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# Control system for thiosulfate leaching of intermediate industrial products in metallurgy

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**Abstract.** The efficiency of the process of thiosulfate leaching of intermediate industrial products depends on the composition of the incoming raw materials, the operational control of which is impossible. In this paper, we propose upgrading of the process control system which allows reducing the downtime of the process equipment.

## 1. Introduction

In the case of using multi-component raw materials [2] in non-ferrous metallurgy, as a rule, several alternative technologies are developed [3]. In the process of pilot testing, technological indicators are specified, which determine the best option of the technology selected for the manufacturing process.

For the correct organization of the collection, storage, disposal, enrichment and processing of raw materials must be correctly classified. According to the classification, all industrial raw materials are divided into three large groups: 1: solid materials, 2: liquids, 3: gases.

In the process of beneficiation of the prepared raw materials, the industrial companies use one of the following methods: gravitational, electrostatic, electromagnetic beneficiation or flotation.

Gravitational beneficiation of the prepared raw materials is based on the difference in the particle densities of the separated raw materials in the air or in liquid media. Depending on the medium, the method is divided into pneumatic gravitational or hydrodynamic gravitational methods [8]. As a liquid medium, the industrial companies use water or heavy organic liquids, as well as suspensions and solutions. Gravitational methods are most efficient in the separation of materials with a large density difference (separation of plastics and metals, separation of magnesium and aluminum from heavy metals such as copper, iron, tungsten, etc.).

The electrostatic method of enrichment of multicomponent raw materials is based on the difference in electrical conductivity and electrical capacity of the components of raw materials and the interaction of the electric field and the particles of the beneficiated material, which depends on the dielectric permittivity and electrical conductivity. This method is most efficient in separating metals from non-metals, as well as metals with high electrical conductivity, such as Si, Al, from metals with low electrical conductivity and semiconductors.

The flotation beneficiation method is based on different hydrophilicity of substances, i.e. wettability of the surface of the raw material components of aqueous solutions of special substances called flotation agents. Hydrophilic substances include oxides, some metals. In this process, they are wetted with water



and remain in solution. Particles of hydrophobic substances such as graphite, plastic, sulfur, sulfides of some metals are carried away by air bubbles and concentrated in foam on the surface of the liquid. Hydrophilicity of specific substances is regulated by the applied composition of flotation agents, which can ensure the separation of almost any material.

Cementation [9] is an electrochemical process of metal separation from the solution (melt), based on the difference between the equilibrium electrode potentials of the cemented metal and the cementing metal. It should be noted that the cementation process is simple in hardware design and efficient in the allocation of electropositive metals, for example, Au, Si, Pt (in the case of low concentrations) of strongly acidic solutions.

The method of electrodialysis based on the use of directional motion in the electric field of ions generated by direct current. Electrodialysis is successfully used for concentration of electronegative metals in solution, desalination of waste and wastewater and desalination of sea water.

A well-known chloride method for processing sulfide ores includes firing a mixture of sulfide and oxidized ores and table salt in a chlorine atmosphere at a temperature of 500-600°C for 4 hours, followed by leaching. At the same time, 73-75% of platinum metals are extracted into the solution [5, 8, 9]. The disadvantage of this method is the low extraction of platinum metals into the solution; 27-25% of platinum metals can not be extracted.

An analogous method of processing silicon-containing alloys of platinum and noble metals for a set of essential features and purpose is the method of processing products containing ruthenium and rhodium, including chlorine treatment in hydrochloric acid and the separation of the formed solid and liquid phases by filtration [4]. The disadvantage of this method is that it does not allow to extract completely platinum and noble metals from silicon-containing alloys of platinum and noble metals.

Unlike other hydrometallurgical processes [6] such as the processes of leaching (dissolving), hydrochlorination, electrolysis solutions, cementation, solvent extraction, ion exchange etc., the aim of the thiosulfate leaching is complete extraction of precious metals from industrial products (secondary raw materials) and the translation of base metals in solution.

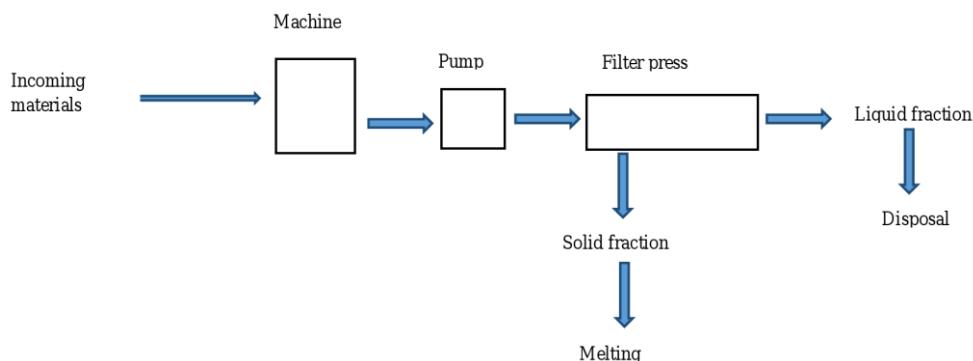
The problem considered in this paper is to increase the efficiency of the process control of the complete extraction of all platinum metals, silver and gold from silicon alloys with platinum and noble metals. For this purpose, in the method of processing silicon-containing alloys of platinum and noble metals, including chlorine processing and separation of the formed solid and liquid phases by filtration, chlorine processing is performed at a temperature of 300-850°C to form a liquid phase in the form of liquid silicon tetrachloride and the solid phase of the powder of platinum and noble metals in the elemental state, the solid phase after filtration is washed and platinum and noble metals are extracted. This process includes the stages of application of expensive equipment and is critical in the overall process of production of precious metals [9]. At the same time, the modernization of the applied control system of this process can significantly increase its efficiency, reducing non-production costs.

## 2. Process description

The process considered in this paper can be described as follows [8]. Intermediate products come from the relevant production site, as the accumulation of a batch of a predetermined volume provided by the technological process. A sample (chemical analysis of the composition) of the incoming material (industrial product) is sent for analysis during transmission between production sites. The incoming material is loaded into the machine (2 parts of water are poured, the stirrer is turned on, 1 part of the material is loaded) and water leaching is carried out. The material is processed with the use of chemical reagents (sulfuric acid is introduced-the process of dissolution, heating, and sodium thiosulfate injection for precipitating noble metals). Then, a sample proof of the resulting solution is taken for the laboratory analysis.

The analysis should show the absence of noble metals in the solution, which should signal that all noble metals precipitated as a result of chemical reactions. In this case, the main part of the process is considered completed. If the analysis shows the content of noble metals in the solution above the norm, the re-injection of sodium thiosulfate is carried out. If the content of noble metals fits the standards, the

solutions are sent for filtration. The main purpose of filtration is to separate the solid and liquid parts. The solid part contains the noble metals obtained by precipitation with sodium thiosulphate, and sent for smelting. The liquid part containing other metals and is sent for disposal (figure 1).



**Figure1.** Leaching process.

The absence of laboratory analysis of the material entering the process input affects directly the production process. With the regulatory use of chemical reagents, the sample selected for analysis may not pass strict control on the content of noble metals, which leads to re-processing, an increase in the consumption of reagents, the processing time of incoming material, labor, material reserves. The filtration process is adversely affected by the overspending of chemical reagents and the lack of analysis of the composition of incoming raw materials, which may contain, in particular, silicon. Silicon, in turn, tightens the filter cloths of the filter press and stops the filtration, which leads to a complete stop of the process during the repair of the filter press. Pneumatic pump is used for filtration. When the filtration is stopped, after the pneumatic pump, excessive pressure is created in the pipeline, which, with prolonged exposure, destroys the working membranes of the pneumatic pump, which leads to its failure.

Thus, the lack of analysis of the composition of incoming raw materials directly affects the production process and the performance of the equipment [4], which affects the financial performance of the enterprise. The filtration process is the most important element at this stage of material processing, because after filtration the material goes to melting, that is, the stage of obtaining the finished product – metal-follows, and the disruption of the filter disrupts the rhythm of the entire production.

### 3. Efficient control system

The above-mentioned problems of the existing technological process can be reduced to the presence of two main disadvantages [7]:

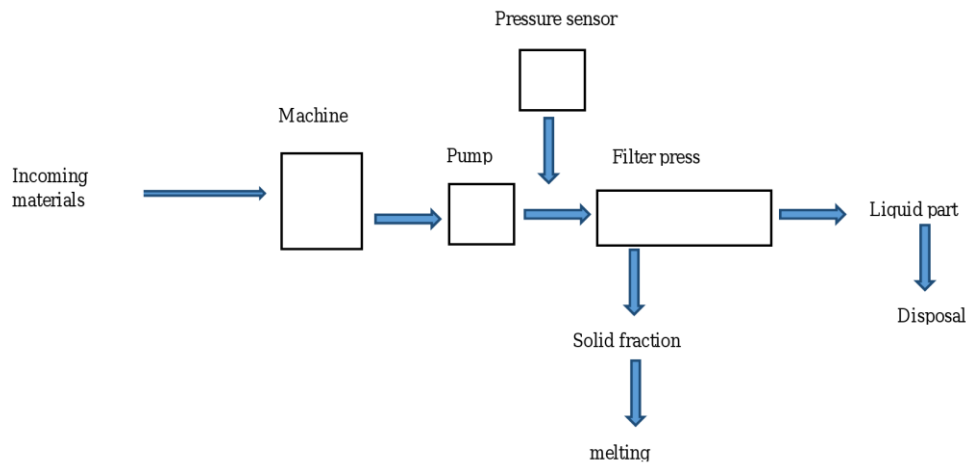
- Lack of control over the composition of incoming raw materials-industrial products;
- No control over the efficiency of the air pump at the inlet of the filter press.

To normalize the filtration process, we need to exclude the delivery of the incoming material without analyzing the composition of the raw material and to minimize the content of silicon.

Control of the incoming material composition, of course, would be the most efficient means of solving these problems: when the composition of the material beyond the standards of the technological process, it is possible to adjust the composition of chemical reagents, or rejection of the intermediate products at the entrance of the process. At the same time, such control is long-lasting, requiring several days for the analysis, requiring a significant restructuring of the entire process, taking into account the time spent on the analysis, the organization of locations and means of transportation for the temporary storage of batches of the intermediate products in the process of analysis.

At the same time, the construction of the control system for the pneumatic pump allows to solve the following problems:

To prevent breakage of the expensive equipment and to avoid further downtime of the entire production site, we propose the following modernization of the process control system (figure 2). At the inlet of the filter press, a pressure sensor is installed on the line from the pump to the filter press, as well as a pump control system (in the simplest form-an automatic switch for overpressure).



**Figure 2.** Modernized process scheme.

At the same time, the pressure measured in the pump filter path depends both on the specific installation site of such a sensor and on the design features of the pump and press. It is almost impossible to set the cut-off threshold in advance. The pump control system, therefore, must include a classifier of process states [1] with two classes: normal/non-normal state (clogged filter press) and one informative feature (the indication of the pressure sensor). Such a classifier requires setting a threshold value, that is, working in training (learning) mode. For training, we propose to use the data of the analysis of the collected samples of the solution for the presence of noble metals, as well as silicon. As mentioned above, a significant drawback of the analysis procedure is the inability to use its results for operational process control due to the duration of the procedure. Thus, correlation of retrospective results of the given analysis (in particular, concerning the content of silicon) with the corresponding indications of the pressure sensor are the training data for our classifier.

It is sufficient to set a minimum threshold pressure for the state of the process, in which the silicon content is beyond the established norm. In the future, the operation of the controller can be adjusted.

#### 4. System efficiency

To analyze the process of processing of intermediate products, we investigate the data of production process collected during 3 months. The basis of the analysis is the structure of the process i.e. the stages at which the failures of the equipment occur. A detailed analysis of the production indicators of the current process is given in table 1.

The total downtime of the production site in case of failure caused by the failure of the air pump, in each time period is calculated according to the following equation (variable designations are given in table 1):

$$T_T = T_D A + T_N B + T_F C + T_P D.$$

**Table 1.** Some production indicators of the current technological process (for the quarter).

Indicator	1st month	2nd month	3rd month
A: number of failures	3	2	4
TN: Time needed for a single filtering operation, minutes		20	

TF: Time needed for a single filtering operation in the case of a failure, minutes		250	
Failure downtime, $TD=TF-TN$		220	
B: Number of the pneumo-pump failures	2	1	2
TP: Pneumo-pump replacement time, minutes		45	
C: Number of replacements of filter elements	1	0	1
TF: Replacement time for filter elements, minutes		120	
D: Number of filter element washings	3	2	4
TW: Washing time of filter elements		45	
TT: Total downtime at failure in each period, minutes	1005	575	1270
		Total: 2850	

Total downtime for 3 months = will be:  $T_O(1) + T_O(2) + T_O(3)$ . Calculations give an estimate of downtime for the quarter, equal to 2850 minutes-almost two days per quarter. Implementation of the process control scheme indicated in figure 2, allows to exclude from total time terms related to the variables of  $T_N$ ,  $T_F$ ,  $T_W$ . This is 870 minutes or 14.5 hours (27.3%) for the period.

## 5. Conclusion

The current practice of thiosulfate leaching of the intermediate industrial products does not take into account the unstable composition of raw materials, which leads to long downtime of the production site (about 8 days a year). At the same time, the proposed modernization of the existing control system with the use of indirect indicator control (pressure at the input of the pump filter) is able to reduce the downtime by more than 25% without significant change of the scheme of the process.

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