Optimization of filter media structures with GeoDict

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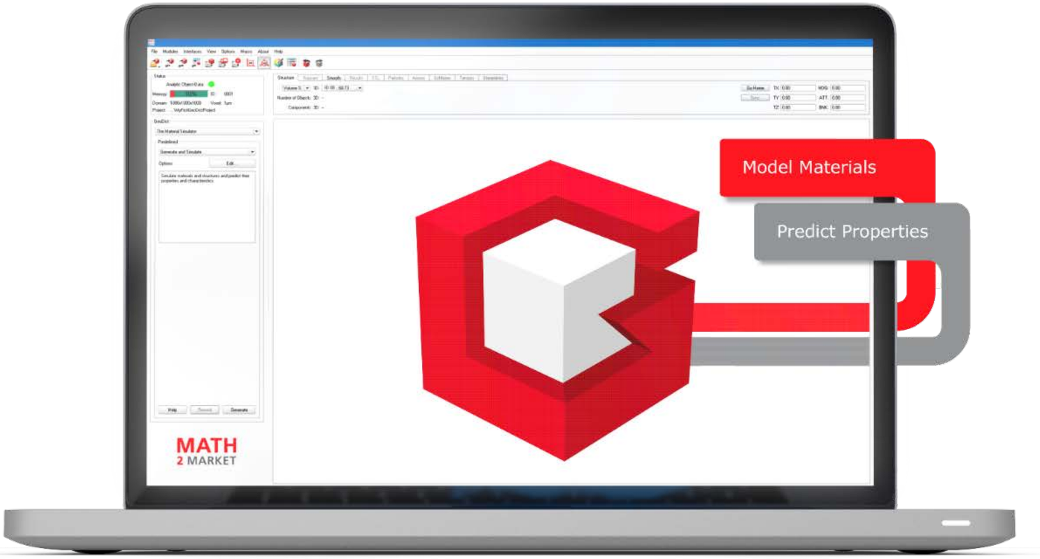
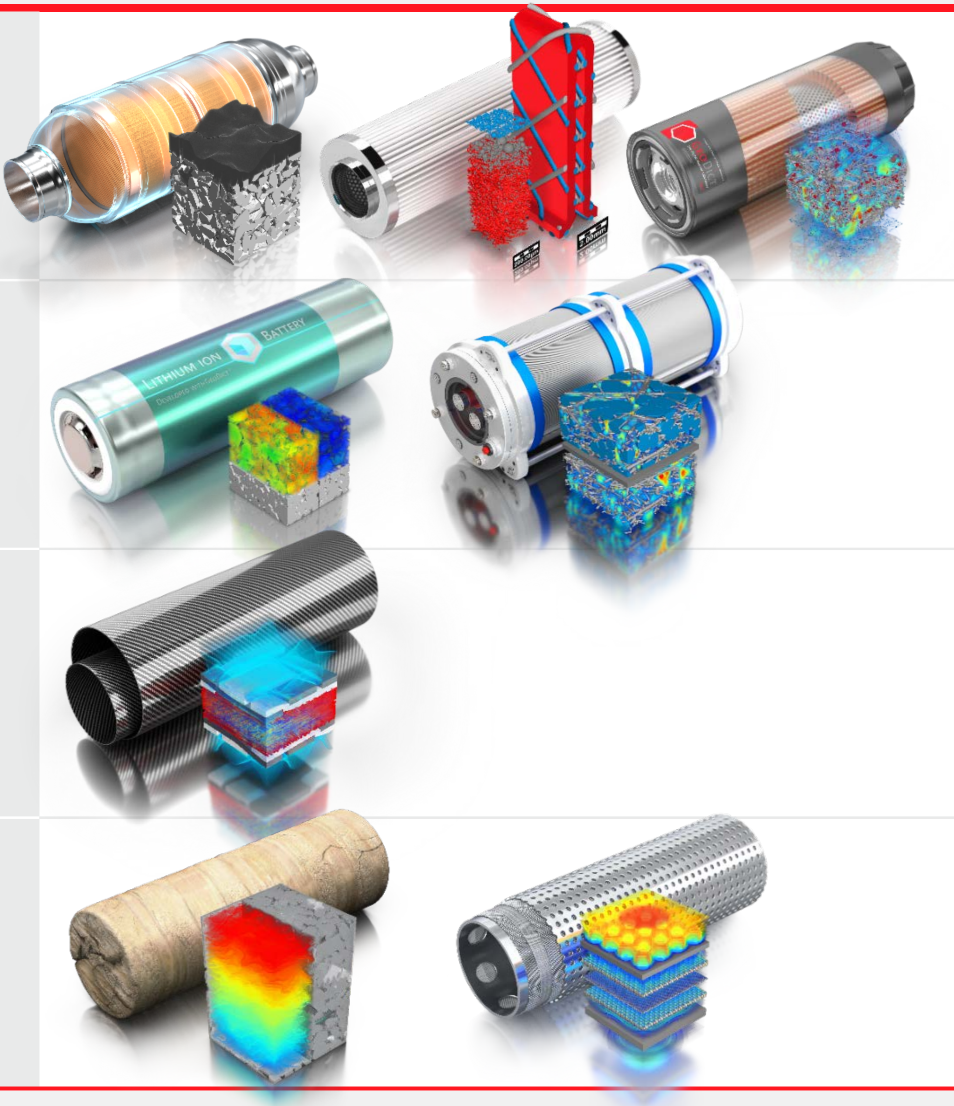


Math2Market GmbH overview

GeoDict The Digital Material Laboratory

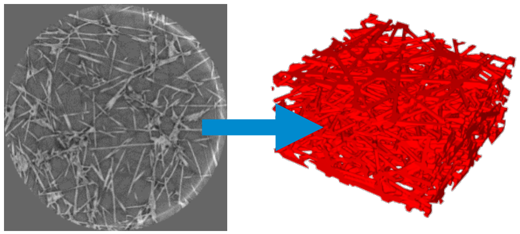
Filtration	Mostly automotive, filter media & filters for water, sludge, oil, air and fuel
Electrochemistry	Fuel cell media & battery materials, catalyst materials
Composites	CFRP, GFRP, mostly automotive, lightweight materials
Oil and Gas	Digital rock physics, digital sand control



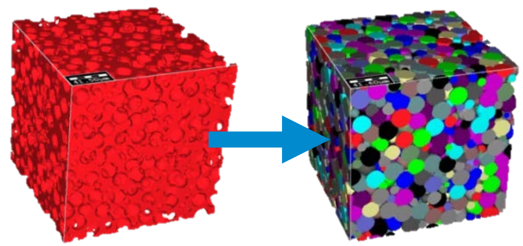
GeoDict introduction

With GeoDict you can…

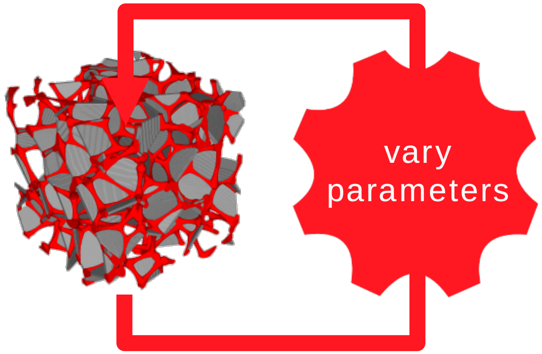
Import µCT & FIB-SEM



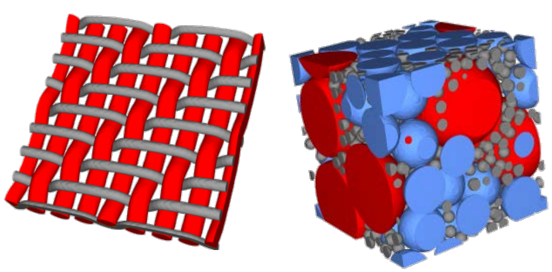
Analyse Materials



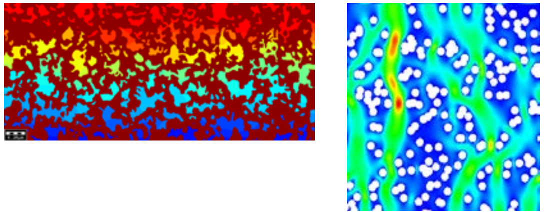
Optimize Materials



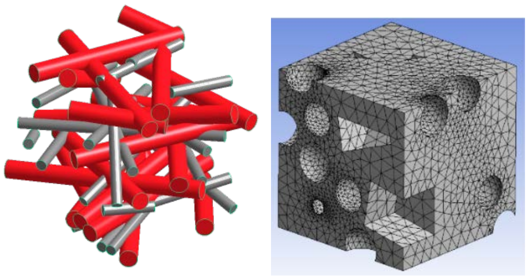
Model Materials



Analyse Properties

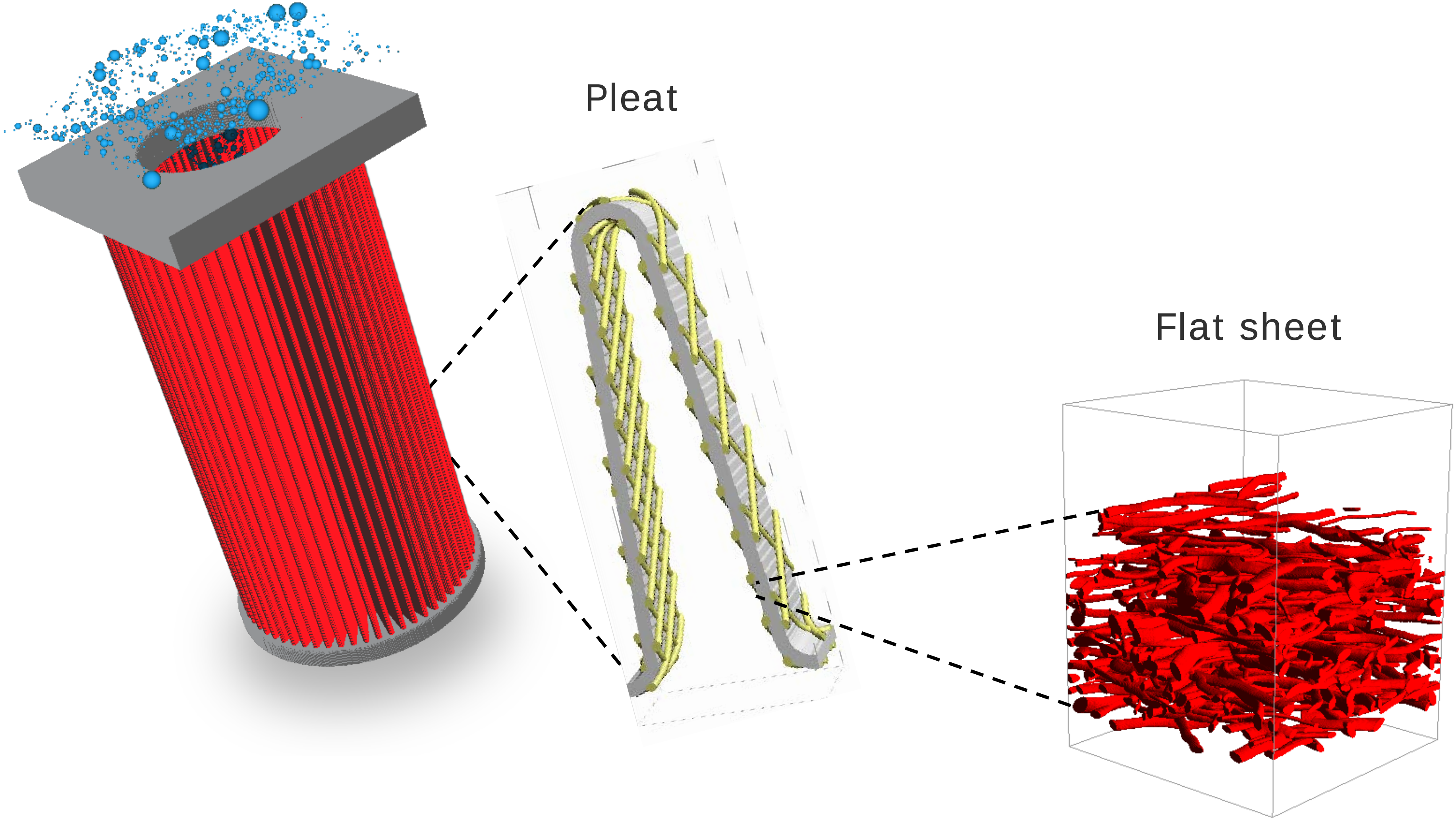


Export Materials



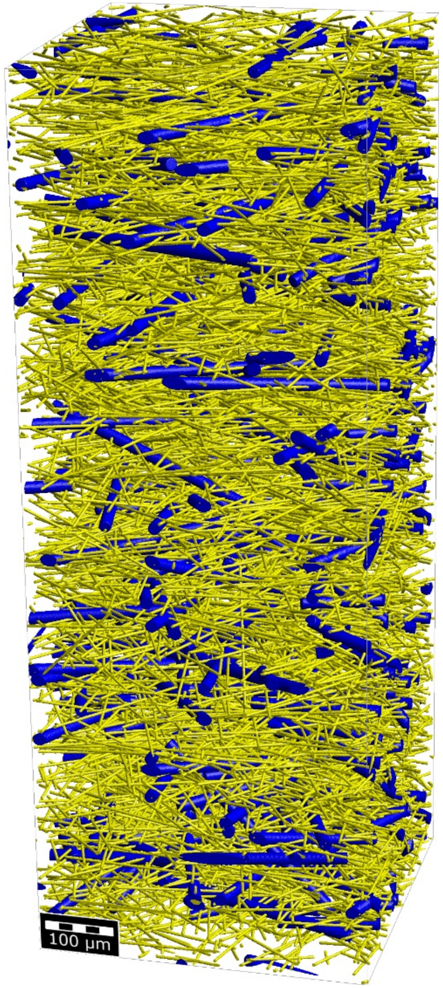
Modeling, simulation & optimization of micro-structure of filter media

Simulate filtration at different scales

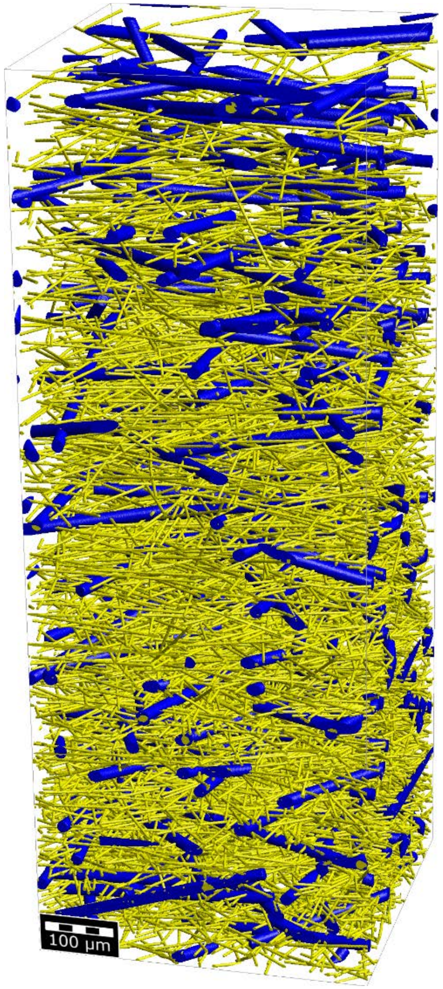


Modeling of three different types of filter media structures

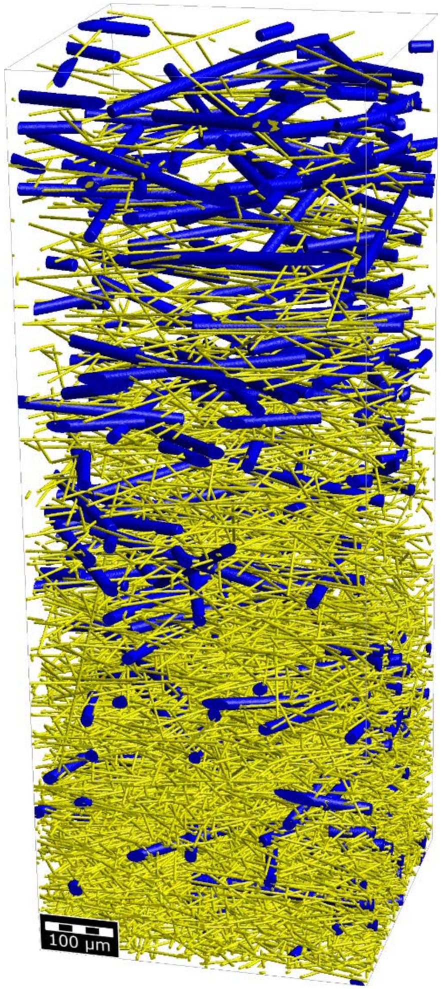
Homogeneous



Linear



Exponential



Modeling of three different types of filter media structures

Thick glass fibers
- Homogeneous

+

Thin glass fibers
- Homogeneous
- Linear
- Exponential

=

Three structure types
- Same initial pressure-drop
- Same β ratio

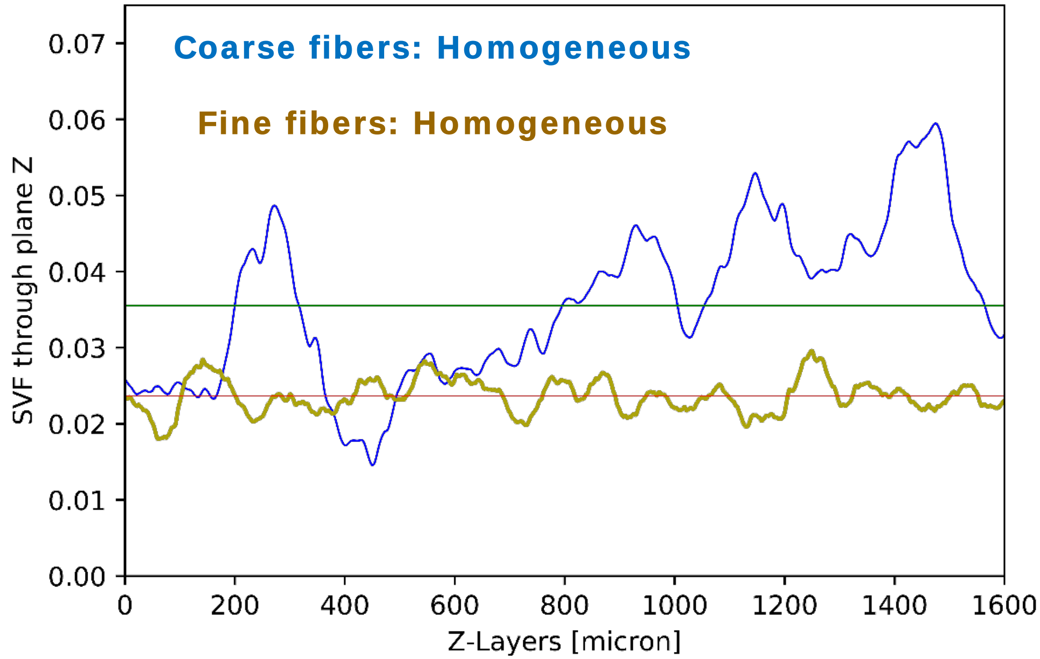
Thick fibers (blue):
Diameter: 20 µm
Orientation: Anisotropic 8/1
Material: Glass
Vol. ratio: 60%

Thin fibers (Yellow):
Diameter: 4 µm
Orientation: Anisotropic 8/1
Material: Glass
Vol. ratio: 40%

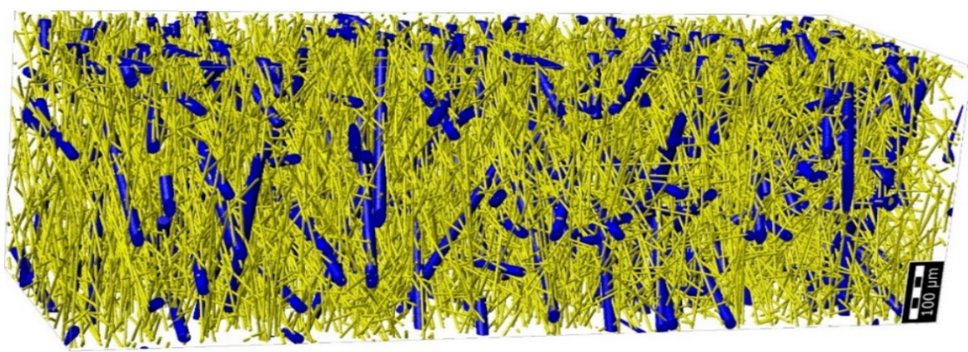
$$\beta_d = \frac{n_{d,U}}{n_{d,D}} = \frac{100}{100 - e}$$

Anisotropic Orientation: The material is compressed in the Z-direction & the fibers are isotropic in the XY-plane (Z-slice). The higher the value of the first component of Anisotropy, the stronger is the anisotropy.

Homogeneous media



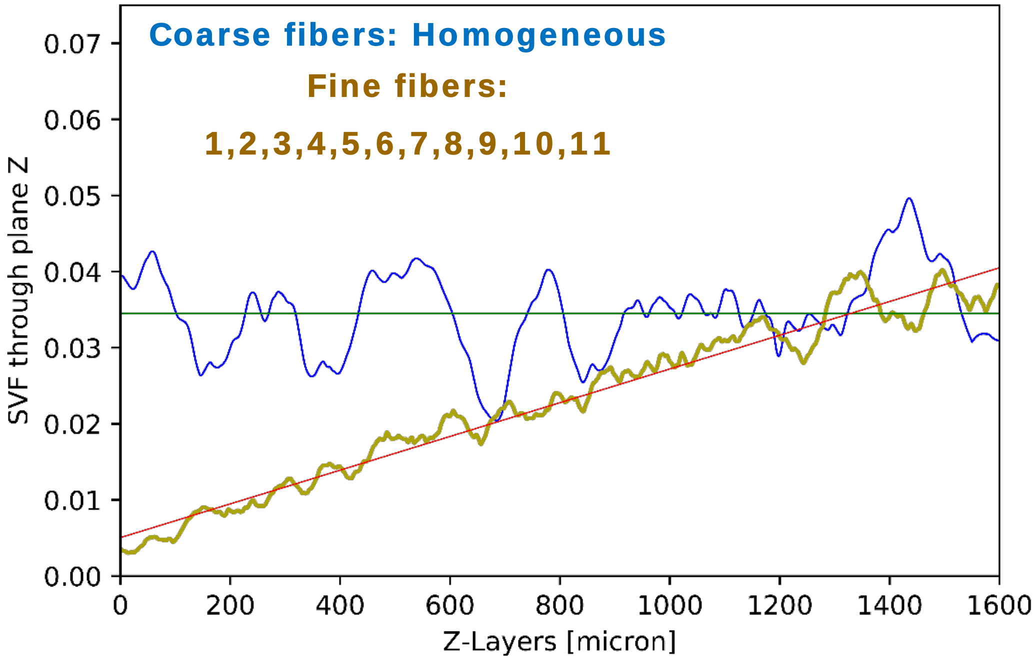
Flow direction



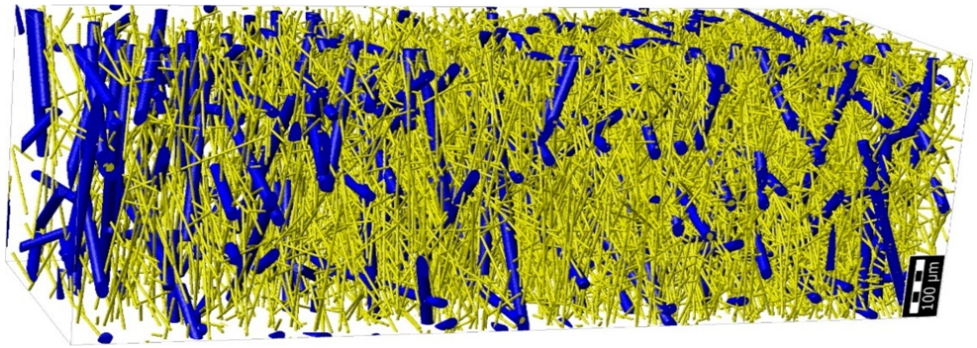
Domain

600x600x1600 µm

Linear media



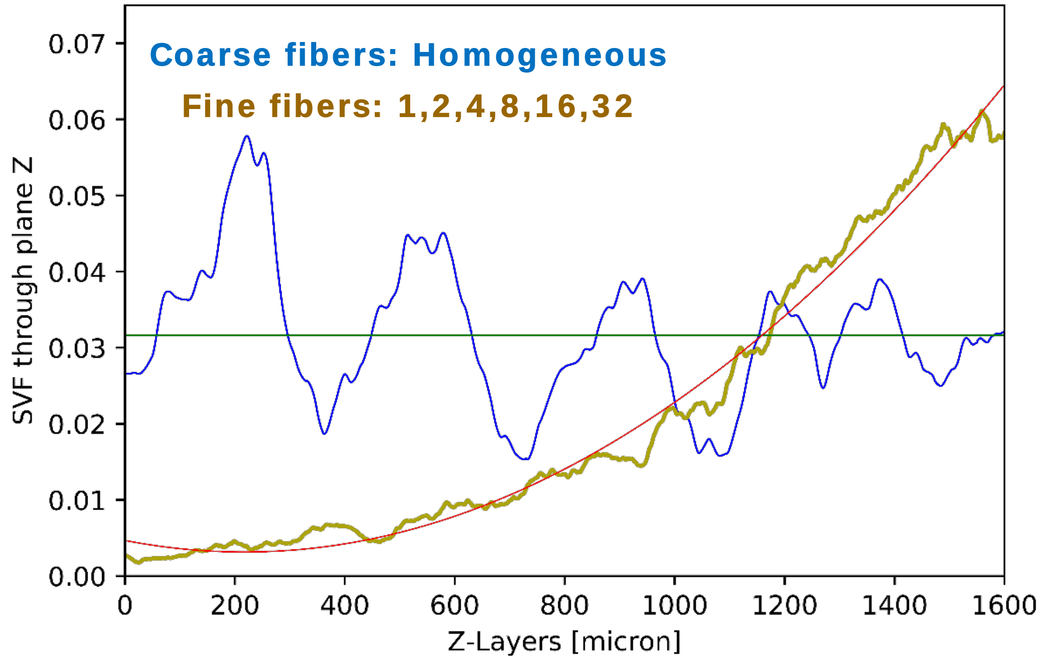
Flow direction



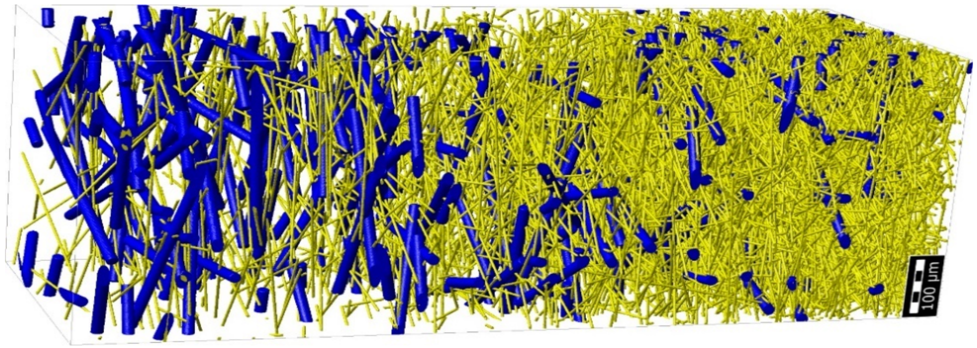
Domain

600x600x1600 µm

Exponential media



Flow direction



Domain

600x600x1600 µm

Structural comparison of the three filter media types

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 percentage in domain (porosity in %)	6.11 (93.89 %)	5.9 (94.1 %)	5.43 (94.57 %)
Volume coarse fiber / Volume fine fiber	60/40	60/40	60/40

Particulate oil flow parameters

Used Fluid: Oil

Temperature: 20 °C

Used Particles: ISO Fine A2 test dust

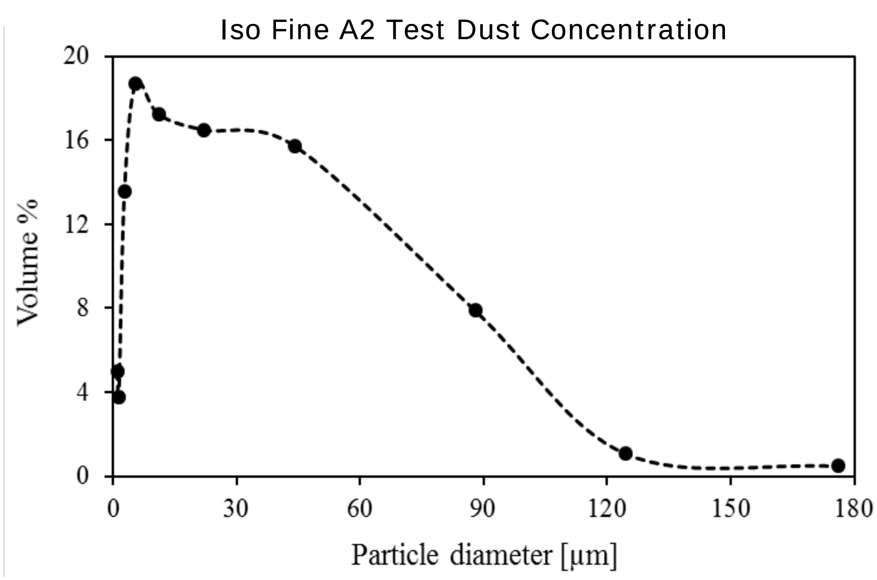
Particle Density: 2560 kg/m³

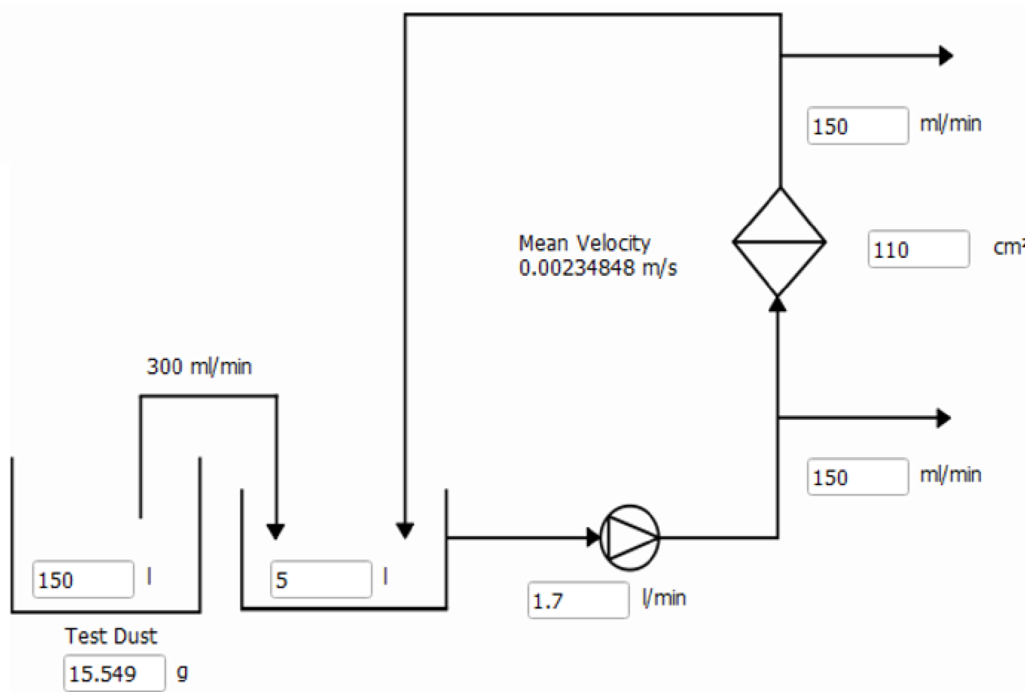
Particle Collision Model: Sieving

Solver: LIR (Adaptive grids based)

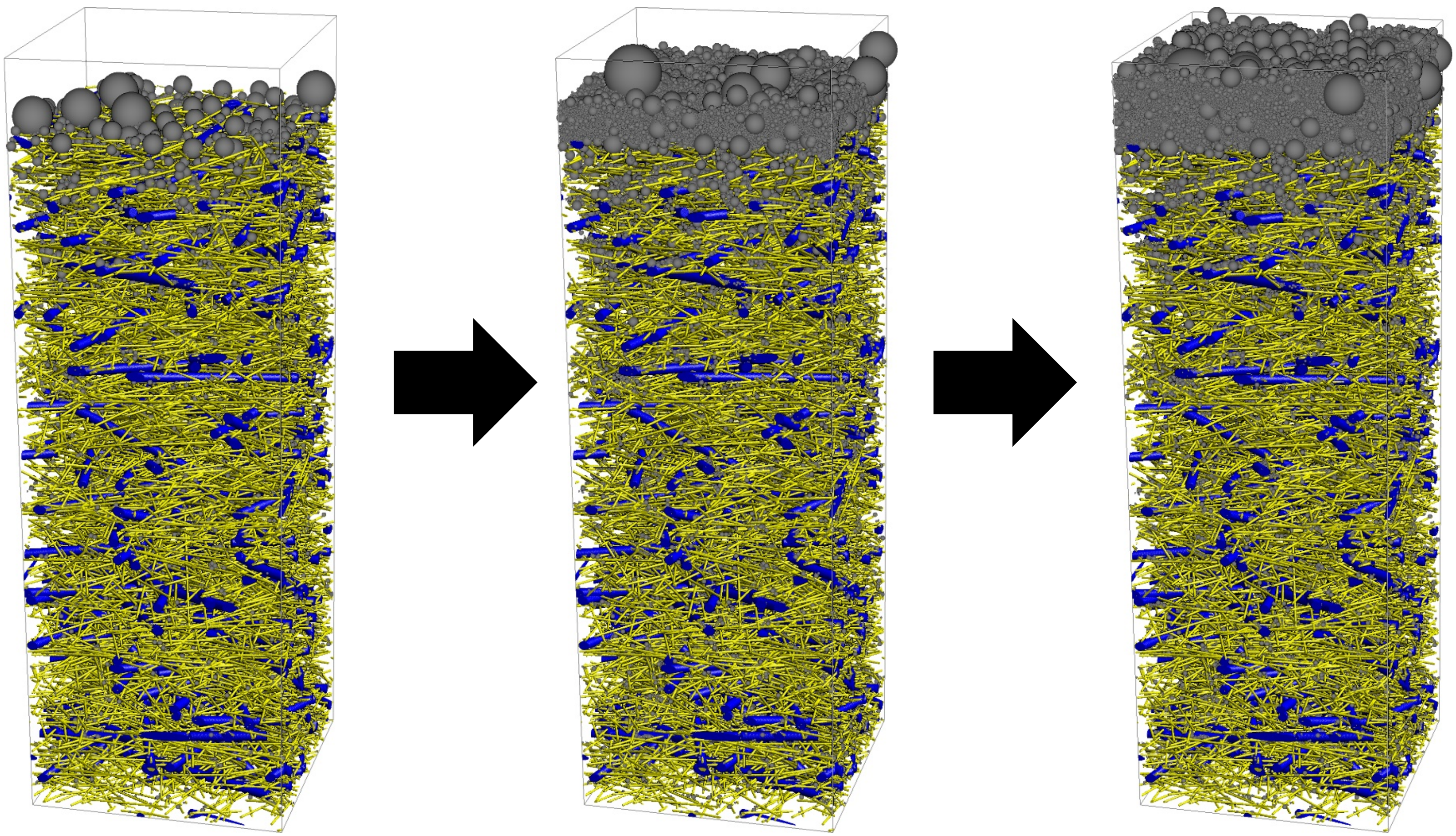
Flow regime: Laminar

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



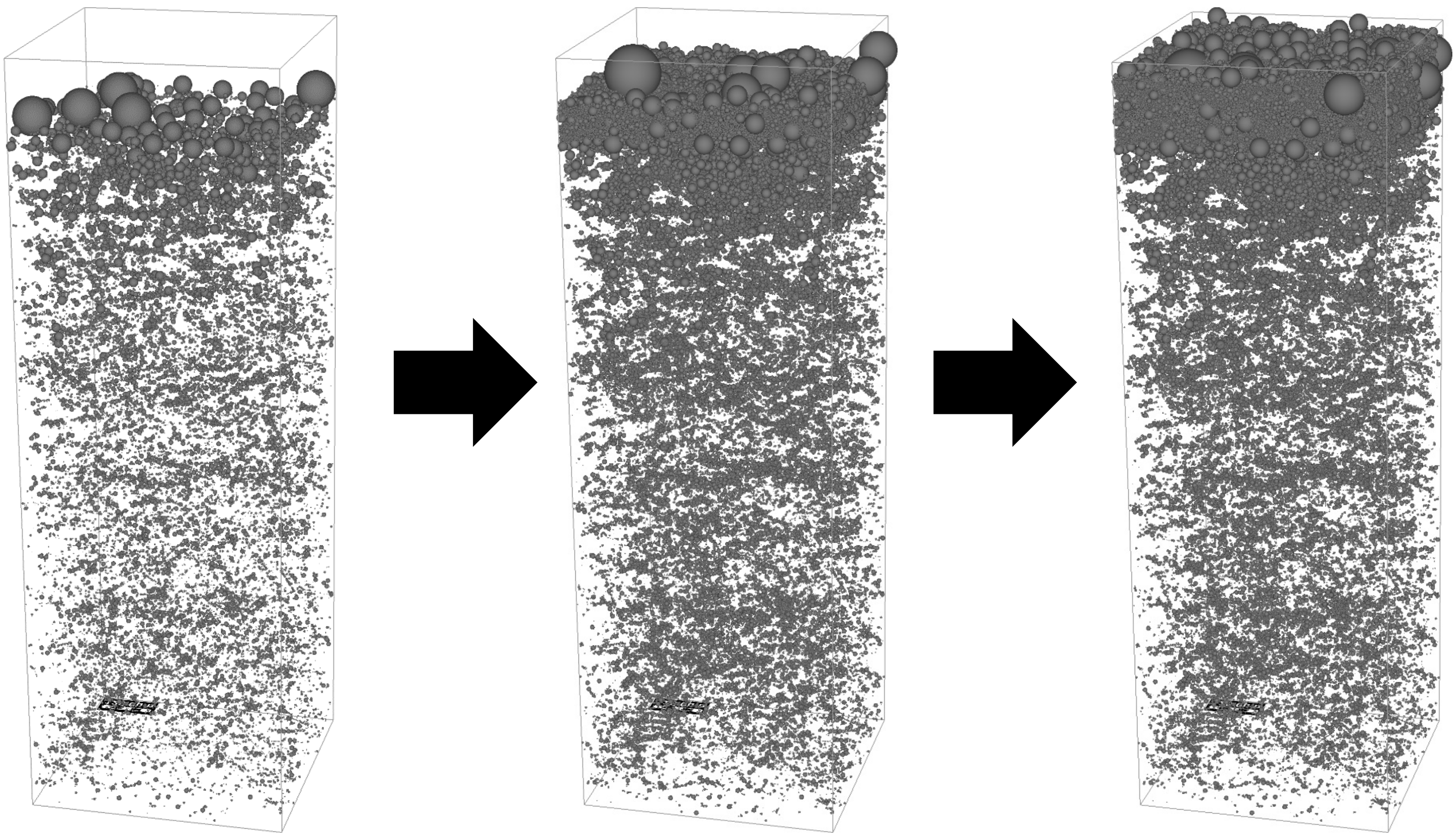


Transient filtration simulation (Homogeneous media)



2650 s   8733 s   11340 s

Transient filtration simulation (Homogeneous media)

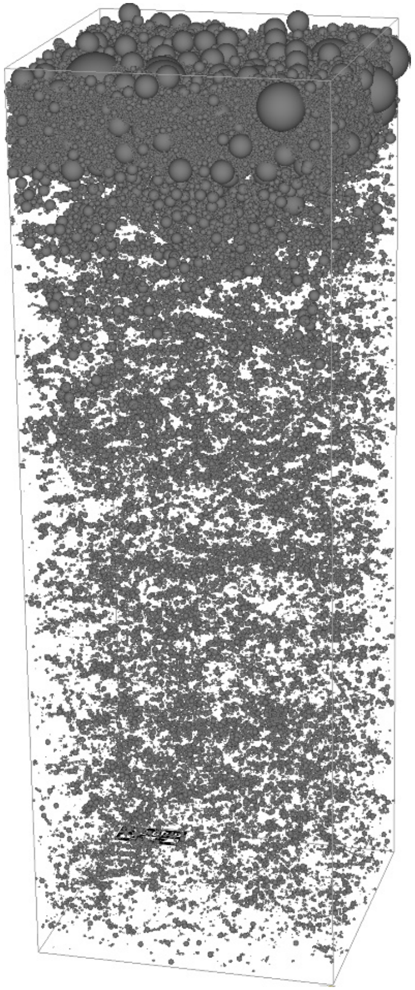


2650 s | 8733 s | 11340 s

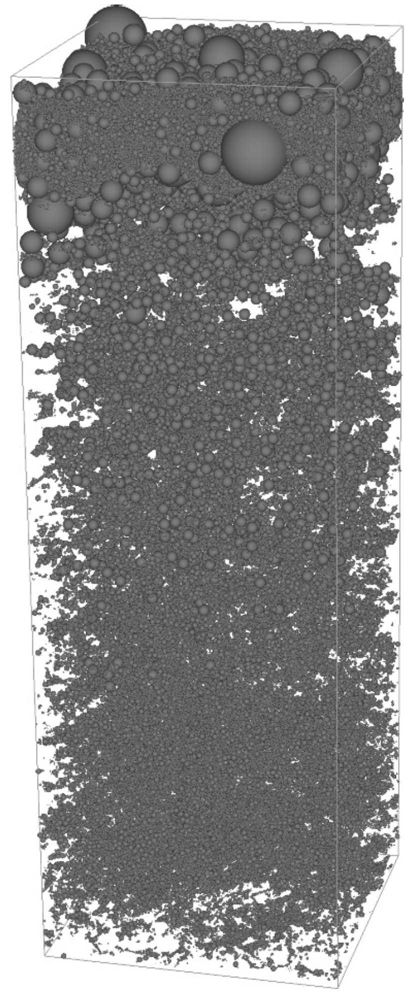
Animation of the transient filtration simulation (Linear media)

Comparison of the three media types

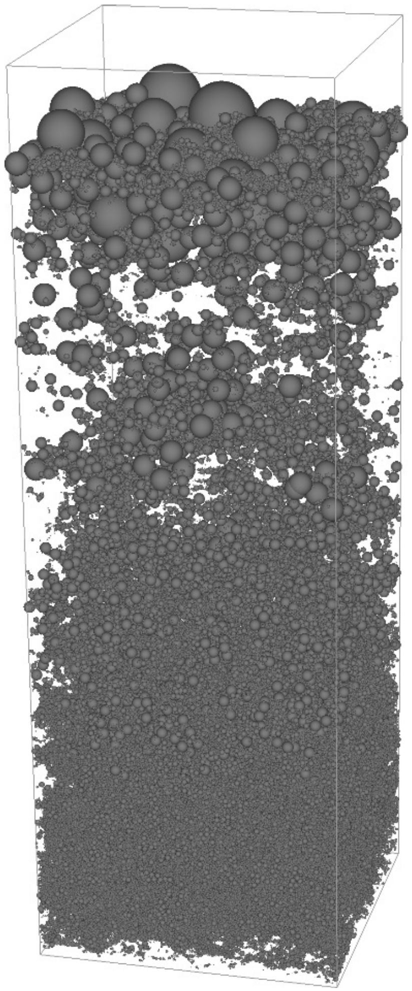
Homogeneous



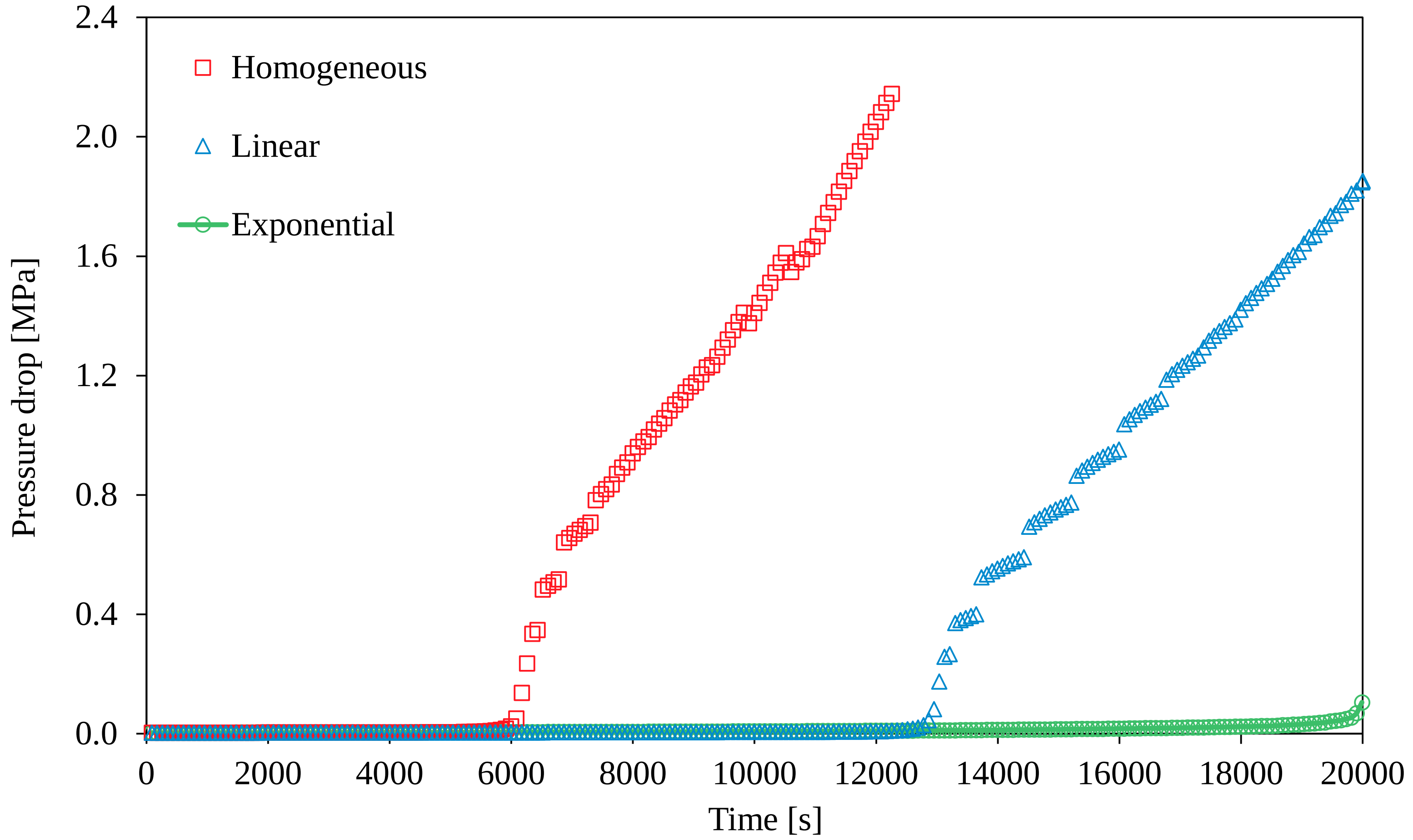
Linear



Exponential



Multipass simulation results: Pressure-drop over time



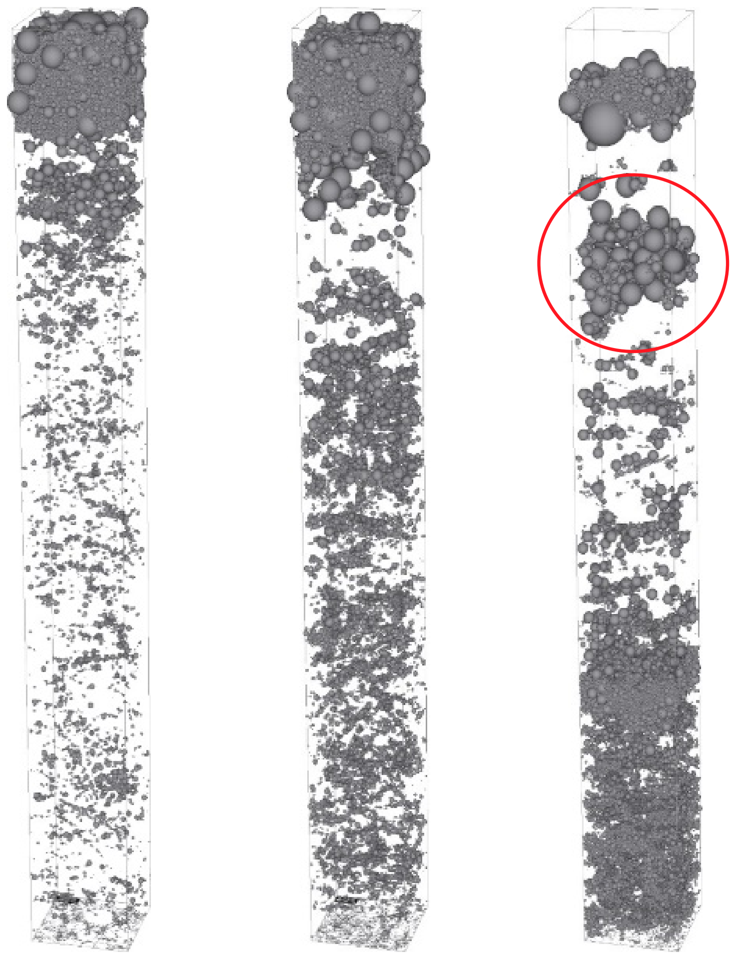
- The exponentially increasing media shows the lowest pressure-drop increase through the life-time simulations.

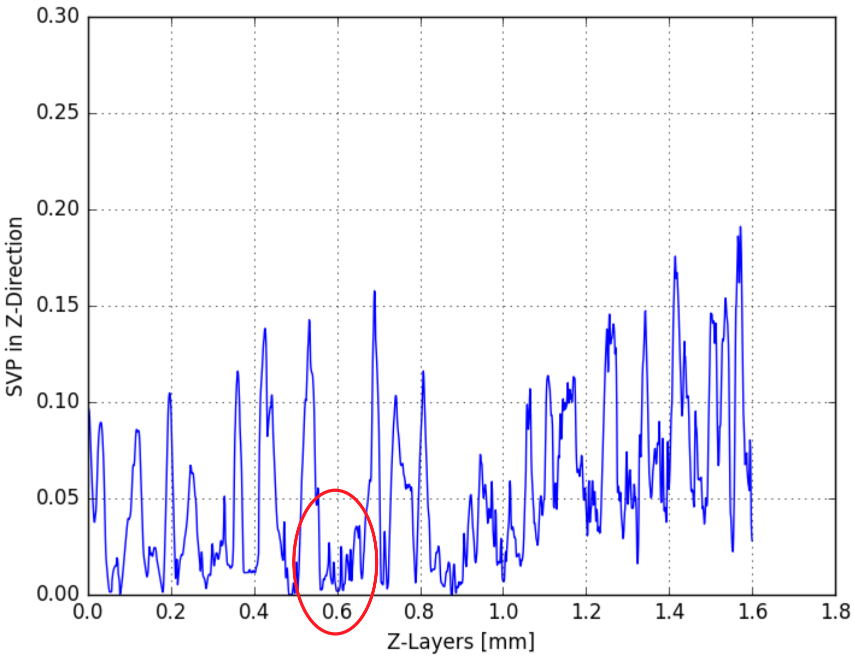
Multipass simulation results: Pressure-drop over total deposited dust

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 [m^2]	5.47E-11	5.48E-11	5.53E-11
$\beta_{22\mu m}$	200	200	200
Object solid volume percentage in domain (porosity in %)	6.11 (93.89 %)	5.9 (94.1 %)	5.43 (94.57 %)
Volume coarse fiber / Volume fine fiber	60/40	60/40	60/40

Selection of a representative computational domain

Domain 200x200x1600 µm





Sub-cakes can form, if there is a gap between high and low solid volume fraction.
Such sub-cakes will lead to a lower DHC.

Conclusions

- ✓ The macroscopic properties can be optimized by modification of the micro-structure of filter media.
- ✓ Computational domain has to be large enough to be representative.
- ✓ 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.
- ✓ Results are published recently:

  M. Azimian, C. Kühnle, A. Wiegmann, Design and optimization of fibrous filter media using life-time multi-pass simulations, Chemical Engineering & Technology, 2018.

Thank you for your attention.

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