Petroleum Research

Petroleum Research 2018 (December-January), Vol. 28, No. 102. 1-3

DOI: 10.22078/pr.2018.3148.2462

Modeling the Impact of Diverting Agents on Acidization of Heterogeneous Carbonate Reservoir Based on Radial System

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DOI: 10.22078/pr.2018.3148.2462

Received: February/13/2018 Accepted: June/17/2018

INTRODUCTION

In carbonate reservoirs, acid is injected to dissolve carbonate rocks and create a new conductive path commonly known as a "wormholes" [1]. Wormholes bypass the damaged area and consequently facilitating production of oil and gas. While wormholes incredibly increase matrix acidizing efficiency, and they are extremely complex to be designed. Wormhole formation and propagation depend on injection rate, injected volume, type of acid and its concentration, rock heterogeneity, and formation type and temperature [2]. In highly heterogeneous porous media, more acid preferentially flows into the high-permeable region(s) and leaves the low-permeable region(s) underreacted. To alleviate this problem, diverting agents such as viscoelastic-surfactant (VES) and in-situ gelled acids are used to uniformly treat near wellbore area.

A rheological model based on experimental data has been developed by Hosseinzadeh et al [3]. The rheological model is used for in-situ gelled acids by considering the main factors such as shear rate, pH and temperature. Here, we developed their model in 2D radial flow has been developed by us, and then the efficiency of the rheological model by injecting in-situ gelled acid in radial flow through highly heterogeneous porous media has been investigated by us. The result shows that in a radial system, propagation of wormholes is not enough to bypass a damaged area in low-permeability regions in comparison with the propagation of wormholes in a linear system.

TWO SCALE CONTINUUM MODEL

The in-situ gelled acid is a shear-thinning fluid, and its flow in porous medium is described by modified Darcy's law [3];

$$\mathbf{U} = -\frac{1}{\mu_{\text{eff}}}\mathbf{K}.\nabla P \quad (1)$$

where U is the Darcy velocity vector, K is the permeability tensor, P is the pressure, and, μ_{eff} is the effective viscosity of the in-situ gelled acid. It is assumed that the rock dissolution does not change the density of the fluid, the mass balance equation is given by

$$\frac{\partial \varepsilon}{\partial t} + \nabla.\,\mathbf{U} = 0 \quad (2)$$

in which the first term accounts for the effect of local volume change by dissolution. The mass balance equation for H+ is as follows:

$$\frac{\partial(\varepsilon C_f)}{\partial t} + \nabla.(\mathbf{U}C_f) = \nabla.(\varepsilon \mathbf{D}_e.\nabla C_f) - k_c a_v (C_f - C_s) \quad (3)$$

where ε is the local porosity; U is the Darcy velocity vector; C_f is the cup-mixing concentrations of the acid; C_s is the concentration of acid at the fluid-solid interface; D_e is the effective dispersion tensors of acid; a_v is the interfacial area per unit volume of the medium available for reaction, and t is time. The change in the porosity due to dissolution is as follows:

$$\frac{\partial \varepsilon}{\partial t} = \frac{R(C_s) a_v \alpha_c}{\rho_s} \quad (4)$$

in which α_c is the dissolving power of the acid (defined as grams of solid dissolved per mole of acid reacted), ρ_s is the density of the solid phase, and $R(C_s)$ is the rate of the dissolution reaction. The mass balance equation for the polymer component is:

$$\frac{\partial(\varepsilon C_p)}{\partial t} + \nabla.(\mathbf{U}C_p) = \nabla.(\varepsilon \mathbf{D}_{ep}.\nabla C_p) \quad (5)$$

where Cp is the polymer concentration, and D_{ep} is the effective dispersion tensors of polymer in solution.

NUMERICAL SIMULATION

Numerical solution of Eqs. 1 to 5 is achieved by finite volume method using an implicit backward Euler scheme for the temporal domain solved sequentially. In the present study, results are reported with fixed size at 100) 250×100 cells in the r-direction and 250 cells each in the θ-direction). In other words, 0.4 of aspect ratio is used in this work.

CONCLUSION

Pressure drop across the core decreases uniformly during injecting Newtonian fluid has been demonstrated by Hosseinzadeh et al [3]. However, pressure drop first increases and then decreases in a period of injection of non-Newtonian fluid, mainly because viscous fluid blocks the permeability wormhole and divert fresh acid into the lower permeability region. In addition, it is important to highlight that pressure drop along the core is a key parameter to identify the mechanism of flow diversion. More accurately, the large viscosity of the spent acid is considered as the key parameter to divert acid from the high permeability region to the low permeability region.

Hydrochloric acid, %15 with %2 of in-situ gelled acid has been injected at the constant rate in 2D radial flow as shown in Fig. 1. It can be observed from Fig. 1 that unlike the large propagation of wormholes in low permeability regions in the linear system, only a few short wormholes are created in the radial system. The

reason is that several wormholes are formed in high permeability regions and prevent diverting acid from high permeability region to low permeability region in a radial system. In other words, in-situ gelled acids are not too efficient to stop propagation of several wormholes in high permeability region and thus allow more acid to propagate in low permeability region.

In brief, the existing model could not react or respond to divert acid from in high permeability region to low permeability region in the radial system.

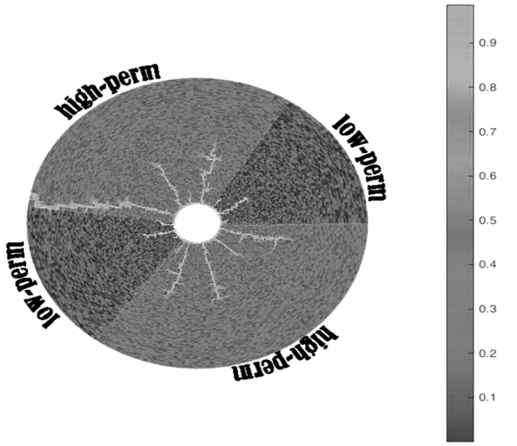

Figure 1: Non-Newtonian acid propagation in a radial system.

REFERENCES

[1]. Daccord G., Touboul E. and Lenormand R., *"Carbonate acidizing: toward a quantitative model of the wormholing phenomenon,"* SPE Prod Eng, Vol. 4, No. 01, pp. 63-68, 1989.

[2]. Kalia N. and Balakotaiah V., *"Modeling and analysis of wormhole formation in reactive dissolution of carbonate rocks,"* Chem. Eng. Sci., Vol. 62, No. 4, pp. 919-928, 2007.

[12]. Hosseinzadeh B., Bazargan M., Rostami B. and Ayatollahi S., *"Modeling of wormhole propagation in carbonate rocks by use of in-situ-gelled acids,"* SPE J., Vol. 22, No. 6, pp. 2032-2048, 2017.

[5]. Gomaa A. M., Mahmoud M. A. and Nasr-El-Din H.., *"Laboratory study of diversion using polymer-based in-situ-gelled acids,"* SPE Prod & Oper, Vol. 26, No. 3, pp. 278-290, 2011.