RECYCLING OF IRON ORE PROCESSING WASTES FOR REDUCTION OF INDUSTRIAL IMPACT ON THE ENVIRONMENT

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ABSTRACT

The paper presents the results of the research on the recovery of hematite from stockpiled tailings produced by the mineral processing plant of Olcon JSC (the northern-western Arctic zone of Russia). The authors investigated material composition of tailings samples and determined its granular and mineralogical characteristics. The content of total, magnetic and hematite iron in a sample of the tailings dump material is 8.76%; 1.53% and 3.67% respectively. The technology for hematite concentrate production from the tailings material has been substantiated, including several stages of spiral separation to recover the rough concentrate and its following concentration by a shaking table. The authors have determined optimal conditions for the disintegration of the middlings of the spiral separation, which made it possible to achieve selective liberation of the grains of valuable mineral. A recommended technological flowsheet for the processing of the tailings dump material provides for the production of hematite concentrate with a total iron content of more than 62% and through recovery of hematite iron of about of 76%. Involvement of the tailings in processing will help to reduce the human impact on the environment and improve ecological situation in the plant area.

Keywords: *industrial waste, tailings, hematite, spiral separation*

INTRODUCTION

The formation and accumulation of a significant mass of mining wastes containing ore and non-metallic components is an inevitable part of the development of most ore deposits. These wastes occupy huge land areas; change the natural landscape, soil and vegetation cover; negatively affect the atmosphere and water system, and pollute the environment.

Mining and mineral-processing wastes are one of the world’s largest chronic waste concerns. Their reuse should be included in future sustainable development plans, but potential impacts on a number of environmental processes are highly variable and must be thoroughly assessed. The chemical, mineral, granular compositions and physical properties of wastes determine which uses are most appropriate and whether reuse is economically feasible. If properly evaluated, mining waste can be reused to re-extract valuable minerals, supply construction materials, and repair surface altered by mining and mineral processing [1]. So recycling of industrial wastes which were generated after mining and mineral processing activities is a promising task for both ecology and mining industry.

More than 300 thousand hectares of Russia are occupied by mining-induced wastes. The mass of stored material varies in range from 40 to 80 billion tons according to various sources [2]. The amount of the wastes recycling does not exceed 10% of their annual generation. Most of the mining waste is used in the building industry and in few cases they are developed to recover associated valuable components which had not been recovered from the ores previously [3].

Today scientific interest in wastes recycling is increasing due to the depletion of rich iron ores at many deposits, the complication of the mining conditions, and the payments for the wastes generation and storage. Scientists are conducting research aimed at secondary recovery of iron minerals from tailings material [4], [5], [6], [7]. The results of these studies show the possible production of iron ore concentrates from mineral processing wastes. Waste rock minerals contained in the tailings can be used in the production of concrete, bricks, ceramics [8], [9], [10].

In this regard, the problem of utilization of iron-containing tailings dumps is of particular relevance. One of the promising objects is a tailings dump of the processing plant of Olcon JSC. It contains significant reserves of the valuable component in the tailings produced during iron ore processing at the processing plant with the magnetic-gravity technology. The tailing dump has accumulated more than 500 million tons of stored mining-made waste and their annual growth is up to 10 million tons. These tailings contain mainly one ore mineral which is hematite. The loss of hematite with tailings is caused by ineffective operation of the jigging machines at the plant. Therefore the study of additional recovery of iron from such wastes is a promising task, since they could become a potential source for production of both iron ore concentrate and quartz-containing product without the use of energy-intensive crushing and grinding processes.

RESEARCH OBJECT AND METHODS

Wastes of Olcon JSC are accumulated by two tailings dumps (main and emergency) which are located near Olenegorsk town and were formed as a result of processing of iron ore for 66 years. Figure 1 shows a satellite image of the tailings dumps.

Fig. 1. *Satellite images of waste dumps.*

The studies of recovery of iron ore concentrate from the emergency tailings dump were conducted earlier [11]. In this paper we examined the possibility of recycling of the main tailings dump. The area of this tailings dump exceeds 1,100 hectares.

A representative sample of tailings material was taken during drilling in various sections of the tailings dump with a grid of about 500x500 m. Only 17 boreholes instead of the planned 25 boreholes were drilled due to the water presence in some sections of the tailings dump. The depth of the secondary deposit varies from 15 m to 31 m. The authors analyzed the drilling samples from different zones at different depths using chemical analysis methods to estimate iron content. Analyzing the content of various forms of iron in the samples, they have found out absence of gravitational differentiation of the material in terms of density depending on the depth of occurrence, i.e. with an increase in the borehole depth, the content of hematite and magnetite in most boreholes does not increase. Calculation of the average content of valuable components in boreholes has allowed identifying areas of the tailing dump with the highest content of iron. Figure 2 shows the locations of boreholes and the average contents of total, magnetic and hematite iron. As can be seen, the richest areas with Fe_{hem} content up to 5.9% are located in the northern part of the tailing dump.

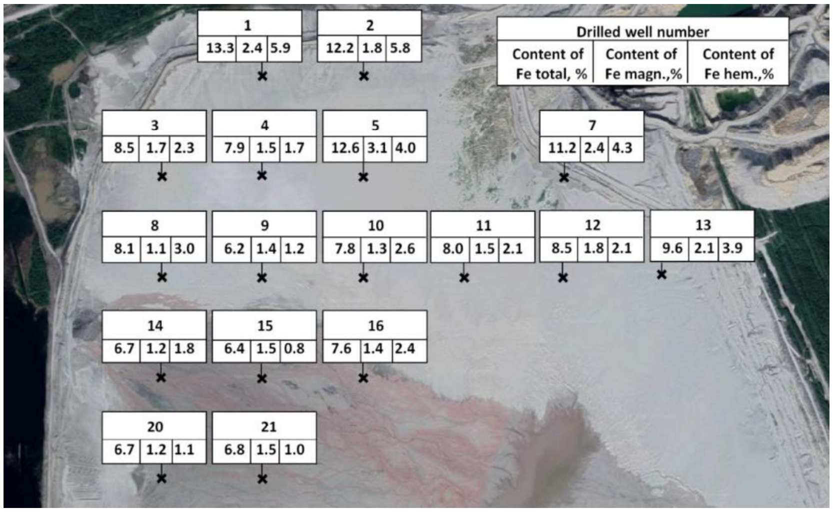

Fig. 2. *Average contents of various forms of iron for wells drilled at the tailing dump*

The content of total, magnetic and hematite iron in a combined sample of the tailings was 8.76%; 1.53% and 3.67%.

To determine the mineral composition of the sample, the authors have carried out its mineralogical analysis using X-ray phase analysis at diffractometer D2 Phaser. The main minerals of the sample are quartz with a mass fraction of 57.8% and silicates, represented by feldspars (13.0%), amphiboles (10.3%), pyroxenes (5.9%) and micas (3.8%). The content of hematite in the sample is 5.2%, and magnetite - 2.1%.

Figure 3 shows granular composition of the material, content and distribution of hematite iron by size classes. The most part of the sample is represented by particles with a size of -0.63 +0.1 mm, which yield is 61.8%. The amount of material with a grain size of more than 1 mm is about 13%, and the content of sludge particles (-0.071 mm) is about 10%. A slight increase in the mass fraction of iron with a decrease in the particles size can be noted. A significant part of hematite iron (up to 63%) is distributed in the fraction -0.63 +0.1 mm.

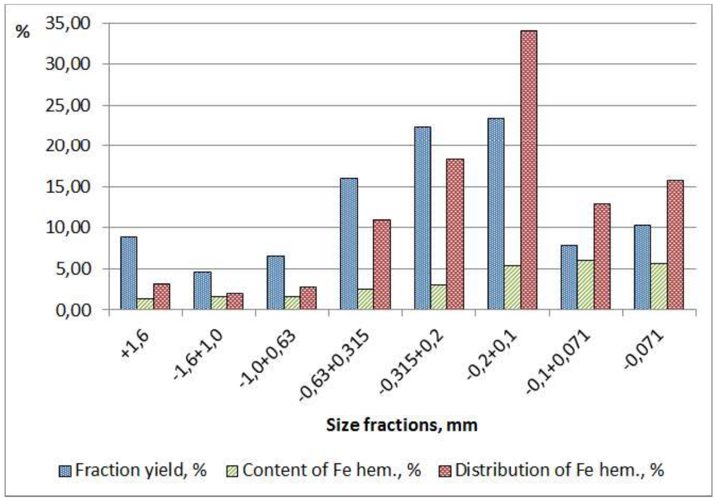

Fig. 3. *Granulometric characteristic of the tailings with Fe_{hem} content and distribution by size classes*

The results of mineralogical analysis conducted with use of stereoscopic microscope Leica MZ-6 have shown quite high total content of liberated hematite in the sample (about 70%), while about 98% of it is distributed in the material finer than 0.63 mm. The degree of liberation of hematite over 95% is achieved in the size fraction of -0.2 mm.

So, revealed features of the tailings material (difference in densities of waste rock and valuable minerals, low content of -0.071 mm fraction, high hematite liberation) create suitable conditions for its processing by means of gravity separation methods. In the following technological studies the authors used the spiral separators (SHV-500, VSR-500), shaking tables (SKO-0.5, Holman-Wilfley-2000), a ball mill and a vibrating screen to study the possible recovery of iron ore concentrate from industrial wastes.

RESULTS AND DISCUSSION

The spiral separation which is widely applied for hematite ore concentration [12] was used as the main processing method for the tailings. The authors have considered two-stage spiral separation in two different layouts: 1) recleaning of the combined concentrate and middlings of the first stage of the spiral separation at the second stage; 2) recleaning of only the middlings of the first stage at the second stage. The results of tailings dump material separation are shown on Figure 4. Both versions of the flowsheet have similar indicators in terms of recovery, but the variant with recleaning of the combined concentrate and middlings (Figure 4 (b)) provides for concentrate with higher content of total and hematite iron, so obtained separation indicators allow choosing this layout for the separation technology. The authors have recovered rough hematite concentrate with a yield of 13.73%, $Fe_{tot.}$ content of 34.95% and $Fe_{hem.}$ recovery of 70.54%.

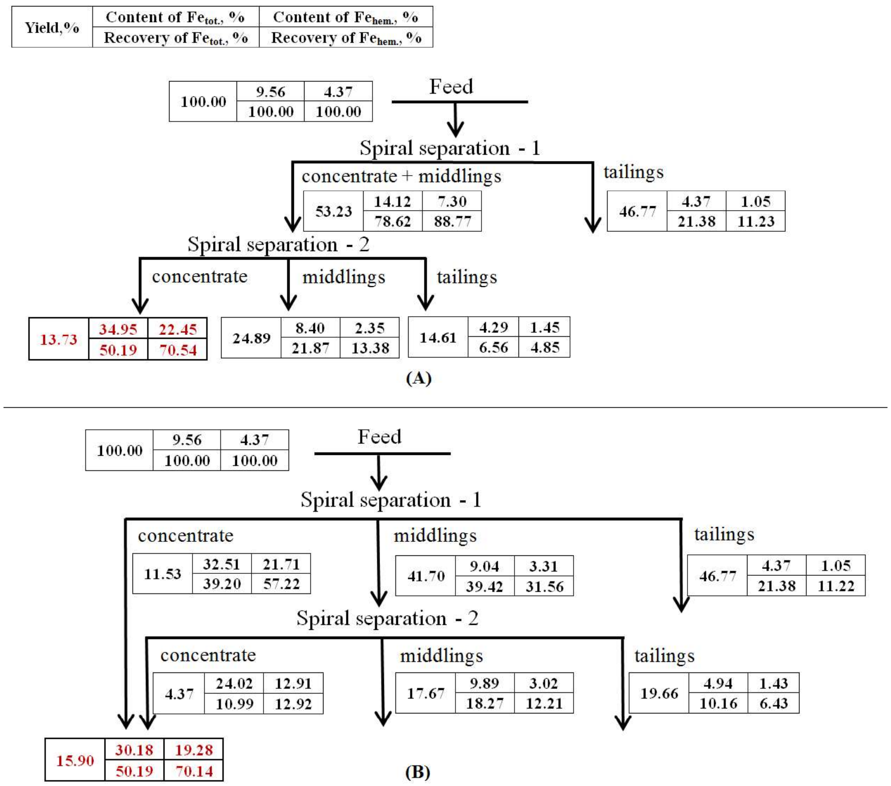

Fig. 4. *Different layouts of two-stage spiral separation (A – recleaning of the combined concentrate and middlings at the second stage; B - recleaning of the middlings at the second stage)*

The rough concentrates were processed using the shaking table. Achieved results indicate that the table concentrate contains more than 62% of Fe_{tot} with operation recovery of Fe_{hem} up to 80% when rough concentrate contained from 30% to 45% of $Fe_{tot.}$. Losses of Fe_{hem} with the tailings of this operation are 5-10%. Comparison of the obtained indicators with the results of high-intensity wet magnetic separation and spiral separation of rough hematite concentrates has shown higher separation efficiency of the concentration on the table. This fact determines the choice of this beneficiation method as a finishing operation.

During the operation of spiral separators, the middlings products are formed in addition to the concentrates and tailings. In terms of quality these products are comparable to the feed of the flowsheet; however, they accumulate intergrowths of hematite with waste rock minerals. Therefore the concentration of such a product will be difficult without milling and effective liberation of hematite intergrowths. To maximize the liberation of hematite in the middlings of spirals this material was grinded using a ball mill and a vibrating screen to a size less than 0.2 mm. Grinded middlings is favourable for gravity separation as the fraction of liberated hematite grains is 95% and the yield of the -0.071 mm size class did not exceed 17%. Further separation of milled middlings was conducted by the spirals and the shaking table.

As a result of conducted research, a technological flowsheet for hematite concentrate production from tailings dump material was developed (Figure 5).

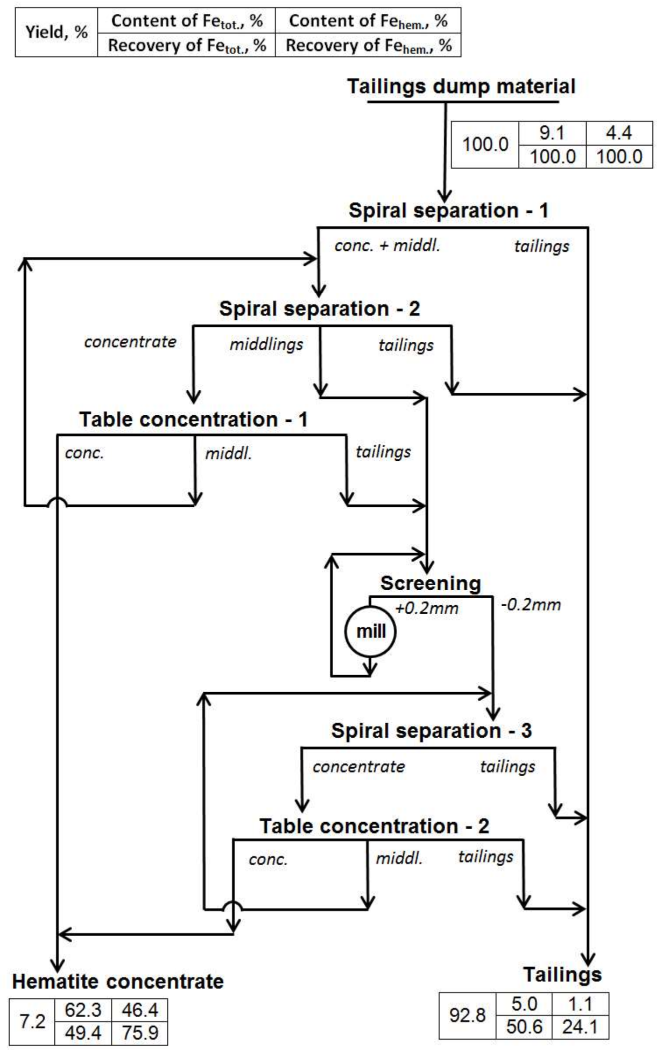

Fig. 5. *Flowsheet for production of hematite concentrate from tailings dump material.*

The technology provides for production of concentrate with 62% Fe_{tot} content and through recovery for Fe_{hem} of about of 76%. The yield of hematite concentrate is about 7%.

CONCLUSION

The problem of recycling of mineral processing waste is an urgent task both in Russia and worldwide due to reduction of mineral resource bases of mining companies and a decrease in the quality of mined ores. The study of the material composition of a representative sample has revealed the suitability of this material for gravity concentration due to the low content of fine particles with a size of less than 0.071 mm and the sufficient difference between the density of valuable and waste rock minerals and high hematite liberation.

It was shown that two-stage spiral separation allows recovering rough hematite concentrates with a 35% total iron content and hematite iron recovery of about of 70%. Separation of the rough concentrate with the concentration table provides for the hematite concentrate with a total iron content of more than 62%. The mineralogical and technological studies have substantiated additional grinding of middlings of the spiral separation for the hematite liberation. The feasibility of further separation of the milled middlings with the use of the spirals and the shaking table has been established, which has allowed increasing recovery of hematite into the final concentrate.

The technology for recycling of mineral processing waste has been developed, which ensures the production of hematite concentrate with a yield of about 7%, 62% total iron content and 76% recovery of hematite.

Thus, the processing of industrial hematite-containing wastes ensures the achievement of two significant goals at once: firstly, production of a marketable product in the form of hematite concentrates, and secondly, reduction of the negative impact on the vulnerable natural environment of the Kola Peninsula. The object of the future research is evaluation of possible options for the development of the tailings dump based on the analysis of geological and technical mining requirements, with the estimation of capital and operating costs.

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