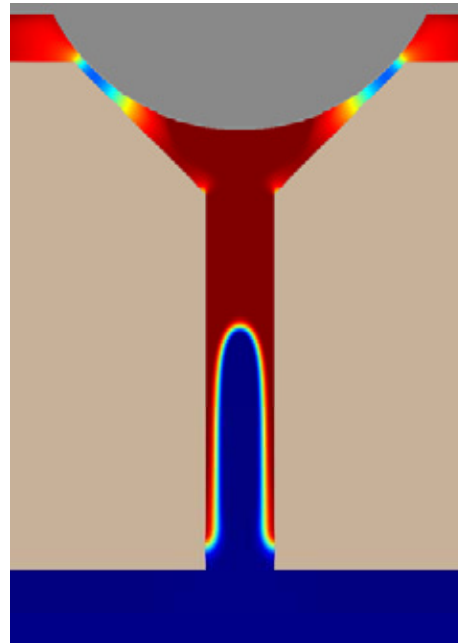Presented at the COMSOL Conference 2009 Milan

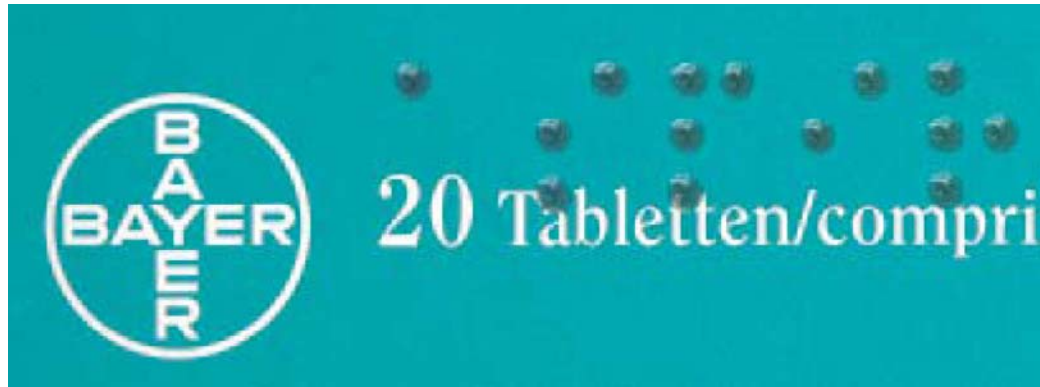# Multiphysics Modelling of a Micro Valve

Bern University of Applied Sciences

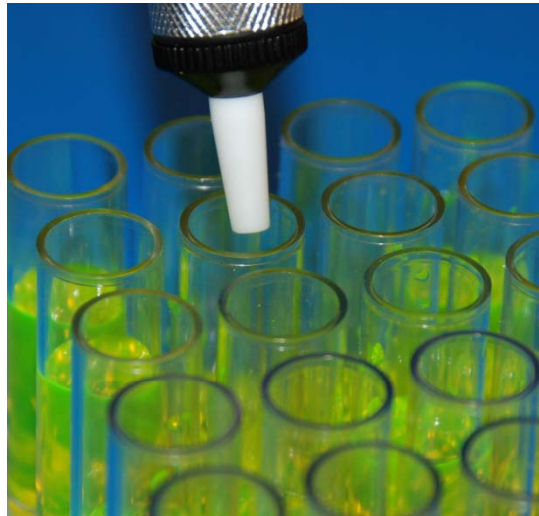Institute of Print Technology, Prof. Fritz Bircher

Philip Marmet

Content

- Introduction

- Modelling

- Results

- Conclusion

Applications
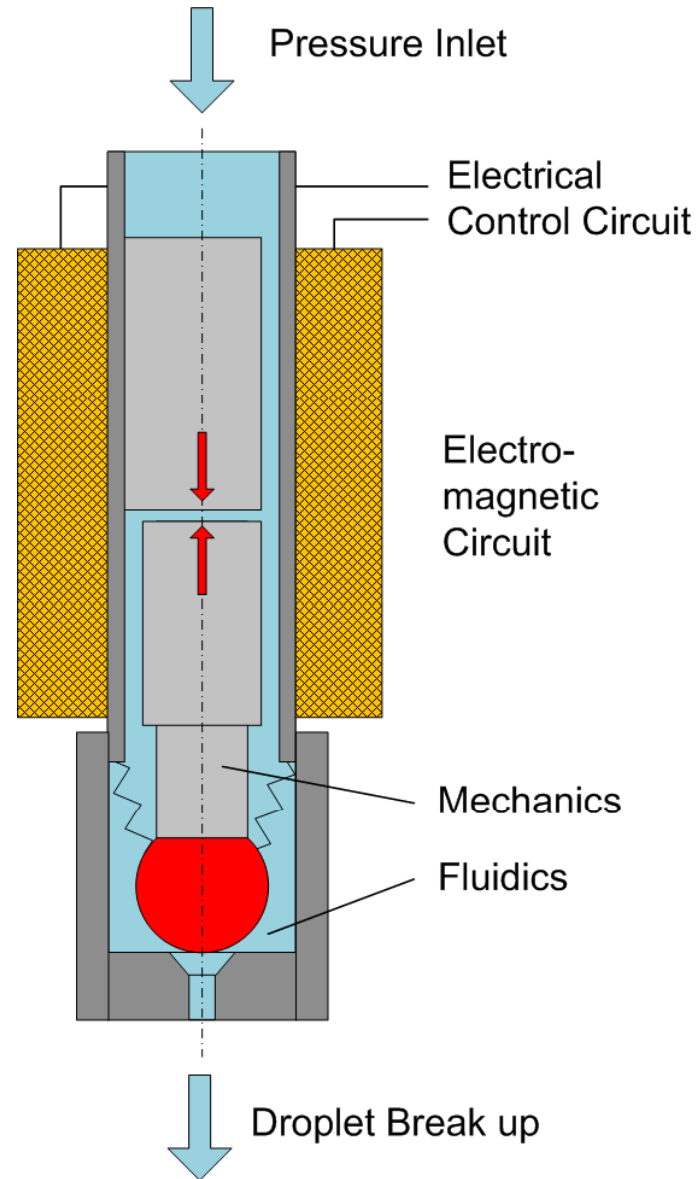
Introduction

Braille printing

Dispensing in chemistry

Objectives

- Understanding the processes

- Accelerate the development process

- Building up competence in multiphysics modelling

Introduction

Schematic buildup

Introduction

Pressure Inlet

Electrical Control Circuit

Electro-magnetic Circuit

Mechanics

Fluidics

Droplet Break up

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Modelling

Model Structure in Comsol Multiphysics

ODE
(Ordinary Differential Equations)

Electrical Subsystem

Voltage or Current Control

Mechanical Subsystem

Dynamic of the Plunger Motion

PDE
(Partial Differential Equations)

Electromagnetic Subsystem

Magnetic Force and Induction Currents

Fluidic Subsystem

Fluid Flow and Droplet Break up

Modelling

Model Structure in Comsol Multiphysics

ODE
(Ordinary Differential Equations)

Electrical Subsystem

Voltage or Current Control

Mechanical Subsystem

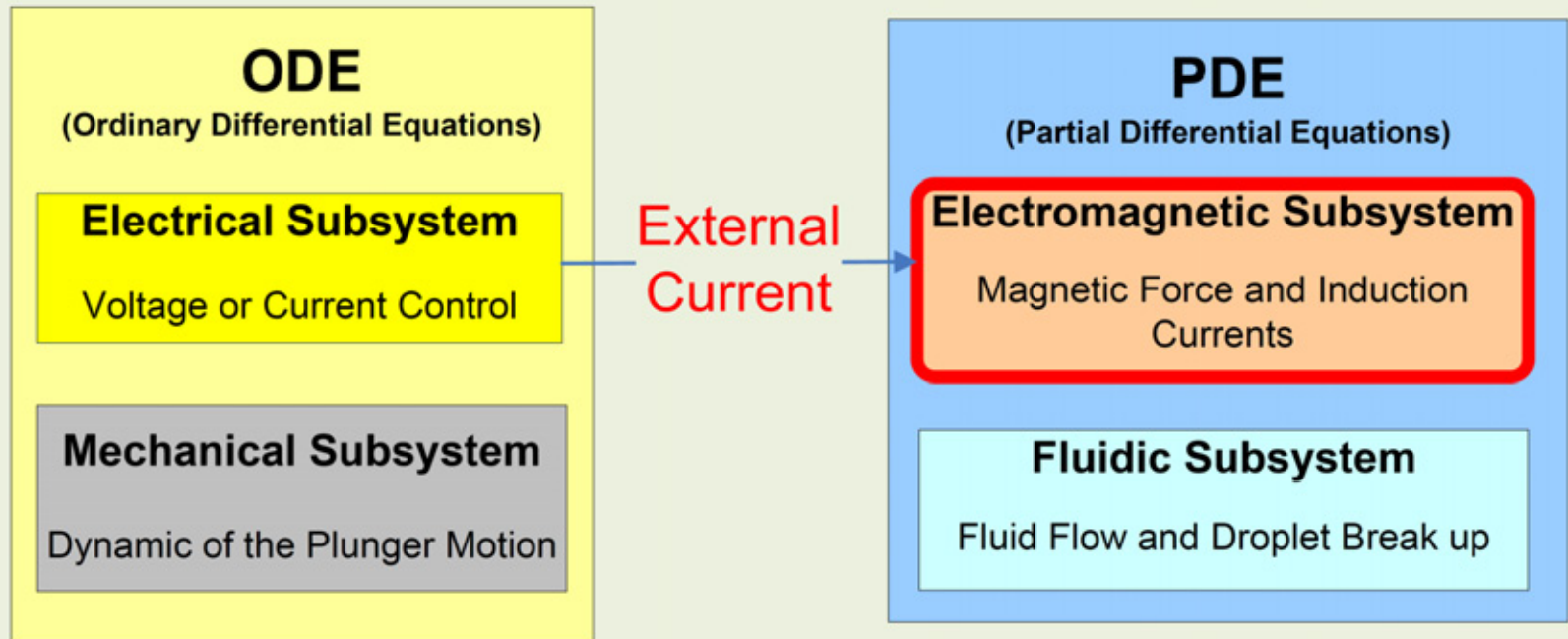Dynamic of the Plunger Motion

PDE
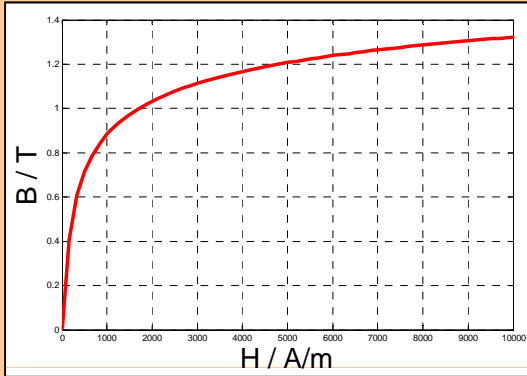**(Partial Differential Equations)**

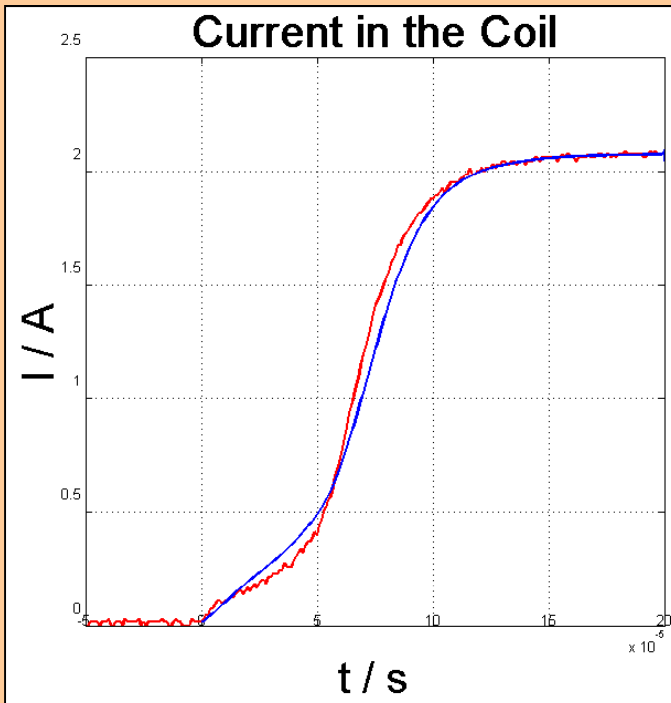### Electromagnetic Subsystem

Magnetic Force and Induction Currents

Fluidic Subsystem

Fluid Flow and Droplet Break up

Modelling

Model Structure in Comsol Multiphysics

ODE
(Ordinary Differential Equations)

Electrical Subsystem

Voltage or Current Control

Mechanical Subsystem

Dynamic of the Plunger Motion

External Current

PDE
(Partial Differential Equations)

Electromagnetic Subsystem

Magnetic Force and Induction Currents

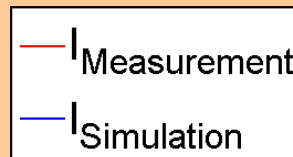**Fluidic Subsystem**

Fluid Flow and Droplet Break up

Modelling

Nonlinear Magnetic Material

B=f(H)

Induction Currents

Current in the Coil

$I_{Measurement}$

$I_{Simulation}$

PDE
(tial Differential Equations)

Electromagnetic Subsystem

Magnetic Force and Induction Currents

uidic Subsystem

low and Droplet Break up

Modelling

Model Structure in Comsol Multiphysics

ODE
(Ordinary Differential Equations)

Electrical Subsystem

Voltage or Current Control

Mechanical Subsystem

Dynamic of the Plunger Motion

External Current →

PDE
(Partial Differential Equations)

Electromagnetic Subsystem

Magnetic Force and Induction Currents

Fluidic Subsystem

Fluid Flow and Droplet Break up

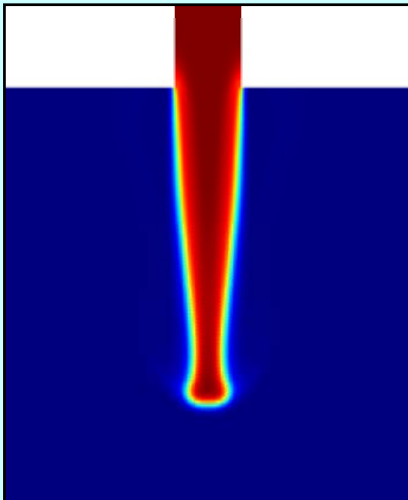**Modelling**

0.8 m/s

0 m/s
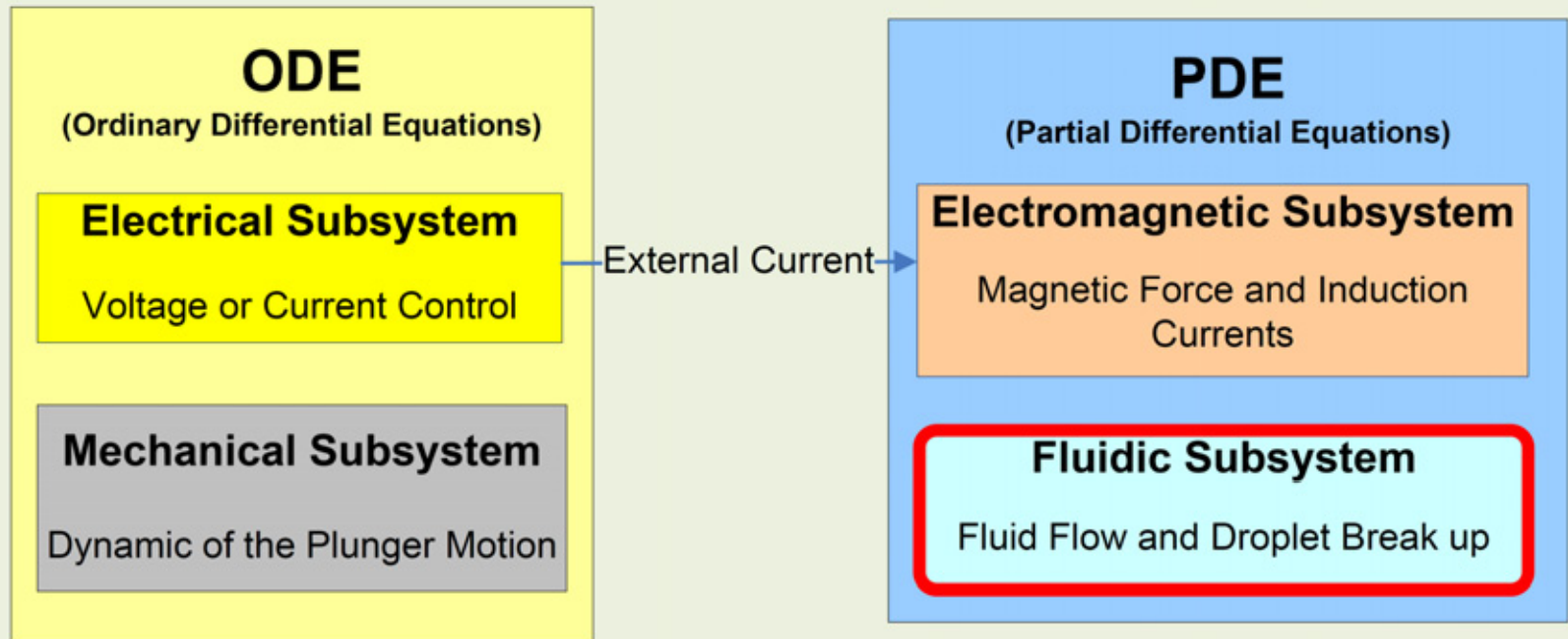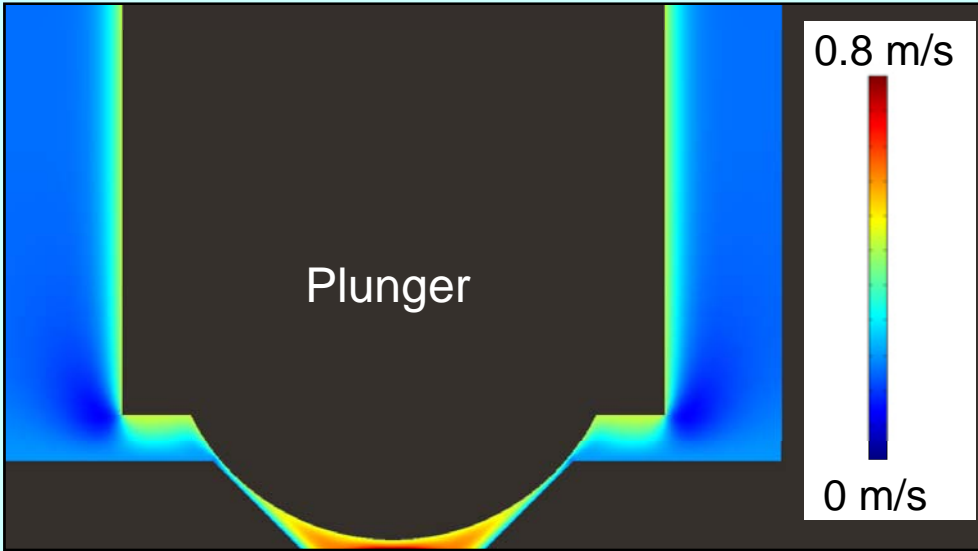
Velocity

Plunger movement

- Velocity: Moving Wall

- Displacement: Moving Mesh (ALE)

Plunger
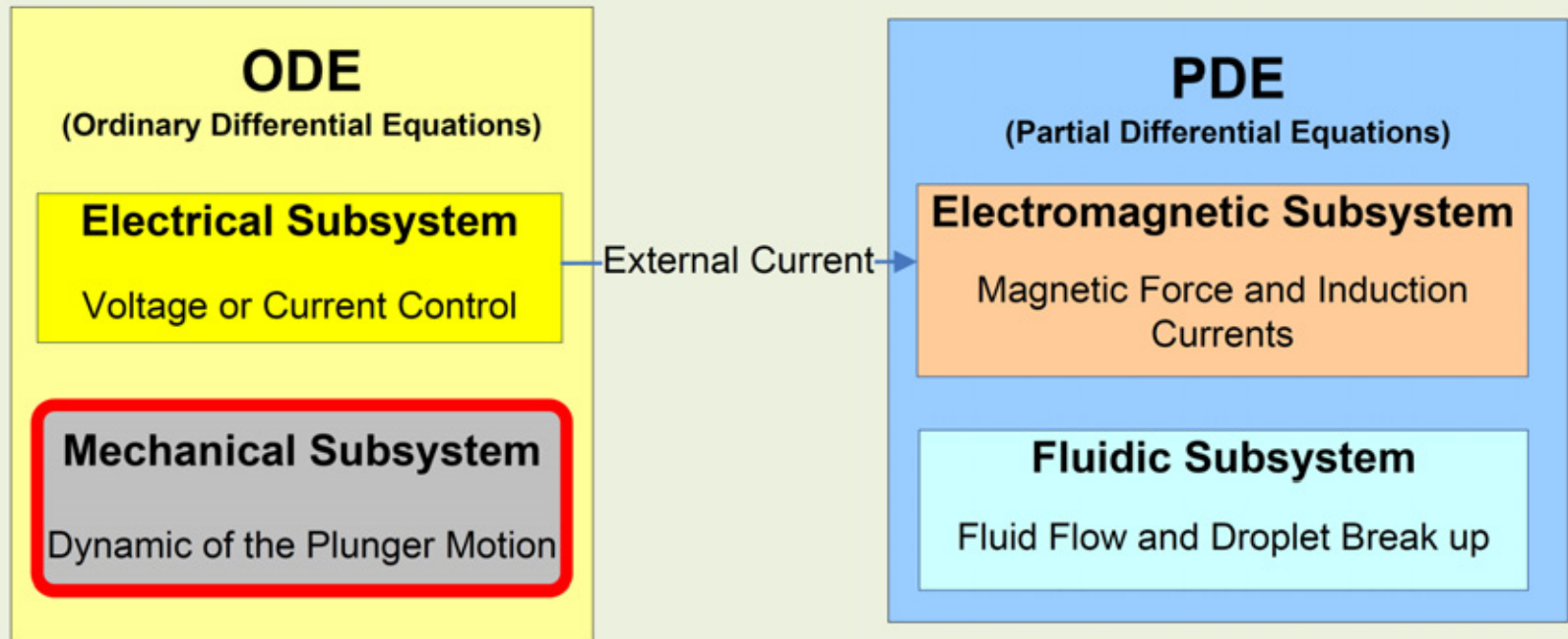
- Two-Phase Flow

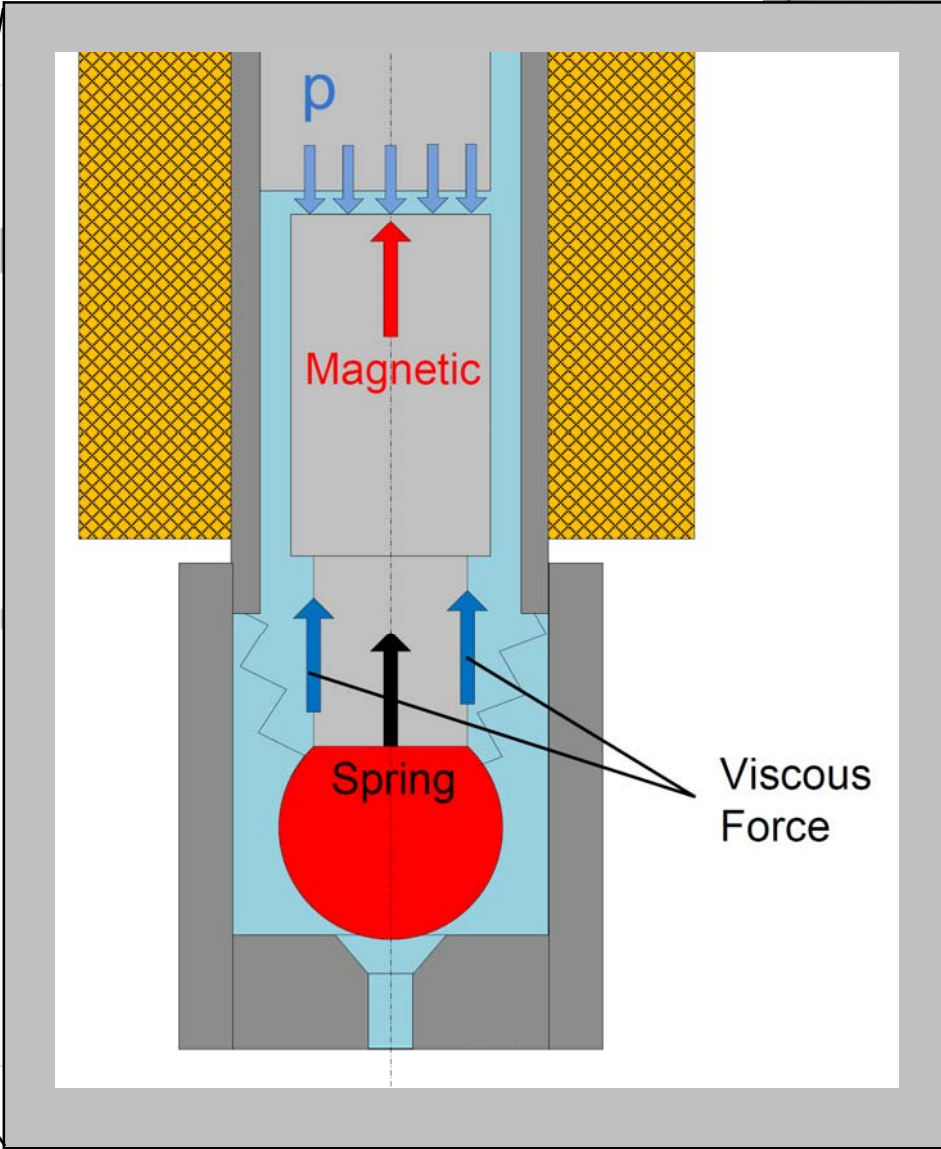- Surface Tension Force
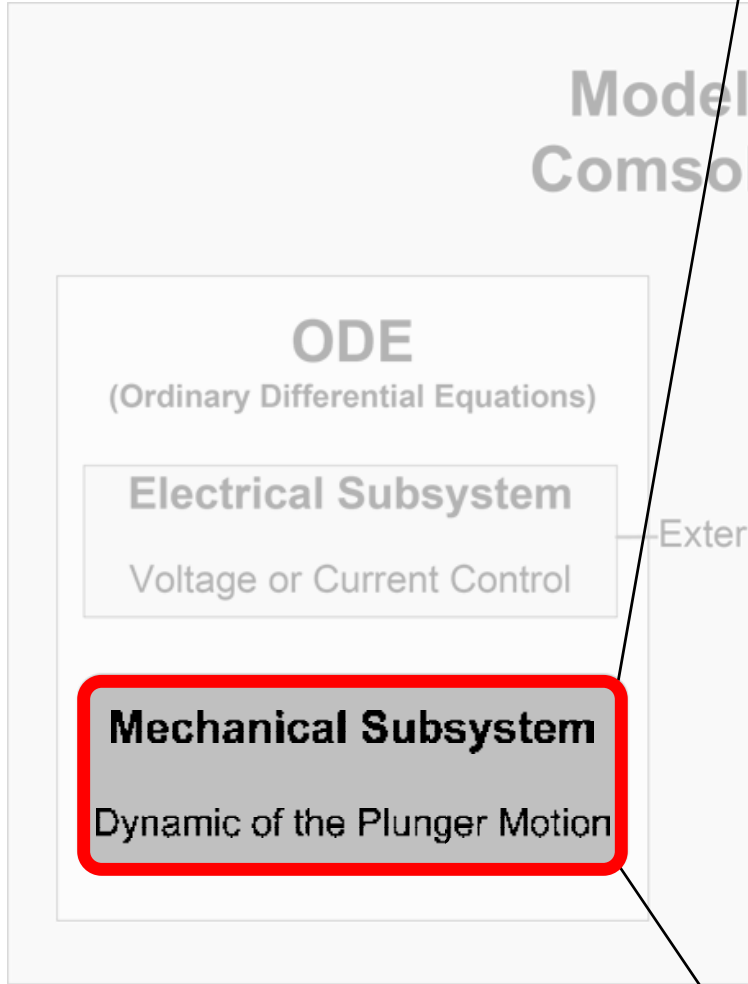
- Droplet Break up

Fluidic Subsystem
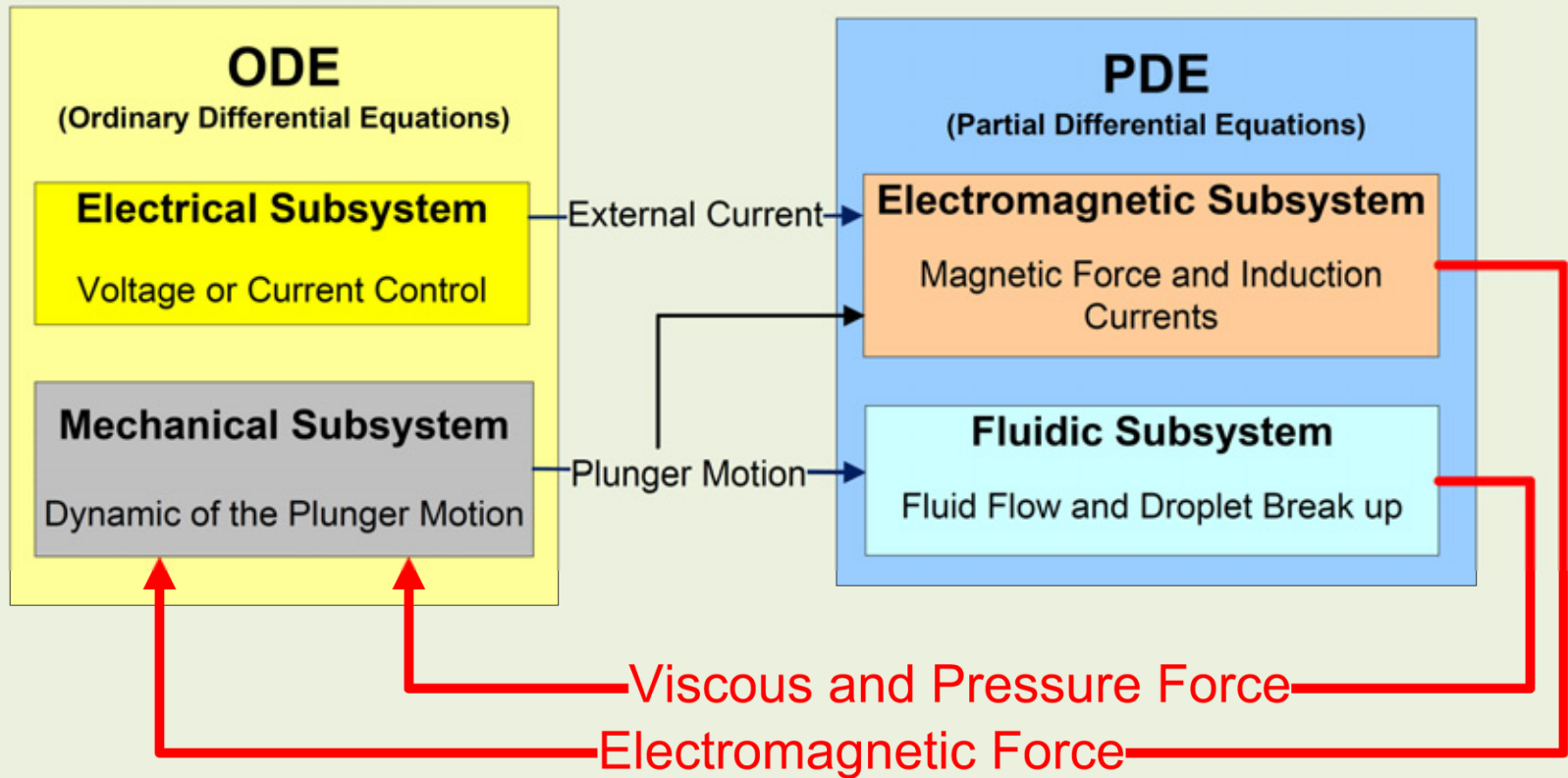
Fluid Flow and Droplet Break up

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Modelling

Model Structure in Comsol Multiphysics

ODE
(Ordinary Differential Equations)

Electrical Subsystem

Voltage or Current Control

Mechanical Subsystem

Dynamic of the Plunger Motion

External Current →

PDE
(Partial Differential Equations)

Electromagnetic Subsystem

Magnetic Force and Induction Currents

Fluidic Subsystem

Fluid Flow and Droplet Break up

Modelling

Model
Comsol

ODE
(Ordinary Differential Equations)

Electrical Subsystem

Voltage or Current Control

—Exter

Mechanical Subsystem

Dynamic of the Plunger Motion

p

Magnetic

Spring

Viscous Force

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Modelling

Modelling

Model Structure in Comsol Multiphysics

ODE
(Ordinary Differential Equations)

PDE
(Partial Differential Equations)

Electrical Subsystem

Voltage or Current Control

—External Current→

Electromagnetic Subsystem

Magnetic Force and Induction Currents

Mechanical Subsystem

Dynamic of the Plunger Motion

Plunger Motion

Fluidic Subsystem

Fluid Flow and Droplet Break up

——Viscous and Pressure Force——

——Electromagnetic Force——

Electromagnetics

Results

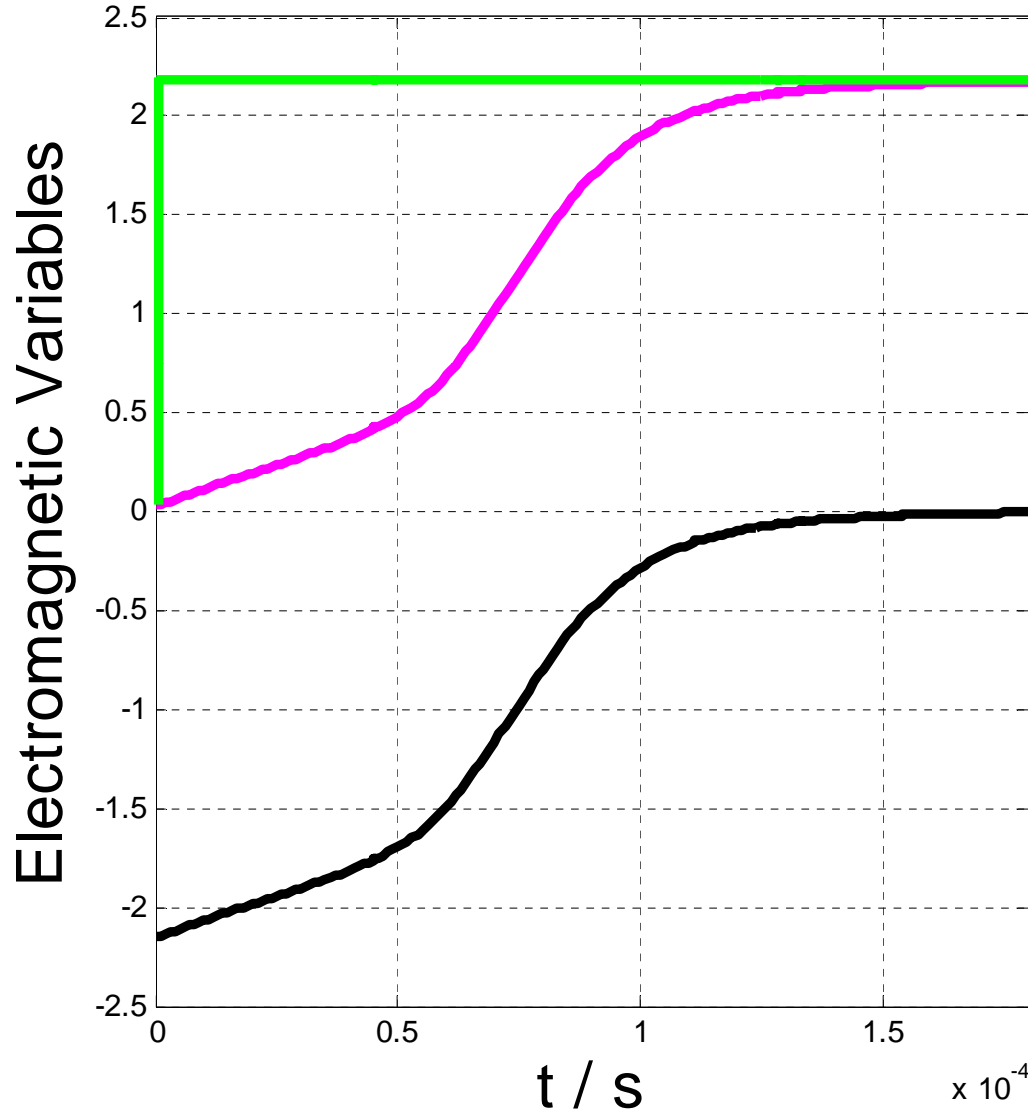**Magnetic Flux Density [T]**
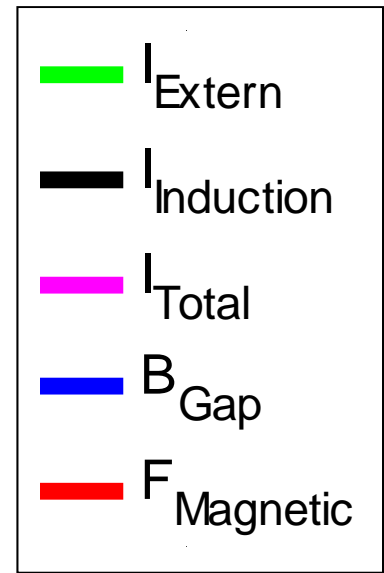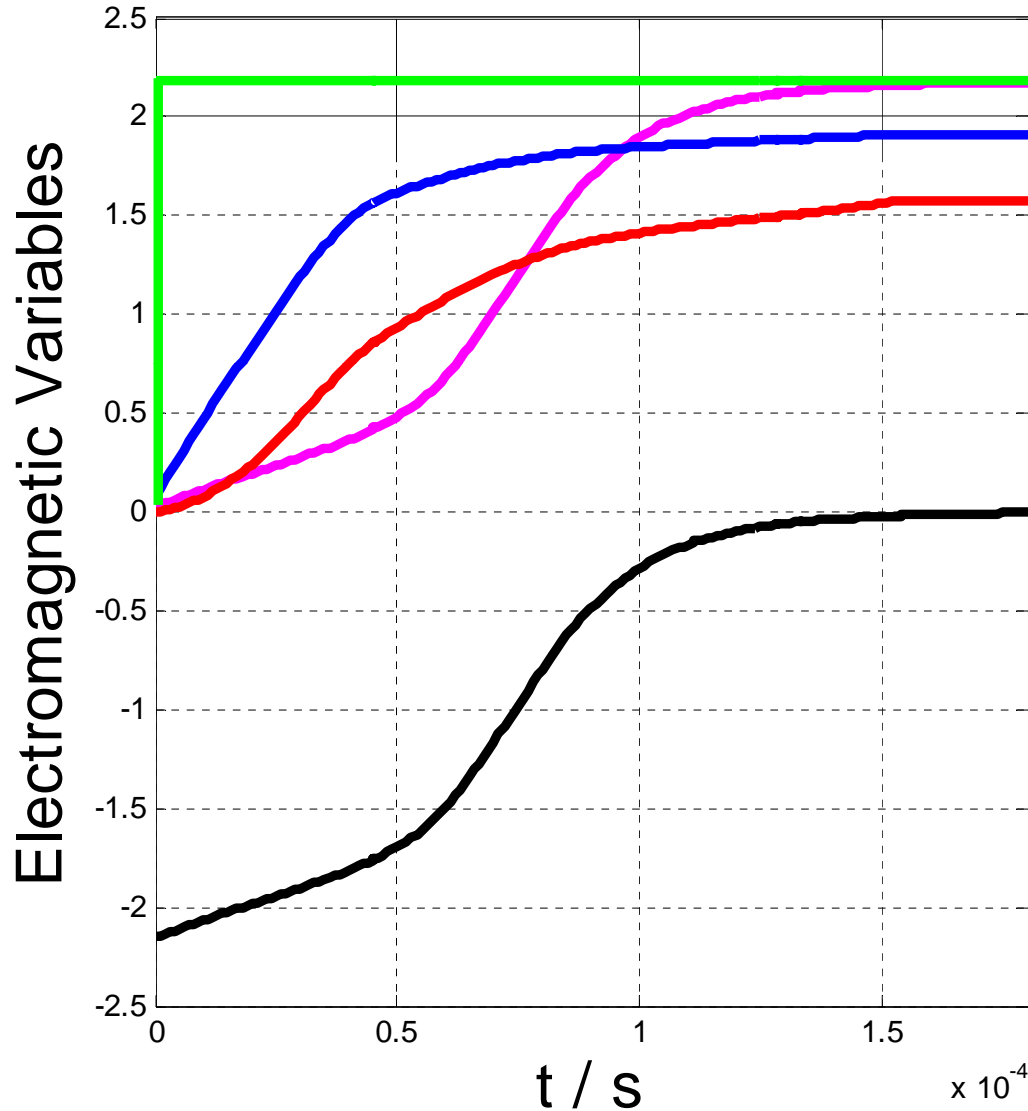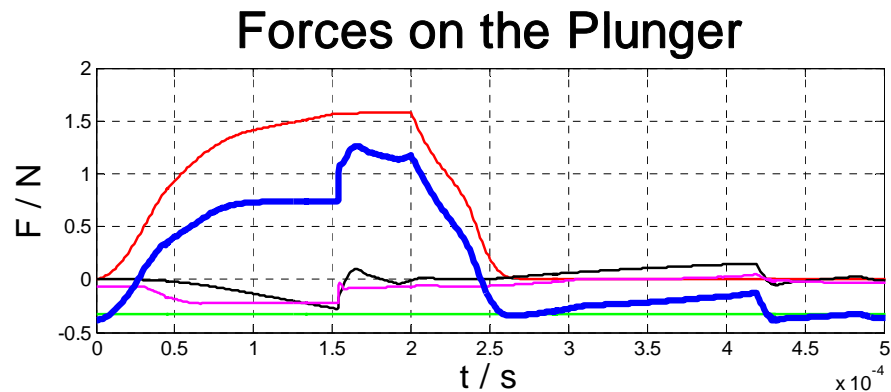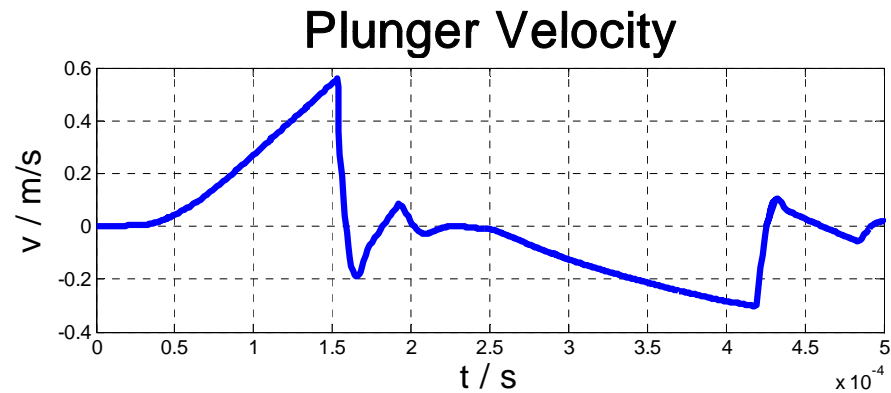
Air Gap

Moving Plunger
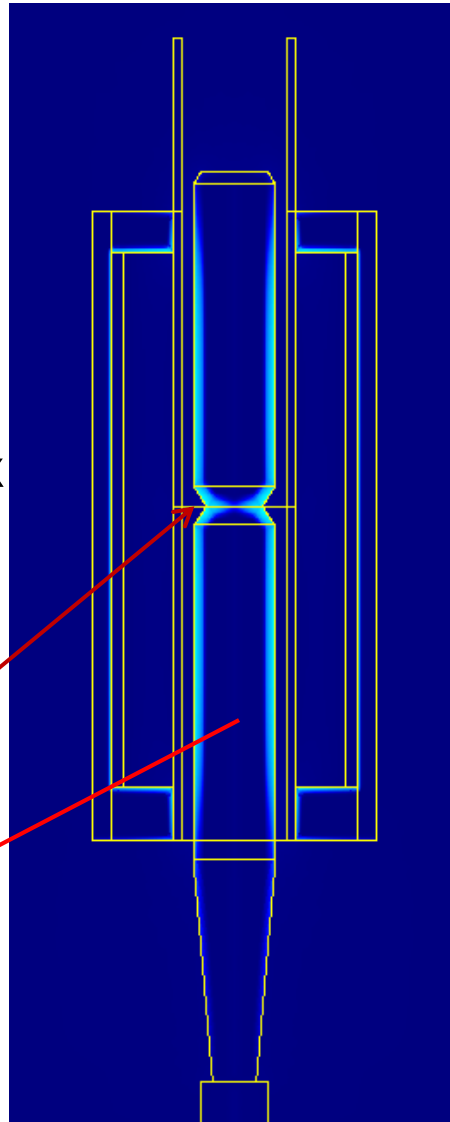
Induced Current Density [A/m²]

Coil

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Electromagnetic Subsystem
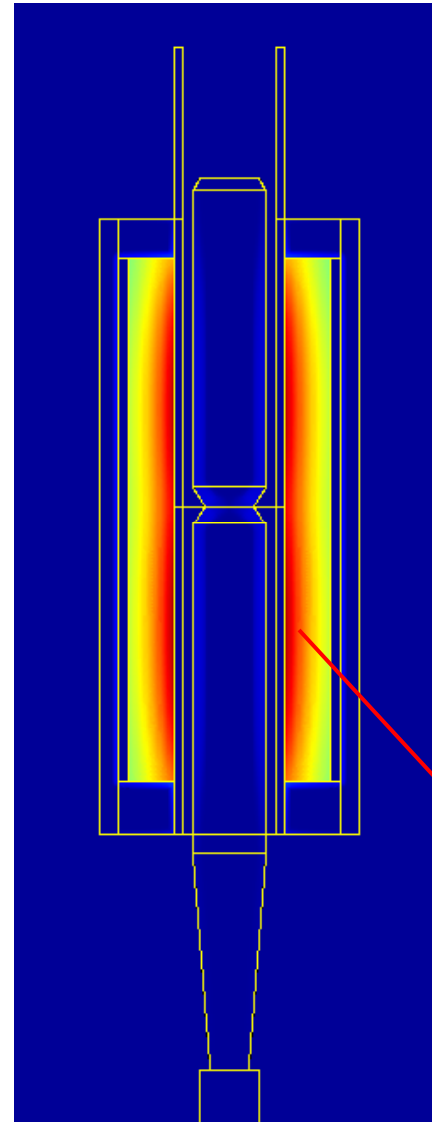
Results

Results

Electromagnetic Subsystem

Legend:
- I_{Extern}
- $I_{Induction}$
- I_{Total}
- B_{Gap}
- $F_{Magnetic}$

Electromagnetic Variables vs t / s ($\times 10^{-4}$)

Mechanic Subsystem

Results

Plunger Position

Plunger Velocity

Forces on the Plunger

Legend:
- $F_{Magnetic}$
- $F_{Viscous\ Stress}$
- $F_{Pressure}$
- F_{Spring}
- $F_{Plunger}$

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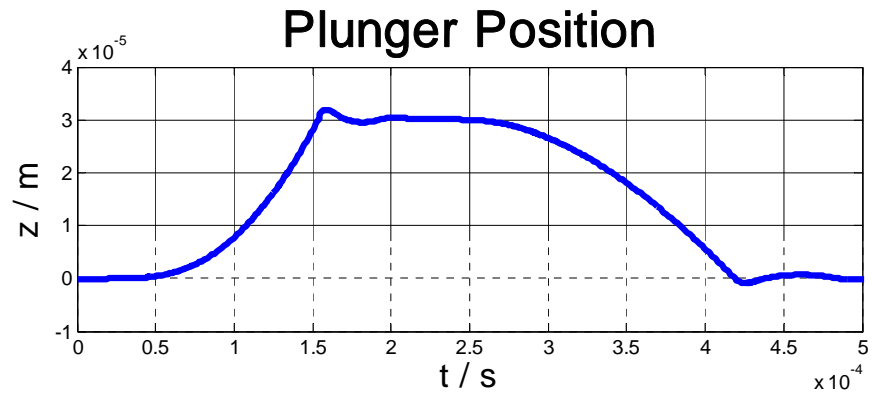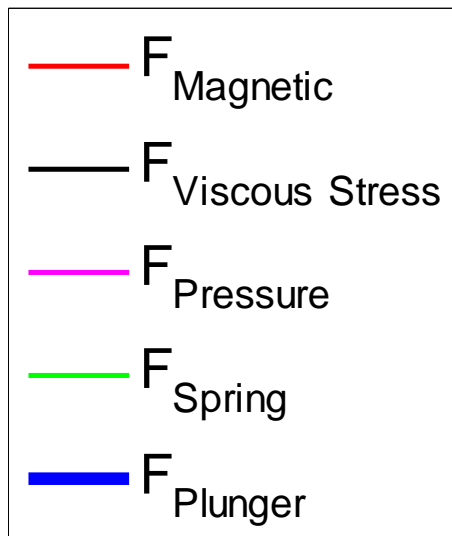
Fluid in the nozzle
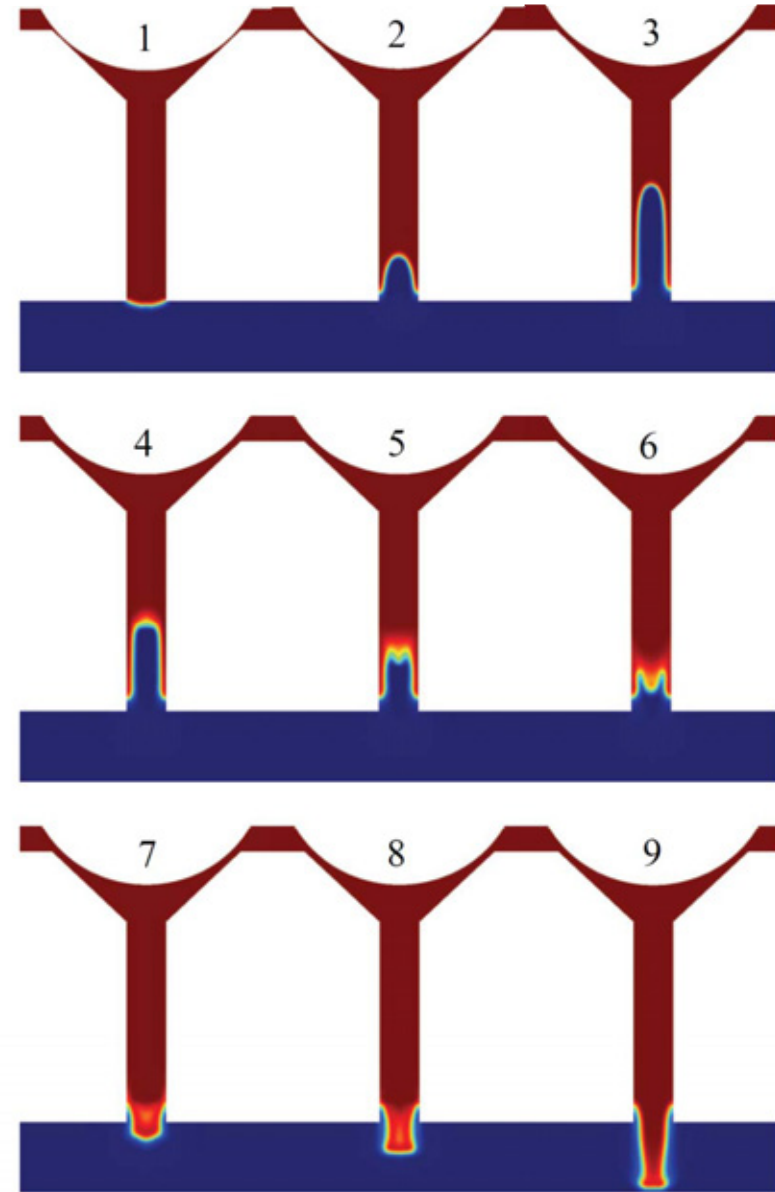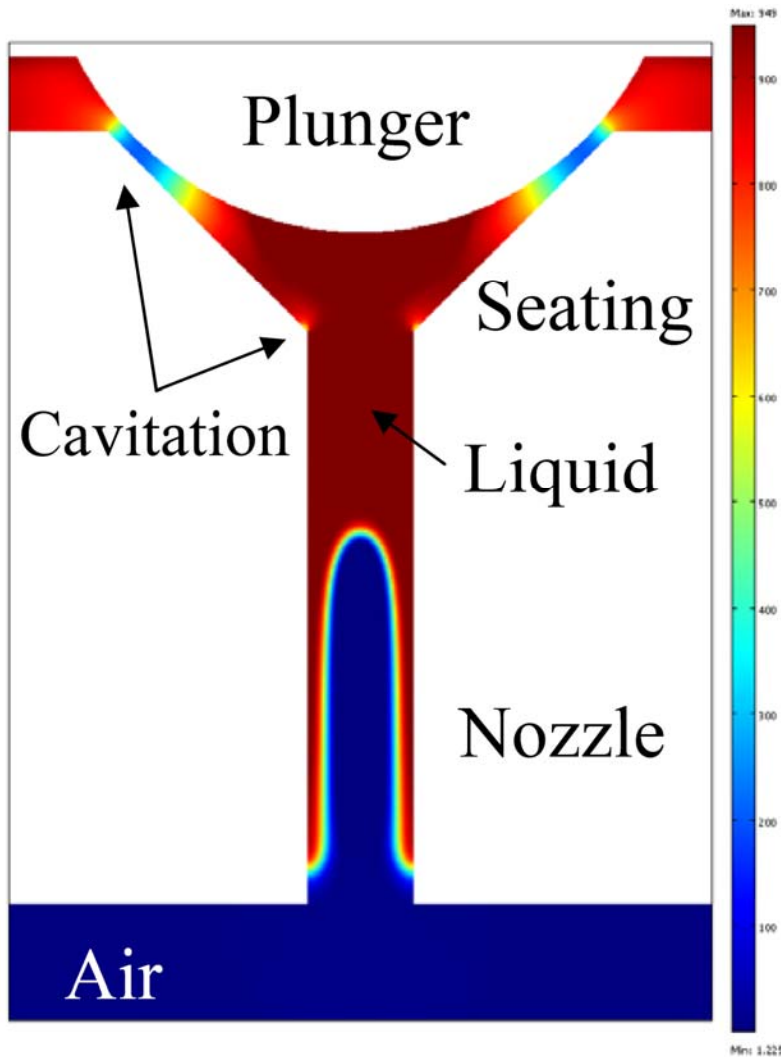
Results

Highspeed recording
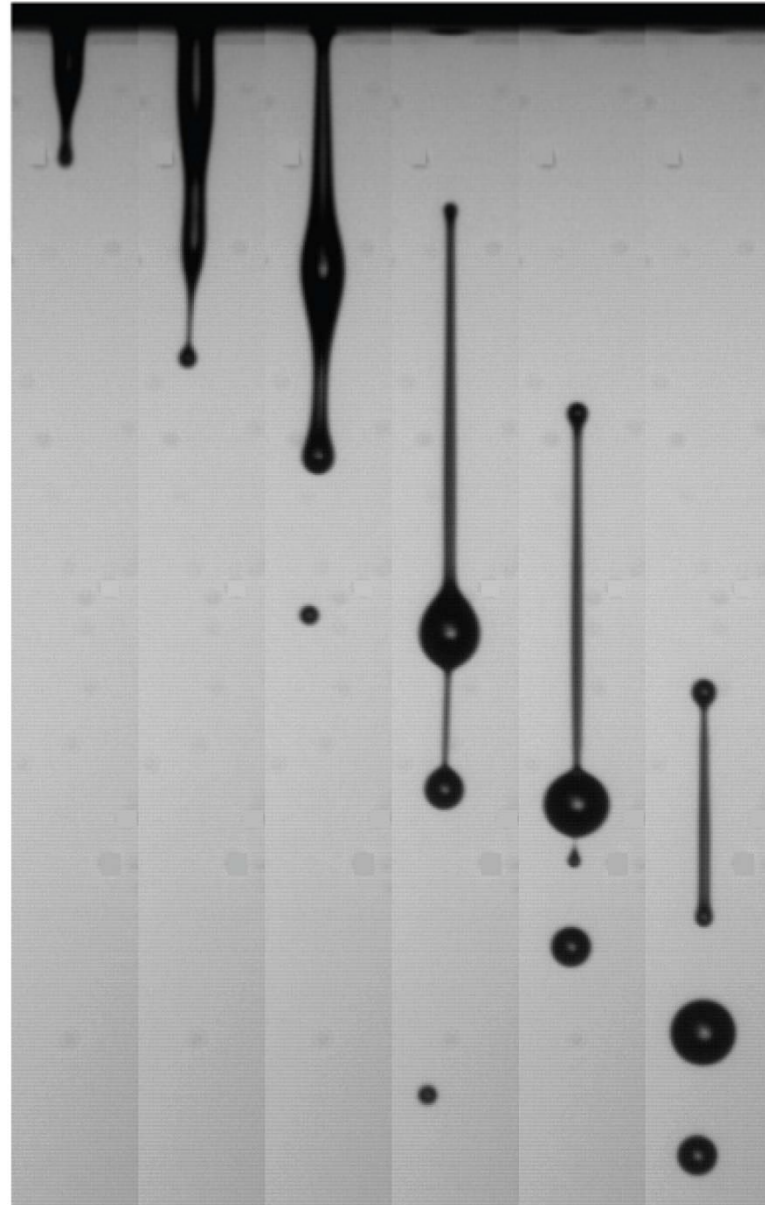
Results

Conclusion

Conclusion

- Thorough understanding of the physics involved

- Competence in multiphysics modelling

  - Interdependency of the subsystems is fundamental

- Development process

  - Flexible implementation of the entire system in Comsol Multiphysics

Thank you!

Philip Marmet

www.printtechnology.ch

Bern University of Applied Sciences
Institute of Print Technology, Prof. Fritz Bircher