THREE-DIMENSIONAL GEOMECHANICAL MODEL OF THE TASHTAGOL IRON-ORE DEPOSIT

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INTRODUCTION

A large number of studies are devoted to investigation of characteristic features of the geomechanical state and behavior of the rock mass of the Tashtagol iron-ore deposit. Characteristics of the regional stress field are obtained on the basis of analysis of tectonic structures [1, 2]; the dependence of the physical properties of the component rocks on depth is determined using statistical analysis of experimental data; the level of stresses acting in the ore deposit and lateral rock is established by instrument [3-5]; production schemes for the working of the deposit are examined with allowance for its proneness to shock [6].

Among the studies performed, no attempt has been made to construct a three-dimensional model of the deposit in which basic geomechanical characteristics of the entity would be defined more precisely in combination. The present study fills this gap. Attention is given to the following factors in the model's construction; the interrelation between local and regional stress fields; the three-dimensional geological structure of the deposit and the actual configuration of the worked space; the location of structural faults and their condition; and, the relief of the locality.

According to the terminology that we adopted in [7], the Tashtagol deposit is considered a natural entity on the local level. All calculations were performed by the finite-element method using the 3MKÉGK program, which is oriented toward the solution of three-dimensional problems of geomechanics for media with discontinuities [8].

Characteristic Features of Construction of Finite-Element Model

A local Cartesian coordinate system was initially introduced to formulate machine-readable data on the structure of the deposit; the x-axis was directed across the strike of the ore bodies (azimuth θ = 40°), the y-axis along the strike, and the z-axis vertically upward. The coordinate origin was placed on the zero horizon coinciding with sea level.

The region investigated with dimensions of 2400, 2800, and 1000 m along the respective coordinate axes was selected so as to be completely situated within the block bounded by the Tashtagol and Kochurinsk fractures with the upper boundary at elevation +70 m, below the minimum (+120 m) elevation of the relief.

Data on faults of a lower hierarchical level than the above-mentioned fractures are defined more precisely within the limits of the region investigated. The data are borrowed from [2, 9] and plans for mining operations. All faults are steeply dipping, and the angle of incline is 80-90° [9]. Only faults that had completely intersected the region investigated were included in the model; information on these faults was contained in at least two independence sources. A restriction on the number of more precisely defined faults was also partly caused by the potential of the computer facilities.

The contours of the ore deposit were taken from production plans for mining operations at the horizons from 0 to −490 m (heavy lines in Fig. 1); they were then numbered in the local coordinate system introduced.

The local coordinate system was referenced to geographical coordinates to include data on local relief in the model. The relief was taken from a 1:50,000 map; linear interpolation was employed when necessary.

The computational region was discretized in two stages. The plane region was first divided into rectangles on each horizon with allowance for the configuration of the ore bodies and faults (thin lines in Fig. 1). A three-dimensional grid of...
finite elements (hexahedrons) was then laid out from plane elements. The dimensions of the elements were selected as 30 x 30 x 35 m on average in the zone where mining operations are conducted, and were enlarged beyond its limits. Discontinuities were modeled by plane contact-elements [8]. On the whole, the region under investigation was partitioned into 20,000 elements.

Physical Properties of Rocks

The physical properties of the basic rocks contained in the deposit are presented in Table 1. This information summarizes data derived from many sources. For a worked space, Young's modulus was reduced by one order

\[ E_0 = kE, \quad k = 0.1, \]  

and a density of up to 2,000 kg/m³ was selected.

The deformation properties of the faults were not investigated in the region under consideration; they were therefore estimated by methods described in [7, 10]. The thickness \( h \) of the disjunctive faults in the deposit fluctuates from 3 to 50 m and is associated with the structural hierarchy of the mass [11]. Focusing attention on the transverse dimensions of the ore bodies and Shamanskaya and Egorov's data [1] on the average distance between faults, a value \( h = 6 \) m was adopted for the calculations. Accordingly, the nominal stiffnesses \( K_n \) of the contact-elements (with the use of which the fracture faults were modeled) were selected equal to 10 GPa/m on the "rock—rock" contact, and 15 GPa/m on the "ore—ore" contact. In the worked space, \( K_n \) was reduced by two orders.

The tangential stiffnesses of the contact-elements were initially calculated from the relationship [10]

\[ K_{t1} = K_{t2} = 0.1 K_n. \]  

They were then estimated using data derived from field observations on displacements in the mass in accordance with the following procedure. The relative displacements (benchmark stations were located in cross-cuts) caused by the working of