Optimization of Nonwoven Filter Media Characteristics

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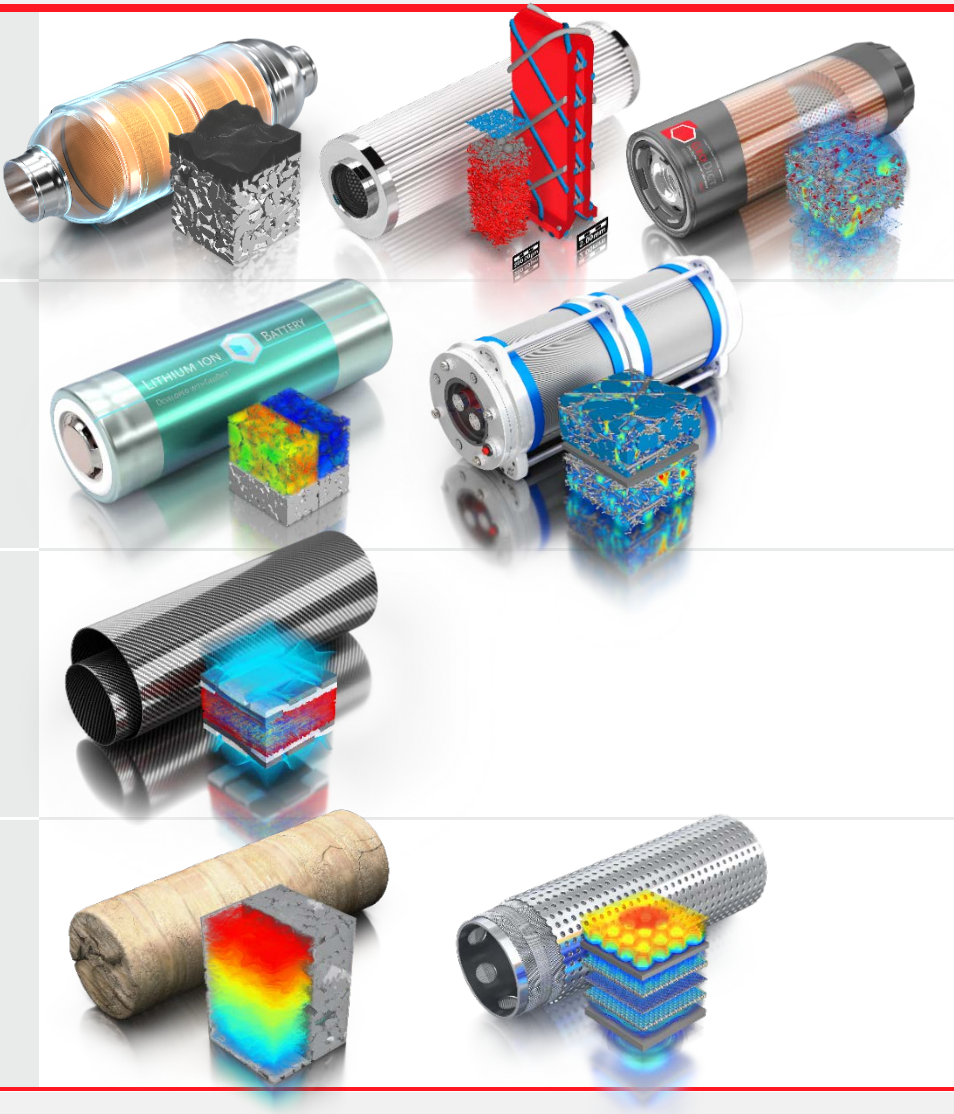
4/24/2018

GeoDict (The Digital Material Laboratory)

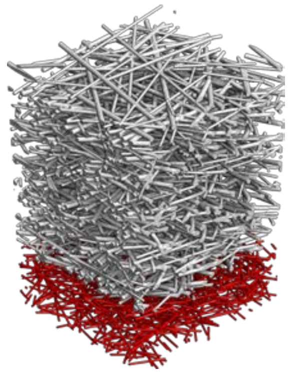
Filtration	Mostly automotive, filter media & filters for water, sludge, oil, air and fuel
Electrochemistry	Fuel cell media & battery materials, catalyst materials
Composites	CFRP, GFRP, mostly automotive, lightweight materials
Oil and Gas	Digital rock physics, digital sand control

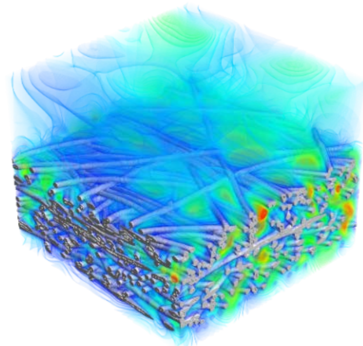


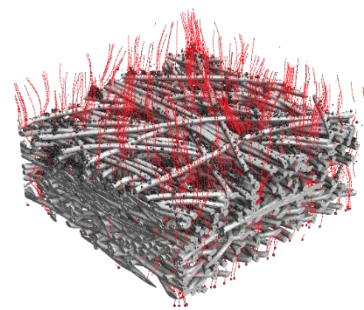
The GeoDict® Workflow

OPTIMIZE

IMPORT	MODEL	ANALYZE	PREDICT	EXPORT







ExportGeo-Base
ExportGeo-CAD
ExportGeo-Fluent
ExportGeo-Abaqus

Import: Diverse ways to import materials for modeling

Model: Detailed material models created in 3D

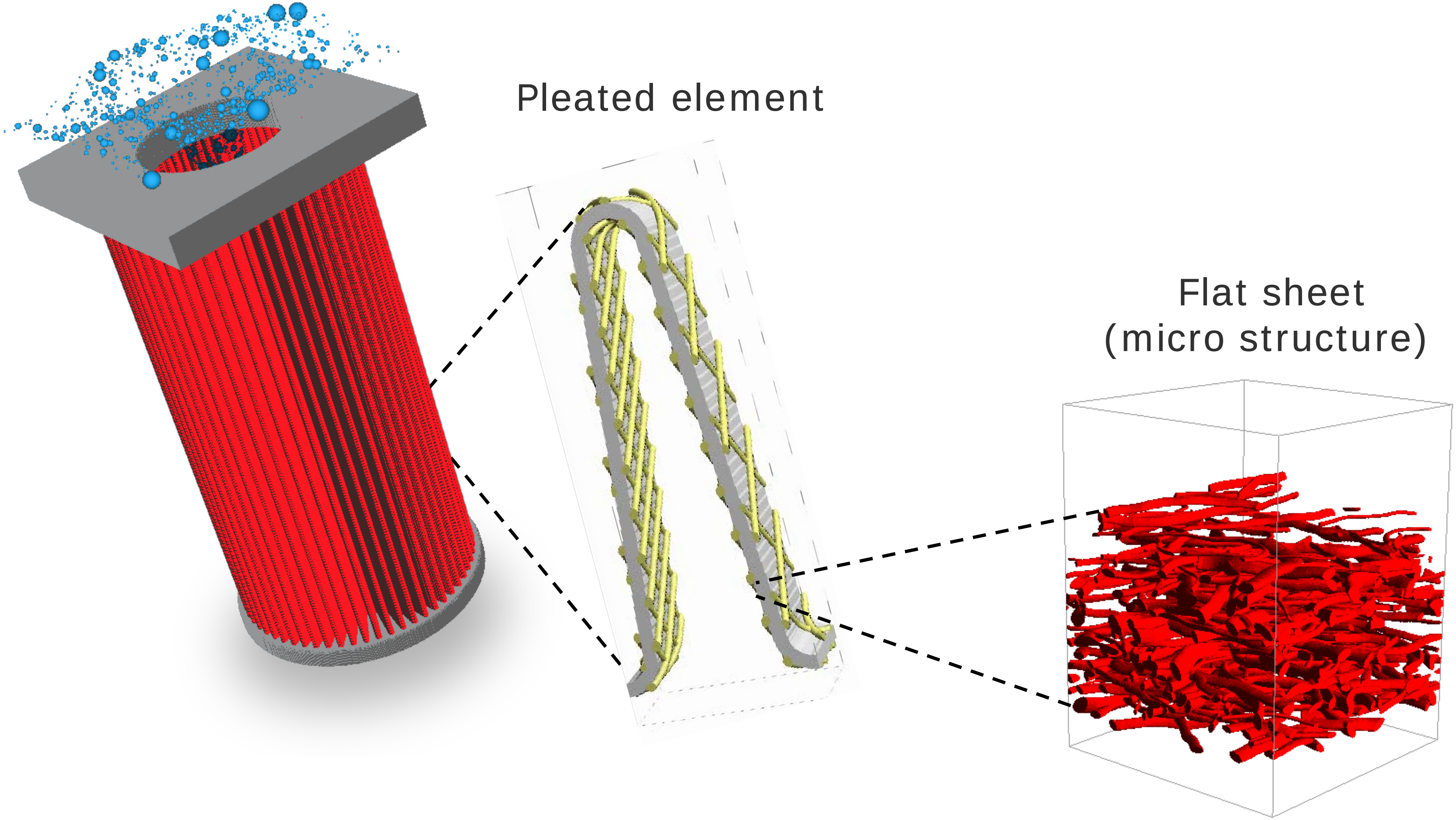
Analyze: Extensive analysis and evaluation of structural material properties

Predict: In-depth analysis and prediction of material behavior

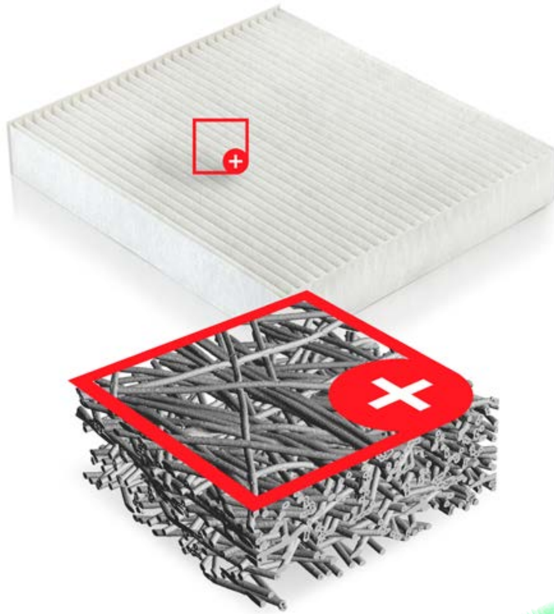
Export: GeoDict models made available for standard workflows

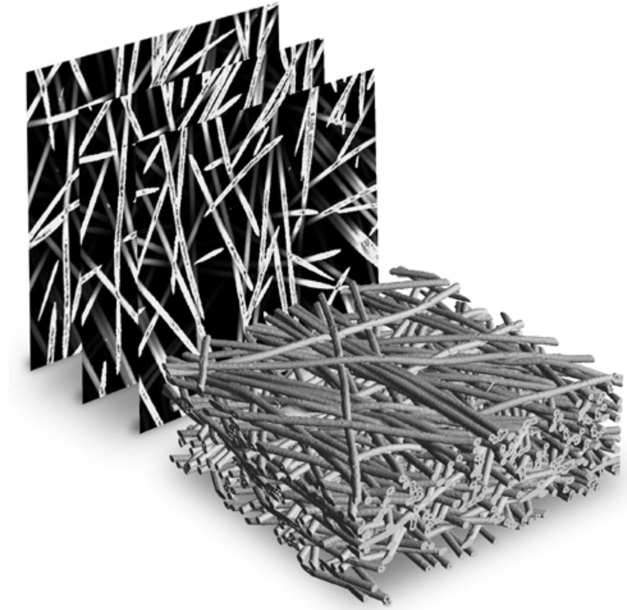
Modeling, simulation & optimization of micro-structure of filter media

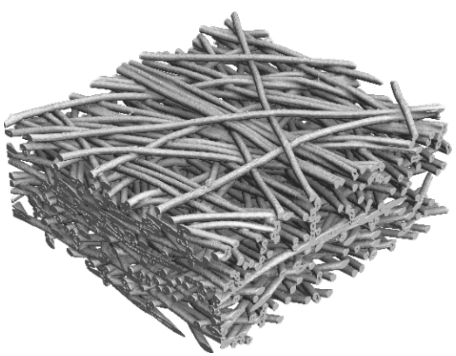
Simulate filtration at different scales

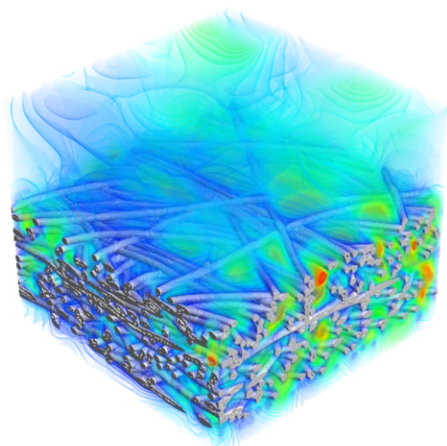


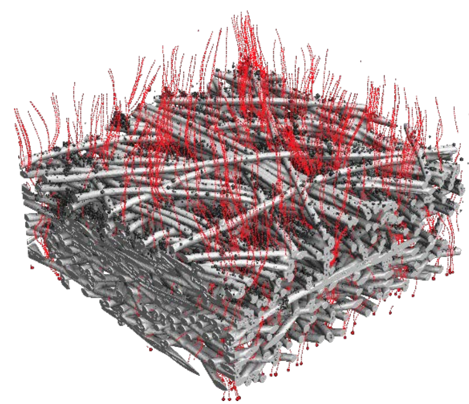
Simulation on the micro-structure of the filter media

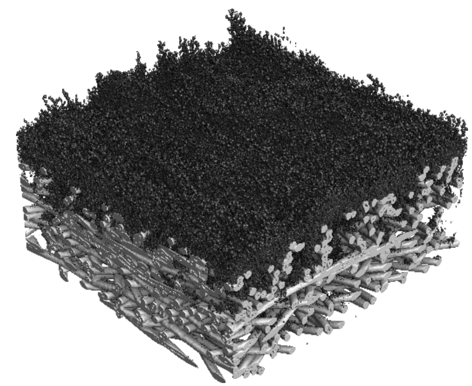








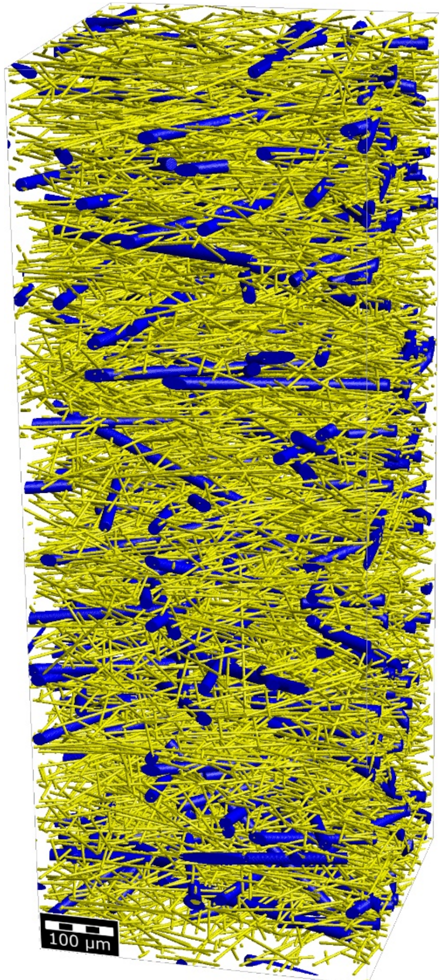




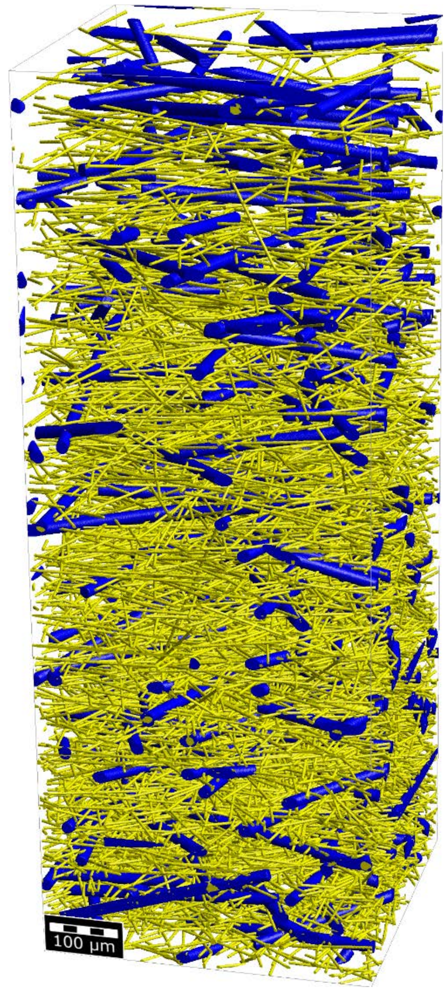
Particulate flow simulations

Modeling of three various filter media structures

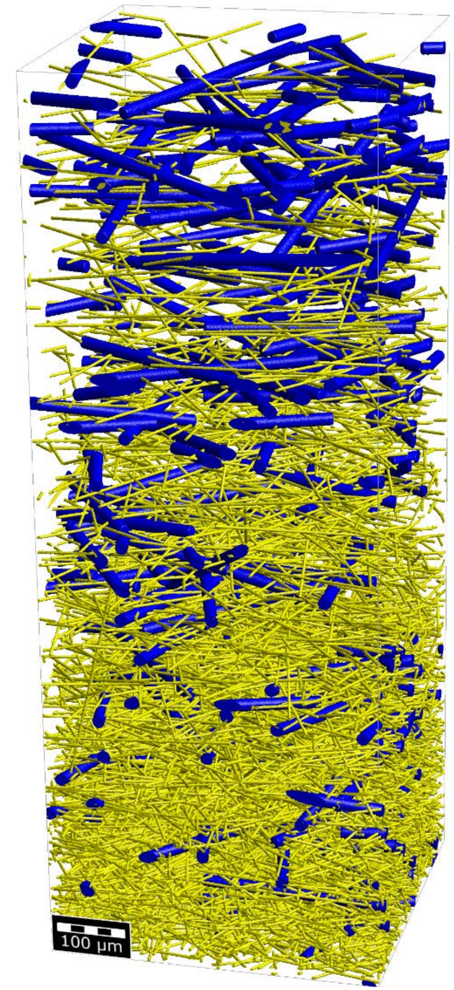
Homogeneous



Linear



Exponential



Modeling of three various filter media structures

Thick glass fibers + Thin glass fibers = Three various structures

- Thick glass fibers
  - Homogeneous
- Thin glass fibers
  - Homogeneous
  - Linear
  - Exponential
- Three various structures
  - Same inital 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%

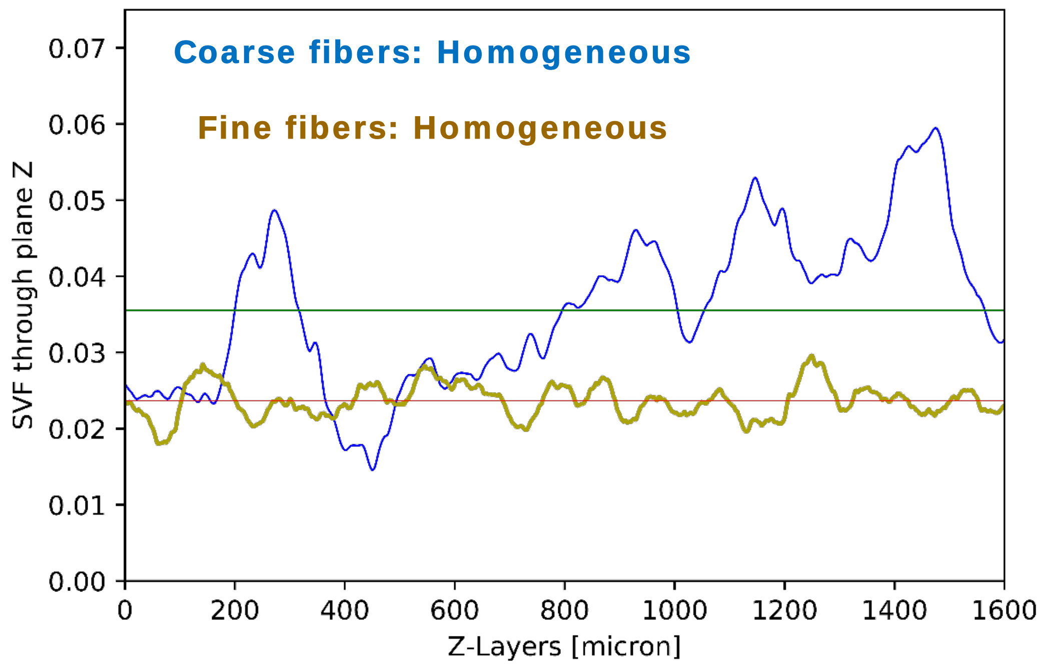
$$\beta_d = \frac{n_{d,U}}{n_{d,D}} = \frac{100}{100 - e}$$

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.

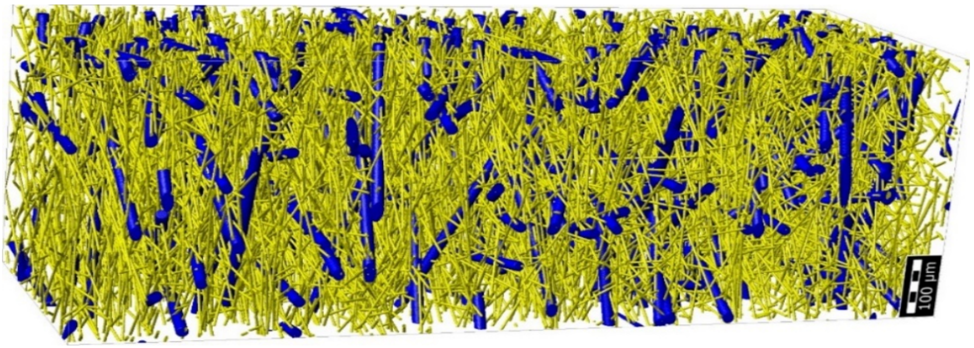
Structural comparison of the three various filter media

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 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

Homogeneous media

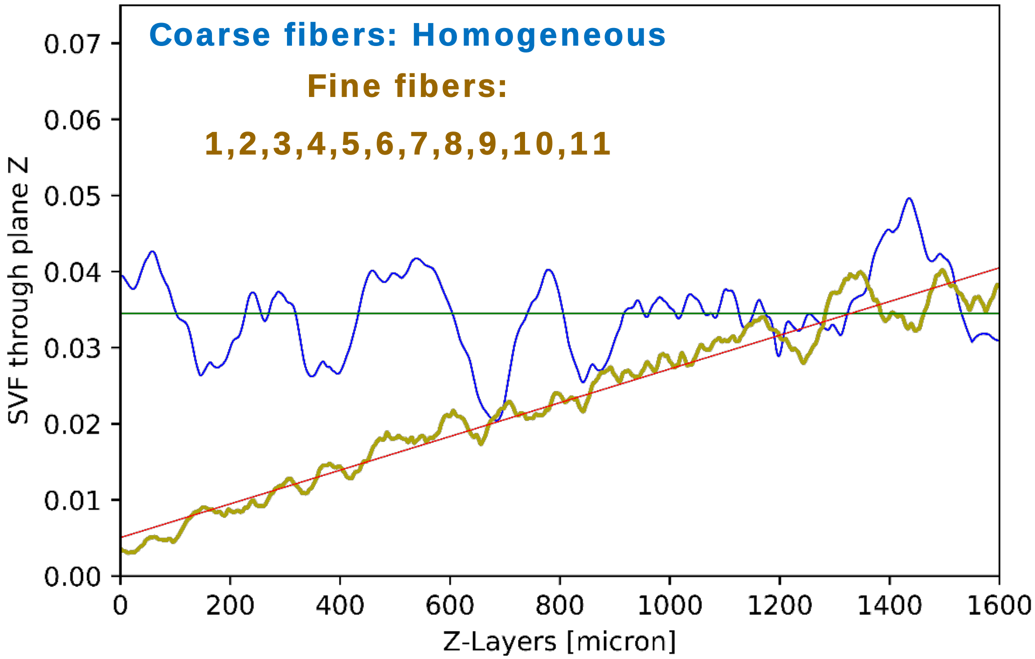


Flow direction

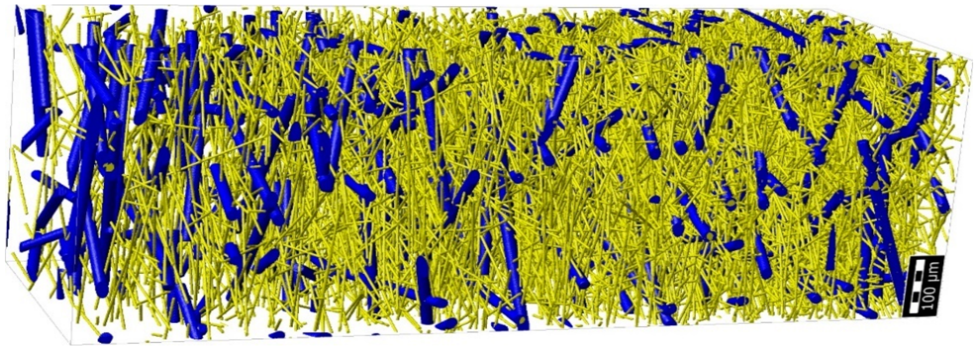


Domain

600x600x1600 µm



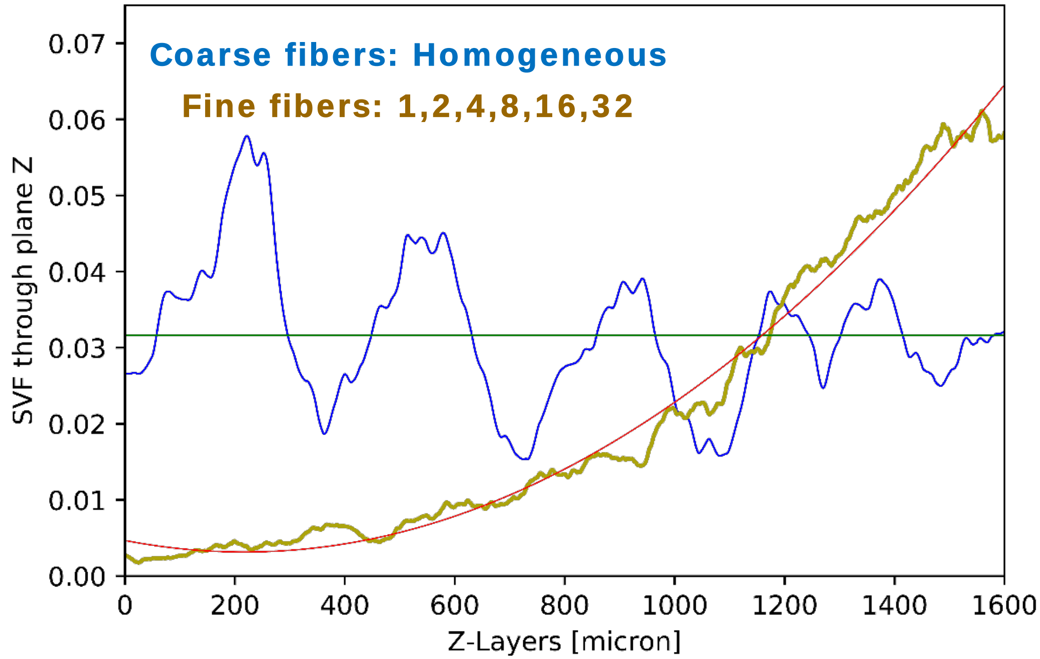
Flow direction



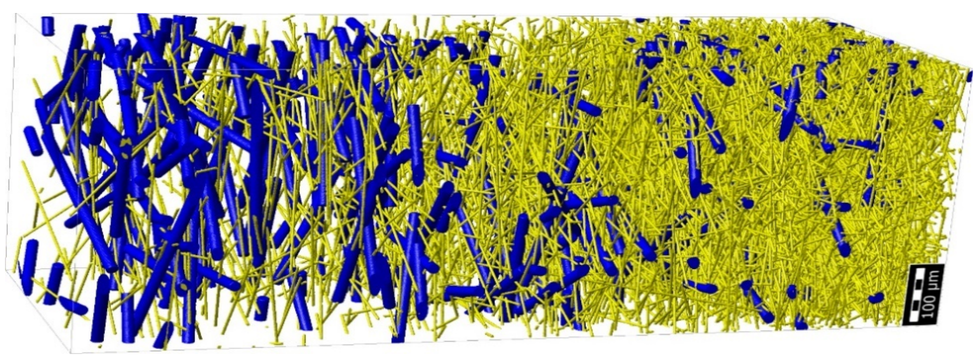
Domain

600x600x1600 µm

Exponential media



Flow direction



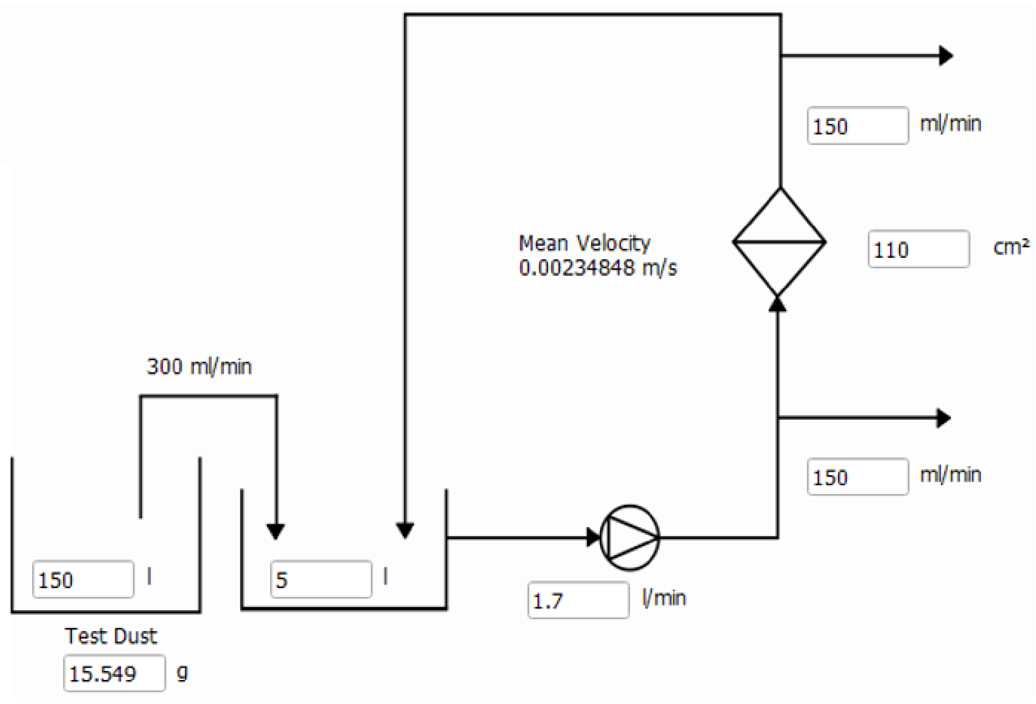
Domain

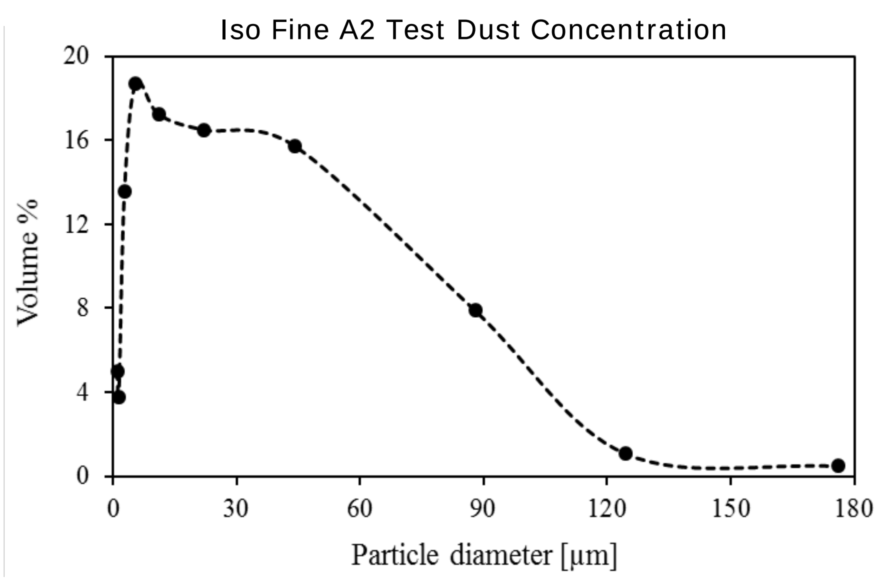
600x600x1600 µm

Particulate oil flow parameters

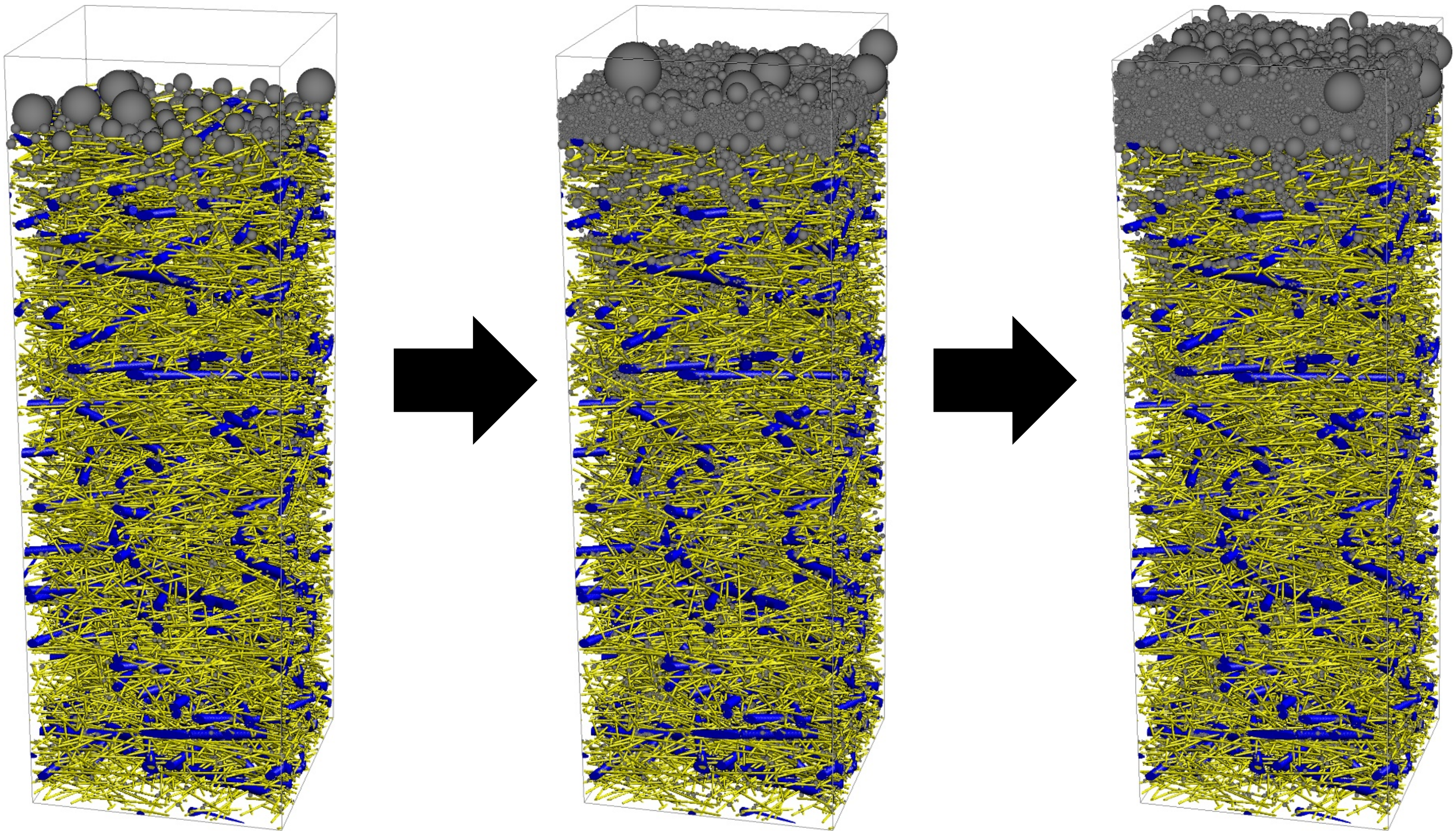
Used Fluid:	Oil
Temperature:	20 °C
Solid particles:	ISO Fine A2 test dust
Particle density:	2560 kg/m³
Particle collision model:	Sieving
Solver:	LIR (Adaptive grids based)
Flow regime:	Laminar

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



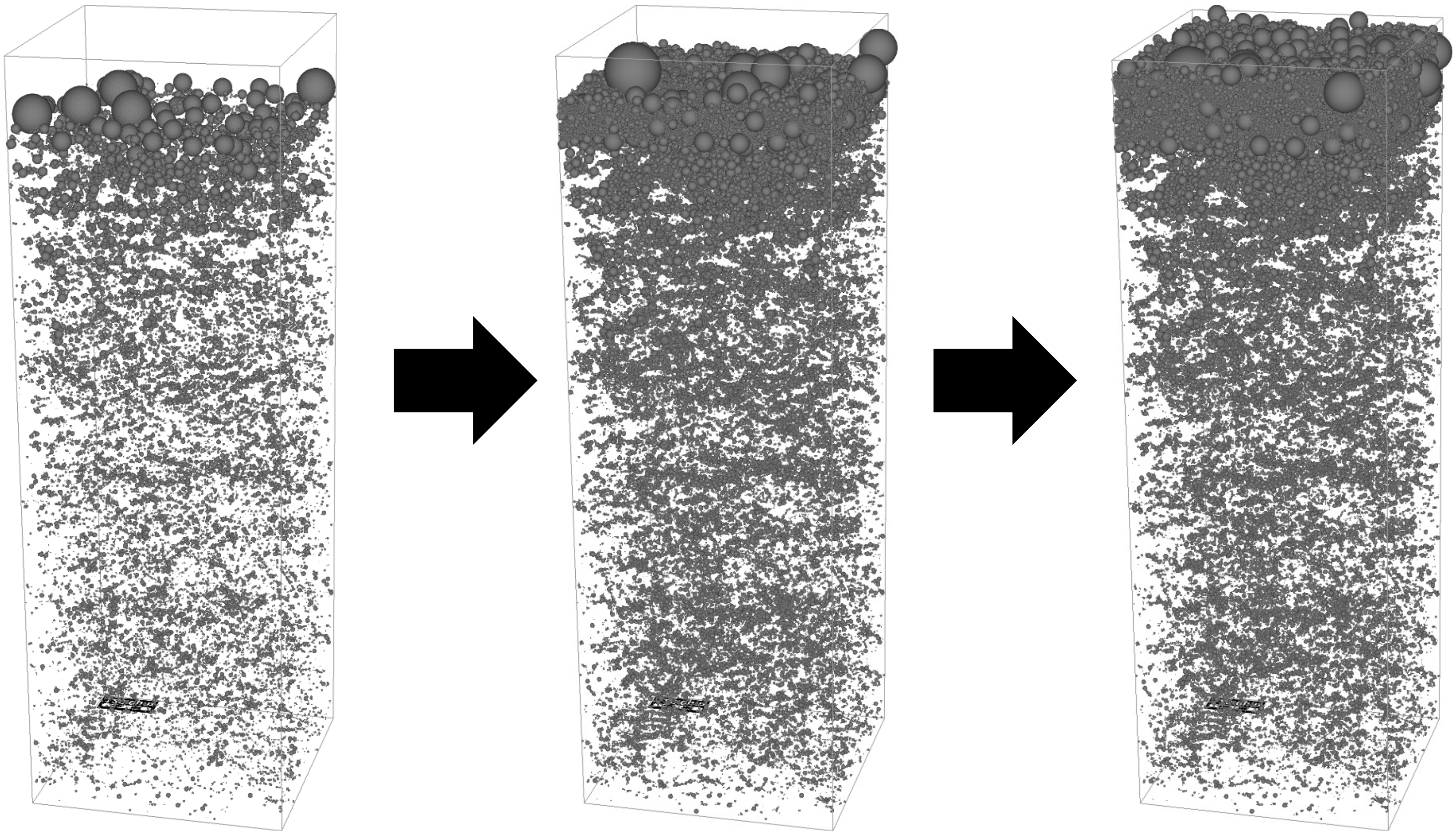


Transient filtration simulation (Homogeneous structure)



2650 s | 8733 s | 11340 s

Transient filtration simulation (Homogeneous structure)

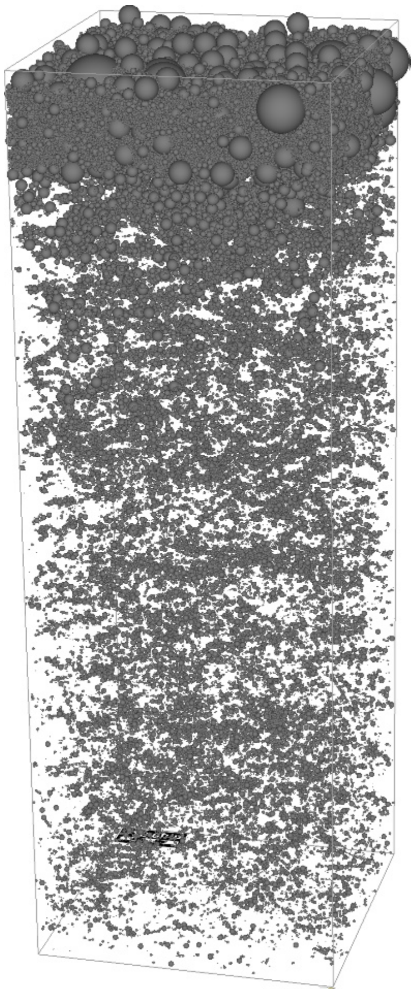


2650 s   8733 s   11340 s

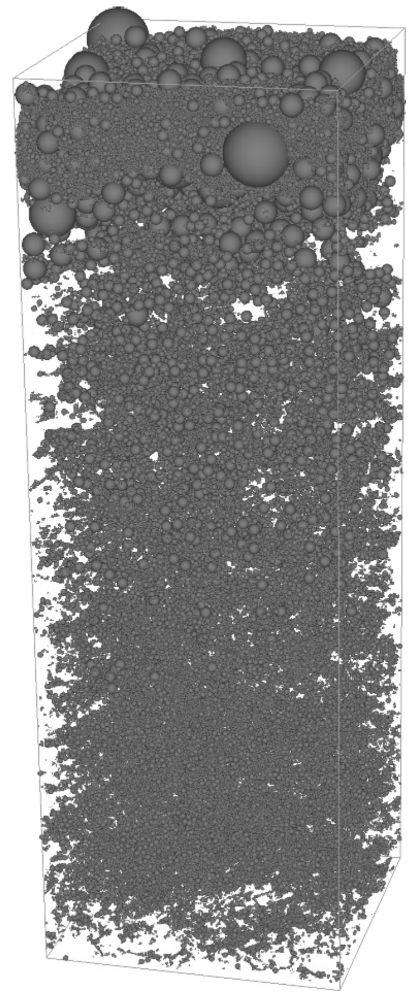
Animation of the transient filtration simulation (Linear structure)

Comparison among the three structures

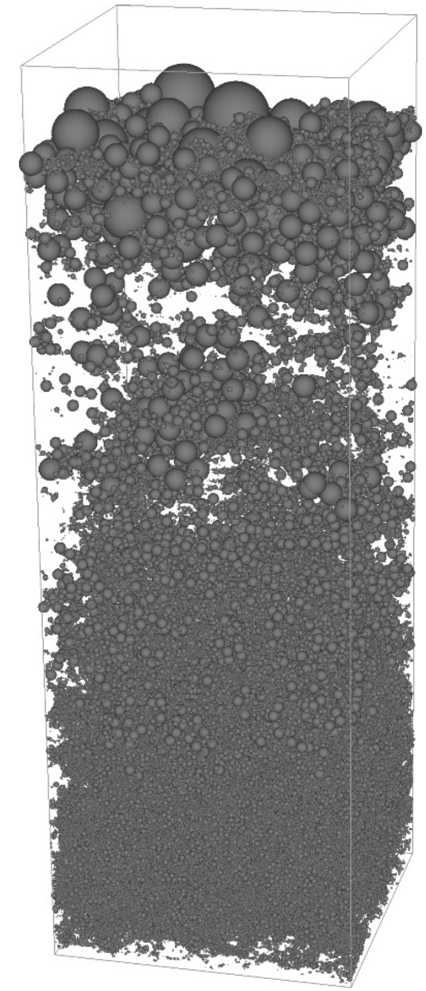
Homogeneous



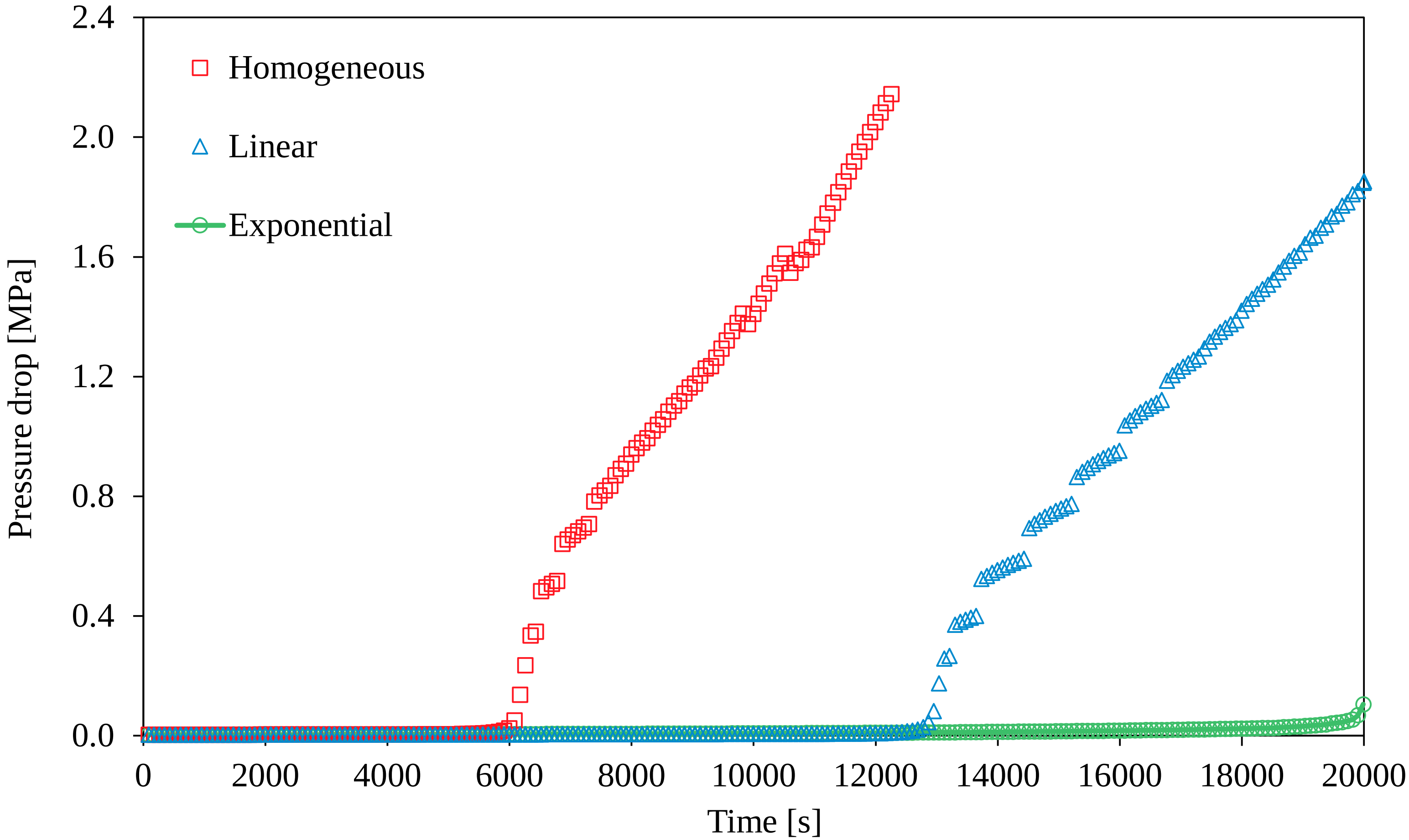
Linear



Exponential

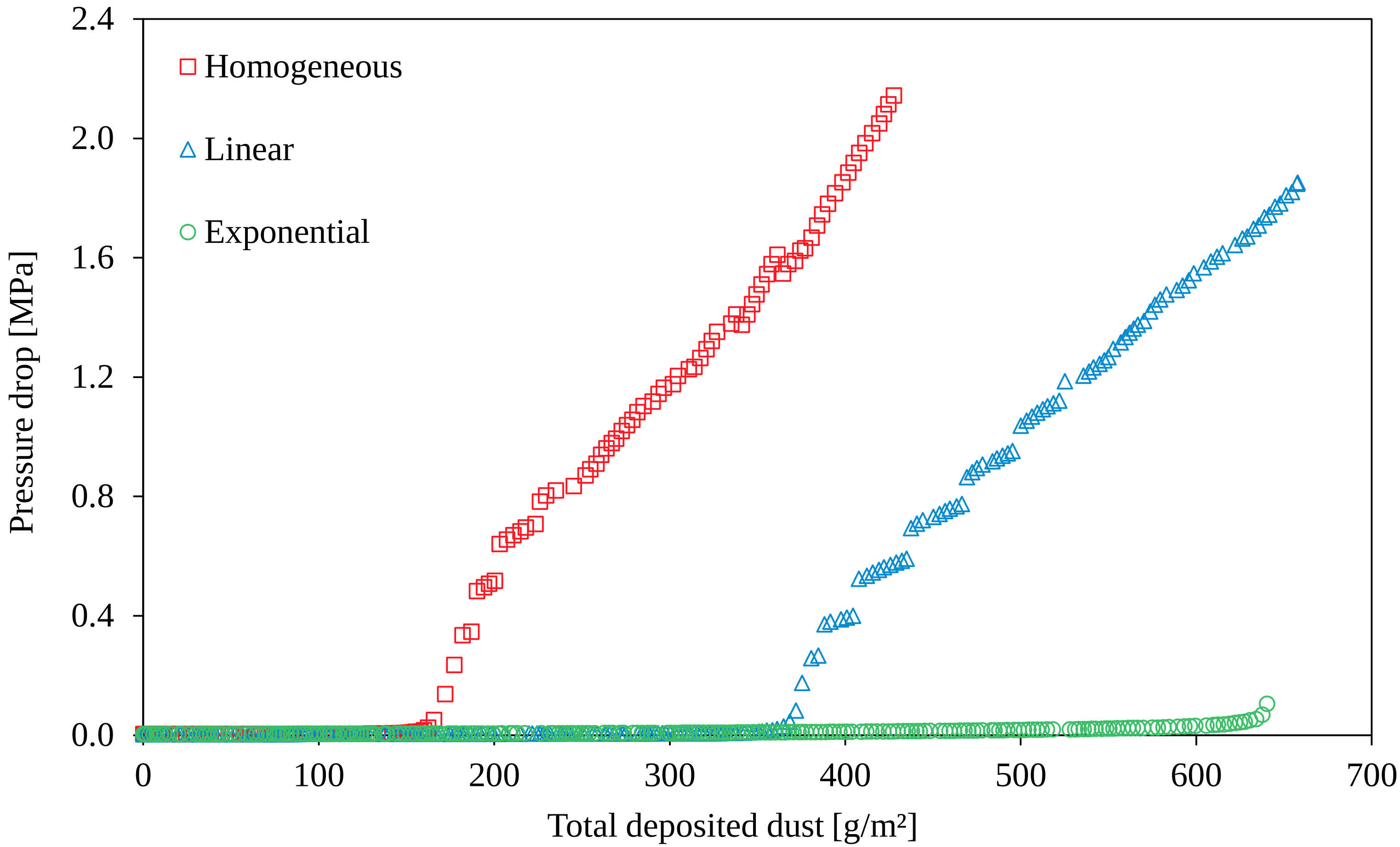


Multipass simulation results:
Pressure drop over time



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

Multipass simulation results:
Pressure-drop over total deposited dust



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

Save in material

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
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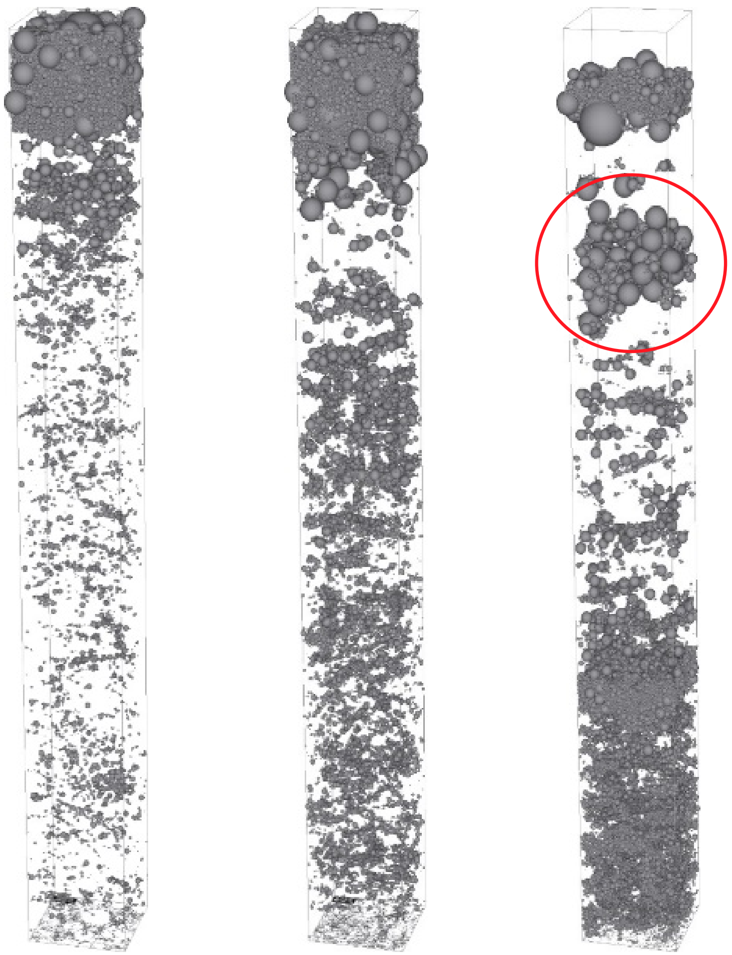
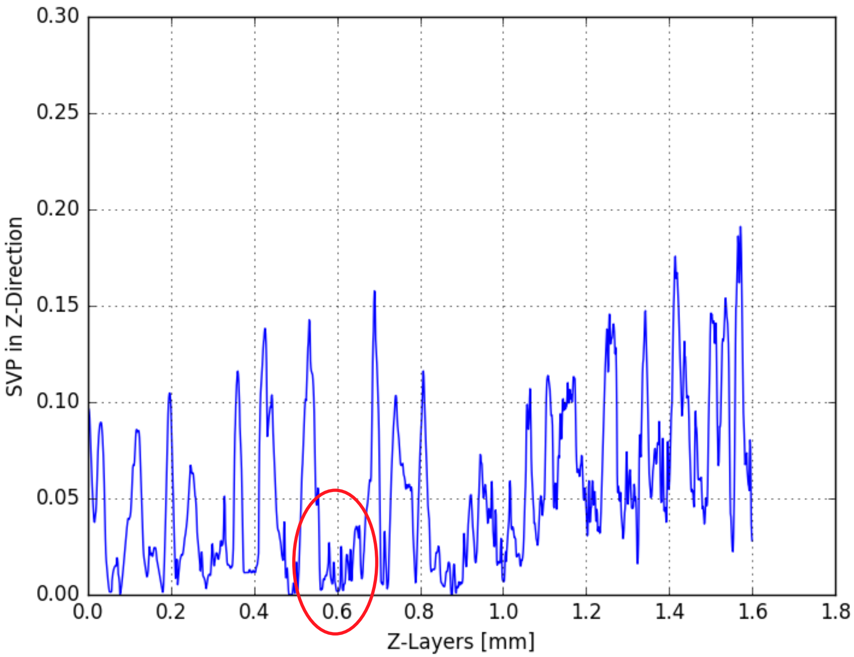
Selection of a representative computational domain

Domain 200x200x1600 µm





Subcakes can form, if there is a gap between high and low solid volume fraction.
Such subcakes will lead to a lower DHC.

Conclusions

- ✓ By modification of the micro-structure of filter media, the macroscopic properties can be optimized.
- ✓ 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 41, No. 5, 2018. doi.org/10.1002/ceat.201700585

Thank you for your attention.

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