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Acidizing flowback optimization for tight sandstone gas reservoirs

Jinghong Hu [a], Hong Liu [b], Dan Wu [a], Junjing Zhang [c, *]

[a] Beijing Key Laboratory of Unconventional Natural Gas Geology Evaluation and Development Engineering, China University of Geosciences, Beijing, China
[b] School of Petroleum and Gas Engineering, Chongqing University of Science and Technology, Chongqing, China
[c] ConocoPhillips Company, Houston, TX, USA

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ABSTRACT

The physical properties of Sichuan tight sandstone formations include low porosity and low permeability. Fortunately, micro-fractures are well developed in this area, and the development of a reservoir is thus possible. Acidification can repair reservoir damage and improve single-well production; however, gas well production can change after acidizing: some wells improve, while others decline. After many studies, the flowback system after acidification has been shown to play an important role in determining the acidizing effect. Therefore, optimizing the flowback system after acidification can significantly influence the results of acidizing. A series of velocity sensitivity experiments have been performed, and their results show that the velocity sensitivity is high. Based on fluid mechanics principles, an optimization model of the acid flowback is constructed using experimental results; as a result, the relationship between the pressure drop in the wellhead and the choke size can be calculated, and a reasonable choke during the process of acid flowback can be determined using the methods described in this paper. The results are of great significance in optimizing the flowback system after acidification and also in enhancing the gas production of single wells.

1. Introduction

When the flow rate of a fluid that is compatible with a reservoir's rock is above the critical velocity, the permeability may continue to decrease; this is called the velocity sensitivity effect. During the process of production, drilling, stimulation and water injection, fluids flowing in the reservoir may cause particle migration, blocked pores and a decline in permeability. In different reservoirs, the degree of damage due to particle migration is principally determined by the velocity of the fluids. A reasonable velocity of the fluids is thus a critical parameter to aid the development of reservoirs. The velocity sensitivity is related to the characteristics of the reservoir rock and the fluid properties. Damage to the reservoir will likely occur due to particle migration. The reasons for the velocity sensitivity of reservoirs can be explained better by interface mechanics and percolation mechanics (Shi et al., 2003).

Laura K. (1982) showed that the stress and velocity are the primary factors that cause reservoir damage. The purpose of the velocity sensitivity experiments performed in this study is to determine the relationship between the fluid velocity and the change in permeability; to determine the critical velocity; and to evaluate the decline in permeability that is caused by the velocity sensitivity effect. Experiments are the primary method to study the stress-velocity sensitivity. The velocity sensitivity effect will be significantly enhanced as the effective stress increases (Penny and Conway, 1993). A series of experimental results show that a foamy fluid can reduce the damage caused to a reservoir (Penny and Conway, 1991). In recent years, studies on the sensitivity of fractures or crack-porosity carbonate reservoirs primarily focused on the stress sensitivity and the conventional fluid sensitivity (He et al., 2005; Lorenz, 1999; Qanbari, 2012; Li et al., 2007a,b). A group of experiments on stress-velocity sensitivity have been performed in the DaQing Oilfield and the ChangQing Oilfield (Sun et al., 2013). A full diameter core test can describe the real velocity sensitivity more accurately, particularly in reservoirs where the fractures and pores are well developed (Li et al., 2007a,b).

The tight sandstone gas reservoir investigated in this study is located in the southern Sichuan Basin; the sandstone in this area is characterized by a low porosity and a low permeability, but micro-fractures do grow well in this area. However, the gas production of

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* Corresponding author.
E-mail address: junjing.zhang@conocophillips.com (J. Zhang).

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Table 1
Evaluation standard of the velocity sensitivity.

Velocity sensitivity index (%)	≤5	5–30	30–50	50–70	>70
Sensitivity degree	None	Weak	Mid to weak	Mid to strong	Strong

Table 2
Velocity sensitivity evaluation results of the formation water.

Core NO	Depth (m)	K_{max} ($10^{-3}\mu m^2$)	K_{min} ($10^{-3}\mu m^2$)	D_K	Sensitivity degree	Remark
#1	3679.06	19.897175	10.780940	45.8	Mid to weak	Formation water
#2	3358.37	2.103619	1.696637	19.3	Weak	Formation water
#3	3342.38	33.936314	3.541181	89.5	Strong	Formation water
#4	3350.23	4.958226	3.796585	23.4	Weak	Formation water
#5	3467.28	42.040754	30.773832	26.8	Weak	Formation water
#6	3467.65	29.564354	9.447996	68.0	Mid to strong	Formation water
#7	3428.73	8.787063	2.968038	66.2	Mid to strong	Formation water
#8	3540.78	108.456064	87.863140	18.9	Weak	Formation water
#9	3340.70	2.383921	0.913012	61.7	Mid to strong	Formation water
#10	3540.69	1.120748	0.571362	49.0	Mid to weak	Formation water

wells after acidizing has been known to change; the effect of the acidizing flowback is the key factor to determine the final quality of the acidizing process. To optimize the acidizing flowback in this area, experiments and theories are both considered in this paper. First, the range of the critical velocity is obtained by velocity sensitivity experiments under experimental conditions. Second, based on the theory of the similarity principle, a critical velocity model of the acidizing flowback is built, and the critical velocity is calculated. Lastly, a model of the relationship between the pressure drop in the wellhead and the choke size is built based on the principles of fluid mechanics. Considering the effect of the invasion radius of the acidizing construction, a reasonable choke during the process of the acid flowback can be calculated.

2. Velocity sensitivity experiments with formation water

2.1. Evaluation program with formation water

1) Select the cores to use for testing, and then test the cores permeability in air;
2) Each core was saturated with formation water for 48 h in a vacuum;
3) Slowly adjust the confining pressure to 2 MPa while maintaining the confining pressure above the core upstream pressure; the value must be controlled to 1.5–2 MPa. Then, open the valve on the import side and in the displacement pump; the pump speed should not exceed 1 mL/min. At this time, gas will be displaced to the upstream pipeline of the core and is then discharged from the exhaust valve. When the gas is removed upwards, the pipeline is full of fluids, and the fluids begin to flow from the exhaust valve. The displacement pump or gas source should then be closed.
4) Open the outlet valve of the gripper, and then close the exhaust vent;
5) Measure the permeability of the formation water (K_W);
6) During the experiments, set different flow rates (e.g., 0.50, 0.75, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0 mL/min), and measure the formation permeability (K_f) under different flow rates;
7) $(K_{i-1}-K_i) \times 100\%/K_{i-1}$ is used to determine whether the damage to the reservoir due to the velocity sensitivity would occur. When this value is more than 5%, damage will likely occur; this flow velocity can thus be defined as the critical velocity:

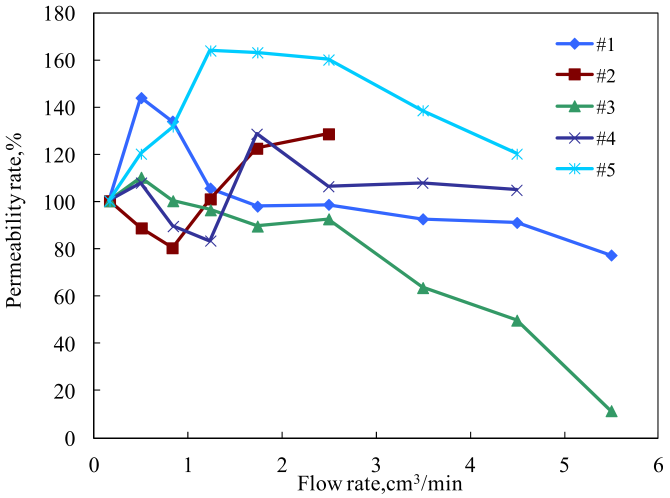

Fig. 1. Curves of the velocity sensitivity experiments 1–5.

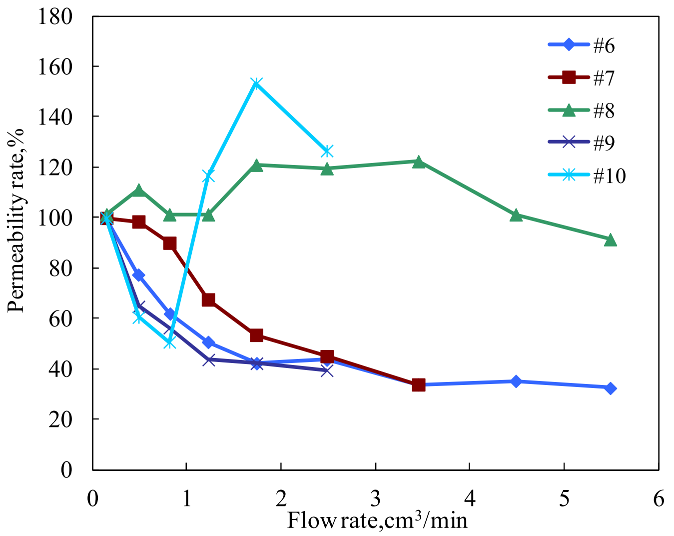

Fig. 2. Curves of the velocity sensitivity experiments 6–10.