SYSTEM ANALYSIS OF ORE FLOTATION FACILITIES

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Abstract. *This article discusses the issues of analysis and synthesis - the object and elements of flotation systems, in the management of a single-layer bubbling working area of the flotation apparatus, using the example of ore dressing.*

Keywords: *flotation, thinking, control, enrichment, optimal solution, technology, process, computer, model, system, automation, regulation.*

Introduction

One of the most important concepts of modern science is the system. Having arisen in cybernetics, it acquired the status of a philosophical category, so wide and its general application. The concept of "system" makes it possible to carry out mathematical formalization of the objects under study, which provides deep penetration into their essence and the achievement of broad generalizations, as well as the establishment of new patterns [1; pp.119-120].

System analysis has its own history. Initially, the object under study was considered as a single-level system (one hierarchical level), later the definition of the macrokinetics of the process and the microkinetics of the process in the selected system (analysis at two hierarchical levels) appeared. There is a leap in decision-making processes from bottom-up analysis of processes at a deep underlying level to bottom-up synthesis of a large complex system. At the same time, systems at intermediate stages were sometimes insufficiently studied and analyzed. For example, when developing new technological schemes, one can often observe a jump from the analysis of the hierarchy of processes at the atomic-molecular level to the actual technological lines [2; c.93-96].

The terms systems theory and system analysis [5; pp.99-100] or, more briefly, a systematic approach, have not yet found a generally accepted, standard interpretation. Although the chronology of science dates the birth of systems theory and system analysis to the middle of the last century, nevertheless, it can be understood that the age of the theory under consideration is exactly as long as Homo Sapiens exists. Even in the definition of the concept of a system [3; c.79-86, 4; c.126-135, 5; pp.100-102] you can find quite a lot of options, some of which are based on deeply philosophical approaches, and the other uses everyday circumstances that prompt us to solve practical problems of applied orientation [1; c.120-122].

Any system consists of parts that are interconnected and interact with each other and with the external environment, i.e. A system is a fairly complex object that can be divided into constituent elements or subsystems. These elements are informatively related to each other and to the environment. The set of connections forms the structure of the system [8; pp.274-281].

The basis of the modern approach to solving the problems of chemical technology is system analysis. Systems analysis is a strategy for studying complex systems, such as chemical engineering processes in particular. Mathematical modeling is used here as a research method, and the main principle is the decomposition of a complex system into the simplest interconnected subsystems (principle of system hierarchy) [6; c.177-179, 7; c.82-98]. An example of a system can be any chemical-technological apparatus, installation, production line, workshop, plant, etc. (for example, the process of flotation of a complex of noble metal ores) [9; c.45-68].

The flotation complex of processed materials is widely used in various industries, in particular, in the processing of gold-bearing materials, in the mining industry, in the production of fertilizers, etc. In many cases, the flotation complex functions in conjunction with other physical-mechanical and physical-chemical processes and is the limiting stage that determines the performance of the machine as a whole and the quality of the resulting product [2; c.97-105].

We have proposed a method of sequential execution, first of system analysis and then transition to finding a solution: an algorithmic formula, first analysis, then system synthesis.

The proposed method allows you to analyze the system without much difficulty, following which the indicators are initially determined - the input, output parameters of the object (system) and analyzes the process occurring in the system. Then follows the definition of the relationship of parameters. If necessary, the system under consideration is divided into constituent elements, the parameters of each considered element of the system and the process occurring in this element are specified. This makes it possible to synthesize optimal solutions [10; pp.22-23]. In general, the methodology of system analysis and synthesis of the optimal system implies the following sequence of actions:

The first stage (actual system analysis) [11; pp.7-8]:

- The selected object - element - system and the process occurring in it are preliminarily studied. In most cases, the object is considered as a black box. Requirements to the system are formulated [11; pp.7-8].

- In each system (element) there are many processes and phenomena, from the set of which the processes necessary for the correct decision-making are selected; the studied process in the system is preliminarily studied [10; pp.22-23].

– The input and output parameters of both the system itself and the process under study are determined. Determining the relationship of system parameters in most cases requires deepening research [10; pp.22-23].

– Subsystem elements are defined. For a group of tasks of the composition and structure of the object under study, it is possible to determine the elements of a functional subsystem without taking into account processes. The considered system (element) is divided into component sub-elements, the process and its parameters are specified for each selected sub-element, and so on. An unlimited deepening into the system is carried out - the division of elements (systems) into subsequent subsystems. It is carried out as necessary and according to the possibilities of research in order to make the optimal decision [11; pp.8-9].

The second stage (Determination of the relationship and mutual influence of parameters)

Here, depending on the type and type of object and on the content of the initial task, each researcher can use a large arsenal of methods for system analysis of the subject area and the specific industry at the request of which the research is being conducted. Determining the quantitative ratios of the parameters requires the use of an appropriate arsenal of mathematical apparatus.

This leads to the need to refer to mathematical or computer models [11; pp.8-9].

The third stage (Choice of the optimal solution)

Here, on the basis of system analysis, the requirements are refined and specified, optimality criteria are selected, both for the starting, initial system, and for the decomposed subsystems of each hierarchical level. A method for finding the optimal solution is substantiated. The desired optimal solution is determined [11; pp.8-9].

The first stage - the beginning - system analysis is universal for all sciences. The second and third stages can be performed depending on the task for each specific industry. System analysis opens the way for many existing methods in different sciences to search for optimal systems [11, p.8-9].

Algorithmic formula for system analysis

To analyze specific systems, we have proposed an algorithmic formula that can be expressed as:

CA = 2+1 ˃ ((system +process) →parametres) · n,

Here: 2 - means joint consideration of the original system and the process under study occurring in it; 1 - means all the necessary parameters of the system and process taken together, the parameters are subsequently divided into input and output. In the case of a multi-stage system analysis, they deal with a certain number of subsystems "n" [12, p.1-2].

The technological process of flotation occurring in the apparatus, as a control object, is shown in Fig.1.
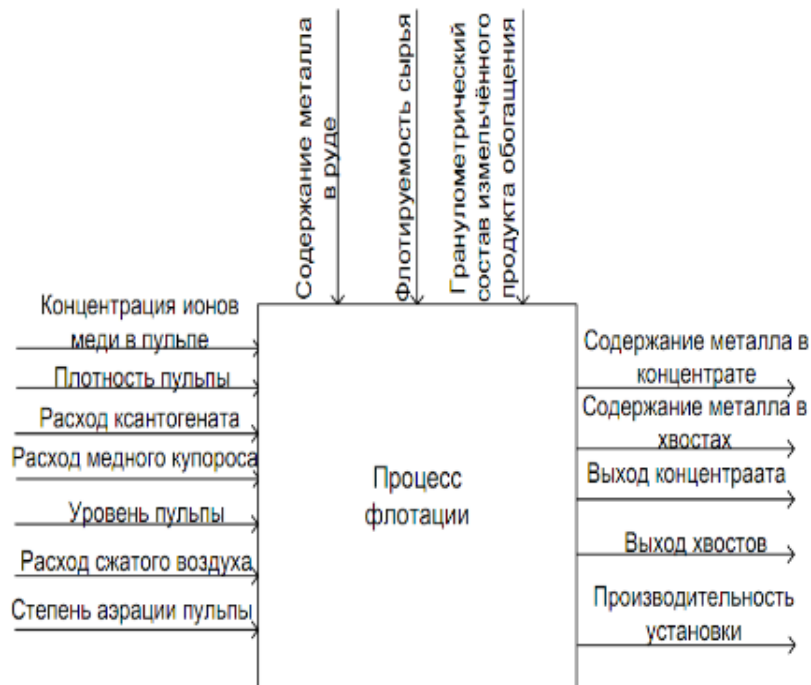
Fig. 1. Parametric indicators of the apparatus and the technological process of flotation
The first stage of system analysis of the optimization object.

An analysis of the system and processes occurring in flotation machines makes it possible to identify the main input and output parameters. The input parameters are: pulp density, concentration of metal ions in the pulp, xanthate consumption, pulp consumption, compressed air consumption, pulp level, pulp aeration degree. Disturbing influences are: the metal content in the ore, the floatability of raw materials, the granulometric composition of the crushed beneficiation product. The output parameters are: metal content in the concentrate, metal content in the tailings, consumption of the outgoing pulp, concentrate and tailings. Determining the optimal parameters requires studying the technological process of the flotation apparatus (Fig. 2)
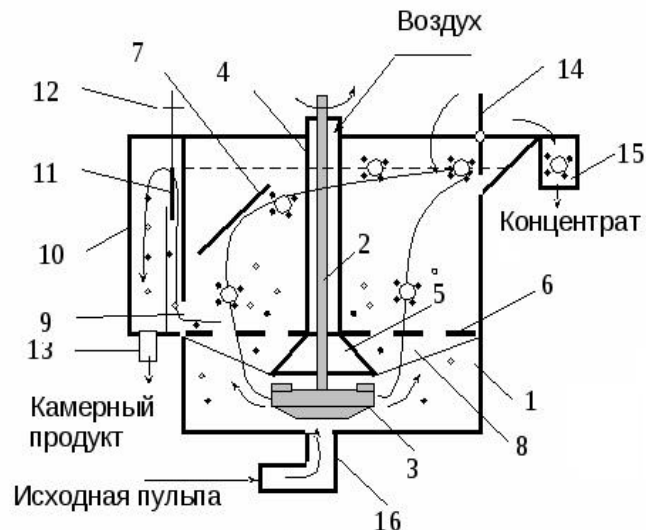
Fig. 2. Scheme of the flotation apparatus

1- camera; 2 - impeller shaft; 3 - impeller; 4 - casing pipe; 5 - above the impeller glass; 6 - soothing grid; 7 - impact plate; 8 - cross; 9 – overflow pocket window; 10 - overflow pocket; 11 – overflow pocket gate; 12 – steering wheel for controlling the gate of the overflow pocket; 13 - branch pipe of the chamber product of the overflow pocket; 14 - foam removal device; 15 - chute for receiving the concentrate; 16 - supply pipe.

FPM-PMO 1.6 pneumomechanical flotation machine (Mining equipment plant)	Number of chambers of one flotation machine 16 Chamber volume 1.6 m3 Overall dimensions: length 1750 mm, width 1600 mm Flow rate up to 5 m3/min

The flotation apparatus is considered as the main research system. The main basic system is defined as a bubbling cube - this is a working area, which consists of subsystems, the elements of which are divided into corresponding elements included in six hierarchical levels. Multi-stage system analysis allowed the author to develop computer models and identify the optimal flotation conditions in the bubbling zone and the control system of the object under study.

Issues of mathematical modeling are solved by the identification analytical method. The ore flotation apparatus was studied as a system consisting of a number of elements; the processes and phenomena occurring in the elements of the flotation apparatus are considered and analyzed.

At the second level of the hierarchy, elements called quasi-apparatuses are considered, both from the point of view of a system of interconnected elements, and from the point of view of the regularities of the processes occurring in each of the considered elements. At the third hierarchical level, a working chamber is considered, which consists of a number of elements and in which all input and output parameters are identified. At the next level of the hierarchy, the liquid phase was studied, which is a suspension with crushed ore of valuable components, which promotes good adhesion of gas phase particles. The input and output parameters of the considered quasi-apparatus are determined. The elements and processes occurring in the gas phase are studied. On the basis of deepening to the next, lower level of the hierarchy, the elements and processes occurring in the gas phase, consisting of elements of gas supply, its distribution, as well as transition and exit through the foam layer, are studied. For each composite quasi-element, input and output

parameters are determined. At the next hierarchical level, a gas distribution system was studied, consisting of quasi-elements of sparging and grinding gas bubbles. For these links, the input and output parameters are also defined.
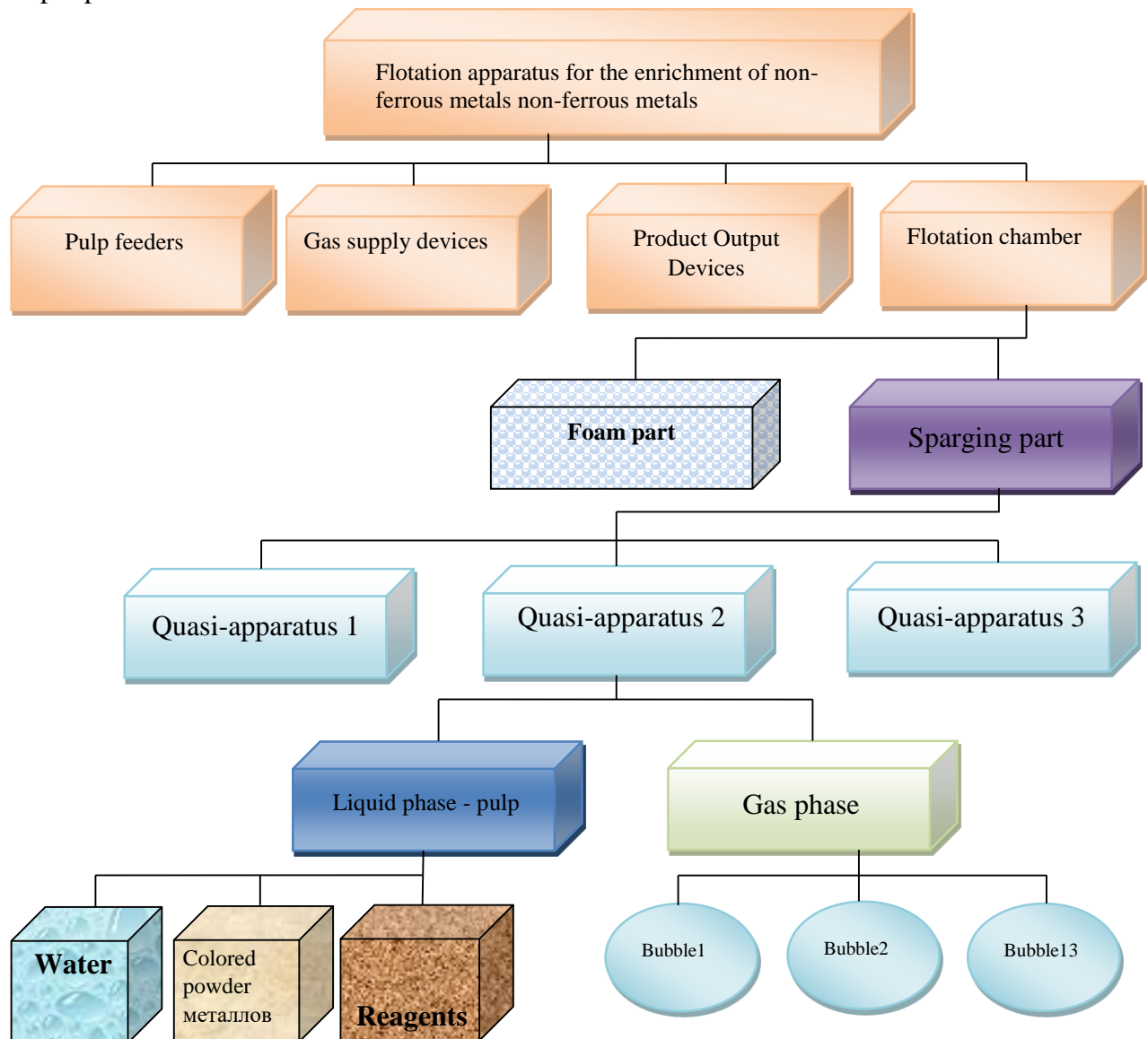
Fig. 3. Hierarchical system of the flotation apparatus for the enrichment of non-ferrous metals

An analysis of the functioning of a quasi-apparatus makes it possible to compile mathematical or computer models of the processes occurring in the considered apparatuses. Generalizing local models, it is possible to compile a generalized computer model of technological processes occurring in the flotation apparatus as a whole. A method for sequential execution of procedures (algorithm) of system analysis with subsequent transition to finding the best solution is proposed.

An analysis of the ore flotation apparatus based on systemic thinking was carried out (Figure 3). The ore flotation apparatus was studied as an object consisting of a number of elements. The processes and phenomena occurring in the elements of the flotation apparatus are analyzed.

Analysis of an object at the level of quasi-layers of substance

Sparging part- the working chamber with its elements - is shown in the diagram (Fig. 3). As noted above, the motion of gas bubbles could be formalized using partial differential equations.

The attachment of valuable components to the bubbles is carried out both as the bubbles move up; but, on the other hand, the process proceeds in time. Sometimes the formalization of the process under consideration is carried out using second-order differential equations. As a rule, the solution of partial differential equations using the methods of computational mathematics is carried out either by translating differential equations into algebraic expressions of one of the arguments of the differential equation into transformation equations. Therefore, it seems that a more acceptable way would be mental layers arranged vertically. Therefore, we use the term quasilayer.

Each quasilayer is characterized by input and output parameters. The input parameter of each layer, from the point of view of the gas phase, is a vector whose components are the flow rate and concentration of valuable components in this quasi-layer. For more complete definition, the layer under consideration is called the i-layer, so the components entering it can be called indicators (i-1) of the layer. In addition, this layer also contains a liquid phase, a hydrodynamic structure characterized by mixing. We fix it in the form of a hydrodynamic model of ideal mixing, according to which the concentration of valuable components at all points of the volume of the apparatus is the same. The basis of the mathematical model of the object is the equations of material and heat balance, and the kinetic and hydrodynamic features of the processes and phenomena under consideration and their boundary and initial conditions are taken into account. All this, taken together, is then formed into a computer model of the bubbling layer as a whole.

Thus, a systematic analysis of the bubbling zone of the flotation apparatus was carried out.

Analysis at the liquid phase level

One of the elements of the working area is the liquid phase. The liquid, coming from the bottom of the apparatus into the middle part of the flotation apparatus, spreads over the entire volume of the working area.

The bubbling gas exiting and distributing in the bubbling elements leads to a complete displacement of the liquid throughout the entire bubbling zone. Therefore, for the liquid phase, one can accept the hydrodynamic structure of the model of complete (ideal) mixing. Passing through the liquid, the gas phase has the hydrodynamic conditions of ideal displacement, i.e. moves upward without mixing vertically.

Therefore, on the basis of quasi-layer representations of the bubbling layer, it is possible to formalize the pattern of changes in the concentration of valuable components in the gas phase, while for the liquid phase the content of valuable components throughout the entire volume of the apparatus can be considered the same.

The input parameters of the liquid phase are: pulp consumption, the content of valuable components of the pulp, the content of reagents in the pulp. The main input parameters are complemented by other variables: pulp density, pulp total solids, pulp reagent content, pulp acidity, etc.

To calculate mathematical models and the process itself, we use only two parameters. The output of the bubbling bed i.e., for the working chamber for the liquid phase will be the flow rate of the exiting liquid in the form of pulp and the concentration of valuable components in the exiting liquid (or it can be called tailing at the exit). As for the foam layer, a small amount of liquid will leave in the foam layer.

Gas phase analysis

The movement of gas occurs through the pipeline from the gas distribution device. The gas then enters the bubbling zone of the liquid phase. The gas distribution system consists of a bubbler

and a rotating element, which further reduces the size of the bubbles, providing movement. The gas phase from the liquid phase passes into the foam layer, from the foam layer goes into the atmosphere. Thus, the gas phase itself consists of a certain number of quasi-elements (Fig. 3).

The first quasi-element of the considered subsystem is a pipeline, in which the input parameters are the pressure and the flow rate of the incoming air. The air coming from the side of the pipeline overcomes the hydraulic resistance, which depends on the diameter and other parameters of the apparatus. The output variable of this element is the flow rate of air entering the zone of the quasi-device. The input parameters are: air flow and pressure, as well as the power spent on the formation of bubbles and their interaction. The output parameters are: air flow, air bubble diameter, particle diameter and air temperature. The transformation of gas phase bubbles occurs in two zones. For the zone of the quasi apparatus in the form of a bubbler, the input parameters are such gas quantities as flow rate, pressure and temperature of the gas.

At the outlet of the bubbler, we have the following parameters: bubble diameter, gas flow rate and temperature. With the initial flow rate and temperature, it enters the bubble separation zone, where, due to the large revolutions of the rotating element, their sizes decrease. Here, the main output parameters are the gas flow rate and the particle diameter, the temperature here may not change. As a result, bubbles of a certain diameter and with a certain temperature are obtained. In addition, the concentration of valuable components in the composition of the gas phase must be taken into account in the bubbling zone.

The gas leaves the bubbling zone with a certain content of valuable components and enters the foam zone, where the gas, releasing valuable components, is released into the atmosphere. The considered element of the bubbling zone from the point of view of the gas phase consists of a number of subelements, which we call quasilayers.

To characterize this process, one could use the picture of successive saturation of the gas phase with vapor bubbles with particles of valuable components attached to the bottom and write partial differential equations in the form of the Fick equation, etc.

However, due to computational difficulties, it is more expedient to create algorithms that use elements of a piecewise linear interpretation.

Analysis of processes and phenomena at the level of gas bubble formation

The study of technological processes that occur or can occur with bubbles in a liquid allows us to understand how the general laws of physics manifest themselves in specific phenomena. When solving the tasks set, the following research methods were used [12; p.2-3]:

– analysis of various sources of information;

– performing experiments aimed at revealing different properties of bubbles.

It is also necessary to study the technological processes that occur or can occur with bubbles in a liquid, and understand how the general laws of physics reveal themselves in specific phenomena. During the flotation process, the bubble rises, near the surface of the liquid, the gas contained in it passes into the vapor phase. At the considered level of the hierarchy of the flotation process, there are many phenomena and effects that occur with a gas bubble and depend on its size, on the properties of the liquid, the size and shape of the apparatus, as well as the type of gas with which the bubble is filled, etc. The bubble turns out to be one of the main participants in the studied processes that predetermine the behavior of gas bubbles, many important factors of physical and chemical phenomena and the effects of the flotation process at different levels of detail. These processes can be organized in a better way, and the phenomena can be used with

great success if they are deeply understood and reveal the physical laws governing the behavior of the phases interacting during flotation [13; pp.2-3].

The development of optimization systems makes it possible to improve the operation of the flotation complex, reduce the loss of raw materials and valuable components in process waste, and reduce the cost of water and energy.

The development of optimization systems requires the study and compilation of mathematical and computer models of the object (flotation process) at the modern level. The method of multistage system analysis makes it possible to obtain more accurate mathematical models.

Let us turn to the issues of compiling a computer model of the process of flotation of valuable components. The process is mainly considered as an object with lumped parameters, but more accurate calculations will be performed using a computer model of the process in the form of an object with distributed parameters.

Even better results can be achieved using analytical mathematical models obtained by studying the corresponding multilevel hierarchical structures of optimization systems.

For the case of single- and multi-capacity objects, algorithms for identifying computer models obtained by analytical methods are used. Finding the parameters of optimal systems for optimal control allows achieving a number of advantages.

The gas bubble crushing system contributes to the formation of smaller bubbles, which, on the one hand, are better able to attach valuable components to themselves due to the increase in surface. On the other hand, a decrease in the size of the bubbles helps to reduce the speed of movement of the bubbles, which creates more favorable conditions for better attachment of valuable components to the surface of the bubbles.

Various factors contribute to the phenomenon of attachment of valuable components to the surface of the bubbles. One of the main ones is the reagents added to the pulp. Another indicator is the movement of bubbles through the bubbling bed. Lifted to the upper part of the apparatus, the bubbles make oscillatory movements. The question of oscillatory motions was considered by me in earlier published works. The description of oscillatory movements adequately reflected the phenomena of attachment of valuable ore components to the bubbles. However, these issues require additional study and special experiments, which was not included in the goal of this work. At the same time, the efficiency coefficient, in our opinion, turns out to be high, but these questions are left for further research. Meanwhile, the study of the movement of bubbles of small sizes (from 1 to 5 mm) shows that in a small area the movement of bubbles proceeds at the same speed without acceleration. To reflect the movement of bubbles, you can use the Archimedes equation, which relates the force and resistance of the liquid phase to the movement of bubbles. From this point of view, it will be possible to determine the speed of the bubble.

From the equality of the Archimedes force and the resistance of the liquid to the movement of a gas bubble, it is possible to determine the speed of movement of an individual gas bubble. Knowing the velocity of the gas phase, it is difficult to determine the time it takes for the gas phase to pass through the bubbling liquid layer.

Thus, the formalization of the movement of gas bubbles in the bubbling zone is carried out. On the other hand, the attachment of valuable components to the gas phase depends on the content of valuable components in the pulp. The issue under consideration is associated with significant

difficulties of an analytical nature, and therefore the empirical approach is used and the general equation of mass transfer is used.

The analysis indicates that air bubbles in the liquid phase play an important role in the solution of crushed precious metal ores. From the point of view of system analysis, the bubble is also a quasi-apparatus, located in another quasi-apparatus. The bubble, moving upward due to oscillatory motion, is saturated with particles of noble metals that are in suspension, that is, in the liquid phase. The input parameters of the quasi-apparatus are the concentration of the bubble or the concentration of the valuable component in the mass of the bubble. In general, we can talk about mass concentration, or in other cases, we can operate with a parameter - volume concentration.

Another input parameter is the flow rate of the incoming valuable component of the liquid phase in the selected bubble. Another input variable is the bubble surface, directly related to the diameter and shape of the bubble. The operation of the bubbler contributes to the production of a monodisperse phase.

The output parameter of the bubble is the mass of the bubble, the mass of the attached material, or the concentration of valuable components. By analyzing the relationship between input and output parameters, rational solutions can be found to improve the functioning of the flotation apparatus.

Conclusion

1. The ore flotation apparatus was studied as a system consisting of a number of interconnected elements, the components of the flotation apparatus were analyzed, the processes and phenomena occurring in the elements in the units of the flotation apparatus were analyzed.

2. The processes and phenomena occurring at the second level of hierarchies are analyzed; the behavior of elements, called quasi-apparatuses, is studied, both from the point of view of a system of interconnected elements, and from the point of view of the regularity of the processes occurring in each element under consideration.

3. At the third hierarchical level, a working chamber consisting of a number of elements is considered, in which all input and output parameters are identified.

4. At the next level of the hierarchy, the liquid phase was investigated, which is a suspension with crushed ore of valuable components, which contributes to good adhesion of particles of the gas phase. The input and output parameters of the considered quasi-apparatus are determined. The elements and processes occurring in the gas phase are studied. On the basis of deepening to the next, lower level of the hierarchy, the elements and processes are studied, which proceed in the gas phase, consisting of the elements of gas supply, its distribution, as well as the transition and exit through the foam layer. For each composite quasi-element, input and output parameters are determined.

5. At the next hierarchical level of the hierarchy, a gas distribution system was studied, consisting of quasi-elements, bubbling and grinding of gas bubbles. For these links, input and output parameters are also defined.

6. A quasi-apparatus for the gas phase, which is a gas bubble distributed in the liquid phase, was studied separately. For this case, the input and output parameters of the bubble are also defined. An analysis of the functioning of a quasi-apparatus makes it possible to compile mathematical or computer models of the processes occurring in the considered apparatuses. By

generalizing local models, it is possible to compile a generalized computer model of the process of technological processes occurring in the flotation apparatus as a whole.

7. A method of sequential execution of procedures (algorithm) of system analysis with subsequent transition to finding the best solution is proposed.

REFERENCES

1. Вершинина И. П. Системный анализ и математическое моделирование процесса развития течения аномально-вязкой жидкости во вращающейся вокруг своей оси трубе Научная библиотека диссертаций и авторефератов disserCat Волгоград, 2004, 146 с.

2. Горшкова К. Л. Системный анализ и автоматическое управление процессом транспортировки вязкой нефти, http://d21221703.samgtu.ru/sites/ d21221703.samgtu.ru/files/ gorshkova_dis.pdf, Альметьевск – 2015, 165 с.

3. Подлесных В.И., Кузнецов Н.В. Теория организация.- М.:ДРОФА, 2013.– 352с.

4. Семенова И.Н. Автоматизация технологических процессов: Курс лекций. Ч.1/ Норильский индустриальный институт. - Норильск, 1996. -76с.

5. Агафонов В. Системные принципы стратегического планирования. Кластерный подход. М.: Palmarium Academic Publishing, 2014.– 572с.

6. Гапонов Г.А., Санакулов К.С., Колтунова Л.Н. Исследование и совершенствование технологии обогащения медно-молибденовых руд Алмалыкского горно-металлургического комбината// Сб. докл. Науч. практ. конф., Эрдэнэт, 2001. - С. 177-179.

7. Фазлуллин М.И. (ред.) Кучное выщелачивание благородных металлов Монография. — М.: Издательство Академии горных наук, 2001. — 647 с.

8. Алексеев А.Ф., Алексеев Ф.Ф., Дегтярев Г.Л. Анализ и синтез нечетких систем управления с запаздыванием и импульсами. Вестник КГТУ им. А.Н.Туполева. 2012. № 2. С. 274-281.

9. Афонин В.В. Моделирование систем: Учебно-практическое пособие / В.В. Афонин, С.А. Федосин. – М.: Интернет-Университет Информационных технологий; БИНОМ. Лаборатория знаний, 2010. – 231 с.

10. ArtikovA., Multi-step method of computer model formalization with fuzzy sets application. WCIS-2004, world conference on intelligent systems for industrial automation, Tashkent-2004, TSTU.

11. http://victor-safronov.narod.ru/systems-analysis/papers/to-question-of-systems-analysis-development.html.

12. *Подоляк, М. В. автоматизация процесса флотации золотосодержащих сульфидных РУД//Молодёжь и наука: Сборник материалов VIII Всероссийской научно-технической конференции студентов, аспирантов и молодых учёных, посвященной 155-летию со дня рождения К. Э. Циолковского [Электронный ресурс].—Красноярск: Сибирский федеральный ун-т,2012.—:* http://conf.sfu-kras.ru/sites/mn2012/section03.html

13. https://xreferat.com/102/2249-1-puzyri-v-zhidkosti.html