Analysis of different liquid-liquid combinations and conditions for the formation of a stable cone-jet mode in electrospray emulsification processes

A.W. Kamau¹, Gatari M. J.¹, J.C. M. Marijnissen¹,² and L.L.F. Agostinho³

¹Institute of Nuclear Science and Technology, University of Nairobi, Nairobi, 30197-00100, Kenya
²University of Florida, Gainesville, FL 32611, United States
³NHL University of Applied Sciences, Rengerslaan 10 Leeuwarden, The Netherlands

Keywords: ethylene glycol-hexane, liquid properties, charged droplets, monodisperse distribution.

Support by Wetsus Academy, NHL University of Applied Sciences, International Science Programme and the University of Nairobi is acknowledged.

Electrohydrodynamic atomization (EHDA) is the breaking up of a liquid into droplets under the influence of a strong electric field (kV/cm). Cloupeau and Prunet-Foch (1994) have shown that there are different modes generated depending mainly on the electric field characteristics and flow rate for the same liquid. Barrero et al (2004) have afterwards mentioned some electrospray characteristics when the continuous media is another liquid i.e electrospray emulsification process. Later, Jaworek (2008) published some applications of the electrospray under similar conditions. In this work the conditions necessary to obtain cone-jet mode in electrospray emulsification different liquid-liquid combinations i.e water-hexane, water-paraffin oil, ethylene glycol-hexane and glycerol-hexane were studied. Additionally, the liquid combination which allowed electrospraying in a stable cone-jet mode, was further analyzed regarding produced droplet size, size dispersion and the stability of the generated emulsion.

For the experiments, the dispersed phase was pumped through a nozzle into the continuous phase. A high voltage difference was applied to the nozzle while a counter electrode (ring), placed at 1 cm below it, was kept grounded. A high-speed digital camera coupled with a microscopic lens was used to capture the images of the electrospray. Among all the tested combinations, ethylene-glycol-hexane and glycerol-hexane systems generated stable cone-jet mode. For ethylene glycol-hexane, the cone jet was obtained when the electric potential was set between 6 and 8 kV and the flow rate at 0.5 mL/h. Other modes were observed for this same flow rate at different potentials i.e. dripping and micro-dripping modes between 0 and 2kV, an intermittent cone-jet mode between 3 and 5kV, and a multi-jet mode (two steady cone-jets) for potentials bigger than 8kV. At the onset of the cone-jet mode, the tip of the jet manifested ‘whipping instabilities’. After recording, the images of the droplets were analyzed with an imaging software (ImageJ). Results indicated that between 3 and 5 kV, the spray was rather polydisperse. For the stable cone-jet mode (potentials 7kV and 8kV), a bimodal distribution with average diameters of ~4μm and 8μm was observed. Theoretical calculations using the same approach suggested by Hartman et al (1999) indicated that the average droplet size (d) varied with the flow rate (Q) as d ~ Q^{0.33}. The spray electric current scaled with the flow rate by I/I_{0} ~ (Q/Q_{0})^{0.5}, where Q_{0} and I_{0} are the characteristic values of flow rate and its respective current.

During the experiment, the droplet dispersion into the continuous phase was observed to be enhanced in the presence of the electric field. The analysis done with different liquid-liquid combinations indicated that the liquids properties interfacial tension, the ratio between the liquids electrical permittivity and the viscosity ratio can be used as important parameters to determine whether a stable cone-jet could be generated.

Figure 1. A steady cone jet mode observed over time (ethylene glycol-hexane system at 0.5mL/h and 6kV)


