ANNOTATION

on PhD thesis of Orakbayev Y.Zh.
in specialty 6D070200 - "Automation and Control"
on the topic: "Research and development of effective control systems of the in-situ leaching process"

Actuality of work. As it is known, the geotechnological method of mining is the most effective, and it is being introduced and actively used in Kazakhstan. The effectiveness of this method of mining is largely determined by an operational assessment of the main parameters of the hydrodynamic state of the wells and layers of the ore body and a control system based on these estimates.

The peculiarity of the process of in-situ leaching is determined by the process of filtration of liquid in the soil. The permeability of ores and host rocks is one of the most important conditions for the movement of leaching solutions, therefore, in the modeling of in-situ leaching processes, the study of filtration properties is one of the main tasks. However, using this method, undeveloped stagnant zones arise, and it is therefore necessary to conduct studies to increase the extraction of mineral by determining the optimal control systems for electric drives of submersible pumps and operating modes of wells, as well as controlling the filtering currents in the formation.

The current practice and management systems of the geotechnological field are characterized by the fact that the management of the technological process of in-situ leaching consists mainly in maintaining the balance consumption characteristics for leaching and grout products. Tasks for expenses are formed on the basis of geotechnological data and experience, and the skills of the mine geotechnician. In this case, the process is maintained under conditions of information uncertainty of the current characteristics of the filtering properties of the medium, such as the permeability of the ore body, which connect the filtration rate with the pressure gradient.

In-situ leaching has a number of characteristics that require specific and effective means of control. In-situ leaching occurs underground and can not be directly observed and controlled. The monitoring of in-situ leaching is limited to injecting the leach solution into the filling wells and pumping out grout solutions from the recovery wells, as well as a limited number of observation wells.

At present, much attention is paid to the development of more effective algorithms for managing the technological processes of in-situ leaching. This is due to the fact that the management of the in-situ leaching process occurs in conditions of information insecurity of the technology due to lack of information on basic parameters such as piezoelectric conductivity (porosity) of the ore body. All this leads to a decrease in the efficiency of the process of in-situ leaching. In this regard, it is very important to develop new approaches and management methods that increase the effectiveness of the process of in-situ leaching.

Objective. Develop a structure for identifying the hydrodynamic parameters of the in-situ leaching process and, on the basis of constructing an effective hierarchical control system to optimize the management of the subsurface leaching of uranium.

The main idea of the work. Development of a three-level control system for optimal distribution of leaching solutions, and synthesis of control systems for the effective recovery method, by determining "stagnant zones" based on numerical simulation. Construction of mathematical models and identification of analytical dependencies for substantiation of optimal control of in-situ leaching technology aimed at efficient operation.

Objectives of the study. In accordance with the goal, the following scientific tasks have been identified, which must be solved in this work:

- identification (evaluation) of the filtration properties of the ore body (porosity coefficient) for each filling well of the geotechnological field unit;
- distribution of the leaching solution from the filling wells of the block, in accordance with the task obtained from the average control level;
- develop a predictive model of the leaching process for the block;
- implement the algorithms for the distribution of the leaching solution in blocks of the geotechnological field according to the indications of the content of the useful product in the grout solution;
- to conduct research of management models on sensitivity, stability, uniqueness and assess the degree of their adequacy;
- study of the effect of changes in well production rates on the leaching solutions of hydrodynamic stagnant ("dead") zones formed by current lines in a series of filling wells;
- build numerical models to identify stagnant zones of the in-situ leaching process in Comsol MultiPhysics;
- develop software that implements algorithms in industrial controllers;
- to test the algorithms in industrial conditions.

Object of study. The object of the study is the method of extracting minerals by an in-situ leaching process that consists of filling well and pumping wells and an aquifer where the ore body is located.

Methods of research. In the course of solving the tasks posed, the theory of automatic control, methods of mathematical modeling, modeling of objects in partial derivatives, numerical modeling using finite element methods, identification methods, methods of hydrodynamic exploration of wells, methods of signal processing will be used.

As modeling tools, modern application packages were used: Matlab, Comsol MultiPhysics.

Scientific novelty of the work:

- an algorithmic three-level control system for the process of in-situ leaching;
- methods for estimating the filtering properties of the ore body (task of parametric identification) for the process of in-situ leaching;

- methods and tools for developing mathematical models of the object management process are proposed;

- algorithmic maintenance of a problem of distribution of leaching solutions is developed:

➢on the wells on the basis of the evaluation of the porosity of the ore body;

➢ on the block on the basis of evaluation of the concentration of the productive solution;

➢on the geotechnological field (by blocks) based on the estimation of the calculation of uranium reserves;

- numerical models are built for determining stagnant zones in Comsol MultiPhysics;

- modes of operation (stationary and non-stationary) are proposed to increase the efficiency of the in-situ leaching process at the level of the geotechnological field;

- processed and analyzed the results obtained in industrial tests of identification and control algorithms for adjusting the algorithmic and software systems;

The following scientific provisions are made for defense:

- algorithmic three-level control system of the in-situ leaching process for optimal distribution of leaching solutions;

- identification of the filtration properties of the ore body (porosity coefficient) for each well of the geotechnical field block, by measuring the level of the leaching solution in the well (budget version of the level gauge) and the leaching solution flow rate and solving the problem of well testing (hydrodynamic studies of wells);

- the results of numerical models that show stagnant zones in existing modes of in-situ leaching in Comsol Multiphysics;

- results of studies of numerical models of operating modes (stationary and non-stationary) for wells to completely wash out stagnant zones and increase the efficiency of the in-situ leaching process at the level of the geotechnological field;

- analysis of the results obtained in industrial testing of identification and control algorithms for adjusting the algorithmic and software systems.

Practical significance of the research results:

The developed measuring instruments and control methods will allow to test the budget variant of level measurement in the filling wells, using the level and flow characteristics of the leach solution, an algorithm for evaluating the filtering properties of the medium (ore body) is developed. On the basis of the obtained estimates of the current filtering properties of the ore body, algorithms for the optimal distribution of leaching solutions over blocks of the geotechnological field have been developed. In addition, at the top level of management tasks will be solved and algorithms will be developed to select a stationary or non-stationary leaching regime for washing away stagnant zones of the ore body along geotechnological field blocks. The developed system of optimal management of uranium mining processes will reduce the costs of material and energy resources of

production, improve the quality of products and reduce the environmental consequences of the technologies used.

The obtained results of the optimal algorithm for the distribution of the leaching solution from the filling wells and the effective operating conditions of the submersible pumps of the pumping well were used in the development of the research work: "Development of network models for the synthesis of the optimal control system for in-situ uranium mining", State Registration No. 0113RK00566, 2013-2015.

The developed device for data collection and transmission laid the foundation for the technical support of research work: "Development and implementation of the pilot project of the integrated automated control system for the heat-supply complex in Taldykorgan," No. State Registration No. 3927 / GF4, 2015-2017.

Specific personal participation of the author in obtaining scientific results is as follows:

- setting research objectives and ways to implement them;
- development and construction of mathematical models of wells and ore body, identification of parameters of in-situ leaching.
- development of an algorithmic hierarchical control system for the process of in-situ leaching;
- determination and evaluation of the predictive model in numerical modeling to identify stagnant zones in the in-situ leaching model in Comsol Multiphysics;
- determination of well operation modes for increasing the efficiency of the in-situ leaching process in the geotechnological field;
- practical implementation of the effective distribution of leach solutions and the development of a wireless hydrostatic level sensor.

Approbation of work.

The main results of the work were reported and discussed at the International Scientific and Practical Conference "The Role and Place of Young Scientists in Implementing the New Economic Policy of Kazakhstan" of the International Satpaev Readings (Almaty, 2015); at The 15th International Scientific Conference Information Technologies and Management (Riga, 2017); at the International Scientific and Practical Conference "Mathematical Methods and Information Technologies of Macroeconomic Analysis and Economic Policy" (on the occasion of the 80th birthday of Academician A. Ashimov) (Almaty, 2017); on Lubelskie Dni Nauki i Biznesu. Pod patronatem honorowym Polskiego stowarzyszenia tomografii procesowej I Komitetu elektrotechniki polskiej akademii nauk. Warsztaty doktoranckie. WD2016. Science conference (Lublin, 2016); on Environmental Engineering V: proceedings of the fifth National Congress of Environmental Engineering, (Lublin, Poland, 2016).

Publications. On the theme of the thesis 13 works were published.

Of these, 6 abstracts at conferences, including 5 international ones, 2 articles published in foreign conferences (Poland, Lublin), 3 articles in journals recommended by the Higher Attestation Commission, 1 article in the engineering

and technical journal, 3 articles published in foreign publications, included in the international database on quoting Scopus.

The structure and scope of the dissertation: Dissertational work consists of an introduction, five sections of the main content, conclusions and applications, a 60 bibliographic list, of 113 contains pages, 62 figures and 2 tables.