Original Article

Study of the Intensification of the Process of Filtration of Leaching Solutions During the Processing of Copper Production Waste

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Abstract

The article presents methods of filtration, settling, and investigates the separation of an insoluble residue, in particular, lead and precious metals from pulp obtained as a result of leaching fine converter dust of the Almalyk MMC JSC copper smelter with sulfuric acid of various concentrations. For each method, the optimal settling and filtration rate is established depending on time and temperature. The filterability of the pulp (leaching solution) with sediments, which is formed during the processing of dust by the hydrometallurgical method, has been studied. The technological scheme of the chain of devices for the settling and filtering solutions for leaching fine converter dust has been developed. It is recommended for use in the production of the developed automated thickener-settler for settling and thickening the solution before filtration, which helps to intensify the filtration process, since the size of the converter dust is very fine, therefore, during the filtration process, it clogs the fabric filter.

Keywords: Converter Dust, Sulfuric Acid, Dissolution, Pulp, Solution, Insoluble Residue, Precious Metals, Non-ferrous metals, Filtration, Clarification, Settling, Technology.

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INTRODUCTION

The current situation in the mining and metallurgical industry is characterized by the intensification of modern operational production in the industry, the integration of machinery and equipment, the search for new equipment and, above all, the endless race that affects the processing and chemical industries, metallurgy and a number of other industries, the degree of economic conditions of which is largely determines the level of economic well-being of the republic [1].

At the same time, one of the main technological processes that determine the efficiency of the processing industry, non-ferrous metallurgy enterprises, and a number of others is the process of filtering process pulps and waste solutions or sludge [2, 4].

The processes of separation of suspensions, including filtration, have become most widespread in non-ferrous metallurgy enterprises. The latter are distinguished by a full cycle of processing natural mineral raw materials: from ore mining, including the subsequent concentration of useful minerals, to the production of metals with their subsequent processing, and in the processing of man-made waste to extract valuable components from them with their subsequent disposal [2, 3, 6].

This paper shows the possibility of intensifying the filtration process during the processing of converter dust from the copper smelter of Almalyk MMC JSC. Converter dust is a white or light gray fine mobile powder with a particle size of less than 14÷30 μm [1].

A literature review of existing methods for processing identical wastes shows that copper and zinc are recovered using a sulfuric acid leaching method. Based on the physicochemical properties of converter dust, a processing flowsheet was developed, which shows that copper and zinc pass into solution during sulfuric acid leaching. In the process of filtration and washing, an undissolved precipitate and a solution containing copper and zinc sulfates are separated from the pulp, which are transferred to the cementation process to obtain cement copper and a zinc-containing intermediate.

MAIN PART

In order to extract valuable components from converter dust, experiments on dust leaching were carried out at a ratio of T:L = 1:5 with sulfuric acid with a sulfuric acid content of 80÷120 g/l in the pulp at a temperature of 60-90 °C for 2 hours [2].

When converting converter dust, one of the limiting stages of the process is the separation of liquid from solid phases. Studies have been carried out to determine the settling rate (thickening) and pulp filtration.

The study of the process of filtration of the insoluble residue was carried out on a model unit, consisting of storage units, a temperature-controlled reactor, and a PVF-47/3B vacuum filter. An acid-resistant filter cloth “Chlorin” was used as a filter.

To settle the leaching solution, a thickener-settler was used, which is a radial thickener (Fig. 4.), Mounted in the side wall of the pipe for pumping out the clarified part of the pulp.

RESULTS AND DISCUSSIONS

The results of pulp filtration after acid leaching of converter dust are shown in Table 1. The filtration rate and moisture content in the cake are significantly affected by the pulp temperature and the rarefaction created during filtration.

Table 1. Results of pulp filtration after acid leaching of converter dust at the Copper smelting plant (CSP) of JSC AMMC

№	Vacuum, mm Hg st.m	Temperature, °C	Filtration rate, kg/m^2·h		
			by pulp	by draft	by filtrate
1	300	20	140,2	57,6	82,6
		30	156,8	66,3	90,5
		40	174,9	73,7	101,2
2	400	20	182,5	75,2	107,3
		30	198,4	83,3	115,1
		40	215,7	91,6	124,1
3	500	20	228,8	94,3	134,5
		30	249,9	103,0	146,9
		40	272,7	112,7	160,0

The filtration results show that with an increase in temperature from 20 to 40°C, the filtration rate at a vacuum of 400 mm Hg. Art. Rises from 75.2 to 91.6 kg/m^2·h in terms of cake. With an increase in pulp temperature from 20 to 40°C, its viscosity decreases by 20-30%, which is very significant. With an increase in temperature, along with a decrease in viscosity, a drop in the surface tension of the liquid is also observed. With an increase in rarefaction, the filtration rate increases significantly, however, fine particles of the solid product go into the filtrate, due to the extraction of valuable components to be separated, it decreases.

Solid particles in the pulp are in a finely dispersed state and during filtration they clog the pores of the filter cloth. As a result, the filtration rate drops sharply and the moisture content of the sediment increases.

To improve the pulp filtration process and reduce the moisture content of the sediment, changes were made to the technological scheme, according to which the pulp after leaching is sent to a thickener-settler, where, under the action of polyacrylamide, the fastest settling of solid particles and suspension occurs. The clarified solution is pumped out and collected in a reservoir for the productive solution. The thickened precipitate is sent to the suction filter, after which the filtrate is sent to the reservoir for the productive solution. The sludge is used as a raw material for the extraction of lead and precious metals.

Determining the optimal conditions for the separation of liquid and solid phases is inextricably linked with the implementation of other technological operations, since the pulp after the treatment of ores with sulfuric acid is subjected to settling or filtration. The rate of these processes is characterized by the physicochemical properties of the dispersion medium and the dispersed phase. Thus, the rate of settling of a finely dispersed solid phase in a liquid solution depends on the shape and density of particles, size, as well as the density and viscosity of the dispersion medium, and under certain conditions it can be determined from the Stokes law [5, 7]:

$$v_0 = \frac{1}{18} d^2 (\delta_1 - \delta_2) \frac{1}{\mu}$$

Where, v_0 - particle settling velocity, m/s; d - particle diameter, m; δ_1 - particle density, kg/m^3; δ_2 - medium density, kg/m^3; μ - medium viscosity coefficient, kgs/m^2.

Finely dispersed suspensions in the sedimentation mode usually settle without a clearly defined boundary with a gradual clarification of the suspension layer and an increase in the mass of dense sediment at the bottom of the dish [7, 8].

Studies of the settling process were carried out in a measuring cylinder with a capacity of 1 dm^3 made of heat-resistant glass. the cylinder was heated from the outside with hot water. The temperature was measured with a digital thermometer. Sulfuric acid pulp was poured from the reactor into a cylinder and the temperature was adjusted to a predetermined value. The suspension in the cylinder was actively stirred for 30 s. After removing the stirrer from the cylinder, the stopwatch was turned on and the movement of the interface between the clarified and thickened layers was observed.

We studied the influence of various physical and chemical factors on the process of settling pulps obtained during the processing of converter dust by sulfuric acid leaching: - the influence of the duration of the process; - influence of temperature; - the influence of a surfactant (polyacrylamide - PAA).

The sedimentation time of the suspension was recorded by the amount of the clarified part of the pulp at a temperature of 20, 40 and 60°C.

The degree of clarification φ, (%) was calculated by the formula [8, 9]:

$$\varphi = \frac{V_{oc}}{V_{общ.}} \cdot 100$$

Where, V_{oc} is the volume of the clarified part, cm^3; $V_{общ}$ is the total volume of the suspension, cm^3.

The results are shown in table 2.

After a certain settling time, the pulp particles settle on the bottom of the cylinder. At the beginning, the particles settle faster, but after some time, when the resistance force of the medium is equal to the driving force, the particles settle evenly and slowly at a constant speed.

Table 2. The results of settling the acid leaching pulp of converter dust at the CSP of JSC AMMC

t, °C	Degree of clarification, %								
	10 min	20 min	30 min	40 min	50 min	60 min	70 min	80 min	90 min
without adding PAA									
20	10,3	31,4	50,4	63,9	69,8	71,7	73,1	73,9	74,6
40	12,2	35,3	54,3	68,7	73,3	75,0	76,6	77,9	78,4
60	14,6	36,8	55,9	72,3	75,7	77,4	77,9	78,5	79,1
with the addition of PAA with a concentration of 20 g/m^3									
20	20,1	52,8	69,8	75,6	78,2	79,8	80,7	81,4	82,1
40	24,3	55,4	75,6	80,1	81,3	82,5	83,9	84,4	84,9
60	25,8	57,1	77,9	82,1	82,9	83,7	84,5	85,3	85,9

As can be seen in Figure 1, when the pulp is kept for 30 minutes, intensive precipitation is observed, but when it continues up to 90 minutes, the degree of pulp clarification continues to increase slightly.

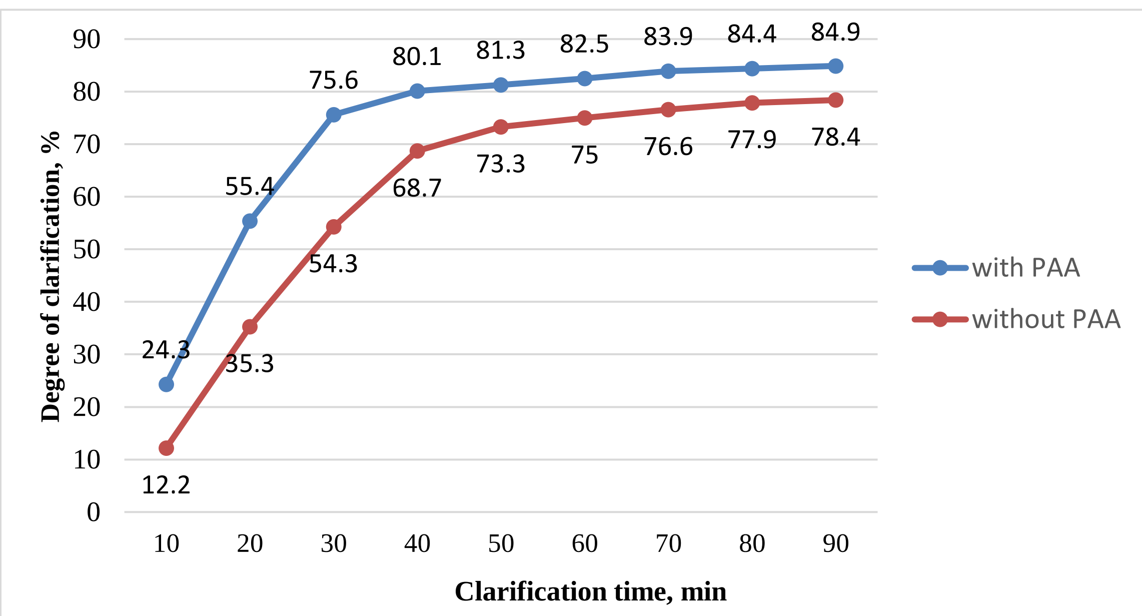

Fig. 1. Change in the degree of pulp clarification after leaching depending on time at a temperature of 40˚C.

The initial section (up to 20 minutes) characterizes the free fall of relatively large particles. Sections of curves between 20 and 40 min. characterize the transition zone, where particles from the free fall zone pass into the constrained mode zone. This is caused by an increase in the concentration of solid particles in the lower part of the column of the solution to be clarified.

The data obtained indicate that the rate of pulp clarification is significantly affected by temperature.

Table 2 shows that with an increase in the duration of the process of settling the sulfate pulp at all values of its temperature, the clarification rate increases.

The addition of surfactants to the settled suspension, for example, polyacrylamide (PAA), also affects the course of pulp clarification. PAA intensifies the process of pulp clarification. In order to intensify the process of clarification of sulfuric acid pulps, studies were carried out with the addition of surface-active substances (surfactants).

In the second series of experiments, the effect of PAA concentration on the settling process was studied. PAA was introduced into the pulp in the form of a solution with a concentration of 20 g/m^3 before mixing the pulp. The data obtained show that the addition of PAA can significantly affect the rate of clarification.

The results of experiments to study the effect of PAA on the settling process are presented in Table 2. Thus, the degree of clarification of the pulp based on converter dust and sulfuric acid after 10 minutes reaches 24.3 and 12.2%, with a maximum degree of clarification of 78.4 and 84.9 %, respectively with and without the addition of PAA, at a temperature of 40°C.

Next, the filtration rate of the sediment of the settling process on a vacuum filter was determined. The most important parameters that determine the efficiency of the filtration process are the resistivity of the sediment and the resistance of the filter wall [10].

The filtration rate was determined on a PVF-47/3B vacuum filtration device, maintaining a working vacuum within 0.35-0.96 kg·f/cm^2, fixing the filtration time. The surface area of the filtering partition is 0.008 m^2. Filtration results are shown in Table 3.

Table 3. Results of filtration of thickened sludge after acid leaching of converter dust at the CSP of JSC AMMC

№	Vacuum, mm Hg Art.	Temperature, ºC	Filtration rate, kg/m^2·h		
			by pulp	for the rest	by filtrate
1	300	20	378,5	155,5	223,0
		30	426,5	180,3	246,2
		40	470,5	198,3	272,2
2	400	20	474,5	195,5	279,0
		30	525,8	220,7	305,0
		40	573,8	243,7	330,1
3	500	20	526,2	216,9	309,4
		30	654,7	269,9	384,9
		40	709,0	293,0	416,0

The results on the filtration rate showed that the pulp after leaching and thickening of the sediment is well filtered, regardless of the initial ratio of S:L and temperature. An increase in rarefaction and temperature of the filtration process leads to an increase in the filtration rate through the pulp, through the solid phase and the filtrate (Fig. 2.).

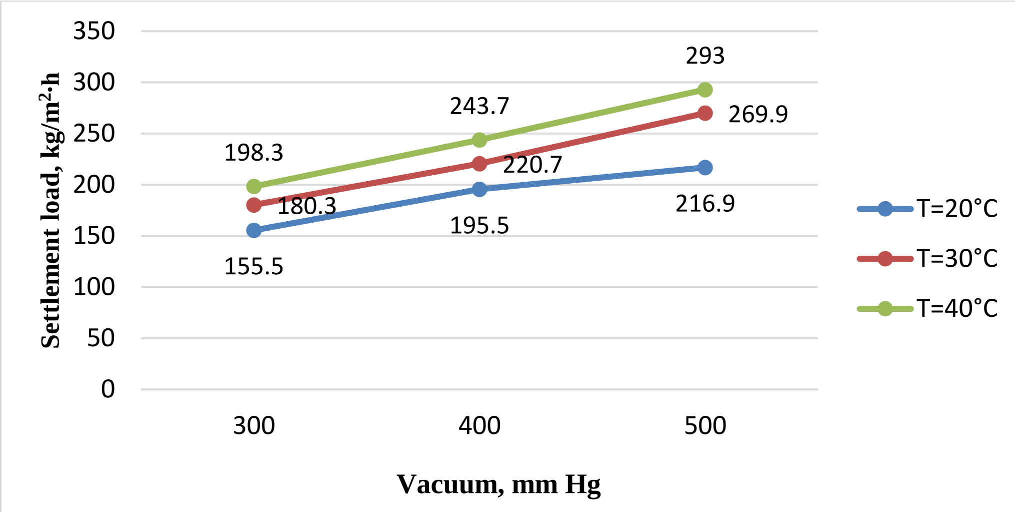

Fig. 2. Change in thickened sludge filtration rate depending on vacuum and temperature

As can be seen from the obtained data, temperature increase and rarefaction have a significant effect on the pulp filtration rate. Thus, an increase in temperature from 20 to 40°C at a rarefaction of 400 mm Hg. increases the sediment filtration rate from 195.5 kg/m^{2}·h to 243.7 kg/m^{2}·h, i.e. the pulp filtration rate before and after settling increases by almost 2.7 times.

Based on the results of studies on the study of the process of filtering the insoluble residue from the products of sulfuric acid leaching of converter dust, we developed a schematic diagram of a separation unit using a thickener-settler followed by filtration (Fig. 3).

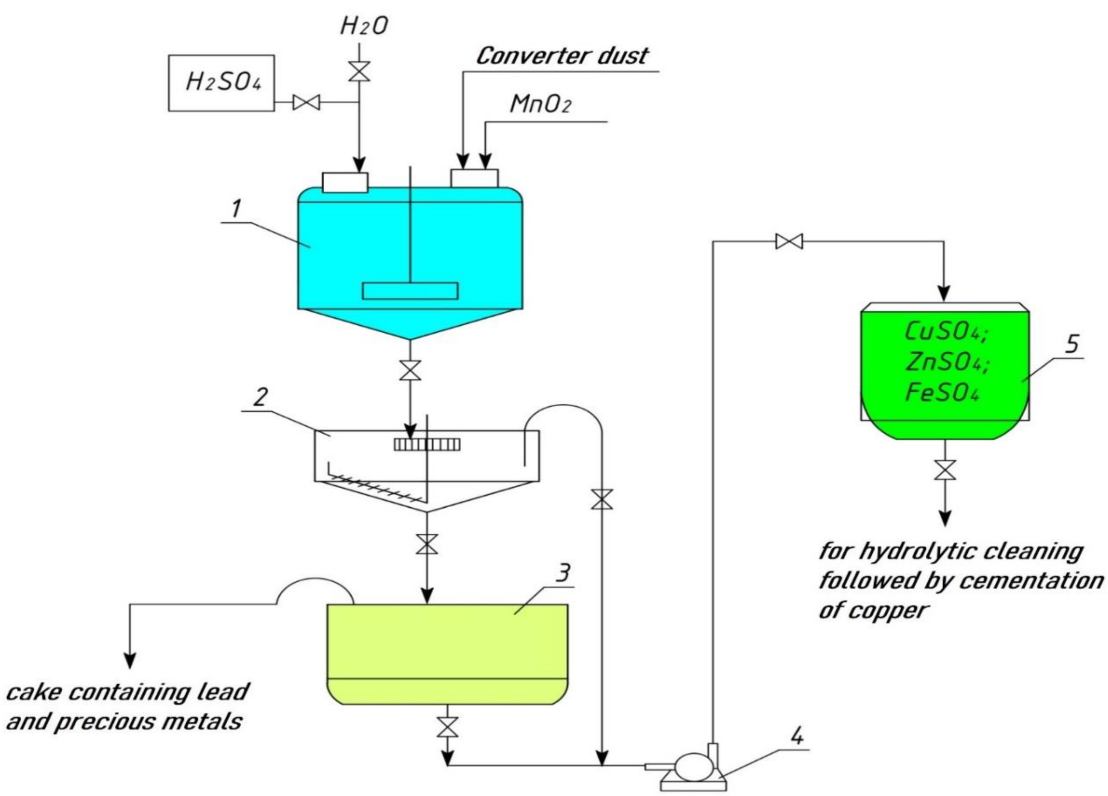

Fig. 3. Schematic diagram of the circuit of the unit for separating the insoluble residue using a thickener-settler with subsequent filtration

1 - Reactor; 2 - Thickener-settler; 3 – Suction filter; 4 - Sump; 5 - Centrifugal pump; 6 - Collector for leaching solution.

According to which the pulp after acid leaching enters the thickener-settler (2), where the insoluble residue is settled from the liquid phase, i.e. solutions of copper and zinc sulfates. The clarified solution is pumped out by a centrifugal pump (4) to a tank for acid leaching solution (5), the sediment is removed from the bottom of the settler and enters the suction filter (3), where the filtrate is separated from the cake under vacuum. The cake separated from the filtrate is washed with water. The filtrate after filtration on the suction filter is pumped out by a centrifugal pump (4) to the collection tank for the acid leaching solution (5), the filtered cake, consisting mainly of lead sulfate, containing small impurities of quartz and noble metals, enters the upper part of the reactor (1) for salt leaching.

The reactor (1) is a vertical cylindrical apparatus with a conical bottom. The apparatus is jacketed and equipped with a stirrer. The temperature in the reactor is maintained at 80°C.

The thickener-settler (2) is a radial thickener (Fig. 4.), mounted in the side wall of the pipe for pumping out the clarified part of the pulp. To pump out the clarified part of the pulp, the depth of the clarified part is determined using sensors.

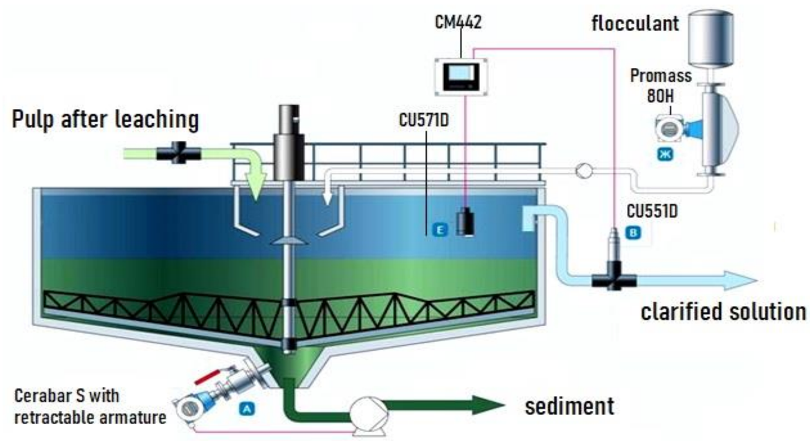

Fig. 4. Schematic diagram of the thickener-settler

To measure the level of the pastel, various sensors are used. This is a submersible float density meter, a Turbimax CU551D submersible turbidity meter or a Turbimax CU571D echo sounder. The echo sounder compares favorably with the fact that it practically does not need to be cleaned, and cannot get under the thickener stroke.

The process of salt cake leaching is similar to that of acid leaching. In this case, the lead chloride solution is collected in the receiver (5), and silica and precious metals remain in the filtration cake.

CONCLUSION

Thus, the analysis of the conducted experiments allows us to draw the following conclusions:

- The results of the study on clarification and filtration of the pulp indicate its applicability in production conditions, where it is necessary to separate the solution from the undissolved part of the product.
- As a result of the inclusion of the thickening process before filtration, the amount of sludge supplied to the filter cloth is sharply reduced, as a result of which the filtration time is reduced, the humidity of the sediments is reduced to the required 16-18%, the extraction of copper and zinc sulfate into solution increases, the transition of lead sulfate and undissolved parts of the components into sediment, which are further used to extract lead and precious metals, the consumption of electricity is reduced, which leads to an increase in the technical and economic indicators of converter dust processing.

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