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Study on Electrocoalescence process: Review

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Abstract: This paper reviews the current understanding of electrocoalescence of water droplets in oil, highlighting particularly the mechanisms proposed for droplet–droplet and droplet–interface coalescence under the influence of an applied electric field, as well as various factors influencing the electrocoalescence phenomenon. The type of electric field such as alternating, direct and pulsed direct current, plays a significant role, depending on the design and setup of the system. The concept of effect of shear, turbulence and viscosity ratio are highlighted in this paper. The integration of processes like microwave radiation and flotation with electrocoalecscence is also discussed. Theconceptof an optimum frequency is also discussed here, relating to the electrode design and coating. More investigations, both experimental and by computer simulation, should be carried out to study the electrocoalescence phenomenon and to contribute to the design and operation of new electrocoalescers.

Keywords: Emulsions, Electrocoalescence, Electric Field, Simulations.

1. Introduction

There exist several techniques for enhancing the separation of water-in-oil emulsions, such as the addition of chemical demulsifier [1], pH adjustment [2], gravity or centrifugal settling [3], filtration [2], heat treatment and electrostatic demulsification [4,5]. From the energy efficiency point of view, electricaldemulsification is considered to be the best among the above methods [4,19].

The electrical phase separation concept has been used in the petroleum industry for separating water incrude oil dispersions by applying a high electric field onto the flowing emulsion to effect flocculation and coalescence of dispersed water droplets [6,7]. The technique which was used to promote phase separation of an aqueous dispersion from an organic phase, and developed an effective separator for solvent extraction[8,9]. Some coalescence can occur due to Brownian motion and differential sedimentation, but these effects are insignificant compared to electrocoalescence [10]. Generally, an irreversible rupturing of the emulsions can occur in an electric field due to the coalescence of droplets [11,19]. In low electric fields, however, water droplets attain a linear chain-like configuration, though the electric field is not high enough to induce coalescence. When the field is switched off, the droplets return to a random distribution [12,13].

The concepts here are believed to be the interaction between the drops and the externally applied electrostatic field, resulting in drop charging and agglomeration, and eventually coalescence. Generally, external electric fields can cause the coalescence of drops at an interface, and drop–drop coalescence in a dielectric fluid. When two drops approacheach other, the interface is separated by a thin film of oil determining emulsion stability. Thus demulsification requires rupturing of this interfacial film [14]. Generally, the main purposes of an applied electrical field are to promote contact between the drops, to help in drop–drop coalescence, and to encourage drop–interface coalescence. However, coalescence may also cause phase inversion of emulsions [15]. Water-in-oil emulsion stability can be assessed by several techniques such as the ‘bottle test’, turbidity measurements [16], time-domain dielectric spectroscopy (TDS) [17] and the differential scanning calorimetry (DSC) technique [18]. Stability of water-in-oil emulsions in high electric fields can be investigated by the TDS technique [11,19].

A greater understanding of the processes taking place during the water in oil emulsion separation in an electric field, especially the actual coalescence process, should provide the knowledge for optimum design of the electrode geometry and the type of electric field. It can also reduce the residence time in order to minimize the size and weight of the equipment. The state-of-the-art in the current understanding of turbulent coalescence, as well as the effect of shear,mechanism and models influencing electrocoalescence process are reviewed here, thus directing us towards a greater understanding of electrocoalescence process.

2. Literature Review

The literature review provides the methodology used, research design, base, techniques of analysis & results of the electrocoalescence process. The purpose of this study is to examine & resume on various studies conducted by researchers on electrocoalescence.

P. Atten,(1993) [20]proposed the formula giving the interaction force between two droplets and the equation governing the evolution of polydispersed emulsions. He derived expressions for the coalescence rate when retaining only the field induced interaction between the droplets and the characteristic coalescence time was estimated. He also concluded that the shear rate plays important role in bringing the droplets into contact.

Bailes and Kuipa(1996,2001) [21] developed an electrical separation technique in which the resolution of stable water in kerosene emulsion in pulsed DC fields and an insulated high voltage electrode is enhanced by mildly bubbling the emulsion with air.He also worked on new method with a difficult emulsion and compare electrically augmented emulsion breaking with and without air under continuous flow conditions over a range of emulsions and air flow rates, applied voltages and pulsation frequencies.

Chen and Taylor(1994) [22] studied the effect of application of AC electric field on the structure of water in crude oil emulsion using molecular dynamic simulations. The results showed that solid interfacial film is a key factor for the prevention of coalescence between the droplets in the electric field.

Fernandez(2009) [23]reported a coupled effect of shear and electrostatics for emulsions with less conducting dispersed phase . He also examined the significance of viscosity ratio on emulsions of drops immersed in electric fields by means of direct numerical simulation and showed viscosity ratio affects the effective viscosity of the system. If the viscosity ratio is decreased then effective viscosity decreases; when the viscosity ratio is increased then the effective viscosity increases.

Noik(2006) [24] presented some technological tendencies like integration of electrostatic demulsification with centrifugal separation; other kinds of combination such as electrostatic demulsification with microwave radiation and electrostatic demulsification with flotation.

Urdahl(2001) [25] reviewed correlations to estimate the maximum stable droplet diameter in laminar and turbulent flows. He also showed that different mechanisms can contribute to the electrostatic coalescence such as Brownian motion, sedimentation, laminar shear, turbulent shear or turbulent inertia.

Chiesa and Melheim(2006) [26] used numerical simulations to show that turbulence enhances the electrocoalescence rate over a wide range of water cuts in the oil.

Cottrell and Speed(1911) [6] filed the first patent on electrocoalescence, observing the coalescence mechanism when a high potential was applied to a pair of wire electrodes in an aqueous-in-oil emulsion.

Adamiak(1999) [27]investigated the deformation of two perfectly conducting, uniform size drops in a uniform electric field numerically. He used the Finite Element Method to solve the shape change equations while the electric field distributions over the drop interface was solved by Boundary Element Method.

Raisin(2011) [28] concluded that the rate of elctrocoalescence dependent on the deformation of leading surfaces, drop motion and the drainage of the oil film between the drops. It was observed that the time of contact for closely spaced very small droplets with high viscosity ratio is no longer compared to deformable larger drops.

Giljarhus and Munkejord(2011) [29] used Finite Element Method to solve the head-on collisions of two drops in the flowing medium and predicted that as the flow capillary number increases, drop deforms more and the contact area becomes larger. They observed that it takes a longer time to drain the film and thus the coalescence time is longer and also concluded that the electrococapillary number increases, the coalescence time decreases.

Dong(2002) [30]suggested that decreasing interfacial tension in absence of electric field can resist the coalescence as large deformations inhibit the film thinning. However in presence of electric field the increased deformation on decreasing interfacial tension assists the coalescence.

Bird(2009) [31] derived an expression critical cone angle at drop contact which is a function of electrocapillary number and also predicted the cone angle at drop contact at 30.8^0 which was close to the experimentally observed value.

Taylor(1988) [32]reports two distinct types of behaviour. In type I, very stable droplet chains form between the electrodes, on the application of an A.C. electric field, resulting in current leakage through the chains. Drop–drop coalescence is prevented by rigid interfacial films. However, with the addition of an oil-soluble surfactant, the type I characteristics transforms to type II, where rapid droplet coalescence occurs, indicating the lack of any chain formation and enhanced mobility of the interfacial film. Without a rigid film, the neighbouring droplets tend to stick together and coalesce to form larger drops in an electric field. Thus, coalescence is more likely to occur before chain formation when the interfacial film is compressible.

Brown and Hanson(1965) [33]observing an optimum coalescence frequency for each system, suggested that vibrations and cavitation within the drop are responsible for the film rupturing, leading to coalescence of drops at an aqueous/oil interface. Moreover, they also suggested that it is the field inside the drop, rather than the charge it carries, that is responsible for enhancing the coalescence. They concluded that the electrical forces for coalescence are short range, and enhance film rupture. Therefore, the selection of the optimum frequency is very important, especially at low voltages, depending on the insulation material and its thickness, and liquid composition. Without insulation, the optimum frequency is determined by the electrical properties of the continuous phase.

Levan(1981) [34] took into account the effects of induced circulations and interfacial tension gradient to get revised expression for drag coefficient.

Williams and Bailey(1986) [35]used a laser light-scattering technique to look at the size distributions of water droplets in emulsions leaving an electrocoalescer. The volume median diameter was observed to increase with time, showing that drop–drop coalescence occurred in the emulsion. Under observation at low electric field strength, the drop size increase was small. Under a strong applied electric field, it increased very fast initially, but relatively slow after that. Therefore, coalescence effects attributed to sedimentation and Brownian motion are relatively insignificant compared to dipole and migratory coalescence produced in strong electric fields.

Allan and Mason(1961) [36] observed that the addition of small amounts of surfactant in the heptane layer significantly increased the rest time of water drops at a water/heptane interface. It was observed that water droplets have larger deformation at the interface due to decreased interfacial tension.

3. Conclusion

The purpose of this review was to understand the different aspects of electrocoalescence process. Electrocoalescence of two drops involves three steps mainly; approach of droplets, draining of thin film of the interfaces; creation of capillary bridge and merging of two droplets. Various mathematical models have been highlighted here, which depend on the mechanism and the type of electric field applied. Factors influencing the coalescence efficiency have also been highlighted and reviewed. The several types of electric field which may be applied have been highlighted such as A.C., D.C. and pulsed D.C.The concept of an optimum applied frequency has been introduced together with that of a pulsed D.C. electric field, depending on the relaxation time of the various dielectrics, electrical properties of the continuous phase and the electrode coating material, and their thicknesses.From this review paper, it has become clear that more investigations, both experimental and theoretical, are needed to study the electrocoalescence phenomenon at a microscopic level. This will help to elucidate the role of various parameters in the coalescence of two droplets, and between a droplet and an interface. This knowledge will then contribute to the design and operation of more efficient as well as more compact electrocoalescers.

4. References

[1]. R.A. Mohammed, A.I. Bailey, P.F. Luckham, S.E. Taylor, Dewatering of crude oil emulsions: Emulsion resolution by chemical means, *Colloids Surf. A, 83(3),* (1994) 261–271.

[2]. K.J. Lissant, Demulsification: Industrial Application, *Surfactant Science Series, 13,* Marcel Dekker, New York, 1983.

[3]. D. Sun, S.C. Jong, X.D. Duan, D. Zhou, *Demulsification of water-in-oil emulsion by wetting coalescence materials in stirred-and packed-columns, Colloids Surf. A, 150* (1999) 69–75.

[4]. M. Goto, J. Irie, K. Kondo, F. Nakashio, *Electrical demulsification of w/o emulsion by continuous tubular coalescer, J. Chem. Eng. Jpn. 22 (4)* (1989) 401–406.

[5]. R.A. Mohammed, A.I. Bailey, P.F. Luckham, S.E. Taylor, Dewatering of crude oil emulsions: Rheological behaviour of the crude oil–water interface, *Colloids Surf. A, 80,* (1993) 223–235.

[6]. F.G. Cottrell, J.B. Speed, Separating and collecting particles of one liquid suspended in another liquid, US Patent 987,115 (1911).

[7]. F.G. Cottrell, Process for separating and collecting particles of one liquid suspended in another liquid, US Patent 98,711,421 (1911).

[8]. P.J. Bailes, S.K.L. Larkai, An experimental investigation into the use of high voltage D.C. fields for liquid phase separation, *Trans. IChemE, 59 (4),* (1981) 229–237.

[9]. P.J. Bailes, S.K.L. Larkai, Liquid phase separation in pulsed D.C. fields, *Trans. IChemE, 60 (2),* (1982) 115–121.

[10]. T.J. Williams, A.G. Bailey, Changes in the size distribution of a water-in-oil emulsion due to electric field induced coalescence, *IEEE Trans. Ind. Appl. 1A–22 (3),* (1986) 536–541.

[11]. H. Fordedal, Y. Schildberg, J. Sjoblom, J.L. Volle, Crude oil emulsions in high electric fields as studied by dielectric spectroscopy: influence of interaction between commercial and indigenous surfactants, *Colloids Surf. A, 106,* (1996) 33–47.

[12]. D. Sun, X. Duan, W. Li, D. Zhou, *Demulsification of water-in-oil emulsion by using porous glass membrane,J. Membrane Sci., 146,* (1998) 65–72.

[13]. H. Brandenberger, D. Nussli, V. Piech, F. Widmer, *Monodisperse particle production: a method to prevent drop coalescence using electrostatic forces,J. Electrostatics, 45,* (1999) 227–238.

[14]. A. Bhardwaj, S. Hartland, *Kinetics of coalescence of water droplets in water-in-crude oil emulsions, J. Disp. Sci. Technol.,15 (2),* (1994) 133–146.

[15]. F. Groeneweg, W.G.M. Agterof, P. Jaeger, J.J.M. Janssen, J.A. Wieringa, J.K. Klahn, On the mechanism of the inversion of emulsions, *Trans. IChemE, 76 (A),* (1998) 55–63.

[16]. M. Frenkel, R. Shwartz, N. Garti, *Turbidity measurements as a technique for evaluation of water-in-oil emulsion stability, J. Disp. Sci. Technol., 3 (2),* (1982) 195–207.

[17]. M. Ese, J. Sjoblom, H. Fordedal, O. Urdahl, H.P. Ronningsen, Ageing of interfacially active components and its effect on emulsion stability as studied by means of high voltage dielectric spectroscopy measurements, *Colloids Surf. A, 123–124,* (1997) 225–232.

[18]. C. Dalmazzone, H. Seris, Use of the DSC technique to characterize water-in-crude oil emulsions stability, *Revue de l'InstitutFrancais du Petrole, 53 (4),* (1998) 463–464.

[19]. Eow, JS, Ghadiri, M, Sharif, AO and Williams, TJ, *Electrostatic enhancement of coalescence of water droplets in oil: a review of the current understanding Chemical Engineering Journal, 84 (3),* 2001, 173-192.

[20]. Atten, P, *Electrocoalescence of water droplets in an insulating liquid,J. Electrostatics, 30,* (1993) 259–270.

[21]. Bailes, PJ., Kuipa, , *The effect of air sparging on the electrical resolution of water in oil emulsions, Chemical Engineering Science, 56,* 2001, 6279-6284.

[22]. Chen, T.Y., Mohammed, R.A., Bailey, A.I., Luckham, P.F., Taylor, S.E., *Dewatering of crude oil emuslions, 4. Emulsion resolution by the application of an electric field. Colloids Surf., A: Physicochem. Eng. Aspects 83,*1994, 273-284.

[23]. Fernandez, A., Shear flow of an emulsion of drops less conductive than the susupending fluid immersed in an electric field by numerical simulation. *Colloids Surf., A: Phiscochem. Emg. Aspects 338*, 2009, 68-79.

[24]. Noik, C., Chen, J., Dalmazzone, C.S.H., *Electrostatic demulsification on crude oil: a state-of-the-art review. Soc. Pet. Eng., SPE-103808-PP,* 2006, 1-12.

[25]. Urdahl, O., Wayth, N.J., Fordedal, H., Williams, T.J., Bailey, A.G., Compact electrostatic coalesce technology. In Sjonlom, J.(Ed.), *Encyclopedia Handbook of Emulsion Technology.* CRC Press, New York, 2001.

[26]. Chiesa, M., Ingebrigtsen, S., Melheim, J.A., Hemmingsen, P.V., Hansen, E.B., Hestad., Investigation of the role of viscosity on electrocoalescence of water droplets in oil. *Sep. Purif. Technol., 50,* 267-277.

[27]. Adamiak, K., Force of attraction between two conducting droplets in electric field. *Thirty-Fourth I.A.C. Annual Meeting IEEE 3,* 1999 1795-1800.

[28]. Raisin, J., Reboud, J., Atten, P., *Electrically induced deformations of water-air and water-oil interfaces in relation with electrocoalescence, J. Electrostat.* 69, 2011, 275-283.

[29]. Giljarhus, K.E.T., Munkejord, S.T., Numerical investigation of electrostatically enhanced coalescence of two drops in flow field. *In: IEEE-ICDL.,* 2011.

[30]. Dong, J., de Almeida, V.F., Tsouris, C., *Effects of applied electric fields on drop-interface and drop-drop coalescence. J. Disper. Sci. Technol. 23(1-3),* 2002, 155-166.

[31]. Bird, J.C., Ristenpart, W.D., Belmonte, A., Stone, H.A., *Critical angle for electrically driven coalescence of two conical droplets. Phys. Rev. Lett. 103,* 2009, 164502.

[32]. Taylor, S.E., *Investigations into the electrical and coalescence behavior of water-in-crude oil emulsions in high voltage gradients. Colloid Surf. 29,* 1988, 29-51.

[33]. A.H. Brown, C. Hanson, Effect of oscillating electric fields on coalescence in liquid–liquid systems, *Trans. Faraday Soc. 61,* 1965, 1754.

[34]. Levan, D.M., Motion of droplets with a Newtonian interface. *J. Colloid Interface Sci. 83,* 1981, 11-17.

[35]. Williams, T.J., Bailey, A.G., Changes in the size distribution of a water-in-oil emulsion due to electric field induced coalescence. *IEEE Trans. Ind. Appl. IA-22(3),* 1986, 536-541.

[36]. R. S. Allan., S. G. Mason, Effects of electric fields on coalescence in liquid-liquid systems, *Trans. Faraday Soc. 57,* 1961, 2027-2040.