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Modeling of multiphase electrohydrodynamic flows involving dynamical charging effects

Yun Ouedraogo*[1], Erion Gjonaj[1], Herbert De Gersem[1] and Sebastian Schöps[2]

[1] Institut für Theorie Elektromagnetischer Felder, Technische Universität Darmstadt, Schloßgartenstraße 8, 64289 Darmstadt, Germany.
E-mail: {ouedraogo, gjonaj, degersem}@temf.tu-darmstadt.de *www.temf.tu-darmstadt.de*
[2] Graduate School CE, Technische Universität Darmstadt, Dolivostraße 15, 64289 Darmstadt, Germany. E-mail: schoeps@gsc.tu-darmstadt.de *www.graduate-school-ce.de*

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In the presence of strong external electric fields, induced forces in liquids drive fluid flow. The electrical conductivity of liquids leads to free charge accumulation at fluid interfaces, affecting in turn the electric field distribution. This effect can result in generation of charged droplets from uncharged liquid bodies, as in electrosprays, where the charged spray is formed by exposing the liquid to external electric fields prior to its atomization. Such multiphase electrohydrodynamical problems require an electroquasistatic (EQS) field description, in order to capture dynamic charging effects as well as free charge transported in atomized liquids.

We propose a method for numerically solving multiphase electrohydrodynamical problems involving dynamic charging effects in multiple droplets. Topology changes are implicitly handled by a Volume of Fluid based interface representation used for the solution of the Navier-Stokes equations and EQS field problem. The EQS charging behaviour is described by treating the free charge as a primary quantity and by considering free charge transport in fluids in addition to ohmic conduction effects. Numerical simulations are performed using the Finite Volume method as provided by the OpenFOAM framework.

The applicability of the model is illustrated with the electrically induced detachment of liquid droplets from the tip of a capillary in an on-demand droplet generator [1], showing the dependency of detachment dynamics on the electrical conductivity of the test liquids. In a second step, the dynamics of droplets oscillating on insulator surfaces [2] and their relevance on partial discharge inception voltage estimation are considered.

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