Dynamics of water separation in destruction of water-in-oil emulsions

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Abstract. The dynamics of drop formation and settling processes in breaking water-in-oil emulsions of the West Siberian oil fields was experimentally studied. The investigation results of drop formation in the water-in-oil emulsions were presented. The residual water content in oil was determined after the settling process at the varied initial water content, temperature, and hydrodynamic conditions of emulsion formation.

1. Introduction

Oil treatment in the field involves separation of oil from water, mechanical impurities, and dissolved gases. The processes of dewatering and desalting are complicated. They include drop formation and settling stages and depend on the conditions of emulsion formation and the effectiveness of their breaking [1, 2].

Currently, mathematical modelling is effectively used to study and design petroleum refining processes applying simulated dynamic models and modeling systems [3–9].

The lack of effective methods for estimation of residual water content in oil makes modelling and designing of crude oil treatment units more difficult. It is virtually impossible to consider the influence of water-in-oil emulsions breaking processes in the modelling of dewatering process for systems with real-time fluids without experimental data. Studying the dewatering process dynamics ensures estimating the time of steady-state regime attainment in the system under certain technological conditions.

In the works [10-12] it is shown that studying the water-in-oil emulsions breaking processes is possible by using the real-time oil samples as the objects of research instead of model fluids. Therefore, the aim of this research is to study the water-in-oil emulsions formation and breaking processes of West Siberian oil fields.

2. Object and methods of research

The objects of research were the oil samples of West Siberian fields, the physical-chemical properties of which were determined with the standard methods in the laboratory "Natural Fuel and Utilities Lab" of Tomsk Polytechnic University (table 1).

Table 1. Physical-chemical properties of oil samples

Parameters	Oil sample 1	Oil sample 2	Oil sample 3	Oil sample 4
Density at 20 °C, kg/m^3	814.6	826.5	830.0	862.2
Kinematic viscosity				
at 20 °C, m^2/s	2.75	3.70	4.72	11.44
at 50 °C, m^2/s	1.29	2.30	2.36	4.86
Paraffins content, mass%	0.03	3.5	1.27	0.98
Asphaltene and tar contents	0.01	2.65	0.76	1.03
	0.19	7.57	16.0	14.33

The experimental technique is specified in the work [13]. Emulsions were obtained by mixing oil and tap water with dissolved sodium chloride (40 g/l), 10, 20, 30 % by volume. Each sample of the water-in-oil emulsion in the amount of 100 ml was put into a 200 ml conical flask and manually mixed for 10 min. After that the emulsion was mixed by the automatic paddle mixer ER10 for 10 min.

Two mixing regimes were applied: 1000 rpm (v_1) and 2000 rpm (v_2), which ensured different water-in-oil emulsion dispersion degree.

The obtained water-in-oil emulsions were poured in the 100 ml measuring flasks and put into the thermostat for maintaining temperature regime (20 and 50 °C). Further, the amount of settled water was traced after certain time periods. The measurement error was 1 vol.%.

The process of drop formation was studied with the microscope "LOMO" R2U42. It is a standard measuring microscope with vertical lighting and 100 times amplification.

3. Results and discussion

The study of initial water content influence on the settling process, intensity of emulsion mixing, and temperature was carried out for the selected West Siberian oil samples (figures 1-3, tables 1, 2).

The research results of water separation from oil (sample 2) with various water content at two mixing regimes and temperature 20 and 50 °C are presented in figures 1, 2.

As it can be observed, at the first mixing regime, the time of emulsion breaking decreases from 40 to 18 min. with an increase in temperature to 50 °C (figure 1a and 1b). The speed of water separation decreases with an increase in mixing intensity, the time of steady-state regime attainment for settling process rises and reaches nearly 50 min. at 20 °C (figure 2a and 2b).

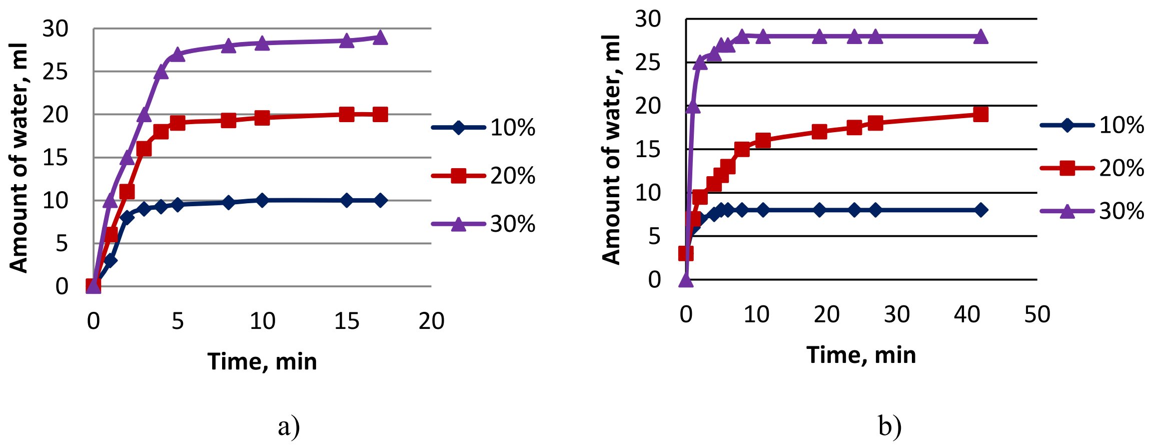


Figure 1. Dependence of settled water amount on time at various water content in oil (v_1=1000 rpm, a) T=50 °C, b) T=20 °C)

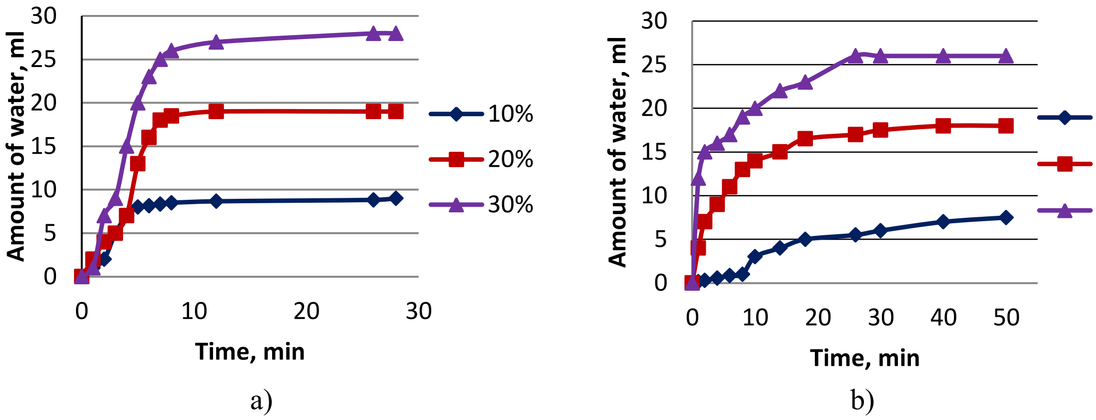


Figure 2. Dependence of settled water amount on time at various water content in oil (v_2=2000 rpm, a) T=50 °C, b) T=20 °C)

The selected oil samples (table 1) vary in their physical-chemical properties. The density varies from 815 to 862 kg/m^3, whereas kinematic viscosity increases continuously and reaches its maximum value of 11.44 m^2/s at 20 °C.

In figure 3 the dynamics of water separation is presented for the various oil samples under the same conditions of emulsion formation.

It is shown that for the oil samples 1 and 2, which have relatively low values of density and viscosity, the amount of separated water is virtually equal, and time of steady-state regime attainment is 15 and 25 min. respectively (table 2). It may be noted that high speed of water separation is observed for these oil samples during the first 10 min. With an increase in density and viscosity of oil (samples 3 and 4), the speed of water-in-oil emulsion breaking declines significantly, the amount of unseparated water increases, and the system attains steady-state regime within the period of more than 50 min.

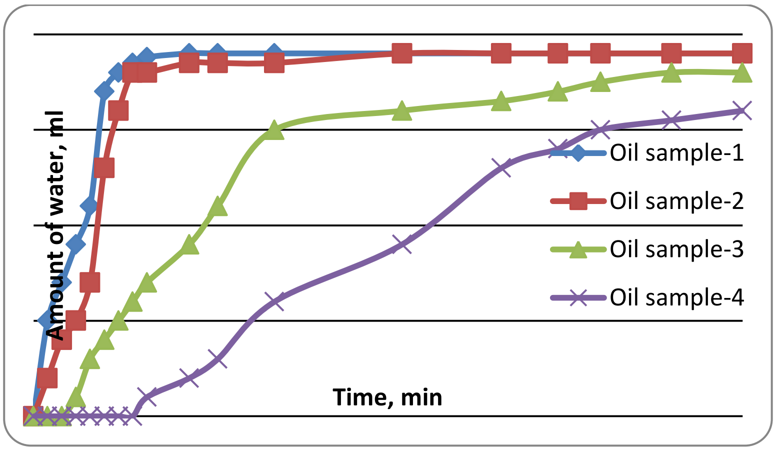


Figure 3. Dependence of settled water amount on time for various oil samples (v_2=2000 rpm, T=50 °C)

Table 2. Results of dewatering process for various oil samples (water content is 20 vol.%, v_2=2000 rpm, T=50 °C)

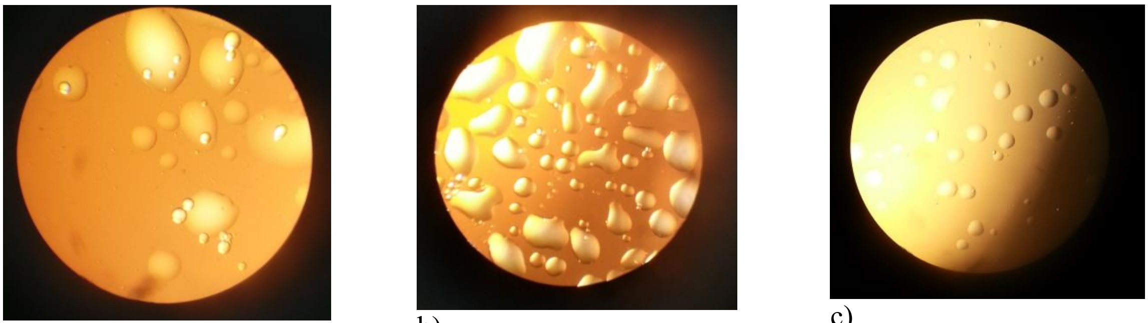
Parameters	Oil sample 1	Oil sample 2	Oil sample 3	Oil sample 4
The amount of settled water, vol.%	19	19	18	16
The time of settling process, min	15	25	45	

> 50

The settling process generally depends on the settling speed of water drops of certain diameter, which is formed depending on the process operating conditions. Therefore, one of the research stages is the observation of drop formation process and drop sizing.

The most probable particle size in the dispersed phase depends on physical-chemical properties of oil, oil-field water, multiphase flow regime, temperature, and other factors. Dispersing content of water-in-oil emulsion is constantly changing in the processes of its formation and breaking. The features of water drop formation for the various oil samples are studied with visual methods under similar conditions of emulsion formation.

The pictures of drops for various fresh water-in-oil emulsions are presented in figure 4. The diameters of forming water drops under different hydrodynamic conditions are estimated. For example, maximum drop diameters are within the range of 120–350 μm for the oil sample 2, and for heavy oil (sample 4) drops have much lower sizes (≈80 μm), which corresponds to the dynamics of water separation from oils with various physical-chemical properties (figure 3) and conforms to the theoretical laws of drops formation and settling [1, 2, 13].



a) b) c)

Figure 4. Pictures of water drops in emulsions (water content is 10 %, mixing regime corresponds to v_2; a) oil sample 1, b) oil sample 2, c) oil sample 4

4. Conclusion

It is shown that physical-chemical properties of oils and content of dispersed phase significantly influence the residual water content and time of water separation process.

As a result of experimental research it is found out that the more stable finely-dispersed systems are formed with an increase in water-in-oil emulsion mixing intensity, dewatering of these systems is possible at higher temperature.

Thus, the obtained results can be used for analysis and selection of process conditions for dewatering of oil with various physical-chemical properties and for modelling crude oil treatment technology [14].

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