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MODELLING THE GROWTH OF A COLMATAGE AGENT FOR RESERVOIR SWEEP IMPROVEMENT UNDER WATER FLOODING

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Summary. The paper describes the formation of plugging aggregates deep within the formation, on the walls of the pore channels and in the free pore space, resulting in a local increase in flow resistance due to the complete blockage of individual pore channels. A model of growth of colmatant detached from the walls of the porous medium in the near wall flow is proposed, which takes into account not only the influence of hydrodynamic flows on chemical reactions occurring in the system The model takes into account not only influence of hydrodynamic flows on chemical reactions in the system, but also inverse influence of growing clay ball on flow pattern. Industrial testing of proposed bridging compound was carried out on Binagadi oil field (Azerbaijan).

Introduction

Secondary recovery techniques extend a field's productive life generally by injecting water or gas to displace oil, resulting in the recovery of 20 to 40 percent of the original oil in place. Enhanced oil recovery (EOR) involves injecting a fluid into an oil reservoir that increases oil recovery over that which would be achieved from just pressure maintenance by water or gas injection.

Over time, due to viscous differentiation and reservoir heterogeneity, flushed channels with increased zonal permeability are developed in reservoirs, reducing the effectiveness of water treatment (Dake, 1998).

The importance of improving well injectivity and increasing waterflood coverage remains significant because of the ever-changing reservoir conditions, high economic costs and tightening environmental requirements.

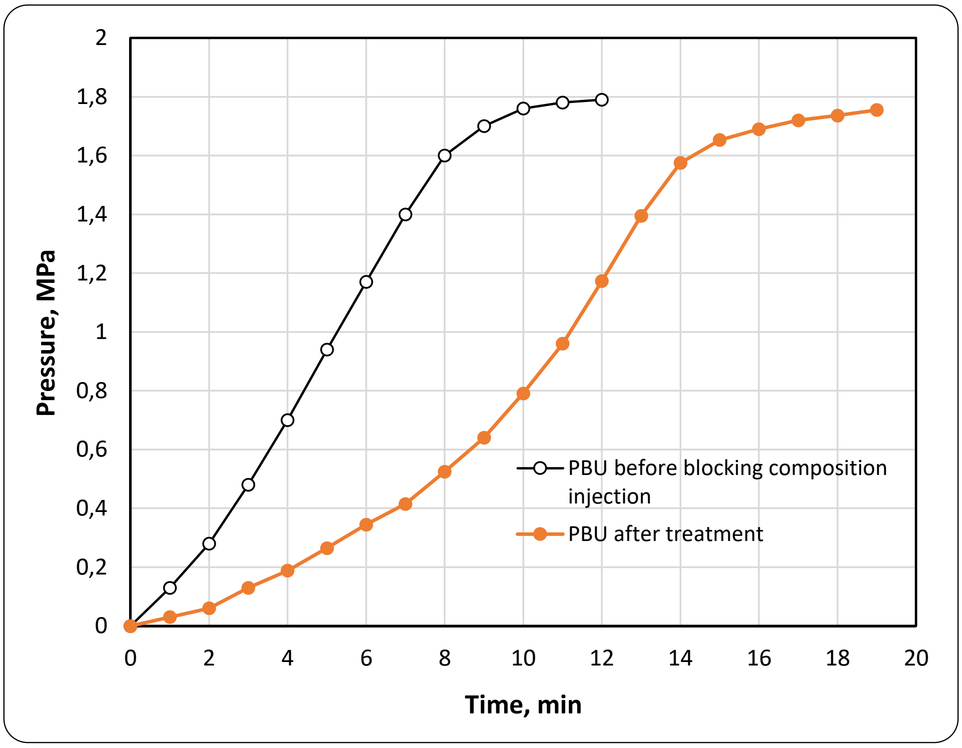
Experiments have shown that the alkaline solution significantly affects the swelling of clay minerals, as the montmorillonite content decreases with increasing concentration of Na_2CO_3 solution and reaction time in a closed medium (Panahov et al., 2023). However, the dissolution rate of montmorillonite slows down when the concentration of OH^- ions in bentonite decreases. The swelling strain of bentonite also decreases with increasing Na_2CO_3 concentration and reaction time (Panahov et al., 2023; 2019; 2018). The void coefficient at saturation of samples dissolved in the same solution for the same reaction time can be expressed by the fractal swelling model $e = kp_s^{D_s-3}$. The fractal dimension, D_s, increased slightly with increasing reaction time and concentration of Na_2CO_3 solution due to the dissolution traces on the surface.

After primary adsorption, bentonite macromolecules provide strong bonding of dispersed aggregates to the rock surface, forming a stable mass in the dynamic flow. Another part interacts with bentonite macromolecules in the flowing fluid and forms aggregates in the form of one or more particles with bentonite molecules attached to them.

Therefore, the formation of aggregates deep in the formation on the pore channel walls and in the free space of pores leads to a local increase in flow resistance by completely blocking single pore channels, which in turn leads to a change in filtration flow directions and an increase in waterflood sweep efficiency of the formation.

Lab test

The process effect was evaluated using pressure build-up curves before and after injection of blocking solutions. As can be seen from the figure, when the proposed method is used, pressure build-up time in the porous medium increases, which indirectly indicates a decrease in hydraulic conductivity of the system (Figure). And this suggests a higher blocking capacity of the proposed method.



Build-up curves before and after treatment with blocking composition

A model of clayey colmatant growth in the near-wall flow was considered, taking into account not only the influence of hydrodynamic flows on the flowing in the system, but also the reverse effect of the growing colmatant on the flow character. Analytical solutions were used to determine the velocity field of the fluid near the colmatant layer. This study showed that hydrodynamic flows may have a significant impact on the pore-clogging processes. As a result of "evolution" of colmatants, aggregates of complex structure are formed. It is shown that the process of aggregate formation depends on the ratio of characteristic values of injected fluid velocity and aggregation velocity. When the forming structures do not have an inverse effect on the flow, the systems are described by "reaction-diffusion-convection" equations.

Theoretical background

Usually only random particle movements (chemical diffusion or random movement of individuals in population-type models) (Field, Burger, 1985; Murray, 1977; Turring, 1952) and sensitivity to gradients of substances involved in the processes (Woodward et al., 1995) are considered in the models.

A similar approach is applicable to the modelling of structure formation processes in a stationary medium: the kinetic part of the system and the geometry of the domain in question (Lobanov et al., 1999) and is related to the properties of the nonlinear medium.

Although the growing colmatant is a clay structure formed in the solid phase, it is still permeable to liquids due to the large number of pores. In a number of problems, a fundamental point is the presence of shear stresses in the flow, which significantly change the picture of structure formation. In particular, consideration of shear stresses is fundamentally important in the analysis of colmatant aggregation (Tandon, Diamond, 1997).

The process of structure formation has a complex spatial and temporal nature. A phenomenological model of reaction-diffusion type was proposed for its qualitative description (Attaullakhanov et al.,1998). The model under consideration contains a large number of parameters and has a set of solutions. In porous media, both the convective flows themselves and the inverse effect of the growing colmatant on the flow pattern play a significant role. The main objective is to evaluate the effect of filtration on the emerging colmatant structure.

The model of structure formation including convective flows and reagent diffusion can be represented by following equations (Lobanov et al., 1999):

$$\begin{aligned} \frac{\partial \theta}{\partial t} &= D_1 \Delta \theta + \frac{\alpha \theta^2}{\theta + \theta_0} - \gamma \theta \phi - \chi_1 \theta - div(V\theta) \\ \frac{\partial \theta}{\partial t} &= D_2 \Delta \phi + \beta \theta \left(1 - \frac{\phi}{C}\right)\left(1 + \frac{\phi^2}{\phi_0^2}\right) - \chi_2 \phi - div(V\phi), \end{aligned} \tag{1}$$

where θ, ϕ – concentrations of impurity (carbonate solution) and clay at the point x at time t; D_1 and D_2 – diffusion coefficients; $\alpha, \beta, \gamma, \chi_1, \chi_2, \theta_0, \varphi_0, C$ – model kinetic parameters; V – flow velocity.

The equation describing the evolution of the colmatant is as follows

$$\frac{\partial \psi}{\partial t} = 0, \tag{2}$$

where ψ is the unmeasured impurity concentration. Moreover, it was assumed that the formed tangles do not affect the diffusion of impurity and colmatant, i.e. diffusion coefficients do not depend on the K_a concentration of the impurity ψ.

Equations (1) - (2) are written in the moving reference frame connected with the centre of the ball of colmatant. Here it is used that the aqueous solution is a viscous incompressible fluid and the continuity equation is fulfilled

$$divV = 0$$

In the convective flow model, it was assumed that the "clubbing" taking place in the system - does not directly affect the flow rate of the solution. This means that the change in flow was only due to changes in the shape and size of the ball.

We considered the problem on evolution of the ball detached from the particle (wall) of porous medium in near wall layer of viscous incompressible fluid in two-dimensional flat case.

During dimensionless measurement of system (1) - (2) the following values are chosen as a characteristic scale of the problem: u – maximum flow velocity (in the fixed coordinate system), L – characteristic size, defined on the base of investigation of system (1) - (2) without convective flows $L \sim 100 \cdot \sqrt{D_1 / \alpha}$ (Garo et al., 1978), where $L << d$ of capillary is porous medium.

Using analytical expressions for velocity field it is possible to determine variations of reagent concentration distributions with time by solving system (1) - (2) with known velocity field.

Conclusions

The proposed model makes it possible to draw a number of important conclusions. Hydrodynamic flows may have an essential influence on structure formation processes in the system carbonate-in-water with clayey inclusions. The composition forms clay balls of large size and complex shape. It can cause clogging of highly permeable pores of the formation. In addition, it can initiate a plugging process away from the colmatant and lead to the development of in-situ structural formation.

Industrial testing of the proposed bridging compound was carried out on the Binagadi field (Azerbaijan). Technological treatment was carried out at well No. 232852 of Binagadi Oil Company in the Binagadi North field.

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