NUMERICAL MODELLING OF THE STRESSED STATE OF THE FOOT OF A BOREHOLE WITH A STUDY OF DRILL CORE DISKING

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Introduction of mining requires creation of simple and reliable methods for evaluating the stressed state of a rock mass and its rock-burst hazard. One method is determination of the state of the rock mass by drill core disking during drilling of boreholes, i.e., a high conformance method which is reliable for diagnosing the rock-burst hazard and stresses in a rock mass. Experimental studies of drill core breaking into disks has established [1, 2] that the process depends on many factors the main one of which is the stressed state of the rock in the vicinity of the borehole (the foot of it and the drilled core). Results are known of numerical modelling of the stressed state in the vicinity of a drill core [3]. However, the plane problem of stress distribution in the vicinity of a drill core has been resolved. The results obtained do not give complete information about the second principal component of the stress tensor operating orthogonally to the borehole axis.

Solutions are known for the problem of stress distribution at the foot of a borehole by analytical methods although due to the complexity of the general solution they are hardly suitable for practical use. Results of experimental studies have considerable dispersion in their values and they only relate to the center of the foot [4].

Known results were insufficient in order to establish a quantitative correlation between the stress field and drill core disking parameters, and for developing procedures for predicting rock-burst hazard and estimating stresses.

Studies have been carried out by methods of numerical modelling in plane (boundary integral equations method (BIEM)) and volumetric (finite-element method (FEM)) definitions of the problem.

Given in Fig. 1 is the layout of a volumetric model with a borehole of radius R and the distribution of concentration factors for stresses $\sigma_x/\sigma_x^\infty$ through sections 1-4 in the vicinity of the foot of a borehole. Calculations were carried out for the case of uniaxial compression over axis x without side thrust ($\sigma_y^\infty = \sigma_z^\infty = 0$). Results of modelling showed that the magnitude of concentration factors at the center of the foot (Fig. 1b) is $\sim 1.3$, and with departure from the center towards the borehole wall it increases. Here in the direction of axis x (curve 3) it increases more rapidly (by a parabola) than over axis y (curve 4) (almost linearly). Starting from distance x/R $\sim 0.5$ in the direction of axis x the concentration factor increases by a parabola reaching the value $\sigma_x/\sigma_x^\infty|_{x/R=0.8} = 1.4$ and then it increases on approaching the borehole wall. Over axis y the concentration factor increases weakly and at the borehole wall it does not exceed a value of 1.35 with y/R $\to 1$ (curve 4).

With departure from the foot into the depth of the rock mass over axis z the concentration factor decreases and at a distance z/R $= 1.5-2$ it does not exceed 5% of the prescribed stresses $\sigma_x^\infty$ (curve 2).

In section 1 (x/R = 0.16; y = 1.33R) close to the foot (z/R $\to 0$) the value of concentration factor is $\sim 1.4$ (curve 1). With departure from the bottom (z/R $\to 2$) it increases rapidly approaching $\sigma_y/\sigma_x^\infty|_{z/R=1} = 1.75$. Analysis of these results indicates the greatest concentration of stresses at the foot occurs close to the contact of the foot with the walls of the borehole with orthogonal maximum operating stresses in the intact rock mass with $x = \pm R$, whereas in the walls of the borehole at some distance from the foot (more than 4R) the greatest stress concentration is achieved at point $y|_{x=0} = \pm R$.

The next problem consisted of studying the stressed state in the drill core and in the vicinity of the foot of the borehole in plane and volumetric definitions of the problem for the case of an elastic uniform material. Here studies in the plane definition are carried out by the method of photoelasticity and BIEM under conditions of uniaxial compression with different heights of the drilled core. In the volumetric definition of the problem it was resolved by the FEM under conditions of biaxial and triaxial compression.
Fig. 1 Layout (a) and distribution of stress concentration factors $\sigma_x/\sigma_x^\infty$ (b). The numbers of sections 1, 2, 3, 4, and the curves for distribution of stresses over them coincide; for 1 and 2, $x = 0, y = 1.33R$; for 3 and 4, $z = 0.33R$.

Fig. 2. Dependences for stress concentration factor distribution in relation to the change in ratio of height $t$ of a core to its diameter $d$ over the core axis of symmetry; a) plane case with condition $\sigma_2 = -1; \sigma_1 = 0$; b) volumetric case. Stress distribution over line $A-A$, i.e., centers of gravity for calculation grid elements. 1) $\sigma_x^\infty = \sigma_y^\infty = -1, \sigma_z^\infty = 0$; 2) $\sigma_x^\infty = \sigma_y^\infty = -1, \sigma_z^\infty = -0.25$; 3) $\sigma_x^\infty = \sigma_y^\infty = -1, \sigma_z^\infty = 0$; 4) $\sigma_x^\infty = \sigma_y^\infty = \sigma_z^\infty = -1$.

Given in Fig. 2a are curves for the change in horizontal $\sigma_x$ and vertical $\sigma_z$ stresses in the axis of symmetry in the base of the drill core in relation to the ratio of core height $t$ to its diameter $d$ obtained on the basis of solving the problem in a plane definition with $\sigma_2 = -1$ and $\sigma_1 = 0$. It follows from the curves that in both the core and the rock mass tensile stresses $\sigma_z$ arise reaching maximum values in the rock mass at a distance of about 0.1d from the base of the core. Data In these studies made it possible to obtain the following empirical dependence for determining the maximum compressive stresses operating at infinity:

$$\frac{\sigma_z^{\max}}{\sigma_1^{\max}} = -0.2e^{-0.12d/t}.$$

(1)