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Study of SAGD technology possibility for seismic monitoring of heavy oil reservoirs development

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This work is devoted to the investigation of seismic monitoring feasibility for heavy oil fields development using steam assisted gravity drainage (SAGD) method. Distinctive features of these oils are both large values of density and viscosity as well as viscoplastic rheology.

Currently, most software products are not used for solving problems of viscoplastic oil flow, in which rheology depends on temperature. Moreover, for correct determination of acoustic waves velocities it is necessary to provide recalculation of elastic moduli at the end of each time step. Therefore, the main objective of this work is to develop a software package that allows not only carrying out the calculations of non-isothermal flow of viscoplastic fluids, but also determining the values of elastic moduli, density of porous medium and velocities of acoustic waves by the obtained results.

Two-dimensional profile problem of water, oil and gas flow in gravity field is considered. The oil phase is presented by two pseudocomponents that characterize light and heavy fractions, which can gasify. Also oil phase flow is characterized by the threshold pressure gradient which depends on temperature. Water, as a component, may be present in aqueous and gaseous phases. All the phase's compressibilities are the functions of temperature and pressure while the skeleton compressibility depends only on temperature. To calculate the effective elastic moduli, we apply the explicit form of Gassmann's equation.

Solution of this problem was carried out using finite-volume method. Equal pressure and temperature for all phases was taken into account, thus for solving flow problem IMPES method was applied. Also heat losses from base and cap rock are taking into account by the semi-analytical method. Mixture temperature and component distribution in phases is performing after phase equilibrium calculation, in which phase equilibrium constants are determined by Wilson's correlation. The calculation of elastic moduli was performed by Gassmann's model after determination of all the unknowns.

Simulation of acoustic waves propagation is performed by numerical solution of dynamic equations for linear elastic rock in the region where density and elastic moduli distributions were obtained by simulation of steam chamber growth. A WENO fifth order scheme was applied. As a result, the dependence of displacement on time at the boundary of computational domain was recorded.

Obtained numerical results are in good agreement with known analytical solutions and results of simulation on a commercial simulator. Simulation of development scenario of heavy oil reservoir using SAGD technology showed the possibility of determining steam chamber parameters by the result of seismic monitoring. It is established that the maximum change in elastic properties is about 15% in the area of injection well and this value decreases to 6% at the boundary of steam chamber. These changes are sufficient for a noticeable impact on the results of seismic exploration, which allows estimating the size of steam chamber and monitor its dynamics over time.