Universidade Federal de Minas Gerais
Escola de Engenharia
Curso de Graduação em Engenharia de Controle e Automação

EHDA closed loop control system based on real time non-visual spray mode classification

Relatório 2 de Atividades PFC 1

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1 Summary

Electrohydrodynamic Atomization (EHDA), also known as Electrospray (ES), is a way to disintegrate a liquid into droplets by exposing it to a strong electric field. EHDA surveys have contributed as an important tool for the development of water technology (thermal desalination and metal recovery), material sciences (nanofibers and nano spheres fabrication, metal recovery, selective membranes, and batteries), and biomedical application (droplet encapsulation). Besides that, the project is merged with the Energy Transition strategy and Innovation Agenda Agriculture, Water, and Food, Key Enabling Technologies (KETs). Although, there are EHDA applications in industry, stabilizing the cone-jet spray mode is done empirically and based on mean current measurements.

The electric current flowing transported by the spray reveals characteristic shapes for different spray modes. Those shapes cannot simply be summarized by its mean value. In figure one we can see an example of cone-jet mode electrospray.

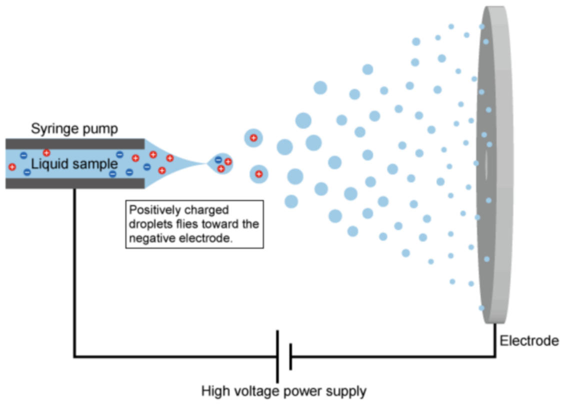

Figure 1: EHDA example

Signal processing techniques can allow a non-visual classification of the spray mode based on the electric current shape. The spray process imposes noise and random sequences on the measured signal making its classification not a trivial task.

Industrial applications demand automated stabilization of a spray mode. This can be achieved by a closed-loop control system. Automated classification of the spray mode is a crucial part of a control system same as the development of an appropriate control algorithm. Signal processing implementations of previous projects of the NHL Stenden Water Technology group are showing good classification results. Further research is necessary to improve the classification accuracy and research and implementation of a suitable classification algorithm. Because of that, the work will be done by the Water Technology Group at NHL Stenden University of Applied Sciences and in combination with Dutch companies to match analysis possibilities with knowledge and infrastructure availability.

2 Introduction

The EHDA setup used in the lab for this project can be seen in the Figure 2. For this project we are going to focus on nozzle to plate configuration and the high voltage will be applied to the nozzle. We use a variety of liquids to make the experiment such as ethyleneglycol + HNO3, ethanol, water + ethanol and 2-propanol. Those liquid properties were already been analysed and considered in the automation routine. The experiment can be made by voltage steps or voltage ramp. Both of the dynamics are being tested. The flowrate is still being used as a constant.

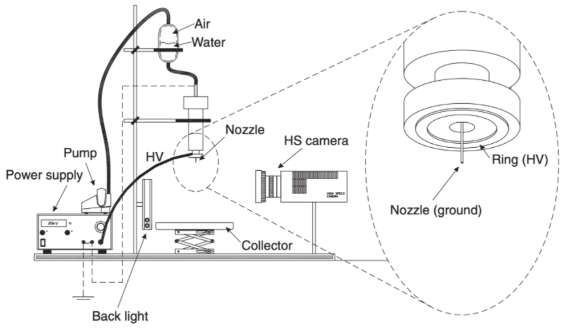

Figure 2: system setup

3 Development

3.1 Peripherals integration

The peripherals automation routine was already developed by another student. In order to continue the research I took some time to understand the physical concept behind EHDA experiments and the project knowledge.

I made upgrades in the routine to include the high speed camera with a hardware triggering routine using an arduino microcontroler. This will be usefull to validate the further classification of the spray dynamics.

3.2 Experiment tests

Initial tests were made to verify the setup assembly and the automation routine integration. In this step I could unterstand in practise how electrospray works.

I noticed that we need a large set of variables in the range to produce the desired dynamics of electrospray, which most of the time is cone-jet mode. Those variables can be the liquid properties such as surface tension, dielectric constant, viscosity, density, electrical conductivity and vacuum permitivity. And also physical variables such as flowrate, system impedance, system temperature, system humidity, nozzle to plate distance, nozzle dimensions and applied voltage.

The instruments used in the setup are:
- High Voltage Power Supply (FUG)
- Oscilloscope TiePie WS6 DIFF
- Humidity and Temperature sensor - DHT11
- High Speed Camera - Photron fastcam mini
- Syringe pump
- Arduino Uno for hardware triggering camera and DHT11 interface

3.3 Data Analysis

According to Sjaaks paper *A Generic Electrospray Classification*[1] we can classify the spray modes using only the current data measured by the oscilloscope. With the relations between the statistical values of mean, standart deviation and median of the signal we can classify if it's in dripping or cone-jet dynamics. In the figure bellow we can see the current data acquired from one experiment and also the statistical levels above. Each sample takes a frame window of 0.5s of current data and then classifies it.

For each sample color the algorithm classifies:
- green: dripping mode
- blue: intermittent mode
- red: Cone-jet mode
- purple: corona spark mode

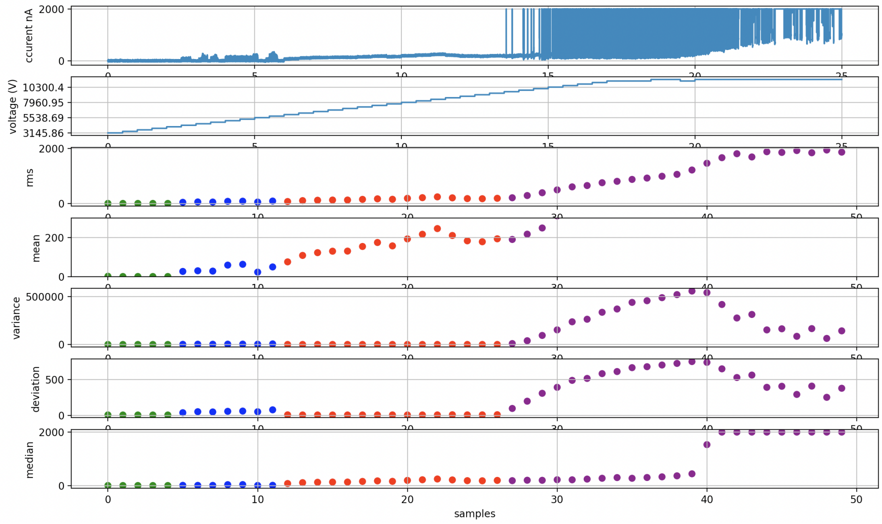

Figure 3: Data Analysis

4 Conclusion

For further steps the following tasks will be done:

- make experiments with different time windows. This will help to see the time needed for the system to stabilize.
- change power supply and oscilloscope libraries to an updated version wich covers both hardwares.
- correct and upgrade plots to make a better sense of the data.
- Include DHT11 temperature and humidity sensor to the setup.
- Thread sincronization in the main routine.

References

[1] S. Verdoold et al. "A generic electrospray classification". In: *Journal of Aerosol Science* 67 (2014), pp. 87–103. ISSN: 18791964. DOI: 10.1016/j.jaerosci.2013.09.008. URL: http://dx.doi.org/10.1016/j.jaerosci.2013.09.008.