ABSTRACT

Dissertation for the Degree of Doctor of Philosophy (PhD) in the Educational Program 8D07202 – "Mining engineering"

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SUBSTANTIATION OF MINING PARAMETERS BASED ON MODELING THE GEOMECHANICAL STATE OF THE ROCK MASS

Relevance of the Study- One of the key challenges in open-pit mining is ensuring safety and improving the efficiency of mining operations. Deposits with simple geological conditions and high concentrations of valuable components in ores have already been exploited or are nearing the end of their mining lifecycle.

The modern development of the mining industry is characterized by increasingly complex operational conditions due to the greater depth of extraction and the involvement of sections or entire deposits with challenging geological conditions. This complexity drives up the cost of resource extraction, necessitating a revision of initial technological solutions and an increase in the final slope angles of pit walls.

This raises the issue of ensuring the stability of pit walls and selecting rational parameters for newly designed benches at deeper horizons, taking into account the geomechanical conditions of development.

A critical requirement for revising the initial design parameters for deposit development is obtaining information about the geomechanical state of the rock mass. This includes data on the stress-strain parameters, geological-structural features of the deposit, and the physical-mechanical and strength properties of the host rocks and ore veins.

As the depth of existing pits increases, slope stability becomes an issue of economic importance and further development for mining enterprises operating open-pit mines. Justifying stable slope and bench parameters in deep pits enables access to deeper ore deposits for active operations.

Thus, ensuring the safety of open-pit mining by substantiating optimal pit parameters, including the general angle of working slopes under various complicating factors and disruptions in ore deposit structure, is a relevant task. This substantiation relies on considering the lithological characteristics and physical-mechanical properties of the near-slope rock mass using analytical modeling.

The **concept of the study** lies in utilizing empirically established relationships between the safety factor, the general slope angle, and the cohesion of the near-slope rock mass of host rocks and ore veins. These relationships take into account structural features and strength properties to justify the parameters of the designed pit through the application of numerical methods for determining optimal bench angles.

The **objective of the dissertation** is to identify patterns of changes in the stress-strain state of the near-slope rock mass in a pit by determining optimal

parameters. This involves considering the geomechanical state of pit slopes, based on lithological characteristics, physical-mechanical, and strength properties using analytical modeling.

Stages of the Research:

- analysis of existing technical solutions for the development of active deposits to identify optimal parameters for conducting open-pit mining operations.
- drilling and documentation of geotechnical boreholes to determine the stability rating of the rock mass.
- investigation of strength parameters and structural features of the near-slope rock mass.
- creation of a three-dimensional block model to process and analyze geotechnical drilling data for forecasting the state of the near-slope rock mass and justifying the parameters for open-pit mining operations.

Object of the Research - The object of the study is the stability of the near-slope rock mass in the "Northern Katpar" tungsten deposit pit

Methodology of the Dissertation:

- analysis of geological-structural and hydrogeological conditions of the near-slope rock mass at the "northern katpar" tungsten deposit.
- review of available data on the physical-mechanical properties of the deposit's rocks and examination of the rock mass's structural composition based on geological exploration results, with the determination of their calculated strength characteristics.
- kinematic analysis of planar sliding stability.
- analytical modeling of the stress-strain state of the rock mass.
- designing the final pit contour.
- numerical finite element analysis to determine the rock strength rating and safety factor of the rock mass.
- construction of geotechnical, structural, block, and geomechanical models of the deposit.

Scientific Novelty of the Dissertation:

- establishment of the relationship between the safety factor, the general slope angle, and the cohesion of the near-slope rock mass during open-pit mining operations.
- identification of patterns in the variation of the safety factor depending on the water saturation of fractures and its impact on the stability of the rock mass.
- development of effective methods for justifying open-pit mining parameters, considering structural characteristics and physical-mechanical properties.
- justification of the general pit slope angle, accounting for the deposit's lithological characteristics, fracture patterns, cohesion, physical-mechanical properties, and the impact of water saturation on the stability of the near-slope rock mass using a 3d block model.

Scientific Provisions for Defense:

- the stress-strain state of the rock mass changes in the form of displacement along intersecting planes and wedge-shaped blocks, as well as the overturning of rock blocks towards the mined-out space.
- the safety factor increases with the growth of the general slope angle of the pit wall and the cohesion of the near-slope rock mass during open-pit mining operations.
- the safety factor decreases with the increase in the water saturation factor of fractures.

Practical Significance of the Study:

- optimal parameters of the designed pit have been justified based on geotechnical investigations of oriented core drilling and kinematic analysis of planar sliding using the dips software to construct a geomechanical model of the deposit.
- optimal pit wall parameters have been determined through the analysis of geomechanical numerical modeling results, providing recommendations for open-pit mining parameters.
- the general slope angle of the pit has been justified, taking into account the lithological characteristics of the deposit, fracture patterns, cohesion, physical-mechanical properties, and the impact of water saturation on the stability of the near-slope rock mass using a 3d block model.
- geomechanical parameters for open-pit mining have been established to ensure rational and safe mining operations, with substantiated ultimate slope angles considering the geological and hydrogeological conditions of the deposit.

Final Reliable Results of the Scientific and Experimental Research in the Dissertation:

- determination of optimal slope angles and probabilistic evaluation of pit wall stability based on the study of the near-slope rock mass structure and its physical-mechanical and strength properties to ensure the safety of mining operations.
- according to the stability assessment of the "northern katpar" pit walls based on numerical modeling results, it was established that the safety factor values across all geological sections are sufficient to ensure the safety of open-pit mining operations.
- formation of a structural model of the "northern katpar" deposit for visualizing and calculating the spatial distribution of lithology and a block-structured model for determining the rock mass stability category to calculate optimal pit wall parameters during the design, construction, mining, and tungsten ore extraction stages.

Personal Contribution of the Author. The research tasks were established, and based on them, applied scientific and analytical studies were conducted, with key scientific provisions formulated. The stability of the near-slope rock mass was analyzed using numerical modeling methods, utilizing finite element analysis to assess the stress-strain state under the influence of various factors.

Implementation of the Dissertation. The research results were implemented in a scientific conference thesis and in the integration of recommendations into the development project for the "Northern Katpar" tungsten deposit. The author completed a scientific internship for research on parameter determination, using equipment, research laboratories, and stands at the Navoi State Mining Institute (Navoi, Uzbekistan), as well as at the "Northern Katpar" mining enterprises to test technological developments.

Structure of the Dissertation: The dissertation consists of an introduction, four chapters, totaling 91 pages, 60 illustrative materials, 24 tables, a list of 96 sources, and four appendices.

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