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RESEARCH ON VISCOSITY REDUCTION OF OIL IN WATER FOR ULTRA HEAVY CRUDE OIL BY USING OF ULTRASONIC WAVE

Delong Xu, Jinjing Deng, Chao Li, Lixin Bai

Institute of Acoustics, Chinese Academy of Sciences, Beijing, China 100190

e-mail: xudelong@mail.ioa.ac.cn

Bin Ding, Jianhui Luo

Research Institute of Science and Technology, CNPC, Beijing, China 100083

The effects of ultrasonic wave on the dilution of diesel and Venezuela ultra heavy crude oil (UHCO) and the oil in water (O/W) viscosity reduction for Fengcheng UHCO are studied in this paper. Both the Venezuela and Fengcheng UHCO are non-Newtonian fluid and their viscosity-temperature curves coincide with each other. The effects of ultrasonic wave on the viscosity reduction for the dilution of diesel and Venezuela UHCO are negative because of the accelerated dissolution of heavy components such as asphaltene under ultrasonic wave. The effects of ultrasonic wave on the viscosity reduction for Fengcheng O/W viscosity reduction with SOWE, 70%SOWE, 80%SOWE and 90%SOEW are active. A decrease of more than 25% viscosity for the O/W viscosity reduction is achieved. Meanwhile, less quantity of viscosity reducer is needed. The emulsion with ultrasonic processing (UP) is more uniform and stable. From the experiments of this paper, cautions must be taken when the ultrasonic wave is used to improve the rheological properties of dilution of UHCO and lighter crude oil or hydrocarbon. And before the UP is used to pilot test in the oil field, the optimal situation such as UP time, electrical power, and the concentration of the emulsion for UP can be chosen from the preliminary experiments. The result is helpful for the UHCO extraction and transportation.

1. Introduction

In the last decades, the global demand for crude oil has grown drastically. Especially in the first decade of the 21th century, it rises from 1% to 1.8% (International Energy Agency (IEA), 2009). For China, it is consuming oil at even higher speed compared with others. Among them, unconventional oil and gas such as ultra heavy crude oil (UHCO) and high pour point crude oil represents more than 50% of the world's recoverable oil resources [1]. Heavy oil is defined as petroleum whose density is less than 20API. But when its density is less than 10API, it's called UHCO or bitumen according to American Petroleum Institute [2]. For example in China, UHCO accounts for a bigger percent in the proven reserves. Therefore, unconventional reservoirs like UHCO are getting more and more attentions in the world. But the difficulties of heavier density, higher viscosity and worse fluidity are faced during the production and transportation of UHCO [3].

Obviously, it is important to lower UHCO apparent viscosity and keep its good fluidity during its extraction and pipe transportation. Heating, dilution and adding viscosity reducer are traditionally among the methods used to lower the viscosity of UHCO. Electrical, electromagnetic and microwave methods et al. are options of heating [4]. Electrical heating is the best alternative of the conventional methods in heating the reservoir at low cost, no environmental effects on the geology of the reservoir. Its limitations include non-uniform heating of reservoir especially most of the energy and heat is concentrated near the wellbore region. Some cases are only applicable in the presence of brine e.g., resistive or joule heating. Electrodes also suffer from the corrosion. Similarly microwaves only travel in line of sight and presence of any hurdle in between the source and target may attenuate them resulting in energy loss.

Dilution is one of the oldest and preferred methods traced back to the 1930s for reducing the viscosity of heavy oils which consists in the addition to heavy oil of lighter liquid hydrocarbons [5]. It is an effective method to reduce heavy oil viscosity and facilitate its good mobility, especially in pipeline. But diluting may facilitate certain operations such as dehydration and desalting etc. which request substantial investments in pumping and pipelines due to the increase of transport volume and need to separate at some point the solvent, processes it and subsequently returns it to reservoirs. What's more, the composition of oil may affect the required oil/solvent ration. Special attention also has to be accorded to stability of asphaltene and paraffin in oil since addition of lighter oil may cause precipitation and clogging which is attributed to the crystallization and deposition of paraffin waxes [6-7]

The formation of oil in water emulsions with the help of surfactant agents is an effective way to reduce the viscosity of UHCO [5, 8]. It can be obtained by shaking, stirring or some other kind of intensive dynamic and /or static mixing processes. To avoid phase separation, surfactants and stabilizing agents are added to reduce oil interfacial tension. But the stability of the emulsions depends on many factors such as the composition of UHCO, surface active molecules, type of surfactants and their concentration, energy in mixing, size of the droplets, salinity and PH of water and temperature etc. Even so , once the oil droplets whose diameter is less than 10μm forms, it does harm to pipelining because such small oil droplets can increase the viscosity of the oil in water emulsion and cause emulsion inversion to an water in oil. The viscosity of the emulsion will increase sharply when it happens.

Ultrasonic wave can also be used to improve rheological properties of crude oil either in reservoirs or in pipeline [9-10]. Despite that the size of ultrasonic vibrator is sometimes limited by the space where it is needed, it can suitable for reservoirs where heavy oil is lying behind water. The advantages of ultrasonic wave for processing oil are environmentally friendly and energy efficient. Some chemical reactions are firing greatly with the presence of ultrasonic wave, even that some reactions cannot react without its presence. Although it has been used for improving the rheological properties of crude oil, there is a little for improving that of heavy crude oil, much less for UHCO and its emulsion of oil-in-water (O/W).

In this paper, the effects of ultrasonic wave on the rheological properties of Venezuela and Fengcheng UHCO are studied. The results show that the rheological properties of the UHCO can be improved though the irradiation of ultrasonic wave in O/W emulsion. But the applications of ultrasonic wave for reducing the viscosity in dilution of higher hydrocarbon and UHCO must be cautious.

2. Materials and equipments

The viscosity in this paper is measured by rheometer (Brookfield RVDVIII, USA) assembled with the accessories of the TC550 constant temperature bath and a small sample adapter. The effects of measuring time, the torque, shear stress and shearing rate et al. on the viscosity value of measured UHCO are studied firstly. Then the suitable measuring situation is chosen for Venezuela and Fengcheng UHCO respectivecly. In the following measurement, the situation is sustained same with cautions to reduce the errors caused by these factors. More details are not given due to the space limitations.

Venezuela and Fengcheng UHCO used in this paper are provided by Research Institute of Science and Technology (RIST), CNPC. Their properties are shown in Table 1. And their viscosity-temperature curve is shown in Figure 1. From Figure 1, Venezuela and Fengcheng UHCO are both non-Newtonian fluid and their viscosity- temperature curve coincides with each other very well. The diesel oil chosen for diluting Venezuela UHCO is 0# diesel according to the GB/T19147-2003 standard of China.

The O/W emulsion for Fengcheng UHCO viscosity reduction is prepared by using active macromolecule viscosity reducer and tap water. The effects of viscosity reducer concentration, the ration of oil and water and the initial agitating speed on the emulsification have been investigated. The optimal condition for reducing viscosity is that the ratio of oil, water and viscosity reducer is 10:3:0.2 % and the initial agitating speed is more than 400 rpm [11]. The aforementioned optimal condition is call "standard O/W emulsion (SOWE)" in this paper. To investigate the effects of ultrasonic on the Fengcheng O/W emulsion, 70%SOWE, 80%SOWE and 90%SOWE are prepared also in which the ratio of oil, water and viscosity reducer is 10:2.1:1.4%, 10:2.4:0.16% and 10:2.7:0.18% respectively. The emulsion is prepared with the tap water and UHCO according to Q/SY118-2013 of CNPC.

Table 1. The Properties of Venezuela and Fengcheng UHCO.

Properties	Density 20℃, g/cm^3	Pour point ℃	Wax m%	Saturate m%	Aromatic m%	Resin m%	Asphaltene m%
Venezuela UHCO	1.0129	26	<1	28.14	35.54	27.20	9.12
Fengcheng UHCO	0.9634	17	<1	51.63	22.02	25.60	0.75

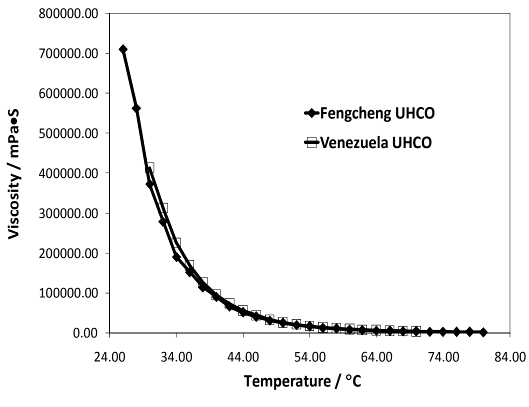


Figure 1. Viscosity- temperature curve of Venezuela and Fengcheng UHCO.

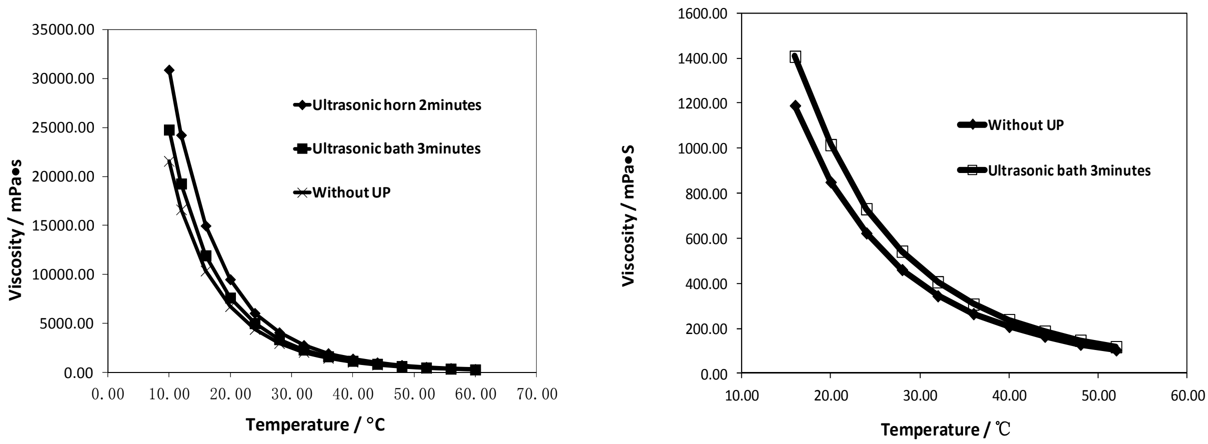
The ultrasonic processing (UP) equipments used are ultrasonic horn (Institute of Acoustics, Chinese Academy of Sciences) and ultrasonic bath (Beijing Goldstar Ultrasonc Equipment Tech Co., Ltd, China). The electrical powers input for ultrasonic horn and bather are 150W and 600W respectively. The basic frequencies are 18 kHz (horn) and 24 kHz (bath). Analytical balance (A & D, Japan), stirring apparatus, beakers, measuring cylinders and so on are also used.

3. Ultrasonic effects on the dilution of diesel and Venezuela UHCO

Two kinds of dilutions are prepared for experiments: 80% Venezuela UHCO and 20% diesel, 70% Venezuela UHCO and 30% diesel. In the diluting process, the mixture is put in 100mL beaker firstly. Then it is put in the constant temperature bath in which the temperature is kept at 50 ℃. It is stirred enough for without UP. When it is processed by ultrasonic horn and bath, it is not stirred.

The viscosity-temperature curves of the dilution are shown in Figure 2. From Figure 2(a), compared with the viscosity of the dilution without UP, that processed by ultrasonic horn and bath has an increase of 25% at 20℃. The increase of ultrasonic horn whose acoustic intensity is higher than that of ultrasonic bath is more than that of ultrasonic bath. In experiments, the optimal processing time for ultrasonic bath is 3 minutes. When the time is longer than that, no more increase of viscosity is observed. From Figure 2(b), the increase of viscosity is 15% compare with that without UP.

It seems that the effects of ultrasonic wave on the dilution of Venezuela UHCO and diesel are negative. Therefore, cautions must be taken when the ultrasonic wave is used to improve the rheological properties of the dilution of UHCO and lighter crude oil or hydrocarbon [9]. The mechanism that viscosity of irradiated sample is relatively higher than non-irradiated samples can be attributed to accelerated dissolution of heavy components that suspended in the diesel, especially the asphaltenic components under the irradiation of ultrasonic wave which corresponds to the higher yield stress values.



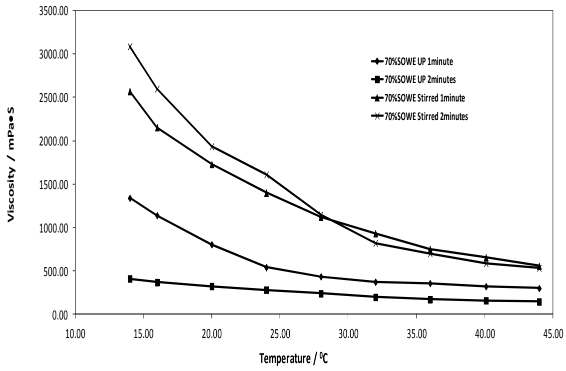
(a) 80%Venezuela UHCO and 20% diesel (b) 70%Venezuela UHCO and 30% diesel

Figure 2. Viscosity- temperature curve of Venezuela UHCO diluted with 0# diesel.

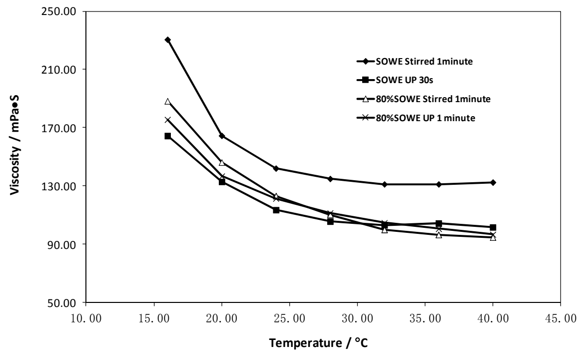
4. Ultrasonic effects on O/W viscosity reduction for Fengcheng UHCO

Four kinds of O/W viscosity reduction for Fengcheng UHCO mentioned above are prepared: SOWE, 70% SOWE, 80% SOWE and 90%SOWE. In experiments, the mixture is put in 100mL beaker firstly. Then it is put in the constant temperature bath in which the temperature is kept at 50 ℃. It is stirred enough for without UP. When it is processed by ultrasonic horn, it is not stirred. In the Ultrasonic Processing (UP), the temperature is kept almost constant.

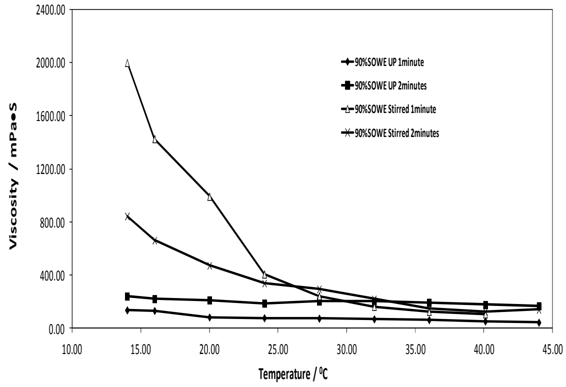
The effects of ultrasonic wave on the O/W viscosity reduction for Fengcheng UHCO are shown in Figure 3 and Figure 4. From these figures, the effects of ultrasonic wave on the O/W viscosity reduction are active obviously, especially when the temperature is low. In Figure 3(a), compared with the viscosity stirred, that processed by ultrasonic wave has a more than 50%decrease of viscosity reduction at 20℃. Due to the cavitation, vibration, jet and shock wave effects, the emulsion with UP looks more uniform. The fluctuations of the viscosity value of the emulsion without UP during measurement are more violet, which means the emulsion is not stable and uniform enough. Sometime the UHCO can be observed that separate with water and surround the measuring rotor. The phenomena can be observed for 80%SOWE, 90%SOWE and SOWE with UP. That's the reason that cause the violet fluctuations of viscosity value for emulsions without UP. For emulsions with UP, the phenomenon is little. In Figure 3(b), the viscosity of the emulsion processed by ultrasonic wave has a more than 25%decrease of viscosity reduction at 20℃. In Figure 3(c), the viscosity of the emulsion processed by ultrasonic wave has a more than 50%decrease of viscosity reduction at 20℃.



(a) 70% SOWE



(b) SOWE and 80% SOWE



(c) 90% SOWE

Figure 3. Viscosity- temperature curve of O/W viscosity reduction for Fengcheng UHCO.

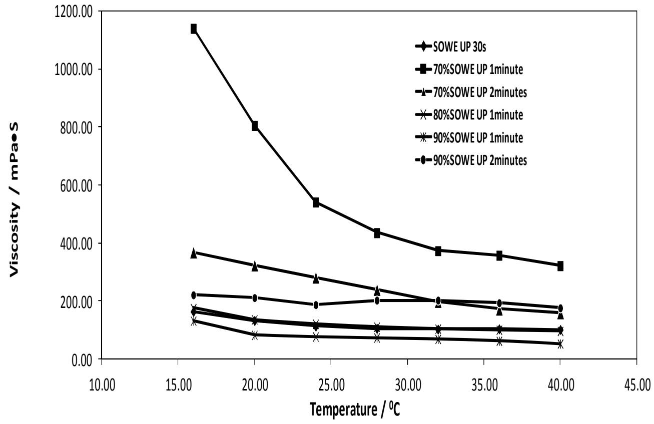


Figure 4. Viscosity- temperature curve of O/W viscosity reduction for different percent SOWEs.

From the results shown in Figure 3, a decrease of more than 25% viscosity for emulsion with UP can be achieved and less quantity of active macromolecule viscosity reducer is needed.

In Figure 4, the curves from top to bottom are: 70%SOWE with 1 minute UP, 70%SOWE with 2 minutes UP, 90%SOWE with 2 minutes UP, SOWE with 30s UP and 80%SOWE with 1minute UP which coincide with each other very well and hard to be distinguished in this figure, and 90%SOWE with 1minute UP. It seems that there is optimal UP time for different percentage SOWE. For example, the viscosity of 90%SOWE with 1minute UP is lower than that with 2 minutes UP. Therefore the ultrasonic processing is used to help reduce the viscosity of O/W viscosity reduction, the optimal such as UP time, electrical power input can be chosen by the experiment for the special situation.

5. Conclusions and discussions

The effects of ultrasonic wave on the dilution of diesel and Venezuela UHCO and the O/W viscosity reduction for Fengcheng UHCO are studied in this paper.

• Both the Venezuela and Fengcheng crude oil are UHCO. Because the Fengcheng is much easier to obtain and do pilot test in the field for us, the experiments for Fengcheng UHCO is preliminary preparation for Venezuela UHCO which is our main interest.

• The effects of ultrasonic wave on the viscosity reduction for the dilution of diesel and Venezuela UHCO are negative. The reason may be that ultrasonic wave accelerates dissolution of heavy components that suspended in the diesel, especially the asphaltenic components under the irradiation of ultrasonic wave which corresponds to the higher yield stress values. Therefore, cautions must be taken when the ultrasonic wave is used to improve the rheological properties of dilution of UHCO and lighter crude oil or hydrocarbon.

• The effects of ultrasonic wave on the viscosity reduction for Fengcheng O/W viscosity reduction with different percentage SOWE are active. A decrease of more than 25% viscosity for the O/W viscosity reduction is achieved. Meanwhile, 30% less quantity of viscosity reducer is needed. What's more, the emulsion with UP is more uniform and stable.

• There is an optimal situation such as UP time, electrical power, and the concentration of the emulsion for UP. Before the UP is used to pilot test in the oil field, experiments must be done to choose the optimal situation.

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