The article discusses the problem of coal outbursts into mined-out space based on the nonstationary and nonequilibrium velocity and temperature approach of the mechanics of inhomogeneous media, presents the math models with and without taking account of intergranular pressure of solid particles, and compares the new assessment with the available calculation and experimental references. Based on the analysis of the mixture flow behavior, the authors have found some rules in the relationships of depression waves, shock waves, initial concentration and diameter of particles in coal-and-gas mixtures.

INTRODUCTION
In the mid-1950s Khristianovich and Nikolsky laid grounds for the classical physico-mathematical modeling of coal and methane outbursts on the basis of the idea of an outburst as a moving two-phase mixture of fine gas and coal particles [1–3]. That model was later on generalized for the movement of gas and fine coal particles in the two-velocity and two-temperature approximation of the inhomogeneous medium mechanics, including disequilibrium desorption [4], and on this basis, within the velocity- and temperature-equilibrium approach, a problem on near-face rock mass advance was formulated as Lagrange’s problem on piston motion and was solved. The analytical solution of the problem on an outburst from a crushed semiinfinite coal bed was presented in [5]; in particular, the outburst wave front velocity was calculated for a single velocity gas and coal mix continuum. Filtration and diffusion of free and occluded methane in a coal bed was modeled in [6]. The present article authors think it interesting to analyze an outburst within new mathematical models of the inhomogeneous medium mechanics, based on considering an intergranular pressure of coal particles, their finite volume density and differences in phase velocities and phase temperatures.

MATHEMATICAL MODELS
Let a methane and coal mix fill some volume. We will use two approaches of the inhomogeneous medium mechanics to the problem solution: neglecting interaction of solid phase particles (Model I) and taking this interaction into account (Model II). In the first case, motion of the gas-and-coal mix will be modeled with the disequilibrium inhomogeneous medium mechanics, taking account of the gas phase pressure only. That model includes equations of conservation of mass, impulse and energy for
the gas and solid phases under assumption of the solid phase incompressibility, as well as equation of state with covolume, considering availability of particles in the gas-and-coal flow. Non-conservatively, the described system of equations is:

\[
\frac{\partial \rho_1}{\partial t} + \frac{\partial \left(\rho_1 u_1\right)}{\partial x} = 0, \quad \frac{\partial \rho_2}{\partial t} + \frac{\partial \left(\rho_2 u_2\right)}{\partial x} = 0,
\]

\[
\rho_1 \left(\frac{\partial u_1}{\partial t} + u_1 \frac{\partial u_1}{\partial x}\right) = m_1 \frac{\partial p}{\partial x} - f_{12},
\]

\[
\rho_2 \left(\frac{\partial u_2}{\partial t} + u_2 \frac{\partial u_2}{\partial x}\right) = m_2 \frac{\partial p}{\partial x} + f_{12},
\]

\[
\rho_1 \left(\frac{\partial e_1}{\partial t} + u_1 \frac{\partial e_1}{\partial x}\right) = \frac{m_1 p}{\rho_1} \left(\frac{\partial \rho_1}{\partial t} + u_1 \frac{\partial \rho_1}{\partial x}\right) - f_{12} (u_2 - u_1) - q_{12},
\]

\[
\rho_2 \left(\frac{\partial e_2}{\partial t} + u_2 \frac{\partial e_2}{\partial x}\right) = f_{12} (u_2 - u_1) + q_{12},
\]

\[
p = \rho_1 RT_1,
\]

where \(\rho_i = m_i \rho_{ii}\) are reduced densities of the phases; \(\rho_{ii}\) are true densities of the phases; \(m_i\) is volume concentration of an \(i\)-th phase; \(u_i, T_i\) and \(e_i\) are, respectively, velocities, temperatures and self-energies of the phases; \(p\) is gas pressure; index 1 marks the gas phase and 2 is for the solid (dispersed) phase; \(R\) is gas constant; \(f_{12} = \frac{3}{8} C_D \frac{\rho_1 m_2}{r_p^2} (u_1 - u_2) |u_1 - u_2|\) is interphase force; \(q_{12} = \frac{3}{2} m_2 \lambda Nu \frac{p}{r_p^2} (T_1 - T_2)\) is heat flow between the phases; \(r_p\) is radius of particles; \(\lambda\) is heat conductivity; \(Nu\) is the Nusselt number. Specific resistance of particles, \(C_D\), was calculated with the use of the formula from [6]:

\[
C_D = \begin{cases} 
C_1 = \frac{24}{Re} + \frac{4.4}{Re^{0.5}} + 0.42, & m_2 \leq 0.08, \\
C_2 = \frac{4}{3m_1} \left(1.75 + 150 \frac{m_1}{Re}\right), & m_2 > 0.45, \\
(m_2 - 0.08) C_2 + (0.45 - m_2) C_1 \frac{0.35}{0.45}, & 0.08 < m_2 \leq 0.45.
\end{cases}
\]

In the second case, i.e. considering the interaction between particles, the authors applied the two-velocity isothermal approach, including the intergranular pressure \(p_3\):

\[
\frac{\partial \rho_1}{\partial t} + \frac{\partial \left(\rho_1 u_1\right)}{\partial x} = 0, \quad \frac{\partial \rho_2}{\partial t} + \frac{\partial \left(\rho_2 u_2\right)}{\partial x} = 0,
\]

\[
\frac{\partial u_1}{\partial t} + u_1 \frac{\partial u_1}{\partial x} = -\frac{m_1 p}{\rho_1} \frac{f_{12}}{\rho_1}, \quad \frac{\partial u_2}{\partial t} + u_2 \frac{\partial u_2}{\partial x} = -\frac{m_2 p}{\rho_2} + \frac{1}{\rho_2} \frac{\partial \rho_2}{\partial x} + \frac{f_{12}}{\rho_2}.
\]

The system (2) involves also an equation for the intergranular pressure:

\[
p_3 = \rho_2 (1 + 2(1 + e)m_2 g_0) \Theta
\]