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FINITE ELEMENT ANALYSIS OF HYDRODYNAMIC INFLUENCE ON MULTI-LAYER DEFORMABLE COAL SEAM WITH DIFFERENT INPUT DATA

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ABSTRACT

In the recent years the interest in methane extraction increased considerably in connection with the operation of mines at large depths, where coal beds are highly gas-bearing and therefore are subjected to outbursts. Preliminary degassing is widely used to prepare coalfields for safe and effective underground mining. However, coal-bed methane can be not only a hazard in active coal mines but a potentially valuable energy resource as well.

A mathematical model for methane extraction process is based on the theory of poroelasticity. A coal seam is considered as a porous medium in which a fluid moves under filtration through porous space. In this case a porous medium can be considered as the superposition of two continua, the skeleton continuum (solid phase) and the fluid continuum (fluid phase). Therefore a coupled-field problem setting should be considered for fluid and solid phases, which implies simultaneous solution for deformation and filtration equations.

The present work suggests a mathematical model of hydrodynamic influence on a multi-layer non-deformable [1,2] and deformable [3] coal seams, based on transient coupled and non-coupled poroelastic equations with regard for nonlinear dependence on the pressure for the filtration coefficients of the coal layer. The processes of fluid filtration in the porous medium and the deformation of the porous body were described in a coupled-field problem setting [4,5]. The computation of the transient poroelastic problem was carried out with the use of the finite element method. In this connection the generalized, or weak, formulation of the problem and the semi-discrete finite element approximations and time integration schemes were provided. The well-known analogy between poroelastic and thermoelastic equations allowed to treat the poroelastic problem as a thermoelastic problem and therefore to apply

thermal-stress analysis modules for numerical simulation in a finite element package. Because of the large spread in the orders of the material modules a transfer to dimensionless variables was performed. The dimensionless problem setting was applied for FEM computations.

As an example, axisymmetrical problem with input data corresponding to a three-layer coal seam in the Krasnodonetsk coalfield of the Eastern Donbass Basin and the experimental characteristics of the hyrofracturing process is considered. The calculated model results allow to obtain two-dimensional pictures of the pore pressure and stress distributions, and determine the values of the pore pressure function at different time moments and different points of the computation area. The plot of the pressure variations along the radial coordinate enables to estimate the radius of the influence zone of the degassing borehole, and this fact has an essential practical importance. It is noted that for the example considered an account of the deformability of the coal seam does not lead to considerable difference in the pore pressure change, compared to pure filtration nonlinear model, but permits to verify results by this simpler model.

Various input data variations were carried out in order to estimate the effect of different problem parameters on the efficiency of the process of hydrodynamic influence on the coal seam. Namely, for original three-layer coal seam of Krasnodonetskoye coal field the parameters of the main coal layer were fixed and such parameters as material properties of associated layers (slates, siltstones, etc.), the coal depth occurrence, the time of the fluid pumping into the borehole, initial seam pressure and the maximum pressure, were being changed starting from initial values. Also the conditions of convective heat transfer were adopted instead of the conditions of 'heat-insulated' boundary on the seam floor and roof, and different values of the convective heat transfer coefficient were set. The results of this analysis allowed choosing an effective type of hydrodynamic influence subject to the parameters of the problem.

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