Detection and optimization of viscous oil viscosity and vissity reducer in alx gas well

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Abstract. The optimum viscosity of heavy oil is the key index to maintain the normal production of gas wells. This paper designs a new detection and optimization method of visit oil viscosity and visibility reducer in alx gas well. Firstly, through the flow pattern criterion and flow pattern distribution diagram of gas-liquid two-phase flow in horizontal pipe, the propagation velocity of wave in the downstream is determined by extreme value method, and the maximum viscosity equation of heavy oil carried by air in annular fog state is established. Then, according to the maximum viscosity equation, the maximum viscosity of the heavy oil carried by the gas flow is 513.7 MPa. Finally, taking alx gas well as an example, 11 kinds of viscosity reducer were selected from water-based viscosity reducer and oil-based viscosity reducer. Under the conditions of wellhead temperature of 9 °C and bottom hole temperature of 34 °C, five samples with different concentrations were mixed with heavy oil, the rheological properties of the sample set were tested, and the rheological parameters and apparent viscosity of heavy oil were calculated. The experimental results show that low dosage of oil-based tackifier can effectively reduce the viscosity of heavy oil, and the optimal dosage range is 22% to 25%.

Keywords. gas well; heavy oil; viscosity; viscosity reducer; rheology

1. Introduction

ALX gas reservoir lie on the southwest of taikang uplift, where is the in western slope of songliao basin area, as with oil ring layered gas reservoir, gas reservoir temperature of 34 °C, wellhead temperature 9 °C. The heavy oil is coexistence with natural gas in gas reservoir, gas wells production process is accompanied by heavy oil output. Due to the high viscosity of heavy oil, it is hard to carry it to the ground by natural airflow, the phenomenon is often appearance which heavy oil adhered to tubing wall and even blocked tubing, therefore, the production of gas well would be affected. so, the viscosity of heavy oil needed to be reduced urgently to made the ring-mist flow of natural gas- heavy oil, finally, heavy oil can be produced by natural airflow of the well bore to maintain normal production of gas well.

The reducing viscosity technology of wellbore mainly include chemical, dilution and thermal method, etc[1], from the gas wells production safety consideration, At present it is difficult to use thermal viscosity, while appropriate to adopt chemical technology of viscosity reduction. Chemical viscosity reducer is widely used under the condition of high temperature (120–300°C) at home and abroad[2,3], but ALX gas wells temperature is 9–34 °C, belongs to the viscosity reduction at low temperature, there is no the precedent at home and abroad.

The flow mechanism which natural air flow of the wellbore carried heavy oil to the ground belongs to the category of gas-liquid two phase flow pattern research. Taitel Y.-Dukler A.E. carried on the earliest and
comprehensive research for the gas-liquid two phase flow pattern transition mechanism of level and close to the level pipe flow, given the flow pattern criterion and flow pattern distribution map[4], Jeffreys H. given the discriminant which started up the waves[6], Barnea D. puts forward the general unified model which judged the gas-liquid two phase flow pattern and given the program diagram which identified the flow pattern[6], their research is directed at the air-water two phase medium, while the relational report have no yet to be seen on gas-heavy oil two phase medium.

In order to do this, according to the flow pattern transition mechanism, this paper determined the target value of heavy oil viscosity reduction, and selected the optimal viscosity agent and dosage by the experiment of heavy oil chemical viscosity reduction in ALX gas well.

2.To determine the target value of heavy oil viscosity

In order to guarantee heavy oil of ALX gas wells can be carry out by the airflow after the reducing viscosity, you first need to determine the target value of viscosity. According to the phenomenon, which the wind blow the surface of the water to make waves, When the function of pressure and shear doing on the waves exceeds the viscous dissipation of the waves, the waves will be aroused on the surface of the water. Jeffreys proposed to use the following formula to judge the conditions of waves generated, also the standard of the laminar flow changing the wave flow[3], namely

$$(v_g - c)^2 c > \frac{4 \mu g (\rho_l - \rho_g)}{s \rho_g}$$

(1)

In the formula $\mu$—the kinematical viscosity of the liquid;

$s$—Jeffreys shading coefficient;

$c$—the transmission speed of the waves to the downstream.

TaitelY and DuklerAE had given the flow pattern distribution map of the double logarithmic coordinate on the basis of their standard which judge the flow pattern [4], as shown in figure 1.

To make heavy oil will be carried out by the air flow of gas Wells, its flow pattern should be mist flow. At this time, the function of pressure and shear doing on the heavy oil is not only more than viscous dissipation function of heavy oil, sufficing Jeffreys formula(1), and air velocity is more than 5 times of formula (1). Therefore, we changed the style of the formula(1) on the basis of the flow pattern distribution map, and got the equation (2) which can carry out heavy oil of the maximum viscosity under a certain air velocity.

$$\mu_l < \frac{s \rho_l \rho_g}{4g (\rho_l - \rho_g)} \left(\frac{v_g}{5} - c\right)^2 c$$

(2)

Solving extreme value of $(\frac{v_g}{5} - c)^2 c$ in formula (2), obtaining $c = \frac{v_g}{15}$, and taking $s=0.02$, then

$$\mu_l < \frac{0.02 \rho_l \rho_g}{4g (\rho_l - \rho_g)} \left(\frac{v_g}{15} - \frac{v_g}{15}\right)^2 \frac{v_g}{15}$$

(3)

Namely

$$\mu_l < 6.04686 \times 10^{-7} \frac{\rho_l \rho_g}{(\rho_l - \rho_g)} \frac{v_g^3}{15}$$

(4)

In the formula $\mu_l$—the maximum viscosity of heavy oil, Pa.s;

$v_g$—the speed of the gas, m/s;

$\rho_g$—the density of the gas, kg/m3;
\( \rho_l \) — the density of heavy oil, kg/m³.

The actual data of ALX gas well is \( \rho_l \approx 947.1 \) kg/m³, \( \rho_g \approx 34.73 \) kg/m³, \( v_g \approx 29 \) m/s, getting the target value of heavy oil viscosity in formula (4)

\[ \mu_l \leq 513.7 \text{mPa.s} \]

thus, to make heavy oil will be carried out by the air flow of gas Wells, Heavy oil viscosity should be reduced under 513.7 mPa. S.

3. Associated heavy oil composition and rheology analysis in gas wells

In order to more effectively reduce the viscosity of heavy oil, firstly we have to analyze the composition and rheology of heavy oil to determine the main factor causing of crude oil thickening.

3.1. To analyze the composition of heavy oil

Component analysis adopt the means of high temperature gas chromatography analysis, the main instruments including AC high temperature simulated distillation apparatus and chromatographic column. By the analysis of knowledge, heavy oil Component include more than 41% pectin content, nearly 19% paraffin content and freezing point 8 °C in ALX gas field, while the lowest temperature of wellbore is 9°C which close to freezing point, these are the main factors of the high viscosity, wherefore, these are the key problems which heavy oil viscosity is reduced in ALX gas field.

3.2. To analyze the rheology of heavy oil

Using RS-6000 high temperature and pressure rheometer tested the rheology of heavy oil from ALX gas wells at different temperatures, And the test data was regressed to get rheological parameters and apparent viscosity of heavy oil, then the viscosity-temperature curve map is shown in figure 2.

![Figure 1: Flow pattern distribution map of TaitelY and DuklerAE](image)

1-dispersed bubble flow; 2-bubble flow and mass flow; 3-impact flow; 4-stratified flow; 5-wave flow; 6-annular flow and spray flow

**Figure 1.** The flow pattern distribution map of TaitelY and DuklerAE
Known from the analysis of figure 2, heavy oil has a strong sensitivity to temperature. The temperature from 9°C to 20°C, viscosity almost reduced in a straight line, the temperature from 20 to 50°C, viscosity showed a trend of slow decline. In the case of 9 °C, heavy oil viscosity is the largest in ALX gas well, It is the key temperature point which viscosity can be reduced to the target value.

4. Viscosity agent optimization

Commonly used heavy oil reduction viscosity agent divided into two categories: water-based and oil-based, in order to effective application in ALX gas well, we chose 11 kinds of reduction viscosity agents which commonly used in thermal recovery and has been industrialized production in the country’s largest heavy oil fields—Liaohe oil field, then tested effects of viscosity reduction in room, in order to optimize the best effects of reduction viscosity agent and dosage.

4.1. Water-based reduction viscosity agent effect assessment

Water-based viscosity agent have the TL-1, TL-2, TL-3, DR in Experiments. The four kinds of water-based viscosity agent were respectively added in 4 copies of the same sample of heavy oil, considering the actual situation of the gas well production, we compounded heavy oil sample which contained 300 mg/L of heavy oil reduction viscosity agent. Using RS6000 rheometer tested the rheology of heavy oil sample which have added heavy oil reduction viscosity agent in 34°C, found out the viscosity value, the results are shown in table 1.

| specimen  | Crude oil | Crude oil+ TL-1 | Crude oil+ TL-2 | Crude oil+ TL-3 | Crude oil+ DR |
|-----------|-----------|-----------------|-----------------|-----------------|--------------|
| Viscosity number, mPa.s | 1179.5 | 1335.7 | 1326.5 | 1328.3 | 1301.7 |

Known from the analysis of table 1, in34°C, the TL-1, TL-2, TL-3 and DR for kinds of viscosity agent, containing 300mg/L of heavy oil viscosity reduction agent sample viscosity value is greater than the value of the viscosity reduction agent, showed that the water-based viscosity agent in not only play a role viscosity under low dosage, instead make heavy oil viscosity increases. This is because the viscosity lowering mechanism of water-based viscosity reducer is that a large amount of water phase
containing viscosity reducer is mixed with heavy oil (generally, water phase accounts for more than 60%) to form oil-in-water emulsion, which greatly reduces the viscosity of heavy oil. Therefore, a large amount of water needs to be injected into the well. BUT for ALX Wells, too much water can kill the gas and leave the reservoir unproductive. If the injection water is small, it will form a water-in-oil emulsion, but make heavy oil. Therefore, water-based viscosity reducer cannot be used for viscosity reduction of heavy oil in ALX gas well.

4.2. Evaluation of viscosity lowering effect of oil-based viscosity reducer

Under the condition of 9 °C and 34 °C, will experiment used C1, Y1, Y2, TY, TJ, CY1J on a total of six mixture containing 10% respectively and heavy oil viscosity reduction agent of heavy oil viscosity reduction agent sample. Using RS6000 rheometer to rheology test sample, find out the viscosity value, under different temperature and draw out the oil-based viscosity agent, viscosity of rendering, as shown in figure 3 and figure 4.

![Figure 3. Viscosity-reducing effects of different oil-based viscosity-reducing agents of 9°C](image)

![Figure 4. Viscosity-reducing effects of different oil-based viscosity-reducing agents of 34°C](image)

As can be seen from figure 3 and figure 4, the viscosity reducing effect of C1, Y1, CJ1J and other four kinds of viscosity reducing agent at 9°C and 34°C is far better than that of the other two kinds of viscosity reducing agents at 10% dosage, and they can be selected for the optimal dosage experiment. That is because C1, Y1 and Y2, Y1J contains a dispersive wax inhibitor, which can change the structure of wax crystals and prevent them from forming large wax groups. Meanwhile, the surfactant can be adsorbed on the surface of the oil pipe to form a polar surface and prevent the adsorption and deposition of non-polar wax crystals on the pipe wall.
4.3. Dosage of oil-based viscosity reducer is optimized
On the basis of evaluating the viscosity reducing effect of oil-based viscosity reducer, the compound of CYIUL viscosity reducer was obtained, and then the dosage of C1, Y1, Y2, CYIYL were optimized. To 5 kinds of viscosity agent respectively with heavy oil mixture containing 10%, 20%, 25% and 30% of heavy oil viscosity reduction agent sample, using RS6000 rheometer under 9℃, 34℃ on the rheology test, the apparent viscosity value of heavy oil, and to map sample viscosity agent relation curve, as shown in figure 5 and figure 6.

![Figure 5. The relationship between sample viscosity and viscosity reducer dosage (9℃)](image)

![Figure 6. The relationship between sample viscosity and viscosity reducer dosage(34℃)](image)

It can be seen from figure5 and figure 6 that the viscosity lowering effect of viscosity reducer Y1 and Y2 is poor. When the dosage is within 30%, the viscosity of heavy oil samples decreases by a relatively small extent. At 34℃, when the dosage of viscosity reducer increased from 10% to 25%, the viscosity of heavy oil samples added with C1, CYIL basically presented a straight line decline. When the dosage of powder decreased more than 25%, the viscosity of heavy oil samples tended to flatten. At 9℃, when the dosage of viscosity reducer increases from 10% to 25%, the viscosity of heavy oil sample added with C1 and CYIL basically declines in a straight line. When the dosage of viscosity reducer exceeds 25%,the viscosity change of heavy oil samples added with C1 and CYIL tends to be flat. Therefore, considering that CYII viscosity reducer is cheaper than C1 viscosity reducer, CYIL viscosity reducer is finally selected.

It can be concluded from the curve in figure 5 that the viscosity of heavy oil at 9℃ should be reduced below the target value of 513.7 mPa, and the amount of CYIL viscosity reducer should not be less than 22%, but the amount is more than 25% after basic no longer drop in viscosity of heavy oil sample, so the
best dosage range of 22%—25%

5. Conclusions

(1) The viscosity of heavy oil should be reduced to 513.7 mPa if the airflow in ALX gas well is to carry out the heavy oil and keep the gas well in normal production.

(2) Under the condition of low dosage, water-based viscosity lowering preparation will form water-in-oil emulsion, which will increase the viscosity of heavy oil. Therefore, viscosity lowering agent cannot be used for viscosity lowering of heavy oil in AL.

(3) CL, CYIJ, CYIL and other three oil-based viscosity reducer can effectively reduce the viscosity of heavy oil in ALX gas well. Considering from the technical indicators and economic costs, the optimal dosage of CYIL oil-based viscosity reducer is selected, ranging from 22% to 25%. However, the viscosity of heavy oil samples will not decrease after the amount exceeds 25%, so the optimal dosage ranges are 22% to 25%.

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