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Effect of Electric Field Strengths on Coalescence of Water Droplets in Crude Oil Emulsion Electrostatic Separation of Water from Crude Oil Emulsion

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Research Article

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ABSTRACT

Crude oil and water produced in the production process of crude oil. The reduction of water levels in crude oil is essential to meet pipeline and export specifications. Several gravitational, thermal, mechanical, and chemical treatment methods are used to minimize the water levels associated with oil. When the emulsion is formed between oil and water, such as water-in-oil emulsion, the process for separating one from each other is difficult. This is because of the stabilization of the water droplet inside of the oil. Electrostatic separation is found to be the optimum technology to overcome the interfacial active surface of the oil around the water droplet. In this work, the water droplets coalescing process was observed under the application of the electric field. The coalescing rates were proportionally increased with the increasing of the electric strengths.

The increasing of the coalescing rates has a positive effect on the degree of separation of water from crude oil.

INTRODUCTION

The emulsion, which is formed between oil and water, is divided into two phases. One phase is dispersed inside another phase, which is called dispersed, or internal phase, while the surrounding or outer phase is called the external or contusions phase which is more level than the internal one. Emulsions can be classified, as are illustrated in the photomicrographs in **Figure 1**, into following groups; water-in-oil (W/O) emulsion, Oil-in-water (O/W) emulsion, and Multiple complex oil-in-water-in-oil (O/W/O) emulsion or water-in-oil-in-water (W/O/W) emulsion.

When the water droplets are dispersed inside the oil, this type of emulsion is known as water-in-oil (W/O) emulsion, but when oil droplets are dispersed inside the water, this type is called an oil-in-water (O/W) emulsion. While the multiple emulsion is a complex liquid system known as “emulsion of emulsions” in which the droplets of one dispersed liquid are further dispersed in another liquid (**Figure 1**).

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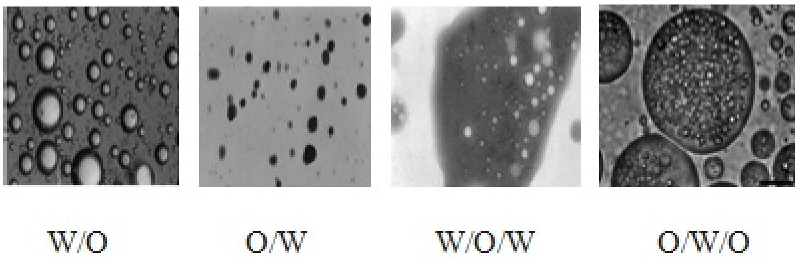

Figure 1. Photomicrographs of the types of emulsions (Reproduced from; Crude oil emulsion, A state of the art review and B P Binks Curr Op Coll Interf Sci 7 (2002) 21-41).

When water is broken up into small droplets and uniformly dispersed in the oil phase, it becomes more difficult to collect and separate them by a confessional process such as mechanical and thermal processes. It has been known that water-in-oil (W/O) emulsions can be efficiently broken in an electrostatic coalesces. This has been practically true in the petrochemical industries, since the early work of Cottrell. Coalescence refers to the process of thinning and disruption of the liquid film between the droplets with the result of the fusion of two or more droplets into larger ones.

The limiting case for coalescence is the complete separation of the emulsion into two distinct liquid phases. The driving force for coalescence is the surface or film fluctuations which result in a close approach of the droplets whereby the surface tension force, that curved around the droplet, is strong thus preventing their separation [1,2]. Coalescence of water droplets when two drops collide with each other, several things must happen before they can coalesce. The film between, and as can be seen in **Figure 2**, the two droplets must be expelled so that their surfaces can come into contact.

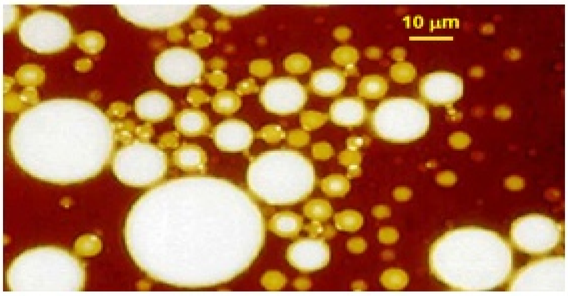

Figure 2. A photomicrograph of an emulsion showing the interfacial film between the droplets (Reproduced from SPE Foundation).

The surface-structure must be destroyed over the area of contact in order that the droplets can actually join, and then they form a single larger drop. These two steps represent the principal obstacles to the coalescence [3,4].

MECHANISMS OF DROPLET COALESCENT (DROPLET GROWTH UP)

The driving force behind the growth of smallest droplets by composing them to form a larger drop undergoes many forces or energy mechanisms such as collision or translational kinetic energy, gravitational potential energy, and the electric charging force.

Droplet coalescence can be assisted by the application of a high-voltage electric field to the emulsion. This is particularly beneficial for polishing the oil and reducing the oil's water content to very low levels. Many studies had proved the effect of electric fields on the coalescing of droplets. Taylor [5,6] investigated the effect of AC field, Bailes and Larkai [1], investigated the influence of pulsed DC fields on the coalescing of adjacent drops, and Eow and Ghadiri [3].

Electrostatic coalescing works by charging the water droplets and increasing the frequency of their collision, which improves their chance of coalescence. The surfaces do not make contact since the Collision Kinetic Energy (CKE) is insufficient to expel the intervening filming layer between any adjacent droplets. The collision kinetic energy of the droplet pair is given in the following equation,

$$CKE = \frac{p\pi}{12}\frac{\left(D^{3}{}_{L}D_{s}^{3}\right)}{D_{L}{}^{3}+D_{s}{}^{3}}\left(V_{L}-V_{s}\right)^{2} \quad (1)$$

Where ρ, DS, DL, VS, and VL are the droplet density, the diameter of the smaller droplet, the diameter of the larger droplet, the velocity of the smaller droplet, and the velocity of the larger droplet respectively. Alternatively, can be written as; where R is the droplet size ration DL/DS as given in equation 2.

$$CKE = \frac{p\pi}{12}\frac{\left(D^3{}_L\right)}{R^3+1}(V_L - V_s)^2 \quad (2)$$

Coalescence processes become faster when the ration of two droplets size (smaller/larger) approaches zero.

Droplet coalescence in which a post-collision droplet is formed whose mass is equal to the sum of the masses of the pre-collision droplets follows droplets contact. The colliding droplets will coalesce when the thickness of the layer or film between any neighboured droplets reaches the critical value. In other words, when the droplets' kinetic energy becomes sufficient to expel the film between them, i.e. the energy of the internal phase becomes greater than the surface tension energy of the external phase. Coalescence occurs when the collision kinetic energy exceeds the value of the surface tension energy that exerted by the external phase (oil phase). This energy always gives a curved power on the droplets and prohibited it from coalesces with other droplets. Generally, electrostatic charges are used to attract or repel differently charged material. When electrostatic separation uses the force of attraction to sort particles, conducting droplets stick to an oppositely charged ones [5-8].

The charge is the measure of the electric current flowing through an object. A charge can be positive or negative. Objects with a positive charge repel another positively charged droplet, thereby causing them to push away from each other, while a positively charged droplet would attract to a negatively charged one, thereby causing the two to coalesce together. As the coalescence of the droplets together as a new bigger drop will be formed because of this coalescing meanwhile the mass will increase as coalescing rate increases [9,10].

The two coalescing mechanisms mentioned above, and after residency, the time have been taken for a sufficient amount coalescing, lead to a change in the direction of the droplets. When the droplets grew up in horizontal motions and become a larger and denser drop, i.e. they are changed in to the drop. As it is given in equation 3, the resulted of gradational/potential force will become out and the drop is subjected to gravity force and a hydrodynamic force. This force will change the direction of the drop due to the increase in mass into the straight down direction toward the water collecting area.

$$PE = mgz \quad (3)$$

Where, PE is the potential energy that applied on the drop system, m, and mass of the drop, g; gravity, and z the distance that the drop takes toward gravity direction. In addition, the viscosity, density of the continuous phase, and the viscosity and diameter of the new drop will affect the separation process. When the droplets coalesced, this produces large drops that settle down due to gravity action. The increase in the size of the drops led to an increase in its settling viscosity. Therefore, the settling velocity of the drop increases the degree of separation and decreases the residence time of the water drop in the water in oil emulsion decreases. The settling velocity of the formed new drop that subjected to gravitational force can express equation 4 as;

$$V_s = \frac{(pc - pd)D_d^2}{18\eta_c} \quad (4)$$

Where; ρd, ρc, are the droplet density, continuous phase density, droplet diameter, and viscosity of the continuous phase respectively [8,9].

Since the coalescence refers to the process in which two or more droplets merge together to form a single larger drop. Therefore, and as illustrated in Figure 3, an external force of electric forces and gravity, play an important role in bringing droplets on the head into collision.

The second stage then consists of the thinning of the interstitial film of the continuous phase and rupturing the film in-between the adjacent droplet. Finally, the two droplets coalesce to form a large drop.

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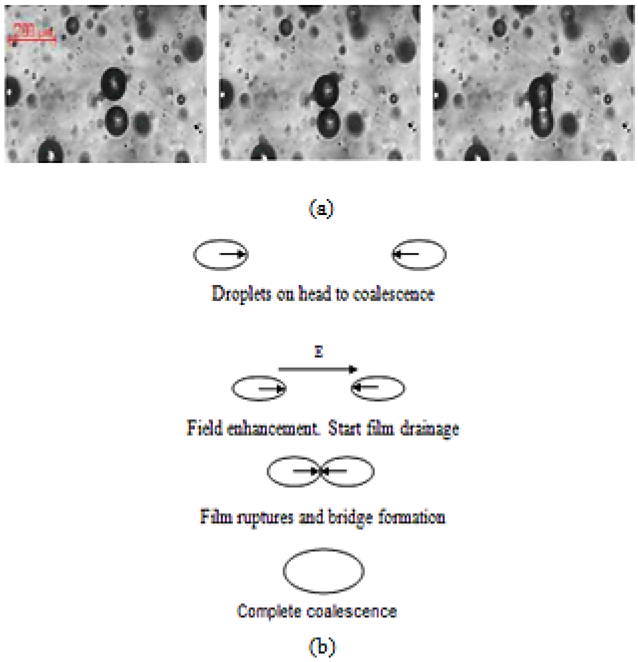

Figure 3. Droplets coalescing processes (a) Schematic drawing of coalescing, and (b) photomicrographs of coalescence photomicrographs of coalescence [10].

MATERIAL AND EXPERIMENTAL METHODS

The experimental rig consists, and as is illustrated in Figure 4, essentially of a cylindrical glass jar connected with the injector device, and two electric electrodes, one as positive and another as a negatively charged electrode. In addition, other devices are attached to the cylinder, as electrometer that is used measure the current strength, multi-meter to give an accurate measurement, a Pico scope, which is used for reading the output results, and a computer for analysis the data.

In this work, the crude oil system, which considered as an external phase is simulated with silicone oil that has as same as the viscosity of crude oil. The use of the silicone oil has an advantage of transparency that assist to watch the oscillations or motions of the water droplets (The internal phase) inside the external phase. The de-ionized water is used in this work to avoid any contaminations that may affect the motion of the droplet. The scenario of work is by injection of the water droplets at the top of the cylinder with constant slow velocity; at the same time, the electric field is applied to cross the oil located between the electrodes.

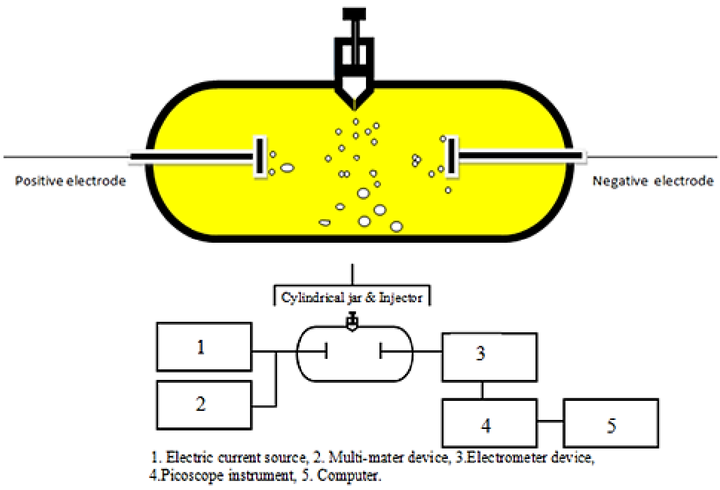

Figure 4. The schematic diagram of the experiment.

RESULT AND DISCUSSION

Experimental data on the oscillation of water droplet were obtained for the motion of the droplets between electrodes in a horizontal motion. When the current is applied, the voltage between the two electrodes was measured. The frequency of the oscillation increases with an increase in the voltage strength. The oscillations of the water droplets start slowly and the faster as when the voltage increases. The droplets sometimes stuck on the electrodes plates.

Experimental data on the motion of the droplets were observed visually, and by using a recording camera and the results were obtained from the voltage and oscillations of these droplets from the resulted output readings of both the voltage change and the oscillation reading data.

The horizontal motion of water droplets, it is the response to the applied voltage and the electric force acting on the droplet causes it. The increase in the voltage strength has an effect on the oscillation of droplets. The applied voltage is plotted against the oscillations of the droplets after the data obtained, as can be seen in **Figure 5** below.

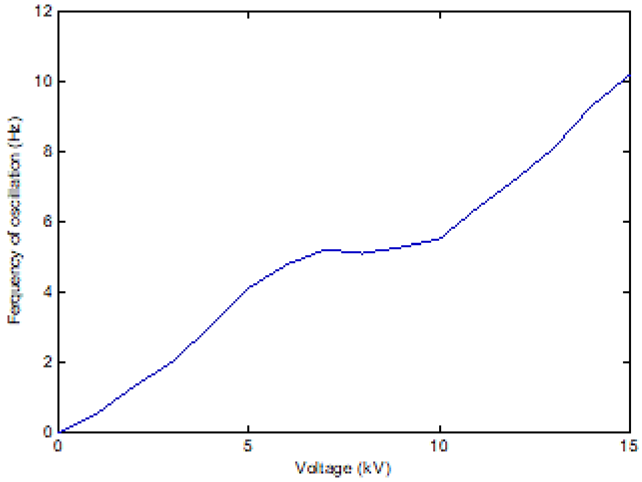

Figure 5. Effect of change on the frequency oscillation (Oscillation of the water droplets inside the oil phase).

CONCLUSION

The Electric strength has an effect on the oscillation of the droplets. The frequency of the oscillation increases with an increase in the voltage strength. The oscillations of the water droplets start slowly and then fast. The size of the droplets formed is increased with the voltage increased.

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