Method for Exploiting High-viscosity and High-pour-point Crude Oil

Wei Xie¹, Lei Chen², Zhixue Xia³, Fang Wang⁴, Jianguo Ou⁵, Wenmao Liu⁶, Xinkun Liang⁷, Jundong Liu⁸ and Zhixian Liu⁹

¹³⁴ Engineering Technology Research Institute of Huabei Oilfield Company, Renqiu, China
² Sino Geophysical Co., Ltd, Beijing, China
⁵ Technical Supervision and Inspection Office of Huabei Oilfield Company of PetroChina Company Limited, Renqiu, China
⁶ Directional Drilling Service Company, BHDC of PetroChina Company Limited, Tianjin, China
⁷ China Southern Petroleum Exploration & Development Corporation of PetroChina Company Limited, Haikou, China
⁸ Bayan Exploration Company of Huabei Oilfield Company, Bayan, China
⁹ Road & Bridge Engineering Co., Ltd of Huabei Oilfield Company of PetroChina Company Limited, Renqiu, China

*Email: cyy_xiew@petrochina.com.cn

Abstract. Because of its high viscosity and high freezing point, high viscosity and high pour point crude oil has always been a difficult problem in production. On the basis of fully studying the viscosity-temperature characteristics of high viscosity and high pour point crude oil, this paper puts forward the idea of hydraulic cutting. This method accurately grasps the freezing point of high viscosity and high pour point crude oil. The high viscosity and high pour point crude oil is cut by high-speed cold water hydraulic cutting near the freezing point, which is cut into fine crude oil particles or crude oil flocs. These fine crude oil particles or flocculent crude oil float in continuous water phase, and are mined to the surface with solid or semi-solid water flow. Thus, the problem of low cost exploitation of high viscosity and high pour point crude oil is solved. This method not only provides an effective technical means for the exploitation of high viscosity and high pour point crude oil, but also greatly reduces the production cost. It has a high application prospect and good economic benefits.

1. Introduction

In China, each oilfield has different scale of high viscosity and high pour point oil reserves. With the continuous depletion of thin oil resources, the major oilfields pay more and more attention to the exploitation of high viscosity and high pour point crude oil. Although many universities, research institutes and on-site engineers are continuously studying the low-cost production of high viscosity and high pour point crude oil. Some measures such as microwave heating, emulsification and viscosity reduction for high viscosity and high pour point crude oil are put forward. However, due to their poor adaptability, they are still in the stage of small-scale test, which cannot be widely applied and cannot form scale benefits.

On the basis of a large number of investigations[1] on the above-mentioned high viscosity and high pour point crude oil production methods, the advantages and disadvantages of the three commonly
used viscosity reduction methods are analyzed, and a scheme for extracting crude oil by hydraulic cutting method is proposed. This method makes full use of the viscosity temperature characteristics of high viscosity and high pour point crude oil. In the vicinity of its freezing point, continuous high viscosity and high pour point crude oil is cut into small crude oil particles or crude oil flocs by water jet, which makes them float in continuous water phase. In this way, it not only reduces the viscous resistance in the transportation of high viscosity and high pour point crude oil, but also prevents the phenomenon of "enema" in the process of oil transportation, which provides an effective technical measure for the exploitation of high viscosity and high pour point crude oil.

2. Mechanism and Experimental Study on Oil Recovery by Hydraulic Cutting

2.1. Characteristics of High Viscosity and High Pour Point Crude Oil

High viscosity and high pour point crude oil belongs to non-Newtonian fluid, so it has its particularity in viscosity temperature characteristics [2][3]. The main characteristics of high viscosity and high pour point crude oil are shown in the following three aspects: first, high viscosity, high density and poor fluidity; the viscosity of ordinary crude oil is usually less than 500mPa·s, while that of ordinary heavy oil is about 500-150mPa·s; the viscosity of high viscosity and high pour point crude oil is usually in the range of 10000-20000mPa·s, from which we can see that its viscosity is very high. The density of high viscosity and high pour point crude oil is usually about 0.95g/cm³, which is very close to the density of water. Second, the viscosity is sensitive to temperature: When the temperature of high viscosity and high pour point crude oil is below the freezing point, the viscosity of crude oil increases greatly, when the temperature of crude oil is above the freezing point, the crude oil shows the characteristics of low viscosity. The third characteristic of high viscosity and high pour point crude oil is that there are less light hydrocarbon components and more asphaltene and gum components in the crude oil, with an average content of 20% - 30%.

2.2. Hydraulic Cutting Experiment of High Viscosity and High Pour Point Crude Oil

2.2.1. Experimental device and sample selection

Figure 1 is the flow chart of the device for hydraulic cutting experiment of high viscosity and high pour point crude oil. The experimental device is mainly composed of high-pressure water pump, accumulator, nozzle, oil-water mixture tank, crude oil booster pump, etc. In this experiment, the water sample for hydraulic cutting is domestic water, and the viscosity of high viscosity and high pour point crude oil is in the range of 500mPa·s -1500mPa·s.

2.2.2. Hydraulic cutting experiment of different crude oil viscosity

The purpose of this experiment is to prepare high viscosity and high pour point crude oil into samples with different viscosities, and to study the morphology of the samples cut by the same water pressure impact in water. The viscosity of the sample configured in the test is shown in Table 1.
Table 1. List of crude oil samples with different viscosities (50°C)

| Sample No. | 1   | 2   | 3   | 4   |
|------------|-----|-----|-----|-----|
| Viscosity (mPa·s) | 500 | 750 | 1000| 1500|
| Freezing point (°C) | 35  | 37  | 43  | 45  |

The water pressure was 0.1MPa (gauge pressure), the nozzle was 1mm in diameter, the water medium was clean water, and the water temperature was 18-25°C. In order to understand the morphology of high viscosity and high pour point crude oil which was higher than and lower than freezing point, the crude oil sample temperature was divided into 5°C higher than freezing point and 5°C lower than freezing point. The test results are shown in Table 2.

Table 2. List of hydraulic cutting experiments of crude oil with different viscosity and freezing point (Water temperature 18°C)

| Sample No. | Viscosity (mPa·s) | Temperature (°C) | Water pressure (Mpa) | Description of sample status after cutting |
|------------|-------------------|------------------|----------------------|------------------------------------------|
| 1          | 500               | 40               | 0.1                  | The crude oil samples are flocculent      |
|            |                   | 30               | 0.1                  | The crude oil samples are coarse flocculent with a small amount of massive crude oil |
| 2          | 750               | 41               | 0.1                  | Crude oil samples are coarse flocculent   |
|            |                   | 32               | 0.1                  | The crude oil samples are coarse flocculent, and the amount of massive crude oil is significantly increased, about 10% |
| 3          | 1000              | 50               | 0.1                  | The crude oil samples are distributed in blocks, about 30% of which are flocculent. |
|            |                   | 38               | 0.1                  | Most of the crude oil samples are in block distribution, with less flocculent distribution. |
| 4          | 1500              | 50               | 0.1                  | Most of the crude oil samples are in block distribution, with less flocculent distribution. |
|            |                   | 40               | 0.1                  | Most of the crude oil samples are massive distribution, and there is no flocculent crude oil. |

It can be seen from Table 2 that when the viscosity of the experimental sample is low, the water temperature has little effect on the experimental results. However, when the viscosity and freezing point of the sample are high, the experimental water temperature has a great influence on the test results. In view of this phenomenon, the impact pressure of water is increased again from 0.1MPa to 0.2MPa, and other conditions remain unchanged. The results are shown in Table 3.
Table 3. List of hydraulic cutting experiments of crude oil with different viscosity and freezing point (Water temperature 18°C)

| Sample No. | Viscosity (mPa·s) | Temperature (°C) | Water pressure (Mpa) | Description of sample status after cutting |
|------------|-------------------|------------------|----------------------|------------------------------------------|
| 1          | 500               | 40               | 0.2                  | The crude oil samples show fine flocculent distribution |
|            |                   | 30               | 0.2                  | The crude oil samples are flocculent with a little lump crude oil |
| 2          | 750               | 41               | 0.2                  | The crude oil samples are flocculent and not massive |
|            |                   | 32               | 0.2                  | The crude oil samples have coarse flocculent distribution |
| 3          | 1000              | 50               | 0.2                  | The flocculent distribution of crude oil samples is about 10%. |
|            |                   | 38               | 0.2                  | Most of the crude oil samples are flocculent and less massive |
| 4          | 1500              | 50               | 0.2                  | Most of the crude oil samples are coarse flocculent |
|            |                   | 40               | 0.2                  | Most of the crude oil samples are flocculent and a few are massive |

The results show that the floc samples increase significantly and the bulk samples decrease significantly after increasing the injection pressure. In order to further verify the cutting effect of high viscosity and high pour point crude oil under different water temperature and pressure, the cutting and crushing experiments at 25°C, 30°C, 35°C, 0.3MPa and 0.4MPa are also added. The experimental results show that when the temperature is higher than 35°C and the pressure is higher than 0.3MPa, part of the emulsion is formed.

The hydraulic cutting test shows that when the water temperature is low and the temperature of high viscosity and high pour point crude oil is above its freezing point, the cutting effect is better, and most of the flocculent crude oil is suspended in the water, which lays a good foundation for the next high-pressure exploitation.

2.2.3. Static flocculation experiment

The static flocculation experiment is to place the cut high viscosity and high pour point crude oil in a transparent glass container and keep it still for a period of time to observe its flocculation. Table 4 lists the crude oil flocculation phenomenon of water oil mixture with different water content after standing for 30min, 60min, 2h, 4h, 8h, 16h and 24h.
Table 4. List of standing flocculation experiments for high viscosity and high pourable crude oil after cutting

| Water cut (%) | 0.5 | 1 | 2 | 4 | 8 | 16 | 24 |
|---------------|-----|---|---|---|---|----|----|
| 30            | No  | No| No| Slight | Slight | Moderate | Moderate |
| 40            | No  | No| No| No   | Slight | Slight | Slight |
| 50            | No  | No| No| No   | No    | No   | Slight |
| 60            | No  | No| No| No   | No    | No   | No   |
| 70            | No  | No| No| No   | No    | No   | No   |

It can be seen from the experimental data in Table 4 that when the water content is 30%, there is a slight flocculation phenomenon after standing for 4 hours; when the water content reaches 40%, the flocculation phenomenon appears after standing for 8 hours; when the water content is greater than 50%, the flocculation phenomenon basically disappears. This shows that when the water content is low, due to the close distance between molecules of high viscosity and high pour point crude oil cut into flocculent or small particles, the gravitational force is also strong. When the water content increases gradually, the distance between the molecules increases, and the attraction decreases accordingly, so the flocculation time increases.

The test shows that in order to improve the efficiency of oil transportation and prevent the occurrence of flocculation, it is the best to set the water content at 40% - 60%.

2.2.4. Pipe wall lipophilic test

Figure 2 is the flow chart of the oil affinity test of the pipe wall. The oil pipe is commonly used in the field. The oil pipe is welded into an annular structure, and a circulating pump is installed in the middle.

![Figure 2. Schematic diagram of the lipophilic test device for the inner wall of the tubing](image)

The mixture of high viscosity and high pour point crude oil and water is continuously circulated in the pipeline through the circulating pump. After a period of circulation, the deposition of crude oil on the inner wall of the pipeline is checked.

The experiment was carried out according to different water cut and circulating time. The experimental results are shown in Table 5.

Table 5. Lipophilic test of pipe wall under different water content and circulation time

| Sample water cut (%) | Circulation time (h) |
|-----------------------|----------------------|
|                       | 2   | 4   | 8   | 24  |
| 30                    | No  | No  | Slight | Slight |
| 40                    | No  | No  | No   | Slight |
| 50                    | No  | No  | No   | No   |
| 60                    | No  | No  | No   | No   |
The experimental results show that when the water content is high, there is no deposition of crude oil in the pipe wall, and when the water content of the sample is low, there is a slight phenomenon of crude oil hanging on the wall.

3. Conclusion
To sum up, the hydraulic cutting technology is a new pumping technology. The implementation of this technology will greatly reduce the cost of other mining methods and simplify the production process. The experimental data show that the technology has strong operability, low cost, and it is not easy to produce flocculation and caking when the water content is constant. It has good popularization value and remarkable economic benefits.

4. References
[1] Pipeline transportation of high viscosity and high pour point crude oil and product oil, petroleum industry press
[2] Li Chuanxian, Li Qigui, experimental study on viscoelasticity of gelled crude oil [J], mechanics and practice, 2000.22 42-50
[3] Gui Ping, Zhang Jinjun, viscoelasticity of waxy crude oil near freezing point, Journal of Petroleum University (NATURAL SCIENCE EDITION), 2003.27 (2) 90-92