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Application of ultrasound on crude oil pretreatment

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Abstract

The ultrasonic irradiation for crude oil pretreatment to enhance desalting process was investigated. The intensity and irradiation time of ultrasound were studied. The settling time and the temperature of treatment for crude oil were also studied. Micrographs in this paper showed that the sizes of water drops were enlarged by more than 30% after the proper ultrasonic irradiation. The crude oil was pretreated for 5 min at 80 °C in the standing-wave field with frequency of 10 kHz and with ultrasonic intensity of 0.38 W cm^{-2}. After the pretreatment, the dewatering rate and desalting rate were up to 92.6% and 87.9%, respectively in 90 min of settling time. The resulting final salt content of 3.85 mg L^{-1} is acceptable for refinery.
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Keywords: Ultrasound; Crude oil; Demulsification; Dewatering; Desalting

1. Introduction

As a current preliminary step of refinery treatment, crude oil is normally desalted to remove species such as chloride which deactivate the refinery catalysts and cause further corrosion of overhead distillation columns [1–4]. In this process, water is deliberately mixed into the oil to dissolve hydrophilic materials. Usually, emulsions are formed of water-in-oil (w/o). In the case of emulsions, when two droplets approach each other, the interfaces are separated by a thin film of oil [5]. The emulsions must subsequently be broken down to recover the “clean” crude oil. Some of the oil fields have already got into the stage of secondary or tertiary oil recovery. The crude oil recovered in this way tends to become ropier and heavier, containing more salts. It may be hard to desalt those oils with conventional methods by electric desalting and dewatering processes. Blackout of the desalting device and current collapse of the electric field usually happened. The oil pretreatment is discontinuous and unsteady. The need of demulsification and the impetus of developing new methods for effective treatment of oil have become more acute [6].

The stability of w/o emulsion was decreased in the presence of ultrasonic irradiation. This was due to the impulse of ultrasonic field. The motion of solid, liquid or bubble particle in an acoustic field had been studied by many researchers in the past, such as Zhao et al. [7], Pangu and Feke [8] and Yutaka et al. [9]. The suspended particles would respond to the acoustic resonant if there was a non-zero acoustic contrasted between the dispersed phase and the suspending fluid. In those methods, a one-dimensional sound field was used to organize the particles into thin parallel bands separated by half of the acoustic wavelength spacing. The particles were separated from their suspending fluid by two methods. Firstly, barriers were placed closely between the bands of particles. Particle-free and particle-rich streams were produced in the acoustic field. It would be transported into separate exit streams [10–12]. Secondly, the particles were also transported to the opposite direction of the flowing fluid by using slowly moving pseudo-standing-waves [13]. It was shown that tiny water drops in the crude oil could be driven and aggregated into bigger ones in a suitable ultrasonic standing-wave field. Therefore, the water drops would settle down easily.

The original emulsion of water in the crude oil is very stable and difficult to be broken [14]. Many researchers were concerned on the dewatering process of the crude oil by ultrasound in oil fields. Seldom of them applied ultrasound on the desalting step of the crude oil, especially in refinery [15,16]. In this paper, ultrasound was applied in demulsification of the man-made crude oil emulsion to desalt. A method moving suspended drops to the nodes of an ultrasonic standing-wave field was given [17]. It was efficient to separate water from oil emulsion with ultrasonic.

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The main purpose of this paper was to demonstrate the method for separating water from oil and to investigate the influences of ultrasonic standing-wave resonator to desalting process.

2. Experimental

Salt content analyzer (ZWC-2001), CS-3 hydrophone, oscillograph, ultrasonic generator and transducer (500 W, 10 kHz, including standing-wave resonator and reverberation resonator), crude oil (Lu-Ning piping, China) were used. The oil had a density of 0.9207 g mL^{-1} (20 °C), a viscosity of 1390 mPa s (20 °C), an original salt content of 53.5 mg NaCl L^{-1}, and an original moisture content 0.29 vol.%. Demulsifier (NS-2003) and dimethylbenzene used as an entertainer to determine the moisture were employed.

The standing-wave resonator was composed with a tube filled with crude oil, a piezoelectric transducer and a reflection surface at the bottom of the resonator as shown in Fig. 1. The distance between the transducer surface and the reflection surface was determined strictly in order to form a standing-wave field in the tube. The distance must be equal to odd times of the ultrasonic half wavelength. If the distance was not equal to odd times of it, a reverberation chamber would be formed instead. Hydrophone was used to measure the ultrasonic intensity. The intensity was calculated as $I = P_a^2/(2\rho c)$. Where, P_a was the amplitude of sound pressure measured by hydrophone and oscilloscope (Pa), ρ was the density of the crude oil (kg m^{-3}), and c was the velocity of ultrasonic in oil (m s^{-1}). The hydrophone was also used to determine whether the standing-wave profile formed.

Crude oil and water were able to form steady emulsifications easily. Tap water was mixed with a proper dosage of demulsifier (vs. water, 400 μg g^{-1}) before adding into the crude oil sample. Thus, an unsteady emulsification was developed, and it was beneficial to the following dewatering and desalting processes.

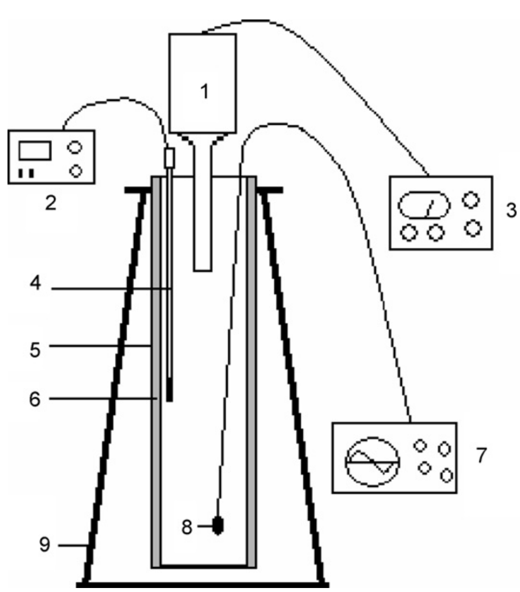

Fig. 1. Model of standing-wave resonator. (1) Ultrasonic transducer, (2) temperature controller, (3) ultrasonic generator, (4) thermometer, (5) standing-wave resonator, (6) insulating layer, (7) oscilloscope, (8) hydrophone and (9) nog.

Dimethylbenzene was used to analyze oil moisture (GB/T8929-2006). Tap water (vs. oil 5 vol.%) was added into crude oil and the settling temperature was about 80 °C.

The typical dewatering and desalting experimental steps were as following, 5 vol.% tap water containing demulsifier was added into the crude oil through static mixers. The salts were extracted from oil phase at the mixing step, and an unsteady emulsification formed at the same time. Then, the tiny drops dissolving salts were aggregated into bigger ones by ultrasonic irradiation. At last, the water dissolving salts were removed by a gravity settling process.

The crude oil was pretreated in several ways, in standing-wave field, in reverberation field and without ultrasonic irradiation, respectively. Every experiment was tested three times. The frequency and intensity of ultrasonic irradiation were 10 kHz and 0.38 W/cm^2, respectively. The irradiation time was 5 min. The temperature of ultrasonic irradiation and settling were usually 80 °C. A settling time of 90 min was usually used.

3. Results and discussion

3.1. The process of dewatering and desalting

Experimental results were shown in Figs. 2 and 3. The dewatering and desalting results in ultrasonic standing-wave field were better than those in the ultrasonic reverberation field. Both of them were better than those without ultrasonic irradiation. Thus, the standing-wave field was chosen as the oil pretreatment in the following experiments.

The settling time was a major factor which influenced the dewatering and desalting results of crude oil. The moisture content (water in volume over total fluid) and the salt content of the crude oil decreased remarkably during the first 40 min of settling as shown in Figs. 2 and 3. And then the trends slowed down with the settling time gone. We knew that bigger water drops were settled down easily and the tiny droplets need much longer time for settlement. The settling velocity of tiny droplets was lower because the settling resistance of tiny droplets was bigger than that of big ones. The influence of settling time was not obvious

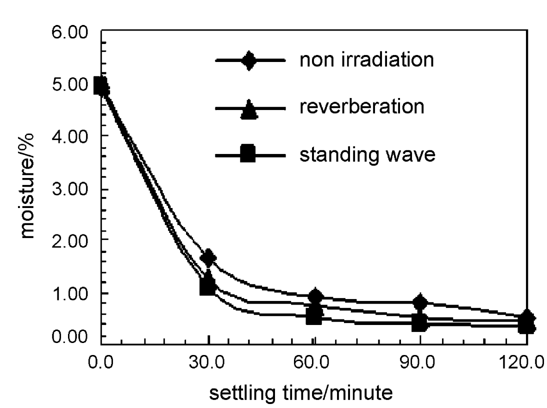

Fig. 2. Moisture content vs. settling time between reverberation, standing-wave and non irradiation. Ultrasonic intensity was 0.38 W cm^{-2}, irradiation time was 5 min, temperature was 80 °C.

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