of separation tests for each mechanical grade the separator and filter bag were cleaned, spillages were collected and marked as a separate product.

3. Results and Discussion

All beneficiation products are divided by quality into two concentrate classes: I – up to 6.5 % CO_2 and II - > 6.5 % CO_2. 6.5 % CO_2 was accepted as a borderline content value for product separation into concentrates with low and high CO_2 content. Actual borderline content can be measured within the range from 3.5 to > 7 %. Using the standard method to determine rock hardness with the Protodyakonov scale, the rock hardness in bauxites was determined to be 7. Simple compression test showed that ore rocks break at the pressure of 35 – 50 kg/cm^2 for GB-1. Particle size distribution of GB-1 sample is presented in Table 1.

Table 1. PSD of an ore sample with grade division.

Grade, mm	Initial sample		+50mm grade		
	Mass, kg	Yield total, %	Mass, kg	Yield spec., %	Yield total, %
+50	207.9	17.26			
-50 +25	161.22	13.38	110.7	53.25	9.19
-25 +13	153.32	12.73	34.78	16.73	2.89
-13 +6	143.72	11.93	21.04	10.12	1.75
-6 +3	102.11	8.48	10.24	4.93	0.85
-3 +1	180.97	15.02	12.44	5.98	1.03
-1 +0	255.28	21.19	18.7	8.99	1.55
Total	1204.52	100	207.9	100	17.26

During the tests each fraction was concentrated separately. The results of tests on SUBR bauxite beneficiation with grade division are indicated in Figures 2 – 5.

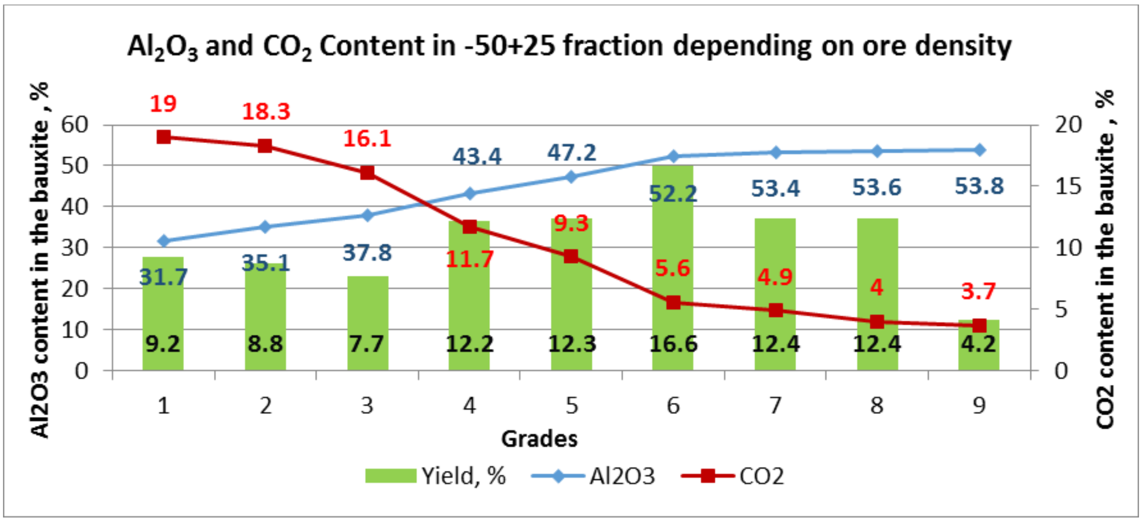

Figure 2. Al_2O_3 and CO_2 content in the bauxite, -50 +25 fraction.

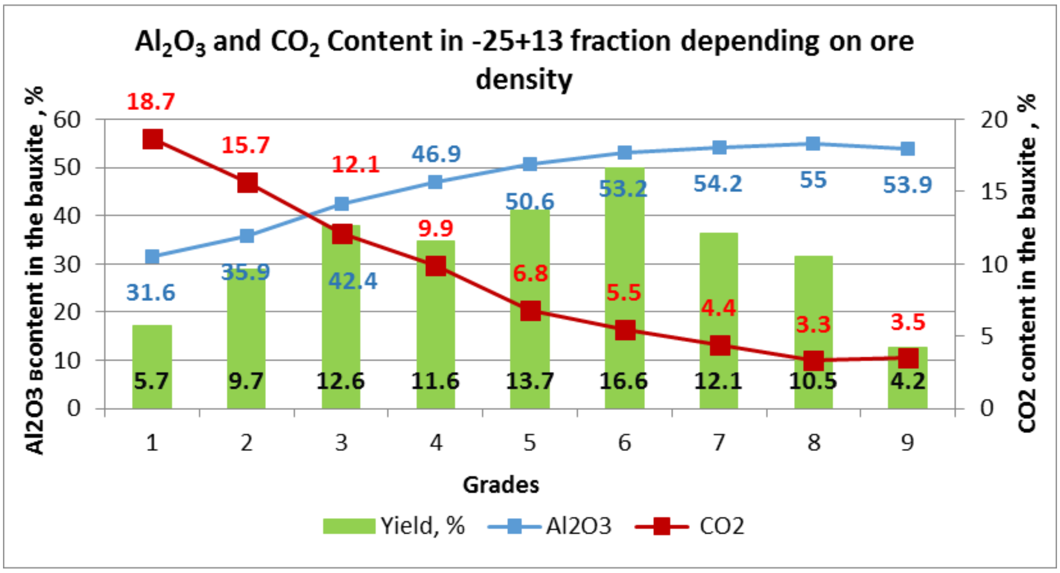

Figure 3. Al_2O_3 and CO_2 content in the bauxite, -25 +13 fraction.

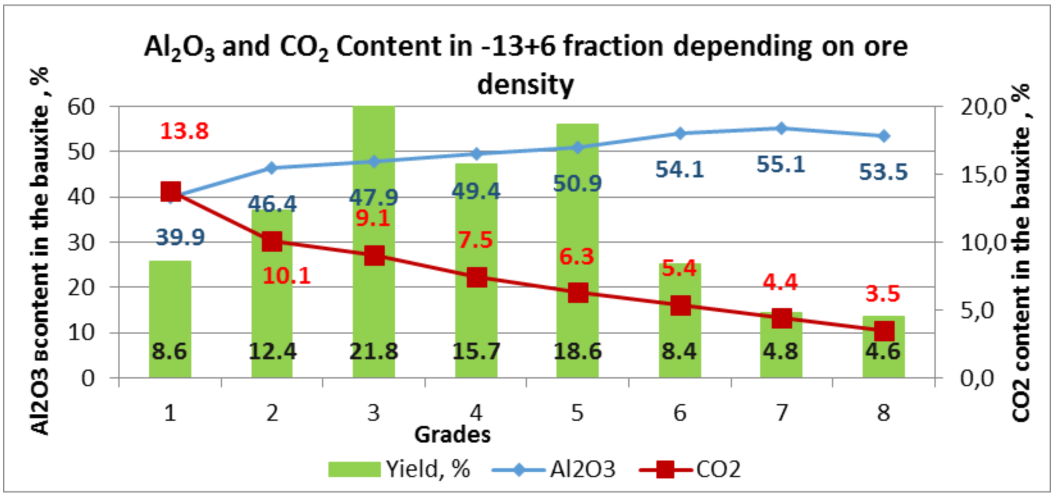

Figure 4. Al_2O_3 and CO_2 content in the bauxite, -13 +6 fraction.

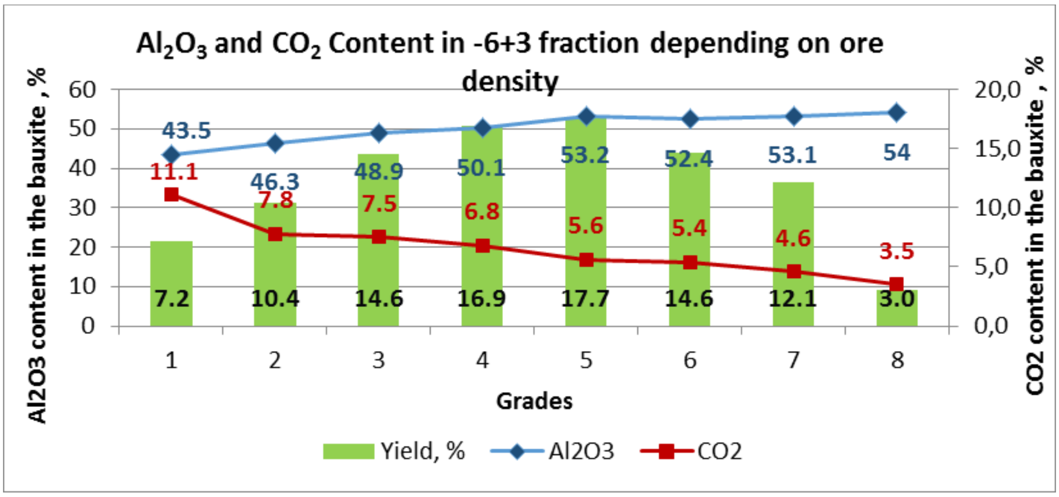

Figure 5. Al_2O_3 and CO_2 content in the bauxite, -6 +3 fraction.

Table 2 shows total calculation of concentrate mixture upon beneficiation of bauxite of initial and grinded size grades.

Table 2. Calculated balance of concentrate mixture after bauxite beneficiation.

Size grade, mm	**Concentrate grade**	**Yield total, %**	**Content, %**	
			Al_2O_3	**CO_2**
-50 +25	II	11.77	42.17	12.73
	I	10.20	51.86	5.00
-25 +13	II	7.58	43.47	11.35
	I	7.60	53.17	5.04
-13 +6	II	7.95	9.40	9.40
	I	5.11	52.47	5.56
Size grade, mm	**Concentrate grade**	**Yield total, %**	**Content, %**	
			Al_2O_3	**CO_2**
-6 +3	II	3.56	47.60	8.29
	I	5.45	52.22	5.59
-3 +1	II	0.85	48.40	6.86
	I	13.41	53.82	4.87
-1 +0	I	22.75	53.52	3.5
Total	**II**	**31.71**	**43.32**	**10.91**
	I	**64.52**	**53.09**	**4.54**
	losses	**3.78**		

4. Conclusions

These tests on beneficiation of North Urals bauxites were carried out using SEPAIR pilot concentration plant in "GORMAShEXPORT" laboratory in October – December, 2018.

Ore preparation for these tests comprised the dividing the initial ore samples into the following mechanical grades: 1-3, 3-6, 6-13, 13-25, 25-50 (mm). + 50 mm samples were grinded with subsequent division into the said size grades.

Initial 0 – 50 mm grade samples and samples produced by grinding +50 mm grade were processed separately.

In course of separation by mechanical grades the bauxite was separated in stages into 6 – 8 products of different density. These products were weighted to calculate the weight balance. Then samples were prepared for taking sample weights.

As a rule all beneficiation products are divided by quality into two concentrate classes: I – up to 6.5 % CO_2 and II - > 6.5 % CO_2. Based on the obtained results estimated balances for beneficiation of initial and grinded grades and their total balance were calculated.

As calculated balances show that a separate processing of initial and grinded grades is not required. After grinding all material is mixed and fed to classification by mechanical grades.

Total estimated balance of GB-1 sample beneficiation proved the following:

- total yield of I class concentrate amounts to 64.52 % with average content of Al_2O_3 53.09 % and CO_2 4.54 %;
- total yield of II class concentrate amounts to 31.71 % with average content of Al_2O_3 43.32 % and CO_2 10.91 %;
- total process losses amounted to 3.78 %. Losses are mainly attributed to material clogging in the equipment, losses in the scrubbers, spillages, etc.

The results of the tests proved the possibility and efficiency of bauxite beneficiation using SEPAIR® dry concentration technology.

5. References

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