Modelling of Droplet Charge Dynamics during an Ink Jet Breakup using COMSOL Multiphysics®

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M. Sturma[1], A. Monlon[2], P. Namy[2] , F. Viry[2], B. Barbet[1]
[1]: MARKEM-Imaje, Bourg-lès-Valence, France
[2] : SIMTEC, 5 rue Felix Poulat 38000 Grenoble France

Outline

I. Background – Motivations – Objectives

II. Modelling and Numerical Model

III. Main Results

IV. Conclusions – Perspectives

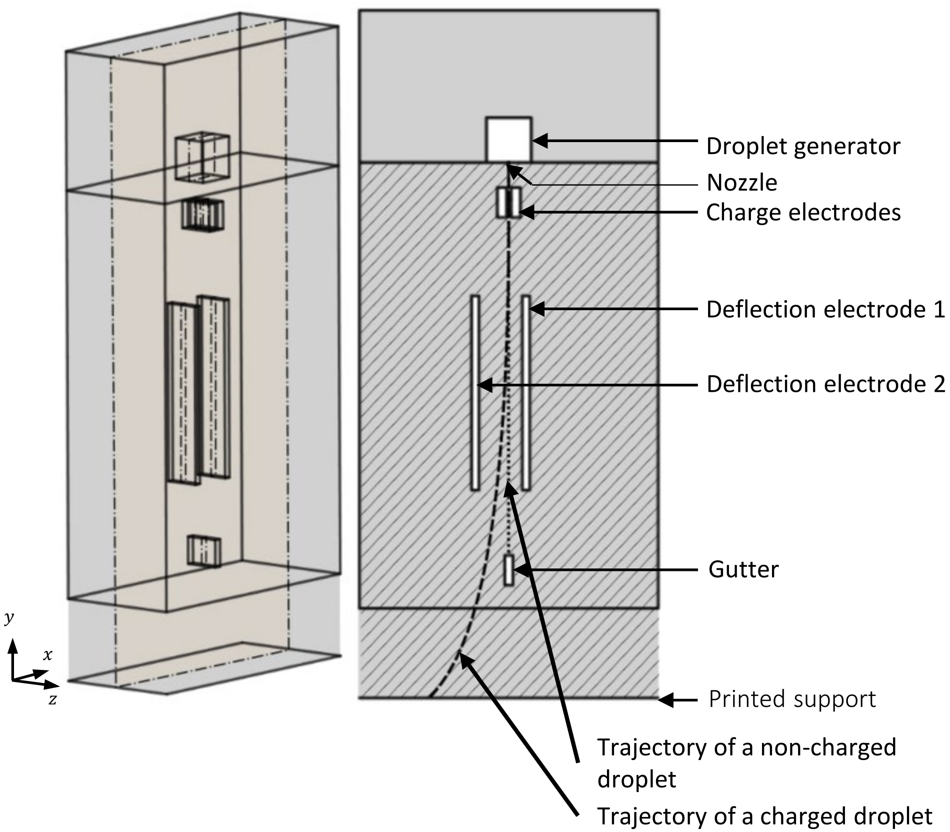
Before starting, who we are… www.simtecsolution.fr

SIMTEC : Fundamentals

- French Numerical modelling consultancy
- Leader in France of the COMSOL Certified Consultants, key partner worldwide
- 7 members Eng.D. + Ph.D.
- Main partners:
  - big international companies
  - laboratories
- Involved in the Research projects like EU FP (SHARK, SisAl)/ PhD supervision

I. Background – Motivations – Objectives

- Collaboration with MARKEM-IMAJE
- Continuous Inkjet printing (CIJ) : high speed printing for marking and coding
- How does CIJ work?
  - ➢ High speed emission of droplets (≈ 100 kHz at ≈ 20 m/s)
  - ➢ Charge of particular droplets (≈ 1 pC)
  - ➢ Deflection of charged droplets in an electric field (≈ 1 kV/mm)
  - ➢ Impact of charged droplets on the printed support
- Goal : maximizing printing quality
- Printing quality depends on:
  - ➢ Breakoff quality at generation
  - ➢ Charge control
  - ➢ Deflection
  - ➢ Interactions during flight

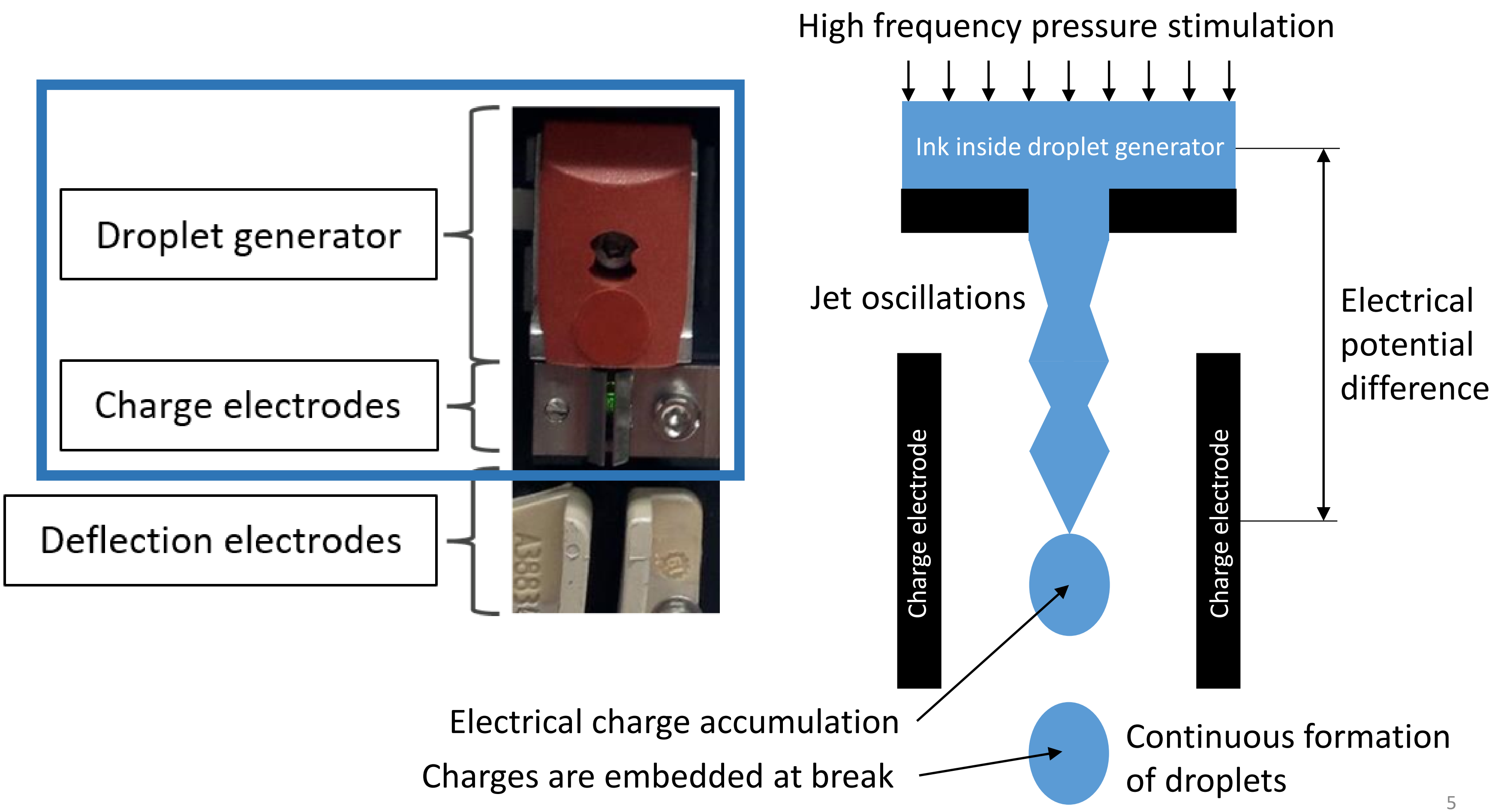


Schematic representation of a print head

Numerical tool to predict the shape of the droplets and the embedded charge

I. Background – Motivations – Objectives

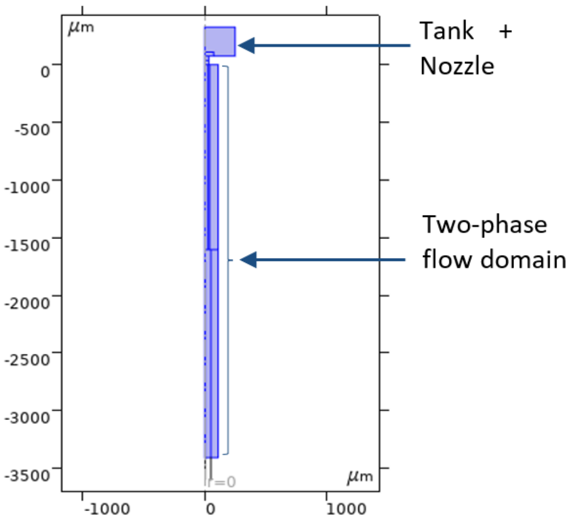
Focus on the droplet formation – charging process



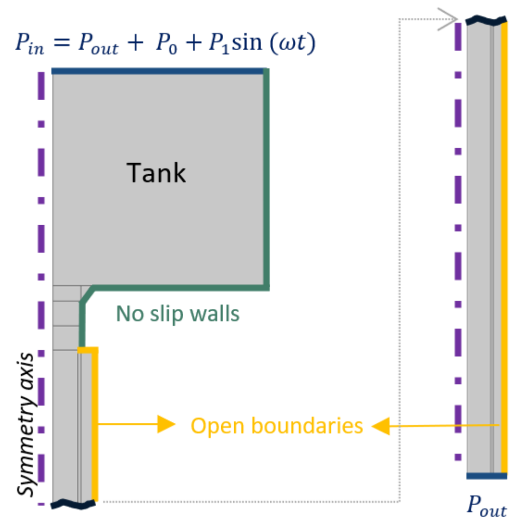
II. Modelling and Numerical Model

CFD model: droplet formation

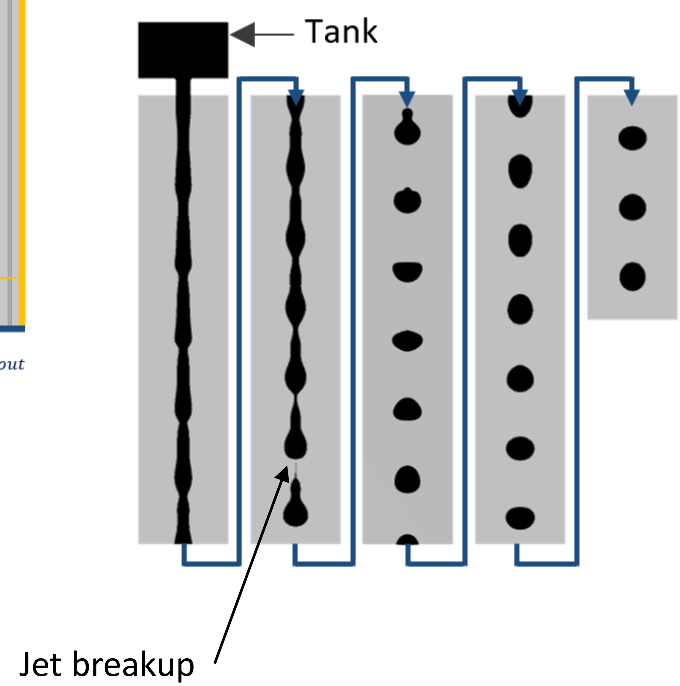
2D-axisymmetric geometry:



Boundary conditions:



→ After solved during ≈ 100 jet periods (periodic state is reached):



Governing equations:

- ➢ Incompressible Navier-Stokes
- ➢ Level-set: *ink* or *air*
- ➢ Including surface tension effects

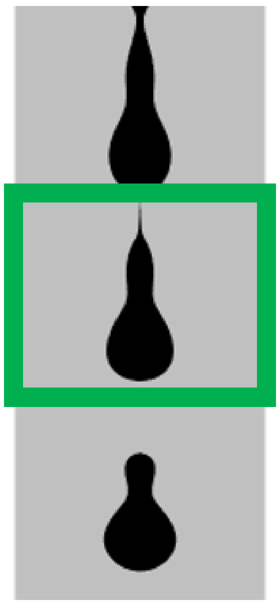
M. Rosello, «Études numérique et expérimentale de l'instabilité de Rayleigh-Plateau: Application aux jets d'encres,» Université Grenoble Alpes (ComUE), 2017.

II. Modelling and Numerical Model

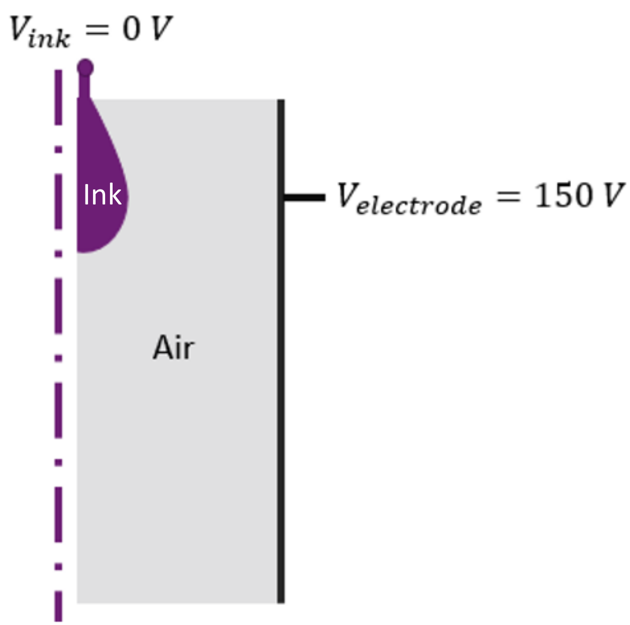
EC model: charge of a breaking droplet

Hypothesis: transient electrical effects are *instantaneous* compared to travelling time of droplets

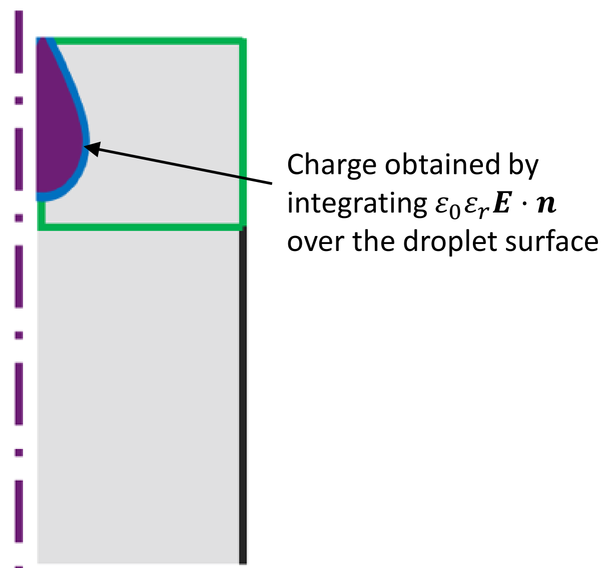
Breaking droplet:



2D-axisymmetric EC model:



Charge measurement:



Two-phase charge conservation equation

- Ink: conductor → $\sigma = 0{,}1\ \mathrm{S/m}$
- Air: insulator → $\sigma \approx 0$

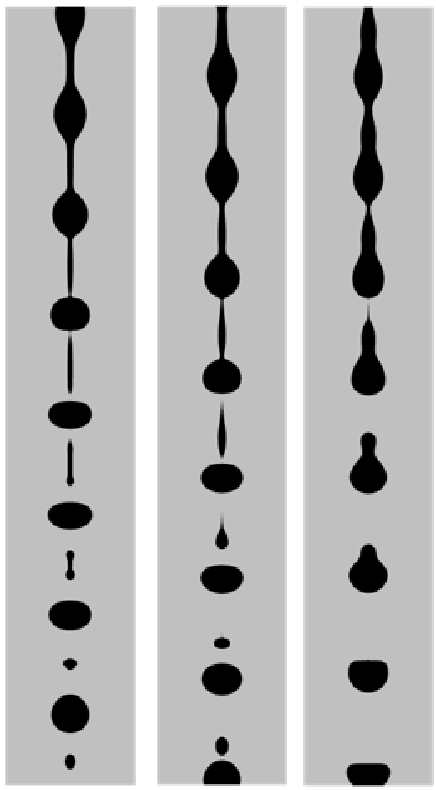
→ Integrating using δ: not accurate

→ Integrating over a surrounding box + divergence theorem: accurate!

III. Main Results

CFD results

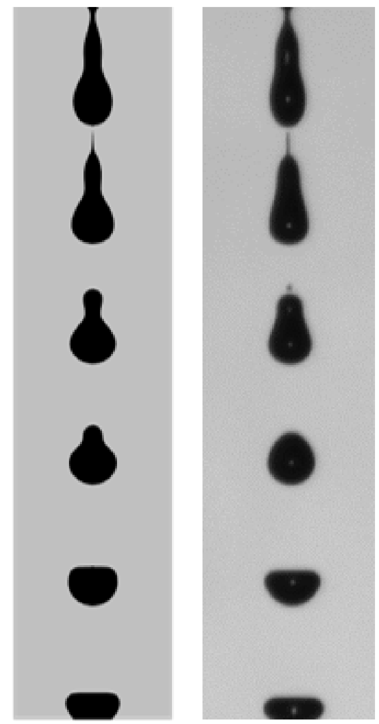
Jet/droplet shapes for multiple stimulation amplitudes



→ Large variety of droplet shapes at break

Model vs. experiment

Model *Exp.*

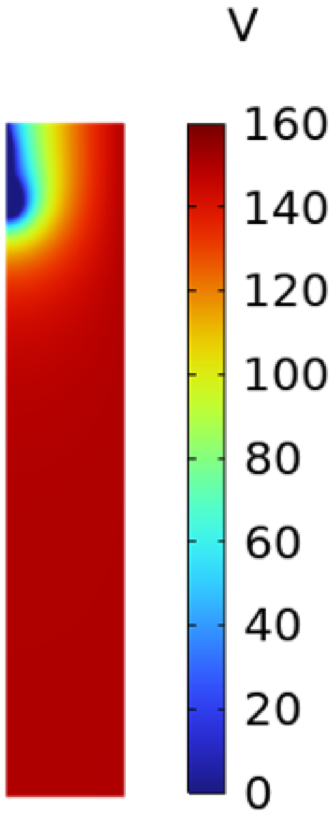


→ **Model and experimental shapes match pretty well ✓**

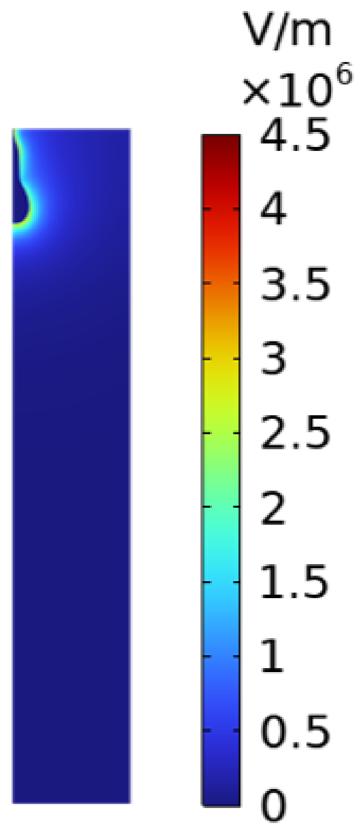
III. Main Results

EC results

Electric potential



Norm of the electric field



Prediction of the embedded charge

$$q = -1{,}248\ \text{pC}$$

→ **Right order of magnitude** ✓

Ink: homogeneous zero-potential

→ **Assimilating air as a *very bad* conductor is a good approach** ✓

IV. Conclusions - Perspectives

→ Ability to quantify and control the charge embedded by droplets is important to ensure printing quality in CIJ

→ **Major contribution :** proof of concept of numerical model to quantify the charge:

- 2D-axisymmetric two-phase flow → prediction of the shape of droplets at break
- 2D-axisymmetric electric field → prediction of the charge embedded at break

→ What about next steps?

- Application to the real geometry in 3D (electrodes are plates)
- History effects: study the impact of previous already charged droplets

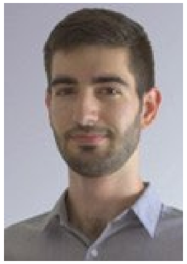
To finish…

Thank you!

Q&A?

Our question: What about a coffee to discuss your topic? ☺




Frédéric Viry
SIMTEC (+33) (0)9 53 51 45 60
frederic.viry@simtecsolution.fr

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