Modeling and simulation of a pressure filtration process based on VDI guideline 2762

FILTECH, The Filtration Event 2018, March 13 – 15, Cologne, Germany

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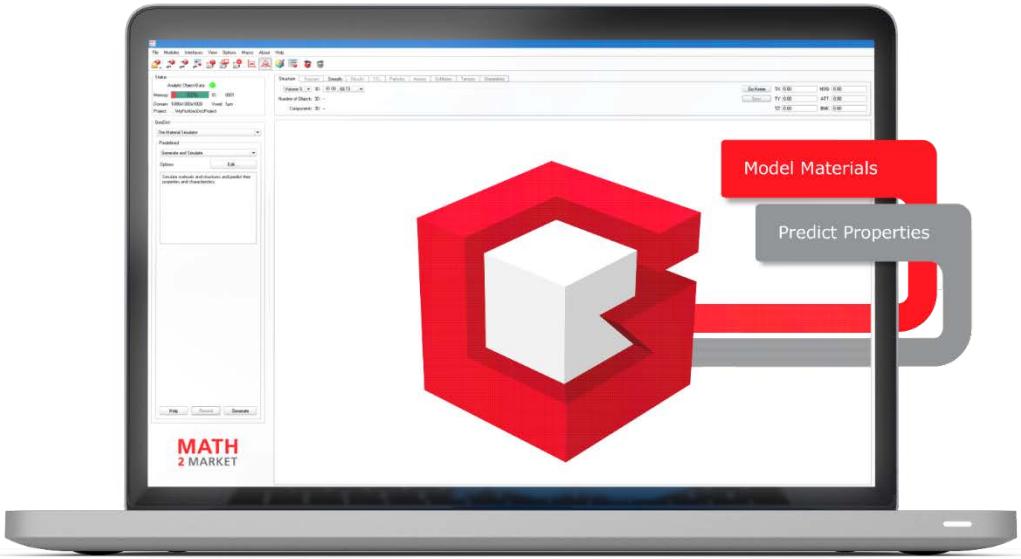
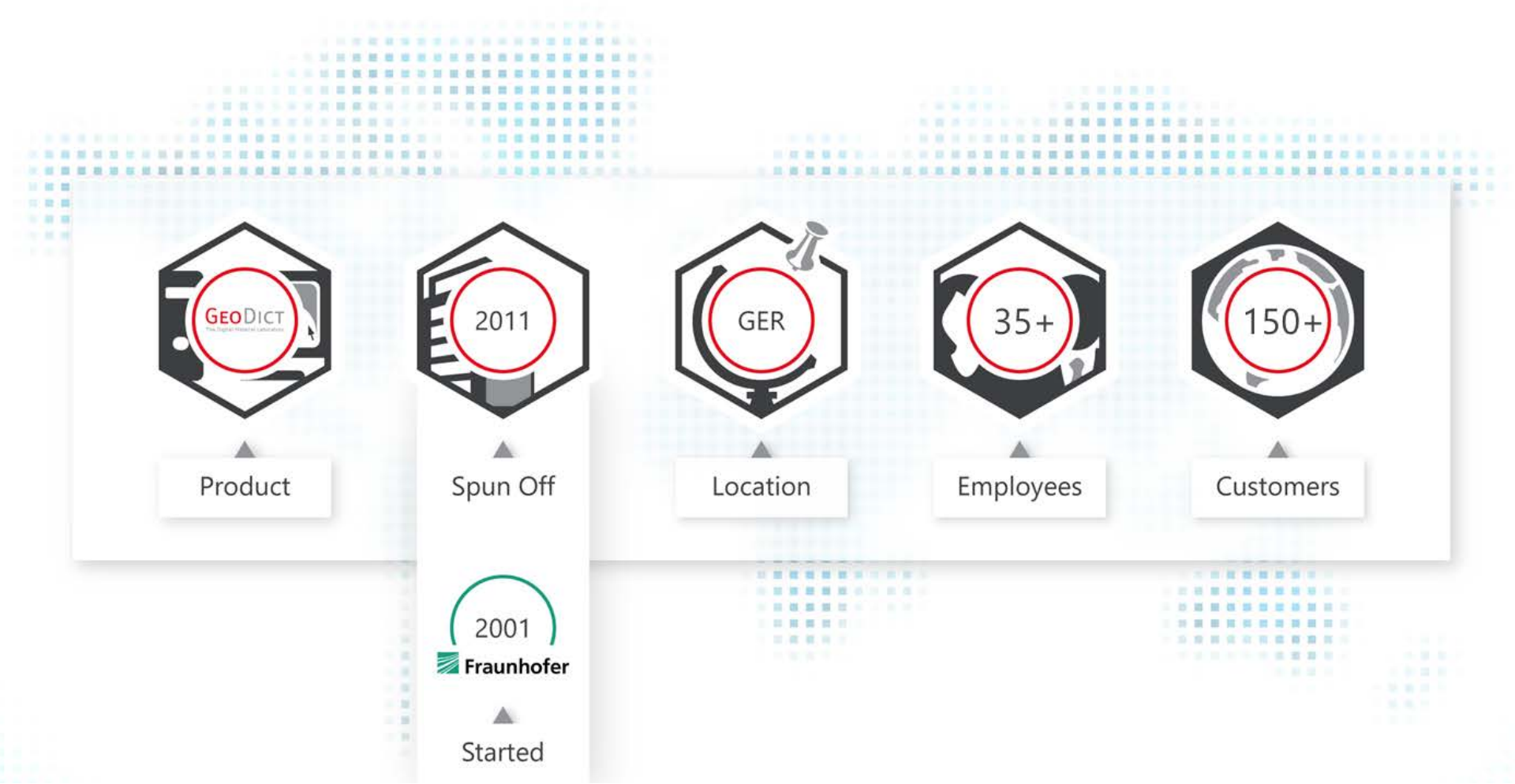
Kaiserslautern, Germany



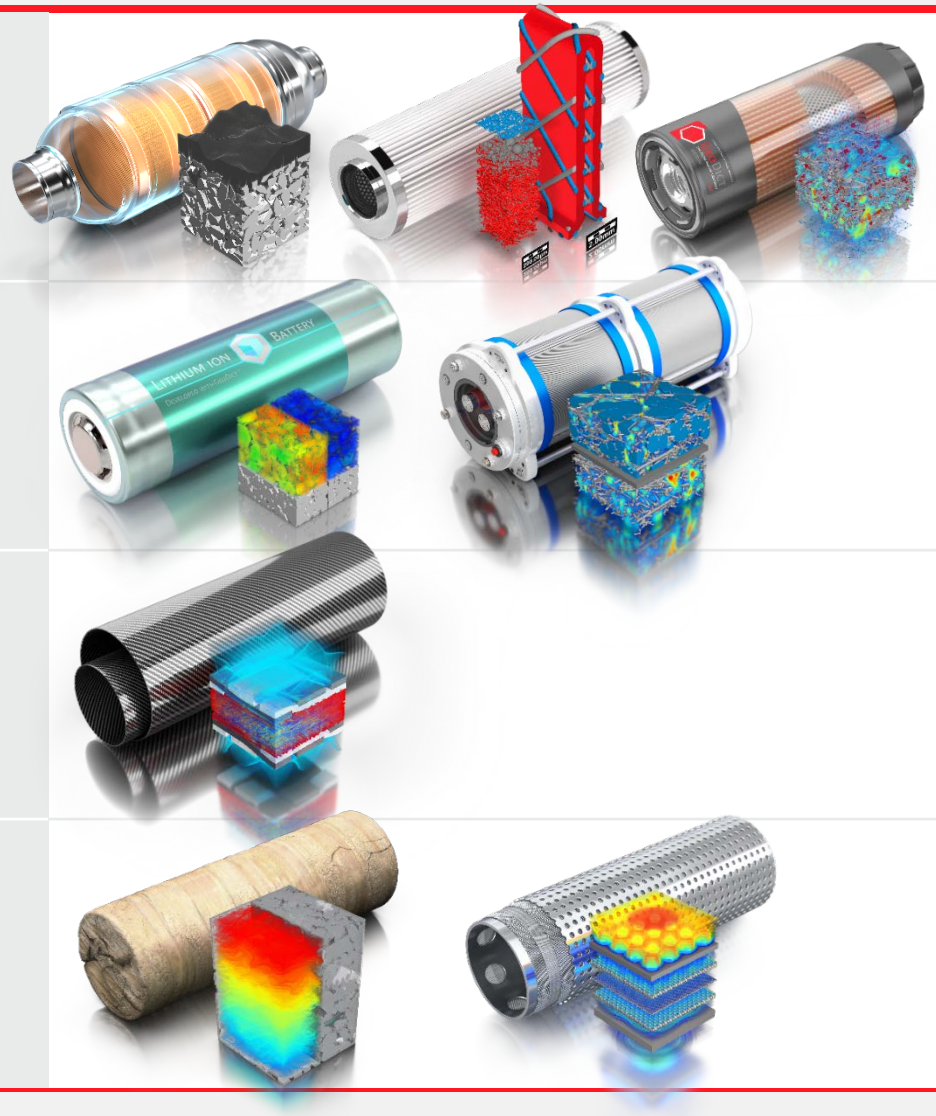
Content

Math2Market GmbH overview



GeoDict (The Digital Material Laboratory)

Filtration	Mostly automotive, filter media & filters for water, sludge, oil, air and fuel
Electrochemistry	Fuel cell media & battery materials, catalyst materials
Composites	CFRP, GFRP, mostly automotive, lightweight materials
Oil and Gas	Digital rock physics, digital sand control

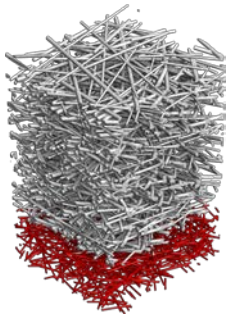


GeoDict workflow

IMPORT

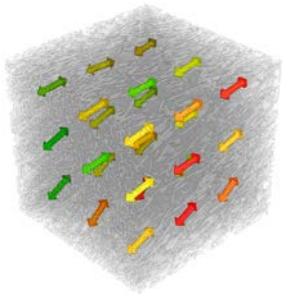
Diverse ways to import material models

MODEL



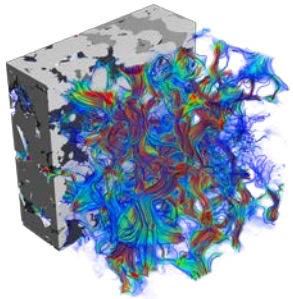
Detailed material models created in 3D

ANALYZE



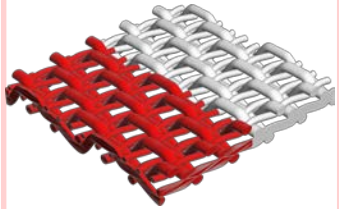
Extensive analysis and evaluation of structural material properties

PREDICT



In-depth analysis and prediction of material behavior

EXPORT

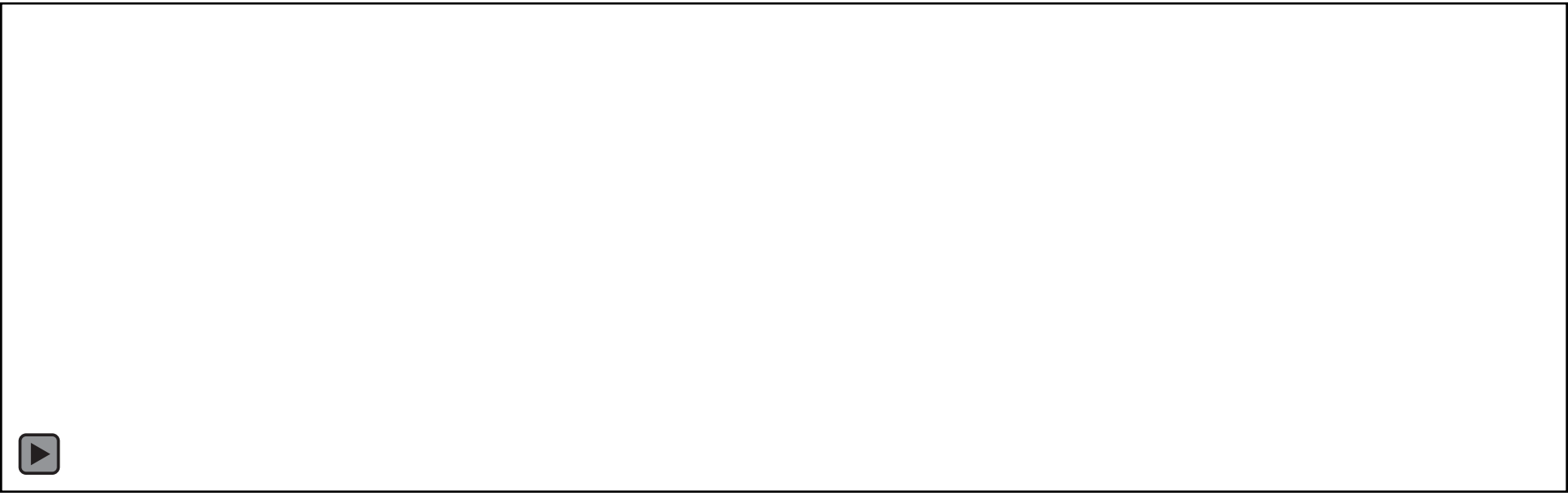


GeoDict models made available for standard workflows

Part I
Simulation on the resolved filter scale

Particulate flow simulations

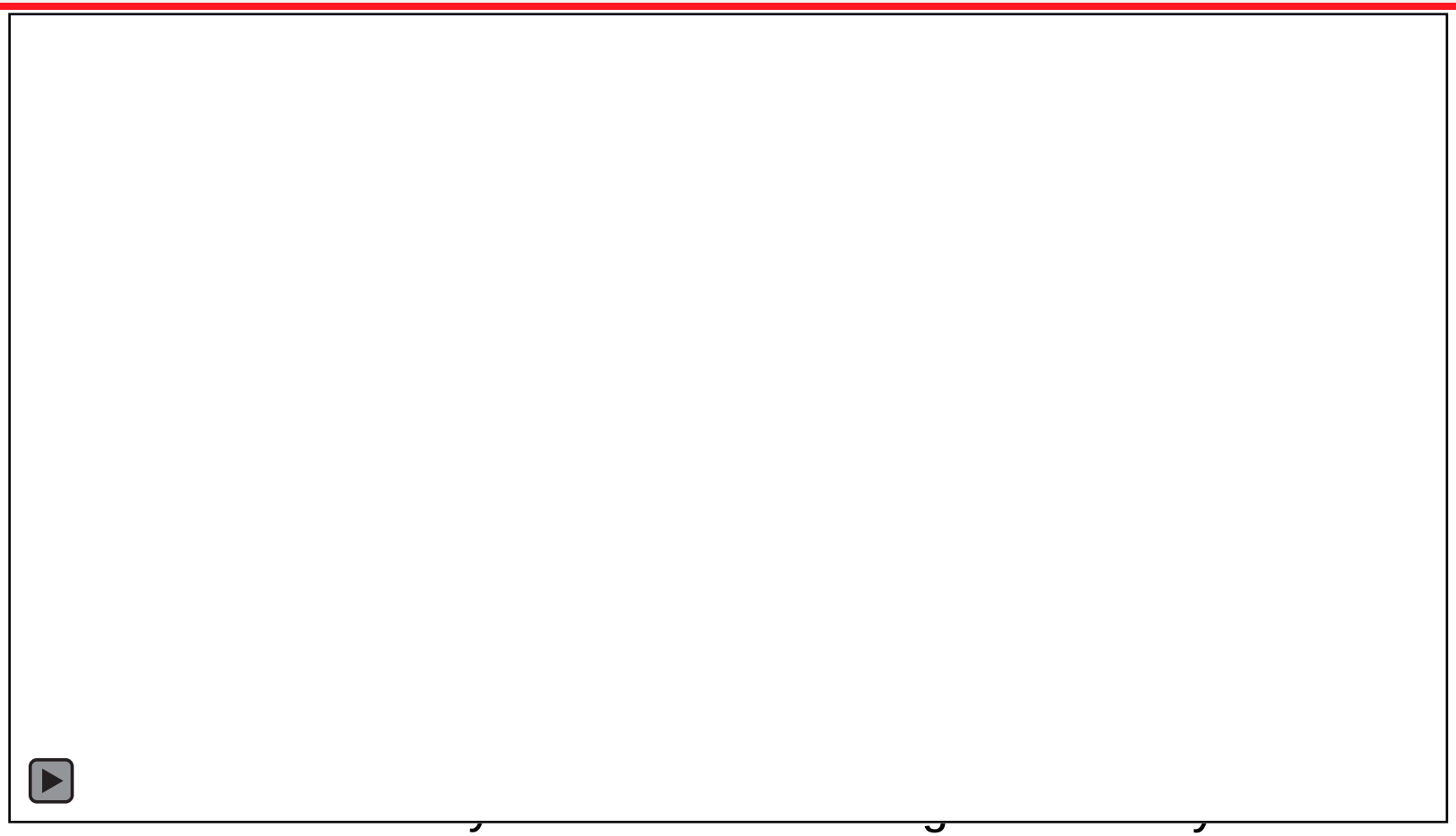
Comparison of different collision models (Implemented in FilterDict)



H = 1e-19
Restitution Coefficient = 0.5

Caught-on-first-touch | Hamaker | Sieving

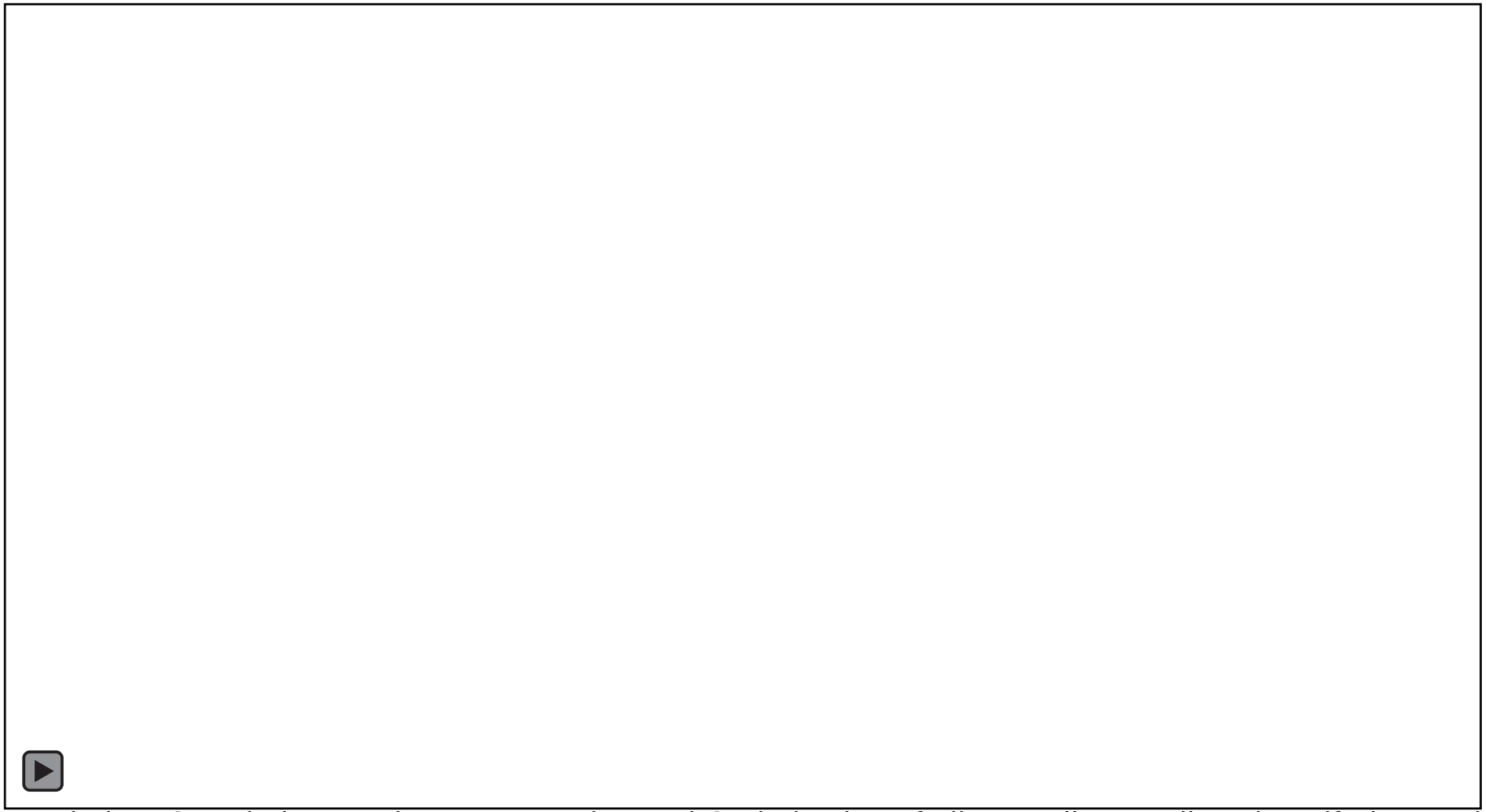
Caught-on-first-touch collision model (air filtration) & Sieving collision model (water/oil filtration)



higher permeability,
“dendrites”

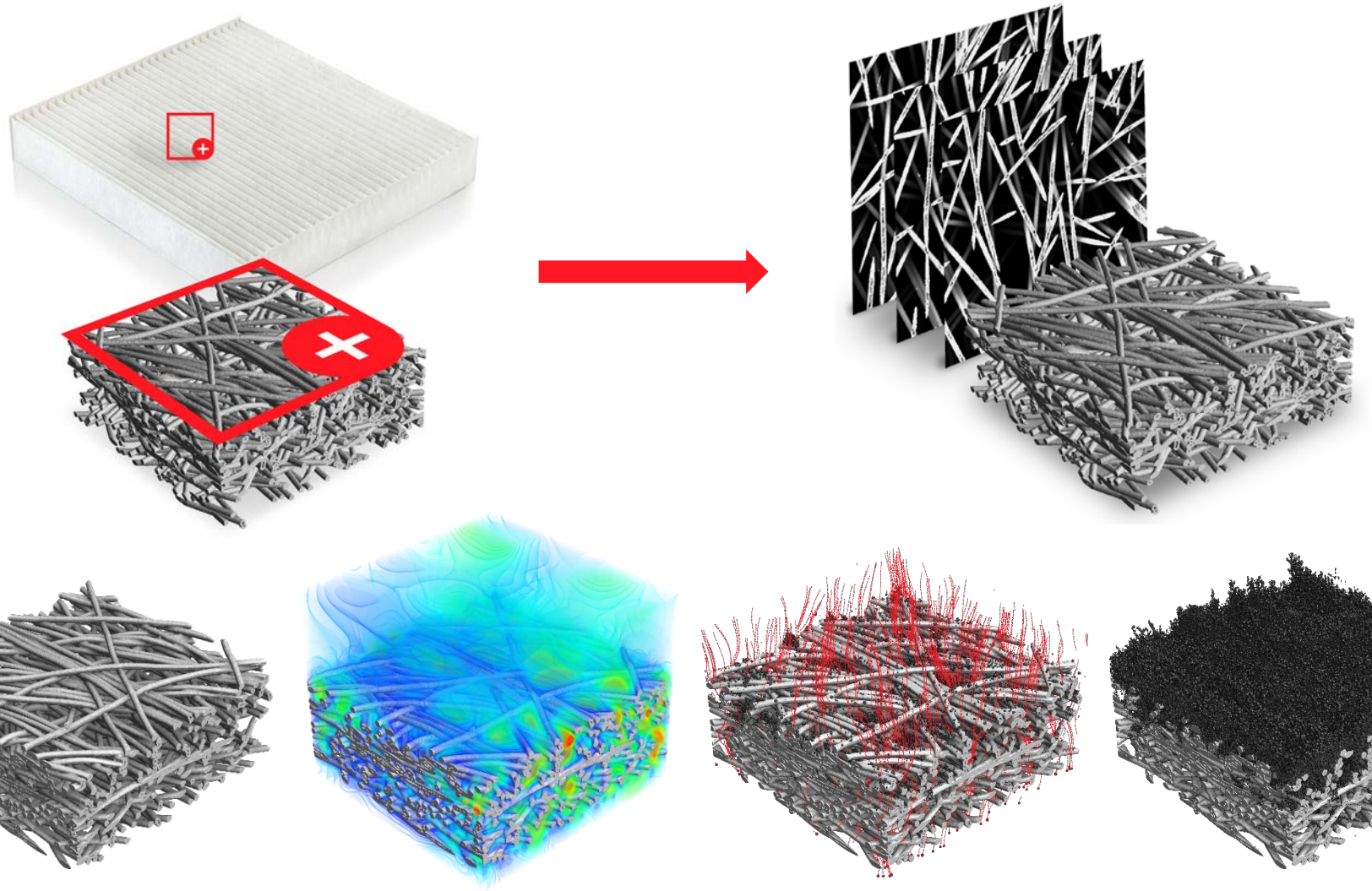
lower permeability,
“dense packing”

Depth filtration & cake filtration (Sieving collision model)

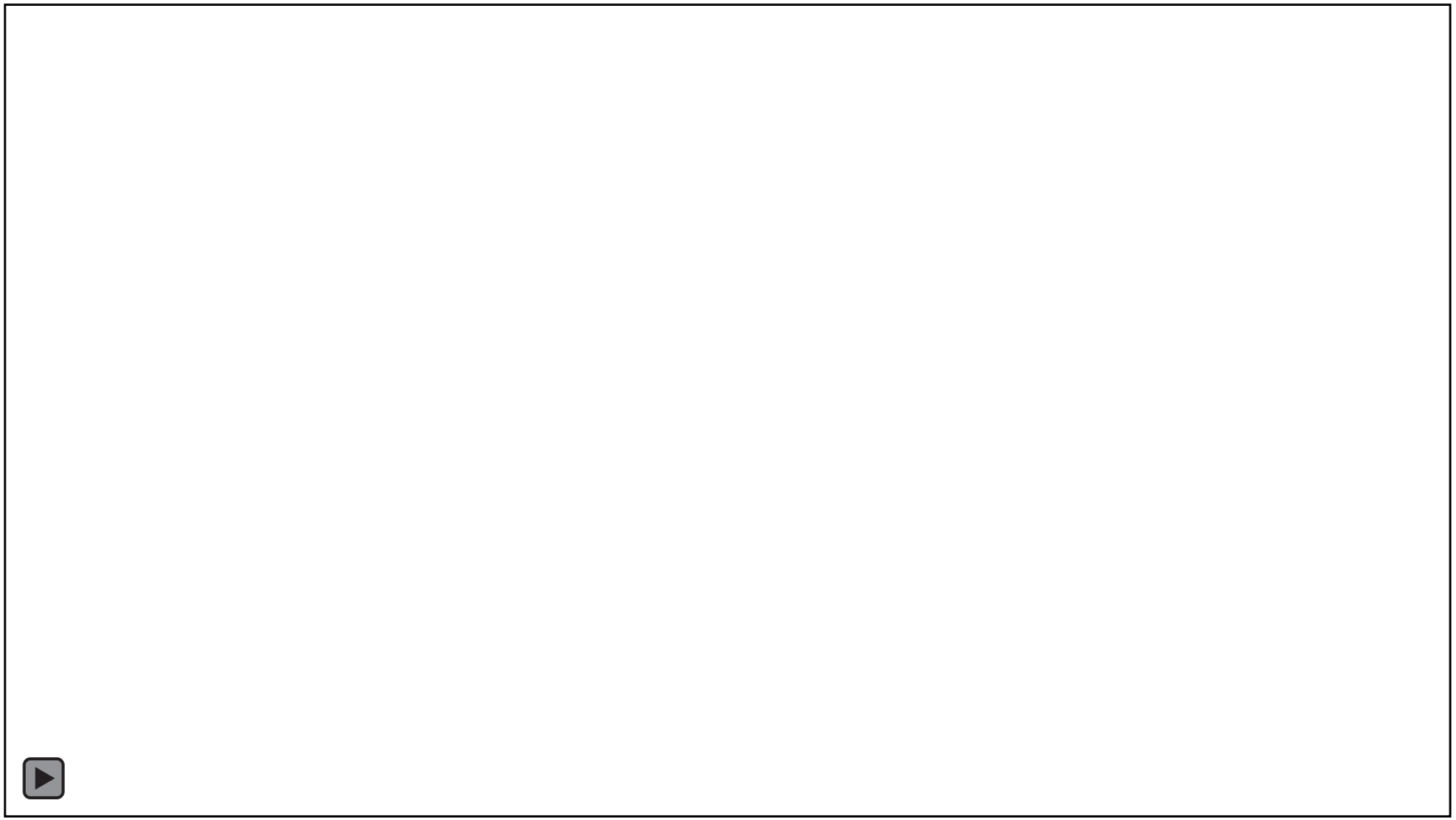


M. Azimian, C. Kühnle, A. Wiegmann, Design and Optimization of Fibrous Filter Media using Lifetime Multi-pass Simulations, Chemical Engineering & Technology, 2018.

Simulation on the resolved media (micro-structure of filter media obtained by µ-CT scan)



Filter capacity & pressure-drop through the life time

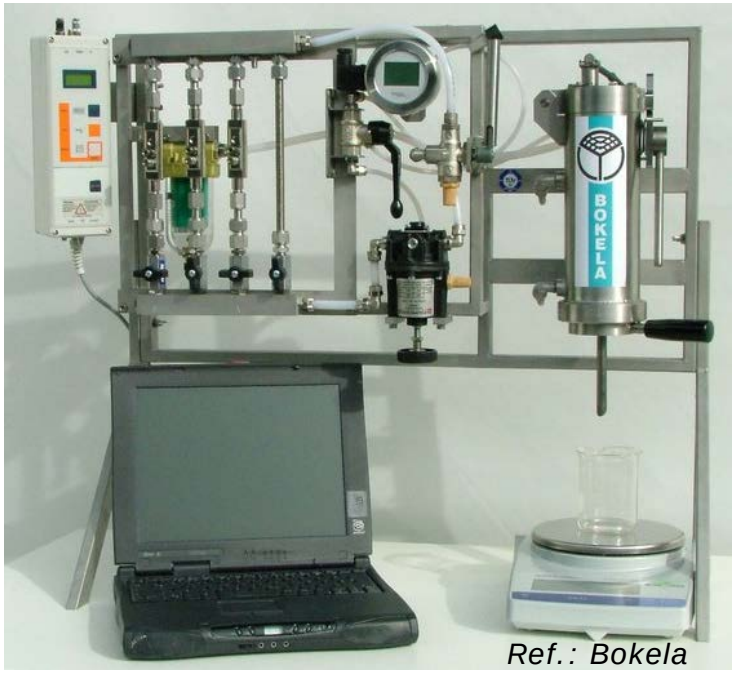


Part II

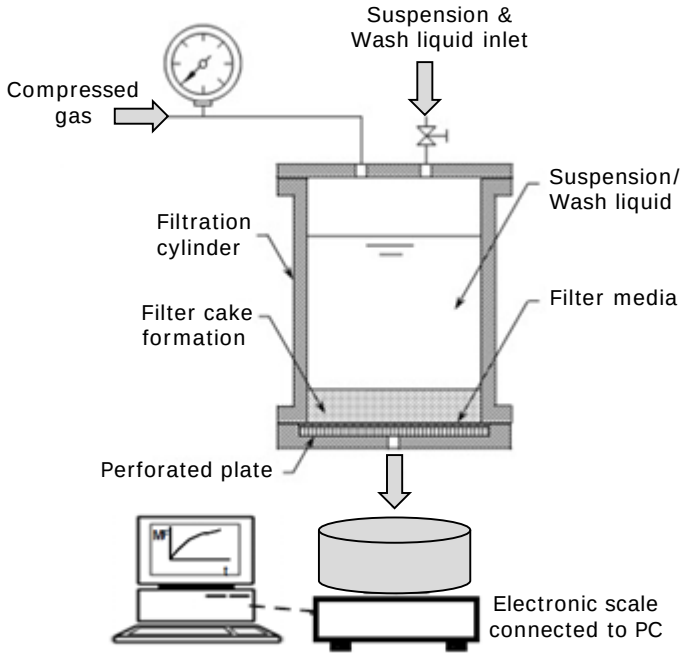
Simulation on the unresolved filter media

Determination of the filtration behavior based on VDI-Guideline 2762

Laboratory test (pressure filtration)



Ref.: Bokela



- Constant pressure difference
- Recording of the filtrate amount as f(t)
- Cake evaluation (Height, moist cake weight, …)
- Analysis of gas permeation point (filtration end)
- Evaluation using the Darcy equation

Darcy equation: $$v = \frac{\dot{V}}{A_0} = \frac{\Delta p}{\mu_L \cdot (\alpha \cdot h_c + \beta)}$$

$\alpha\ [m^{-2}]$: Specific cake resistance

$\beta\ [m^{-1}]$: Filter media (initial) resistance

$h_c\ [m]$: Filter cake height

Filtration process steps

Filtering

Pressure/vacuum to force liquid through the solid bed & filter media → specific cake resistance

Washing

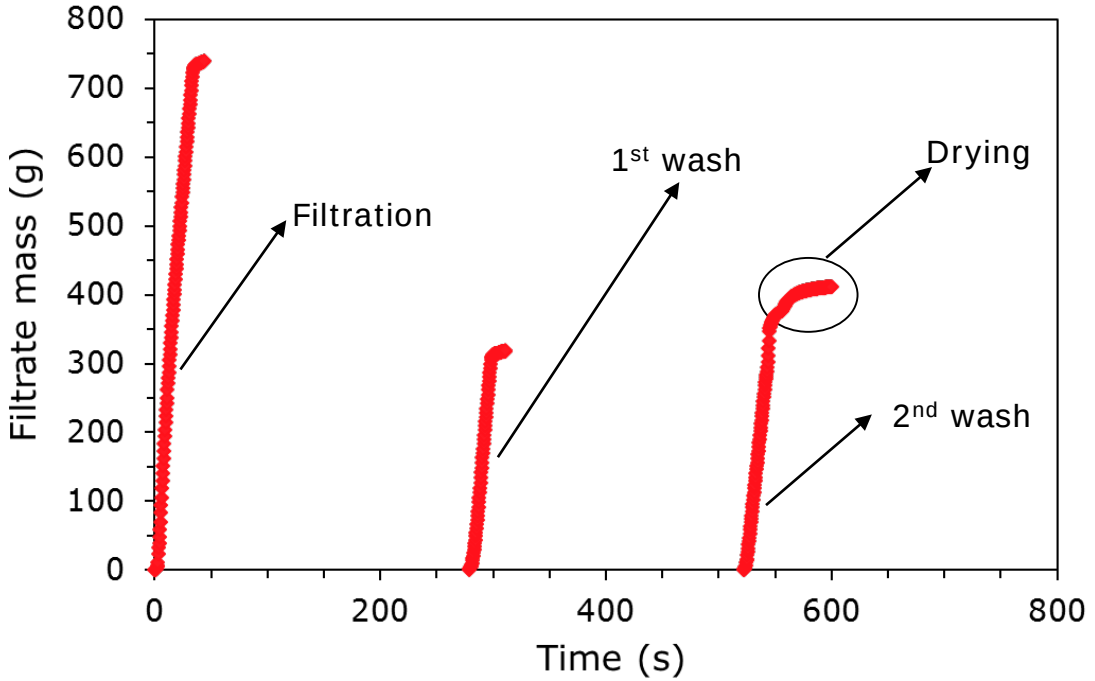
Fresh wash liquid is sprayed on top of the solid cake taking care not to disturb the cake surface

$$\text{Wash ratio } (R_w) = \frac{\text{Volume of wash liquid}}{\text{Cake volume}}$$

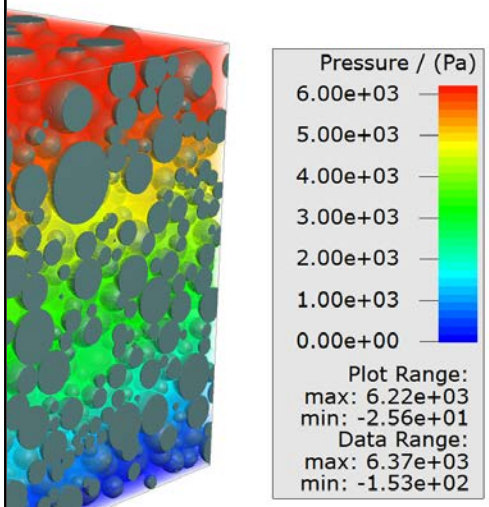
Drying

Pressurized gas is blown down through the filter cake

Filtrate mass recorded with online PC connected to scale



Modeling and simulation on the unresolved media (Filter cake formation based on VDI guideline 2762)



Particles:

Spherical glass beads with density 2450 kg/m^3

Particle size distribution: 14–100 µm

Porous media plate with permeability 1.45e-10 m^2

Flow resistivity: 1.22e+08 kg/(m^{3}s)

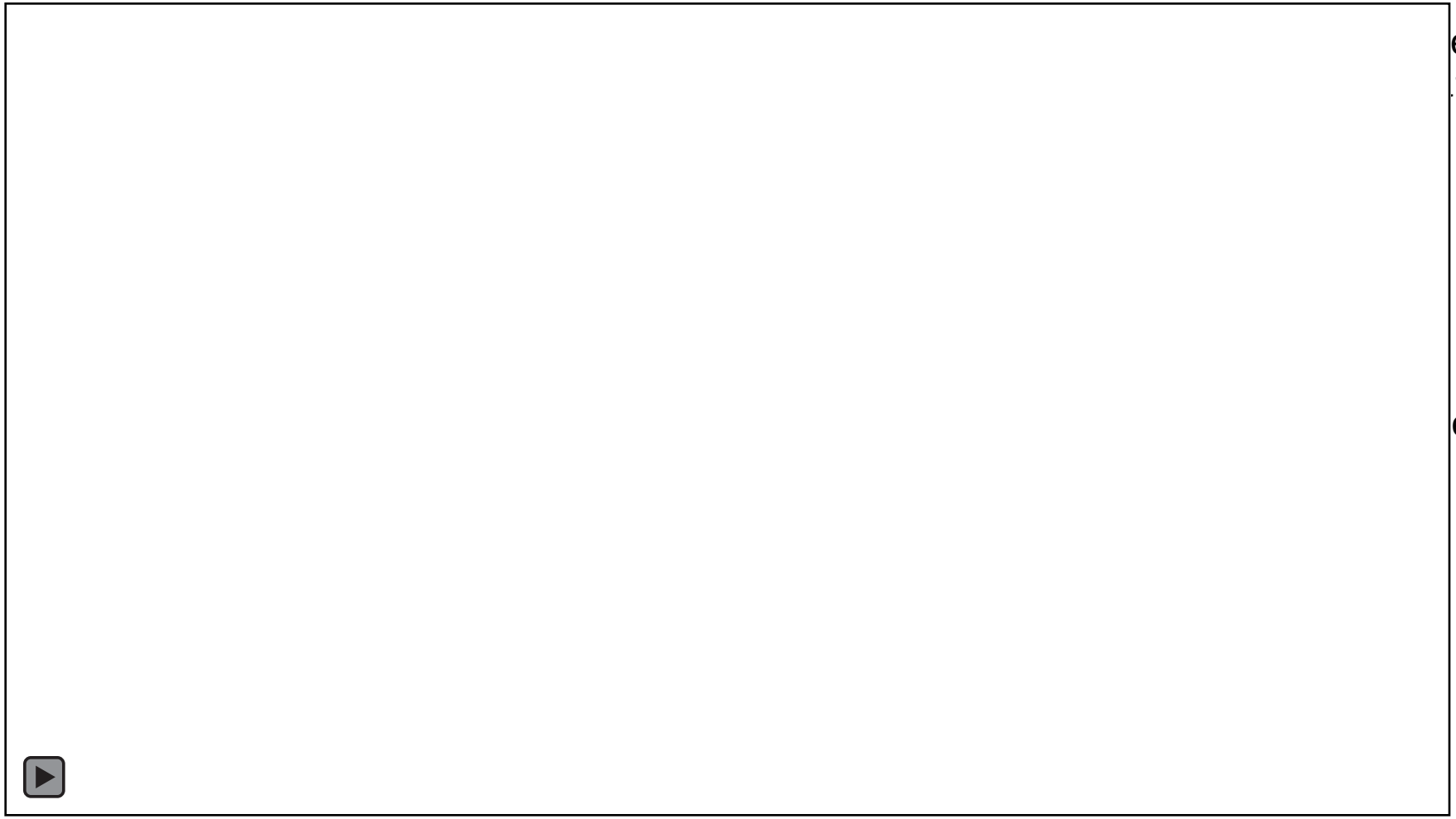
Permeability: 8.12e-12 m^2

Specific cake resistance: 1.23e+11 m^{-2}

➢ Washing process

Washing process of the filter cake (Simulation with SatuDict)

Pore Morphology Method predicts the distribution of the two phases inside porous media

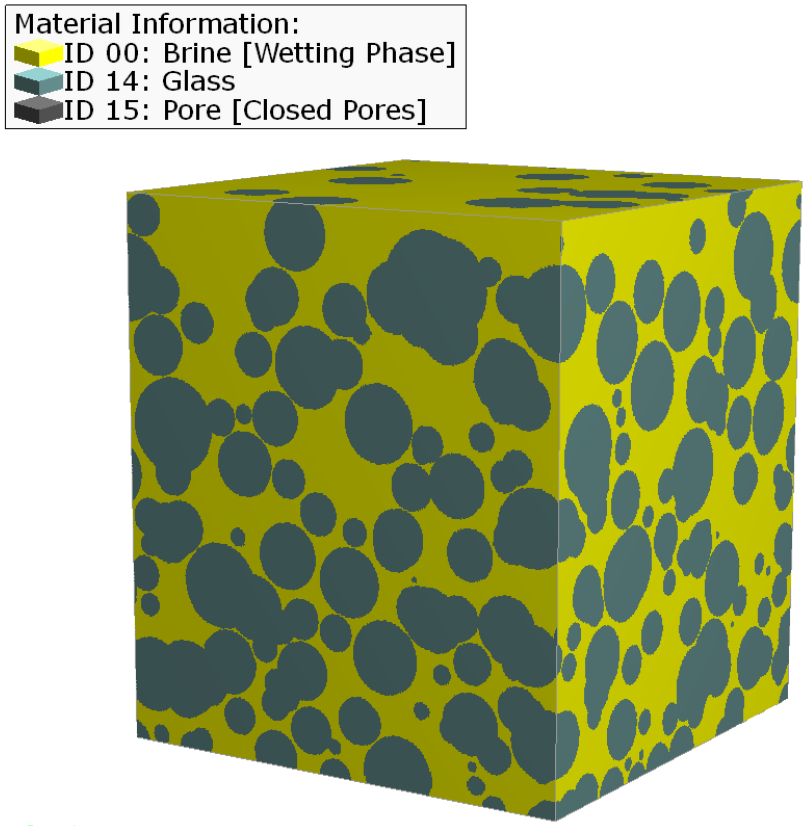


e
ter):

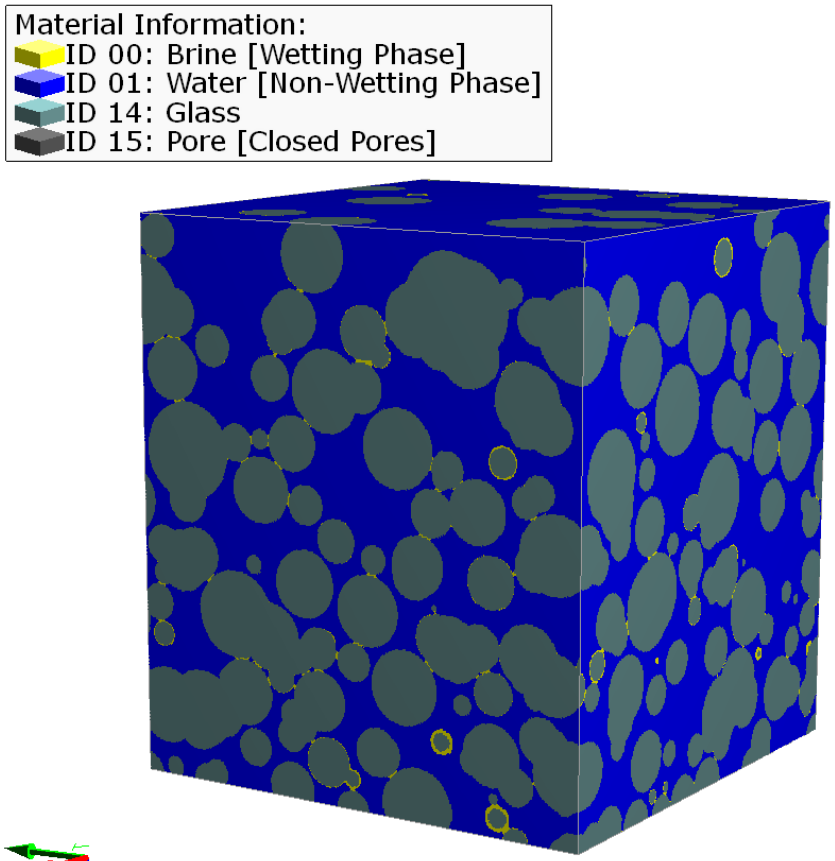
70°

e
110°

Brine & water volume% before & after the washing process



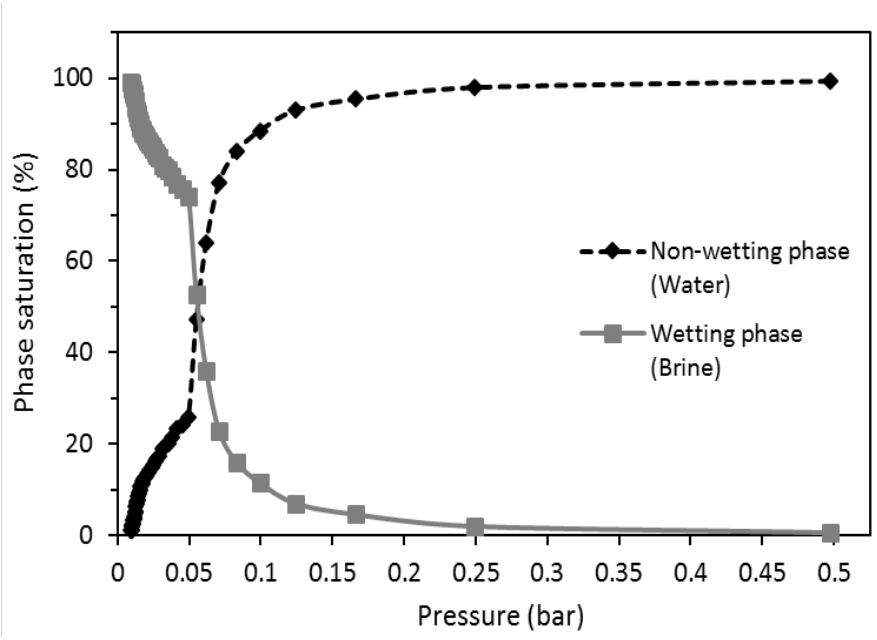
Brine: 39.49%
Glass particles: 60.51%



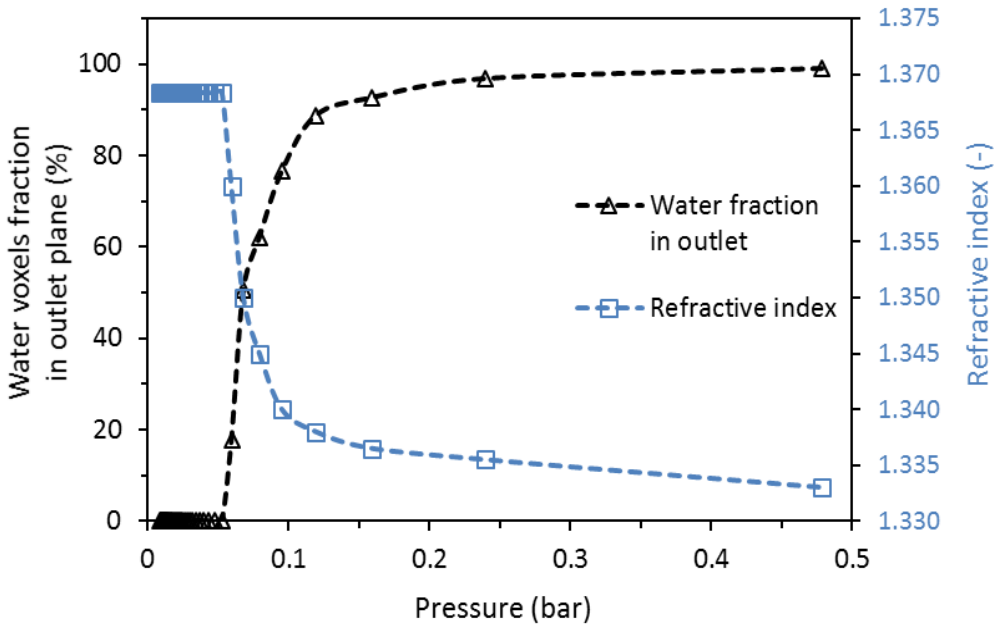
Water: 39.25%
Brine: 0.24%
Glass particles: 60.51%

Phase saturation / fraction as a function of capillary pressure (Washing process)

Brine & water phase saturation as a function of pressure



Water phase fraction in outlet plane of the filter cake



- By measuring the refractive index at the outlet, the optimal amount of washing liquid can be chosen.

(Save in washing liquid amount & washing duration)

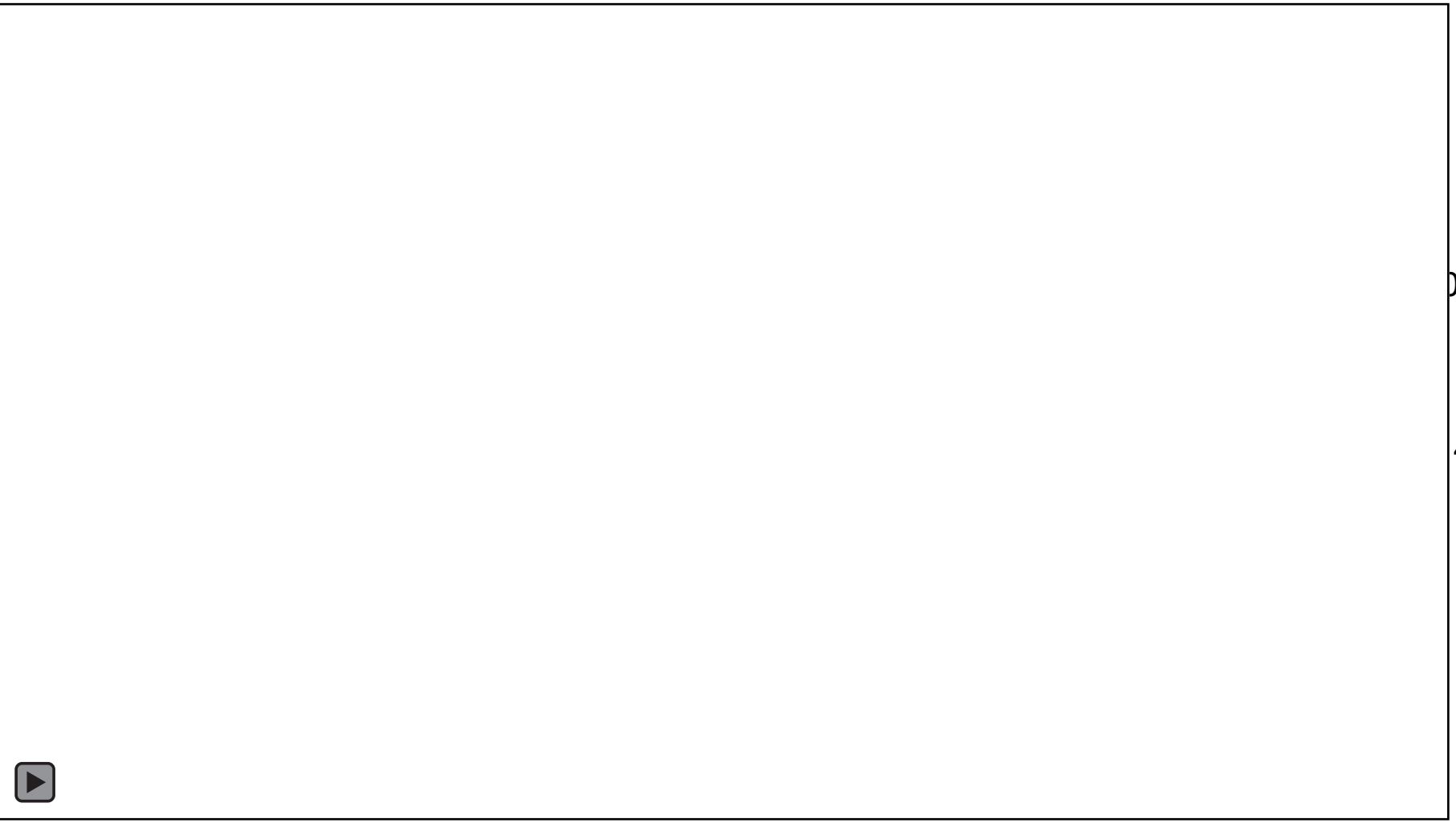
Refractive index (n):

Brine (20 wt% NaCl): 1.3684

Water: 1.333

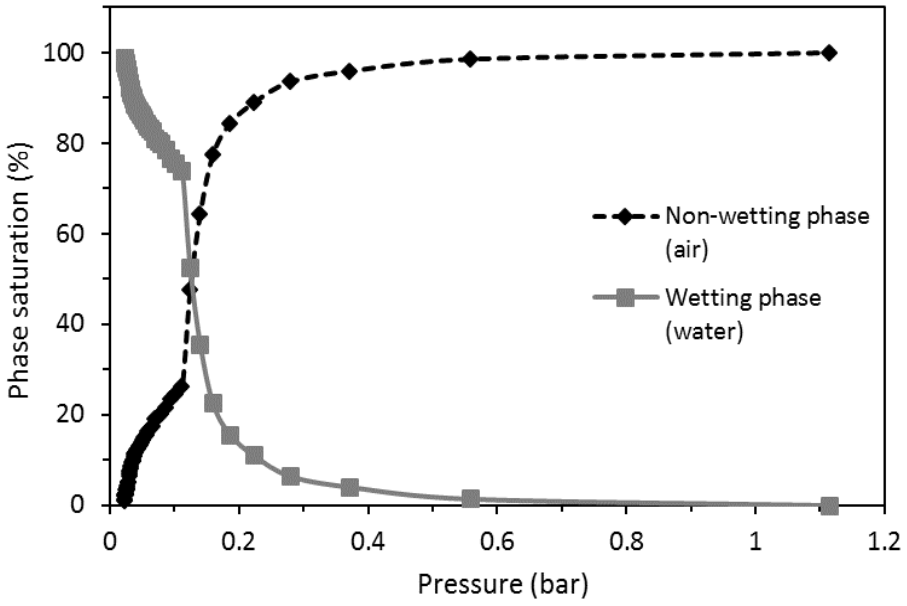
➢ Drying process

Drying process (with pressurized air) of the filter cake (Simulation with SatuDict)

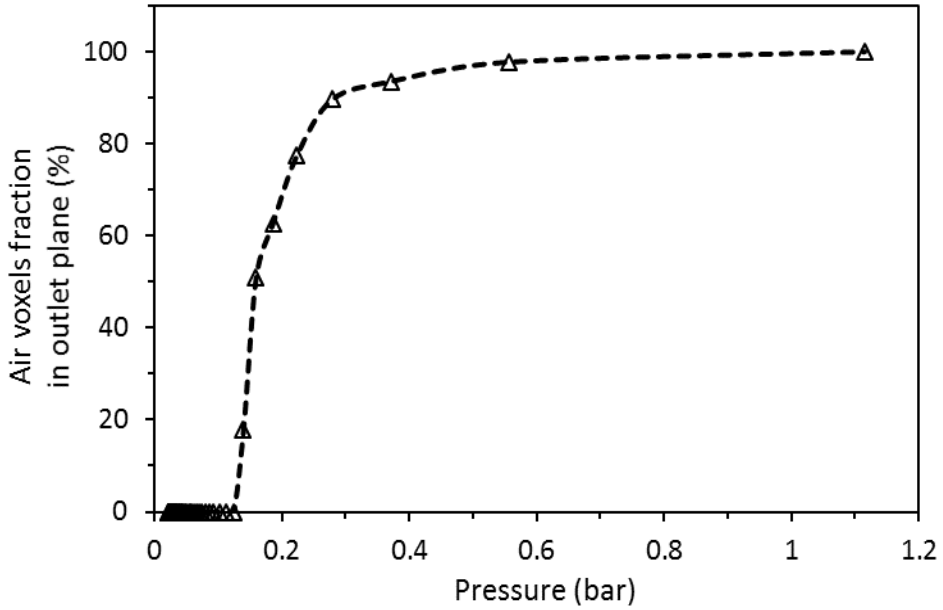


Phase saturation / fraction as a function of capillary pressure (Drying process)

Water & air phase saturation as a function of pressure



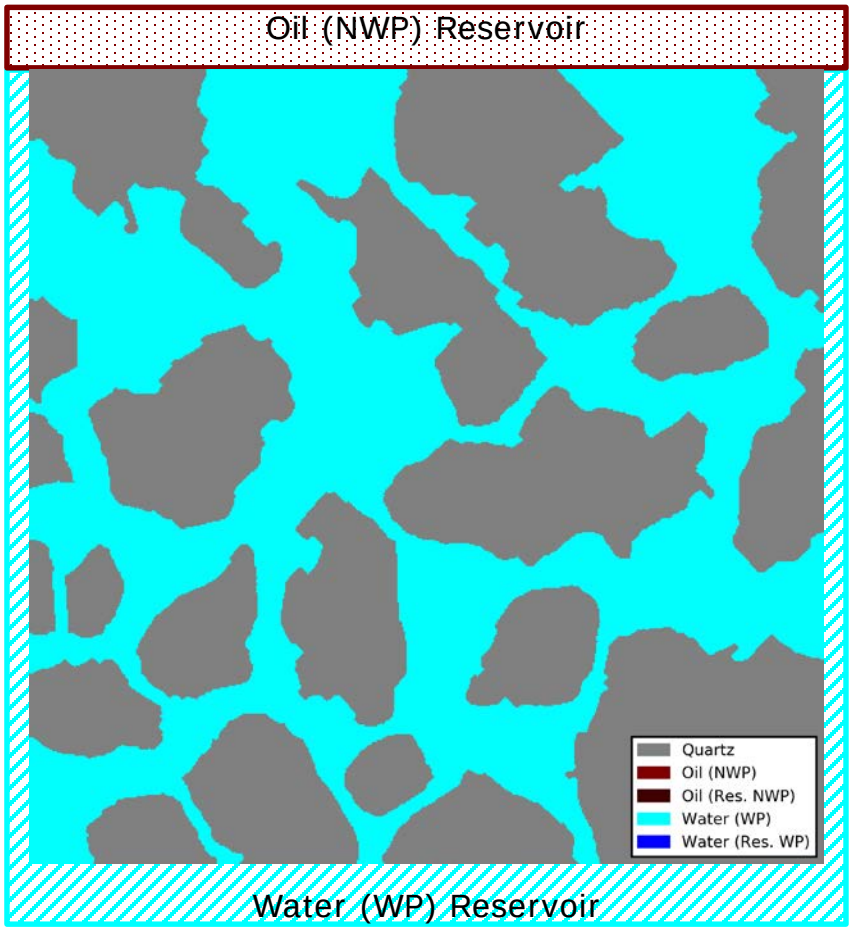
Air phase fraction in outlet plane of the filter cake



- Pressure required for drying process (1.1 bar) is more than two times higher than pressure required for washing process (0.48 bar)

➢ SatuDict functionality

Primary Drainage
Oil displaces Water



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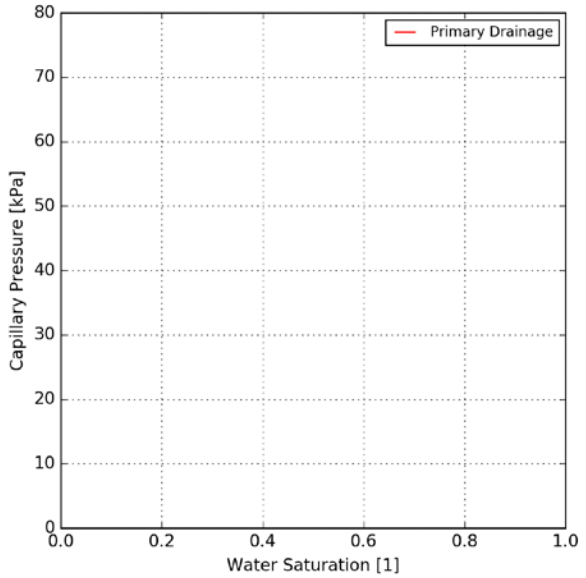

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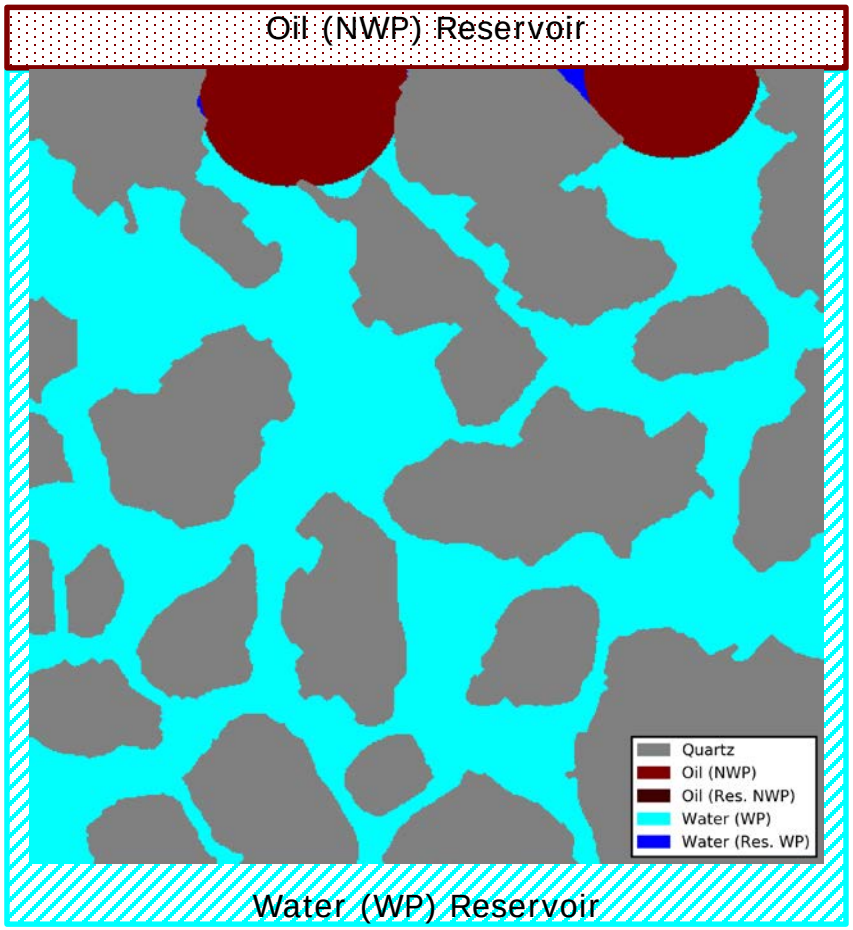

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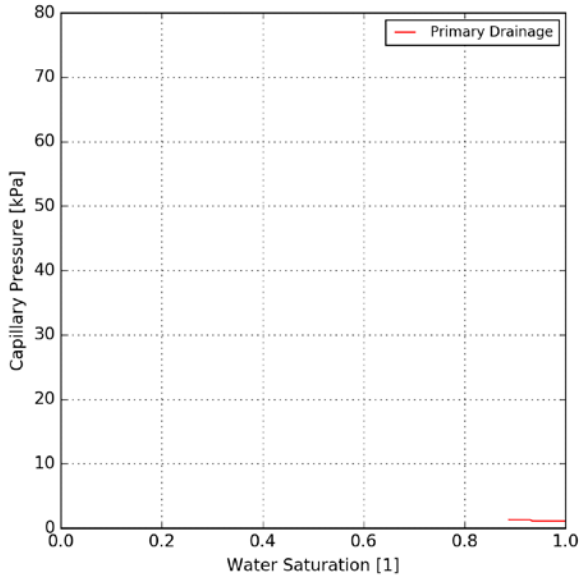

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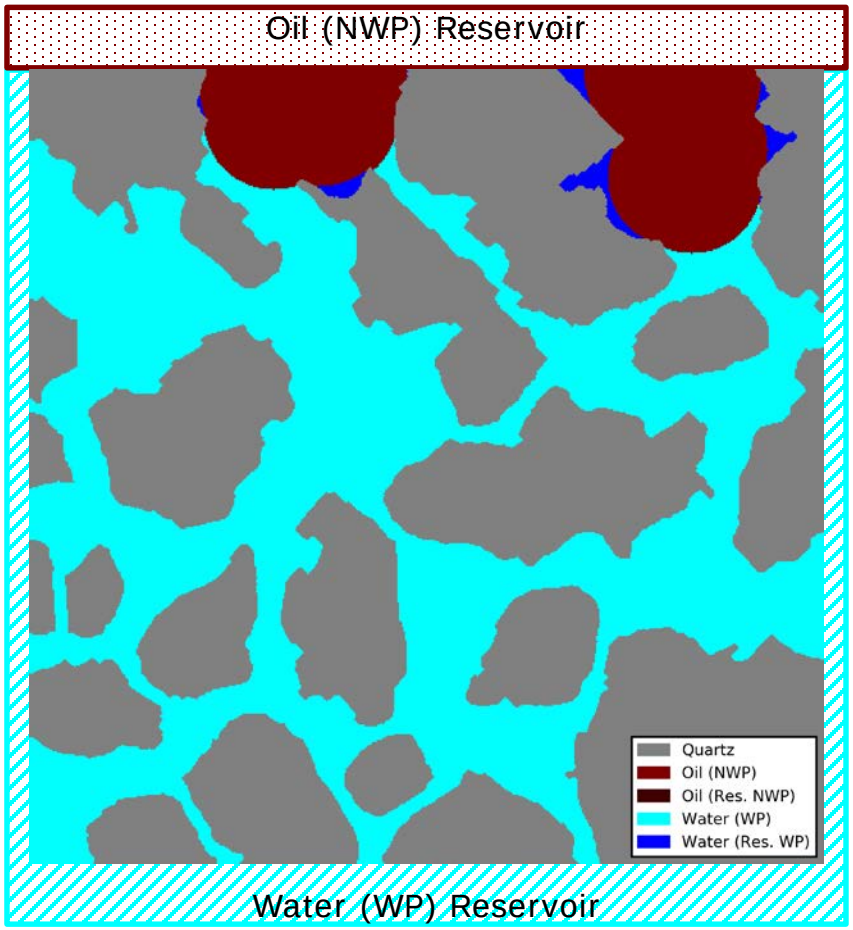

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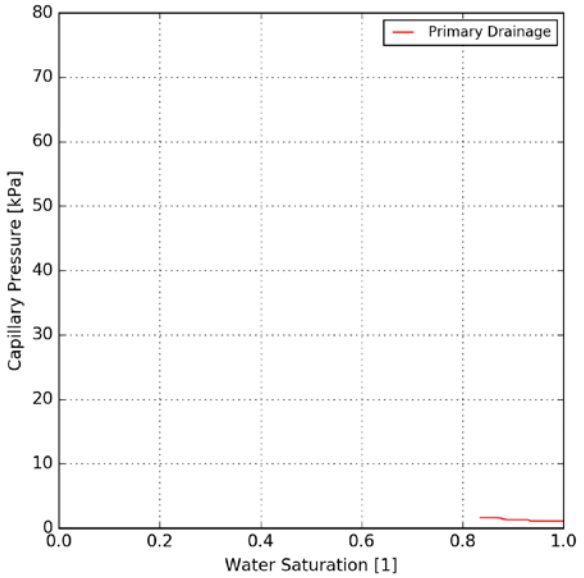

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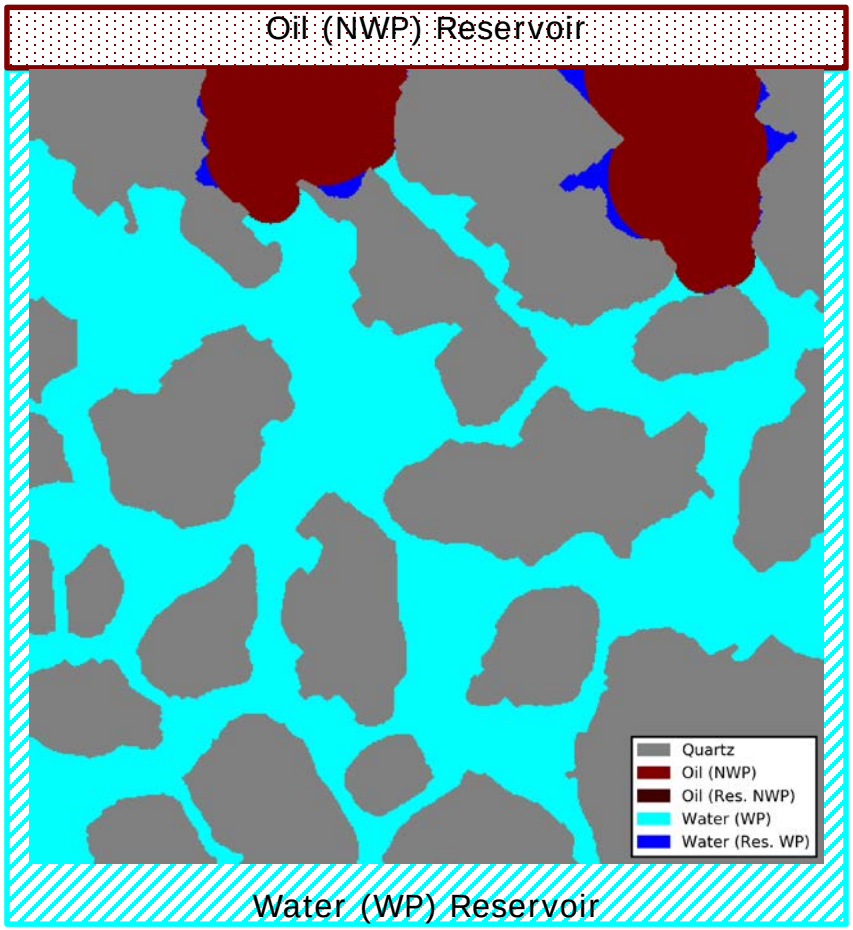

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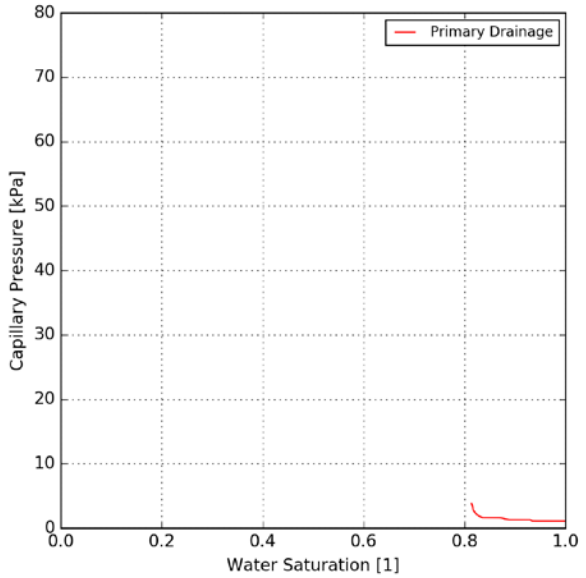

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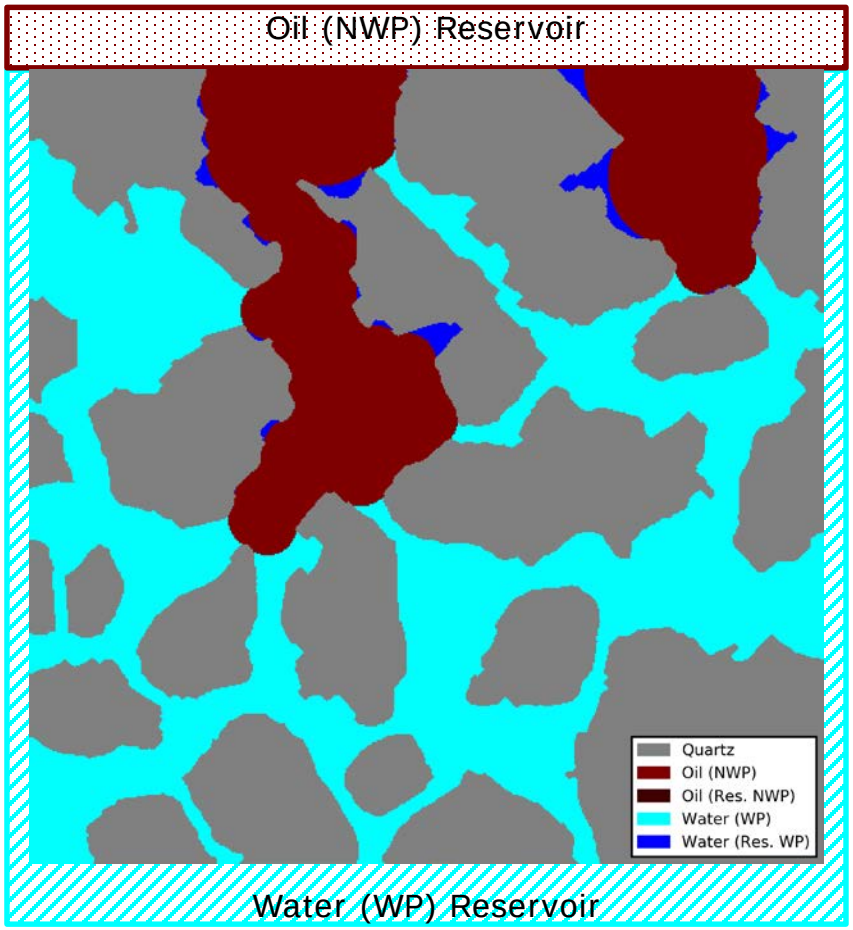

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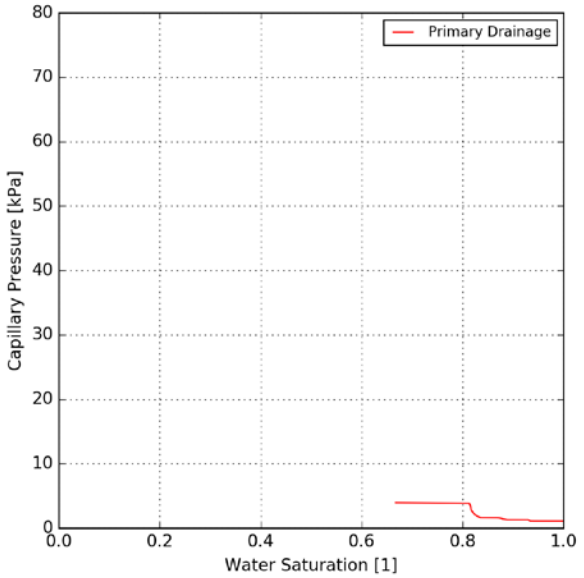

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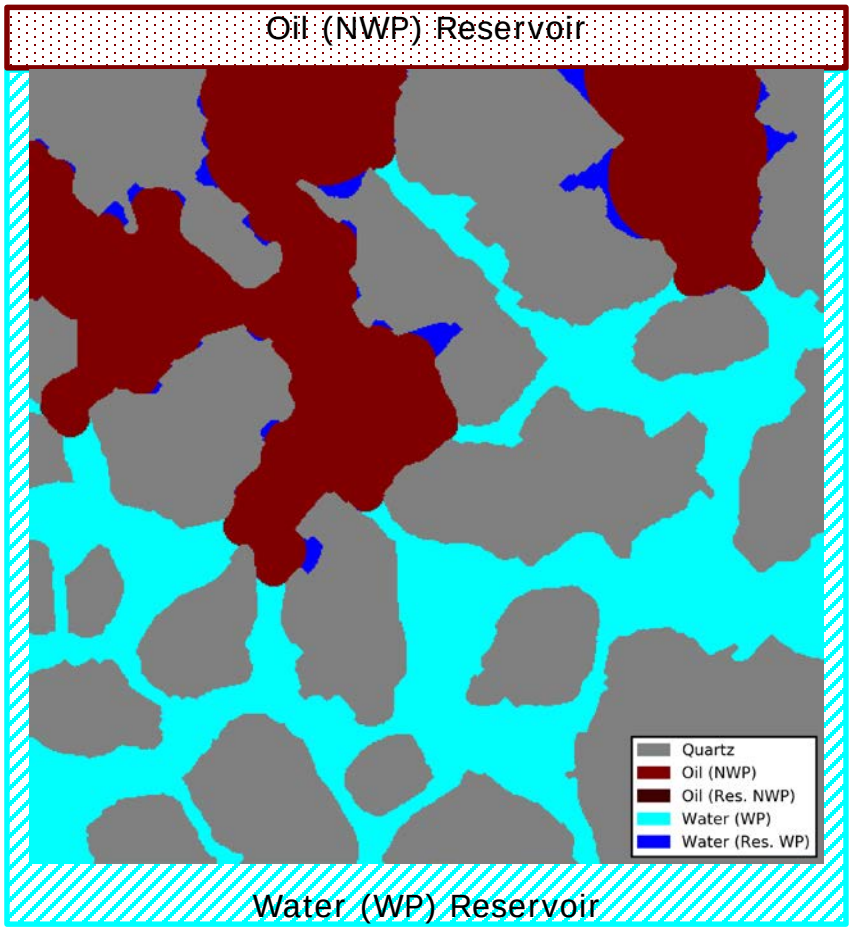

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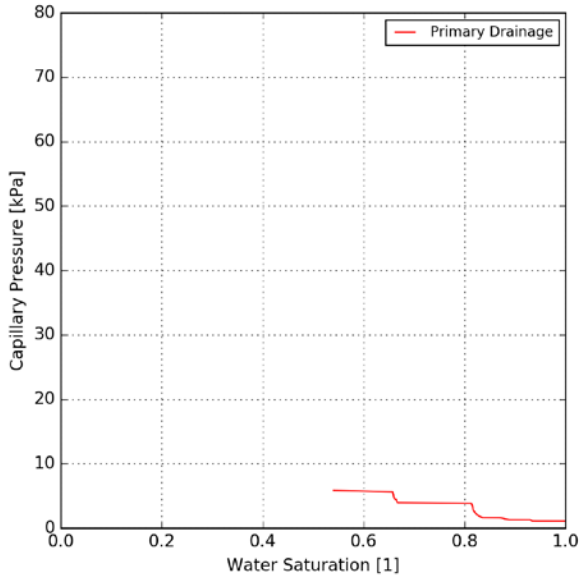

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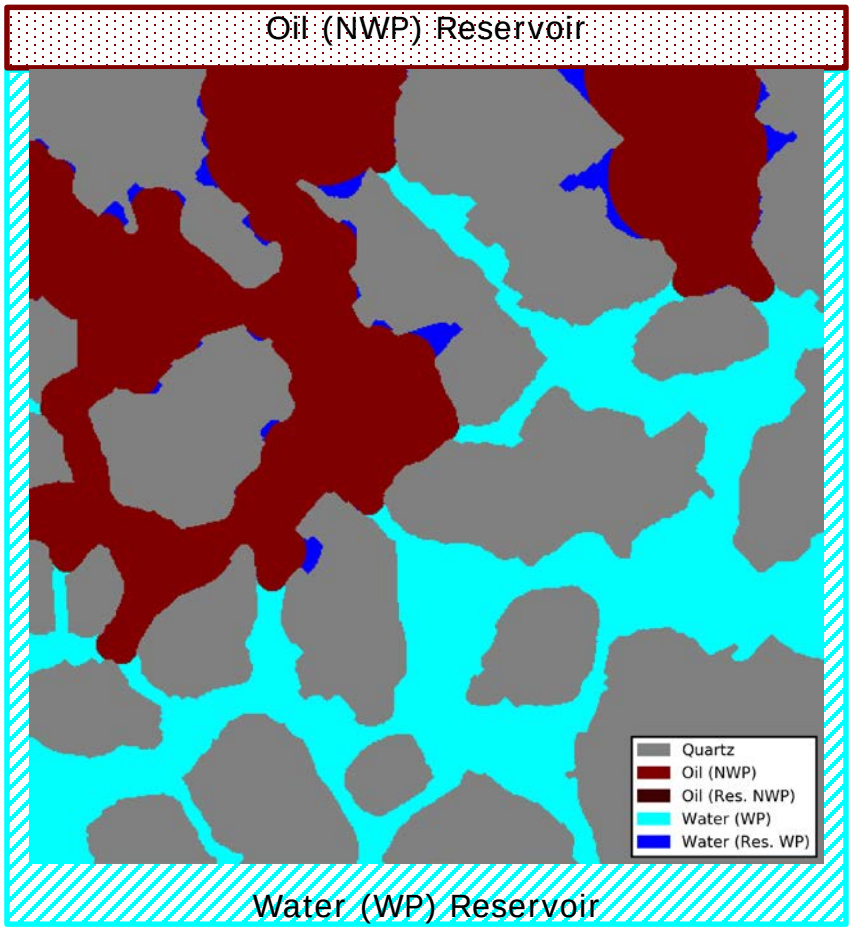

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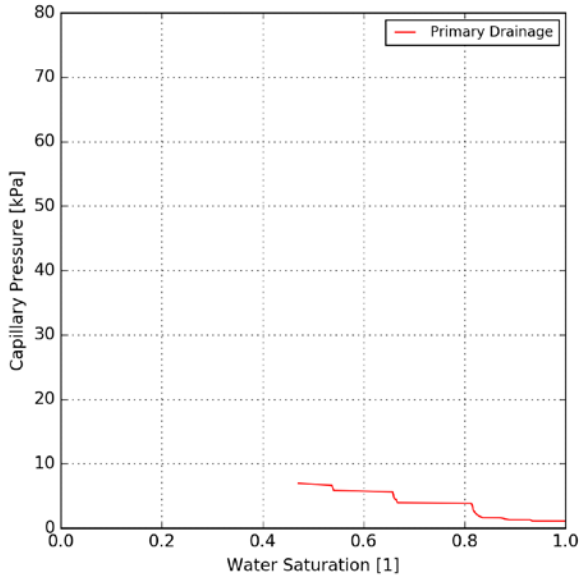

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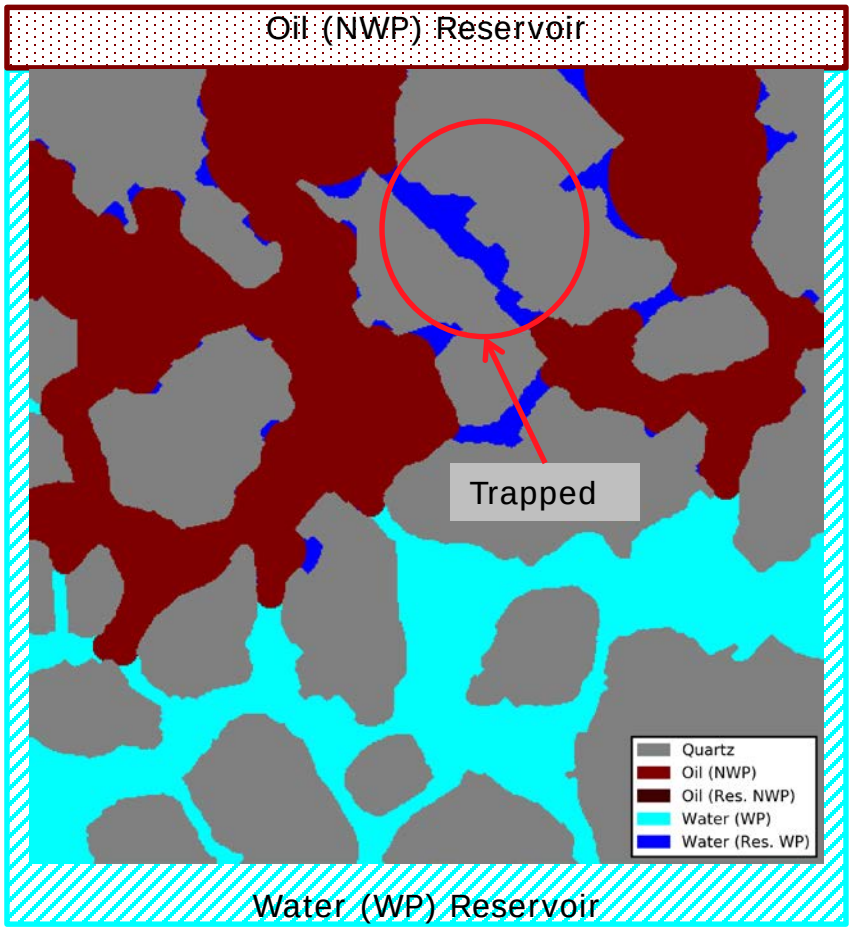

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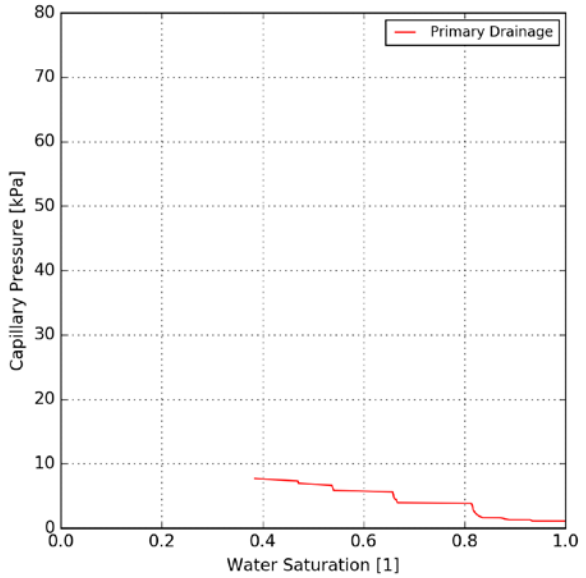

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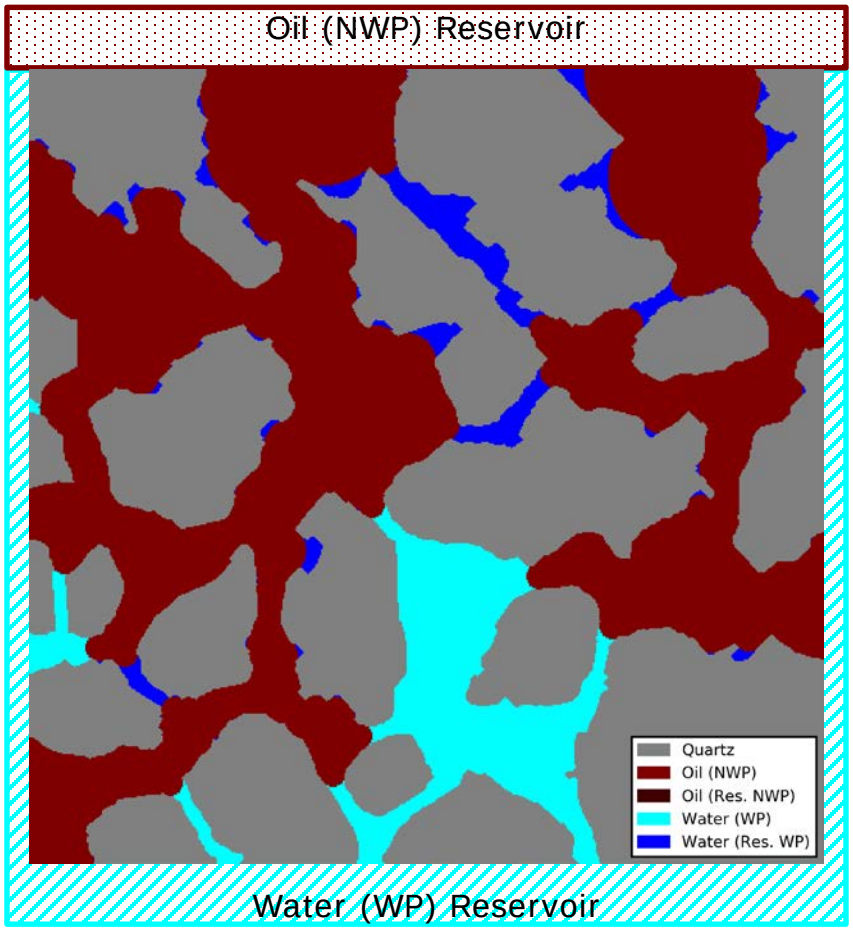

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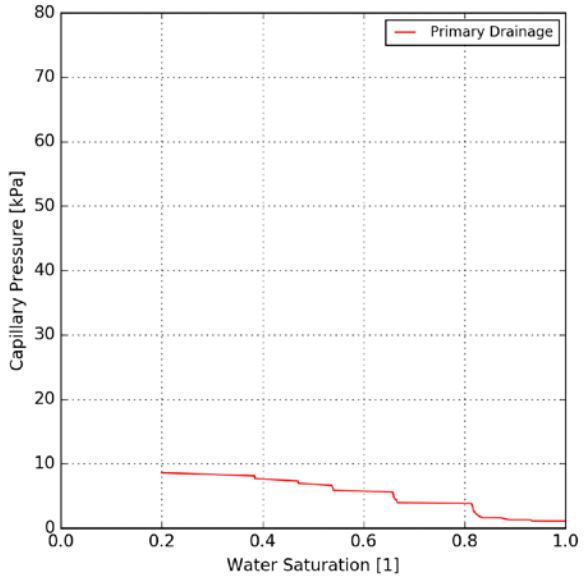

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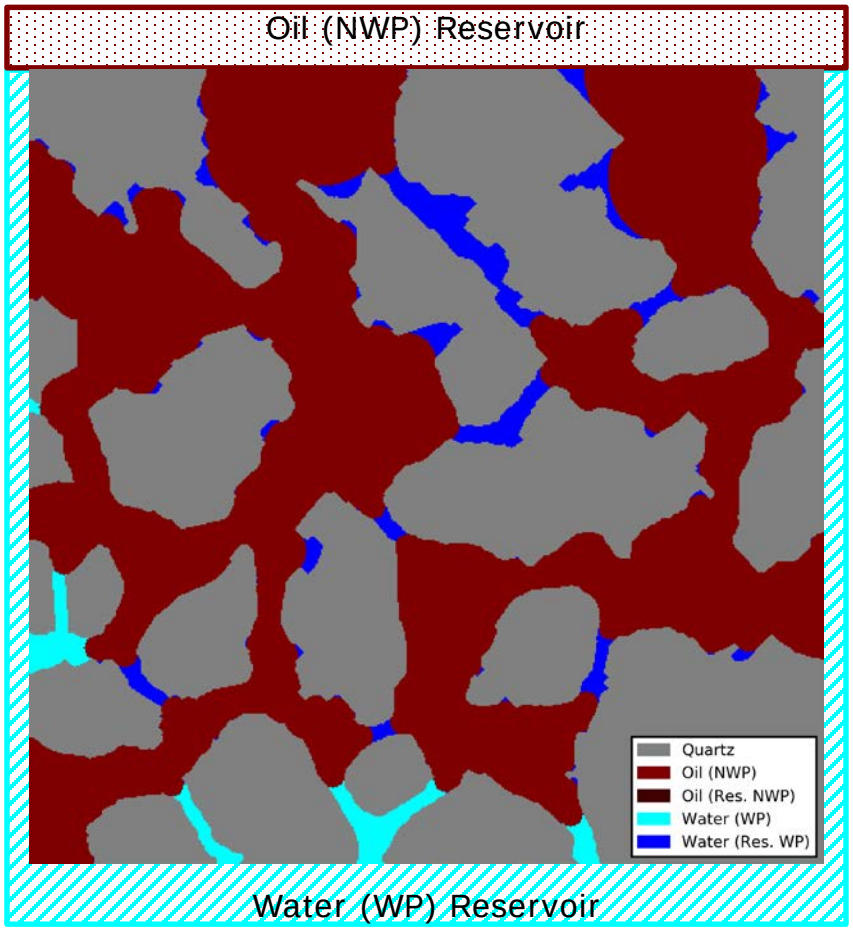

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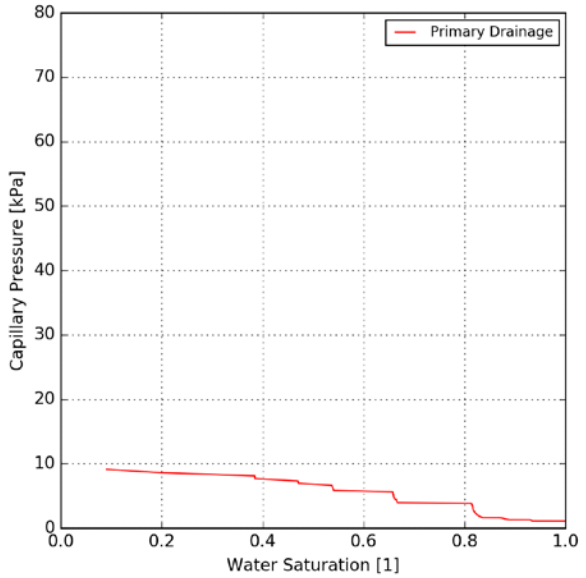

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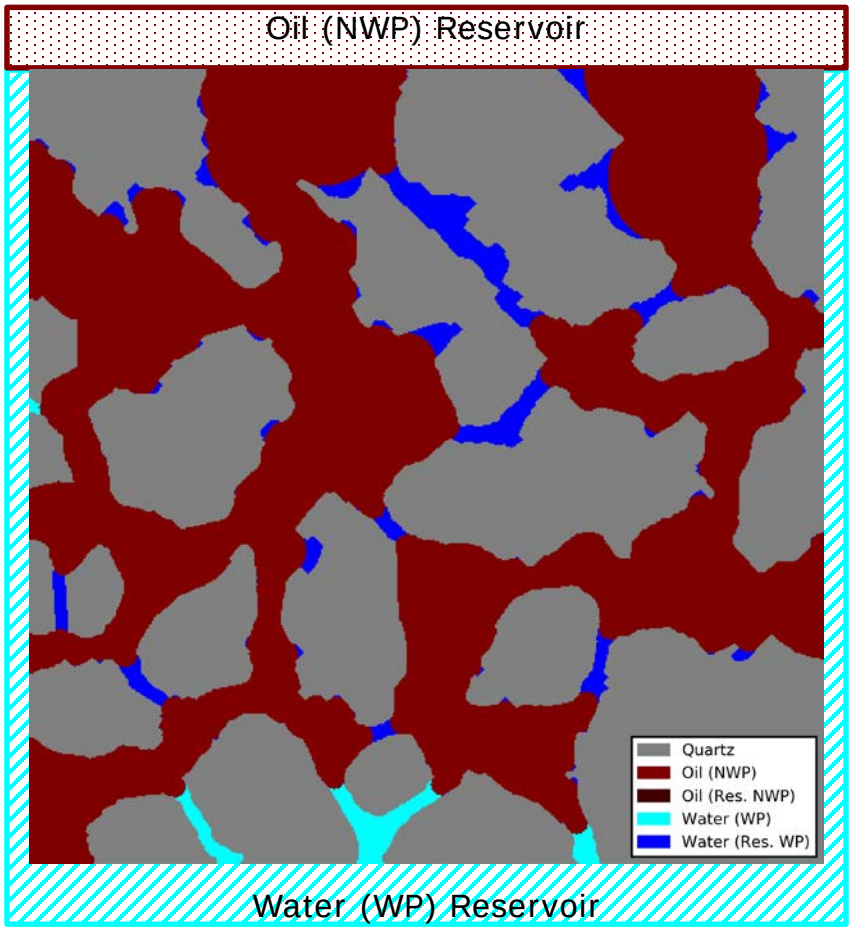

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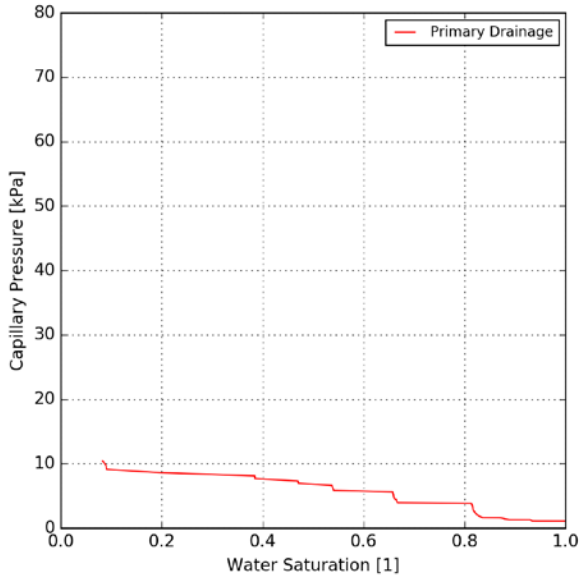
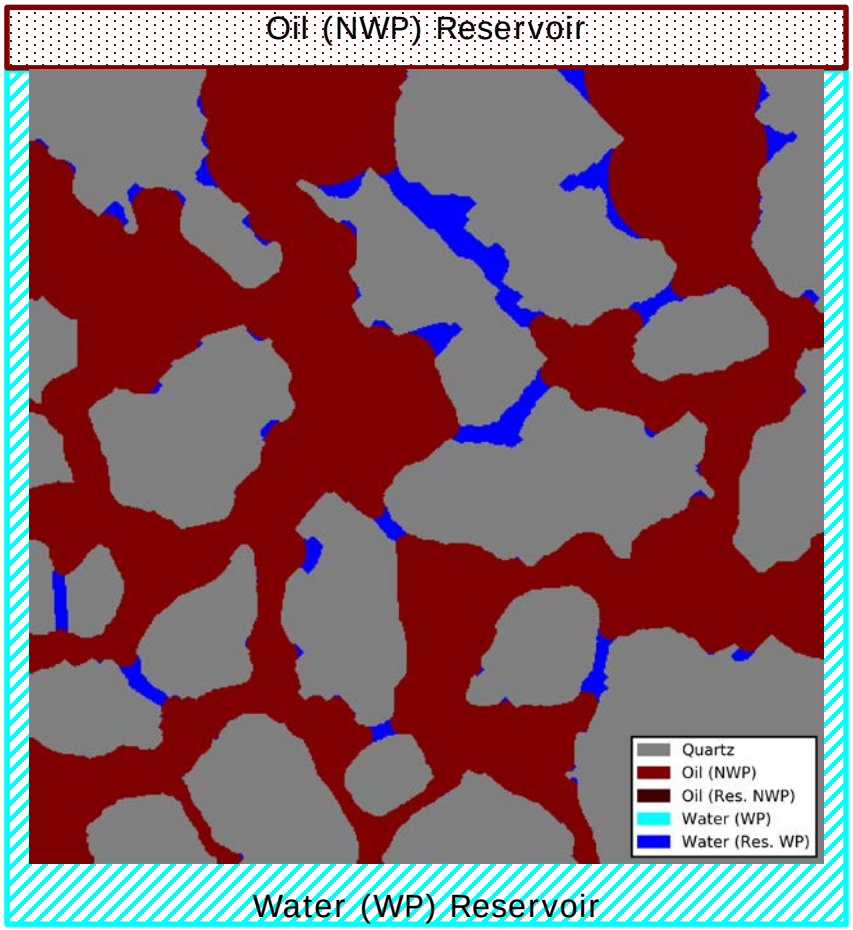
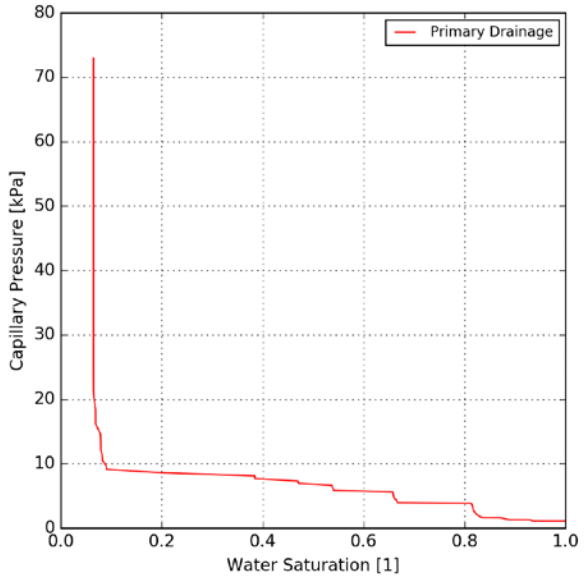


Primary Drainage
Oil displaces Water



1. Choose radii r_{min}, r_{max} and initial radius $r = r_{max}$
2. Move in spheres with radius r from the NWP-reservoir through large-pore-connected mobile NWP
3. Mark mobile WP that is not connected to WP-reservoir as residual WP
4. If $r > r_{min}$ then decrease r and goto step 2



Conclusions

- Simulation of filtration behavior based on VDI-Guideline 2762
- Filtration on the resolved & unresolved media were simulated
- Besides filter cake formation, the washing & drying steps were successfully simulated using GeoDict
- Permeability of filter cake & the specific cake resistance (α) were computed
- Optimal pressure for washing & drying processes were predicted
- Outlook: Optimization in wash liquid amount and washing/drying process time

Thank you for your attention.

Visit us in Hall No: 11.1, at Stand No: A11