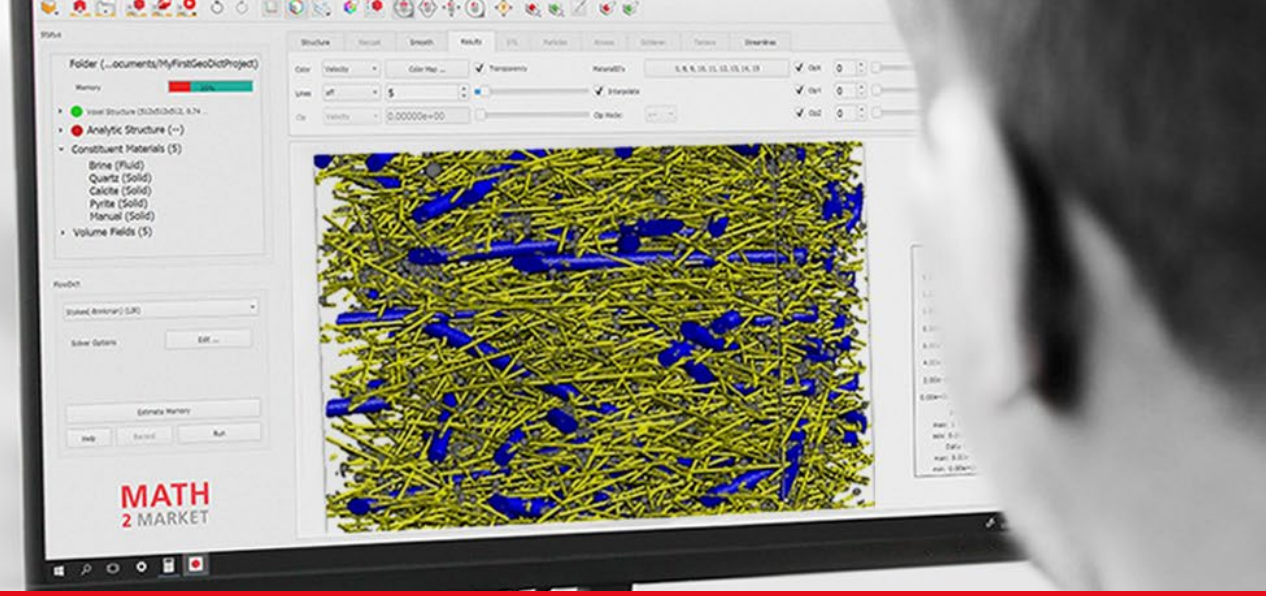
GeoDict
The Digital Material Laboratory



Computer-aided modeling, simulation and optimization of filter media

European Conference on Fluid-Particle Separation
(FPS 2018), October 15 – 17, Lyon, France

Dr.-Ing. Mehdi Azimian, Christopher Kühnle, Dr. Andreas Wiegmann

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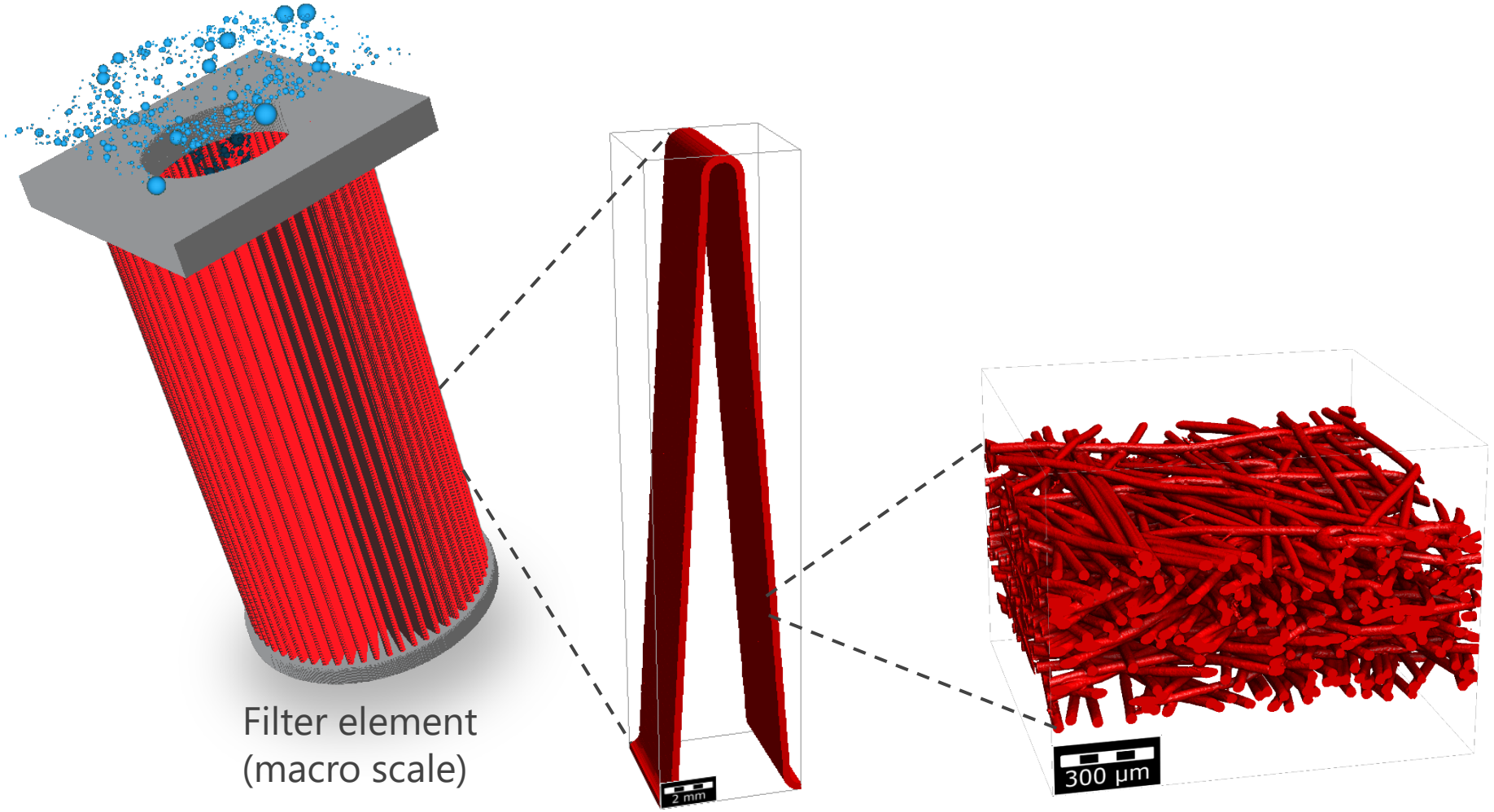
2 MARKET

Introduction

Simulation of filtration at different scales

GeoDict



Filter element
(macro scale)

Single pleated filter
(macro/meso scale)

Filter media
(micro scale)

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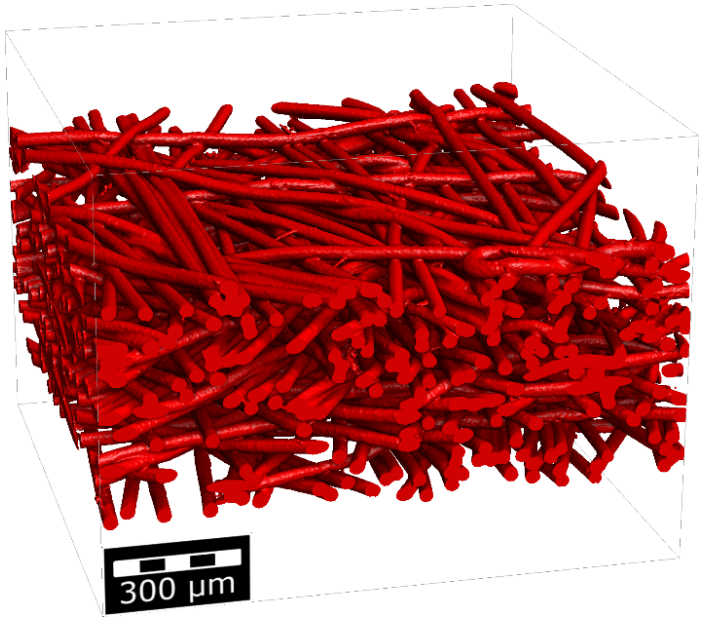
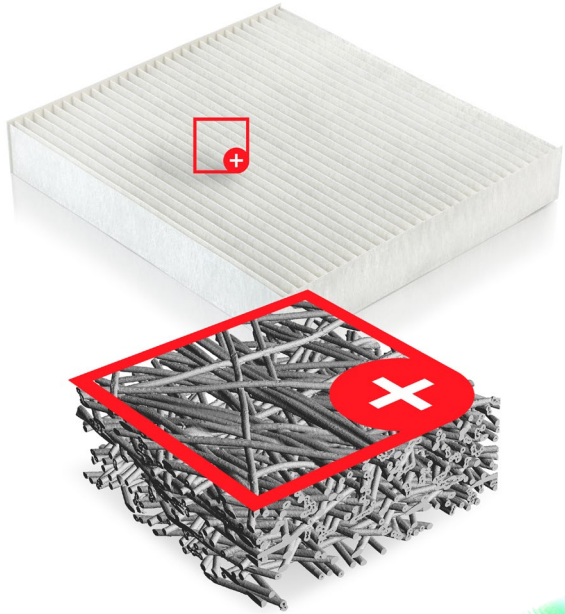
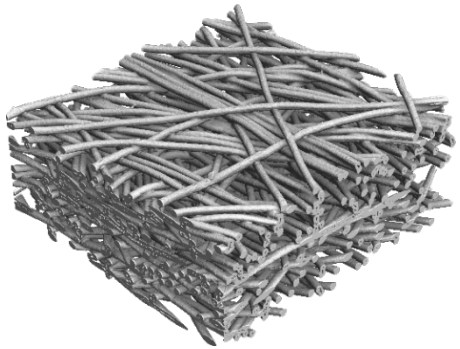
Filter media (micro scale)

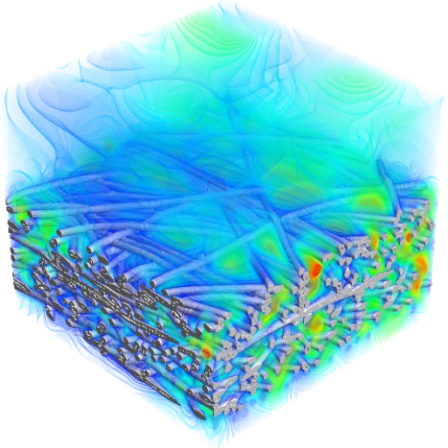


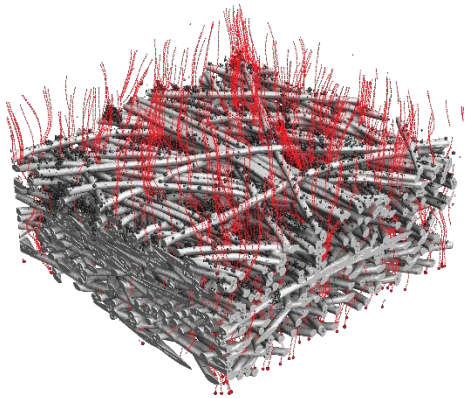
Simulation on the micro-structure of the filter media

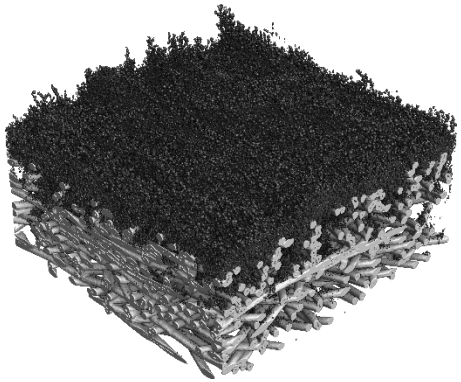
GeoDict











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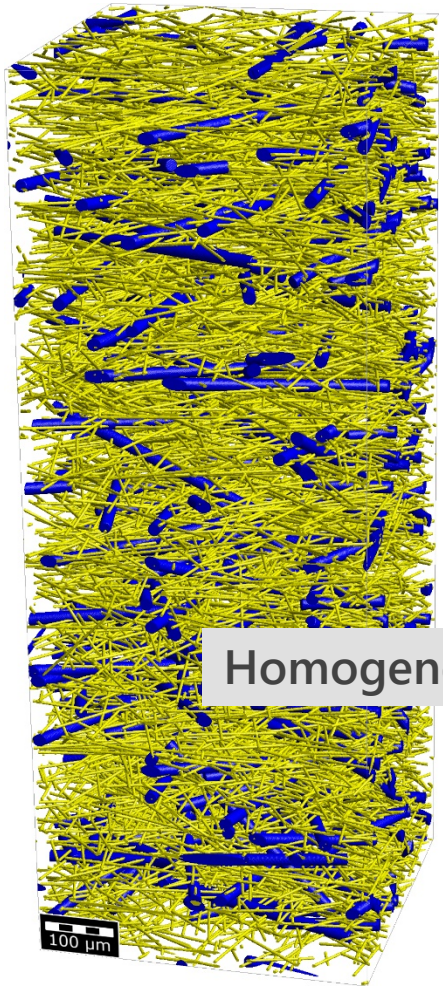
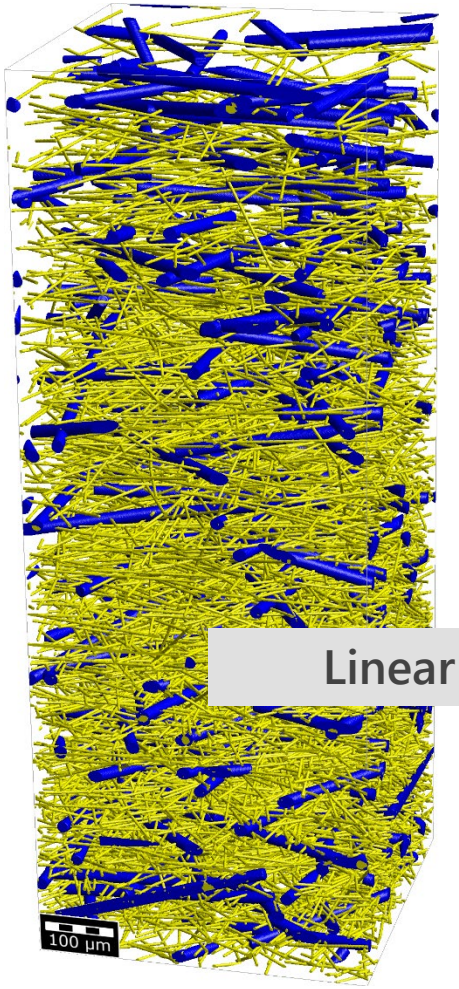
Modeling of three various filter media structures

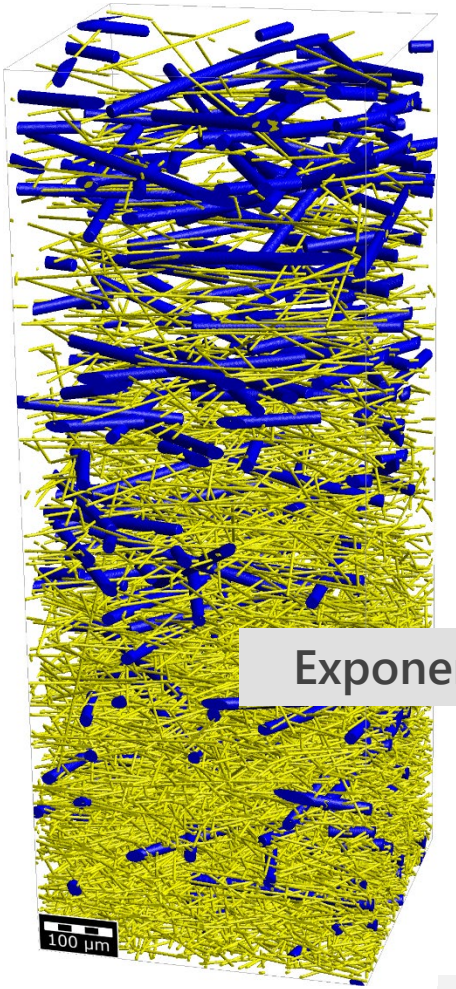
GeoDict



Homogeneous



Linear



Exponential

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Structural comparison of the three various filter media

GeoDict

Structure	Homogeneous	Linear	Exponential
Size [µm]	600x600x1600	600x600x1600	600x600x1600
Distribution of coarse fiber / fine fiber	Uniform / Uniform	Uniform / 1,2,3,4,5,6,7,8,9,10,11	Uniform / 1,2,4,8,16,32
Permeability [m²]	**5.47E-11**	**5.48E-11**	**5.53E-11**
$\beta_{22\mu m}$	**200**	**200**	**200**
Object solid volume percent in domain [%] (porosity [%])	6.11 (93.89)	5.9 (94.1)	5.43 (94.57)
Volume coarse fiber / Volume fine fiber	60/40	60/40	60/40

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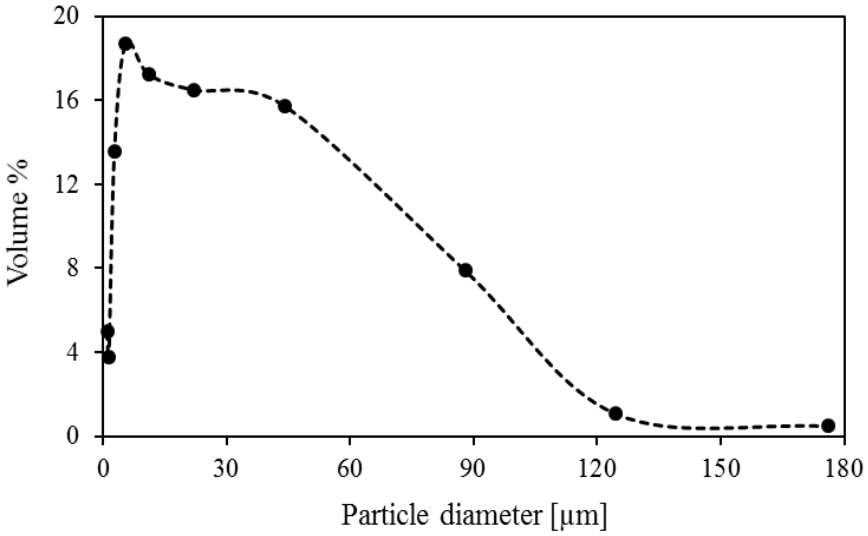
Particulate oil flow parameters

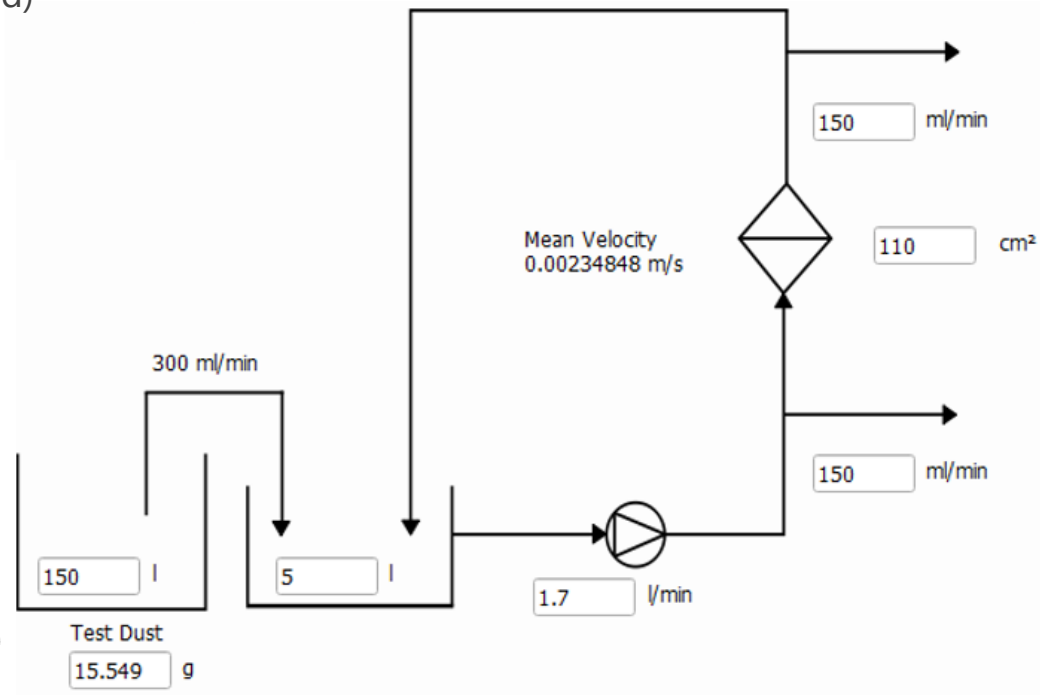
GeoDict

Fluid:	Oil
Temperature:	20 °C
Particles:	ISO Fine A2 test dust
Particle Density:	2560 kg/m³
Particle Collision Model:	Sieving
Solver:	LIR (Adaptive grids based)
Flow regime:	Laminar

Iso Fine A2 Test Dust Concentration



Multi-pass filter test schematic based on ISO 4548-12



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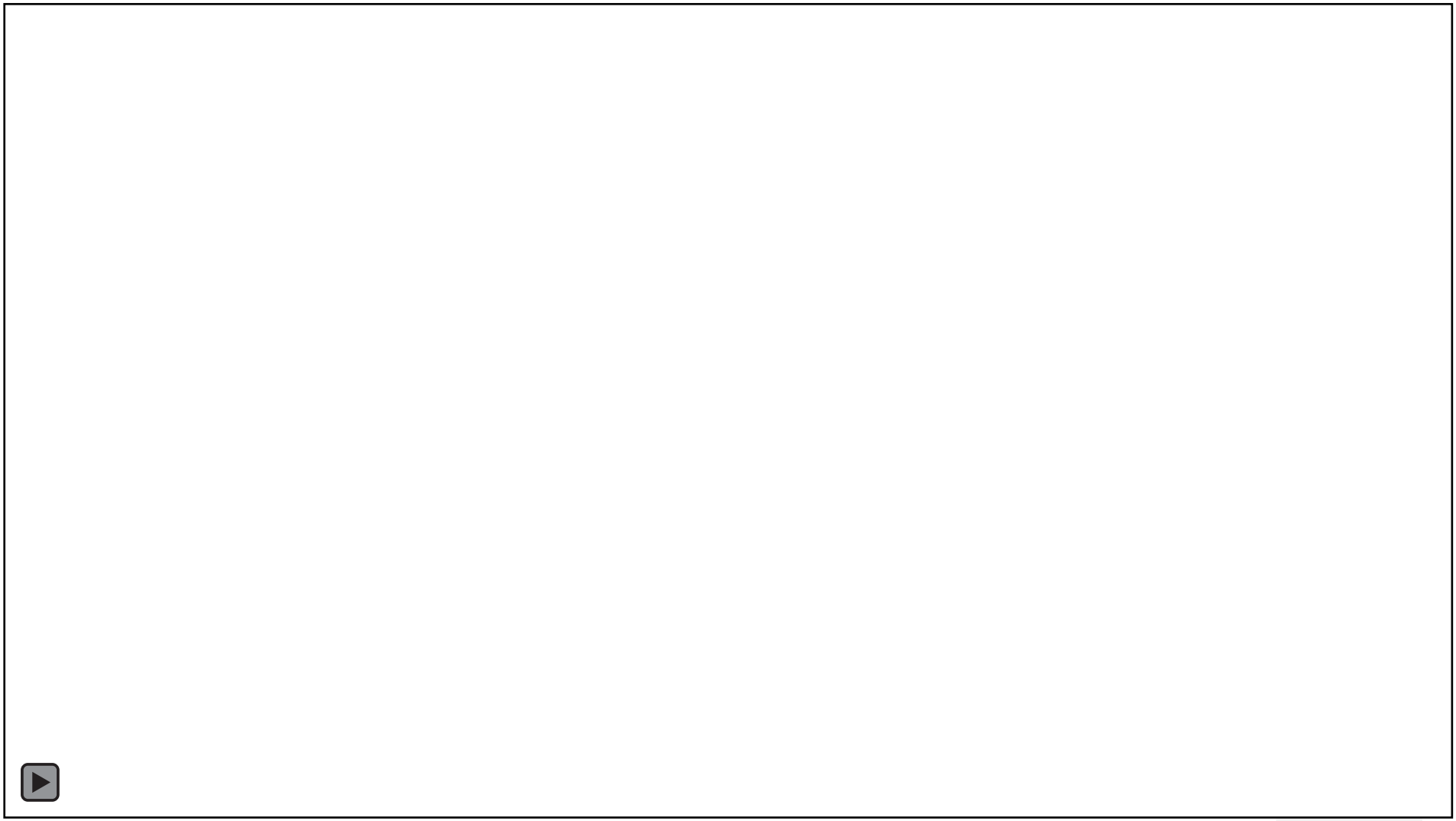
Animation of the transient filtration simulation (Linear structure)

GeoDict



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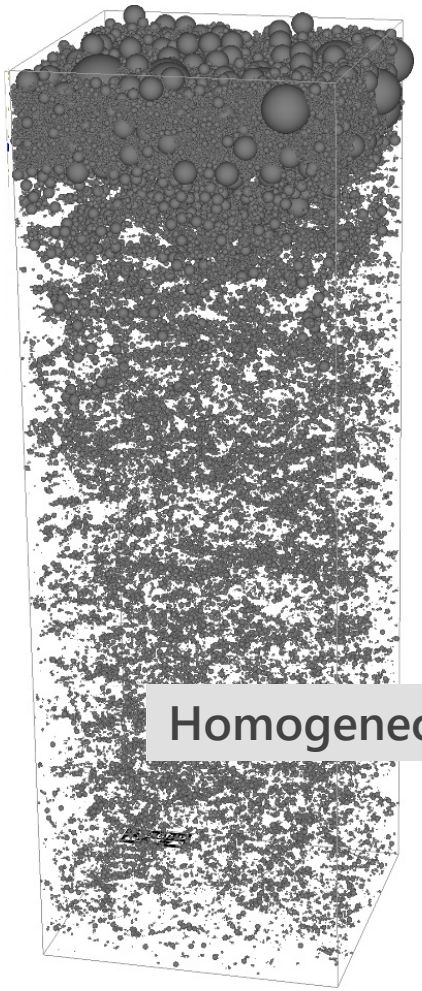
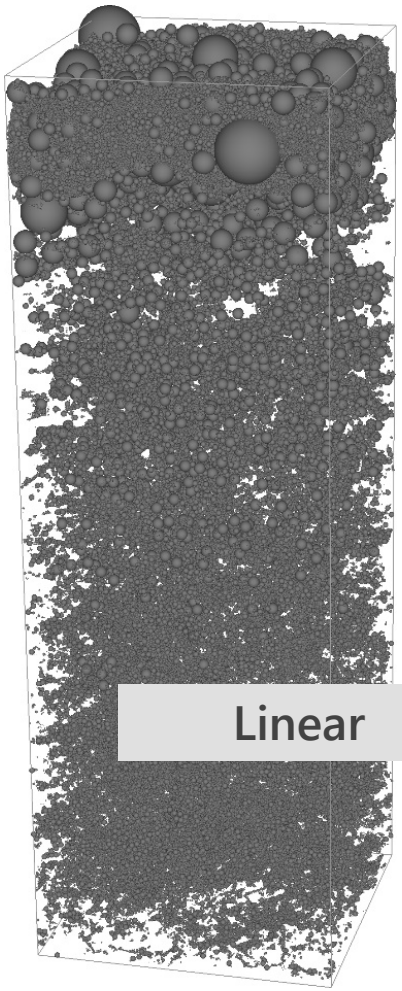
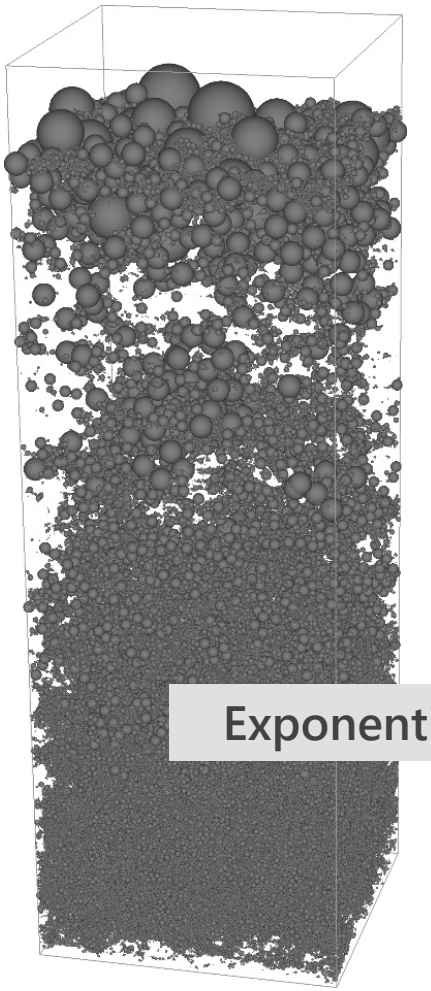
Comparison among the three structures



Homogeneous



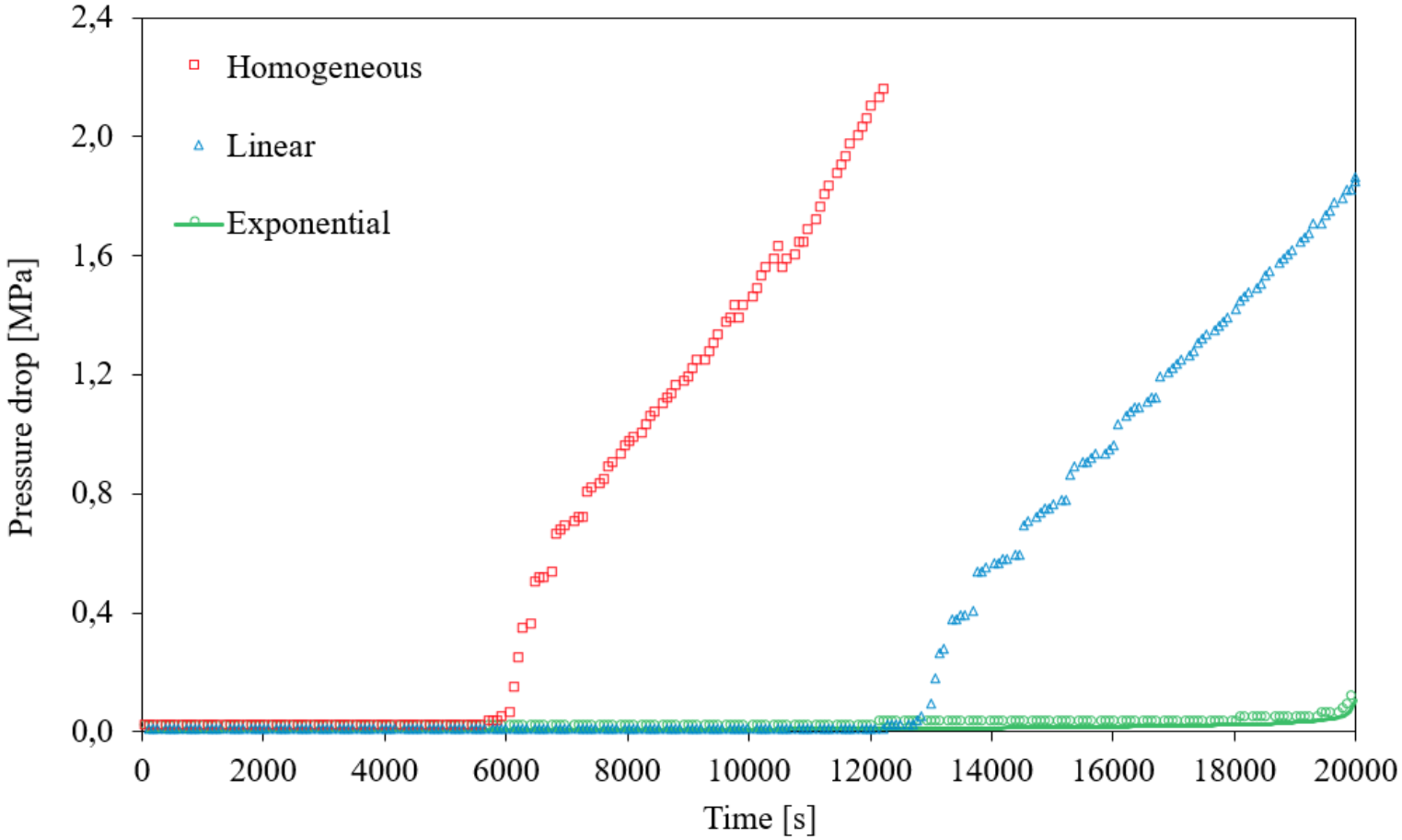
Linear



Exponential

Multipass simulation results: Pressure-drop over time

GeoDict



- The exponentially increasing media shows the lowest pressure-drop increase through the life-time simulations.

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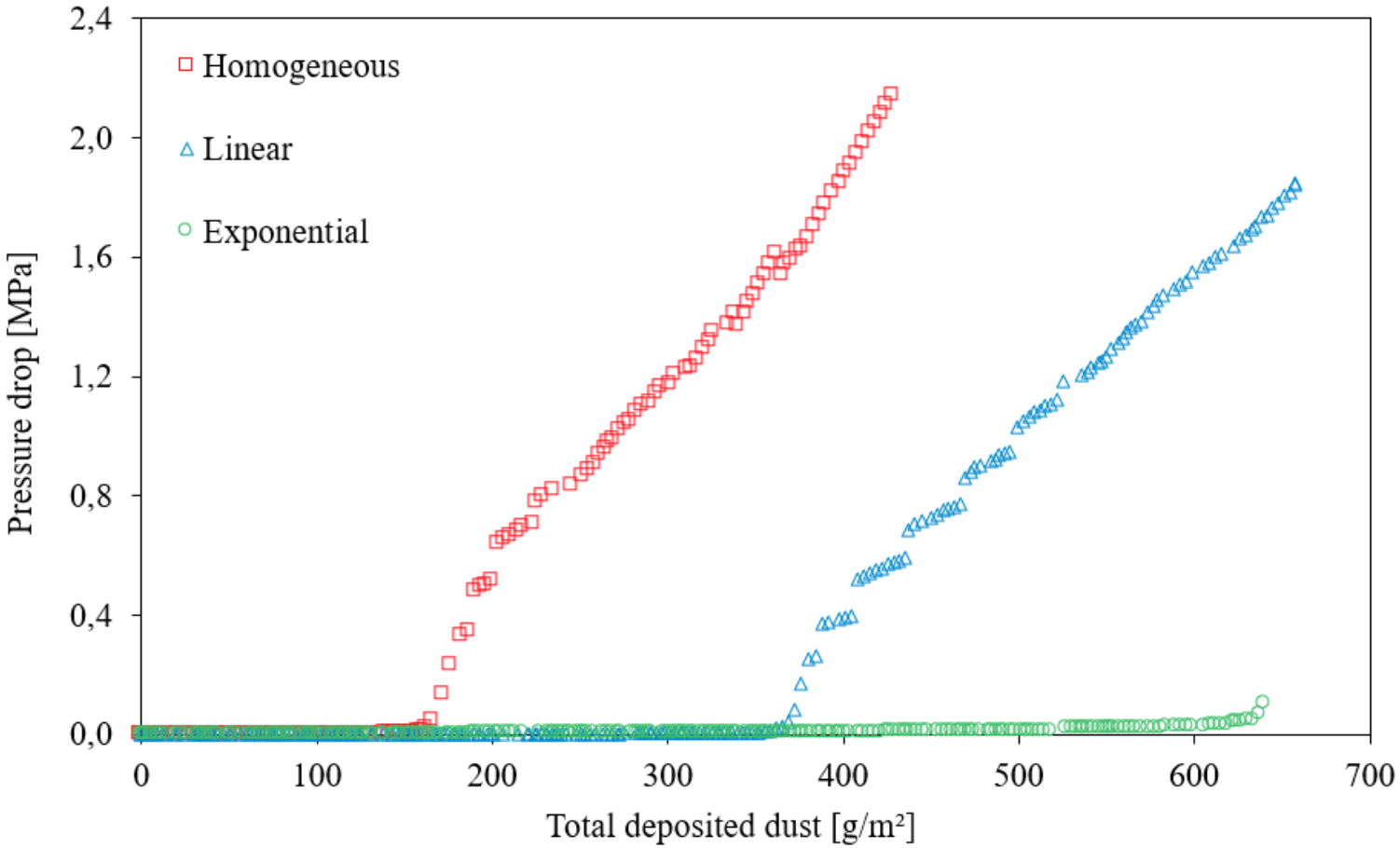
Multipass simulation results: Pressure-drop over total deposited dust

GeoDict



- The exponentially increasing media shows the lowest pressure-drop increase & the highest DHC through the life-time simulations.

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Save in material

GeoDict

Structure	Homogeneous	Linear	Exponential
Size [µm]	600x600x1600	600x600x1600	600x600x1600
Distribution of coarse fiber / fine fiber	Uniform / Uniform	Uniform / 1,2,3,4,5,6,7,8,9,10,11	Uniform / 1,2,4,8,16,32
Permeability [m²]	5.47E-11	5.48E-11	5.53E-11
$\beta_{22\mu m}$	200	200	200
Object solid volume percent in domain [%] (porosity [%])	**6.11 (93.89)**	**5.9 (94.1)**	**5.43 (94.57)**
Volume coarse fiber / Volume fine fiber	60/40	60/40	60/40

M. Azimian, C. Kühnle, A. Wiegmann, Design and optimization of fibrous filter media using life-time multi-pass simulations, Chemical Engineering & Technology, 2018, 41, No. 5, 1–9. doi.org/10.1002/ceat.201700585

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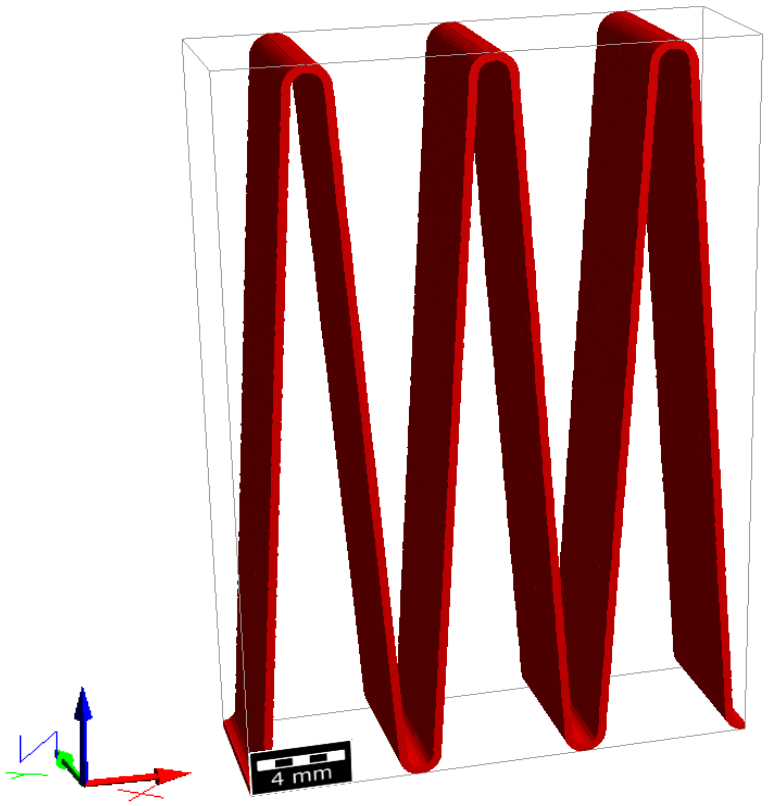
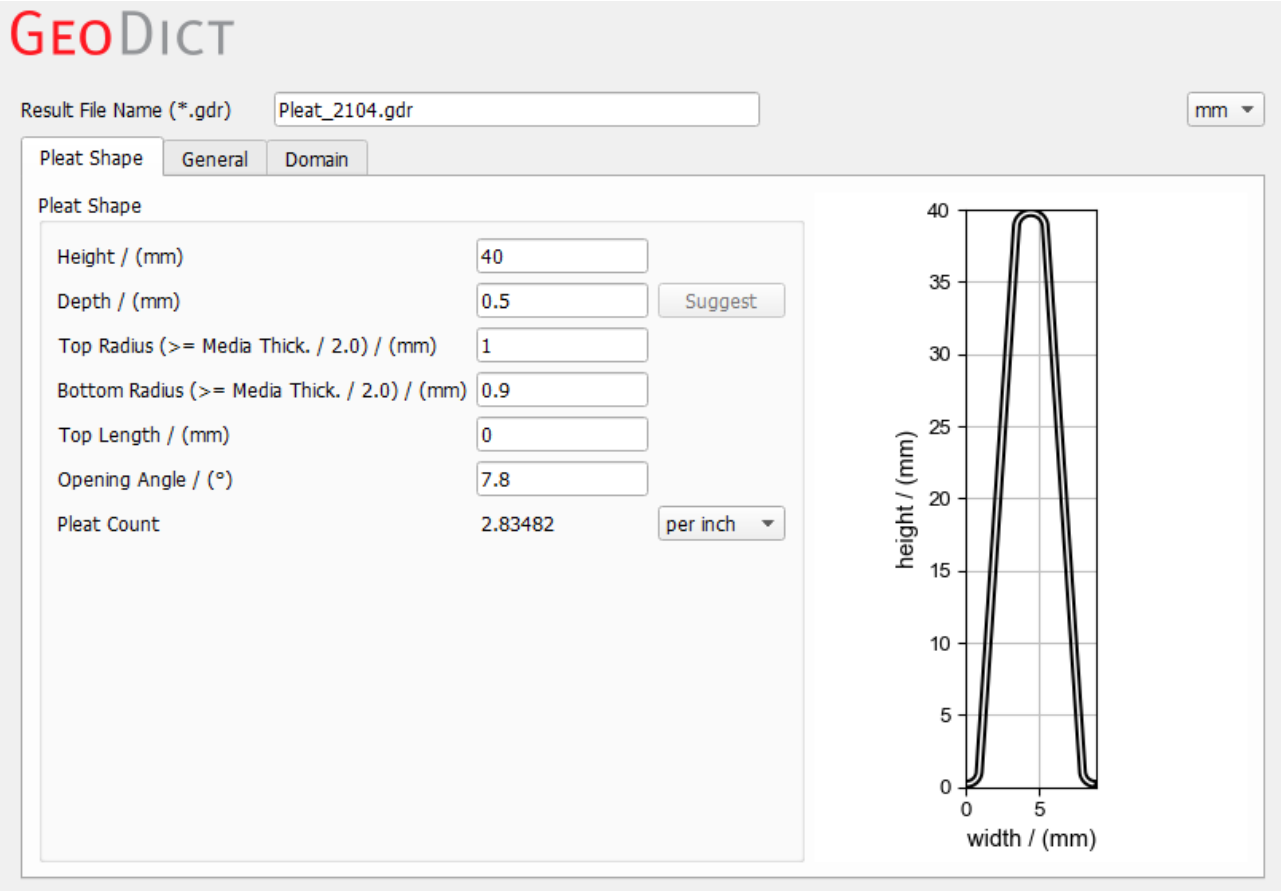
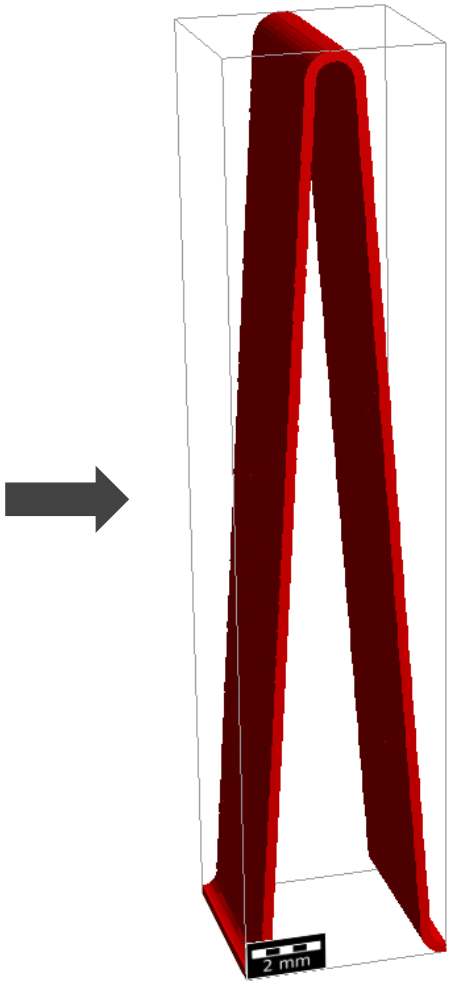
Pleated filter (macro/meso scale)



Geometric model of the pleated filter generated with PleatGeo

GeoDict





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Main input parameters for the macro-scale simulation

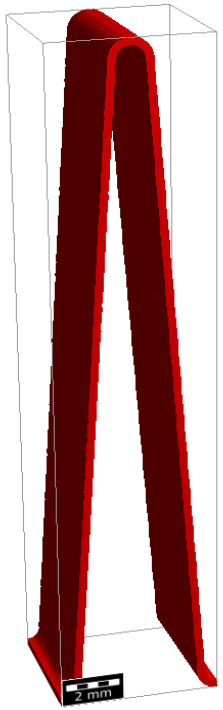
GeoDict

Goal is to model, simulate & optimize pleated filters and to analyze the filtration characteristics such as pressure drop & dust holding capacity.

(Reduction in experiments costs & save time)

Main input parameters for the macro-scale simulation, which are related to the micro-structure of the media, are:

- Permeability of the media
- Max. particle packing density and max. flow resistivity of depth filtration regime (f_{max} & σ_{max} for depth filtration)
- Max. particle packing density and max. flow resistivity of cake filtration regime (f_{max} & σ_{max} for cake filtration)
- Fractional filtration efficiencies (filtration efficiency for each particle size class)



Single pleated filter

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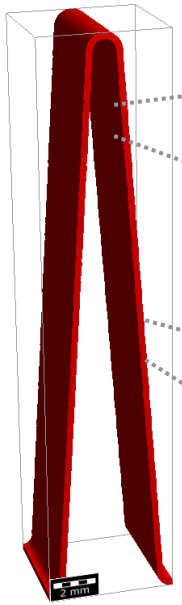
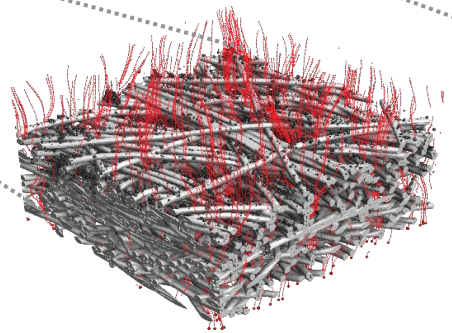
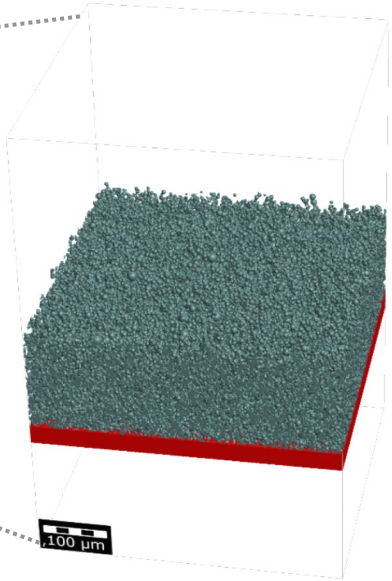
Identification of parameters

GeoDict

Estimate max. particles packing density & max. flow resistivity







Particles deposited in/on pleated filter element

Simulation requires:

f_{max}: max. particles packing density
σ_{max}: corresponding flow resistivity

Particles deposited through the micro-structure

high resolution simulation to approximate:
f_{max} & σ_{max} for depth filtration

Particles deposited on a grid frame

high resolution simulation to identify:
f_{max} & σ_{max} for cake filtration

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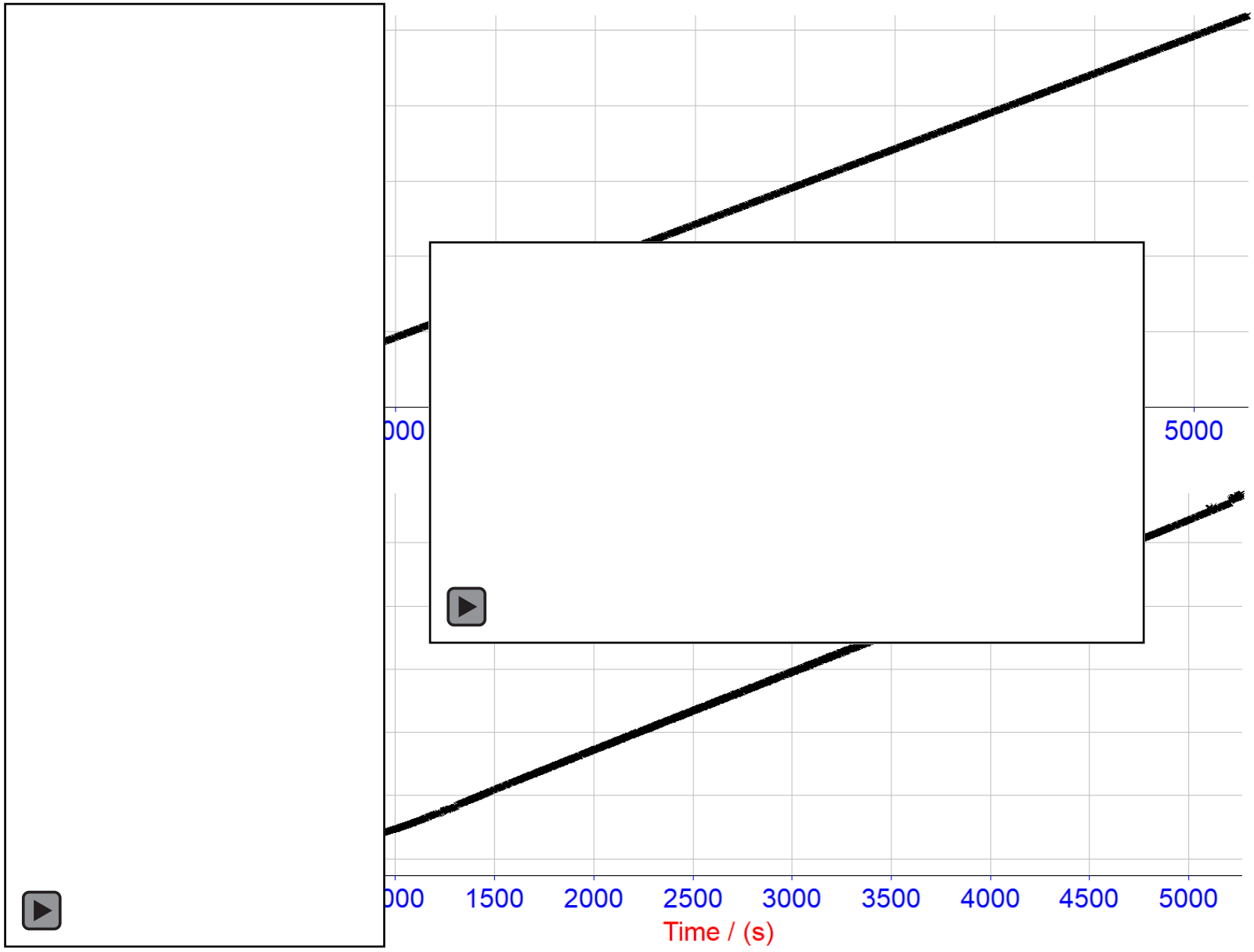
Simulation of the pleated filter clogging

GeoDict



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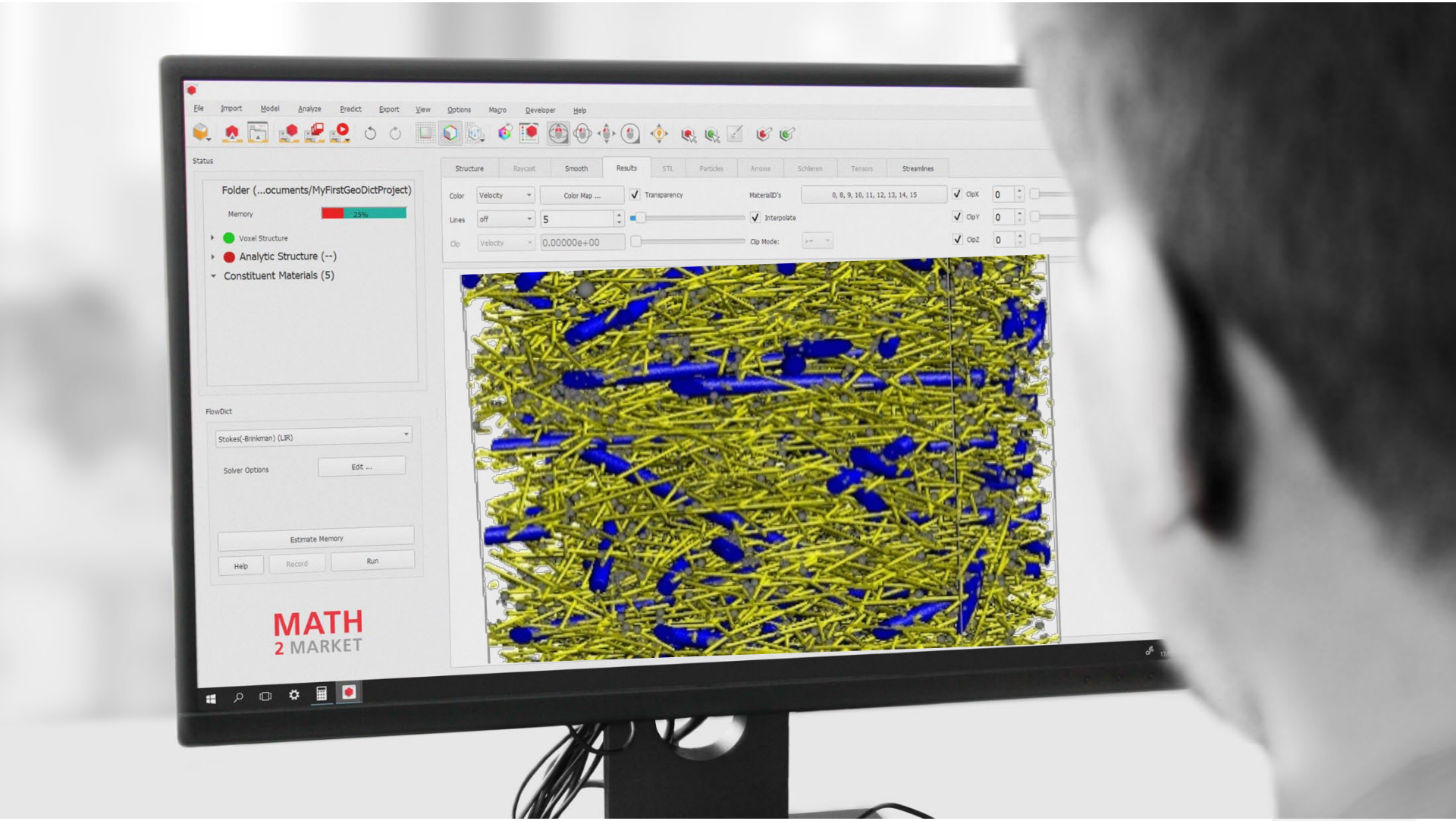
Conclusions

- ✓ The micro-structure of filter media can be modeled using GeoDict structure-generators or by importing µCT-scans &/or FIB-SEM images.
- ✓ By modification of the micro-structure of filter media, the macroscopic properties can be optimized.
- ✓ The gradient distribution of fibers through the media thickness, can improve the filtration characteristics.
- ✓ The exponential media shows the lowest pressure-drop increase & the highest DHC through the life-time simulations.
- ✓ Pleated filter can be modeled using PleatGeo module of GeoDict.
- ✓ Main input parameters for the macro-scale simulation, can be obtained from the simulation of the media micro-structure. (save in experimental tests)

Thank you for your attention.
Visit me at Math2Market booth

GeoDict



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