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MODELING OF MULTIPHASE FLOWS IN FINITE-DEFORMED POROUS MEDIA

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ABSTRACT

This paper describes an approach to mathematical and numerical modeling of multiphase filtration in porous media with finite deformation. This problem is relevant in the number of industrial applications, for instance, in oil industry this problem relates to the need for intensification of oil production at development of low-permeable beds of new deposits, as well as high-flooded reservoirs of existing fields. Forced sampling of oil due to creation of high pressure gradients in the near-well area leads to separation of the gas phase and formation of considerable rock deformations, including their destruction. Modeling of nonlinear dynamics of the multiphase flow of oil, water, and gases through the deformed rock presents considerable difficulties due to the large pressure differences. At the non-linear stage of filtration the role of shear stresses becomes significant.

In this paper, the thermodynamically consistent model of filtering the fluid with an arbitrary number of phases through a porous medium is used in the framework of the approach developed in the works [1]. Equations of motion obtained by the method of thermodynamically consistent conservation laws satisfy the fundamental laws of thermodynamics: the laws of energy conservation and entropy increase; they are the hyperbolic ones, and this guarantees the existence and uniqueness of solutions. The essential property of the derived equations is the ability to represent them in the form of conservation laws. Hyperbolic character and divergent form of all model equations allows the use of efficient numerical methods developed for solving the hyperbolic systems of conservation laws.

The effective method of solving the equations obtained is the finite volume method based on Godunov's method [2] and using WENO reconstruction of initial data in order to achieve the high-order accuracy of spatial approximation of [3] in combination with Runge-Kutta method with high accuracy of time integration [4]. This method, which was good for solving the problems in various areas of science, was used for the analysis of acoustic wave fields in a cylindrically symmetric model of the well in fluid-saturated porous medium in [5].

Numerical calculations were performed for non-linear isothermal filtration of the two-phase oil-water mixture through the deformable porous medium, and the wave fields were calculated. The influence of high-amplitude pulse impact on the nature of multiphase flow is demonstrated here. Figure 1a shows results on water injection into the model well without the acoustic impact. Introduction of the pressure source of high intensity on the hydrodynamic background of filtering the oil-water mixture changes the type of filtration (Fig. 1b).

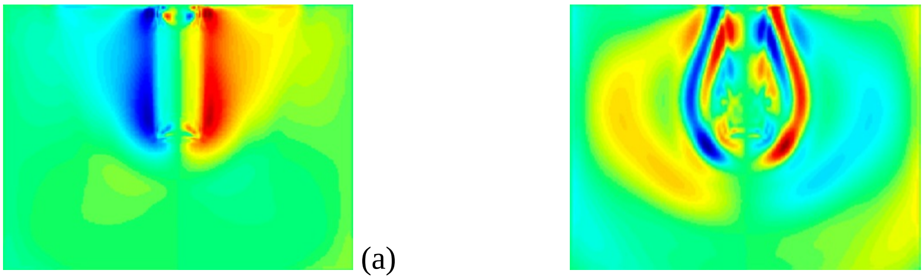
(a) (b)

Figure 1. The horizontal components of water velocity: (a) - the pressure source is absent, (b) - the pressure source of the Ricker wavelet is located in the center of the lower part of the well.

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