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Review

Demulsification techniques of water-in-oil and oil-in-water emulsions in petroleum industry

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ABSTRACT

The difficulties associated with transportation and refining of crude oil emulsions and produced water discharge limitations are among the conspicuous clues that have led the oilfield researchers to probe into practical demulsification methods for many decades. Inconsistent research outcomes observed in the literature for a particular demulsification method of a typical emulsion (i.e., water-in-oil or oil-in-water) arise not only from the varied influential parameters associated (such as salinity, temperature, pH, dispersed phase content, emulsifier/demulsifier concentration, and droplet size) but also from the diverse types of emulsion constituents (namely oil, surfactant, salt, alkali, polymer, fine solids, and/or other chemicals/impurities). Being the main component in formation of stabilizing interfacial film surrounding the dispersed phase droplets, surfactant is the most predominant contributor to emulsion stability, extent of which depends on its nature (being ionic or nonionic, and its degree of hydrophilicity/lipophilicity), concentration, and interaction with other surface-active agents in the emulsion as well as on the salinity, temperature, and pH of the system. In this paper, it is endeavored to overview some of the most commonly exploited demulsification techniques (i.e., chemical, biological, membrane, electrical, and microwave irradiation) of both oilfield and synthetic emulsions, taking into account the emulsion-stabilizing and -destabilizing effects with regard to the dominant parameters plus the emulsion composition. Further, the variations occurring in interfacial properties of emulsions by demulsification process are discussed. Finally, the mechanism(s) involved in emulsions resolution achieved by each method is elucidated. Clearly, the most efficient demulsification approach is the one able to attain desirable separation efficiency while complying with the environmental regulations and imposing the least economic burden on the petroleum industry.

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Abbreviations: EOR, enhanced oil recovery; SP, surfactant-polymer; ASP, alkaline-surfactant-polymer; IFT, interfacial tension; HLB, hydrophilic-lipophilic balance; PEO, poly(ethylene oxide); PPO, poly(propylene oxide); PIT, phase inversion temperature; HLD, hydrophilic-lipophilic deviation; SAD, surfactant affinity difference; WOR, water-to-oil volumetric ratio; CMC, critical micelle concentration; PDMS, poly(dimethylsiloxane); IL, ionic liquid; CMW, chloroform-methanol-water; TMP, transmembrane pressure; UF, ultrafiltration; MF, microfiltration; RO, reverse osmosis; TOC, total organic carbon; TSC, total surface charge; COD, chemical oxygen demand; CFR, cross-flow rate; AC, alternating current; DC, direct current.

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1. Introduction

Demulsification is an intricate process as oilfield emulsions are, in principal, complex, stable liquid-liquid colloidal suspensions comprising of dispersed/internal phase, continuous/external phase, and emulsifying agents basically present at the oil-water interface. An effectual demulsifying route must thus be capable of annulling/minimizing the stability of targeted emulsion, leading to separation of immiscible phases. Demulsification techniques are generally classified into three categories, i.e., chemical, biological, and physical treatments. Physical demulsification includes gravitational settling, centrifugation, pH adjustment, thermal treatment (conventional heating, microwave irradiation, and freeze/thaw), flotation, filtration (adsorption and coalescing filters), electrical demulsification (electro-coalescence), membrane separation, ultrasonic, inertial, and orthokinetic (shear flow). However, physical treatments of emulsions have often been employed in conjunction with other (physical, chemical, or biological) separation methods to establish hybrid systems in order to improve the destabilization of emulsions up to satisfactory levels [1–5].

In this paper, it is attempted to overview the most commonly employed demulsification methods (i.e., chemical, biological, membrane, electrical, and microwave irradiation) by discussing the effective factors involved in contribution to improving their efficiency for separation of emulsions. The rest of demulsification techniques mentioned above are not included in this article.

At first stance, it is useful to introduce the main three phases of crude oil extraction, namely primary, secondary, and tertiary oil recovery processes [6,7]: in primary oil recovery, the reservoir's natural energy sources, including fluid and rock expansion, solution gas, water influx, gas cap, and gravity drainage, produce oil; artificial lift devices such as pumps are usually used to aid in oil extraction. However, only about 10% of the reservoir's original oil in place is extracted during primary recovery. The extraction

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