Research on lowering actuating pressure of injection wells of ultra-low permeable reservoirs

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Abstract

With the improving skills of oil exploration and exploitation, the proportion of the production of ultra-low permeable reservoirs is increasing. But the developing process has encountered many problems, such as poor reservoir properties, high injection actuating pressure, etc. Aimed at lowering the injection actuating pressure of ultra-low permeable oilfield, author has finished the indoor gradient test of actuating pressure, selected and evaluated a system of surface acting agent which later applied in the X oilfield as well. The results show that the gradient actuating pressure of Z reservoir in X oilfield ranges between 0.0308 MPa/cm to 0.2215 MPa/cm. And because the SAA system could largely reduce the surface tension between fluid and rock, the injection actuating pressure then can be reduced by 40%-50%. And its application efficiency was 75%. As a result, it is feasible to use SAA to lower the injection actuating pressure of ultra-low permeable reservoirs.

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Key words: Ultra-low permeability, actuating pressure, SAA (surface acting agent)

1. Introduction

The noticeable developing characteristics of ultra-low permeable reservoirs is high actuating pressure, low effective drawdown pressure between oil well and water well, poor response of oil well, and large amount of well with low production and efficiency. Both poor reservoir property and high surface tension between oil and water can cause high actuating pressure. Ways to improve flood development’s efficiency...
are as followings: (1). fracturing water well. But this can easily lead to the injected water dashed along the crack direction which will eventually reduce the final displacement efficiency; (2). Improve the injection pressure. But the water injection equipment cannot meet the requirements; (3). Reduce the distance between water wells and oil wells, but dense well pattern will increase drilling cost. Therefore, it becomes vital to choose a SAA system which can change the surface tension between oil and water and then reduce the actuating pressure.

2. Infiltrating features of ultra-low permeable reservoir

The infiltrating features of ultra-low permeable reservoir can be included as follows: (1) threshold gradient of pressure is not equal to zero, so liquid can’t flow within a certain gradient; (2) When the pressure gradient is just a little greater than the actuating pressure, the shape of Darcy velocity is a sunken nonlinear curve; (3) When the gradient is greater than a particular gradient, the reservoir system will occur plastic deformation and structure damage and during which Darcy velocity and gradient of pressure are increasing linearly. Now the flow obeys Darcy’s law; (4) infiltrating features is influenced by permeability and fluid property. For instance, the lower the Darcy velocity or the greater the oil viscosity, the longer the extended distance of the curve and the greater the gradient of the actuating pressure is.

3. gradient of actuating pressure test

3.1. Preparation of the experiment

Experimental cores are natural cores from Z reservoir of X oilfield. Their length range from 5cm to 6cm and their diameter are 2.5 cm. The experimental temperature is the room temperature(50°C) and oil used in the experiment comes from Z reservoir of X oilfield which viscosity is 2.77 mPa•S. The main instruments for experiment including: nitrogen tank, core holder, pressure gauge, stopwatch, measuring cylinder, hand-operated pump etc. the experimental principle is described as follows: use nitrogen to push crude oil into the core and control the displacement drawdown by adjusting the discharge pressure. Then draw the relationship between drawdown and rate of flow and use the intercept of the line to acquire the actuating gradient of the pressure.

3.2. The experimental finds and discussion

Actuating pressure test results show as table 1

| Core Numbers | length(cm) | permeability($10^{-3}$µm$^2$) | actuating gradient of pressure(MPa/cm) |
|--------------|------------|-------------------------------|--------------------------------------|
| 570          | 5.764      | 0.42                          | 0.0138                               |
| 573          | 4.690      | 0.10                          | 0.1130                               |
| 574          | 5.384      | 0.65                          | 0.2002                               |
| 576          | 5.212      | 1.01                          | 0.1889                               |
| 577          | 5.616      | 0.88                          | 0.1071                               |
| 578          | 5.672      | 0.41                          | 0.0908                               |
| 579          | 5.720      | 0.60                          | 0.2215                               |
| 612          | 5.590      | 1.01                          | 0.2016                               |
From table 1, we can see fluid in Z reservoir of X oilfield is non-darcy infiltration. The lower the permeability the greater the actuating pressure which ranges from 0.0308 MPa/cm to 0.2215 MPa/cm and this contributes to increasing injection pressure and reducing production of oil well, heavy situation of lacking injection and poor displacement characteristics. As a result, it is necessary to find a SAA to lower the actuating gradient of pressure.

4. Optimize surfactant system

After selecting and evaluating, optimize a non-ionic surfactant system named SZDY-1 is chosen. The influence of this surfactant towards interfacial tension is shown in figure 1. From the chart we can see that with the increasing surfactant concentration, interfacial tension of composite system drops. When the concentration ranges from 0.1% to 1%, on the average, the interfacial tension is under 0.01mN•m⁻¹ which belongs to ultra low value. This shows that the composite system has a high interfacial activity and has an obvious effect.

![Fig 1 the relationship between system concentration and the interfacial tension](image)
5. Test of reducing the actuating pressure

5.1. Preparation of experiment

Experimental cores are low-permeable natural cores which diameters are 2.5cm; the salinity of saturated water is 10.5g/L, and flooding water’s is 5.5g/L; Experimental oil comes from Z reservoir of X oilfield; Using SZDY-1 surfactant system; Experimental temperature is 50 °C.

5.2. Experimental finds and discussion

Use selected surfactant system for some indoor drawdown experiments, the results shown in Table 2.

Table 2 the experimental result of reducing actuating pressure

| Core numbers | $\varphi$ | $K$ /10^{-3}$μm$^2$ | PV | Recovery ratio /% | End Pressure /MPa | Injection surfactant concentration /% | IFT /mN•m$^{-1}$ | Pressure of sequent water flooding /MPa | Injection pressure ratio Before and after drawdown /% | Drawdown rate /% |
|--------------|----------|----------------------|----|-------------------|-------------------|--------------------------------------|----------------|----------------------------------|-----------------------------------------------|--------------|
| 570          | 10.55    | 0.42                 | 2.96 | 36                | 2.5               | 0.5                                  | 0.02            | 1.2                              | 2.08                                           | 52.00        |
| 573          | 9.43     | 0.1                  | 3.47 | 35                | 2.7               | 0.5                                  | 0.02            | 1.6                              | 1.69                                           | 41.00        |
| 574          | 11.55    | 0.65                 | 2.85 | 28                | 1.4               | 0.5                                  | 0.002           | 0.8                              | 1.75                                           | 42.86        |
| 576          | 12.01    | 1.01                 | 2.74 | 26.5              | 2.9               | 0.5                                  | 0.02            | 1.5                              | 1.93                                           | 48.28        |
| 577          | 11.23    | 0.88                 | 4.23 | 26                | 2.3               | 0.5                                  | 0.02            | 1.2                              | 1.92                                           | 47.83        |
| 578          | 10.99    | 0.41                 | 3.89 | 27                | 2.8               | 0.5                                  | 0.02            | 1.5                              | 1.87                                           | 46.43        |
| 579          | 10.35    | 0.6                  | 2.78 | 25.6              | 0.82              | 0.5                                  | 0.02            | 0.5                              | 1.64                                           | 39.02        |
| 612          | 11.92    | 1.01                 | 2.64 | 25.3              | 0.74              | 0.5                                  | 0.002           | 0.4                              | 1.85                                           | 45.92        |

Shown as Table 2, after the mixture injection, the driving pressure can reduce about 46%, and the reduction of the actuating pressure is obvious too. The effect is also evident towards ultra low permeable core. Take the No. 573 core whose permeability is 0.1×10^{-3}$μm$^2$ for instance, after injection, its interfacial tension is 0.02mN•m$^{-1}$ and its actuating pressure reduced to 41.00% and the No. 578 core whose permeability is 0.41×10^{-3}$μm$^2$, after injection, its interfacial tension is 0.02mN•m$^{-1}$ and actuating pressure reduced to 46.43%.

6. The relationship between surfactant concentration and pressure decrease

As shown in figure 2, we used several cores whose permeability are similar and SAA with different concentrations. As can be seen from Figure 2, pressure decrease varies with different concentrations. When the surfactant concentration is less than 0.5%, the lower the mass fraction, the smaller the pressure decreasing rate; When the concentration is greater than 0.5%, even the concentration increases dramatically, No significant change of pressure occurs.
The relationship between surfactant concentration and pressure decrease.

**7. Field Applications**

The selected SAA had been used in the ultra-low permeable X oilfield in March, 2011. Among the four experimental wells, surfactant is effective for three of them, so the effective rate is 75%. And the injecting pressure dropped 5.5MPa on average, as a result, the amount of injection increases 5 m³ averagely which meets the requirement of geology and leads to increasing production. As to the ineffective well, SAA didn’t work might because the oil layer is fine and close and its especially ultra-low permeability.

**8. Conclusion**

(1) The flow in Z reservoir of X oilfield belongs to non-Darcy flow and its actuating pressure which ranges from 0.0308MPa/cm to 0.2215MPa/cm increases with decreasing permeability.

(2) Chose the optimizing surfactant system which is suitable for the ultra-low permeable reservoir of X oilfield. This system contributes to the ultra-low surface tension between oil and reservoir and injection pressure’s reduction of 40% to 50%. Meanwhile the field application effective rate rise to 75%.

(3) It is feasible to add a suitable surfactant system to reduce actuating pressure of ultra-low permeable reservoir.

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