Resource-saving technologies in the processing of nepheline ores by sintering

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Abstract. To solve ecological problems in alumina production, ecological measures were implemented to reduce the consumption of mineral natural resources and by involving secondary technogenic materials in the production. In the processing of nepheline ores, a number of technologies were tested and implemented into production for the introduction of various additives of technogenic raw materials into the raw alumina charge: spent chamotte refractory bricks, ferrotitanium production slag, and combined heat and power plant ash. The introduction of technology for processing of technogenic raw materials provided the use of spent chamotte bricks of more than 70,000 tons, while saving natural raw materials: nepheline ore of about 42,000 tons. In addition to saving mineral resources, work was carried out to reduce waste water discharges into open water basin and reduce the water intake of treated water for production needs. For this purpose, the technological equipment for water supply of the combined heat and power plant was replaced. As a result of the introduction of new cooling towers, the waste water discharges into an open water basin was eliminated and the intake of treated water from the river was reduced by 40.07 million m³ per year.

Introduction

At the modern level and scale of natural resource consumption, the importance of full use factors, resource conservation and involvement in the production of secondary resources is of great importance. The wide involvement of secondary material resources in the production process, including technogenic industrial products, will ensure the preservation of natural raw materials and lead to the development and implementation of low-waste technologies. The limited and non-reproducible nature of mineral resources on the one hand and the high intensity of their exploitation on the other, have led to the need to search for new resource-saving technologies, including in the processing of nepheline ores [1]. The Kiya-Shaltyrsky nepheline mine located in Siberia of the Russian Federation has almost exhausted its resource of unique nepheline ores. And it is searching for new aluminum-containing raw materials. However, at present, the Kiya-Shaltysky nepheline mine has accumulated more than 90 million tons of substandard nepheline ore, which is located in special dumps. The involvement in production using the existing technology is difficult to implement and not economically profitable. Processing of this substandard mineral raw material can be carried out with the introduction of aluminum enhancing additives. The development of technologies aimed at saving
raw materials in the processing of substandard nepheline ores, with the involvement of production waste containing aluminum oxide, is an urgent problem today [2-5].

Results and discussion
The paper evaluates the possibility of using combined heat and power plant ash and ferrotitanium production slag as aluminum raising additives in limestone-nepheline charge. The use of ash as an additive in the alumina raw material charge becomes possible due to the similarity of its chemical characteristics with nepheline ore and the increased content of alumina in it [6, 7]. The content of alumina in the ash of various combined heat and power plants (CHPP) ranges from 27 to 35%.

The sintering charges were based on nepheline ore from the Kiya-Shaltyrskymine, limestone from the Mazulskymine, and white slime formed during the desilting of aluminate solutions. The dosage of white slime was 10% of the weight of the ore mixture for dry materials. As a corrective additive, chemically pure soda was used.

Ash of CHPP is alkali-free raw materials and in comparison, with nepheline ore is characterized by high content of silicon dioxide (55.6%), and a content of iron (6.18%) and lower content of calcium oxide (5.6%). The results of the analysis showed that insertion of ash (3% mass fraction) in the charges leads to increasing content of aluminum oxide in sintering 0.21%, from 16.32% (no ash) to 16.53% (with the addition of 3% ash) and increase the dosage of the ash in the charges up to 10% mass fraction reduces the content of aluminum oxide in the sinter to 16.23%. The actual alkali content in the sintering is lower than the calculated one, which is due to the removal of alkalis during sintering.

To conduct pilot tests, the ash was delivered to the field of the material receiving and loading unit, then fed through a nourishing hopper for joint crushing with the ore to prepare an alumina raw charge. Involvement of ash in the technological process of raw charge preparation in the amount of 1-2% reduces the consumption of the main raw material component - nepheline ore by 6500-7000 tons per year. At the same time, stored waste from combined heat and power plants is disposed of, the harmful impact of production on the natural environment is reduced, and valuable components are extracted from them.

As another additive in the preparation of nepheline-limestone-soda charge, it is possible to use alumina slags of ferrotitanium production of JSC "Klyuchevsky Ferroalloy plant", whose reserves are about 3 million tons [3, 8]. The slag of ferrotitanium production is extremely heterogeneous in phase and chemical composition, since it has a technogenic origin and is represented by a large number of thinly sprouted mineral phases [9]. The content of Al₂O₃ in slag samples is in the range of 59.4-64.5% [8]. Alumina slags even exceed bauxite ores in their content of aluminum oxide, but fine grinding is required to open them and involve them in processing. They can be considered as an additional raw material source for a number of alumina enterprises.

Table 1 - Results of tests chemical analysis from ferrotitanium slag in JSC "Klyuchevsky Ferroalloy plant"

| Name of hematerral | Content of components in the slag, % mass fraction |
|-------------------|-------------------------------------------------|
|                   | Al₂O₃ | CaO | SiO₂ | MgO | Fe₂O₃ | Cr₂O₃ | TiO₂ | Na₂O | K₂O | SO₃ |
| Ferrotitanium slag | 62.5  | 13.5| 1.89 | 6.35| 2.41  | 1.36  | 11.24| 0.52 | 0.18| 0.05|

In accordance with the data of x-ray phase analysis, the main aluminum-containing minerals of ferrotitanium slag are analcime, montmorillonite and hercynite, to a lesser extent iron-substituted grossular. On the basis of these studies, given that currently enter the slag ferrotitanium production in the limestone-nepheline-soda mixture in the raw material plant of JSC "RUSAL Achinsk" from Russia.
is a joint grinding nepheline ore with the 4th stage shredding, it was recommended to change the layout of crushing slag and to grinding in a separate mill. From figure 1 it can be seen that the introduction of 5-10 % of ferrotitanium slag crushed to 100% class - 0.074 mm into the charge increased the content of aluminum oxide in the sintering from 16 to 17.5-18.5% (at the sintering temperature of 1250°C) and from 16.3 to 17.7-18.9% (at the temperature of 1270°C).

![Figure 1. Dependence of the Al₂O₃ content in the sintering on the addition of slag to the charge: 1-sintering temperature 1250°C; 2-sintering temperature 1270°C.](image)

Extraction of Al₂O₃ during the technological leaching of sintering with the introduction of 2-5% slag had a similar character, but with additions of more than 10% slag, there was a slight decrease in recovery in the range of sintering temperatures of 1225-1250 °C. At the same time, an increase in alkali extraction was noted with the introduction of 2-5% ferrotitanium slag at a temperature 1250°C.

A resource-saving technology for processing of spent chamotte refractory bricks used for lining rotary sintering and other heat units was mastered and introduced in production. The chamotte refractories that had served their operational life included impurities of the raw materials of the alumina charge and alumina production products, which can be recovered by adding them as an additive to the raw alumina charge. Studies have shown that the technogenic addition of chamotte refractory bricks to alumina batch even in minimal amounts (0.11% mass fraction), allows to reduce the consumption of nepheline ore while maintaining the same technological parameters for the extraction of alumina. JSC “RUSAL Achinsk” involved more than 70,000 tons of spent chamotterefactory bricks into the charge preparation process and achieved the saving of natural raw materials: nepheline ore about 42,000 tons.

In addition to the work on the involvement of secondary technogenic resources in the production, ensuring the conservation of natural mineral raw materials, and leading to the implementation of low-waste technologies, JSC “RUSAL Achinsk” is carrying out work to reduce the impact of production on water basins and reduce water consumption [10]. As a result of the reconstruction of the power equipment in the CHPP, which is part of the alumina refinery, the waste water discharges into the open water was excluded. This became possible after replacing the cooling system and water supply technology for combined heat and power plant using modern cooling towers [11, 12]. To cool the waste water of the CHPP, two tower cooling towers (TCT) were reconstructed and a new five-section TCT-2000 fan-type cooling tower was built instead of the emergency-stopped TCT-1600, which had higher technical performance and its tests confirmed it. Tests have shown that the CHPP of the TCT-2000 fan cooling tower is 2.5 times higher than the CHPP of the TCT-1600 tower. As a result of putting the tower into operation, the condensing capacity of the CHPP increased by 45 MW. The practical implementation of this technical solution made it possible to exclude the waste water discharges into an open basin and transfer the combined heat and power plant of JSC “RUSAL Achinsk” to a closed water circulation system. As a result of the commissioning from the constructed
cooling towers, the waste water discharge of the CHPP from the cooling water basin was eliminated, and the water basin was converted into a new slurry card to accommodate nepheline sludge and ash and slag waste from the plant. The new slurry map was built using modern technologies with the use of a waterproofing polymer membrane that excludes the effect of the sludge storage facility on groundwater. The elimination of the waste water discharge from the CHPP reduced the discharge of waste water into the Chulym river from 33.5 million m$^3$ in 2013 year up to 5.4 million m$^3$ in 2017 (figure 2).

**Figure 2.** Volume of waste water discharge into an open basin after the transfer of the combined heat and power plant of JSC “RUSAL Achinsk” to a closed water circulation system

In order to reduce the waste water discharge into the open water, industrial sewage treatment plants were built at the same time, which also provided the return of treated water to a closed water cycle. The total intake of treated water from the Chulym river as a result of the introduction of water protection measures decreased by 40.07 million m$^3$/year.

The solution of the above-mentioned ecological problems in JSC “RUSAL Achinsk” has led to a significant reduction in the impact of alumina production on natural water basins, virtually eliminating the waste water discharge into an open basin. Currently, the discharge into the basin is a one-time nature when cleaning the filters of the pumping and filtering station and the works continue to exclude all waste water discharges into the Chulym river.

**Conclusion.**

The research has allowed us to develop resource-saving technologies for processing nepheline ores, which have been successfully tested on an industrial scale. The introduction of various additives of technogenic raw materials into the alumina charge reduces irreplaceable losses of natural raw materials and reduces the impact of waste on the environment. In the course of research, the possibility of using combined heat and power plant ash, ferrotitanium production slag and waste of spent chamotte bricks as aluminum raising additives in the limestone – nepheline charge was studied. Involvement of ash in the technological process of raw charge preparation in the amount of 1-2% reduces the consumption of the main raw material component - nepheline ore by 6500-7000 tons per year. At the same time, stored waste from combined heat and power plants is disposed of, the harmful impact of production on the environment is reduced, and valuable components are extracted from them. As an additive to substandard nepheline ore, alumina slags have been successfully tested, which are superior to bauxite ores in terms of aluminum oxide content. It is determined that their involvement in processing requires fine
grinding. A resource-saving technology for processing of spent chamotte refractory bricks used for lining rotary sintering and other heat units has been developed and implemented in production. After serving their operational life, chamotte refractories were introduced as a raw material additive to the alumina charge. The introduction of technology for processing of waste chamotte bricks has provided savings of 42,000 tons of nepheline ore. In addition to saving mineral resources, work was carried out to reduce the consumption of treated water for production needs. To do this, the technological equipment was replaced and the industrial sewage treatment plants were built, which also provided the return of treated water to a closed water cycle. The total intake of treated water from the river as a result of the introduction of water protection measures decreased by 40.07 millionm³/year. The implementation of ecological protection measures provided a solution to current ecological problems in JSC “RUSAL Achinsk” and led to a significant reduction in the impact of alumina production on the environment.

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