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Formalization Of Tasks To Ensure The Safety Of Emergency And Explosive Operations In The Mining Industry

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Abstract. **The development of quarries and underground mines is characterized by the need to expand their borders and resume the work of temporarily non-working sections of the countries, as well as maintain the capacity for ore production, the reduction of which is associated with a reduction in the active area of ore bodies. At the same time, work intensification is necessary, which is complicated by the limited size of the working area. Such complications can be largely compensated for by increasing the height of the exploding sill. At the same time, work intensification is necessary, which is complicated by the limited size of the working area. Such complications can be largely compensated for by increasing the height of the exploding sill. This is precisely the purpose of the present research, which was carried out by processing arrays of information that allows us to optimize this process. The study was carried out with machine processing of the information and change of the studied parameters.**

Keywords: coulomb criteria, gas, explosion, hydrodynamics, poisson's ratio, simulation, ventilation

I. INTRODUCTION

The purpose of the present work is how to make a choice of preventive measures and means of labor protection. This is done on the basis of a machine survey and all the chosen solutions must be justified, taking into account the occupational risk as well as the blasting in the mining industry. The existing approaches for objective reasons do not provide an opportunity to justify the choice of the necessary measures to maximally reduce the level of occupational risk in case of explosions in mining. Therefore, an effective methodological approach is needed to justify preventive measures, since the level of risk in mining enterprises is still high. The present study is devoted to solving this urgent scientific problem and finding optimal solutions under the many different combinations of factors that influence the performance of this laborious work.

Various methods and combinations of factors that influence the performance of raw material extraction were used in the research.

II. MATERIALS AND METHODS,

The intensity of work is largely determined by the stock of blasted rock mass, which should be sufficient to ensure the effective operation of the required number of excavation, loading and transport equipment. Naturally, in the conditions of deep open pits, as well as when working on temporarily non-working sides, this possibility is significantly reduced due to a significant reduction, mainly in the width of working sites. This reduction can be compensated for by increasing the height of the ledge, as a result of which the stockpiles of blasted rock mass move from the horizontal to the vertical plane. For example, if the working area width is reduced by a factor of 2, the stockpiles of blasted rock mass are practically preserved if the ledge height is increased by a factor of 2 [1-2].

Blasting using standard industrial explosives in the tunnelling of underground mine development results in the release of noxious vapours such as carbon monoxide (CO), nitrogen dioxide (NO_2) and ammonia (NH_3). These noxious gases must be cleaned up in a reasonable time before miners re-enter the work area. Poor procedures for determining the optimum re-entry time after an explosion can result in several injuries, fatalities and production losses. Injuries and fatalities are associated with workers returning to work areas too soon after blasting or workers being in restricted areas immediately

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after blasting. Determining the optimal re-entry time after blasting is vital because overestimation of re- entry time causes production losses, while underestimation causes health and safety problems [3]. Moreover, underground mining operations schedule explosions at the end of the work shift to allow sufficient time for the explosive gases to escape.

The disadvantages of this are:

1. concentrations of harmful gases may not fall below the threshold values before the next shift resumes operation;

2. fans operate at an uncontrolled speed, resulting in relatively high ventilation costs.

Thus, it is necessary to provide the optimum amount of air based on the desired re-entry time after the explosion to eliminate the disadvantages described above.

Dilution with fresh air is one of the best ways to control explosive gases in underground mines. This involves removing contaminated air within reasonable limits. It must be temporarily contained before workers re-enter the work area. An important factor related to dilution and purification of flue gases, which has been neglected, is the optimum location of the exhaust duct[4-5].

On creating safe, productive and cost-effective underground mining operations using a computational fluid dynamics approach. must be achieved by determining:

- blast exclusion zones;
- optimal discharge locations;
- suitable re-entry time after blasting and optimum air quantity based on commonly used ventilation and blasting conditions.

All subsequent crash reviews have demonstrated vital aspects of previous research, viz:

- flue gases and their constituent gases;
- Mathematical modelling of flue gas dispersion;
- determination of re-entry time after the explosion;
- Study of explosive gas propagation in underground mines using computational fluid dynamics.

III. RESULTS AND DISCUSSION,

Scientific research shows that:

1. a comprehensive 4-dimensional analysis of the flow dynamics of underground mine smoke concentrations and clean-up is needed;

2. a detailed study is needed to understand the effect of the supply air outlet location on dilution and smoke removal;

3. there is currently no means of estimating safe blast distances, i.e. blast exclusion zones,

4. There is no comprehensive relationship for estimating re-entry times after an explosion in underground mines.

Mathematical models describing the dispersion of flue gases in the underground mine workings can be used to solve the set problems. The corresponding basic equations and the obtained boundary conditions were complex and coupled nonlinear partial derivative equations.

In those cases when it is impossible to obtain an exact analytical solution of a geomechanical problem, modelling (optical, modelling on equivalent materials, and recently computer modelling) is used as a research method. The main stages of modelling are: construction of a formal model, software simulation process, computational experiments. Software variants allow to obtain elastic-plastic solution under plane deformation conditions, and only elastic solution under plane stress state conditions in homogeneous and inhomogeneous medium [6-8].

The elastic model is a linearly deformable medium, stresses and strains are subject to Hooke's physical law. The elastic problem is solved by the finite element method in the following sequence:

1) input of information about the geometry of the finite element network, its properties and the specified nodal forces and displacements;

2) formation of the vector of nodal and mass forces;

3) direct preparation of information that refers to the next element, in particular the numbers of surrounding nodes, their coordinates, element properties;

4) compilation of the element stiffness matrix (ESM);

5) formation of the system stiffness matrix by sending the MLE coefficients to the appropriate addresses;

6) introducing the given nodal displacements by multiplying them by the corresponding columns of the system stiffness matrix and transferring the results to the nodal force vector;

7) solving a system of equations;

8) printing of nodal displacements;

9) cleaning the field of the nodal force vector from the primary values;

10) calculation and printing of deformations and stresses in elements;

11) calculation of nodal forces from the found stresses and their accumulation in the field of the nodal force vector;

12) printing of nodal forces.

The simplest, most versatile, but most extensive information includes the coordinates of all nodes, the given nodal forces, the given nodal displacements, the numbers of the three nodes surrounding each element, the type number of each element, the modulus of elasticity, the Poisson's ratio, and the volume weight of the elements of each type. The natural stress field is determined by recalculating the load into given nodal forces.

The load can be applied at once or in several steps to observe the deformation process step by step. For example, if the number of steps is set to three, the given nodal force is first divided by three and solved, then doubled, and finally the force will be taken equal to its full value, while the result of the solution does not depend on the number of loading steps. The gravity forces of the elements are automatically taken into account. The introduced volumetric weight is multiplied by the area of the element, equally divided among the three nodes and applied in the direction of the vertical axis. The cutout in the area is simulated by giving values of elastic modulus E=0 and volume weight γ=0 to the group of elements filling this area.

A medium that deforms elastically up to the moment of reaching the limit state and does not change its resistance during its further deformation is elastoplastic. The realisation of such a medium is achieved by combining the FEM and the modified Newton-Raphson (initial stress) method proposed by O. Zenkiewicz, which consists in the following. The elements of the medium are initially endowed with initial elastic properties, and a constant stiffness matrix of the system is compiled. Then the full specified load is applied, the elastic problem is solved and the theoretical stresses and strains are calculated. The difference between the elastic and calculated stresses is considered as the initial stress increment. The initial stress increment of the element is converted into initial nodal forces, which are added to the force vector of the system. The following elastic solution is carried out with the same stiffness matrix but with a new set of nodal forces. The addition of the initial forces increases the elastic stresses in the element, but by an amount smaller than the initial stresses because the added nodal forces are distributed to all elements. Iterations are repeated until the found elastic stresses correspond to the given geomechanical model of the rock mass; in principle, the medium can have any law of plastic flow [9-14].

Under conditions of hydrostatic compression, rocks can be in any magnitude of stress state. However, when the stress-strain state is not equal, the magnitude of tangential stresses is limited by the strength properties of the medium. Deformations of rocks under the action of tensile stresses are typical for the upper zones of slope sliding, as well as for the rock strata settling above the excavated space during underground excavation of minerals for the development system with complete roof collapse. Therefore, it is of interest to predict the expected tensile strains and to determine the beginning of element failure, i.e. - the beginning of cracking or delamination process at the contact of layers [15-26]. The ultimate stresses in the tensile region in the "Geomechanics" program are limited by the tensile strength limit, and they are automatically assumed to be equal to C/5 for elements that do not go into the plastic, and equal to zero for elements that go into the plastic at the previous iteration cycles. In the compression region, the Coulomb criterion is applied, and the ultimate stresses are limited by the compressive strength, which is determined automatically by this criterion, based on the physical and mechanical properties of the rock mass given layer by layer:

$$\sigma_{1=2\mathrm{C}_{ctg}\left(45-\frac{\varphi}{2}\right)+\frac{1+sin\varphi}{1-sin\varphi}\sigma_3} \qquad (1)$$

where *C* - adhesion and angle of internal friction.

The elastic-plastic model of the medium with unstrengthening beyond the strength limit is of the greatest interest in the study of physical processes of rock mass failure around geomechanical objects and possible limiting geotechnical situations. The main points of the numerical implementation of this model are as follows. The algorithm combines two theories - the theory of elasticity and the theory of limit state. The concept of residual strength (resilience) is introduced. σ_1^{ocm} formula (1), where *C* - are parameters of the medium with residual strength. Formally, the only difference from the model with ideal plasticity is the definition of σ1 :

$$.\ \sigma_1 = \sigma_1^{ocm} + \frac{\sigma_1^{np} - \sigma_1^{ocm}}{2\varepsilon_1^{y}}\left(3\varepsilon_1^{np} - \varepsilon_1\right) \qquad (2)$$

where σ_1^{np} –is the ultimate maximum stress (ultimate strength): ε_1^{y}-ultimate elastic strain.

The ultimate stress in the compressive region is limited by the compressive strength, the ultimate

Strength is determined by formula (2) at $\varepsilon_1^{y} \leq \varepsilon_1 \leq 3_1^{y}$, residual strength $\sigma_1^{ocm} = \sigma_1/3$, the ultimate strength is determined by equation(1).

Stable elastic-plastic solutions, taking into account the residual strength, are usually achieved in10-15 iteration cycles. The number of iteration cycles is indicated in the output. If the iteration process has not converged within 100 cycles, there is no hope for convergence in the future and the programme is terminated. To describe the physical and mechanical properties it is necessary to determine the modulus of elasticity E, Poisson's ratio ν, volume weight γ, cohesion C and angle of internal friction of each type of element.

IV. CONCLUSIONS

The input information makes up seven conditional arrays and is prepared in accordance with the programme description. The use of unified design schemes and programs for automated uniform breakdown of design schemes with pre-selected parameters sharply reduces the volume of prepared information, as it is already known in advance, so only adjustments are required for the introduction of a new object or for changes in mining and geological conditions, loading conditions, etc. The output information is presented in the same system of units as the input information, it consists of control information and results of the problem solution. As the control information the following information is printed out: specified characteristics of all types of elements; areas of all elements from the first to the last by ten numbers in a line; total area of the considered area; if the number of specified non-zero forces and displacements does not coincide with the number of corresponding signs, the instruction "check the signs" is issued. If the sum of the specified forces and displacements does not match the control values, the following instructions are issued: "check forces" or "check displacements". If the information check does not reveal any errors, the programme continues to run. From the results of the solution, the following are printed by elements and nodes: element serial number; element state (if sign "0" is indicated for the given element, the element is deformed elastically, if sign "1" - it is deformed plastically, sign "-1" means that the element is torn in at least one direction); principal stresses σ , σ^{12} and angle α between the direction $\sigma1$ and the x-axis; principal strains ε , $\varepsilon12$ and angle β; theoretical values of principal stresses $\sigma1m$ and σ m ; node sequence number; displacements of each node in the x and y axis directions; node forces including gravity forces, including nodes with specified displacements. If necessary, axial values of stresses σ_x , σ_y , σ_{xy} and strains ε_x , ε_y , ε_{xy} are printed.

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