Research and existing problems of pour point depressant/viscosity reducer for crude oil production

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Abstract. The composition and structure of pour point depressant/viscosity reducer for pipeline transportation and its application effect in long-distance pipeline transportation in China as well as the application effect of oil-soluble viscosity reducer and water-soluble viscosity reducer for wellbore lift in low-viscosity and high-viscosity heavy oil wells in China are introduced. The main technical problems existing in the study of viscosity reducer for heavy oil formations drive are presented.

1. Introduction
The production process of crude oil mainly includes formation drive, wellbore lift and pipeline transportation. According to its viscosity, crude oil can be divided into conventional crude oil, heavy oil, extra heavy oil and super extra heavy oil [1].

Chinese conventional crude oil generally has high wax content [2], pour point and viscosity, and poor fluidity. Because of higher colloid asphaltene content, heavy oil, extra heavy oil and super extra heavy oil generally have higher viscosity and poor fluidity. In order to improve the fluidity of crude oil and ensure safe production, thermal method is mainly adopted in the production process to consume a large amount of energy, and the use of pour point depressant/viscosity reducer to improve the fluidity of crude oil is an effective way to save energy and reduce consumption [3].

After years of arduous work, Scientists worldwide have made great progress in the research of pour point depressants and viscosity reducers [3-7], a series of which were developed and proved to be suitable for the pipeline transportation and wellbore lift of crude oil. Pour point depressants and viscosity reducers have been widely used in pipelines and wellbores [8-13], and moreover brought forth substantial economic and social benefits.

In reservoir conditions, for conventional crude oil, its fluidity is generally good, which poses little problem to formation drive, water flooding is used. In comparison, for heavy oil, extra heavy oil and bitumen, because its fluidity is poor, thermal technology is mainly used to solve the difficulties of formation drive. For normal heavy oil, water flooding is used, but the oil recovery of water flooding is only 5-25%, the main reasons is the higher viscosity of normal heavy oil, so the study of viscosity reducer for normal heavy oil has great significance to improve oil recovery of its water flooding.

2. Pour point depressant/viscosity reducer for pipeline transportation
The pipeline transportation of conventional crude oil mainly adopts the method of pour point depressant/viscosity reducer combined heating, while the pipeline transportation of heavy oil, extra heavy oil and super extra heavy oil mainly adopts the heating method.
2.1. The nature of china's conventional crude oil

China's onshore crude oil pipeline has a length of over 23,400 kilometers [14]. Crude oil is mainly transported through pipelines, with the proportion of pipeline transportation reaching over 80%. The nature of crude oil transported by some pipelines is shown in Table 1.

Table 1. The nature of crude oil transported by some pipelines in China.

| Pipeline  | Pipeline length /km | Wax /% | Resin-asphaltene /% |
|-----------|---------------------|--------|---------------------|
| Luning    | 652.6               | 20.60  | 23.70               |
| Zhongluo  | 290.1               | 24.59  | 6.81                |
| Pulin     | 241.9               | 21.4   | 8.0                 |
| Weijing   | 226.4               | 30.8   | 9.90                |
| Donghuang | 251.1               | 18.3   | 21.6                |
| Donglin   | 171.3               | 19.1   | 20.8                |

2.2. Composition of pour point depressant/viscosity reducer of crude oil in china

The main components of pour point depressant/viscosity reducer include ethylene-acrylate copolymer, ethylene-vinyl acetate-sodium allylsulfonate copolymer, vinyl acetate-acrylate-maleic anhydride copolymer and its derivatives, acrylic higher alcohols ester copolymer, ethylene-acrylate copolymer, as shown in Table 2.

Table 2. The Composition Structure of Pour Point Depressant/Viscosity Reducer.

| Pour point depressant | Chemical structure |
|-----------------------|--------------------|
| EVA                   | Ethylene-acrylate copolymer |
| EMS [15]              | A compounded system composed of EVA, vinyl acetate-acrylate-maleic anhydride copolymer and its derivatives, and surfactant |
| F21 [16]              | Ethylene-vinyl acetate-sodium allylsulfonate copolymer |
| BEM [3]               | A compounded system of EVA and acrylic higher alcohols ester copolymer |
| GY [17]               | A compounded system of EVA and other polymers |
| CE [18]               | EVA and its modifiers |
| PAE [19]              | Acrylic higher alcohols ester polymer |

2.3. The application of pour point depressant/viscosity reducer for pipeline transportation

On the basis of the study on the pour point-depress mechanism [20], the BEM pour point depressant developed has good adaptability and modification effect on Chinese crude oil, and has been applied in a number of pipelines such as Luning, Zhongluo, Pulin and Weijing, as shown in Table 3.

Table 3 shows that BEM pour point depressant/viscosity reducer has better pour point-depressing and viscosity-reducing effect. At the dosage of 50mg/kg, the range of pour point depression is greater than 10℃, and the viscosity reducing rate is greater than 80%. After the use of pour point depressant for the pipeline, it saves a lot of fuel oil, reduces the cost of oil transportation, and obtains huge economic and social benefits. In addition, the safety and strain capacity of pipeline operation can be improved after adding agent.
Table 3. Modification Effect of BEM Pour Point Depressant/Viscosity Reducer on Crude Oil Transportation of Some Pipelines in China

| Pipeline | Additive dosage /mg/kg | Pour point /℃ | Pour point depression range /℃ | Viscosity/mPa.s 30℃ | Viscosity reducing rate /% |
|----------|------------------------|----------------|--------------------------------|---------------------|---------------------------|
| Luning   | 40                     | 24             | 5                              | 935                 | 300                       | 68                        |
| Zhongluo | 50                     | 33             | 13                             | 1172                | 60                        | 95                        |
| Pulin    | 50                     | 33             | 15                             | 763                 | 19                        | 98                        |
| Weijing  | 50                     | 37             | 23                             | 1720                | 119                       | 93                        |
| Donghuang| 50                     | 17             | 4                              | 396                 | 334                       | 16                        |
| Donglin  | 50                     | 23             | 3                              | 408                 | 314                       | 23                        |

3. Viscosity reducer for wellbore lift

According to the characteristics of heavy oil in China and the viscosity-reducing mechanism [20], oil-soluble viscosity reducer and water-soluble viscosity reducer are developed and applied in the lifting process of heavy oil wellbore.

3.1. The application of oil-based viscosity reducer in wellbore lift of heavy oil

Oil-soluble viscosity reducer is composed of high-molecular polymer and surfactant containing strong polar groups. The polar groups in the molecule with strong polarity can form hydrogen bonds with the polar groups of colloidal bituminous molecules in heavy oil, which has a good viscosity-reducing effect for heavy oil, and it is suitable for the production of heavy oil with low water content and low viscosity.

The oil in Block 104-5 of Jidong oilfield belongs to low viscosity heavy oil, and the viscosity-reducing effect of oil-soluble viscosity reducer on heavy oil in Block 104-5 is shown in Table 4.

Table 4. Viscosity-reducing Effect of Oil-soluble Viscosity Reducer on Heavy Oil in Block 104-5 of Jidong Oilfield (40℃, 300mg/kg).

| Well No. | Gao 14 | 106-5 | 104-5 | 109-6 | 109-7 |
|----------|--------|-------|-------|-------|-------|
| Viscosity/mPa.s | Before adding | 1130 | 5500 | 1600 | 910 | 1230 |
|             | After adding   | 270  | 1100 | 680  | 490 | 650  |
| Viscosity reduction rate /% | 76  | 80   | 57   | 46   | 47   |

Table 4 shows that the viscosity reduction rate of oil-based viscosity reducer for heavy oil in Block 104-5 of Jidong is 40-80% at the dosage of 300mg/kg.

It is very difficult to exploit the Block 104-5 at the initial stage of production, and good results have been achieved after the application of oil-based viscosity reducer, as shown in Table 5.

Table 5. The Viscosity-reducing Effect of Oil-based Viscosity Reducer on Heavy Oil in Block 104-5 of Jidong Oilfield.

| Well No. | Oil production efficiency /% | Daily oil production /tons |
|----------|------------------------------|---------------------------|
|          | Before adding | After adding | Before adding | After adding |
| 104-6    | 40             | 94             | 3.7           | 4.4           |
| 109-6    | 43             | 96             | 5.5           | 8.3           |
| 111-6    | 97             | 98             | 8.4           | 9.5           |
| 111-7    | 96             | 97             | 10.4          | 10.7          |
Table 5 shows that after the application of oil-based viscosity reducer in Block 104-5, both the oil production efficiency and daily oil production increase, and the daily production of this block increases from the original 20 tons to 230 tons, with obvious effect.

3.2. The application of water-based viscosity reducer in wellbore lift

Water-based viscosity reducer is composed of surfactant and emulsion stabilizer, which can make oil-water system into water external emulsion, with viscosity reduction rate of over 90% for heavy oil.

In the wellbore lift process, the viscosity reducer can be used alone and injected into the bottomhole to form O/W emulsion with heavy oil. Moreover, it can also be used with steam huff and puff. The viscosity-reducing effect is shown in Table 6.

Table 6. Viscosity-reducing Effect of Water-based Viscosity Reducer on Heavy Oil (water content 30%, 300mg/kg, 50℃)

| Heavy oil         | Viscosity /mPa.s | Viscosity reduction rate /% |
|-------------------|------------------|----------------------------|
|                   | No Adding        | O/W Emulsion               |
| Liaohe Gaosheng   | 44800            | 59                         | 99.98                     |
| Jidong Oilfield   | 20500            | 44                         | 99.79                     |
| Liaohe Xinglongtai| 874000           | 56                         | 99.99                     |

The application effect of water-soluble viscosity reducer in some oil wells in Wa 38 block of Xinglongtai oil production plant of Liaohe is shown in Table 7.

Table 7. HEA Application Effect in Wa 38 Block (Compared with former steam injection)

| Well No. | Oil increment /ton | Increased production time /d | Water recovery rate /% |
|----------|--------------------|------------------------------|------------------------|
| 3542     | 1734               | 83.1                         | 8.1                    |
| 35430    | 404                | 25.6                         | 77.5                   |
| 3124     | 1476               | 65.8                         | 58.5                   |

Table 7 shows that both the continuous production days and production of Wa 38 block. According to the statistical data of 15 Wells in Wa 38 block of Xinglongtai oil production plant of Liaohe, accumulative oil increment is 35,870 tons, and the input-output ratio is 1:26.

4. Viscosity reducer for formation drive

Due to low viscosity of conventional crude oil in the formation, water flooding is mainly used as formation drive. Heavy oil formation drive methods include thermal recovery and water flooding, heavy oil with high viscosity adopts heating method, including steam huff and puff, steam flooding, combustion in-situ and SAGD(steam assisted gravity drainage).

Normal heavy oil reserves which can be developed by water flooding account for 30.1% of total heavy oil reserves and 18% of total heavy oil production. Because of high viscosity of heavy oil and serious reservoir heterogeneity, the recovery rate of water flooding of normal heavy oil is only 5-25%.

In order to improve the recovery rate of water flooding for heavy oil, domestic and foreign scholars mainly study alkali flooding, polymer flooding, surfactant flooding, combination flooding and gas flooding, etc. Indoor research has achieved certain results and some technologies have been conducted field tests. In No.3 oil production plant of Dagang oilfield in China, a small-size viscosity reducer flooding is implemented. As it is difficult for small molecule viscosity reducer to form O/W emulsion under the formation condition of low shear strength to reduce viscosity and the presence of high permeability channels, the goal of increasing oil production is not achieved.
Research shows that the key to improve water drive recovery factor of heavy oil is to enlarge swept volume, lowering the viscosity of heavy oil and increasing the viscosity of displacing fluid are the effective ways to enlarge swept volume. There is no research record about heavy oil water flooding EOR technology that can both lower heavy oil viscosity and increase displacement fluid viscosity under the formation condition of low shear strength at home and abroad. According to the theory of molecular design, macromolecular viscosity reducer can lower the viscosity of heavy oil and increase the displacement fluid viscosity under the formation condition of low shear strength. The synergistic effect of two functions can greatly improve water flooding recovery factor of heavy oil. Therefore, macromolecular viscosity reducer is one of the key replacement technology after water flooding of heavy oil, which is of great significance to improve water recovery factor of heavy oil, and it has a broad application prospect.

5. Conclusions
BEM series pour point depressant has good pour point depressing and viscosity-reducing effect on high pour point crude oil. After the application of BEM series pour point depressant on the lines of Luning and Zhongluo, great economic benefits have been achieved. Meanwhile, the operation safety and strain capacity of the pipelines have been improved.

Oil-soluble viscosity reducer has good viscosity reducing effect on heavy oil with low viscosity and is suitable for wellbore lift. Water-soluble viscosity reducer has good viscosity reducing effect on heavy oil with high viscosity and can be used for wellbore lift.

Increase the research strength of viscosity reducer for formation drive, including viscosity reducing mechanism, evaluation method and molecular structure design of viscosity reducer.

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