Application of Slick Water with Low Surface Tension in Water-Blocking Damaging Gas Reservoirs

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Abstract: The characteristics of WF gas oil in Jilin Oilfield are low porosity, low permeability, small pore-throat radius, and low formation pressure coefficient, causing that fracturing fluid flow back slowly, decreasing productivity. Laboratory test shows that water blocking damage is the major factor which restricts production of these gas oils. The water blocking damage is caused by fracturing fluid seepage among small pore-throats. The slick water fracturing fluid system is studied, which have low surface tension and high snit-swelling rate, decreasing the rate of water blocking damage to 20%. This system is used in the fracture of Well C609. 15 hours later, gas breaks through. The flow back rate is up to 35% naturally. After gas lifting, the flow back rate is increased to 68%, which is obviously higher than that rate in the similar wells using conventional fracturing fluid. The slick water fracturing fluid system is field applied on 16 wells. The natural flow back rate is from 16.5% up to 31.2%. And the flow back rate is increased from 35% to 70.3% after gas lifting. It is proved that this system is obviously effective and hence shows promising application prospects.

Introduction

The technical trend of simulation of tight gas reservoir is mainly to improve transforming volume, increase the air supply radius, and reduce fracturing operation damage. Water sensitivity and water blocking damage are two key factors that influence the result of gas reservoirs simulation. Make the factors clear that damage the gas reservoirs, and then adopt several feasible countermeasures to reduce the damage.

WF gas oil in Jilin Oilfield is typical tight gas reservoir. It must be fractured to achieve industrial gas output. The average flow back rate is 16.5%, relying on the formation energy after fracturing. The average flow back rate is increased to 35% after gas lifting. The fluid flow back rate in this block is so low that the initial production is little, or even there is no gas, no liquid, and no pressure in initial stage after fracturing. The wells' daily output would rise, and wellhead pressure would be down, when they are shut in for days (one month), or huff and puff nitrogen in these wells. To solve these problems, it is necessary to study the main damage of gas reservoir and then make feasible countermeasures.

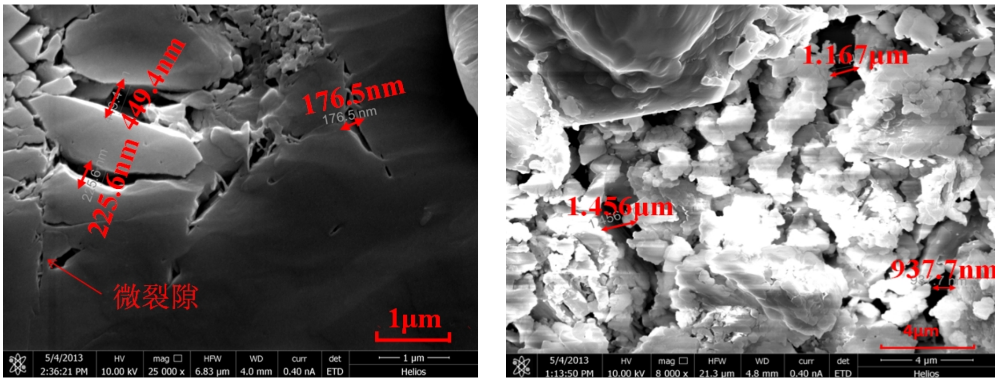
Reservoir characteristics and damage analysis

Poroperm characteristics

The buried deepness of WF gas oil in Jilin Oilfield is from 2000 to 2900 meters. The porosity is from 5.8% to 6.7%. The permeability is arranged from 0.021 to 0.067 mD, tested under the overburden pressure. The formation pressure coefficient is between 0.89 and 0.95, tested on site. The production of the tight gas reservoir is so low, and the fluid flow back slowly after fracturing, mainly because of low porosity, low permeability, and low formation pressure coefficient.

Pore throat characteristics

In order to analysis pore-throat characteristics of this reservoir intuitively, nanometer CT scanner is used. The results of Well C6 and Well C606 are shown in fig.1. Figure 1 depicts that there are a few microcracks, and the pore-throat radius are so small, ranging from 0.1 to 2 micrometers.



a) Well C6 b) Well C606

Fig.1 Images of Nanometer CT scanner

From NMR T2 histogram of Well C6, we can see that the irreducible water saturation is up to 62.46%, and the micropores account for 88% of the total pore space, making it easier for water blocking damage.

Damage factors analysis

According to SY/T 5358-2002 standard, make a test of sensitivity of WF gas field. The results are shown in Table 1. The main sensitivities of WF gas field are acid sensitivity (from weak to strong) and water sensitivity (from weak to strong medium). So select non-acid liquid to prevent from acid sensitivity. And select anti-swelling agent, or optimize mineral concentration of fracture fluid to against water sensitivity.

Table 1 sensitivity analysis

Well Name	interval	formation	water sensitivity	velocity sensitivity	acid sensitivity	alkali sensitivity	stress sensitivity
C6	2524	Shahezi	weak medium, critical mineral concentration:3000mg/l	weak, critical velocity:3cm^3/min	strong medium	weak - weak medium, critical PH:10	weak medium
C11	2853	Huoshiling	strong medium, critical mineral concentration:3500mg/l	weak, critical velocity:2.5cm^3/min	weak	weak - weak medium, critical PH:10	weak medium
C603	2829	Huoshiling	weak critical mineral concentration:3500mg/l	weak medium, critical velocity:2.5cm^3/min	strong	weak - weak medium, critical PH:10	weak medium

After simulated formation water pushed into six core samples of Well C603, the water locking damage rates of core sample effect from 67% to 97%, averagely 82.7%.

On the basis of the experiment of core sensitivity and the experiment of water locking damage above, the reason why the fluid flow back rate is low, the initial production is little, or even there is no gas, no liquid, and no pressure in initial stage after fracturing is that capillary force caused by invasion fluid flooding in small pore-throats is so strong that formation pressure can't against the capillary force. Decrease surface tension of invasion fluid, increase contact angle to almost 90°, and then reduce capillary force, lessening water locking damage in tight gas reservoirs. Eventually, using low surface tension fracturing fluid is an effective way to reduce water locking damage.

Performance evaluation

Conventional performance

WF gas oil is typical tight gas reservoir, where there is brittle rock with high strength. The slick water fracturing fluid system brings forth high net pressure by means of injecting large displacement into the formation. Crack brittle formation, form seam network, and enlarge transforming volume, achieving the purpose of improving production. There is no insoluble residue in slick water. Through optimize formulation to lower water sensitivity and locking damage, it is enough to meet the demand that reduce reservoir damage. The resistance-reducing rate and anti-swelling rate for this system should be high, and the surface tension and the apparent viscosity should be low. The targets of this system used in WF gas field are shown in Table 2.

Table 2 targets of slick water fracturing fluid system

Target name	resistance-reducing rate, %	anti-swelling rate, %	surface tension, mN/m	interfacial tension, mN/m	contact angle, °	apparent viscosity, mPa•s	core permeability damage rate, %	PH
Measured data	70.58	90.1	18.84	0.45	68.7	3.1	14.2	7.6

Water locking damage

Detect gas permeability that different concentrations of surfactant are used to displace the tight core. From fig.2, the rate of water blocking damage is ranged from 80% without surfactant, to under 20%, obviously effective reduced.

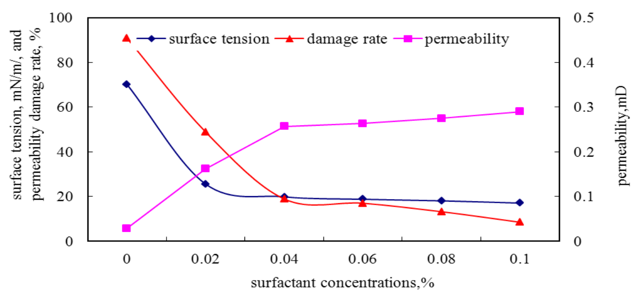


Fig.2 Relationship between concentrations of surfactant and rate of water blocking damage

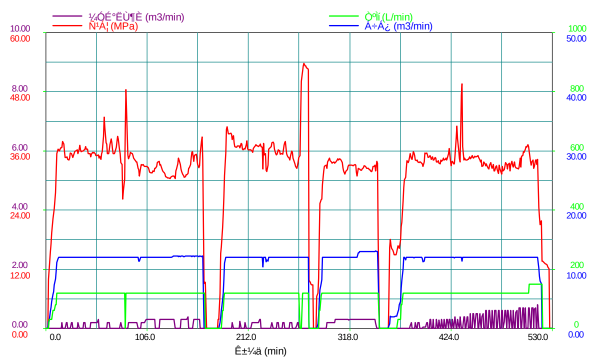


Fig.3 Fracture construction curve of Well C609

Application effects

Select Well C609 as representative of WF gas field. It is a vertical well developed. Its depth is 2838 meters. The porosity is 6.7%. The permeability is 0.067 mD. The formation pressure coefficient is 0.89 MPa/100m. Its formation used is Huoshiling and Shahezi. In all, the characteristics of Well C609 are low porosity, low permeability, and tight reservoir. It is essential to apply the slick water fracturing fluid system studied, to transform the reservoir.

Inject slick water into Well C609 in the whole course of fracturing, and apply sand slug technique, in order to prevent sand plug. Separate layer fractures, and then gas test together. The displacement is $12m^3$/min. Inject 5548 m^3 slick water into Well C609 totally. Three stages of $69m^3$ sand are added. After fracturing fluid flow back 15 hours, gas breakthrough. The flow back rate is up to 35%, relying on the formation energy. And then it is increased to 68% after gas lifting.

There are 15 wells applying this system. Gas breaks through after fracturing fluid flow back 5-33 hours. The average flow back rate is 31.2%, relying on the formation energy after fracturing. The average flow back rate is increased to 70.3% after gas lifting. The results are effective obviously, reducing water locking damage and improving the flow back rate.

Conclusion

In the paper, conclusions are achieved as follows:

(1) The main reason why fracturing fluid flow back slowly, decreasing the productivity of WF gas field, is that water locking damage the formation after fracturing fluid flow into it.

(2) The surface tension of the slick water fracturing fluid system studied in this paper is so small that the water damage is reduced effectively.

(3) The system is applied on 16 wells. Gas breaks through quickly. The flow back rate is increased sharply. It is proved that this system is obviously effective and hence shows fairly good application prospects.

Acknowledgements

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