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Short Communication

Fast and Energy-efficient Demulsification for Crude Oil Emulsions Using Pulsed Electric Field

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The demulsification performance for crude oil emulsions using pulsed electric field with and without demulsifiers was studied to find a fast and energy-efficient way to separate oil and water. Demulsifiers with more branches is more effective in demulsification due to the increased penetrability of the demulsifiers, the dewatering rate of crude oil emulsions by AE 121 can reach up to 96.4 % after 60 min. The optimal voltage, frequency and pulse duration ratio of the pulsed electric field for the electro-demulsification process is 5 kV, 4 kHz and 0.8, respectively and a dewatering rate of 91.3 % after 10 min can be obtained at this condition. There is good synergistic effect between demulsifier and pulsed electric field for the demulsification of crude oil emulsions. The demulsification process by demulsifier and pulsed electric field can save at least 50 % demulsifier compared with the chemical demulsification while it can save 50 % time and energy compared with the pulsed electric field demulsification process.

Keywords: demulsification, crude oil emulsion, demulsifier, pulsed electric field, synergistic effect

1. INTRODUCTION

The emulsification of crude oil is a common problem in the oilfield industry. It is essential to break these emulsions before transportation and prior to refining. About 80% of exploited crude oils exist in an emulsion state, all over the world. The more common emulsions in the petroleum industry are of the water-in-oil type [1-4]. The demulsification process becomes more and more difficult especially for heavy oil emulsions due to the exsitance of large quantities of resins and asphaltenes which can be used as the natural emulsifiers [5-6]; or emulsions with large quantities of remained chemicals such as polymer, surfactant and alkali [7].

How to separate oil and water from emulsions fast and energy-efficiently becomes a major task in petroleum industry. There are various methods for crude oil demulsification, such as electro sedimentation [9], filtration [10], microwave demulsification [11], chemical demulsification [12-13]. Chemical demulsification using demulsifiers is commonly used in the oil field chemistry. The process of demulsification by high-voltage pulsed electric field has gained more and more attention because of the advantages such as low energy consumption, simple structure, and rapid processing speed [8-9, 14-18]. The high-voltage pulsed electric fields can promote the coalescence of water droplets in water in oil emulsions. Water droplets can be polarized by the external electric field and then undergo coalescence through collision within a short period of time [17-18]. Dipole coalescence and oscillation coalescence effects existed in pulsed electric fields are the main factors influencing water droplets coalescence in pulsed electric field, especially oscillation coalescence effects [8, 9, 15].

As to the oilfields in the Loess Plateau of Ordos Basin, it is difficult to built large-scale oil and water treatment center due to geomorphic constraints. How to separate oil and water fast and energy-efficiently in wellsite is now an urgent question. In this paper, the demulsification performance using pulsed electric field with and without demulsifiers for crude oil emulsions was studied to find a fast and energy-efficient way to separate oil and water for crude oil emulsions.

2. EXPERIMENTAL

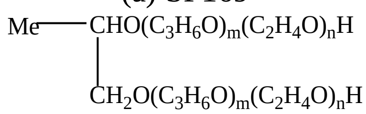
2.1. Material

The crude oil from Yanchi oilfield has a water content of less than 0.5%, and density and viscosity of 865 kg.m^{-3} and 10.2 mPa s (at 50℃). The total salinity of Yanchi formation water is 6744 mg/L: K^+, Na^+ 2198 mg/L; Ca^{2+}, Mg^{2+} 85 mg/L; Cl^- 2334 mg/L; SO_4^{2-} 76 mg/L; HCO_3^- 2051 mg/L.

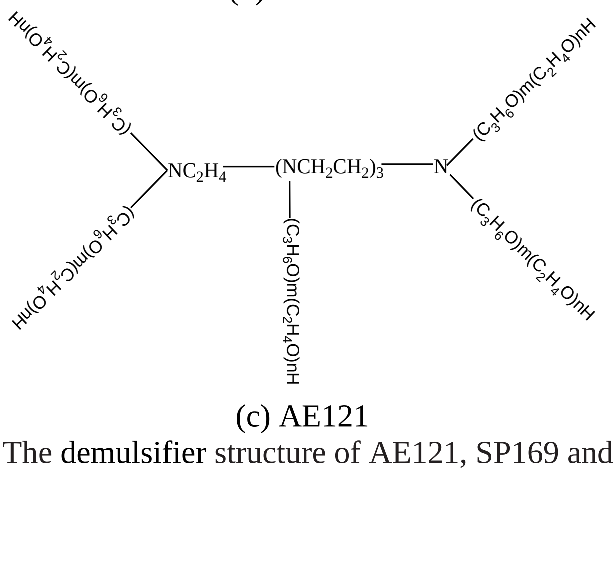
The demulsifiers of AE121, SP169 and BP2040 are industry products which came from Befar Group Co., Ltd and the structure of the demulsifiers is shown in Fig. 1.

$C_{18}H_{37}O(C_3H_6O)_m(C_2H_4O)_nH$

(a) SP169



(b) BP2040



(c) AE121

Figure 1. The demulsifier structure of AE121, SP169 and BP2040**.**

2.2. Preparation of crude oil emulsions

The synthetic crude oil emulsions (water-in-oil type) with a certain amount of water content (25 wt %) was prepared by mixing the purified crude oil and simulation formation water at 40 ℃ using a FM-200 homogenizer (Fluko Corp.) at a rotate speed of 11000 rpm for 10 min.

2.3. Demulsification test

Bottle test was employed to evaluate demulsifier effectiveness according to China Petroleum Industry Standard of SY/T 5281-2000. The dewatering rate φ of the crude oil emulsions was calculated by the following formula:

$$\phi = V_t / V_0 \times 100\% \qquad \text{(Eq. 1)}$$

Where V_0 is the original water volume before bottle test, V_t is the separated water volume after demulsification at a certain time.

2.4. Demulsification using Pulsed Electric Field

The experimental set-up of the pulsed electric field dewatering equipment consists of a high-voltage rectangular pulse generator, a step-up transformer and a set of small cylindrical-type static electric dehydrator. The rectangular pulse generator can produce square wave signal with adjustable voltage, frequency and pulse duration ratio. The crude oil emulsions with or without demulsifiers were placed into the dehydrator and the dewatering rate was calculated by Eq. 1.

3. RESULTS AND DISCUSSION

3.1. Demulsification by demulsifiers

The dewatering rate of crude oil emulsions as a function of demulsification time with and without demulsifiers (the concentration of the demulsifiers is 100 mg/L) was shown in Fig. 2. The three demulsifiers are nonionic surfactants with the average molecular weight of about 3000. The branch number of SP169, BP2040 and AE121 is 1, 2 and 5, introspectively. AE 121 showed the best demulsification performance compared with SP 169 and BP 2040. The demulsifiers can replace the interfacial film between oil and water and thus decrease the strength of the oil-water interfacial film, the demulsifiers with more branches is more effective in demulsification due to the increased penetrability of the demulsifiers [11]. The dewatering rate of crude oil emulsion by AE 121 can reach up to 96.4 % after 60 min.

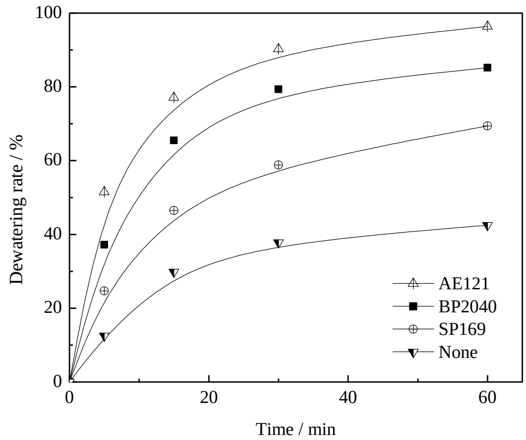


Figure 2. Dewatering rate of crude oil emulsions with and without demusifers (the concentration of the demulsifiers is 100 mg/L)**.**

3.2. Demulsification using Pulsed Electric Field

The influence of voltage, frequency and pulse duration ratio on dewatering rate of the crude oil emulsions using pulsed electric field was shown in Fig. 3~Fig. 5, respectively. It can be seen from Fig. 3 that the highest dewatering rate after 10 min occurred at the voltage of 5 kV. It's mainly because that water droplets under the pulsed electric field gradually stretches with increasing electric field intensity and then breaks down into two small droplets, so there is an optimal voltage of pulsed electric field for the demulsification process [9, 19].

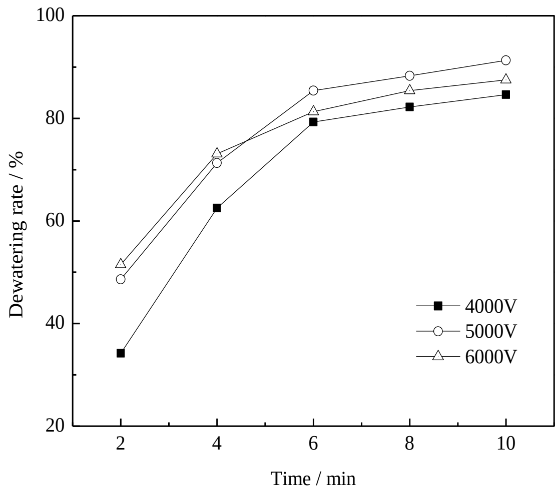


Figure 3. Influence of voltage on dewatering rate of crude oil emulsions using pulsed electric field (frequency is 4 kHz and pulse duration ratio is 0.8).

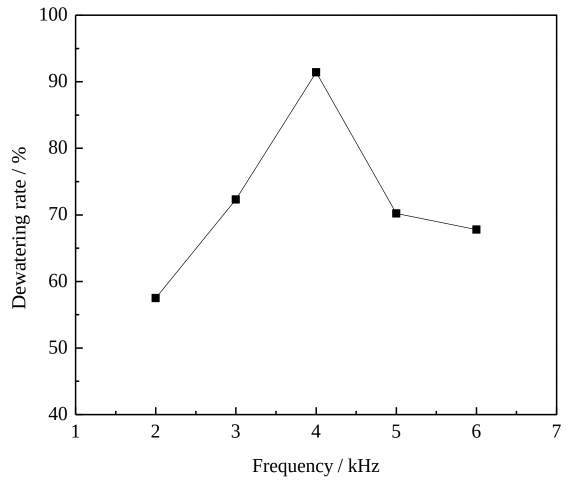


Figure 4. Influence of frequency on dewatering rate of crude oil emulsions using pulsed electric field (voltage is 5 kV and pulse duration ratio is 0.8, 10 min).

Pulsed electric field frequency exerts an important impact on the coalescence of water droplets in crude oil emulsions as illustrated by several researchers. An optimal pulsed electric field frequency can enhance droplet vibration and promote oil film burst and droplet coalescence [15, 19-23]. As shown in Fig. 4, an optimal frequency of 4 kHz of pulsed electric field was obtained for the demulsification process. Pulse duration ratio is the percentage of the pulse width to the total period of the waveform.

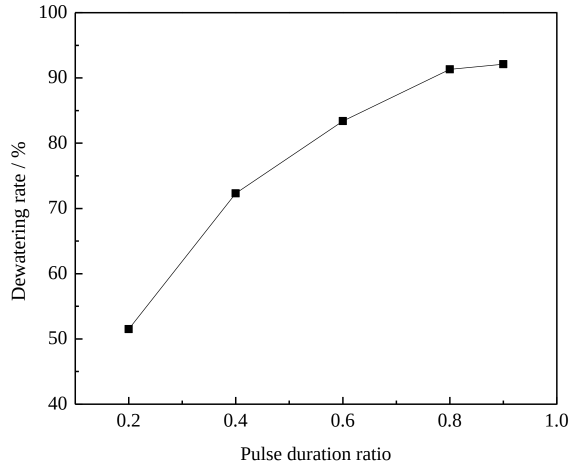


Figure 5. Influence of pulse duration ratio on dewatering rate of crude oil emulsions under pulsed electric field (voltage is 5 kV and frequency is 4 kHz, 10 min).

As shown in Fig. 5, the dewatering rate of crude oil emulsions increased with the increasing pulse duration ratio while the increasing trend became more and more gentle, especially when pulse duration ratio was above 0.8. Besides, high pulse duration ratio means high energy consumption. Therefore, an optimal pulse duration ratio of 0.8 was recommended for the demulsification process.

Different crude oil emulsions need different electric field parameters in the pulsed electric field demulsification process. It is an important subject to match parameters promoting coalescence in the dynamic research of pulsed electric fields and thus to present important guiding significance in the industrial applications of pulsed electric field demulsification technology [19-23]. The demulsification performance of pulsed electric field is dependent upon various factors including the crude oil properties, temperature and the features of crude oil emulsions [24-27]. The viscosity of crude oil is a dominant and representative factor because it reflects both chemical and electrical effects of the crude oil samples[24, 26]. The viscosity of crude oil emulsions, particle size and salt concentration affect the coalescence of water droplets [25, 27].

3.3. Demulsification by demulsifier and Pulsed Electric Field

The dewatering rate of crude oil emulsions using pulsed electric field with and without demulsifiers was shown in Fig. 6. The dewatering rate with demulsifiers increased a lot compared with that without demulsifiers which means the demulsification process using pulsed electric field and demulsifier consumed less time and energy to reach a same dewatering rate compared with that without demulsifier. To reach a dewatering of 91.3%, the demulsification process using pulsed electric field and AE121 consumed 5 min while the demulsification process by pulsed electric field without demulsifier consumed 10 min.

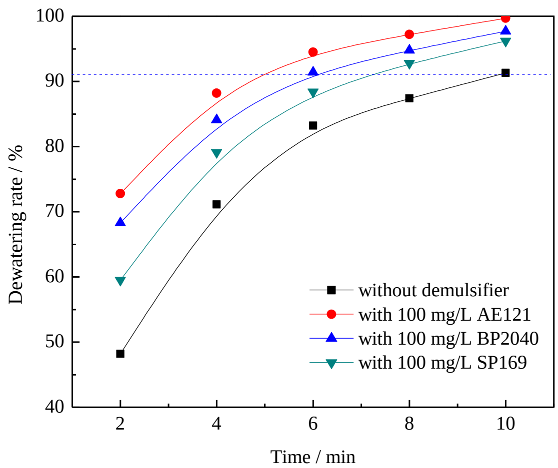


Figure 6. Dewatering rate of crude oil emulsions using pulsed electric field with and without demulsifiers (voltage is 5 kV, frequency is 4 kHz and pulse duration ratio is 0.8).

The influence of demulsifier concentration on dewatering rate of crude oil emulsions using pulsed electric field was shown in Fig. 7. The dewatering rate of crude oil emulsions increased with the increasing demulsifier concentration while the increasing trend became more and more gentle. As to AE121, an optimal concentration of 40 mg/L was recommended for the demulsification using pulsed electric field and demulsifier. The results of Fig. 6 and Fig. 7 showed good synergistic effect between demulsifier and pulsed electric field for the demulsification of crude oil emulsions. The demulsifiers can decrease the strength of the oil-water interfacial film while the pulsed electric field can accelerate the coalescence in emulsions, the demulsication process can be further accelerated using pulsed electric field and demulsifier. The demulsification process by demulsifier and pulsed electric field can save at least 50 % demulsifier compared with the thermo-chemical demulsification while it can save 50 % time and energy compared with the pulsed electric field demulsification process.

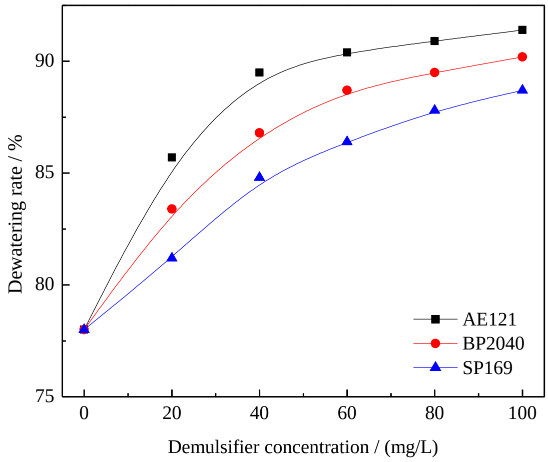


Figure 7. Influence of demulsifier concentration on dewatering rate of crude oil emulsions using pulsed electric field (voltage is 5 kV, frequency is 4 kHz and pulse duration ratio is 0.8 , 5 min).

4. CONCLUSION

Demulsifiers with more branches is more effective in demulsification due to the increased penetrability of the demulsifiers, the dewatering rate of crude oil emulsions by AE 121 can reach up to 96.4 % after 60 min. The optimal voltage, frequency and pulse duration ratio of the pulsed electric field for the electro-demulsification process is 5 kV, 4 kHz and 0.8, respectively and a dewatering rate of 91.3 % after 10 min can be obtained at this condition. There is good synergistic effect between demulsifier and pulsed electric field for the demulsification of crude oil emulsions. The demulsification process by demulsifier and pulsed electric field can save at least 50 % demulsifier compared with the chemical demulsification while it can save 50 % time and energy compared with the pulsed electric field demulsification process.

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