DROPLET DEFORMATION AND COALESCENCE UNDER UNIFORM ELECTRIC FIELD

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ABSTRACT

Drop deformations and flow fields were determined in this study by solving the Navier-Stokes and Laplace’s equations governing the flow field and electric field, correspondingly. The Level Set method was used to study the free interface deformations of a single drop suspended in another viscous fluid and the coalescence between a drop and an interface. The first part of the study focused on the effect of the electric field strength and the two fluids physical properties (conductivity -, permittivity- and viscosity ratio) on the droplet shape. The second part of the study was aimed at the numerical study of the partial coalescence phenomenon and its validation on the ground of experimental data from the literature. The electric field effect on the partial coalescence phenomenon was also examined. In presence of critical electric field strength the coalescence proceeded as a single-stage process.

Keywords: droplet deformation, electro-coalescence, numerical simulation, partial coalescence.

INTRODUCTION

Nowadays, separation processes based on the electro-hydrodynamic principle are widely used in industrial applications, such as petroleum and pharmaceutical engineering, cosmetics, and lab-on-a-ship. Electro-hydrodynamics is the term used for hydrodynamics coupled with electrostatics [1]. In the presence of an electric field, a drop suspended in a viscous fluid may exhibit different dynamics such as deformation, motion, electro-rotation [2]. Taylor [3] proposed the “leaky dielectric model” based on a number of simplifying assumptions in case of a single drop suspended in a viscous phase of two leaky dielectric fluids under an applied electric field. The model shows that the droplet can keep its initial spherical form or undergo a deformation, i.e. get a prolate or oblate steady shape depending on the electric field strength, and the electrical properties of the two fluids (surface tension, viscosity, permittivity, electrical conductivity). The Taylor analytical correlation [3] which predicts droplet deformation D is given by:

\[ D = \frac{A - B}{A + B} + \frac{9B_0}{16} R_{elec}^2 + 1 \left( 2Q_e + \frac{3}{5} \left( R_{elec} - Q_e \right) \right) \frac{(2 + 3\lambda)}{(1 + \lambda)} \]

where A and B are the lengths of the axes of the ellipsoidal drop parallel and perpendicular to the applied electric field, correspondingly.

\[ R_{elec} = \frac{\sigma_{e,1}}{\sigma_{e,2}}, \quad Q_e = \frac{\varepsilon_1}{\varepsilon_2}, \quad \text{while } \lambda = \frac{\mu_1}{\mu_2} \]

stands for the ratio of dispersed and continuous phases conductivities, permittivities and viscosities, respectively. Subscripts 1 and 2 refer to the dispersed and continuous phase, respectively. Boe is the electrical Bond number, which represents the ratio of the electric
and the surface tension forces.

It is given by \( B_{oe} = \frac{\varepsilon_2 \varepsilon_0 d E^2}{\gamma} \), where \( d \) is the drop diameter, \( E \) is the electric field applied on the system, \( \varepsilon_0 \) is the vacuum permittivity, while \( \gamma \) is the interfacial tension. Analytical solutions are developed aiming better understanding of the electric field effect on the drops deformation in view of the experimental difficulties met. But they are only limited to small drop deformations \([3-4]\). Numerical modelling provides an alternative solution of studying large drop deformations. Many numerical studies are carried out on a two-phase flow under an electric field. Feng and Scott \([5]\) investigate numerically steady state deformation of a conductive droplet in an electric field. An excellent agreement between their data and the asymptotic solution of Taylor \([3]\) is found in case of small deviations of drops spherical shape. This data \([5]\) data juxtaposed to the experiment results of Ha and Yang \([6]\) shows also a good agreement. The interaction and distribution of drops in a channel under an electric field is investigated by Fernandez and Tryggvason \([7]\) using two-dimensional simulations in the course of the front tracking method application. The influence of the electric field strength and the dispersed phase volume fraction is quantified. But the authors do not account of the drop coalescence. The level set method is successfully applied (Singh and Aubry \([8]\), Mahlmann and Papageorgiou \([9]\)) to simulate the deformation of a drop in an electric field. Teigen and Munkejord \([10]\) use a sharp-interface approach based on the level set method and the ghost-fluid method to simulate two-phase electro-hydrodynamic flows. The volume-of-fluid method (Hua et al. \([2]\), Lopez-Herrera et al. \([11]\), Tomar et al. \([12]\)) and the lattice Boltzmann method (Kupershtokh and Medvedev \([13]\)) are also successfully applied to simulate drops deformation in an electric field. Lin et al. \([14]\) use the phase field method to simulate two-phase electro-hydrodynamic flow generated by an electric field. Lin \([15]\) introduces a conservative level set coupled to both the electrostatic and the leaky dielectric models. All results obtained are in good agreement with Taylor’s theory for small drop deformations. However, significant differences between the numerical results and those obtained by the asymptotic theory are revealed when the deformation of the drop becomes significant.

Several authors study the electro-coalescence interaction between a drop and an interface (Charles and Mason \([16]\), Mohamed-Kassim and Longmire \([17]\), Chen et al. \([18]\); Blanchette and Bigioni \([19]\); Bozzano and Dente \([20]\). The mechanism of drop-interface coalescence includes four steps: an initial approach, drainage of the trapped continuous phase film, rupture of the film and confluence. The viscosity ratio between the two fluids is assumed equal to one in many studies \([15]\). However, Bazhlekov et al. \([21]\) demonstrated that, in the presence of van der Walls forces, the viscosity ratio affects significantly the drops coalescence. In the presence of an applied electric field, Chiesa et al \([22]\) investigate the effect of the viscosity ratio on the destabilization of water-oil emulsion. Unfortunately, this study provides no information concerning the partial coalescence phenomenon. The latter is studied in absence of an electric field in the work of Chen et al. \([18]\) who focus on a water drop and a water-glycerol mixture. Mixtures of decane-polybutene of a varying amount of polybutene are used for the continuous phase surrounding the drop. The results of this study refer to viscosity ratios ranging from one to five, and therefore cannot be validated for systems of an extreme viscosity ratio. However, it is a benchmark in respect to validation of the numerical models developed in an electric field absence (Teigen et al. \([23]\), A. Ervik et al. \([24]\)). The electric field effect on the partial coalescence phenomenon is investigated by Charles and Mason \([25]\), Allan and Mason \([26]\) and more recently by Teigen et al. \([23]\). Only a few studies have so far been devoted to the effects of an electric field on a two-phase medium of an extreme ratio of viscosities (Ha and Yang \([27]\)). However, in some industrial applications, in the petroleum industry especially, the viscosity ratio can be very small.

The study reported in his communication focuses two-phase media of a viscosity ratio from 0.01 to 0.5. We are interested, on one hand, in the deformation of a single drop suspended in a viscous fluid under an applied electric field, while on the other, in the electric field influence on the secondary drop generation phenomenon. Section 2 of the paper describes the governing equations:
the drop deformations and the flow fields are determined by solving the Navier-Stokes equations governing the flow field and the Laplace’s equation referring to the electric field effect. The level set method for free interface deformations is applied as well. Section 3 presents the numerical technique developed to solve the governing equations, while Section 4 refers to the analysis of the results obtained and the discussion of the effects of the dimensionless parameters governing the system. Subsection 4.1 describes the study of single droplet deformation. Subsection 4.2 is devoted to the study of the coalescence between a drop and a liquid-liquid interface. In fact we investigate the influence of the viscosity ratio on the partial coalescence phenomenon between a water drop in oil and the water deformable interface in presence and absence of an electric field.

We present the validation of our model using the experimental results of Chen et al. [18] in an electric field absence. We study the effect of the viscosity ratio and the electric field applied on the partial coalescence process. The conclusions drawn are presented in Section 5.

GOVERNING EQUATIONS

Following the front-tracking methodology, the problem requires the resolution of the Navier-Stokes equations for each phase, the level set equation and the Poisson’s equation. The problem is considered a bi-dimensional (2D) one.

Interface capturing

The level set method [28] is used to describe the interface and to determine its deformation. The LS function in this formulation takes a value of 0.5 exactly at the interface, while values of 0 or 1 away from the interface. The motion of the interface is then presented by solving the advection equation of the level set including the right-hand re-initialisation term:

$$\frac{\partial \varphi}{\partial t} + \mathbf{u}_i \nabla \varphi = \alpha \nabla \left( \delta \nabla \varphi - \varphi (1 - \varphi) \frac{\nabla \varphi}{|\nabla \varphi|} \right)$$

where $\mathbf{u}_i$ is the velocity vector in phase i, while $\alpha$ and $\delta$ are reinitialisation parameters. Parameter $\alpha$ defines the intensity of reinitialization whereas parameter $\delta$ controls the interface thickness.

Flow equations

The velocity and pressure fields are obtained by solving the Navier-Stokes equations for incompressible fluids. They include surface tension and electric forces and are given by:

$$\nabla \mathbf{u}_i = 0$$

$$\rho \left( \frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla) \mathbf{u} \right) = \nabla \left[ -p + \mu (\nabla \mathbf{u} + \nabla \mathbf{u}^T) \right] + \mathbf{F}_{st} + \mathbf{F}_e$$

where $\rho$ is the density, $\mathbf{u}$ is the velocity vector, $t$ is the time, $p$ is the pressure, $\mu$ is the dynamic viscosity, $\mathbf{F}_e$ is the electric force, while $\mathbf{F}_{st}$ is the surface tension force defined as below:

$$\mathbf{F}_{st} = \gamma H \nabla \varphi = -\gamma \left( \nabla \cdot \frac{\nabla \varphi}{|\nabla \varphi|} \right) \nabla \varphi$$

where $\gamma$ is the interfacial tension and $H$ is the mean curvature of the interface.

The average density and viscosity are represented in terms of the level set function $\varphi$:

$$\rho = \rho_2 + (\rho_1 - \rho_2) \varphi$$

$$\mu = \mu_2 + (\mu_1 - \mu_2) \varphi$$

Electric force equations

Assuming that both fluids of the system are incompressible, the applied electric force on the domain is given as:

$$\mathbf{F}_e = \int \left( -\frac{1}{2} \mathbf{E}^2 \nabla \varepsilon + \rho_e \mathbf{E} \right) \, dx^3$$

where $\rho_e$ is the charge density. The averaged permittivity is given by

$$\varepsilon = \varepsilon_2 + (\varepsilon_1 - \varepsilon_2) \varphi$$

The electric field can be expressed as the gradient of the scalar potential $V$:

$$\mathbf{E} = -\nabla V$$
The Gauss law [14] gives:

$$\nabla \cdot (E) = \frac{\rho}{\varepsilon}$$  \hspace{1cm} (11)

That means:

$$F_e = \int \left( -\frac{1}{2} E^2 \nabla \varepsilon + \nabla (\varepsilon E) \right) \, dx^3 $$  \hspace{1cm} (12)

When both liquids in a two-fluid system are electrically conductive (as in the leaky dielectric fluids model), the governing equation for the electric field takes the form [2, 15]:

$$\nabla \cdot (\sigma E) = 0$$  \hspace{1cm} (13)

In this case, the electric force acting on the fluids is calculated with the application of Eq. (12) and Eq. (13). This is true for simulations related to single droplet deformation.

However, when both liquids in a two-fluid system have weak electrical conductivities they can be considered as perfect dielectric fluids and Eq. (11) reduces to:

$$\nabla \cdot (\varepsilon E) = 0$$  \hspace{1cm} (14)

So, the electric force equation can be expressed as:

$$F_e = \int \left( -\frac{1}{2} E \nabla \varepsilon \right) \, dx^3 $$  \hspace{1cm} (15)

In this case, the electric force acting on the fluids is calculated following Eq. (14) and Eq. (15). This is true for simulations related to coalescence between a drop and a liquid-liquid interface since the fluids considered (oil /water) have very weak electrical conductivities.

**Interface and boundary conditions**

The normal component of the interfacial stress boundary condition is given in an electric field presence by:

$$ (p_1 - p_2) - \left[ \mu_2 (\nabla u_2).n - \mu_1 (\nabla u_1).n \right].n - \frac{2\gamma H}{\varepsilon_0} + \frac{1}{2} E_0^2 E_n $$

where \( n \) is an unit vector normal to the interface.

The continuity of tangential stresses is expressed as:

$$ \left[ \mu_2 (\nabla u_2).n - \mu_1 (\nabla u_1).n \right].t = 0 $$

where \( t \) is an unit tangential vector to interface. The continuity of the velocity fields is given by:

$$ u_1 = u_2 $$

A no-slip boundary condition is imposed at lower, upper and right walls (\( u_i = 0 \)). For both velocity and electric potential, axial symmetry boundary condition is imposed along the axis of symmetry. The electric potential is set to \( V_0 \) at the upper wall and to 0 at the ground. \( V_0 \) value determines the electric Bond number.

**NUMERICAL METHODS**

A 2D cylindrical system implementation is applied and the governing equations (the Navier-Stokes equations, the level set equation and the Poisson’s equation) subjected to the boundary conditions mentioned above are simultaneously solved. The commercially available finite-element-based solver COMSOL Multiphysics 3.5 is used. Both the continuous and dispersed phases are discretized into a number of triangular finite elements. The optimization of the computational time and the memory power of the machine requires to apply an axial-symmetric assumption to all simulations described above. The solver uses a finite element based code to calculate the values of the velocity, the pressure, the electric field and the level set function at each node. A direct linear system solver is used together with a time dependent second order BDF (a backward differentiation formula) to determine each time step. The direct solver is called PARDISO and handles sparse linear systems using LU factorization to compute a solution. A relative tolerance of 0.001 and an absolute tolerance of 0.0001 are used for the time discretization scheme. An irregular mesh is used as it is suitable to have a finer mesh near the drop where the gradients are large. The very fine mesh at the drop interface allows the proper description of the drop deformation. Many simulations of different lengths are carried out aiming at the determination of the most appropriate length of the computational domain. The minimum dimensions of the latter around the drop...
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(Fig. 1a), where the solutions are almost unaffected, are determined to be about three drop radius in r direction ($l = 3R$) and six drop radius in z direction ($h = 6R$) in case of a single droplet deformation. The computational domain in the mesh mode is discretized into a finite number of 4857 elements of 34664 degrees of freedom. In case of coalescence between a drop and a liquid-liquid interface the computational domain is characterized by $l = 6R$ and $h = 12R$. The height of the lower bulk, $h_1$, is equal to $4R$, while the initial distance from the interface to the drop, $h_2$, is equal to $0.04R$ (Fig. 1b). The computational domain is discretized into a finite number of 20000 elements of 133000 degrees of freedom.

RESULTS AND DISCUSSION

Preliminary testing: single droplet deformation

Single droplet deformation in the presence of an electrical field is investigated and compared to the existing analytical solution as a preliminary test for the validation of the numerical approach used here. The deformation of the drop in electric field presence is studied by tracking the interface. As shown in the Fig. 1, the drop which is initially perfectly spherical is suspended between two electrodes separated by $h = 6R$. An electric field $E = \frac{\Delta V}{h}$ is generated in the domain when an electric potential gradient is created. The drop deformation depends on the strength of the applied electric field and on the physical properties of the two fluids. The numerical results obtained are presented in Figs. 2 and 3. A comparison with the Taylor analytical correlation (Eq. 1) is carried out as well. Fig. 2 shows the steady drop deformations for several values of the permittivity ratio, Q, at a fixed electrical Bond number ($Bo_e = 0.1$) and a fixed conductivity ratio ($R_{elec} = 5$). One can see from Fig. 2 that the drop undergoes an elongation along the symmetry axis (gets a prolate shape) when the permittivity ratio is less than 9.25. The drop takes an oblate form when the ratio is equal to 9.25. When the ratio is greater than 9.25 the drop doesn’t deform and keeps its initial spherical shape. These results are in agreement with the Taylor theory and Y. Lin numerical results [15]. Fig. 2 shows also that for small deformations $|D| < 0.05$, our results are in good agreement with Taylor’s

Fig. 1. Schematic diagram of the initial computational domain for the numerical simulation of: a) single drop deformation, b) coalescence between a drop and a liquid-liquid interface (not to scale).
theoretical model [3] (for leaky dielectric fluids). This is no longer true for large deformations for which the theoretical results of Taylor [3] underestimate the drop deformations, as found by Y. Lin [15] and Hua et al. [2]. Fig. 3 illustrates the effect of the conductivity ratio on drop deformations. It is seen that the drop takes an oblate steady shape in case of a conductivity ratio lower than 2; it takes a prolate form when the latter is greater than 2. The drop keeps its initial spherical form when the conductivity ratio is around 2. These results are also in agreement with those of Y. Lin [15]. Fig. 4 illustrates a specific deformation case using a leaky dielectric fluid leading to a prolate steady shape (a), to any deformation absence (b) and an oblate steady shape (c).

Coalescence between a drop and a liquid-liquid interface

Having established the ability of the numerical code to compute single droplet deformation in an electrical field presence, we turn now to explore the characteristics of coalescence between a drop and a liquid-liquid interface. We have to investigate the coalescence phenomenon without any electric field influence. Thereafter we study the influence of an electrical field on the coalescence. The main effective forces applied on the system in an electric field absence are summarized in four dimensionless numbers (Chen et al. [18]):

\[
\begin{align*}
\text{Oh} &= \frac{\mu_1}{\sqrt{(\rho_1 + \rho_2) \gamma d}}; \\
\text{Bo} &= \frac{(\rho_1 - \rho_2) gd^2}{\gamma}; \\
\rho^* &= \frac{\rho_1}{\rho_2}; \quad \lambda = \frac{\mu_1}{\mu_2}
\end{align*}
\]

were Oh is the Ohnesorge number that relates the viscous forces to inertial and surface tension forces, Bo is the Bond number relating viscous forces to interfacial tension forces, \(\rho^*\) is the density ratio, while \(\lambda\) is the viscosity ratio. In the presence of an electric field, two additional dimensionless numbers allow to describe the system plainly: the electric Bond number, \(\text{Bo}_e\) and the permittivity ratio, \(Q_e\). These two dimensionless numbers defined by the Taylor theory (they are presented in the paper’s introduction) are given as:

\[
\text{Bo}_e = \frac{\varepsilon_2 \varepsilon_0 d E^2}{\gamma}; \quad Q_e = \frac{\varepsilon_1}{\varepsilon_2}
\]

Juxtaposition to experimental results

A second drop is usually generated after the merging
of the drop and the deformable interface in case of no electric field effect on the system. This results in an incomplete coalescence. The partial coalescence between a water deformable interface and the water drop which is merged in a mixture of 20% polybutene in decane is experimentally studied by Chen et al. [18]. Simulations are conducted keeping the physical properties used by Chen et al. [18] aiming our numerical model validation.

The drop diameter, the drop density, the drop viscosity, the continuous phase density, the continuous phase viscosity and the interfacial tension have the values described by: $d = 1.1\text{mm}$, $\rho_1 = 10^3\ \text{kg.m}^{-3}$, $\mu_1 = 10^{-3}\ \text{Pa.s}$, $\rho_2 = 760\ \text{kg.m}^{-3}$, $\mu_2 = 2\times10^{-3}\ \text{Pa.s}$ and $\gamma = 2.97\times10^2\ \text{N.m}^{-2}$.

The dimensionless parameters are given by: $\text{Oh} = 4.17\times10^{-3}$ and $\text{Bo} = 9.59\times10^{-2}$.

Snapshots of the interfacial evolution observed by

![Image of simulations](image_url)

**Fig. 4.** Simulated flow patterns inside and outside the drop for (a) $\text{Relec} = 5$, $Q_e = 0.5$ and $\text{Bo}_e = 0.1$; (b) $\text{Relec} = 5$, $Q = 0.5$ and $\text{Bo}_e = 0.1$; (c) $\text{Relec} = 5$, $Q_e = 120$, and $\text{Bo}_e = 0.1$.

![Image of comparisons](image_url)

**Fig. 5.** Comparison between Snapshots of water droplet merging with an interface between 20% polybutene in decane and water from Chen’s experience [18] (left) and from our numerical results (right). $\text{Oh} = 4.17\times10^{-3}$, $\text{Bo} = 9.59\times10^{-2}$.
Effect of viscosity ratio on the coalescence

A series of simulations is realized to investigate the viscosity ratio effect on the coalescence phenomena of a system of a viscosity ratio lower than that used by Chen et al. [18]. The physical properties used in the experiments of Chen et al. are taken into account in these simulations. The only exception refers to the continuous phase viscosity, $\mu_2$, which is varied to provide wide-ranging of the viscosity ratio $\lambda$ at constant dispersed phase viscosity, $\mu_1$. Fig. 6 illustrates the time evolution, in case of different viscosity ratios, of the dimensionless mass of the water remaining in the volume occupied initially by the spherical water drop. The ratio $m/m_0$ decreases initially with the viscosity ratio increase. It becomes nearly constant in the viscosity ratio range between $\lambda = 0.13$ and $\lambda = 0.5$ for times greater than about 5ms. Then it decreases regularly until complete coalescence. The beginning of the plateau corresponds to pinch-off and therefore to generation of a secondary drop, while the end of the plateau corresponds to the beginning of coalescence of the secondary drop with the interface. The plateau disappears in the viscosity ratio range between $\lambda = 0.01$ and $\lambda = 0.12$. This indicates the absence of a secondary drop. It is worth noting that the coalescence in the cases discussed is not a multi-step but rather single-step process.

Effect of the electric field on the coalescence

Series of simulations are performed to investigate the influence of the electric field on coalescence phenomenon. The physical properties considered are again identical with those used by Chen et al. [18], but an electric potential gradient is generated between the upper wall and the ground. Fig. 7 shows snapshots of the interface evolution from the numerical simulations for tree values of the electrical Bond number $Bo_e$ (0, 0.05 and 0.1) and a fixed permittivity ratio $Qe = 26.66$ corresponding to permittivities of an water drop and oil ($\varepsilon_1 = 80, \varepsilon_2 = 3$). For lower electrical Bond number ($Bo_e < 0.05$), the behavior is comparable to that in absence of an electrical field ($Bo_e = 0$), but the generated drop is much closer to the interface than in the case without an electric field. Fig. 7c shows that the evolution in case of
A higher electrical Bond number ($Bo_e = 0.1$) is different from that of the two previous cases ($Bo_e = 0, Bo_e = 0.05$). It may be noted that the drop continues to coalesce with the interface at $t = 5.8$ ms, while a secondary drop is generated in the other two cases. Fig. 7c shows also that coalescence is almost total at time $t = 7.5$ ms implying that in this case the electric field is strong enough to enhance coalescence phenomenon by eliminating the secondary drop generation.

Fig. 8 presents the time evolution of the dimensionless mass of water, remaining in the volume occupied initially by the spherical water drop, for different Bond electric numbers and a fixed permittivity ratio $Q_e = 26.66$. The ratio $m/m_0$ decreases initially regularly and this decrease is greater for a lower electric Bond number. It becomes nearly constant for times greater than about 5 ms and $Bo_e < 0.09$. This indicates a secondary drop generation. A regular decrease follows then until complete coalescence of the secondary drop. It is continuous, i.e. no plateau is outlined from the beginning to the end of coalescence for $Bo_e > 0.10$. This is an indication of the absence of a secondary drop. Furthermore it means that the coalescence is a multi-step process for $Bo_e < 0.09$, while it is single-step one for $Bo_e > 0.10$. 

Fig. 7. Snapshots of numerical results showing the electric field influence on the drop-interface coalescence efficiency. The initial drop diameter $d = 1.1$ mm, $Oh = 4.17 \times 10^{-3}$ and $Bo = 9.59 \times 10^{-2}$, a) $Bo_e = 0$; b) $Bo_e = 0.05$; c) $Bo_e = 0.1$.

Fig. 8. Time evolution of the dimensionless mass of water remaining in the volume occupied initially by the spherical water drop for different Bond electric numbers. The initial drop diameter is $d = 1.1$ mm and the other fixed parameters are: $Oh = 4.17 \times 10^{-3}$, $Bo = 9.59 \times 10^{-2}$ and $\lambda = 0.5$. 

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**Note:** The diagrams and text are not directly transcribed due to the limitations of the text-based format. The figures and text are meant to convey the relationship between the Bond number and the coalescence process in an electrical field.
CONCLUSIONS

The influence of an external electric field on the drop deformations was considered in the present work. The drop was suspended into a liquid between two parallel electrodes placed in leaky dielectric fluids. A numerical model based on the level set method was elaborated and validated with the theoretical leaky dielectric and other numerical models. The partial coalescence phenomenon was investigated. A numerical model based on the level set method was validated using the experimental results obtained by Chen et. al. They referred to the study of the partial coalescence between a water drop in 20 % polybutene in decane and a deformable water interface. It was found that the model provided good accuracy for drop coalescence with a deformable interface tracking accurately the time-evolution of the drop shape. The study was extended to the investigation of the viscosity ratio as well as the electric field on the partial coalescence. Various numerical simulations for different sets of the viscosity ratio and the electric Bond number were performed. The results showed that the drop coalescence with the bulk phase was not complete and a daughter drop was left behind (partial coalescence) when the viscosity ratio ranged between 0.13 and 0.5. There was no secondary drop in case of a lower viscosity ratio.

The coalescence observed was not a multi-step, but rather a single-step process. It was also found that the coalescence was a single-step process in presence of critical electric field strength, while above it the process took place as a multistage-step one.

The current results provided further insight into partial coalescence. It should be emphasized that the theoretical and computational frame work developed concerned pure liquid-liquid systems. In practice, the phases may contain surfactants or impurities and the resulting surface activity leads to additional forces that may change the coalescence behavior. The main perspectives of this work would be to extend the simulations in this respect.

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