# Numerical study of dynamic phenomena in the coal seam with taking into the account the influence of gas filtration and diffusion

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Coal beds are media with hierarchically organized structure, in which the processes of gas transfer in solid framework produce the significant influence on the mechanical response. Numerical simulation of such media requires special methods to describe as the motion of a solid frame as the transfer of gas in the pores and channels, taking into account the interconnection between these processes. In the paper the symbiotic cellular automata (SCA) method is proposed, which is the combination of conventional [Wolfram, 1986] and movable cellular automaton [Psakhie et al., 2001] methods (CCA and MCA, consequently). In the framework of SCA method the investigated medium is considered as a superposition of two interrelated media. One of them is described by a set of MCA and another — by a mesh of CCA [Zavsek et al., 2005]. The step of calculation consists of two main substeps. First of them is the step of the MCA model, called "mechanical step". At this substep motion equations of movable automata are solved. In other words, the process of mass transfer of solid due to mechanical loading is simulated at the first substep. Next for the mechanical — "net" substep is performed on a mesh of CCA. At this substep the process of mass transfer of gas in the pores and channels is considered, as well as the values of the forces acting on the movable cellular automata from gas phase are calculated. The configuration of pores and channels through which gas propagates, is projected to the mesh of classical cellular automata from the MCA layer. This symbiotic approach combines solutions of mechanical and gas dynamic problems and allows description of multiphase heterogeneous media.

During simulation of coal we used the following main assumptions.

1. Isothermal approximation ($T$=const) is used for considered system "porous solid — gas/liquid".
2. Description of fluid transfer in filtration volume is done on the basis of linear model of stabilized flow of liquid and gas (Darcy law) [Alekseev et al., 2007].
3. Description of diffusion mechanism of gas transfer (transfer of gas molecules in solid-phase framework) is done using Fick law.
4. Calculation of fluid pressure is done using Van der Waals equation. Possibility of phase transition "gas↔liquid" is taken into account. When considering phase transformation, it is assumed that in two-phase state the pressure is constant. In corresponding interval of fluid specific volumes the Van der Waals dependence of pressure ($p$) on specific volume ($V_{spec}$) is replaced by the segment of isobar horizontal line ($p$=const).
5. Simulation of processes of adsorption and desorption on the outer surface of porous solid is carried out using the equation, which is written on the basis of Darcy law.
6. The influence of pressure of contained gases/liquids on solid-phase framework is calculated within linear approximation of porosity dependence on material mean stress [Borisenko, 1985]. Within the framework of present approach the gas-liquid fluid is considered as homogeneous multicomponent two-phase mixture. Phase composition for each component (fluid) is calculated independently of other components. Influence of absorbed gas molecules (molecules located in crystal lattice) on increase of elastic energy of solid-phase framework is not taken into account.

Verification of proposed approach was carried out by means of comparison of the results of modeling of the samples of fine detritus in the $CO_2$ atmosphere with the results of experimental studies performed by researchers of Velenje coal mine (Faculty of natural sciences and engineering, University of Ljubljana, Slovenia) [Pezdic et al., 1999]. These results demonstrate a qualitative agreement between model and experimental data. The effect of the $CO_2$ on the mechanical response and the failure of the samples of fine detritus was studied. Mechanical properties of fine detritus and xylite inclusions were used as given in [Zavsek et al., 2005]. The response and failure of fine detritus under uniaxial compression in the $CO_2$ atmosphere and in vacuum have been simulated. Results of simulation have shown that the presence of external gas pressure resulted in an increase of strength and ultimate strain of specimens without a noticeable change in Young's modulus. Also, the fracture pattern of specimens has undergone some changes.

It is clear that the proposed approach does not cover the entire spectrum of processes in a multiphase heterogeneous medium. Nevertheless, proper selection of model parameters allows obtaining good agreement with the results of natural experiments. This demonstrates the correct formulation of the problem and qualitatively correct description of the basic processes occurring in the system.

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