ABSTRACT

of a Doctoral thesis for the degree of Doctor of Philosophy (PhD),
Specialty 6D070700 "Mining"

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INCREASE OF EFFICIENCY OF BOREHOLE URANIUM MINING BY INTENSIFICATION OF UNDERGROUND LEACHING PROCESSES

Actuality of the topic

Kazakhstan has 14% of the world's proven uranium reserves and ranks second after Australia, with 70% of them suitable for borehole development. Underground leaching of uranium is used in Kazakhstan at 26 sites, grouped into 13 uranium mining companies. Total natural uranium production is more than 40% of the world total.

The number of production wells and process blocks at uranium underground leaching plants increases annually. This is caused by a gradual decrease in the productivity of the uncovered blocks and a decrease in the well utilisation rate from 0.9 to 0.7-0.6. As well as the predominance of fine-grained aggregates of kaolinite, potassium feldspar and gypsum in ores form multi-component, complex soluble sediments including particles of silica, gypsum and clay minerals. They contribute to a more intensive decline in the productivity of geotechnical wells, which has raised the problem of intensification. At the same time, there are no effective tools to improve well productivity and prevent sedimentation over the long term under difficult mining-geological conditions. Development of production blocks under these conditions is often accompanied by serious complications and irreversible reduction in the permeability of the near-wellbore formation zone (NFZ), which dramatically increases development time and additional costs. The proportion of idle wells in the fields is increasing, requiring complex workovers that are comparable in cost with the construction of new wells.

Chemical methods of intensification based on interaction of acid solutions at gypsum deposits are used to increase efficiency of borehole uranium mining (Mamilov V.A., Bitimbayev M.Zh., Yusupov Kh.A., Yazikov V.G., Zhatkanbayev E.E.). Other authors proposed scientific-technical solutions on selection of rational parameters of opening and intensification of borehole uranium mining in low-permeable ores (Molchanov A.A., Duisebayev B.O., Alikulov Sh.Sh., Karimov I.A.). The research results obtained by the authors served as the basis for the search and development of a new direction to improve the efficiency of underground uranium leaching under multicomponent and complex sedimentation.

Analysis of these and other works shows that the search for new ways to improve the efficiency of borehole uranium mining under complex mining-geological conditions, is an urgent, scientific, and engineering task.

The study objective is to establish the regularities of changes in the properties and structure of sediment-forming components from the composition and concentrations of chemical reagents to improve the efficiency of borehole uranium mining.

The idea of the work is to use a complex of multifunctional chemical reagents, increasing the efficiency of underground uranium underground leaching by intensifying geotechnological processes under complex mining-geological conditions.

Research tasks

To achieve the above objectives the following tasks were formulated to solve:

1. To study the composition and structure, physical and chemical characteristics of ores of the productive horizon and sediment-forming components in the near-filter zone of wells of uranium deposits in the Syrdarya depression.
2. Determine the patterns of filtration characteristics of ores of productive horizon and uranium recovery parameters depending on the composition of ore-bearing rocks and chemical reagents of multifunctional purpose.
3. To develop a methodology for justification of rational parameters of multifunctional chemical reagents application to increase the efficiency of borehole uranium ore mining.

Scientific statements for the defence

1. Intensity of sedimentation during borehole uranium mining increases exponentially depending on the granulometric and mineralogical characteristics of ores of the productive horizon.
2. The low filtration rate of solutions in low-permeable ores can be prevented by adding sulphamic acid and lignosulphonate to the leaching solution.
3. Rational parameters of chemical reagents usage are reached at directly proportional increasing of sulphamic acid rate from 0,2 to 0,4 kg/t of rock mass, and lignosulphonate rate from 0,1 to 0,2 kg/t of ore mass at increased values of fine-grained fraction from 40 to 60 % from total mass of ore productive horizon. At the same time, the area of treated rock mass increases by 50 %, on account of spreading of chemical reagents in the productive horizon.

Main research results and their practical significance

1. The X-ray phase studies and comparative analysis of mineralogical composition of ores and sediment-forming components of Santon, Maastricht and Kampan productive horizons helped to establish the main factors affecting filtration characteristics of ores. It was determined that presence of gypsum over 5% and clay minerals over 20%, as well as heterogeneity of ores of productive horizon form sediments that complicate borehole uranium mining processes. The

ratio of fine-grained aggregates, kaolinite, clay minerals to medium-grained fractions in the rock mass determines the sedimentation rate and reduction of filtration characteristics of ores of productive horizon.

2. Based on the established regularities of changes in the properties and structure of sedimentation and filtration characteristics of ores, chemical reagents were selected to effectively destroy and prevent the processes of sedimentation during borehole uranium mining. This is achieved through the use of sulphamic acid, as a solution pH reducer with complexing properties, lignosulphonate as a foaming agent and solvent for clay minerals. During the uranium leaching from core materials, the recovery of uranium from ore was increased from 70% to 80%. Specific consumption of sulfuric acid was decreased from 50 to 40 kg H_2SO_4/kgU at the expense of increase of filtration speed from 0,5 to 0,6 m/day.

3. The technology of treatment of productive horizon of geotechnological wells with low filtration characteristics of ores by selected complex of chemical reagents of multifunctional purpose was developed. It provides filtration of sulfamic acid 0.2 - 0.4 kg/t GRM, lignosulfonate 0.1 - 0.2 kg/t GRM into productive horizon depending on quantity of carbonate and clay minerals, filtration coefficient of ore in productive formation. Efficient parameters of new technology application are substantiated, depending on mineralogical characteristics of host rocks of the productive horizon. On the whole, the intensification of uranium leaching at the stage of development of production blocks and reduction of specific sulphuric acid rates are provided under complex mining-geological conditions of uranium mining enterprises of the Republic of Kazakhstan.

Research object: the uranium deposits of the Syrdarya depression.

Research subject: technology for borehole mining of uranium ores.

Research methodology

Scientific research was carried out using analysis and generalisation of scientific-technical information, methods of mathematical statistics for processing experimental data and feasibility study of various technology options. Laboratory works were implemented employing theoretical generalisation of the experimental data, X-ray phase method of investigation of mineralogical characteristics of samples of core materials and sediment-forming components. Experimental work on geotechnical boreholes confirmed the results obtained using the developed test methodology. It provides data collection and monitoring, tracking, comparative analysis of geotechnological characteristics of wells before and after tests with a complex of multifunctional chemical reagents.

Scientific novelty. Regularity of changes in physical and chemical characteristics of sediment-forming components from mineralogical composition of ores of productive horizon and concentration of sulphuric acid during borehole development was established. Effective parameters and concentrations of chemical reagents for increasing uranium recovery during leaching in low-permeability ores

were determined. The regularity of chemical reagents consumption change on particle size distribution and mineralogical characteristics of ore productive horizon at intensification of borehole uranium mining was established.

Relevance to the direction of scientific development or state programmes

The thesis was developed in accordance with the following projects: AP05131477 "Development of new technology for underground uranium leaching using a complex of synergistic chemical reagents for borehole uranium ore mining" (2018-2020);
AP08856422 "Development of innovative technology for intensification of borehole uranium mining using a hydrodynamic decolmatation device combined with a complex of multipurpose chemical reagents" (2020-2022), within grant funding for scientific and (or) science and technology.

Publications and approbation of work

The main provisions of the dissertation work were reported at E3S Web of Conferences 2020, the international scientific-practical conference "Rational use of mineral and technogenic raw materials under conditions of Industry 4.0" (Almaty, 2019), the scientific-practical conference "Satpaev Readings'2019" (Almaty).

Approbation of the developed technology for intensification of borehole uranium mining was carried out in the Materials Research Laboratory at the Institute of Higher Technologies, within the R&D framework on the topic "Pilot tests for intensification of uranium recovery under complex mining-geological conditions through selection of optimal composition of solutions for repair and workover with development of technological regulations for geotechnological fields" (2020) at uranium deposits of the Syrdarya depression.

Fifteen papers were published on the thesis topic. Of these, six are in the 2nd quartile of the Scopus (Scopus) database, five are in the 3rd quartile of the Scopus database, and four are in conference proceedings. Each article published by the doctoral student has made a worthy contribution, they reflect the presented defensive statements and results obtained by the doctoral student in the course of the research.

Doctoral candidate received 3 copyrights for developed technology of borehole uranium mining intensification:

- "Method of borehole uranium mining from carbonate and low-permeability ores";
- "Mobile unit for hydrodynamic treatment of technological wells";
- "Method for intensification of uranium underground leaching.

Scope and structure of the work

The thesis consists of an introduction, three sections, a conclusion, a list of references and appendices. The volume of the dissertation is 100 pages of typewritten text, 26 tables, 44 figures, list of references including 74 titles.

Conclusion

1. The sediment-forming components of the Santonian and Mastrichtian stages are predominantly composed of gypsum (90 - 98 %) and silica (2 - 10 %), whereas the Campanian stage sediments are multicomponent and include quartz (10 - 40 %), gypsum (10 - 30 %), calcite (5 - 20 %), clay minerals (20 - 40 %). This is due to the complex structure and high heterogeneity of the ore-bearing rocks of the productive formation.
2. Under laboratory conditions, the combined effect of a complex of multifunctional chemical reagents was established. It allows increasing filtration speed in ores from 0.5 to 0.62 m/day, decreasing the liquid to solid ratio value from 1.32 to 1.2 while achieving 70% uranium recovery from ore. At the same time, specific consumption of sulphuric acid per unit of dissolved uranium is reduced from 50 to 40 kg/kgU.
3. A methodology was developed and tested to calculate and process the near-wellbore zone and the productive horizon, the use of which made it possible to increase the efficiency of borehole uranium mining in complex mining and geological conditions, taking into account the filtration characteristics of the productive horizon ores. The effective area of chemicals spreading in productive horizon within radius of 10 to 25 m from the well was determined. As a result, the productivity of producing wells increased from 4.0 to 6.0 m^3/hour, the average period of wells uninterrupted operation increased from 20 - 30 days to 45 - 60 days.
4. The parameters of application of multifunctional chemical reagents complex depending on mineralogical characteristics of ores of productive horizon and composition of sediment-forming components were substantiated. This makes it possible to increase filtration characteristics of near-filtration reservoir zone, uranium content in productive solution by 20%, increase productivity of production wells and injectivity of injection wells by 20 - 30%, reduction of block development period and operating costs for production by 5%.