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Effect of Electric field strengths on Coalescence of Water in crude oil droplets (Separation of water from crude oil emulsion

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Abstract

Crude oil and water are produced together in the production of crude oil. The reduction of water levels in the 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, but 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 stabilization of 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 water droplet. Dispersed water drops in organic liquids, such as water-in-crude oil emulsions, are commonly encountered in the oil, chemical and biochemical industries. The formation of water-in-crude oil emulsion during oil production is undesirable from both a process and product quality point of view. Natural coalescence of drops in such emulsion is constrained because of a thin film of oil between drops not allowing their spontaneous coalescence, and consequently water-in-crude oil emulsions, despite being thermodynamically unstable, can be kinetically very stable for long periods of time. In this work, the water droplets coalescing process was observed under the application of 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. For the separation of dispersed water drops from oils an electric field may be used to enhance their coalescence. Water droplets can be removed from a continuous oil phase by several methods such as chemical demulsifiers, gravity or centrifugal separation, pH adjustment and heating treatment and membrane filtration separation. However, nowadays one of the most effective and utilized method from viewpoint of energy efficiency is electrostatic demulsification. The combination of high energy efficiency, since it permits a reduction of the use of heat, and also the fact that it avoids the use of chemical demulsifiers makes this technique environmentally friendly. The utilization of electrical methods for dehydrating crude oil emulsions is not new and has been well reviewed. In the petroleum industry, the first work on electrocoalescence dates from the work of Cottrell in applying external electric fields to crude-oil emulsions. Electro-coalescence is a process to assist approach, contact and finally coalescence of water droplets in oils with a low dielectric permittivity in order to increase their size, thus accelerating their settling velocity and reducing their separation time. The electrostatic effects arise from differences in properties of oil and water, where water has dielectric permittivity and conductivity values much higher than those of the oil, leading to polarization effects in water drops. The amount of dispersed aqueous phase is a key feature to choose the type of electric field. Historically the alternative current (AC) electric field is the oldest and commonest configuration used extensively in crude oil emulsion treatment, as it can tolerate high water contents. In contrast, the direct current (DC) electric field has been less common in the past and has been used more in the treatment of refinery emulsions with low water content in order to reduce electrolytic corrosion.

Generally, the presence of an electric field promotes contacts between drops, enhancing drop–drop and drop–interface coalescence. Hence, research has been carried out on the application of various types of electric fields in the electrocoalescence at a micro-scale level. However, this process could cause some undesirable phenomena such as secondary droplets formation, reducing the separation efficiency. Here the effect of pulsatile electric fields (PEF) on the secondary droplets formation has been investigated. The emulsion stability can be due to the presence of naturally occurring surfactants in the crude oil, such as asphaltenes, resins, waxes, and naphthenic acids. Asphaltenes and resins are the heaviest and the most polar fraction of the 2 crude oil and are believed to be the major components responsible for emulsion stabilization. In the presence of a very low frequency PEF or DC electric field three distinct drop-drop and drop-interface interaction patterns are observed: complete coalescence, partial coalescence and rebound without coalescence. The first is the ideal pattern not leaving any secondary droplets. It has previously been shown that an increase in the electric field strength and/or a decrease in the interfacial tension result in non-ideal patterns in drop interface coalescence.

The application of PEF shifts the coalescence pattern from a non-ideal to an ideal one in both drop-drop and drop-interface coalescences. Three waveform types, i.e. square, sinusoidal and sawtooth waves have been applied to the coalescence process. It is shown that the sawtooth waveform is the most effective in reducing the secondary droplets formation in drop interface

coalescence, followed closely by the sinusoidal one. The observation of videos sequences suggests that a threshold frequency exists above which a non-ideal pattern switches to an ideal one. For drop-drop coalescence this threshold frequency depends on the PEF amplitude and the size of primary drop pairs, as for bigger primary drop pairs and larger amplitudes of PEF the threshold frequency would be higher. When using pulsatile electric fields higher field strengths can be applied for systems having a high water content without causing field breakdown, as compared to constant DC field. This is useful in optimizing the electro-coalescence process.