Light Metals 2015

ALUMINA AND BAUXITE

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ALUMINA AND BAUXITE

Bauxite and Beneficiation

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Light Metals 2015
Edited by: Margaret Hyland
TMS (The Minerals, Metals & Materials Society), 2015

THEORY AND PRACTICE OF BAUXITE X-RAY SORTING

Vladimir Shemyakin[1], Sergey Skopov[1], Gennady Klimentenok[2], Andrey Panov[2]
[1]NPK «Technogen», 620149, 1-4, Bardina Street, Ekaterinburg, Russia
[2]UC RUSAL Engineering and Technology Centre (VAMI), Saint Petersburg, 199106, Russian Federation

Keywords: Bauxite beneficiation, X-ray radiometric sorting, SUBR bauxites, Timan bauxites, global applicability.

Abstract

Problem of bauxite grade declining is now becoming a global scenario. That is why, for many years, scientists have been studying the problem of bauxite beneficiation. Complex mineralogy of bauxite, high content of alumina and process limitations often make traditional beneficiation techniques ineffective.

The use of different kinds of radiation jointly with sorting techniques has been intensively studied in Russia, that resulted in development of new direction of beneficiation – X-Ray sorting. Currently this is a separate direction of beneficiation widely and selectively applied for lump separation of different ore types, including bauxites. This can be used for reduction of silica content and carbonate/sulfur removal in bauxites. The paper shows feasibility to use this technique for improvement of quality of hard to beneficiate bauxites located in the Urals, Russia and analyzes applicability of this method to other bauxites of the world.

1. Introduction

Bauxite as one of the main alumina-bearing ores is an exceptional and very difficult product for beneficiation [1]. High content of the valuable component – aluminum oxide and the presence of macro and trace impurities with different physical and chemical properties impose high requirements to selectivity and efficiency of beneficiation processes.

Radiometric beneficiation includes a whole range of different methods based on characteristics of rock and impurity minerals while being treated with different kinds of radiation emissions (including light, ultraviolet, radio, X-ray, etc.). The main property consolidating different processes of this direction of beneficiation is connected to general nature of the wave's interaction with substances. The essence of the described methods is the impact of certain radiation on the substance, registration and measurement of intensity and density of different radiation types flow reflected from the sample, comparison of the measured intensity to the etalon value and further sorting using the "yes or no" principle.

During last 50 years in the leading countries of the world scientists and process engineers were involved in development of different methods of pre-beneficiation, including different types of radiation for detection of valuable components in lumps of minerals. As a result a new trend in beneficiation of large mineral lumps was created – X-ray radiometric sorting [2]. The priority in implementation of X-ray beneficiation methods on industrial scale belongs to Russia. With development of different ore sorting methods the process of X-ray radiometric separation (XRS) has established itself as the most universal and selective method.

Emergence of new equipment or new technology has its roots and its history. X-ray separators were created as a result of general development of radiometric beneficiation methods or automatic sorting methods. Under this concept in the Soviet Union were united all methods used to sort ore a variety of radiation types. Combination and the patterns of these different radiation energies and ranges numbered up to hundreds of possible embodiments of radiometric methods, which in principle could separate a wide variety of minerals (bulk material, portions of ore) on the content of components with varying efficiency, but only 4 - 6 of them have become realistic and technically feasible.

Historically (in 50-ies of the 20th century) first appeared auto X-ray method for sorting of uranium ores by natural radioactivity of decay products of uranium (formerly just called "radiometric"). Many mining and processing enterprises are aware of other radiometric methods, which have also found practical application:

- photometric (sorting by light and color attributes);
- X-ray luminescent (diamonds sorting);
- gamma method (reflectivity and absorptivity of gamma radiation, in particular for sorting iron ores and coal).

X-ray radiometric method began to be explored in the 50-60-ies of the last century as a method for analyzing of composition of different materials and ores on the basis of radioactive sources and subsequently was proven in practice of geophysical prospecting and sampling of minerals. Gradually (in 60-70-ies), this method found application in research of lump separation (VIMS, Irgiredmet Institutes), where high technological capabilities, selectivity and efficiency of the method for various types of minerals were discovered.

Further, by the efforts of the staff of Irgiredmet and IFKIA (Irkutsk branch of the Kiev Institute of Automation), "Sibtsvetmetavtomatika" and "Almazzolotoavtomatika" (Krasnoyarsk) in the 80-ies and early 90-ies of the last century the first prototypes of X-ray separators were created and the tests proved efficiency of their industrial application. The state program for development of radiometric methods for benefication developed in 1982 by the Ministry of Metallurgy of the USSR largely contributed to this.

Industrial X-ray radiometric separators (TU 3132-015-05820239-1996 TU 3132-015-05820239-2001) were developed by experts of LLC "RADOS" (Krasnoyarsk) and became commercially available in Russia since 1995.

During these years number of separators with proven industrial approbation fabricated on various mining and metallurgical enterprises exceeded one hundred. The main conclusion drawn from the practice in the application of the X-ray radiometric separation method for beneficiation of different types of minerals and industrial wastes is that XRS technology should be widely used in mineral processing. In the same way, as the radiometric beneficiation of radioactive ores (in the Soviet Union were built around 110 radiometric factories) and X-ray separation of diamond ore (only in Russia Yakutia diamond factory currently operate about 400 separators) have become common technologies.

First separators were manufactured and delivered to the gold mining industry (in particular, the company "Eldorado" North-Yenisei district of Krasnoyarsk region - a set of 3-separators).

Since 2010, production of X-ray separators in the Urals has been started. During 3 and half years more than 30 different types of industrial separators with various sensors (proportional and semiconductor) were manufactured for enterprises of Russia, Kazakhstan, Mongolia, Chile, India, South Africa and China.

Using this type of X-ray beneficiation it is possible to process lumps from 5-10 mm to 250 – 300 mm. The most common low limit of sorted material is lump size of 20-25 mm. The production rate of a separator is sharply reduced with reduction in lump size fed to separation below 5-10 mm.

Production rate of X-ray separators depending on the size of the material (machine class) ranges from 2.3 tons to 25-30 tons per hour. To improve performance by 25-30% the last generation of separators is equipped with pneumatic actuator (instead of electrical ones) for the actuators of sliding type.

The most actively implementation of X-ray radiometric separation is conducted at the enterprises of uranium and copper industries. Thus, at Priargunsky Mining and Chemical Combine operates X-ray complex consisting of 12 separators. At the mining enterprises of the Ural Mining and Metallurgical Company more than 20 separators are in operation. In particular, in 2013 in the North of the Ural a sorting complex consisting of 6 separators with capacity of about 600,000 tons per year for beneficiation of copper sulfide ores was commissioned (Figure 1).

Figure 1. An X-Ray Separation Complex

2. Description of the X-Ray radiometric method

The indispensable condition for X- ray beneficiation of minerals is application of the appropriate radiation source. During interaction of primary radiation with chemical elements its absorption, dispersion or reflection occurs as a rule accompanied by emission of the secondary radiation.

X-ray separation is conducted on special beneficiation equipment – X-ray separators. Using this type of X-ray beneficiation it is possible to process lumps from 5-10 mm to 250 – 300 mm. The most common low limit of sorted material is lump size of 20-25 mm. Production rate of a separator is sharply reduced with reduction in lump size fed to separation.

The XRS is used for the following tasks:

- separation of minerals ready for processing without additional beneficiation;
- preliminary beneficiation with separation of lump tails;
- preliminary separation of the mineral into individual process types which is practical to processes using different technological flows.

Operating principle and general view of the separator are presented in Figures 2 and 3.

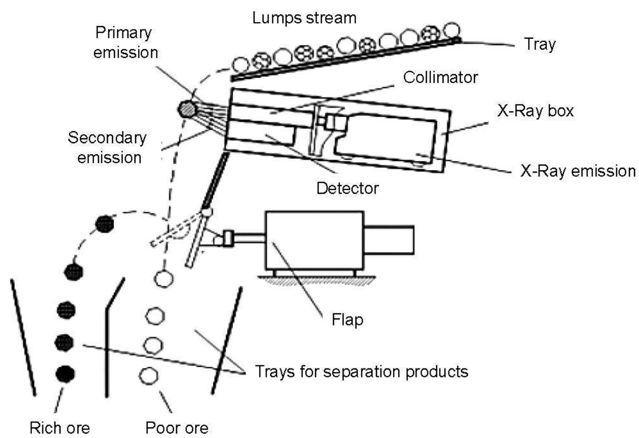
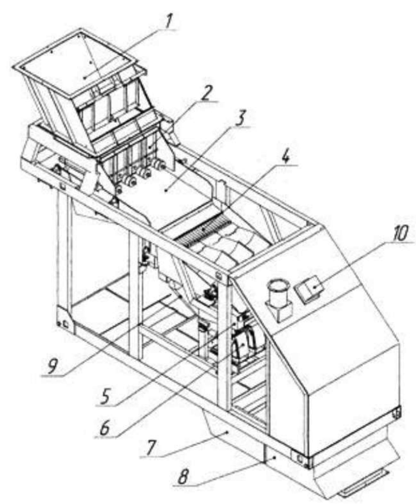


Figure 2. Principle of X-Ray Radiometric Separation



1 transition bin;
2 Gate bin;
3 Vibrational feeder; 4 Handler;
5 X-ray box;
6 Actuators;
7-8 Discharge chutes of sorted products;
9 Discharge chute of spillage;
10 Video control

Figure 3. X-Ray Separator layout

The machine (sortable) class of product size is supplied on the receiving bin. The vibrating feeder of separator provides continuous measured feeding of ore from receiving bin on the destacker. The destacker forms 4 flows (streams) of ore with lump supply in the zone of measuring and sorting in the regime of fall. Each lump is exposed to the scanning X-ray radiation by natural movement of lump in the narrow slot of irradiation. The spectrum of the secondary radiation from the lump is subject to automatic computer processing with characterization of the analytic parameter of the separating attribute and benchmarking of the produced value with the threshold set. The measuring control system of the separator yields the control signal for operation of actuator to the lump. The actuator presented by electromagnetic gate is activated and changes the trajectory of the lump fall, directing into the chute of the selected product. The remaining lumps fall directly in the tails chute.

Formed mainly by the minerals having in its composition light elements, bauxite occupies a special place in the technology of X-ray radiometric separation. X-ray separator unit cannot directly detect the presence and content of the main mineral forms of useful and harmful components such as Al, Si, S and CO_2. For such ores the main task is to determine separation characteristics which are closely correlated with the target components of bauxite and can be readily determined by the measuring unit of the separator. In the course of studies we were able to identify the relationship of aluminum minerals and harmful impurities with characteristic lithological varieties of bauxite and the bedrocks. For bauxite raw materials such parameters are the intensity in the channels of calcium and iron. Figure 4 shows examples of spectra of diluting rocks samples (limestone) and bauxite.

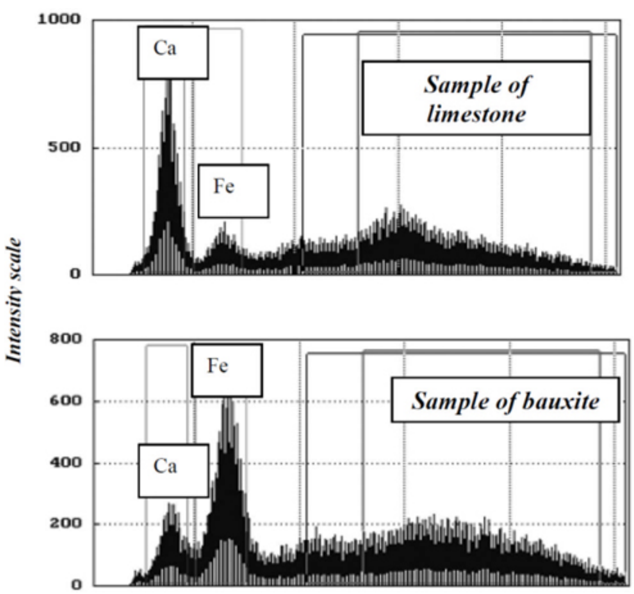


Figure 4. Examples of limestone and bauxite spectrum

Analytical parameter of each lump P_{Ca} or P_{Fe} is a function of the content of the analyzed element (Ca and Fe), and calculated by the spectral ratio method:

$$P_{Ca} = N_{Ca} : N_S \text{ or } P_{Fe} = N_{Fe} : N_S \qquad (1)$$

where: N_{Ca} and N_{Fe} - number of pulses of the characteristic X-ray fluorescent emission of the analyzed element (calcium and iron, respectively) recorded by controlled electronic detector, in the selected analytical ranges, the emission is a part of secondary emission from the lump;

N_S - number of secondary, dispersed emission spectrum pulses recorded from the same lump.

Further, in section 3, selection of specific analytical parameters for separation purposes is described.

3. Study of application to Russian bauxites

To date, the largest Russian alumina refineries are mainly processing bauxite from two deposits - North Urals (SUBR) and Timan (STBR). As the reserves are mined the bauxite quality of both deposits is gradually deteriorating, and this refer to both: the content of alumina and major contaminants. For this reason lots of efforts are made to compensate this, both in terms of mining operations, and beneficiation.

Bauxite mining at SUBR is underground under complicated mining conditions. Currently carbon dioxide in SUBR in-situ bauxite is 3.0 – 3.5%. However due to bauxite dilution by bedrock CO_2 content in bauxite product ranges from 3.5 to 5.3%. The reason for this is deterioration of mining conditions such as decrease in the stability of the overburden, complication of geodynamic conditions expressed in the rock pressure manifestation in the form of rock bursts, as mining depth increases.

A somewhat different picture emerges when developing open-pit Timan bauxite mine. These bauxites have lower quality as compared to SUBR bauxites, but have relatively low cost of production and transportation, as well as the almost complete absence of carbonates. At the same time, due to the structural features of the ore bodies it is almost impossible to organize selective extraction that results in significant dilution of bauxite with waste rock, which negates the benefits of open mining.

Applicability of X-ray sorting to improve the quality of bauxite is related to the structural features of the ore bodies and bedrocks of each particular deposit. Diasporic bauxites of SUBR can be qualitatively divided into several lithological varieties: red stain and non-stain, jasperoid red, variegated gray, bleached and pyritized [3]. All types of bauxite are different as far as the content of major components and impurities is concerned. The content of alumina in the lithological varieties is also different, ranging from 49.2 to 56.4%, content of silica - from 3.22 to 7.90%, carbonates from 1.20 to 2.95% and sulfides - from 0.5 to 6.5%. Average fluctuation range of the components does not show an accurate picture of their distribution. Lump material of gross mined SUBR bauxite as a rule presents specific lithological varieties.

Bed rock is represented mainly by limestones: light gray, reefogenic, light gray massive, dark-gray bituminous, amphipore as well as by lime-shale and ore breccia. Limestone of ore horizon (underlying) is relatively pure white, light gray limestone with nests and veins of red – bauxite breccia. Limestone roof of ore horizon (covering) is represented by brown limestone with inclusions of veinlet concretions, veins of bituminous shale and clay. The mineral composition is variable.

In the course of mining different lithological varieties of bauxite and bedrocks behave differently during crushing. The difference in strength properties of lithological varieties of bauxite and host rocks enables to redistribute them by various size classes, as follows:

- fine classes (below 100 mm) are presented by almost all red stain bauxites species and, to a large extent, red non-stain species;
- in coarse classes (above 100 mm) the bulk of bearing rocks - dark gray and light gray limestone, jasperoid and variegated bauxites are concentrated.

This feature allows by screening operation to separate from original bauxite undersize product less than 100 mm with CO_2 content below 3.5%. The +100 mm class can be successfully enriched by X-ray radiometric separation.

Pilot trials of X-ray radiometric separation were made in two stages. In the first stage it was decided to separate limestone using the analytical parameter $P_{Ca} = N_{Ca}: N_S$ = (0.07 units). In the second stage it was suggested to remove high-iron fraction with high content of sulfides and silicates (first of all chamosite) from bauxite, which was largely purified from limestone, using the analytical parameter PFe = NFe: NS = 3.0 units. This method allows to beneficiate bauxite not only from carbonates but also sulfides with simultaneous increase in alumina / silica ratio.

Major results of X-ray radiometric beneficiation of all size grades (including the summary results) of bauxite mine "Cheremukhovskoye" are presented in Table. 1

Table 1. The results of X-ray separation of bauxite from mine Cheremukhovskoye

Size after crushing, mm	Products of separation	Yield, %	Content, %					Al_2O_3/ SiO_2	Recovery, %	
			Al_2O_3	SiO_2	CO_2	S_{total}	Fe_2O_3		CO_2	S_{total}
Initial class + 200 mm										
-200 +100	Limestone (Ca > 0.07 unit)	28.4	19.37	5.76	25.06	3.27	9.2	3.36	63.69	26.30
	Low iron bauxite (Fe < 3 unit)	51.5	50.65	4.52	7.11	3.71	19.8	11.21		
	High iron bauxite (Fe > 3 unit)	20.1	51.73	4.98	1.97	3.44	23.8	10.39		
	Bauxite	71.6	50.95	4.65	5.67	3.63	20.9	10.96	36.31	73.70
	Total:	100.0	41.8	4.96	11.17	3.53	17.6	8.46	100.0	100.0
-100 +25	Limestone (Ca > 0.07 unit)	20.7	14.35	6.10	28.51	3.91	6.7	2.35	67.76	25.80
	Low iron bauxite (Fe < 3 unit)	60.4	53.56	4.50	4.36	3.20	21.3	11.90		
	High iron bauxite (Fe > 3 unit)	18.9	53.48	4.95	0.92	2.09	25.1	10.80		
	Bauxite	79.3	53.54	4.61	3.54	2.94	22.2	11.61	32.24	74.20
	Total:	100.0	45.43	4.91	8.71	3.14	19.0	9.25	100.0	100.0
Initial class – 200 + 100 mm										
-200 +100	Limestone (Ca > 0.07 unit)	14.4	35.72	4.45	14.43	2.77	14.6	8.03	35.74	12.54
	Low iron bauxite (Fe < 3 unit)	51.0	50.85	4.59	6.07	3.00	20.1	11.08		
	High iron bauxite (Fe > 3 unit)	34.6	52.30	4.87	1.85	3.62	24.1	10.74		
	Bauxite	85.6	51.44	4.70	4.36	3.25	21.8	10.94	57.58	93.11
	Total:	100.0	49.17	4.67	5.81	3.18	20.7	10.52	100.0	100.0
-100 +25	Limestone (Ca > 0.07 unit)	7.7	20.32	4.09	27.28	2.72	9.4	4.97	42.42	6.89
	Low iron bauxite (Fe < 3 unit)	64.6	53.72	4.42	3.78	3.30	21.4	12.15		
	High iron bauxite (Fe > 3 unit)	27.7	52.48	4.73	1.48	2.52	22.6	11.10		
	Bauxite	92.3	53.35	4.51	3.09	3.07	21.8	11.83	57.58	93.11
	Total:	100.0	50.80	4.48	4.95	3.04	20.8	11.34	100.0	100.0
Initial class + 100 mm										
-200 +25	**Limestone (Ca > 0.07 units)**	**19.4**	**25.44**	**5.23**	**21.17**	**3.11**	**10.9**	**4.86**	**52.37**	**18.33**
	Dressed bauxite	**80.6**	**51.55**	**4.67**	**4.64**	**3.33**	**21.6**	**11.04**	**47.63**	**81.67**
	Total:	**100.0**	**46.48**	**4.78**	**7.84**	**3.29**	**19.5**	**9.72**	**100.0**	**100.0**

The sorting results (including those presented in Table 1) suggest that efficient beneficiation is achieved by separation treatment of size fractions -100 +50 and -50 +25 mm. Removing of carbonates in the tails of separation exceeded 64% with CO_2 content above 25.5%. Carbonate content in the enriched product obtained during separation of classes, extracted from the original bauxite of mine "Cheremukhovskoye" with size 200 mm was more than two times lower than in the sample delivered to beneficiation (5.28% vs. 10.76% CO_2 in the initial product). After beneficiation of fractions extracted by crushing and sieving of the original bauxite with particle size of -200 + 100 mm, the indicators to extract carbonates into separation tails were much lower - 36-42% and CO_2 content of the enriched bauxite was 1.5% lower than in the feedstock delivered for beneficiation (4.24% vs. 5.74%). In general, the tests showed that the X-ray separation allows to remove from coarse size of mine "Cheremukhovskoye" to the tails separation more than 52% of carbonates with output 19.4% and to obtain enriched bauxite of higher quality by reducing CO_2 from 7.84% to 4.64% with simultaneous Al_2O_3 content increase from 46.48% to 51.55% and alumina/silica ratio increase from 9.72 to 11.04 units.

Lithological and mineralogical analysis has shown the following. In the tails of separation were separated mostly low-quality bauxite and limestone. They contained 61.4% of gray variegated and pyritized bauxite, 19.5%, limestone and only 14% of various red lithological varieties of bauxite. Dressed bauxite is represented in roughly equal proportions by red (33.4%) and gray (43.6%) lithological varieties of bauxite, with limestone content not exceeding 0.8%.

In general, evaluating the effectiveness of waste material removal from the coarse lump fractions of bauxite from mine "Cheremukhovskoye" we can specify high rate of limestone extraction in the tails of separation - 82.2%.

Evaluation of the distribution of main minerals by X-ray radiometric separation products revealed the following:

- calcite content in the so-called lump fraction bauxite "machine class" constitutes only 15.5%, in the tails of the separation it reached 43.9%;
- siderite content being 2.5 % in the "machine class", almost doubled in the tails of separation and reached 4.8%;
- diaspore in the tails of separation does not exceed 22.8%, while in the original bauxite fed for separation, its content is 48.2%;
- boehmite content in separation tailings decreased to 1.2% as compared to 1.7% in the machine classes.

Thus the main factors influencing technological parameters of the separation process are:

- composition of diluting bedrock (ratio of limestone hanging and lying laterally, proportion of gray and mottled porphyry bauxite in ore, systems of deposits mining, percentage of dilution, etc.);
- number and quality of bauxite size fractions supplied to X-ray radiometric separation (the larger the amount of bauxite delivered for separation, the higher figures of carbonates removal in the tails; and the larger is amount of carbonates presented in diluting carbonate rock in the form of limestone, the more efficiently they are removed);
- effectiveness of direct screening of the original bauxite (the smaller is class size obtained by screening, the higher is the overall performance of beneficiation, the better the small classes will be removed at screening, the higher will be performance at X-ray radiometric separation);
- optimal parameters of lumpy fractions crushing (the less is the amount of small classes formed at crushing, the better are overall parameters of the dressed bauxite quality);
- threshold of separation at X-ray radiometric separation and methodological support of the beneficiation process (the higher sensitivity of the separation complex, the higher possibility of carbonates selective removal; the more perfect mathematical model of the measurement, the deeper beneficiation can be achieved).

Accumulated research experience of the separation process for SUBR bauxite was successfully used in the study of Timan bauxite.

Timan bauxites (STBR), in particular of Vezhayu Vorykvinskoye deposit, according to its mineral composition are classified as hematite-boehmite bauxites. They can be quite clearly divided into two main varieties: porous red stains with pink, gray, green and yellow spots, mainly pelitic, with small amounts of debris; and stone - with the presence of mottled greenish, yellowish, with clastic and pseudo clastic structure. Each of these types has heterogeneous mineral composition, quality and physical properties. In general, red pelitomorphic bauxites are less strong and of higher quality, and stony bauxites are more strong and of inferior quality. The texture of the rocks is massive, lenticular-layered, and the structure is brecciated, gravelite, psammitic and pelitic. Bauxites are mainly low siliceous, ferruginous.

The main components are as follows, %: Al_2O_3 – 42.8-56.9; SiO_2 – 4.9-15.0; Fe_2O_3 – 3.4-38.5; TiO_2 – 1.1-3.3 and FeO – 1.2-14.0. The main rock-forming minerals are boehmite, hematite, minor are chamosite, kaolinite, goethite and diaspore. Similarly to SUBR bauxite, STBR bauxite can be subdivided into a number of lithological varieties with particular distinguishing features.

Test and pilot trials by X-ray radiometric separation of Middle Timan bauxite were carried out on the samples representing three ore types: Bayer, sinter and off-balance stock. The total mass of the process sample was more than 6 tonnes. Bayer and sinter bauxite process samples were selected from stockpiles prepared for shipment of the STBR Mine. Off-balance bauxite sample was selected directly in the mine.

For investigation of selection of beneficiation thresholds by X-ray radiometric separation the most typical and representative lithological varieties of bauxite were selected from technological samples of the Middle Timan bauxite of the size -100 + 40 mm.

Each selected lump of bauxite lithological variations was subjected to thorough washing to remove surface leather coats and subsequently crushed in order to obtain a fresh surface, free from various impurities. Then, on the SRF2-30 X-ray radiometric separator using X-ray spectra, the values of separation algorithm P_{Fe} were determined (see Table 2).

Table 2. Lithological types of Middle Timan bauxite

Lithological types	Value P_{Fe}, units	Content, %			Al_2O_3/ SiO_2
		Al_2O_3	Fe_2O_3	SiO_2	
Rocky	33.3	42.95	27.78	10.47	4.1
Eluvial	26.2	48.98	27.65	7.49	6.5
Partially discolored	25.0	46.80	18.29	13.72	3.4
Colluvial	24.5	49.67	29.20	2.49	19.9
Chamosite	22.9	51.50	18.45	11.78	4.4
Ferrous	22.8	41.18	22.68	14.76	2.8
Discolored	20.4	47.00	17.73	15.16	3.1
Kaolinized	13.0	40.34	16.37	27.93	1.4
Kaolin -clay	10.6	52.10	4.67	22.44	2.3

It has been found that the spectra of lithological bauxite variations by X-ray characteristic of iron greatly differ. According to the investigation of individual bauxite lumps the average spectra were determined for lithological varieties of the presented process samples. All pieces of the same lithological variation (within a single process samples) were combined after determining the X-ray spectra and were directed to samples separation and subsequent chemical analysis.

Analysis of the results enables to establish the following:

- with decrease in size of material for all kinds of Middle Timan bauxite, there is slight increase in silica ratio, mainly due to decrease in the content of silica in fine classes, with no noticeable increase in alumina content in them;
- Fe_2O_3 content in fine classes (especially in the size below 5 mm) significantly increased (up to 29-30%);
- Certain types of lithological varieties of bauxite (colluvial and partially eluvial) have higher silica ratio;

- Different lithological varieties have different intensities characteristic X-ray spectra of iron;
    - Lithological variations of higher quality (especially, higher silica ratio) as a rule have intermediate (average) value the spectra intensity of iron.

The results of studies of the characteristic X-ray spectra for different lithological varieties of bauxite enable to assume a principle possibility of X-ray radiometric beneficiation of Middle Timan bauxite using the P_{Fe} algorithm.

As a result of classification of different types of bauxite samples by size, test and pilot testing by X-ray radiometric separation the main parameters and process patterns were established. As a result of X-ray radiometric separation bauxite product, tailings and sortable class of 20 mm size were obtained.

Summary parameters of X-ray radiometric separation process of different types of the Middle Timan bauxite are shown in Table. 3

Table 3. Process parameters of Middle Timan bauxite separation process

Separation products	Yield %	Components, %					Al_2O_3 / SiO_2
		Al_2O_3	SiO_2	Fe_2O_3	FeO	TiO_2	
Off-balance bauxite							
Bauxite product	36.3	48.68	11.73	20.27	2.15	2.43	4.2
Separation tails	21.2	47.11	16.88	21.74	2.40	2.53	2.8
Class -20 mm	42.5	46.69	14.02	24.01	2.32	2.73	3.3
Separation tails	63.7	46.83	13.31	23.25	2.35	2.66	3.5
Initial bauxite	100.0	47.54	12.74	22.17	2.28	2.58	3.7
Sinter bauxite							
Bauxite product	11.6	48.63	8.31	22.31	2.44	2.57	5.9
Separation tails	22.2	46.83	13.45	26.43	2.76	2.67	3.5
Class -20 mm	66.2	47.75	10.88	25.40	3.00	2.73	4.4
Separation tails	88.4	47.52	11.53	25.66	2.94	2.71	4.1
Initial bauxite	100.0	47.65	11.15	25.27	2.88	2.70	4.3
Bayer bauxite							
Separation concentrate	17.6	49.65	6.68	26.01	4.24	2.55	7.4
Class -20 mm	60.3	49.65	7.50	26.40	1.72	2.75	6.6
Bauxite product	77.9	49.65	7.32	26.31	2.29	2.70	6.8
Separation tails	22.1	48.50	9.83	27.35	4.31	2.59	4.9
Initial bauxite	100.0	49.40	7.87	26.54	2.74	2.71	6.3

As a result of chemical and mineralogical analysis it was demonstrated that the main mineral of alumina - boehmite is mainly concentrated in the dressed products (up to 54%). Hematite, which is in close association with chamosite, is mostly concentrated in the tails of separation (to 23%). Chamosite jointly with kaolinite is most common in bleached and variegated lithological varieties of bauxite and in the course of separation concentrates in the tails of separation. Kaolinite is also concentrated in the tails of separation.

The results of pilot tests of X-ray radiometric separation process for different types of the Middle Timan bauxite led to the following conclusions:

1. Proper natural distribution of minerals in lithological varieties of bauxite allows to raise alumina / silica ratio by X-ray radiometric separation.
2. Out of Middle Timan off-balance bauxite 36.3% of dressed product may be allocated that can be directed for processing into alumina by sintering method.
3. Separation of sinter bauxite allows recovering 11.6% of hydrochemical bauxite which can be directed for processing to alumina, by effective and cheapest Bayer cycle.
4. Separation of hydro chemical bauxite allows increasing the silica ratio to 6.8 units from initial ~ 6.3 units and separate 22.1 % of sinter bauxite with silica ratio 4.9 units.

All of the above opens conditions for effective beneficiation of the Timan bauxites by the described method.

The same approach for initial assessment can be applied to other bauxites of the world, which can make foundation for subsequent tests of XRS method at a pilot facility. In each specific case for a decision of the industrial implementation of XRS the following should be performed:

- to specify material composition of raw material of a specific deposit.
- to identify the factors of separation.
- to select samples of raw materials, corresponding to the average composition of the deposit in the amount of not less than 15-20 t.
- to make a preliminary test on the applicability of the separation process with the model of the separator.
- to specify process modes and parameters of the process on an industrial pilot XRS separator
- to perform feasibility study on the efficiency of the process.

4. Conclusion

X-Ray radiometric separation is an industrially proven technology tested and applied for variety of ores of all major mining commodities. A pilot industrial scale separator facility is available to assess the process applicability and efficiency.

The results of industrial tests on bauxites of Russia suggest high beneficiation efficiency of this method for other bauxites. The method is the most effective for increase of alumina concentration and reducing impurities for bauxites having different lithological forms and for mining operations with small or complicated ore bodies where undesired bedrock is included in the commodity product. This is especially important for developing of low-quality deposits with complex geology.

5. References

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