Experimental study on wettability of crude oil on the surface of plastic alloy pipe in an oilfield field

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Abstract. Non-metallic pipe is widely used in oilfield development in recent years because of its excellent corrosion resistance. In this paper, the wetting properties of the plastic alloy tube surface based on the contact angle of crude oil in some oil fields in Xinjiang Oilfield were experimentally studied. The wettability of the plastic alloy tube surface and its influence on the flow resistance were discussed. The wettability of metal surfaces was compared. This experimental study is helpful for the oilfield to make reasonable pipe selection.

1. Introduction

Non-metallic pipe is a heterogeneous engineering material, and its material and structure are very different from steel pipes [1]. Compared with traditional steel pipes, non-metallic pipes have good corrosion resistance and hydrodynamic properties. They have the characteristics of high strength, toughness, and long life. At the same time, they do not need cathodic protection, and have good economic benefits. It is widely used and provides a strong guarantee for the safe and efficient development of oilfields [2]. Xinjiang Oilfield has been using four non-metallic pipes: glass steel pipes, plastic alloy pipes, polyethylene plastic composite pipes, and flexible composite pipes in the production process since 1999. As of now, the total length of non-metallic pipelines used in Xinjiang oilfields is 4794.68km, of which 228km are glass steel pipes, 550km are polyethylene plastic composite pipes, and 383km are flexible composite pipes. Plastic alloy pipes are the most widely used. It is applied to oilfield water injection, crude oil gathering and exporting, with a total of 2813.68km [3]. The extensive use of plastic alloy pipes in Xinjiang oil fields has effectively alleviated problems such as pipeline leakage, corrosion, and scaling. Although plastic alloy pipes have been widely used, the industry standards and enterprise standards of pipe materials are relatively general, there is currently no specific standard for Xinjiang oilfield design, can't get reasonable guidance when faced with different oil properties, usage environment, etc. Therefore, there are still many problems in the actual production of plastic alloy pipelines in the oilfield, such as poor site adaptability, waxing on the inner wall of the pipeline, and oil layer adhesion [4].

In order to make full use of the low friction characteristics of plastic alloy pipelines and meet the production needs of oil fields, it is necessary to consider the wettability of the transported medium and plastic alloy pipe materials in combination with the characteristics of the oil field transportation medium, and reasonably choose the pipe materials according to the actual situation to avoid Various common
problems to increase oilfield production and reduce maintenance costs. Therefore, studying the wettability of plastic alloy pipes is of great practical significance to ensure the efficient and safe production of oil fields.

2. Experiment content
The instrument used in the experiment is the JC2000C1 interfacial tension measuring instrument. Under normal temperature and pressure conditions, measure the surface tension of crude oil from area A and crude oil from area B in Xinjiang Oilfield, and tap water. The contact angles of the above three media and the inner surface of the plastic alloy tube and the surface of the 20 # steel plate were also measured. The physical properties of the two crude oils are shown in Table 1.

|                   | Crude oil from area A | Crude oil from area B |
|-------------------|-----------------------|-----------------------|
| Freezing point(℃) | 20.5                  | 16.5                  |
| Reverse phase point(%) | 35~45               | 10~20                 |
| Oil density(kg/m³) |                       |                       |
| 20℃               | 889.3                 | 821.3                 |
| 40℃               | 867.2                 | 813.2                 |
| 60℃               | 854.5                 | 800.9                 |
| Viscosity(mPa*s)  |                       |                       |
| 20℃               | 10600                 | 20℃                   |
| 40℃               | 433                   | 40℃                   |
| 60℃               | 52                    | 60℃                   |
|                   |                       |                       |

3. Experimental results and discussion

3.1. Surface tension
The surface tension of the experimental medium is shown in Figures 1-3, and the surface tension data is shown in Table 2.

**Table 1. Crude oil properties**

**Figure 1. water surface tension**

**Figure 2. Surface tension of crude oil from area A**
According to the measured surface tension data, it is known that the surface tension of water in the three experimental media is the largest, and is much greater than that of the two crude oils. The surface tensions of the two crude oils are not much different, so when comparing the contact angle data of the two crude oils, the effect of different surface tensions of the crude oil medium on the contact angle can be ignored.

3.2. Surface wettability experiment
The experiments used water, crude oil from area A and crude oil from area B as the media. The static wettability experiments were performed on the inner surface of the plastic alloy pipe and the surface of the 20 # steel plate. The contact angle data were measured as shown in Figures 4-5, Table 3 below.

| Water(N/m) | Crude oil from area A(N/m) | Crude oil from area B(N/m) |
|------------|----------------------------|---------------------------|
| 64.38×10^{-3} | 27.85×10^{-3} | 25.28×10^{-3} |

**Figure 3.** Surface tension of crude oil from area B

**Table 2.** Experimental media surface tension data

**Figure 4.** Contact angle of water, crude oil from area A and area B on the surface of plastic alloy pipe

**Figure 5.** Contact angle of water, crude oil from area A and area B on the surface of 20 # steel
Table 3. Contact angle experimental data

| Materials Experimental | Experimental media | Left | Right | Mean | Left | Right | Mean | Mean |
|------------------------|--------------------|------|-------|------|------|-------|------|------|
| Plastic alloy pipe     | Water              | 97°  | 91.5° | 94.25°| 12.5°| 19°   | 15.75°| < 10.00°|
|                        | crude oil from area A | 18.33°| 18.33°| 18.33°| 63.6°| 63.6° | 63.6° |
|                        | crude oil from area B | —    | —     | —    | —    | —     | —    |
| 20 # steel             | Water              | 62.88°| 62.88°| 62.88°| 18.33°| 18.33°| 18.33°| 63.6° |
|                        | crude oil from area A | —    | —     | —    | —    | —     | —    |
|                        | crude oil from area B | —    | —     | —    | —    | —     | —    |

According to the wettability of the same medium on different materials, the contact angle of crude oil from area A on both materials is relatively small, and the contact angle of the crude oil from area A on the plastic alloy pipe lining is slightly smaller than the contact angle on the surface of 20 # steel plate, which indicates that the wettability of crude oil from area A on the two materials is approximately the same, so under the same flow conditions, A crude oil in the two types of pipelines are subject to greater flow resistance, and the difference is small. The contact angle of crude oil from area B on the plastic alloy pipe lining is very small, less than 10°, which is much smaller than the contact angle of B crude oil on the 20 # steel plate. Similarly, according to the comparison of the contact angle of water on two materials, it can be known that the water flow resistance in plastic alloy pipes is small, and the contact angle of water on the plastic alloy pipe lining is very large, greater than 90°, indicating that the material has hydrophobic characteristics.

According to the wettability of different media on the same material, in plastic alloy tubes, the wettability between B crude oil and the material is the best, A crude oil is the second, and both are much larger than water, that is, the same flow conditions, the contact area between water and the inner pipe wall is the smallest, and the flow resistance generated is also the smallest. The resistance produced by A crude oil is larger, and the resistance produced by B crude oil is the largest.

Considering the emulsification type of the medium in the pipeline, the flow resistance generated by the plastic alloy tube when transporting the o/w emulsion is small, and transporting the w/o emulsion is bigger. When both medium are w/o type, the flow resistance produced by the A crude oil is smaller. Similarly, in the 20 # steel pipe, the wettability between A crude oil and the material is the best, much larger than water and B crude oil, and the wettability of the latter two is approximately the same, under the same flow conditions, the resistance of water and B crude oil in the pipe is relatively small, which is much greater than the resistance produced by A crude oil. When transporting A crude oil, the o/w emulsion is subjected to less flow resistance, when B crude oil is transported, the type of emulsification has little effect on the flow resistance. Although for both crude oils, when both materials are transporting o/w media, they all have less resistance than w/o media, however, due to the hydrophobic nature of plastic alloy materials, this material is more capable of reducing energy loss due to flow resistance when transporting o/w media.

4. Conclusion

According to the wettability experiments on the inner surface of plastic alloy pipes and 20 # steel surface of water, crude oil from area A and area B, we found that:

1) When transporting a crude oil that has been dehydrated or transporting a crude oil from area A and the type is w/o, compared with 20 # steel, the flow resistance generated in the plastic alloy tube is not much different.
(2) When transporting a crude oil that has been dehydrated or transporting a crude oil from area B and the type is w/o, the flow resistance generated in the 20 # steel pipe is much smaller than the plastic alloy pipe.

(3) Plastic alloy pipes are hydrophobic. When transporting water and two types of crude oil with o/w emulsification, the flow resistance produced is smaller than that of 20 # steel pipes.

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