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Technical Note

A new approach to obtain rheological relations for saturated porous media

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1. Introduction

Hydrogeomechanical models are important for solving various problems in hydrogeology, hydrogeoecology, oil production and geophysics. The main modern concepts of hydrogeomechanics are presented, for example in Refs. [1,2]. Oil depletion in some Russian oil fields necessitates formulating models that take into account the variation of the stress–strain state of the rock mass caused by chemical interactions between components of underground fluid and the material of the porous skeleton, in order to perform effective enhanced oil recovery. Those models are also essential in problems of hydrogeology, such as filtration of solutions in clay layers, suffusion processes and karst processes.

The above-mentioned chemical interactions usually cause the variation of the mass of the porous matrix [3]. That is why it is important to perform additional research into the influence of this variation on rheological relations, which are required to obtain a closed model of deformations of filtrating porous media. It is also necessary to perform systematic development of main equations of underground mass-transfer in this case. Whlie those questions did not receive exhaustive explanation in specialized literature, it makes sense to obtain required equations and examine most important applications.

2. Mass balance equations of porous skeleton and percolating liquid

First, it is essential to develop a set of equations of filtration in a deformable porous medium with porous and variable-mass skeleton. From the definition of the volume strain of the porous medium θ:

$$\theta = (V - V_0)/V_0. \tag{1}$$

Assuming values of θ are small, we can obtain the following expression:

$$V = V_0 \exp \theta \tag{2}$$

where V is the representative volume of the porous medium, and the subscript "0" stands for initial values at zero time. Therefore, for the mass of the porous medium we have

$$M_s = (1-m)\rho_s V_0 \exp \theta \tag{3}$$

where ρ_s is the density of the solid phase and m is the porosity of the rock. If the last equation is differentiated with respect to time, we find

$$\frac{\partial m}{\partial t} = \frac{(1-m)}{\rho_s}\frac{\partial \rho_s}{\partial t} + (1-m)\frac{\partial \theta}{\partial t} - \frac{(1-m)}{M_s}\frac{\partial M_s}{\partial t}. \tag{4}$$

The mass balance of the solid material of the porous skeleton is described by the equation

$$\partial[(1-m)\rho_s]/\partial t + \mathrm{div}[(1-m)\rho_s \mathbf{W}] = j \tag{5}$$

where $\mathbf{W}$ is the velocity of the solid phase, and j denotes the source/sink of the mass of the porous skeleton caused by interface interaction. The porous skeleton is assumed to lose its mass during interface interaction; so, hereinafter j will represent the discharge of the mass. The mass of the material of the porous skeleton in the

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[1] http://kpfu.ru/eng
[2] http://www.jscc.ru/eng/index.shtml

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