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DOI: 10.31643/2026/6445.34
Metallurgy

Research into the possibility of air separation of cake at the Pavlodar aluminum smelter

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Received: *November 1, 2024*
Peer-reviewed: *December 11, 2024*
Accepted: *May 14, 2025*

ABSTRACT

Air separation can play a key role in the sintering process of the charge material in the alumina production at the Pavlodar Aluminum Plant. During sintering, sinter dust is formed, which must be effectively separated from the bulk material, since its fine fraction is a source of formation of a solid phase carried away with the solution, which increases the number of secondary losses of valuable components. The use of air separation will solve this problem, providing a high degree of separation of the sinter product into coarse and fine fractions, thereby intensifying the further process of hydrochemical processing of the sinter from the sintering furnaces. The main goal of these studies was to reduce the loss of valuable components from the sinter, namely aluminum oxides and alkali, which are carried away with the solid phase of the tubular apparatus effluent. This paper considers the preliminary classification of sinter dust in air separators and its separate leaching. Extensive (pilot) laboratory tests determined the separation boundary of sinter classes (– 0.25 mm), which allows increasing alumina extraction by ~ 2% and suggests a reduction in the number of operating furnace lines by 0.26 units by reducing ballast flows, and the optimal indicator of air separation efficiency was determined to be ~ up to 97%. The results demonstrate the importance of air separation in ensuring the quality of the sinter product and improving the efficiency of alumina production technology as a whole.

Keywords: air separation, extraction of valuable components, alumina, sintering process, sinter.

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Introduction

Air separation is a technological process in which polydisperse systems are separated into fractions based on the settling velocity of particles of various sizes under the influence of centrifugal gravitational forces in a horizontal or upward flow. The overall function of a classifier is to separate particles into coarse and fine fractions [1]. The air separation process is widely used worldwide in various industries [2]. For example, in China, air separation is used for classifying coking coals, for separating and processing valuable components from spent lithium-ion batteries, and for separating fly ash [[3], [4], [5]]. In the existing process flow at the Pavlodar Aluminum Plant (PAP), the leaching of sinter from the sintering shop is carried out in tubular leaching units, from which a solid phase, the so-called "gray" sludge, is carried out along with the non-desiliconized aluminate solution [6]. Upon further residence in the aluminate solution during the autoclave desilication stage, the "gray" sludge becomes enriched with aluminum oxide and alkali, causing their loss from the aluminate solution.

To address the existing problem, a technical solution was proposed: separating the sinter dust through preliminary classification in air separators. This would enhance the efficiency of the sinter hydrochemical processing (Figure 1).

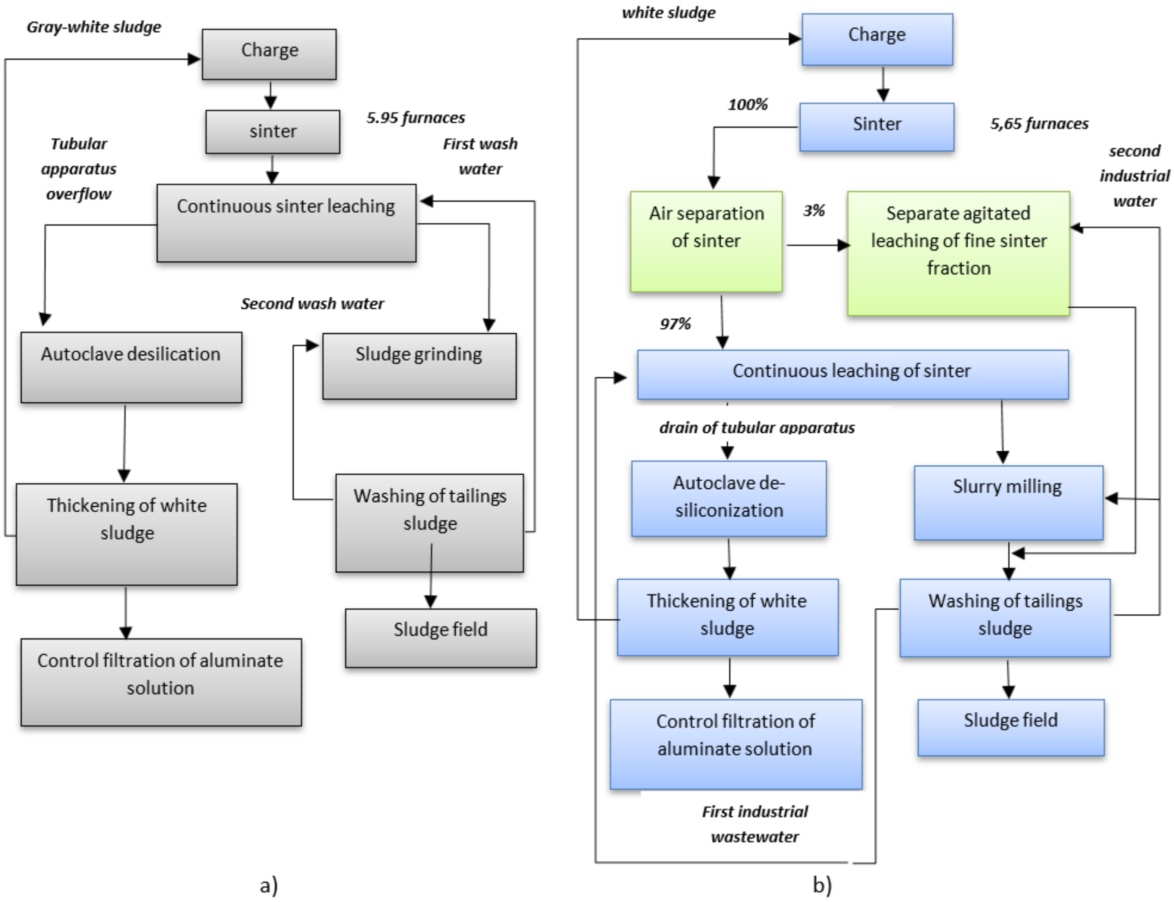


Figure 1 – a) Existing sinter leaching process at PAP;
b) Proposed process with preliminary sinter classification

There are several methods for eliminating the conditions for the formation of "gray sludge," which have been utilized in the production practice of PAP. One such method is leaching the sinter in a "Reacol" column-type apparatus [7].

According to this scheme, the sinter was first classified on separate drum screens with a mesh size of 5 mm (the usually used sizes are 10 and 8 mm), and then the separated sinter fraction was subjected to agitation leaching in a "Reacol" column-type apparatus with a pulsed supply of the leaching agent – water.

The use of a metal mesh with a rather large mesh size of 5 mm on the existing drum screens was technologically unjustified. With this technology, using a particle size of -5 mm, under-leaching of the sinter was observed, as well as losses of valuable components along with the sludge. The pulsed supply mode of the leaching agent in the "Reacol" type apparatus did not ensure complete extraction of valuable components from the sinter.

In addition, there was an inefficiency in the sinter separation and rapid mechanical wear of the classifying metal mesh, increased circulation flows of the sinter, which increased the energy costs at the crushing unit.

The next method involves separating the solid phase from the slurry discharge of the tubular leaching units using hydrocyclones [8]. A pilot-industrial installation of a battery of 10 hydrocyclones with a diameter of 150 mm was assembled for testing. The slurry discharge from one tubular leaching unit was subjected to classification.

This method also did not prove effective for the technological process of PAZ. Frequent cases of "sanding" of the hydrocyclones led to a high content of solid particles in the overflow, which was sent for autoclave desilication. As a result, the task of reducing the ballast flow to the sintering furnaces was only 50% solved.

The use of larger hydrocyclones with a diameter of 250 mm also did not solve the problem of the ballast flow and even reduced the efficiency of sludge removal to 30%.

The Boksitogorsk Alumina Plant of RUSAL employs a method of classifying and leaching sinter that is similar to our proposed method. Alumina-containing sinters are classified by a 0.5 mm fraction, and the fraction finer than 0.5 mm is combined with aspirational sinter dust and mixed with under-sludge water, thus performing agitation leaching of the mixture, after which it is directed to co-washing with the sludge from leaching sinter fractions larger than 0.5 mm.

The technical solution implemented at the Boksitogorsk alumina plant was also applied at another RUSAL alumina plant - Achinsk. Testing of the proposed method was carried out with crushed sinter from an industrial stream. This method showed significant extraction of aluminum oxide from the fine fraction.

In the presented technology, implemented and tested at the RUSAL alumina plants, the preliminary separation of the fine part of the sinter is carried out by mechanical screening. The method of mechanical screening implies the use of capital-intensive structures, since conveyor routes and metal-intensive sorting units are required to move the bulk material (sinter). The optimal screening mode for powdered materials is operation within the 1-3 mm range. At smaller screening limits, energy consumption per 1 ton of product increases significantly, the dimensions of the equipment increase, and the need for frequent replacement of the screens arises [9]. For classifying materials with a particle size of less than 1 mm, it is advisable to use air classification. By regulating the speed and trajectory of the air flow, the size of the separated particles can be varied [[10], [11]].

Air separation is based on the ability of material particles, located in a vertical, horizontal or centrifugal air flow, to fall out of it under the influence of gravity, centrifugal inertial forces, or the combined effect of these forces under certain conditions [12].

For successful air separation, the air flow must have a homogeneous velocity field. For particles of a single size, called the separation boundary, dynamic equilibrium must be established throughout the entire separation zone. Particles of other sizes must be carried out of the separation zone in different directions: smaller than the separation boundary – in one direction, larger – in the other. The forces acting on a particle of any size must be adjustable within a wide range [10].

The design of air separators should provide the ability to regulate the air flow velocity and uniform distribution of the material being sorted, as well as the complete and timely removal of material particles separated by size from the separator. The separation boundary can be controlled by changing the operating mode of the classifier, for example, by changing the air flow velocity. It is known that the separation efficiency is determined by two factors: the concentration of the material and the design of the apparatus [13].

Review articles [[14], [15], [16]] provide a detailed examination of each type of equipment for particle separation.

In the article [17], the authors describe one of the novelties of air classifiers, which uses the inertial-gravitational design principle for separating solid particles.

Experimental part

According to the developed standards of the organization, Joint Stock Company Aluminum of Kazakhstan (JSC "AK"), the following research methods were carried out: sieve analysis of sinter, chemical analysis of liquid phases, and X-ray spectral analysis.

The following were used for testing:

- Laboratory separation unit from Lamel 777 (Minsk);
- Stand-mounted air gravity classifier from URAL-OMEGA (Magnitogorsk);
- Semi-industrial enrichment plant with a pneumatic separator of the "Sepair" type from GORMASHEXPORT (Novosibirsk).

Results and Discussion

The first stage of laboratory research aimed to determine the boundary particle size in the sinter that is carried away with the aluminate solution from the tubular apparatuses and is a source of formation of "gray" sludge.

By conducting numerous samplings of the overflows from all tubular apparatuses, it was established that the boundary size is the (-0.25) mm fraction. This dimensional fractional composition was to be removed, and separate leaching performed. It was also established that the average content of the (-0.25) mm fraction in the crushed sinter entering the tubular leaching units was approximately 3%.

In laboratory conditions, the sinter was classified into fractional compositions: (+0.25) mm and (-0.25) mm, and their separate leaching with liquid agents used in production conditions was carried out.

Table 1 presents the results of the separate leaching of the sinter.

Table 1 – Results of the separate leaching of the sinter

	Composition of Solid Phase					Extraction		Composition of Liquid Phase							
	%					%		g/L							
	Na_2O	Al_2O_3	SiO_2	CaO	Fe_2O_3	Na_2O	Al_2O_3	Al_2O_3	Na_2O total	Na_2O carbonate	Na_2O caustic	M caustic	% soda	SiO_2	M_{si}
	Initial sinter, including the fraction - 0.25 mm														
Sludge	**1.85**	**4.40**	19.5	40.7	24.3	**89.4**	**84.9**	107.5	84.3	2.6	81.7	1.3	3.1	2.28	49.0
	Sinter without the fraction -0.25 mm														
Sludge	**1.48**	**3.81**	19.3	40.3	24.0	**92.2**	**86.9**	110.2	87.3	2.3	85.0	1.3	2.7	2.25	49.0

Table 2 – Results of separate agitation leaching of the fine fraction of the sinter

Name	Состав жидких фаз						Состав твердых фаз				
	g/L						%				
	Al_2O_3	Na_2O total	Na_2O carbonate	Na_2O caustic	M caustic	% soda	Na_2O	Al_2O_3	SiO_2	CaO	Fe_2O_3
Original sinter							15.7	19.0	12.9	25.7	18.4
Weak leaching water	18.4	16.7	0.9	15.8	1.41	5.4					
Sludge							1.97	4.77	18.7	38.4	27.4
Liquid phase of the sludge	35.4	32.7	2.1	30.6	1.42	6.4					

Technological leaching of the isolated fine fraction of sinter (-0.25 mm) was carried out with weak wash water at a temperature of 75 °C and a leaching time of 3 minutes.

The coarse fraction of sinter (+0.25) mm was leached under production conditions used in tubular leaching units with strong wash water at a temperature of 85 °C and a time of 45 minutes. As can be seen from the data in Table 1, when removing the fine fraction (-0.25) mm from the sinter, the extraction of alumina and alkali from the coarse sinter increases by 2.0 and 2.8%, respectively.

The alumina content in the sludge after the separation of the fine fraction (-0.25) mm from the sinter with weak wash water, for a short leaching time (no more than 3 minutes), was approximately the same level as in the waste sludge - 4.77% (Table 2).

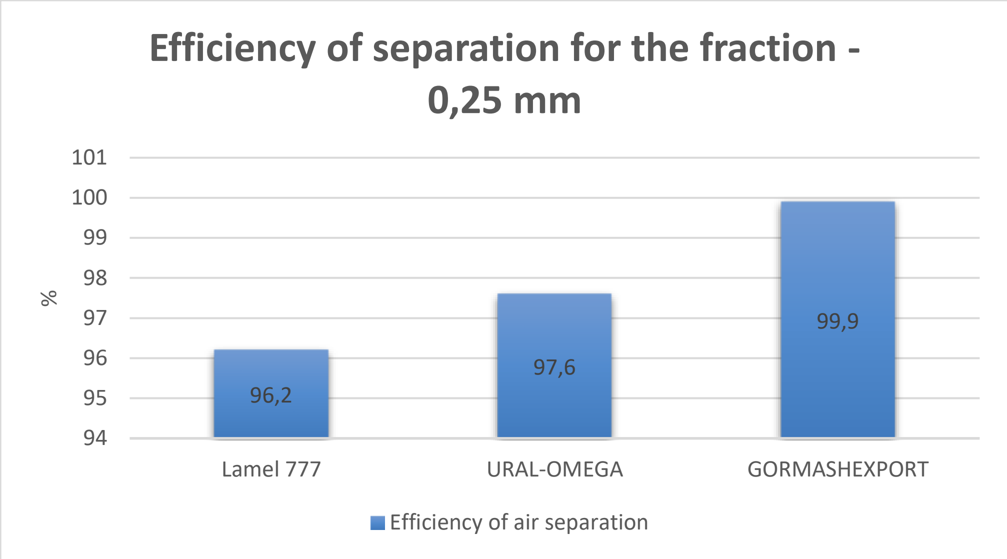
Table 2 presents the results of separate agitation leaching of the fine sinter fraction.

It was established that with separate leaching of the fine sinter fraction (-0.25) mm for a short time, 3 minutes, the fine sinter has time to leach without secondary losses. This indicates that the conditions for the formation of "gray" sludge are eliminated. Under production conditions, the fine fraction of sinter (-0.25) mm should also be leached with weak wash water.

The purpose of the second stage was to determine the conditions for thickening the sludge after separate leaching of the sinter fraction (-0.25) mm. According to the conditions of the designed production process, the dedusted coarse sinter fraction (+0.25) mm after leaching in a tubular leaching unit and grinding in a rod mill was mixed with the sludge from the leaching of the fine sinter fraction (-0.25) mm under conditions of re-pulping with weak wash water. Then, according to the scheme, the mixture of sludges after hydrocycloning was sent to the head washer of the washing line.

Planned mixtures of sludges from separate leaching of the sinter were prepared, with their further thickening in laboratory conditions using a flocculant. Based on the results of the laboratory work, satisfactory thickening of the sludge mixture after separate leaching of the sinter was determined.

Based on the data from the studies, it was hypothesized that, under production conditions, the sludge after the separate leaching of the fine sinter



Graph 1 – Indicators of pilot tests for air separation of sinter.

fraction (-0.25 mm) would satisfactorily settle in a mixture with the rod mill sludge and not be carried away with the overflow (with strong wash water) from the head washers.

To confirm the results of the laboratory tests on the classification of the fine part of the sinter, a pool of companies producing shelf-type air classifiers and pneumatic separation devices with nozzle air supply was identified. Companies such as Lamel 777, URAL-OMEGA, and GORMASHEXPORT were selected [[18], [19], [20]].

The graph below shows the efficiency of air separation of sinter, as implemented by the above-mentioned companies, which allows for an assessment of the comparative results of their work.

Based on the conducted tests from all three companies, the possibility of air separation of sinter was confirmed. An air separation efficiency indicator of ~ up to 97.0% was determined for the declared boundary fraction of sinter (-0.25) mm.

The highest contamination - up to 40% of the sifted fine fraction with sinter of the neighbouring larger (+0.25) mm fraction - is present on the Lamel 777 classifier. Less contamination with the (+0.25) mm fraction, from 12 to 24%, is present on the GORMASHEXPORT classifier (using SEPAIR technology) [21]. The minimum contamination with the (+0.25) mm fraction, from 10 to 15%, is present on the URAL-OMEGA classifier.

According to the results of the sinter separation pilot tests, in terms of technical equipment and completeness, as well as the possibility of integration into the technological scheme in the existing production facility, the most suitable is the classifying installation of the company URAL-OMEGA from Magnitogorsk (Figure 2).

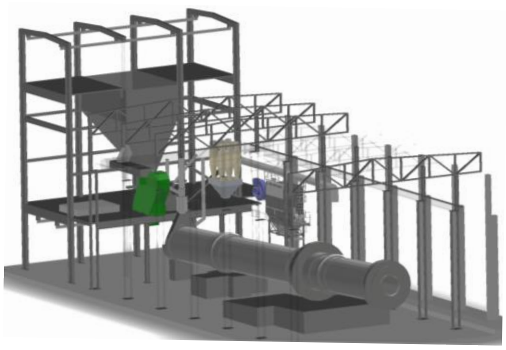


Figure 2 - Classifying the unit of the URAL-OMEGA company on a tubular leaching unit.

Conclusions

Based on extensive laboratory research, it has been established that removing the fine part of the sinter, 0.25 mm, with subsequent separate leaching allows increasing alumina extraction by ~ 2% without worsening the sludge settling performance during washing.

The possibility of air separation of sinter at the PAZ sintering stage has also been confirmed, and the optimal air separation efficiency indicator has been determined to be ~ up to 97.0%.

The classifying unit of the URAL-Omega company showed the most suitable test results for air separation of sinter for the technological process of the PAZ sintering stage.

The result of the technical solution of preliminary air separation of sinter will be an increase in the overall alumina extraction by 2% and a reduction in the number of operating furnace strands by 0.26 units due to a decrease in ballast flows, respectively, a decrease in losses of useful components (alumina and alkali), as well as a positive impact of the scheme on the environmental situation of the shop.

Conflicts of interest. On behalf of all authors, the corresponding author declares that there is no conflict of interest.

CRediT author statement: **G.Abikenova:** Management, conceptualization, data curation; **D.Dauletov, S.Tverdokhlebov:** Author's supervision, reviewing and editing; **I.Danchenko:** Research, writing - original draft preparation.

Acknowledgments. This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.

Cite this article as: Abikenova GK, Tverdokhlebov SA, Dauletov DD, Danchenko IS. Research into the possibility of air separation of cake at the Pavlodar aluminum smelter. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2026; 338(3):112-119. https://doi.org/10.31643/2026/6445.34

Павлодар алюминий зауытында күйежентекті ауда ажырату зерттеу мүмкіндіктері

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Мақала келді: *1 қараша 2024*
Сараптамадан өтті: *11 желтоқсан 2024*
Қабылданды: *14 мамыр 2025*

ТҮЙІНДЕМЕ
Әуе сепарациясы Павлодар алюминий зауытының глинозем өндірісіндегі шихтаны күйдіру процессінде аса маңызды рөл атқаруы мүмкін. Күйдіру кезінде күйдіру шаңы түзіледі, оны негізгі материалдан тиімді түрде бөлу қажет, себебі оның ұсақ фракциясы қатты фазаның қалыптасуының көзі болып табылады, бұл пайдалы компоненттердің екінші жағындағы жоғалту мөлшерін арттырады. Әуе сепарациясын пайдалану осы тапсырманы шешуге мүмкіндік береді, күйдіру өнімін ірі және ұсақ фракцияларға жоғары дәрежеде бөлу арқылы, осылайша күйдіру пештерінің спекасын гидрохимиялық қайта өңдеу процесін интенсификациялайды. Бұл зерттеулердің негізгі мақсаты спецификациядан пайдалы компоненттердің, атап айтқанда, алюминий оксидтері мен сілтілердің, қатты фаза бойынша түтікше аппаратының ағысымен бірге ұшып кетуін азайту болды. Бұл жұмыста ауа сепараторларында спекалық шаңның алдын ала жіктелу процесі және оны жеке шаймалау қарастырылады. Кеңейтілген зертханалық сынақтар спеканың кластарын бөлу шегін (– 0,25 мм) анықтады, бұл глиноземді ~ 2%-ға көбейтуге мүмкіндік береді және балласттық ағындарды төмендету арқылы жұмыс істейтін пештік жіптердің санын 0,26 бірлікке қысқартуды жорамалдайды. Ауа сепарациясының тиімділік көрсеткіштері ~ 97% деп анықталды. Алынған нәтижелер спекалық өнімнің сапасын қамтамасыз ету және глинозем өндірісінің технологиясының тиімділігін арттыру үшін ауа сепарациясының маңыздылығын көрсетеді.

Түйін сөздер: ауаны бөлу, жіктеу, пайдалы компоненттерді алу, глинозем, спекание үдерісі, спек.

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Исследование возможности воздушной сепарации спека на Павлодарском алюминиевом заводе

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Поступила: *1 ноября 2024*
Рецензирование: *11 декабря 2024*
Принята в печать: *14 мая 2025*

АННОТАЦИЯ
Воздушная сепарация может сыграть ключевую роль в процессе спекания шихты в глиноземном производстве Павлодарского алюминиевого завода. Во время спекания образуется спековая пыль, которую необходимо эффективно отделять от основного материала, т.к. ее мелкая фракция является источником образования твердой фазы, выносимой с раствором, что увеличивает величину вторичных потерь полезных компонентов. Использование воздушной сепарации позволит решить эту задачу, обеспечивая высокую степень разделения спекового продукта на крупную и мелкую фракции, тем самым интенсифицируя дальнейший процесс гидрохимической переработки спека печей спекания. Основной целью данных исследований являлось снижение потерь полезных компонентов из спека, а именно оксидов алюминия и щелочи, которые уносятся вместе с твердой фазой слива трубчатого аппарата. В данной работе рассматривается процесс предварительной классификации спековой пыли в воздушных сепараторах и ее раздельное выщелачивание. Расширенными лабораторными испытаниями была определена граница разделения классов спека (– 0,25 мм), что позволяет увеличить извлечение глинозема ~ на 2% и предполагает сокращение количества работающих печных ниток на 0,26 ед. за счет снижения балластных потоков, определен оптимальный показатель эффективности воздушной сепарации ~ до 97%. Полученные результаты демонстрируют важность воздушной сепарации для обеспечения качества спекового продукта и повышения эффективности технологии глиноземного производства в целом.

Ключевые слова: воздушная сепарация, классификация, извлечение полезных компонентов, глинозем, процесс спекания, спек.

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