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ОСОБЕННОСТИ УЧЕТА ТРЕЩИНООБРАЗОВАНИЯ В ЗАДАЧЕ МОДЕЛИРОВАНИЯ НАПРЯЖЕННО-ДЕФОРМИРОВАННОГО СОСТОЯНИЯ ГОРНОГО МАССИВА

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FRACTURING SPECIFICITY IN ROCK MASS STRESS-STRAIN STATE MATHEMATICAL MODELING TASK

Introduction

Rock mass stability analysis is an integral part of mining projects' design stage, referring to various mining enterprise activity factors improvement such as technical and economic performance, workers' safety and so on. Today, mathematical modeling methods are actively employed to solve this problem. The construction of digital models representing geomechanical processes allows to assess the current stress-strain state of rock mass, as well as to predict its future state. At the same time, more accurate analysis results performed by computer models can be achieved by taking into account a large number of factors affecting mechanical and density properties in the mining area. In addition, as underground mining depths increase, monitoring current stress-strain state and controlling rock mass stability become increasingly difficult [1].

The most important factor influencing rock mass state is fracturing, a characteristic that can be interpreted as a set of discontinuities of a specific rock mass sample [2]. Thorough study of historical fracturing, being a result of long-term impact of geomechanical, tectonic, physical and mechanical processes, with the help of imitation modeling, allows researchers to determine the nature of future rock deformations.

The above statement underlines the relevance of this research work. At present, taking into account rock mass fracturing in its stress-strain state analysis process remains an important and significant task in geomechanics.

Considering stress-strain state modeling task difficulty, the goal of this research work was to identify modern approaches to rock mass stress-strain state mathematical modeling with the consideration of fracturing. To achieve this goal, the following tasks were set: to identify fracturing specificity as one of rock characteristic; to conduct a review of existing rock fracturing mathematical modeling methods; and to determine strengths and problems of current rock mass stress-strain state modeling methods. In terms of practical value, the results of this work can be understood as materials preparation for subsequent research related with rock mass stress-strain state modeling methods improvement.

Research methodologies

In the modern concept of fracturing, a large number of individual fractures and fracture systems characteristics are highlighted, allowing them to be classified according to various features [1]. Depending on their origin, fractures can be divided into natural and anthropogenic. Geometric classification distinguishes longitudinal, transverse, oblique and conformable fractures. The paper [3] presents a classification based on three parameters: stiffness perpendicular to the fracture, tangential stiffness, and shear strength of the fracture. In this classification, each parameter can take "high", "medium" or "low" value. Stiffness data is obtained by determining parameters characterizing fractures' surface: adhesion; internal friction angle; roughness coefficient. It is noted that this classification is used to model different types of fractures and to take into account structural heterogeneities when assessing the stress-strain state of rocks [4].

In the field of fracture systems research, a set of parameters is also highlighted, including the density, width, length, angle and incidence azimuth of the fractures, etc. Fracturing intensity, a parameter which characterizes the reduction in the physical properties of the rock, is modeled in the work [5] based on the azimuth of the strike, the angle of incidence and the frequency of fractures in the system. The fracturing intensity parameter, in turn, determines the reduction of rocks elastic modulus and the reduction of rock strength properties in direct proportion to the coefficient k, calculated using formula (1) [6]:

$$k = \frac{1}{1 + 0{,}5 I_T}, \tag{1}$$

where I_T – fracturing intensity.

Particular attention is paid to the modeling methods of fractures formation processes resulted by anthropogenic impact, in which some specific rock mass state parameters are taken into account. The following processes can be cited as examples:

1. Well drilling. In this case, due to the presence of stress concentration zones around the wellbore, anthropogenic tensile fractures on the well walls are formed [7].
2. Hydraulic fracturing. Unlike drilling, hydraulic fractures propagate into an undamaged area of the formation. In addition, modeling considers the properties of fracturing fluid, proppants and other features [8].

Results discussion

In accordance with the goal of this work and the methodologies used, the following research results were formed. First of all, it was proved that rock fracturing plays an important role in stress-strain state modeling task, either being single fractures analysis or a fracture systems analysis.

In the first case, fracturing determines the structure of rock mass and therefore directly affects stress vector field distribution. Thus, during finite element method calculations, at each stage, for all selected systems, fracture parameters like shear and tensile strengths across weakened surfaces should be calculated.

In the case of fracture system analysis, it is impractical to model every small fracture, which leads to approach when fracturing is associated with the physical and mechanical properties of the rock, such as its elasticity and strength. According to this, there is a fracturing intensity parameter calculated from fracture system characteristics which value is used to assess said rock properties.

As another part of the study, an analysis of several rock mass state mathematical models was conducted. First of all, it is worth noting that various factors, such as the block nature of the environment, blocks strength parameters, different types of rock mass discontinuities and significant dimensions of models do not allow for analytical solutions to be employed for rock mass state assessment task. At the same time, field experiments are expensive and do not allow to predict state dynamics during mining operations compared to numerical methods, which explains the high popularity of these methods in mining area. Today, the following mathematical modeling methods are actively used: finite difference method (FDM), finite element method (FEM), and boundary element method (BEM), among others. The advantages of most popular finite element method include versatility, flexibility in model geometry, model scaling, accuracy control in calculations and optional anisotropy in models.

So, fracturing processes in rock mass can be analyzed using methods like FEM, but the biggest problem to consider is that calculations for these methods are too cumbersome for manual calculation, even in the case of solving simple problems. Moreover, to achieve high accuracy, stress-strain state modeling requires many parameters to be taken into consideration, forcing developers to find a compromise between simulation speed and accuracy using large computational resources and algorithms optimization.

Conclusion

As the end of this work, it can be noted that geomechanical processes in rock mass currently have been studied in detail by many researchers, allowing the development of mathematical models that can predict the state of rock mass with high accuracy for specific terrain conditions. Fracturing is also considered as the main factor in the decline of rock strength and elastic modulus. The main limitation with these models is that they require a large number of parameters to be considered for each point in the mass. There can be a vast number of points on the grid, and even with the development of computing power, numerical methods optimization remains the main task for future research on this topic.

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