Particle Control

Innovation of Combustion Particle Control Technologies Assisted by Numerical Modelling

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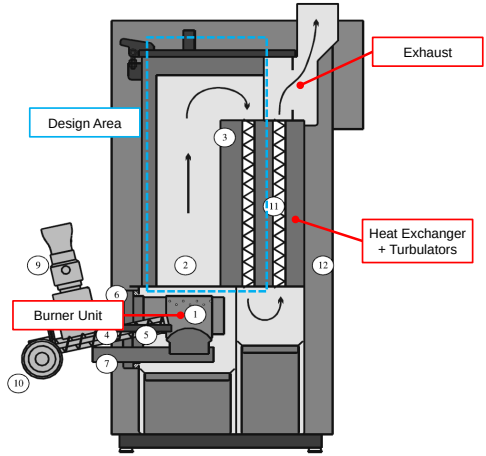
Introduction

Industrial Relevance

- Cleaning of exhaust gases
- Promote renewable energy sources
- Electric filter producer *OekoSolve*

Introduction

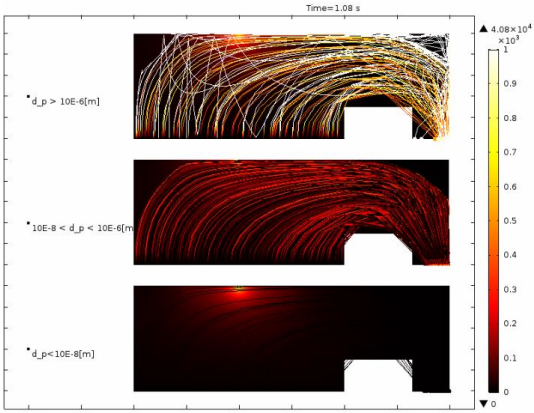
Pellet Burner



from: Liebi LNC LPK Pellet Burner Technical Documentation, 30.08.2011, www.liebilnc.ch

Particle Trajectories

Entire study overview and topic definition



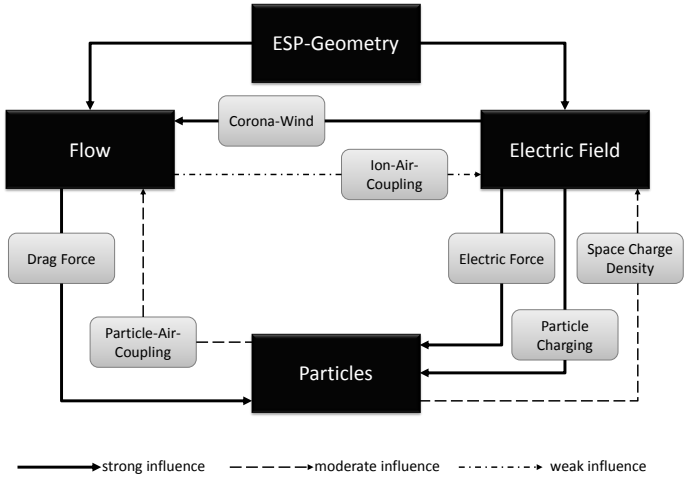
Color legend:particle charges in number of elementary charges

Features

1. CFD
2. Electrostatics
3. Particle charging processes
4. Particle deposition study
5. Geometry variations
6. Parameter variations
7. ...

Here: Focus on improving air ionization processes

Coupled Physics



Physical Model

Electrostatics governing equations

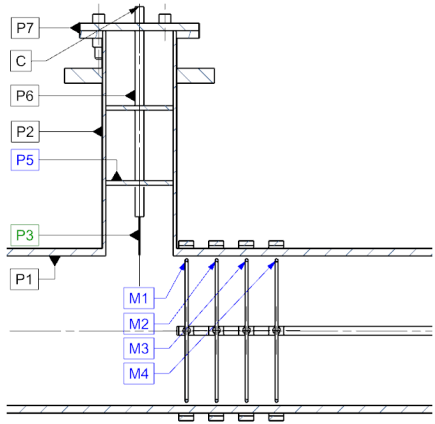
$$\nabla^2 \phi = -\frac{\rho_{el}}{\varepsilon_0} \tag{1}$$

$$\boldsymbol{E} \nabla \rho_{el} = -\frac{{\rho_{el}}^2}{\varepsilon_0} \tag{2}$$

ϕ electric potential
ρ_{el} space charge density
ε_0 vacuum permittivity
$\boldsymbol{E}$ electrical field

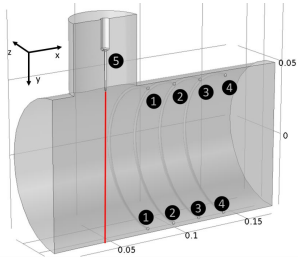
Numerical Model

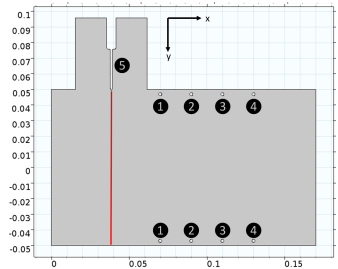
Laboratory test rig



Numerical Model

COMSOL implementation



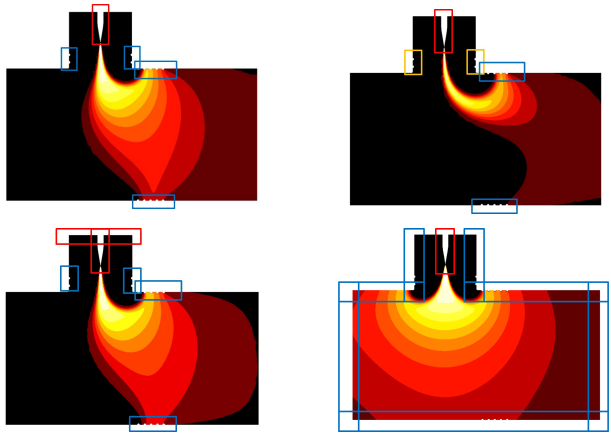


units in m

Boundary	Part	2D	3D
1	Ring 1	ground	ground
2	Ring 2	ground	ground
3	Ring 3	ground	ground
4	Ring 4	ground	ground
5	Electrode	voltage & charge	voltage & charge

Numerical Model

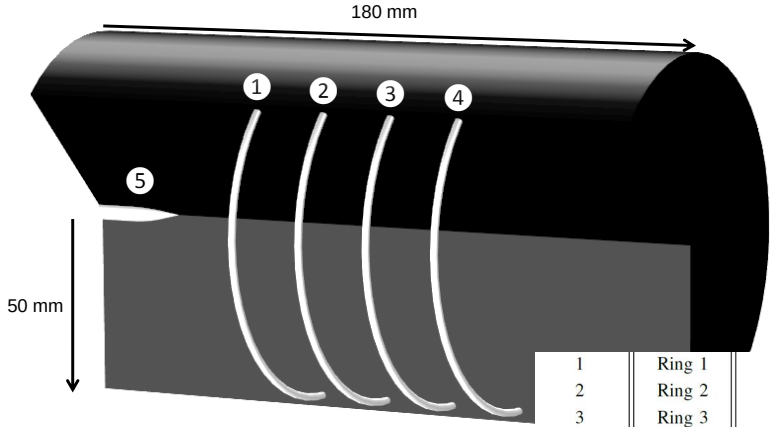
2D results - charge density distribution comparison



blue: ground / red: -20kV / orange: -5kV

Validation Model

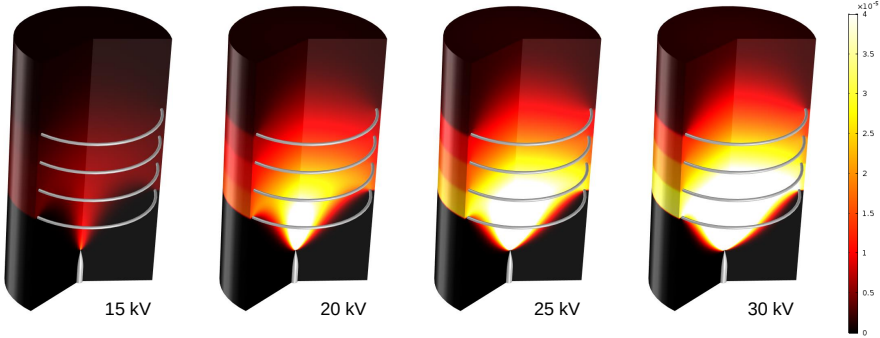
2D axissymmetric geometry



1	Ring 1	ground
2	Ring 2	ground
3	Ring 3	ground
4	Ring 4	ground
5	Electrode	voltage & charge

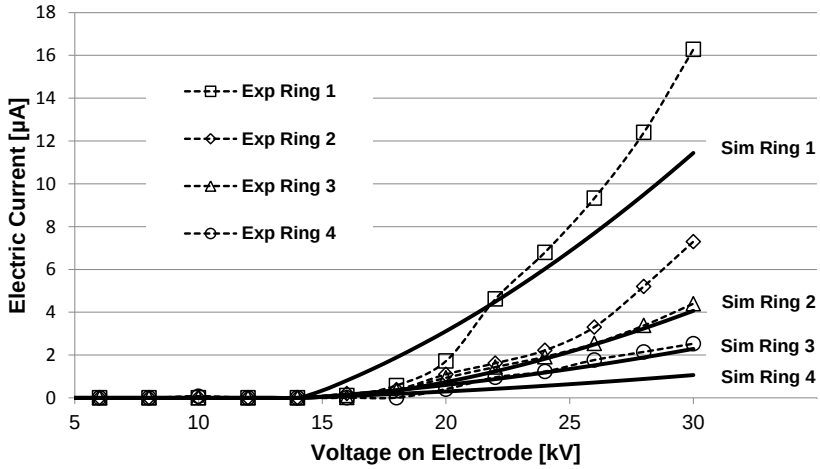
Validation Model

Results - comparison of space charge density $[C/m^3]$



Validation Model

Comparison with test rig data



Summary

Discussion

- 2D model → qualitatively appropiate
- 3D model → not practicable
- 2D axissymmetric model → trade-off

Achievements

- Model conceived, tested and applied
- Successfully assist measurements and ongoing R&D

Conclusion & Outlook

- From test-case to industrially relevant model → demonstrates the power of multiphysics modelling for innovation purposes
- Further investigation and improvement guidance

Thank you for your attention!

Fruitful discussions with

- Beat Müller
- Trpimir Brzovic
- Daniel Jud

from OekoSolve AG are gratefully acknowledged. Further thanks to the Swiss *Commission for Technology and Innovation*.

Modelling Objective

Physical understanding

- Deep understanding of the occurring effects
- Spot relevant factors for optimization

Assisting empirical work

- Compare simulation results and experimental data
- Guidance on measurement approaches

Predictive purposes

- Accelerate further R & D
- Feasability and performance studies

Appendix

Corona Onset Field Strength

$$E_0 = 3 \times 10^6 f_r \left(m_s + 0.03 \sqrt{\frac{m_s}{\frac{d_e}{2}}} \right) \tag{3}$$

$$m_s = \frac{p}{p_{ref}} \frac{T_{ref}}{T} \tag{4}$$

Appendix

Particle Charging Processes

Diffusion Charging

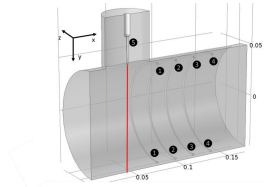
$$q_d(t) = \frac{2\pi\varepsilon_0 k T d_p}{e} ln\left(1 + \frac{t}{\tau_d}\right) \tag{5}$$

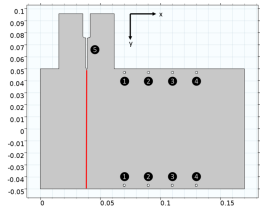
Field Charging

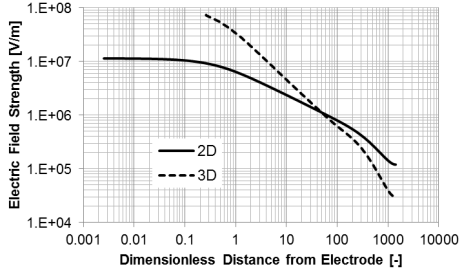
$$q_f(t) = \left(\frac{3\varepsilon}{\varepsilon + 2}\right)\pi\varepsilon_0 E {d_p}^2 \frac{t}{t + \tau_f} \tag{6}$$

Appendix

2D/3D comparison - Electrical field strength magnitude

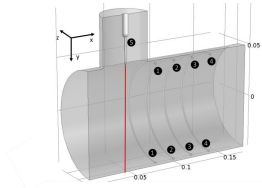


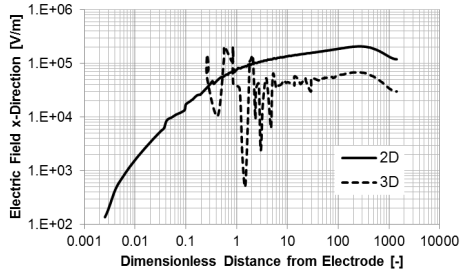




Appendix

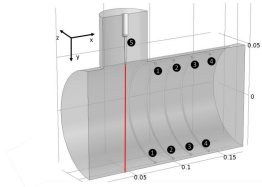
2D/3D comparison - Electrical field strength x-direction

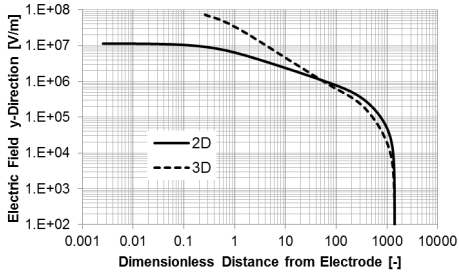




Appendix

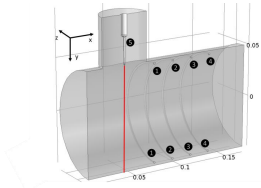
2D/3D comparison - Electrical field strength y-direction

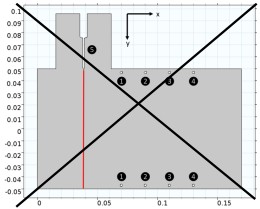


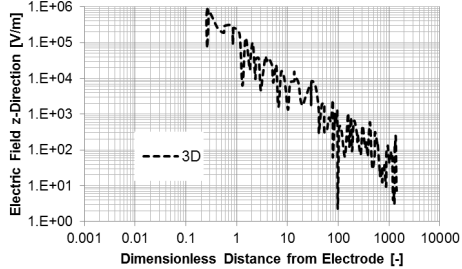


Appendix

2D/3D comparison - Electrical field strength z-direction

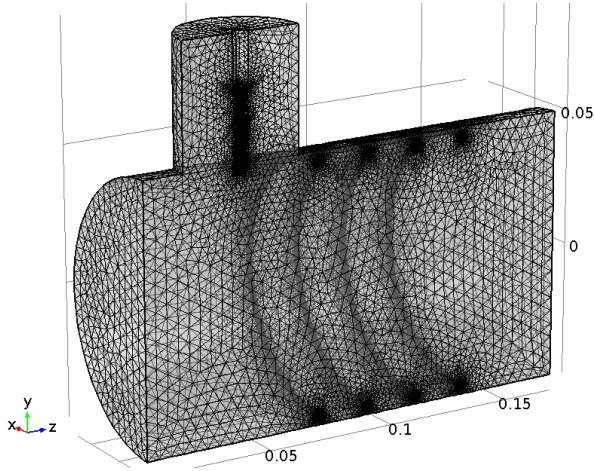






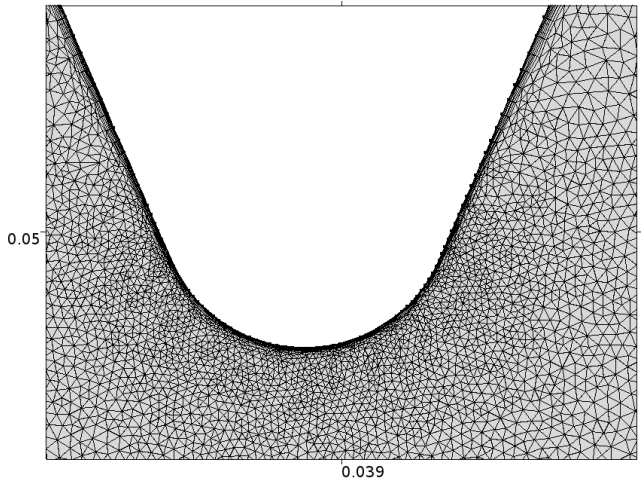
Appendix

Mesh 3D



Appendix

Mesh 2D



Appendix

Mesh 2D axisymmetric