Electrohydrodynamic Atomization (EHDA): automatic classification and data analysis

M. M. Novelli[1,2], P. A. Gabriel[1,2], K.S. Moreira[2], L. P. Di Bonito[2,3], K. Glanzer[2], L. L. F. Agostinho[2]

[1] Department of Control and Automation Engineering, Federal University of Minas Gerais, Belo Horizonte, 31270-901, Minas Gerais, Brazil
[2] Lectoraat Water Technology, NHL Stenden University of Applied Sciences, Leeuwarden, 8917DD, The Netherlands
[3] Department of Mathematics and Physics, University of Campania Luigi Vanvitelli, Caserta, 81100, Italy
*matheus.mnovelli@gmail.com

NHL STENDEN university of applied sciences — UFMG — Living Lab Biobased Brazil Education Research Innovation

Introduction

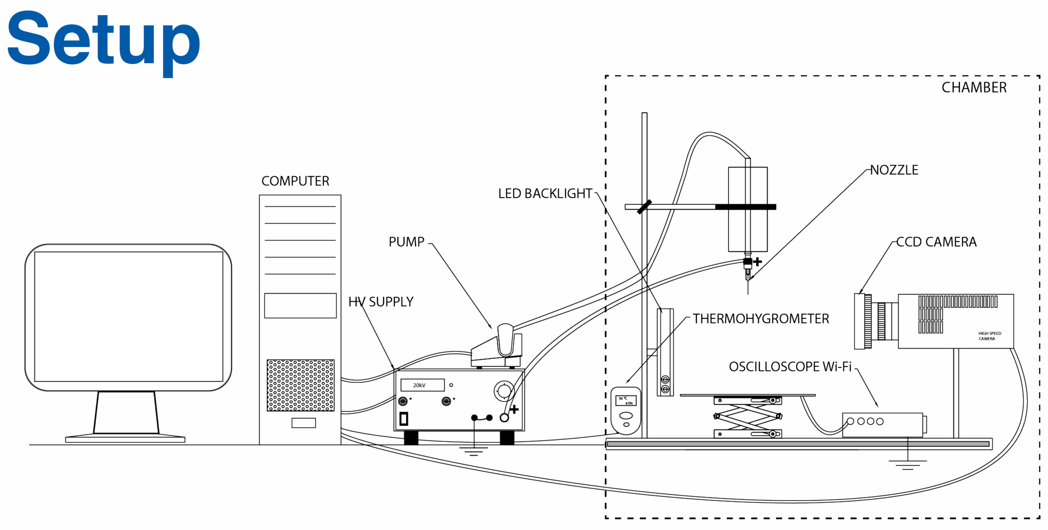
Electrohydrodynamic Atomization (EHDA) is a technique used to break a liquid into droplets using strong electric fields. The balance between forces on the charged liquid meniscus defines the electrospraying dynamics (Chen et al., 1997). According to Cloupeau & Prunet-Foch, 1989, by manipulating the physical-chemical properties of the liquid and experimental setup characteristics, it is possible to form different electrospray modes. There are four common modes in EHDA: dripping, intermittent, cone-jet and multi-jet.

Verdoold et al. (2014) introduced a new method for classifying electrospray modes by measuring the current through the system, diverging from the traditional approach of optical observations of the liquid meniscus. Building upon Verdoold proposal, we have created a system that automatically classifies electrospray modes in real-time using the electric current. The software generates a huge amount of data that can provide many insights about the EHDA, specially about the influence of physical-chemical properties of the liquids on the EHDA modes.

Objectives

- Map different liquids using the EHDA mode mapping system
- Investigate the relation between liquid physical-chemical charcateristics and the classified EHDA modes.

Setup



The experimental setup (Figure 1) is integrated with the computer, allowing the automatic operation of actuators (power supply and syringe pump). An oscilloscope is used, connected to the ground line, to collect the current data at high sample rate.

Figure 1: Electrospray setup

EHDA mode classification

For multipurpose applications the classification routine developed in this work was configured for real time operation. The flowchart in the Figure 2 provides a brief overview of how the software works.

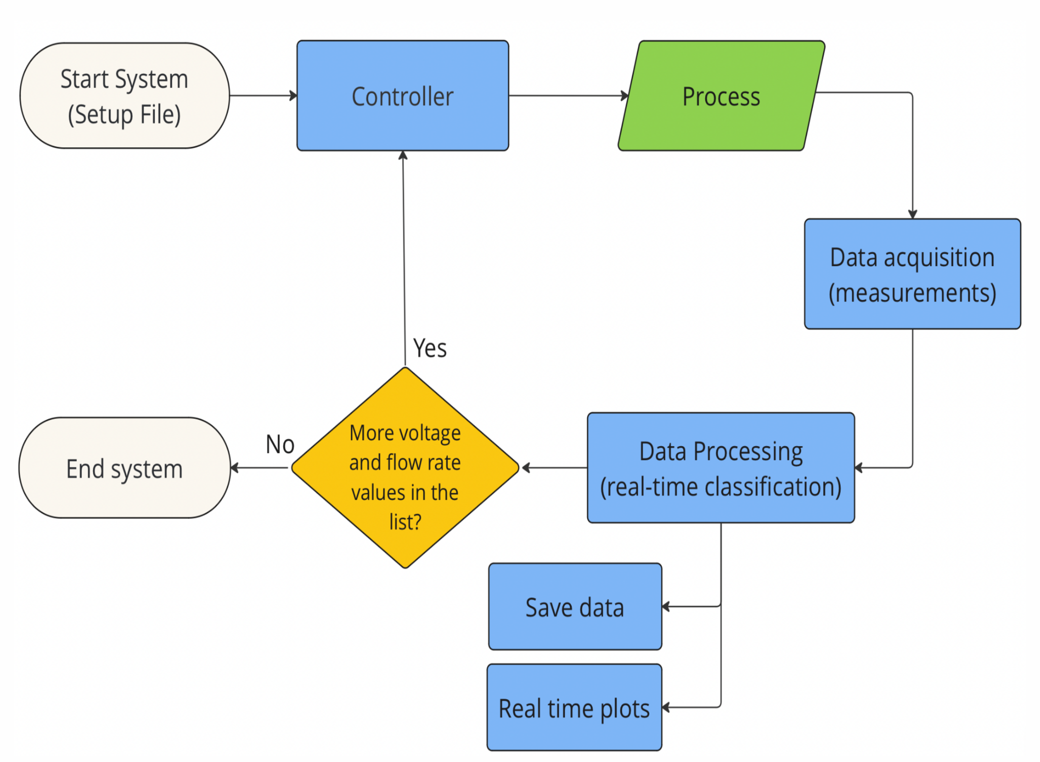


Figure 2: Software Flowchart

Physical-chemical analysis

Different liquids were mapped and their physical-chemical properties are presented in table 1.

Table 1: Physical-chemical properties of mapped liquids

Liquids	Conductivity (μS/m)	Surface Tension (mN/m)	Density (g/cm3)	Viscosity (mPa.s)
EWP 532	39	27.4	0.917	4.56
EW 55	8.2	27.9	0.930	2.33
EW 82	9.5	24.1	0.854	2.33
EWP 541	29.2	27.2	0.947	3.80
EWG 343	1.06	30.1	1.04	5.47
EWG 172	3.05	44.66	1.01	3.76
EWG 262	5.52	39.1	0.968	2.71

Data analysis

The maps show the dripping (blue), intermittent (red), cone-jet (yellow), multi- jet (purple), corona/sparks (pink) and undefined/instable (green) mode for each point within the voltage versus flow rate range tested. The x-axis is Q/Q_0 and the y-axis Y (Ganan-Calvo 2018).

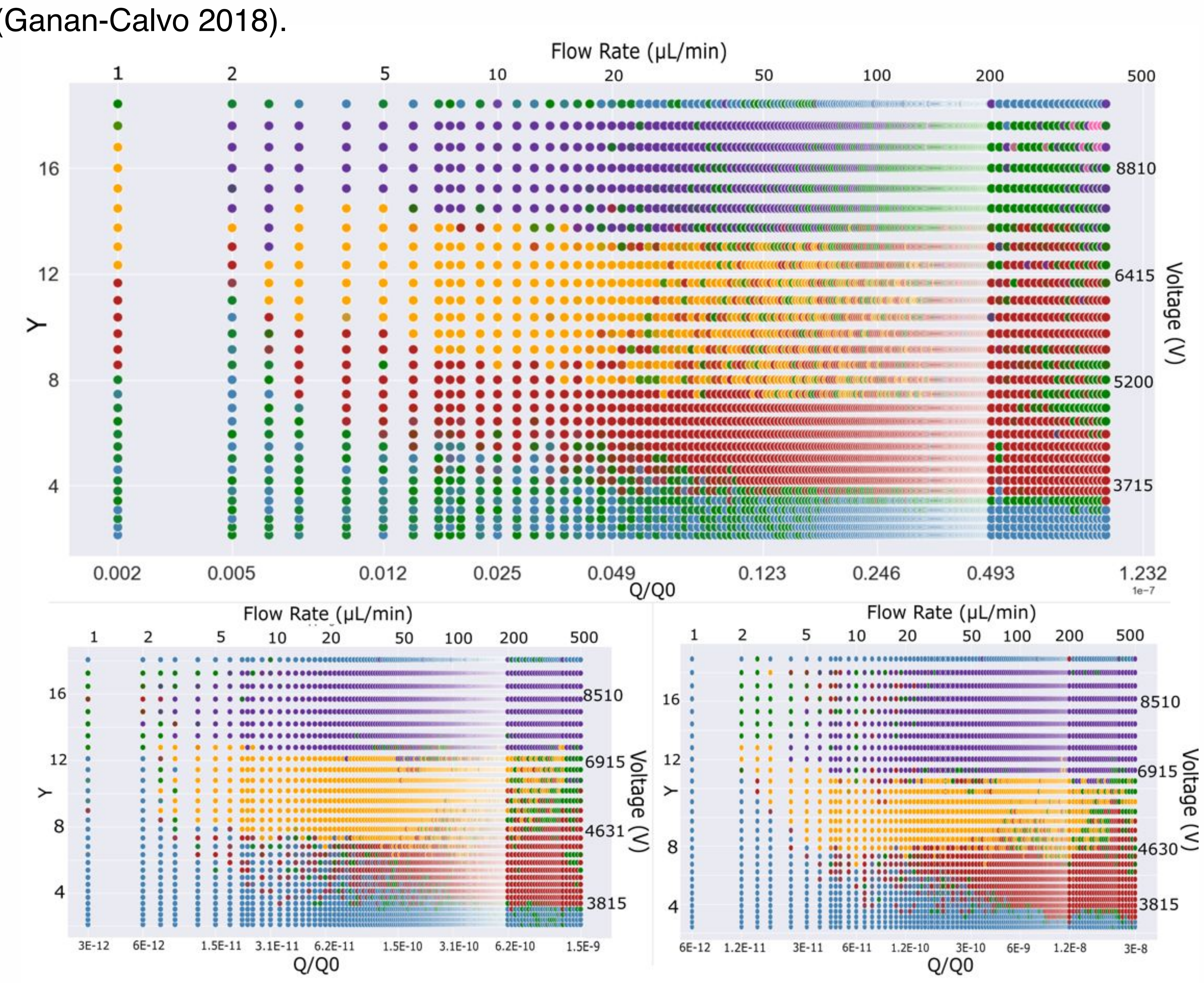


Figure 3: Map of the (a) EWP532 (b) EW55 and (c) EW82 generated by the automatic classification.

Different liquids (table 1) were tested to see how their properties affect mapping. Figure 4 shows cone-jet window outlines for three liquids. In Figure 4a, conductivity variations shift the window leftward (lower flow rates), as reported by Ganãn-Calvo. Figure 4b demonstrates the effect of increasing viscosity.

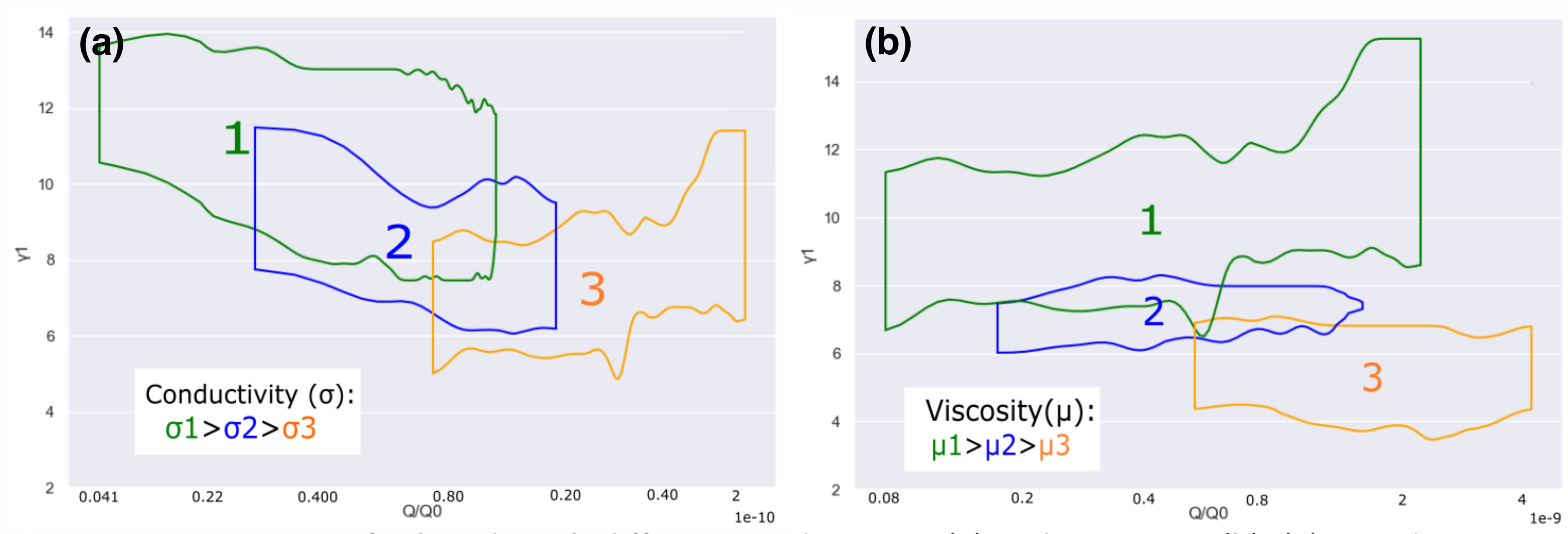


Figure 4: Cone-jet zone for liquids with different conductivties (a) and viscosities (b). (a) Liquid 1 is EWP532, Liquid 2 is EWP541 and Liquid 3 is EWG343. (b) Liquid 1 is EWG343, Liquid 2 is EWG172 and Liquid 3 is EWG262.

Conclusion

The automatic mapping of several liquids made it possible to evaluate the influence of physical-chemical properties on EHDA modes. Results obtained via mapping liquids with different conductivities and viscosities have shown shifts of the cone-jet mode window according to reported in the literature. These findings represent a significant advancement in EHDA automation, offering promising opportunities for broad adoption in diverse industrial and commercial applications.

References

[1] Chen, D. R., & Pui, D. Y. H. (1997). *Aerosol Science and Technology*, *27*(3), 367–380.
[2] Grace, J. M., & Marijnissen, J. C. M. (1994). *Journal of Aerosol Science*, *25*(6), 1005–1019.
[3] Gañán-Calvo, A. M., López-Herrera, J. M., Herrada, M. A., Ramos, A., & Montanero, J. M. (2018). *Journal of Aerosol Science* (Vol. 125, pp. 32–56).
[4] Cloupeau, M., & Prunet-Foch, B. (1989). In *Journal of Electrostatics* (Vol. 22).

Acknowledgement

This work was supported by NHL Stenden, Gilbert Technologies and University of Minas Gerais. We would like to thank the support given by Gilbert Technologies.