Processing of waste (tails) after flotation of copper production slag to obtain iron oxide pigment

Alisher Samadov[1], *Nilufar* Askarova[1*], *Rano* Toshkodirova[1], *Nigora* Akhmedova[1], *Olmos* Boltayev[1], *Komiljon* Mirzayev[2], and *Asadjon* Kambarov[1]

[1]Almalyk branch of Tashkent State Technical University after Islam Karimov, Almalyk, 110101, Uzbekistan
[2]Yangiyer branch of Tashkent Chemical Technological Institute, Yangiyer, 121002, Uzbekistan

Abstract. At this work, the processing of waste after flotation of copper production slag to obtain iron oxide pigment is presented. Based on the results of the experiments, the influence of various factors and parameters on the processing of iron-containing waste (tailings) of the copper concentration plant-2 of the AMMC was studied; This approach is both uncomplicated and efficient for extracting Fe_2O_3, which is regarded as a primary ingredient in the manufacturing of iron pigment. It was found that when caustic soda is used for alkaline roasting, the iron oxides in the tailings react with nitrates and hydrates to form an insoluble solid phase. Additionally, it was discovered that firing temperatures above 350 °C result in the formation of a sodium aluminate compound. This compound and the iron compounds dissolve in solutions and negatively affect the quality of the resulting Fe_2O_3 pigment.

1 Introduction

Currently, the industrial enterprise JSC Almalyk MMC generates more than 30 million tons of waste annually: 22 km^3 of wastewater and up to 10 billion tons of solid waste, the central part of which is slag and tailings from processing factories, waste from mining and mineral processing, and metallurgical waste [2, 6].

The basis of waste-free technology is the Development and implementation of fundamentally new technological processes that exclude any waste, various drainless technological schemes, and water circulation cycles based on effective treatment methods. Waste is also widely used as secondary raw materials [3, 11].

On "Almalyk MMC, CCF-2 processed dump slag by flotation in the amount of 421.9 thousand tons, together with copper ore. The extraction of copper from raw materials was 82.06%, gold 62.5%, and silver 63.04%. When comparing the performance of the factory using ore and when processing slags from the CS together, The factory managed to improve its production of metals: copper by 2346 tons and a certain amount of gold and silver. Involvement in slag processing made it possible to obtain additional metals and cover the

Corresponding author: asadbekkambaraliev161@gmail.com

shortage of raw materials (ore) at CCF-2. Further laboratory and pilot tests showed that the best results were obtained by separate processing of slag and ore [13]. It has become possible to extract molybdenum from a collective concentrate obtained from ore and use slag flotation tailings containing 35–37% iron [10, 12].

Based on the above, the plant's management decided to process slag and ore separately. Thus, 622.2 thousand tons of slag were processed separately. Slag processing is carried out according to a two-stage grinding scheme: main flotation and control flotation.

Copper smelting slag contains a high amount of iron, reaching 41.40–65.70% in terms of FeO. The silicic acid content is 16.34–35.70%. These two oxides represent the main part of the slag, so the study of these slags was carried out within the framework of the FeO-SiO_2 system [8].

Therefore, flotation tailings differ significantly from the original sulfide ores, not only in content but also in the degree of mineral oxidation in the surface layer and the presence of a significant number of intergrowths and slimy particles. Therefore, tailings material is a more complex enrichment object, and its processing using existing technologies is ineffective. Some useful components are lost in the processing of tailings. In addition, the tailings from the CCF-2 enrichment plant are rich in iron content [9].

The tailings output from CCF-2 JSC "Almalyk MMC" is more than 600 tons annually. Due to the protection of ecology and the external environment, such material is not stored. Currently, these tailings are used as binding compounds in cement and building materials. However, this material can serve as a raw material for producing valuable components such as iron and noble metals. [5]

The prospect and priority development of technologies for the utilization and processing of iron-containing waste is determined by the following provisions: 1) Processing technologies make it possible to obtain valuable metal-containing components, reducing the volume of waste released into the environment; 2) Selective mining technology provides the ability to select areas of initial ore raw materials with the required level of metal content by the requirements of ore processing enterprises; 3) Possibility of extracting associated valuable components (gold, silver); 4) The accumulation of unprocessed waste materials, including iron-containing waste, causes a severe environmental problem. Along with its promise, the study and Development of technology and methods for the disposal and processing of iron-containing waste encounters the following serious problems: 1) increased costs for experimental research and sample analysis; 2) the objects of research are ores with a low content of valuable components and a high level of complexity and difficulty for extraction, which requires the introduction of innovative and effective methods of enrichment and processing [1].

Waste-free and low-waste technology is a modern direction for the Development of industrial production. The main goal of this direction is to reduce the harmful effects of industrial waste on the environment. Non-waste technologies provide the opportunity for complex processing of raw materials, and the Development of such technological processes helps. As a result of the Development of these technologies, it is possible to use natural resources more efficiently, recycle industrial waste, reduce the amount of waste, and reduce its negative impact on the environment [14-16].

The work aims to develop methods for processing waste (tailings) from flotation enrichment of copper production slags with the extraction of valuable components and the production of the iron oxide pigment Fe_2O_3.

2 Methods

In waste raw materials, iron is in sulfide, and oxide forms with a silicon dioxide compound. Iron sulfide compounds do not react with acids and require additional technology to convert them into an oxide compound. From the results of the chemical analysis of tailings, we can conclude that traditional methods for processing copper slag tailings do not allow complete extraction; therefore, it is possible to use an unconventional method for extracting valuable components based on the combination method of pyro- and hydrometallurgy. Sulfide and complex chemical compounds of iron do not dissolve in acids, so alkaline roasting adds NaOH to the charge, followed by leaching of the cinder. This is a simple and effective method for extracting Fe_2O_3, which is considered a raw material for the production of pigment iron.

Laboratory experiments are being carried out to study the optimal parameters of roasting and leaching.

To conduct the experiments, iron-containing technogenic waste (tailings) from copper processing plant 2 of Almalyk MMC JSC is used with the following chemical composition (Table 1).

Table 1. Chemical composition of tailings after slag flotation CCF-2 JSC "Almalyk MMC".

Product name	**Content, %**								
	FeS	**Fe_2O_3**	**Fe_3O_4**	**SiO_2**	**Al_2O_3**	**CuO**	**ZnO**	**Ag_2O**	**CaO**
Tailings CCF-2 AMMC	10-15.0	49.0	69.0	33.3	6.73	0.617	1.56	0.0014	2.31

Table 1 shows that the iron content in the waste tailings of flotation of copper production slags, in some cases, exceeds the content of iron-containing ores of natural occurrence.

The firing of slag tailings with sodium hydroxide goes through the formation stage of ferritic and silicate compounds of metals with sodium. They decompose to metal hydroxides according to the reactions:

$$Fe_2SiO_4 + 5NaOH \rightarrow Na_2SiO_3 + Na_2FeO_4 + NaFeO_2 + H_2 \quad (1)$$

Slagtail is fired in a muffle furnace at t > 300–350 °C, with a firing duration of 60–80 minutes. The reaction begins with the formation of sodium-complex compounds. When the temperature rises to 400 °C, iron oxide content increases significantly. However, in the presence of Al_2O_3 in the tailings (Table 1), when the roasting temperature rises above 350 °C, sodium aluminate $NaAlO_2$ is formed, which quickly dissolves in water and can worsen the precipitation of iron hydroxide $Fe(OH)_3$ in the sediment. The dependence of firing on time is shown in Figure 1.

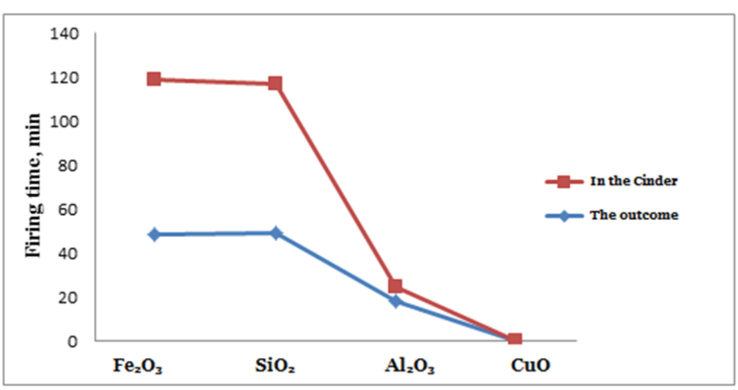

Fig. 1. Dependence on firing on time.

From Figure 1. It can be seen that the oxide compounds of the charge components increase during firing. Firing slag tailings with sodium hydroxide in a muffle furnace at t = 350 °C, its main components being sodium ferrate Na_2FeO_4 and sodium silicate Na_2SiO_3. Fayalite (Fe_2SiO_4) may also be present. During further processing, it is necessary to consider that the resulting product is represented by soluble complex sodium compounds: Na_2FeO_4, $NaZnO_2$, and Na_2SiO_3. When firing slag tailings with sodium hydroxide, the degree of opening of silicon dioxide increases with increasing temperature and excess hydroxide [7, 17-18].

3 Results and Discussion

Firing slag tailings with sodium hydroxide in a muffle furnace at t = 350 °C, its main components being sodium ferrate Na_2FeO_4 and sodium silicate Na_2SiO_3. Fayalite (Fe_2SiO_4) may also be present. During further processing, it is necessary to consider that the resulting product is represented by soluble complex sodium compounds: Na_2FeO_4, $NaZnO_2$, and Na_2SiO_3. When firing slag tailings with sodium hydroxide, the degree of opening of silicon dioxide increases with increasing temperature and excess hydroxide [7]. The dependence of the extraction of iron oxide into cinder on temperature is shown in Figure 2.

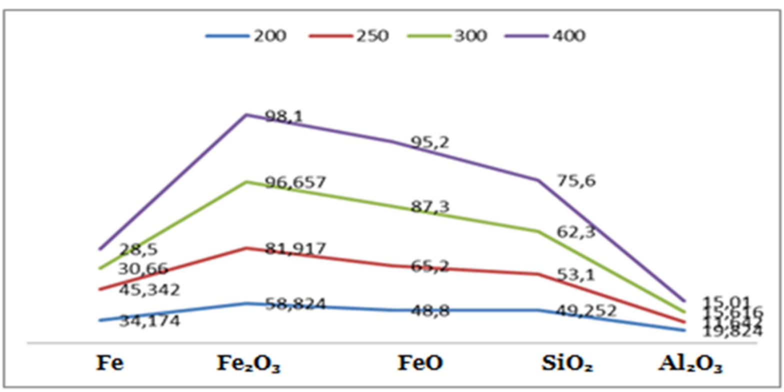

Fig 2. Dependence of caustic roasting of tailings on temperature.

Figure 1 shows that with increasing temperature, the content of iron oxides increases by 98%; however, with an increase in temperature above this, sodium aluminate appears in the cinder, which closely binds with iron oxides and leads to the sintering of the material. Therefore, it is advisable to perform alkaline firing at 300-350 °C.

According to reaction (1), reactions occur with the formation of three chemical compounds, which, during aqueous leaching, silicon dioxide is transferred into solution (2), and iron hydrates remain in the sediment according to reactions (3)-(4).

$$Na_2SiO_3 + H_2O \rightarrow 2Na^{+} + SiO_3^{-2} + H_2O \quad (2)$$

$$Na_2FeO_4 + H_2O \rightarrow NaOH + Fe(OH)_3 + O_2 \quad (3)$$

$$NaFeO_2 + 2H_2O \rightarrow NaOH + Fe(OH)_3 \quad (4)$$

After water leaching, the cake is filtered and subjected to acid leaching with sulfuric acid at 30 g/l at 50 °C. The acid leach solution is neutralized with ammonia or calcium carbonate at pH 6. Upon neutralization, red-orange small shavings precipitate Fe_2O_3. It

https://doi.org/10.1051/e3sconf/202452402014

should be noted that acid leaching can be abandoned if impurities such as $Cu(OH)_2$, $Na_2[Zn(OH)_4]$, $NaZnO_2$, etc.

The cake content after water leaching and extraction into solution is shown in Figure 3.

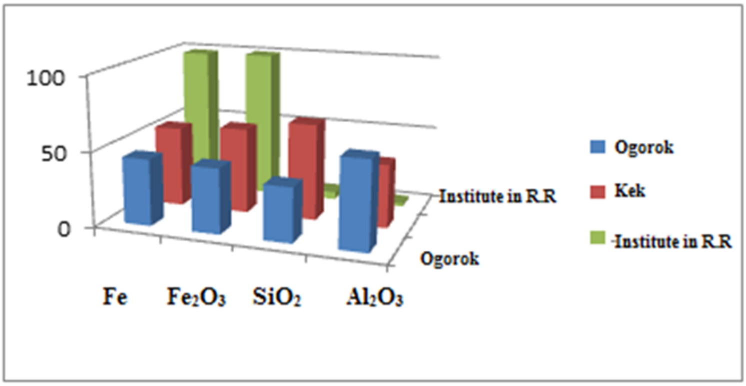

Fig 3. Extraction of iron oxide into solution after acid leaching.

4 Conclusion

Based on the results of the experiments, the influence of various factors and parameters on the processing of iron-containing waste (tailings) of the copper concentration plant-2 of the AMMC was studied; it was determined that when using caustic soda for alkaline roasting, iron oxides of various modifications present in the tailings form nitrates and hydrates of the corresponding components, which are converted into an insoluble solid phase. It has also been determined that firing temperatures above 350 °C form a sodium aluminate compound, which, together with iron compounds, dissolves in solutions and deteriorates the quality of the product, i.e., the resulting Fe_2O_3 pigment.

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