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Original article

Experimental study on influencing factors of acid-fracturing effect for carbonate reservoirs

Nianyin Li*, Jinxin Dai, Pingli Liu, Zhifeng Luo, Liqiang Zhao

Key State Laboratory of Oil and Gas Reservoir Geology and Exploitation in Southwest Petroleum University, China

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ABSTRACT

Acid fracturing treatment is the key technique for stimulation and stable production in carbonate reservoirs. In order to improve the carbonate reservoirs acid fracturing effect, in this paper, with a large number of experiments as the main research methods, study on influencing factors of acid-fracturing effect for carbonate reservoirs from increase the effective distance of living acid, increase acid corrosion eched fracture conductivity, reduce the acid fluid loss, etc. The effective distances of live acid calculated with reacted acid limitations measured in different acid systems are quite different from those calculated according to previous standard. Fracture conductivity is one of the key parameters that affects acid fracturing effects, but it's difficult to be predicted accurately due to the strong randomness of acid-rock reaction as well as various influence factors. Analyses of the impacts on fracture conductivity resulted from the rock embedment intensity, closure stress, acid dosage, rock-acid contact time, acid fluid loss, acid pumping rate through self-developed small-core fracture capacity test instrument. Fluid loss during acid fracture can be well controlled by thickened liquid as well as solid particles, but formation damage occurs inevitably. Foamed acid is a specific fluid with high viscosity, low fluid loss, small friction resistance, good retarding property, strong fracture making ability, easy flowback and low damage, which is an ideal acid system for low pressure and low permeability carbonate reservoirs. In this paper, the theoretical study on percolation mechanism and fluid-loss control mechanism of foam (acid) in porous medium are presented with the help of visual microscopic model fluid drive unit.

1. Introduction

Presently, the developed low permeability reservoirs is over 1/3 of total producing reserves in china, while the undeveloped ones share a greater proportion of unutilized geological reserves. However, the developed ones are mostly in low-production and low-efficiency state. How to improve the effects of developed reservoirs? How to make use of the undeveloped ones quickly and efficiently? Fracturing and acidizing technology plays an irreplaceable role.

Carbonate reservoirs are widely distributed in China, including Sichuan Basin, Tarim Basin, Bohai Bay Basin, Buried Hill Ordos Basin Palaeozoic sector, etc [1]. Compared with sandstone reservoirs, the lithology of carbonate reservoirs is relatively simple, but cracks and caves are well developed. when fracturing the carbonate reservoirs, those features may make the sand packed fracture short and narrow due to filtration, and the fracturing fluids seeping into the layer may damage reservoir, and even improper operation cause sand bridge, which bring no effect to stimulation. However, acid fracturing of carbonate reservoirs has a strong advantage.

2. Reservoir characteristics of high bridge lower Palaeozoic reservoir and the necessity of acid fracturing

According to the production test of layers, the stable productivity of single well is required to be improved by stimulation to achieve the whole development of gas reservoir. The reservoir

* Corresponding author. Southwest Petroleum University, No. 8 Xindu Ave., Chengdu, Sichuan Province 610500, China. Tel: +86 13880924239.

E-mail address: linianyin@swpu.edu.cn (N. Li).

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geological assessment analysis and test data demonstrate there is a certain degree reservoir damage, and acid fracturing is needed to eliminate the damage caused during drilling or completion. Some well layers in the gas reservoir have low effective permeability and remarkable dual-medium characters. In this case, nature fractures will significantly affect reservoir production. Thus, stimulation is needed to form long effective acid-etched cracks and improve reservoir seepage area thereby enhancing single well productivity. Small gas layers are serious heterogeneity, which need acid fracturing to improve the average contribution ability. Therefore, large acid fracturing technique is an important mean to increase the production.

3. Analysis of acid fracturing influencing factors

The two most important factors that affect the acid fracturing effects are acid effective distance and acid-etched fracture conductivity. Effective fracture length is influenced by acid filtration property, acid-rock reaction speed, acid flow velocity in the cracks as well as acid type. Acid-etched fracture conductivity is affected by closure stress, acid dissolving power, acid-etched shape of acid-rock reaction, absolute dissolved rock volume and so on. Therefore, longer acid-etched crack length and higher conductivity are needed to improve the acid fracturing effect of carbonate formation. Fig. 1 depicts the main factors to control the acid fracturing effect.

4. Testing reacted acid limit and calculating acid effective distance

During acid fracturing, acid flows into the deep formation along cracks with concentration decreasing gradually. When the acid concentration decreases to a certain value that has no corrosion capability, it becomes reacted acid, and generally, reacted acid limit is considered 10% of the live acid concentration. Before active acid becomes reacted one, the distance live acid flows is called effective distance. But indoor experiments find the reacted acid limit of retarded acid system is much higher than previous opinion about the conventional acid. The test results are shown in Table 1.

Table 1 shows the different reacted acid limit values of different acid types, among them: reacted acid limit of self-diverting acid is the maximum (5.87%); Crosslinked acid takes the second place (4.82%); Gelling acid is minimal (2.73%), closing to that of conventional acid (conventional hydrochloric acid is 2%). The final dissolution rates of crosslinked acid and self-diverting acid is found lower than that of conventional acid.

Therefore, corresponding iterative termination conditions are needed to be set according to different acid systems to get acid effective distance, instead of using 10% live acid concentration as iterative termination conditions. Author has published a paper to discuss the calculation methods of acid effective distance, but these methods all use 10% concentration of fresh acid as judge condition, therefore, for retarded acid, those methods couldn't be used to calculate the effective distance. Effective distances of different acids are simulated and calculated based on the above research and the test results of high temperature dynamics reaction, and Fig. 2 shows the calculated acid con-centration distribution along fracture.

According to previous reacted acid standard (10% of fresh acid concentration), the effective distance of Crosslinked acid, Gelling acid and Self-Diverting acid respectively are 108 m, 84 m and 90 m. But according to their own reacted acid concentration limits, the calculation results of effective distance are: Crosslinked acid is maximum (96 m); Gelling acid is the second (81 m); Self-Diverting acid is minimum (77 m). Obviously, reacted acid limit greatly affects acid-reaction distance.

Therefore, during actual acid fracturing, the acid-rock reaction rate of Crosslinked acid and Self-Diverting acid is seemed low, but when comprehensively considering reacted acid limit and the decrease of fracture conductivity caused by acid corrosion, the increasing effective distance may make no contribution to improving acidification effects, thus, various acid systems combination optimization is recommended to get longer effective distance and higher conductivity acid-etched cracks.

5. Effect factors of acid-etched fracture capacity and improving methods

Acid-etched fracture conductivity is one of the key parameters that affects the acid fracturing result, but it is difficult to be predicted accurately due to the high randomness of acid-rock reaction.

5.1. Effect factors of acid-etched fracture capacity

Many factors affect the acid-etched fracture conductivity, and self-developed FCD test instrument—DP-1 is used to research

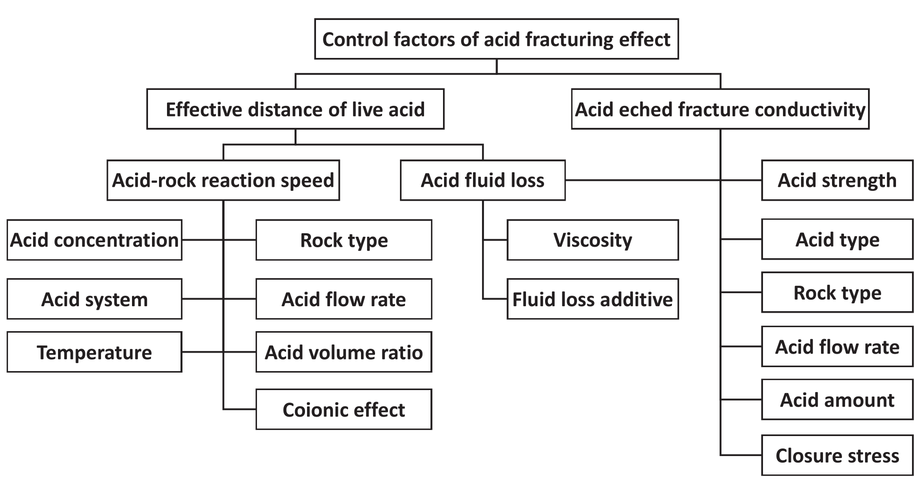

Fig. 1. Main influence influences of acid fracturing.