ROCK BREAKING

SIMULATION OF PENETRATION OF A CHEMICALLY ACTIVE STREAM INTO A BREAKABLE MATERIAL

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Simplification of experiments for studying the penetration of a chemically active stream into material being broken as a result of using specially selected substances for a neutral stream and a model material being broken is discussed. Similarity criteria are presented.

Currently the attention of experimenters is attracted by the considerable energy-saving effect of use in rock breaking technology of streams whose substance enters into exothermic reaction with the material being broken [1, 2]. However, use of actual chemically active streams in breaking tests leads to considerable difficulties: the complexity of experimental equipment connected with generating the stream itself, increased specifications for safe working technology, and special measures of an ecological nature. One way of overcoming them (particularly in the initial research stage) may be substitution of the chemically active stream by a neutral stream with simultaneous selection of the material being broken on whose action the latter would simulate the test phenomenon.

It is clear that before entering into experiments it is necessary to formulate a physicomechanical model for the test phenomenon. We separate as fundamental the following processes: a) chemical reaction in the contact zone of a stream and the material being broken (active zone); b) heat transfer from the latter into the depth of the material; c) breaking and removal by the stream of broken material from the active zone.

Apart from these processes, for a number of materials filtration of the substance of the chemically active stream into the material in the stage of their reaction and reaction kinetics may be important. As a criterion for material breaking we take some temperature $T$, whose achievement leads to its total loss of its strength. As can be seen, the test phenomenon is very complicated to describe mathematically (the nonuniformity and unsteady state of processes should not be forgotten) which does not make it possible to hope for obtaining some stringent numerical results for solving this problem. Therefore, by creating a physicomathematical model for penetration of a chemically active stream into material being broken at this stage we make the following simplifying assumptions:

1) the release of chemical energy in the active zone occurs instantaneously;
2) there is no filtration;
3) heat transfer is only considered for the leading part of the active zone in a spherically symmetrical approximation.
The process of penetration for a chemically-active stream into material being broken is presented in the form of a series of successive micro-events including the fact that broken material heated as a result of heat released in the active zone disintegrates in a spherical layer $r_0 < r < r_*$ and in time $t$, it is removed from the leading part of the active zone. We ignore heat transferred beyond the boundary of the breaking zone. Then the stream is in contact with the surface of material being broken uncovered after washing away the broken layer, enters in reaction with it, and the process is repeated. The picture is illustrated by the concept given in Fig. 1. Numbers 1 and 4 designate, respectively, the chemically-active stream and its reverse flow with the disintegrated material, 2 is broken material, and 3 is the region of material disintegration.

In accordance with 1)–3) mathematical statement of the problem is reduced to solving a thermal conduction equation

$$\frac{\partial T}{\partial t} = \frac{a}{r} \left( \frac{\partial^2 T}{\partial r^2} + \frac{2}{r} \frac{\partial T}{\partial r} \right)$$

for the region $r > r_0$ with initial conditions $T(r) = T_0$ with $t = 0$ and the boundary condition $T(r_0) = T_b$. Here, $t$ is time; $r$ is radial coordinate of the point of observation; $a = \mu/\rho c$ is temperature conductivity coefficient ($\mu$ is thermal conductivity coefficient for the material being broken; $\rho$ and $c$ are, respectively, its density and specific heat capacity); $T_0$ and $T_b$ are respectively the temperature of the material being broken and the boundary of its contact with the chemically-active stream.

$$T_b = \lambda \Theta / c,$$

where $\Theta$ is the specific heat of reaction between the stream and the material being broken; $\lambda$ is the proportion of chemically-active component within it. By solving (1) with the initial and boundary conditions determined above by an operational method [3] we obtain the temperature distribution within the material being broken

$$T = T_0 + \frac{(T_b - RT_0)}{R} \left[ 1 - \text{erf} \left( \frac{R_0(R-1)}{\sqrt{4at}} \right) \right].$$

Here, $R = r/r_0$ is the relative radius of the point of observation; erf(x) is Gaussian error function [3].

![Fig. 1. Simulation of penetration of a chemically active stream into material being broken](image_url)