Journal of Petroleum Science and Engineering 81 (2012) 177–181

Contents lists available at SciVerse ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

Flocculation, coalescence and migration of dispersed phase droplets and oil–water separation in heavy oil emulsion

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ARTICLE INFO

Article history:
Received 26 January 2010
Accepted 9 December 2011
Available online 5 January 2012

Keywords:
heavy oil emulsion
stability
demulsification
droplet size
phase separation
demulsifier

ABSTRACT

The oil–water separation and dispersed phase droplet or flocculate droplet or flocculate size variation in the heavy oil emulsion were analyzed by using the Turbiscan Lab stability analyzer. The demulsification process of the heavy oil emulsion was described as well. The results indicated that three-phase separation took place slowly in the heavy oil emulsion and the emulsion middle layer finally formed between the oil phase and water phase, and the demulsification was mainly caused by the dispersed phase droplets sedimentation. After the chemical demulsifier was added into the emulsion, two-phase separation took place quickly, the emulsion stability data accurately conformed to the emulsion stability model based on the two-phase separation. Comparing the characteristic of the demulsification process of the heavy oil emulsion before and after the addition of demulsifier, it indicated that the coalescence of the dispersed phase droplets is the controlling factor and crucial step of the demulsification.

1. Introduction

Demulsification processes are typically described in terms of a few basic steps including flocculation, coalescence and sedimentation. In fact, any demulsification will be a complex combination of these steps. Demulsification is affected by many factors, and for the sake of easing the study, emulsion stability is considered to depend on the degree of flocculation and coalescence. The stability of emulsion can be evaluated using various methods such as bottle test method, critical electric field measurements and thermal analysis (Aske et al., 2002; Beetge and Horne, 2005; Clausse et al., 2005; Dalmazzone et al., 2009; Opawale et al., 2009).

Heavy oil represents a significant proportion in the world oil and gas resources. Study indicates that heavy oil contains a large number of paraffin particle, pectin, asphaltenes and clay particles, which can act as the nature emulsifiers to adsorb on the oil–water interface to form a rigid film at the oil–water interface. The film limits the coalescence of droplets and consequently leads to a result that the produced heavy oil emulsion through thermal recovery always form high water-cut emulsion with high stability (Zhao, 2001; Kenneth, 2002; Noik et al., 2005). In previous investigations, the chemical demulsifier can change the characteristic of the oil–water interface film and weaken the inhibition of the oil–water interface film to the coalescence of droplets, and then the demulsification processes can be promoted (Mohammed et al., 1994; Kang et al., 2006).

In this paper, the microscopic image of the heavy oil emulsion was investigated by XSJ-2 laboratory microscope (Chongqing Photoelectrical Equipment Corp.) to get 1000 times amplificatory images of the emulsion. The dispersed phase droplet or flocculate size variation and oil–water separation at different temperatures were studied through monitoring the microscopic dynamic characteristic of the heavy oil emulsion in real-time by using the Turbiscan Lab stability analyzer. Furthermore, the demulsification process before and after adding the demulsifier was described elaborately.

2. Experimental

2.1. Materials

- Heavy oil emulsion: Jilin Oil Field, P.R. China.
- Demulsifier PR926: Provided by Weifang Luxing Chemical Industrial Co., Ltd.

2.2. Equipments

XSJ-2 laboratory microscope: Made in Chongqing Photoelectrical Equipment Corp. It can be used to observe the microscopic image of the heavy emulsion to get 40–1200 times amplificatory images of the emulsion. The image analysis software can give the average particle size statistically.

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0920-4105/$ – see front matter
doi:10.1016/j.petrol.2011.12.011

Turbiscan Lab stability analyzer: Made in German ALV-GmbH Company. Turbiscan Lab is a kind of optical instrument to analyze the characteristic of the samples of concentrated colloid and dispersion by measuring the transmittance and backscattering of a pulsed near infrared light ($\lambda = 880$ nm). The transmittance detector received the light which passed through the dispersion at an angle of 180° with respect to the source, while the back scattering detector received the light scattered backward by the dispersion at an angle of 45°. The analysis of stability was carried out as a variation of backscattering (BS) and transmittance (T) profiles. The following formula was applied:

$$BS \approx \frac{1}{\sqrt{\lambda^*}} \tag{1}$$

$$T(\lambda, r_i) = T_0 \; e^{\frac{2r_i}{\lambda}} \tag{2}$$

$$\lambda^*(\phi, d) = \frac{2d}{3\phi(1-g)Q_s} \tag{3}$$

Where λ^* is the photon transport mean free path in the analyzed dispersion, ϕ is the volume fraction of particles, d is the mean diameter of particles and g or d and Q_s are the optical parameters given by the Mie theory. The graphs of the transmitted and backscattered flux of the sample observed can reflect the microscopic characteristic of the sample during the given time. Through measuring the transmitted and backscattered flux of the sample, the dynamic characteristic of the sample such as the phase separation and dispersed phase droplet size variation can be analyzed (Mengual et al., 1999).

2.3. Procedures

The microscopic image of the emulsion was observed by using the XSJ-2 laboratory microscope. The phase separation and dispersed phase droplet size variation of the heavy oil emulsion under different conditions were studied by analyzing the transmitted and backscattered flux of the emulsion obtained through the Turbiscan Lab and the stability data of the heavy oil emulsion after adding the demulsifier was correlated by means of an emulsion stability model based on the two-phase separation (Civan et al., 2004).

3. Results and discussion

3.1. Analysis of the image of the heavy oil emulsion

The distillation result indicated that the water-cut ratio of the heavy oil emulsion was 78% (China National Standards, 2006). The heavy oil emulsion can be considered as W/O emulsion by using the dilution method. The microscope photographs of the emulsion are shown in Fig. 1, from which the main characteristic of the emulsion can be indicated as follows:

(1) The water droplet shape in the emulsion is complicated, and the water droplet size mainly distributes from several micrometers to several hundreds micrometers which is a considerable distribution range (Fig. 1a and b).
(2) The oil and water distribution in the emulsion is complicated, and there are many multiple oil and water distribution such as the types of O/W/O (Fig. 1c) and W/O/W (Fig. 1d).

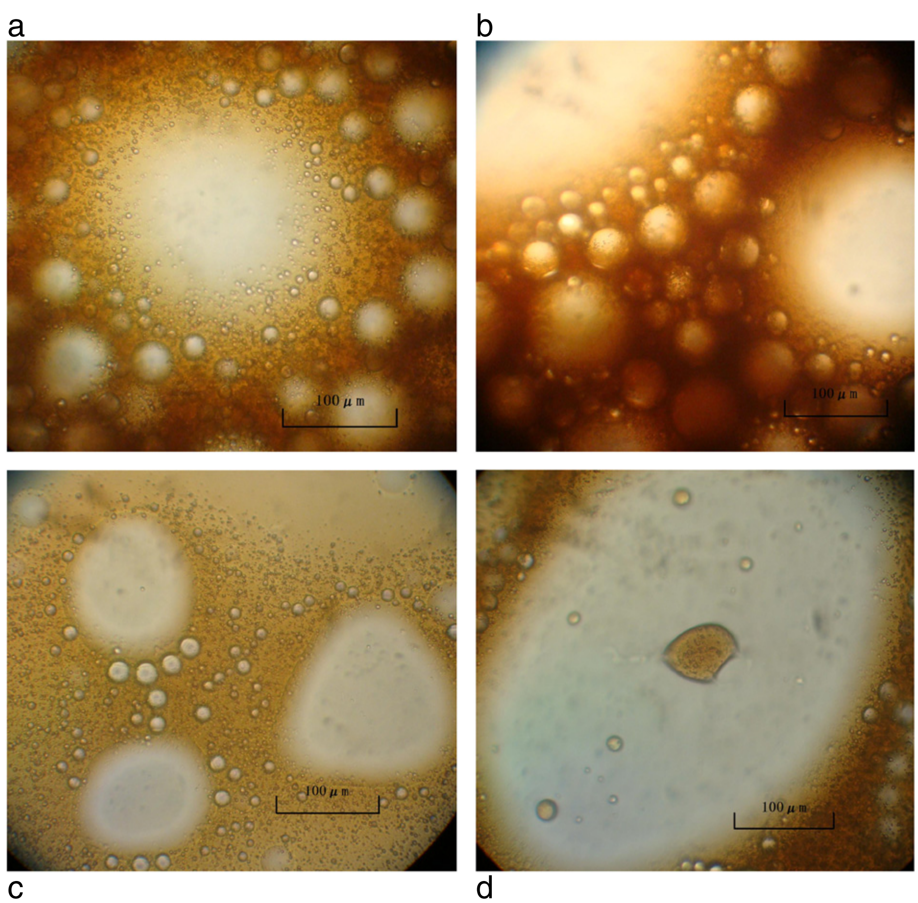

Fig. 1. Microscope photographs of the heavy oil emulsion.