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Research Article

DETERMINATION OF AN ANALYTICAL EXPRESSION OF THE RELATIONSHIP OF SOME PARAMETERS OF THE BOREHOLE WHEN USING VARIOUS SUPPLY IN A WELL

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ABSTRACT

This article discusses the problem of determining the analytical expression of the interconnectedness of such parameters as the movement of the face along the well z(t), the time t(z), the duration of the sublimation phenomenon and the propagation of a blast wave through the rock, as well as the pressure P in the detonation products in the well.

KEYWORDS

Well, bottom hole, detonation, pressure, explosion, differential equation, explosives, rock.

INTRODUCTION

Until now, the bulk of mineral resources is mined through the widespread use of blasting. Increasing volumes of use of chemical explosives in mining industry is particularly acute poses the problem of increasing the efficiency of their use in destruction of rocks. The effect of an explosion in solids is a very

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complex phenomenon, including a variety of physical processes, such as detonation of explosives, propagation of shock waves, destruction and unsteady motion of the medium. To study these processes, the achievements of mathematics, physics and continuum mechanics are used [1, 3].

As a result of research, it has been established that during the explosion of a borehole explosive charge, the following processes occur:

- removal of the stope from a stationary state, which corresponds to time t1;
- movement of the face along the well during t2;
- the outflow of detonation products from the well after the stopper leaves it with a corresponding change in pressure, and in the latter case, if the stope is solid after departure, it continues to exert counterpressure on the outflowing detonation products, and in this case the pressure decrease occurs more slowly than in cases of detonation products flowing out without a stopper or with a stopper made of bulk materials, which after ejection scatters in different directions [2].

THE MAIN RESULTS AND FINDINGS

Time t1, during which the stope is removed from a stationary state is determined by the fact that the beginning of movement of various parts of the stope occurs gradually as they are involved in movement so that the process of moving the stope as a whole will occur only after the longitudinal compression wave runs along it, at least 3-4 times.

It is obvious that the removal of the stope from a stationary state will be determined by the following phenomena [2, 4]:

- the movement of particles relative to each other and the redistribution of energy between them using voltage pulses, taking into account the speed of propagation of elastic waves in the particles themselves and in the pores between them filled with gas;
- adhesion of the stopping particles to the walls of the wells and the formation of a boundary layer near the walls;
- re-arrangement of grains during movement, accompanied by dilatancy.

All these phenomena are determined by a system of the following external and internal parameters: pressure P and density ρ detonation products, well diameter d_w, length l_c, density ρ_3, friction coefficient k_f, Young's modulus E, Poisson's ratio ν stopping, the speed of longitudinal waves in the stopping material C_{lw}. In addition, in the case of using an absorbent stope, this process also depends on the given value of the friction coefficient k^*, η – coefficient of viscosity, adhesion of particles of cutting material C_p, diameter of stopping particles d_p, dilatancy rate λ.

So the time t_1 will be some function of the specified parameters

$$t_1 = f\left(l_c, \rho, C_{lw}, \rho_3, P, k_{mp}, k^*, v, C_p, T, \eta, \lambda, d_w, d_p\right).$$

On the first duration t_1 the phenomenon of sublimation occurs if the pressure in the cavity is greater, how 0,1E breeds. In the second stage, lasting t_2 there is a propagation of a blast wave through the rock, the amplitude of which is greater σ and under the influence of which, behind the leading front of the wave, fine crushing of the rock occurs. This process continues until the pressure decreases to σ. At the next stage, the elastic wave propagates through the rock with the formation of t_3 fields of quasi-static stress and zones of radial cracking - zones of controlled rock crushing. At the fourth stage, a seismic wave propagates through the rock, causing destruction due

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to the breaking off of pieces from the individual parts and unloading of the rock with its return movement to the center of the explosion cavity [2, 5].

Below we will consider the problem of determining the analytical expression of the interconnectedness of the process of movement of the face along the well z(t), time t(z) the duration of the phenomenon of sublimation and the propagation of a blast wave through the rock, as well as pressure P in detonation products in the well in cases of loose and absorbent stopes.

Let's consider two processes of the movement of the stope along the well, which is determined by the laws of conservation of energy and momentum, taking into account the loss of momentum due to friction for absorption stopes.

1. Equation of motion for bulk damming with initial conditions $z(0) = z'(0) = 0$, according to [2], has the following form:

$$m_3 \frac{d_c^2 z}{d_c t^2} = S_c P(1-\sigma),$$

(1)

Where , S_c – well cross-sectional area, m^2;
P – pressure in detonation products, Pa;
σ – sliding friction coefficient;
m_3 – stopping mass, kg.

Simplifying differential equation (1), we obtain:

$$z'' = a,$$

Where designation introduced,

$$a = \frac{S_c P(1-\sigma)}{m_3}.$$

Integrating the equation, we get:

$$z' = at + C_1;$$

$$z(t) = \frac{at^2}{2} + C_1 t + C_2.$$

Considering the initial conditions, $z(0) = z'(0) = 0$, we get:

$$C_2 = 0 \text{ and } z'(0) = 0 \rightarrow C_1 = 0.$$

The solution to the differential equation (1) is an integral curve, the equation of which with the initial conditions $z(0) = z'(0) = 0$ as follows:

$$z(t) = \frac{S_c P(1-\sigma)}{2m_з} t^2.$$

(2)

Equality (2) determines the movement of the stem along the well z(t).

Now, from (2) let's express t through z:

$$t^2 = \frac{2m_з}{S_c P(1-\sigma) z}$$

or finally

$$t = \sqrt{\frac{2m_з}{S_c P(1-\sigma) z}}.$$

(3)

Equality (3) determines the time t(z) the duration of the phenomenon of sublimation and the propagation of a blast wave through the rock.

Next, from (2) we determine the pressure P in detonation products in a well:

$$P = \frac{2m_з}{S_c (1-\sigma) z t^2}. \quad (4)$$

Using equalities (2), (3), (4) we can determine the values of the length of the movement path $z(t)$ in the face and time $t(z)$ the duration of the phenomenon of sublimation and the propagation of a blast wave through the rock, as well as pressure P in the detonation products in the well for the considered movement of the loose stope.

2. Let us consider the process for an absorbent face, the equation of which, with the initial conditions

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$z(0)=z'(0)=0$, according to [2], has the following form:

$$\frac{d_p{}^2 z}{d_p t^2}=\frac{[1-\eta(l_c-z)]P}{\theta l_c} \quad (5)$$

Where , η – viscosity coefficient, MPa·s;

υ – specific gravity of the stopping material, kg/m³.

We write this equation in the form:

$$z''=\frac{[1-\eta(l_c-z)]P}{\upsilon l_c}$$

with initial conditions $z(0)=z'(0)=0$.

Let's transform the equation:

$$z''=\frac{[1-\eta l_c]P}{\upsilon l_c}+\frac{\eta P}{\upsilon l_c}z$$

Let's denote,

$$a=\frac{\eta P}{\upsilon l_3}$$

and

$$b=\frac{[1-\eta l_c]P}{\upsilon l_c}$$

Then the equation will take the following form:

$z''=az+b$ or $z''-az=b$

Solving the equation

$$z''-az=b$$

we will search in the form

$z=z_g+z_p$,

Here z_g – general solution of the homogeneous equation,

z_p– some particular solution to this equation.

3. Let us write a homogeneous linear differential equation of the 2nd order

$$z''-az=0 \quad (6)$$

We will look for a solution to this equation in the form

$$z=e^{\lambda t}. \quad (7)$$

Then

$z'=\lambda e^{\lambda t}$ and $z''=\lambda^2 e^{\lambda t}$.

Substituting these expressions into equation (4), we have

$\lambda^2 e^{\lambda t}-ae^{\lambda t}=0$.

Reducing by an exponential, we get $\lambda^2-a=0$, from here $\lambda^2=a$, the roots of this equation are equal $\lambda_{1,2}=\pm\sqrt{a}$.

The general solution of the differential equation will have the form:

$$z_g=C_1e^{\sqrt{a}t}+C_1e^{-\sqrt{a}t}$$

4. Let's find a solution to the inhomogeneous differential equation

$$z''-az=b \quad (8)$$

We will look for a solution to this equation in the form $z_2=A$.

Then $z'=z''=0$.

We substitute the found expressions into the equation (8):

$-aA=b, A=-\frac{b}{a}\rightarrow z_2=-\frac{b}{a}$.

The general solution of the equation will take the form:

$$z=C_1e^{\sqrt{a}t}+C_1e^{-\sqrt{a}t}-\frac{b}{a}$$

Substituting instead a and b their expressions, we obtain a general solution to the equation (8):

$$z(t)=C_1e^{\sqrt{\frac{\eta P}{\upsilon l_3}}t}+C_2e^{-\sqrt{\frac{\eta P}{\upsilon l_3}}t}+\frac{\eta l_3-1}{\eta}.$$

Using the initial conditions, we determine C_1 and C_2:

To do this, we find the first derivative of the obtained solution:

$$z'(t)=\sqrt{\frac{\eta P}{\nu l_3}}\left[C_1 e^{\sqrt{\frac{\eta P}{\nu l_3}}t}+C_2 e^{-\sqrt{\frac{\eta P}{\nu l_3}}t}\right].$$

Next, using the initial data, we obtain:

$$z'(t)=\sqrt{\frac{\eta P}{\nu l_3}}\left[C_1-C_2\right]=0,$$

$$z(0)=\left[C_1+C_2\right]+\frac{\eta\cdot l_3-1}{\eta}=0.$$

Solving these equations together, we have

$$C_1=C_2,\quad 2C_1=\frac{1-\eta\cdot l_3}{\eta}$$

or

$$C_1=C_2=\frac{1-\eta\cdot l_3}{2\eta}.$$

Then the particular solution, taking into account the initial conditions, will take the following form:

$$z(t)=\frac{1-\eta\cdot l_3}{2\eta}\left(e^{\sqrt{\frac{\eta P}{\nu l_3}}t}+e^{-\sqrt{\frac{\eta P}{\nu l_3}}t}-2\right).$$

(9)

Next, to simplify calculations, we expand the exponentials present in the solution into a Maclaurin series. Let's take the first three terms from each expansion. In the expansion of the Maclaurin series, starting from the fourth term onwards, they are infinitesimals of high order (which can be ignored):

$$e^{\sqrt{at}}=1+\sqrt{at}+\frac{\left(\sqrt{at}\right)^2}{2}+\ldots$$

$$e^{-\sqrt{at}}=1-\sqrt{at}+\frac{\left(-\sqrt{at}\right)^2}{2}+\ldots$$

Further, summing up both expansions obtained, we obtain:

$$e^{\sqrt{\frac{\eta P}{\nu l_3}}t}+e^{-\sqrt{\frac{\eta P}{\nu l_3}}t}=2+\frac{\eta\cdot P}{\nu\cdot l_3}t+\theta(0),$$

$$(\theta(0)\approx 0).$$

The solution to equation (5), satisfying the same initial conditions, is (9), from which we obtain the dependence $z(t)$:

$$z(t)=\frac{1-\eta\cdot l_3}{2\eta}\left[2+\frac{\eta\cdot P}{\nu\cdot l_3}t-2\right]=\frac{\left|\left(1-\eta\cdot l_3\right)\right|P}{2\eta\cdot l_3}t,$$

we'll finally get it,

$$z(t)=\frac{\left|\left(1-\eta\cdot l_3\right)\right|P}{2\eta\cdot l_3}t.$$

(10)

Now, from (10) easy to define expressions for time *t*:

$$t(z)=\frac{2\eta\cdot l_3}{\left|\left(1-\eta\cdot l_3\right)\right|P}z.$$

(11)

In the same way, from (10) the expression for pressure is determined P:

$$P=\frac{2\eta l_3}{|1-\eta l_3|t}z.$$

(12)

Using equalities (10), (11), (12) we can determine the values of the length of the movement path $z(t)$ in the face and time $t(z)$ the duration of the phenomenon of sublimation and the propagation of a blast wave through the rock, as well as pressure P in detonation products in the well for the considered process of absorbent driving.

CONCLUSION

Thus, the expressions for the length of the movement path are defined z(t) in the face and time t(z) the duration of the phenomenon of sublimation and the propagation of a blast wave through the rock, as well as pressure P in detonation products in a well. The above quantities obtained analytically play a critical role in determining the physical processes when using explosives in the mining industry. Using equalities (2), (3), (4), as well as (10), (11), (12), we can determine the values of the length of the movement path z(t) in the face and time t(z) the duration of the phenomenon of sublimation and the propagation of a blast wave through the rock, as well as pressure P in the detonation products in the well for the granular and absorbent stopes under consideration. The resulting equalities are analytical expressions that establish the relationship between the above parameters of the cutting. Using these equalities, you can calculate the values of these parameters to any degree of accuracy.

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