Simulation of Filter Media Using GeoDict

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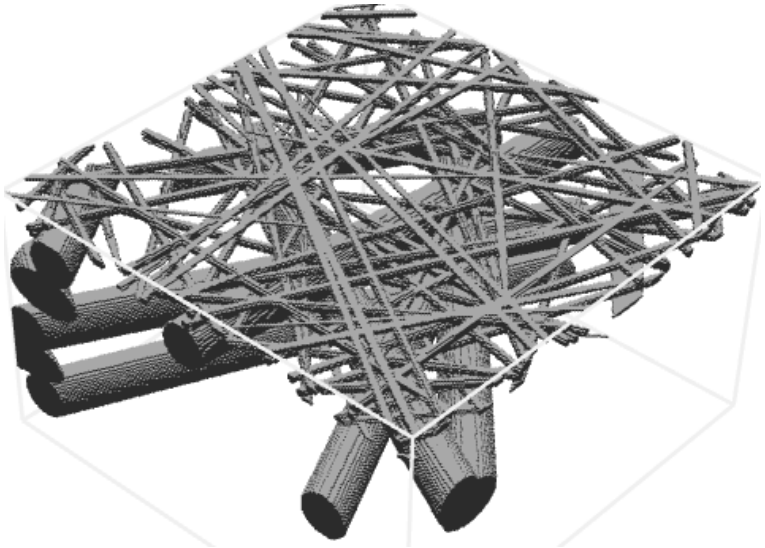
Simulation of Filter Media Using GEO DICT



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Techno- und Wirtschaftsmathematik, Kaiserslautern

9th Symposium *Textile Filters*

Sächsisches Textilforschungsinstitut e.V.

04th – 05th March 2008, Chemnitz

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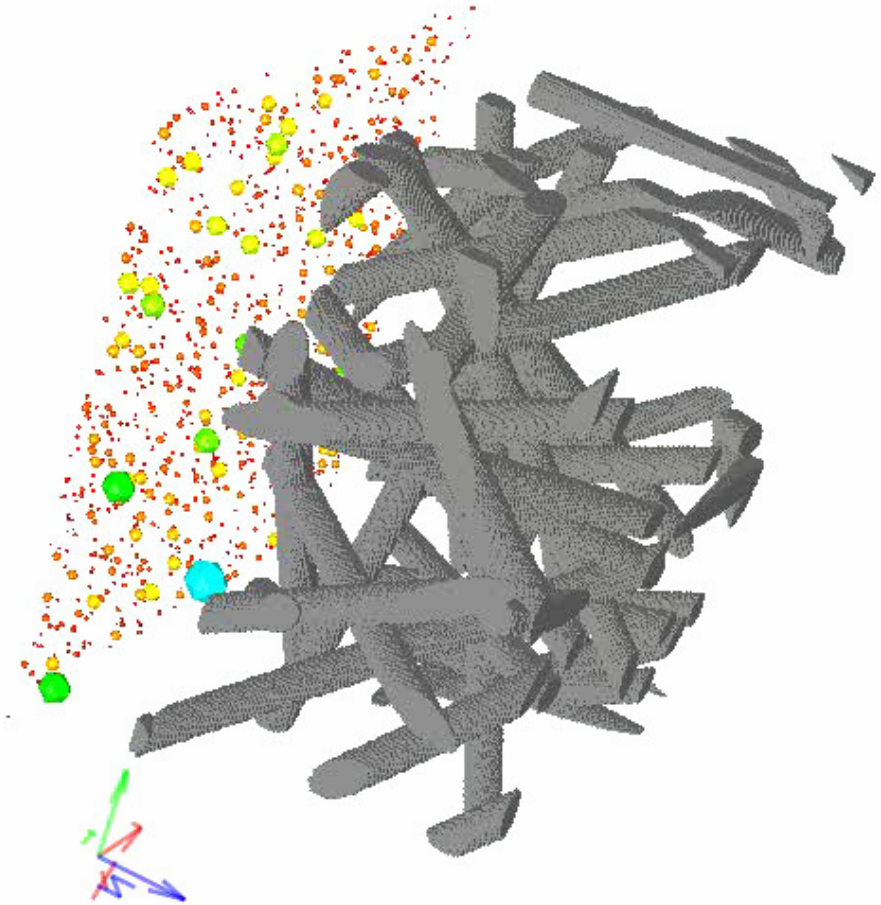
9. SYMPOSIUM | 9th SYMPOSIUM TEXTILE FILTER stfi

Outline

1. Virtual Material Design
2. Structure Generation
   - Nonwoven, Woven, Membranes, Agglomerates, Sinter Materials
3. Simulation
   - Fuel Cells: Bubble Point of a Gas Diffusion Layer
   - Pleated Oil Filters: Pressure Drop
   - Paper Dewatering: Optimum Felt
   - Diesel Particulate Filters: Design Study
4. Summary



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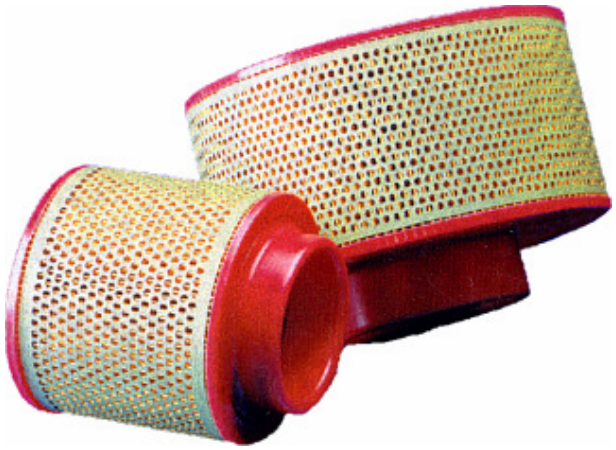
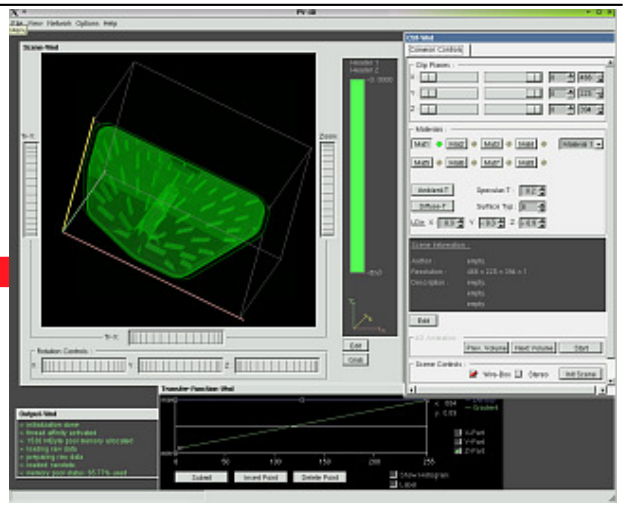
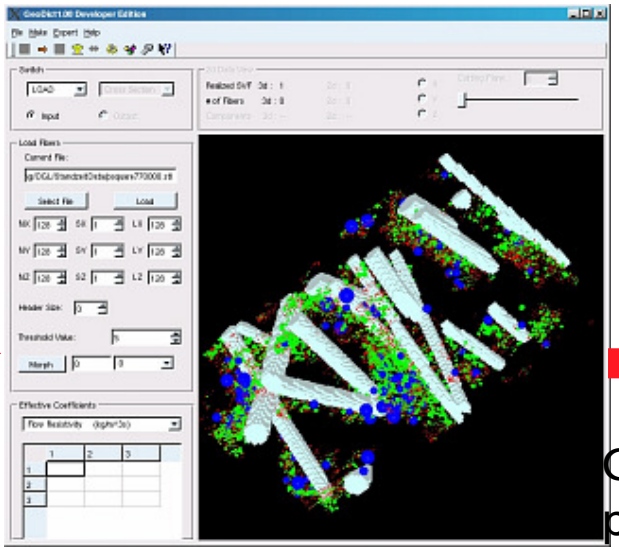
1. Virtual Material Design



Performance requirements reached?



Virtual Design Cycle



Determine / Vary structure parameters

Computation of media properties on the macro scale

Computation of media properties on the micro scale

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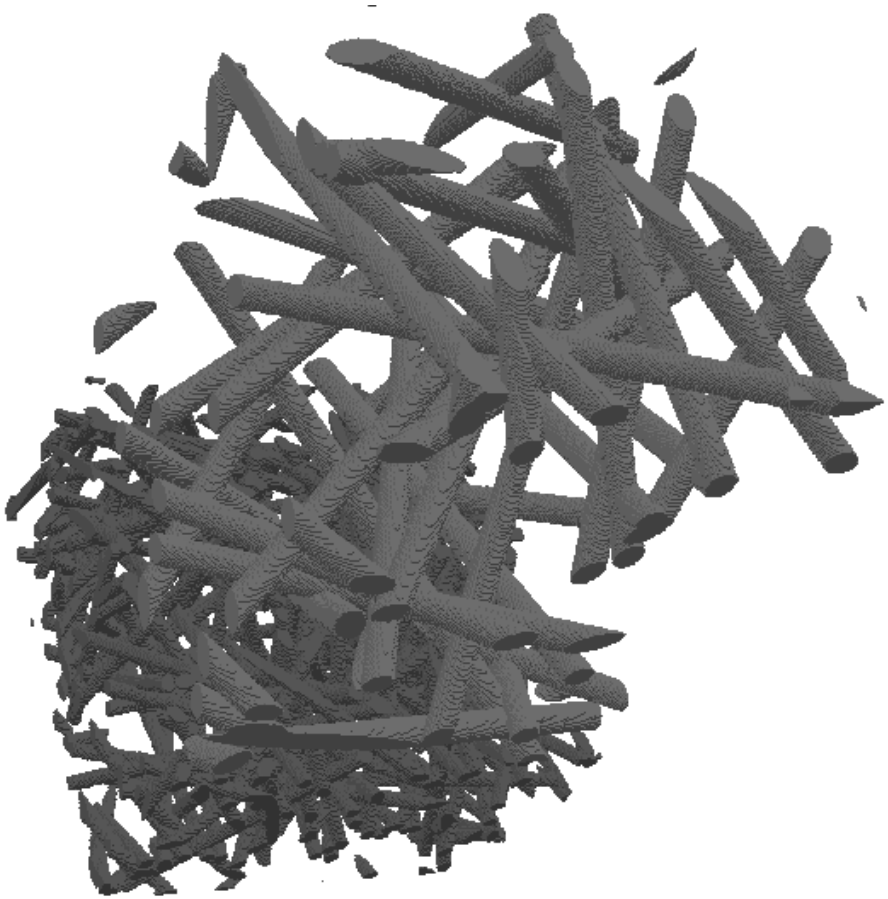
2. Virtual Structure Generation

GEO DICT

Multilayer Virtual Nonwoven

- Stochastic generation of the structure with guaranteed adjustable properties, e.g.
  - Distribution of fiber diameters and cross sections
  - Fiber orientation
  - Porosity
  - Layer thickness
  - …
- Stacking of layers with different parameters
- Use of highly flexible voxel meshes



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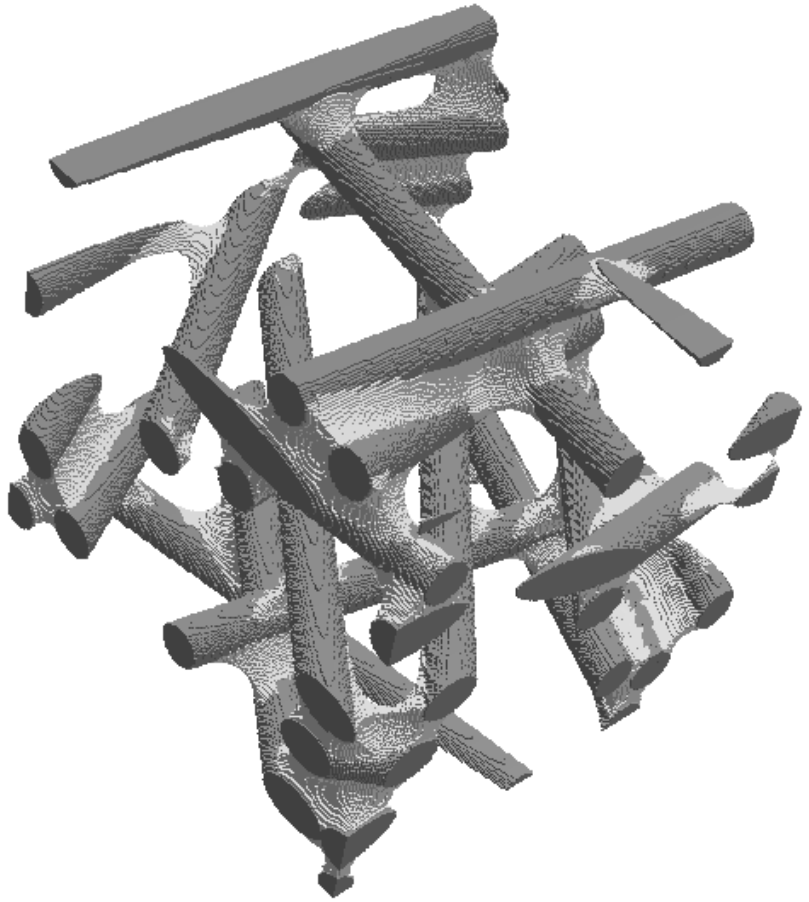
2. Virtual Structure Generation

GEO DICT

Virtual Nonwoven with Binder Material

- Randomly generated nonwoven
- Morphological operations create the binder material
- Amount of binder is an input parameter
- Binder appears as new material with individually assignable properties -> important, e.g. for elasticity computations



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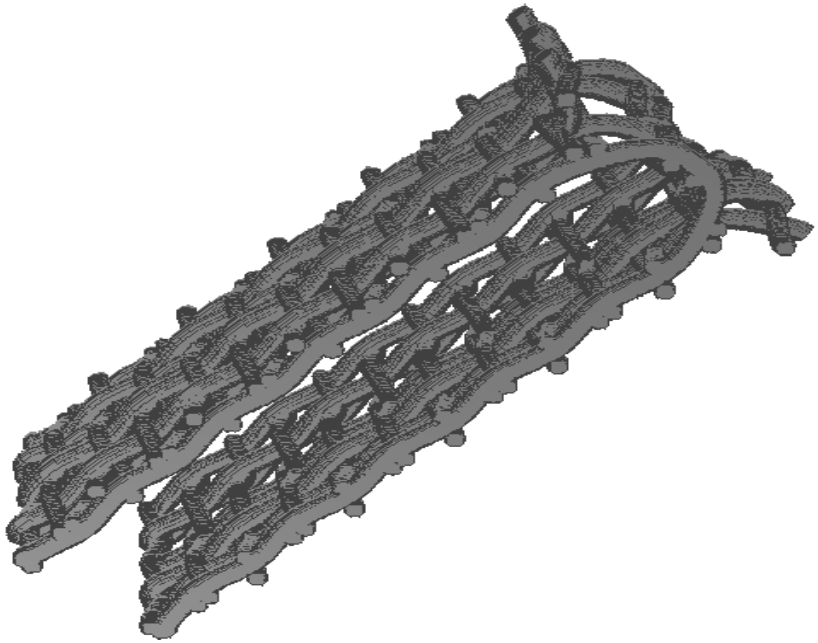
2. Virtual Structure Generation

GEO DICT

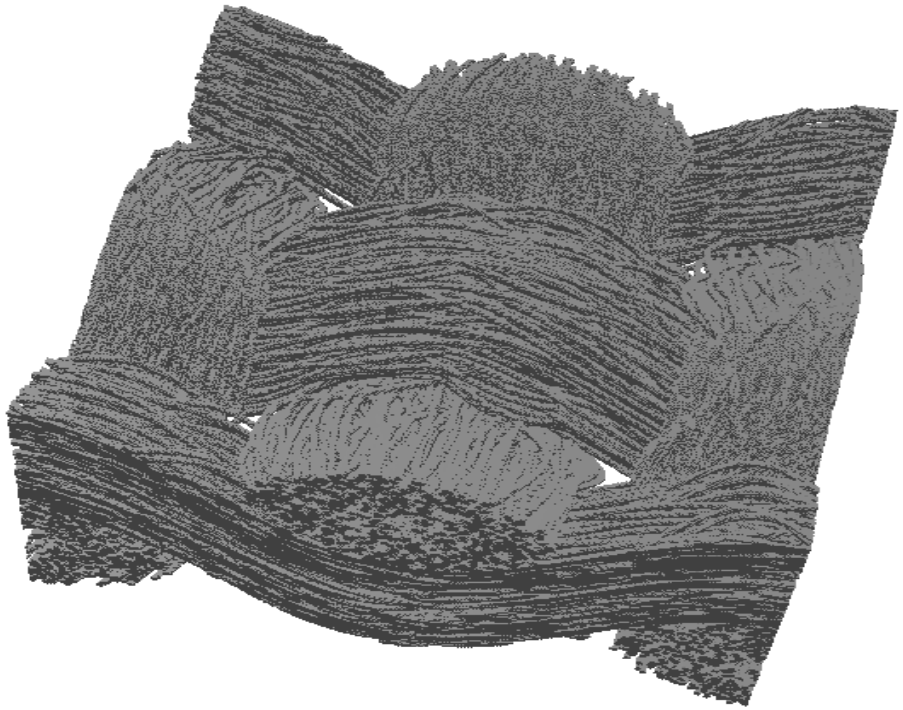
Virtual Wire-Cloth

- Structure is completely deterministic
- Wire-cloth to support a nonwoven in oil filter applications



Virtual Plain Weave

- Mixture of deterministic generation and randomness



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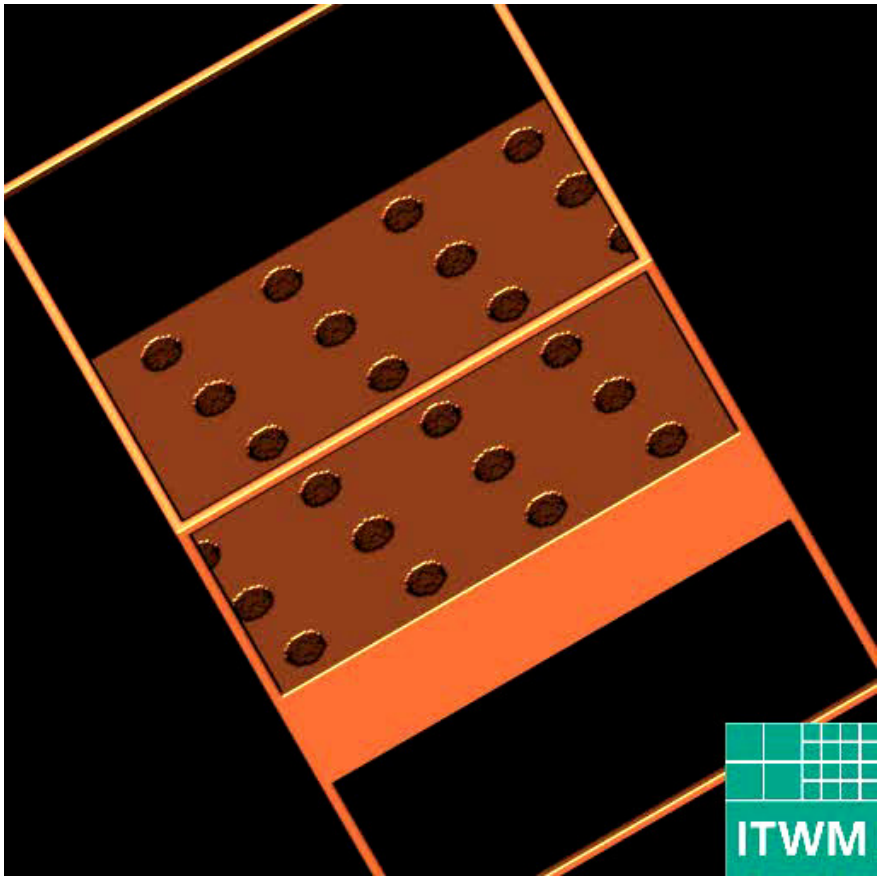
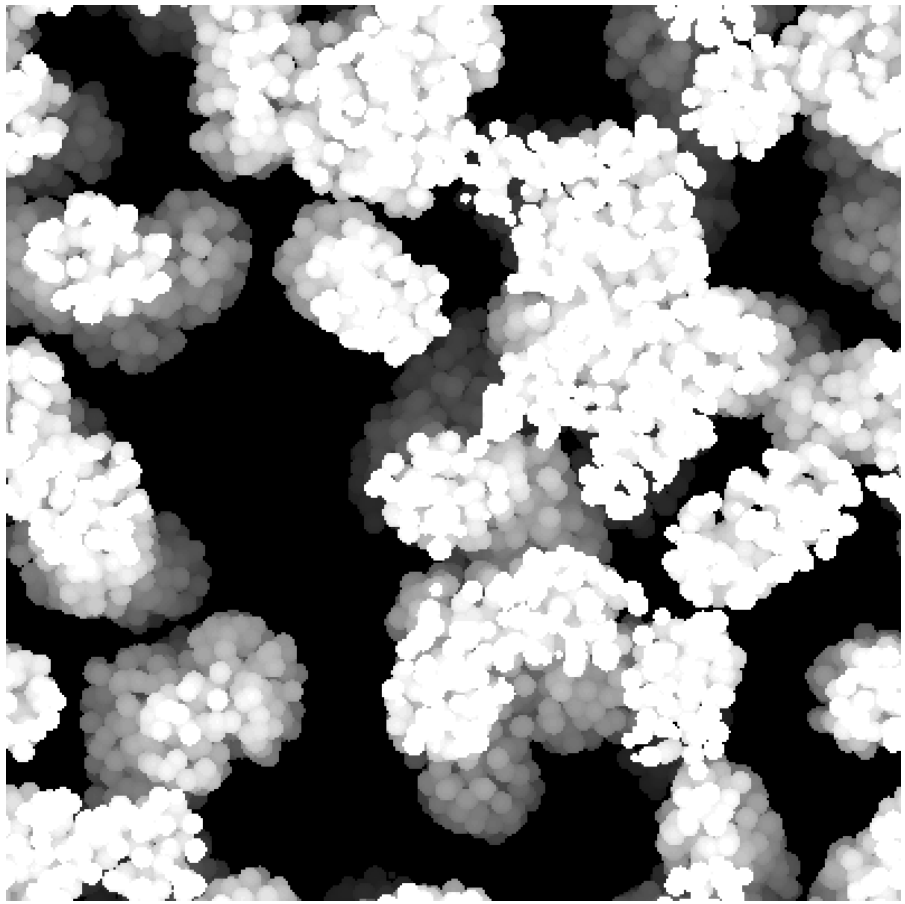
2. Virtual Structure Generation

GEO DICT

Membrane



Agglomerate



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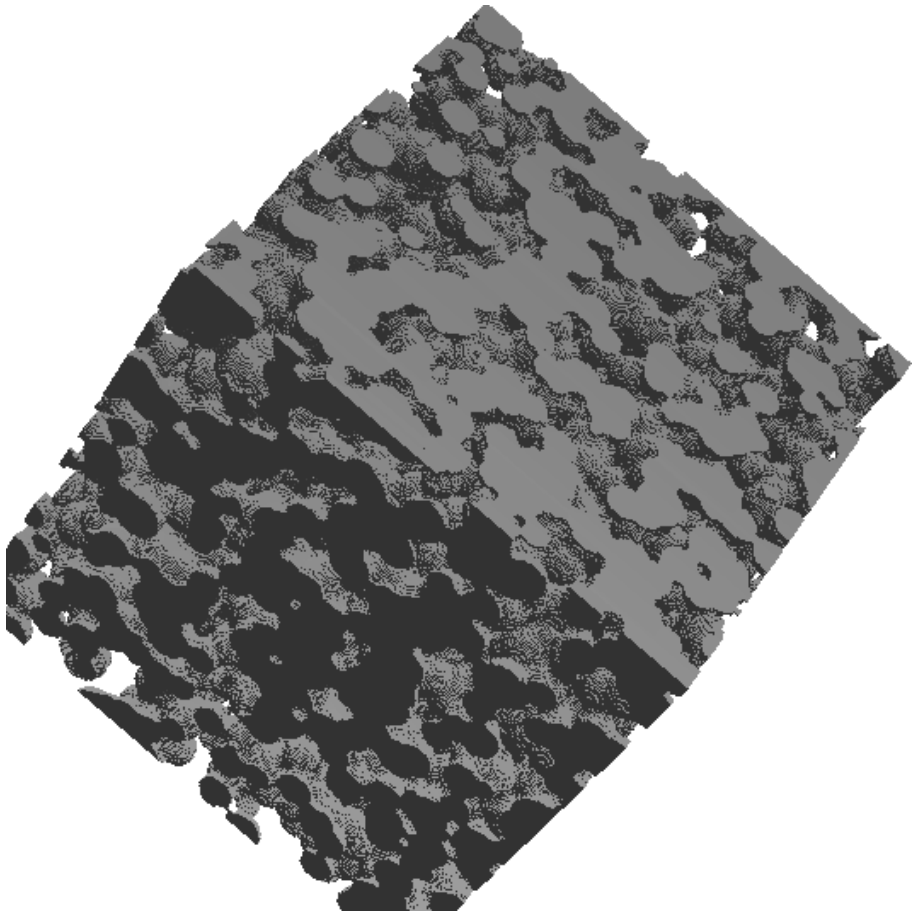
2. Virtual Structure Generation

Virtual Sinter Structure

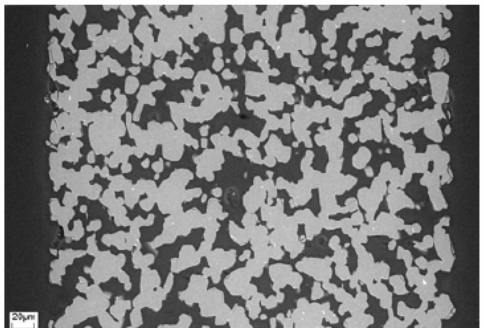
- Stochastic generation based on
  - Packings of spheres
  - Morphological operations (to generate sinter necks)
- Packings of spheres selected to match the initial grain size distribution of the sinter process
- Approach was applied in an industrial project when no tomographies were available due to
  - Difficult preprocessing of samples
  - Too coarse resolution

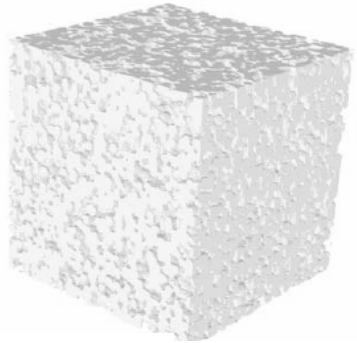


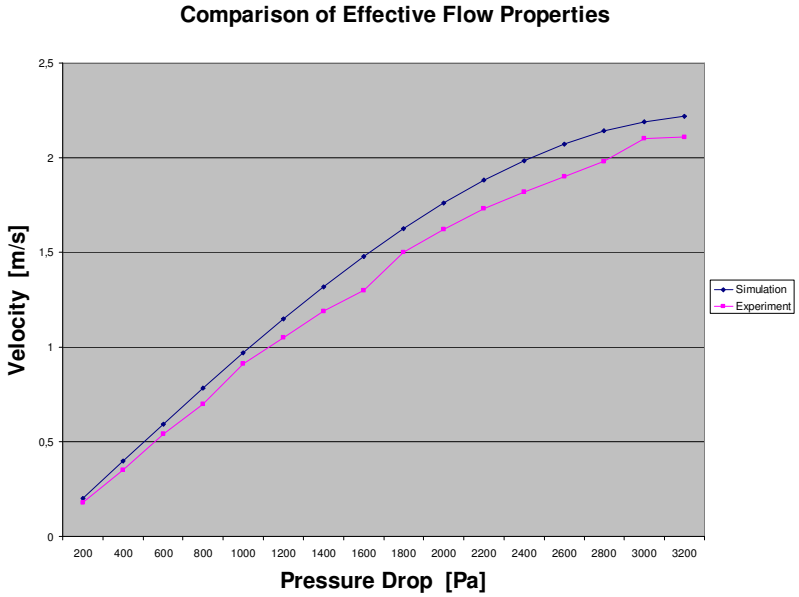
2. Virtual Structure Generation

Quality Measures for Virtual Structures

- "The Eye"
- Porosity, specific surface area
- Chord length distribution
- Pore size analysis
- Flow properties, e.g. effective permeability or flow resistivity
- Bubble point, capillary pressure curves
- Filtration properties
- Acoustic properties







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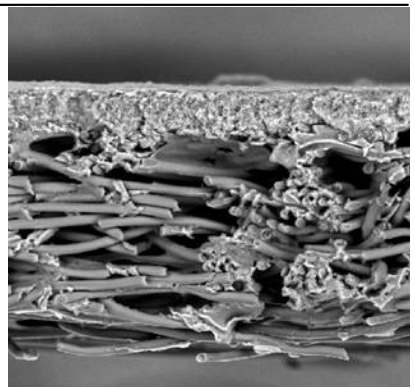
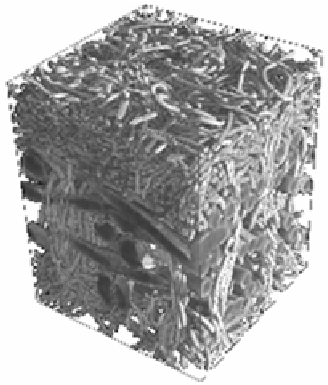
3. Simulation of Structural Properties

GEO DICT

Simulation Examples

- Fuel cells: Bubble Point computation of the gas diffusion layer
- Oil filters: Simulation of the structure dependent pressure drop
- Paper machine: Paper dewatering
- Diesel particulate filters: Design study

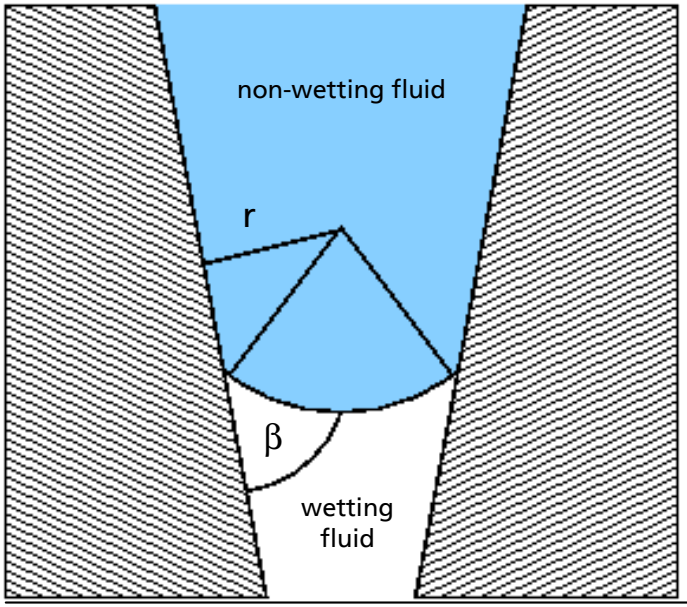




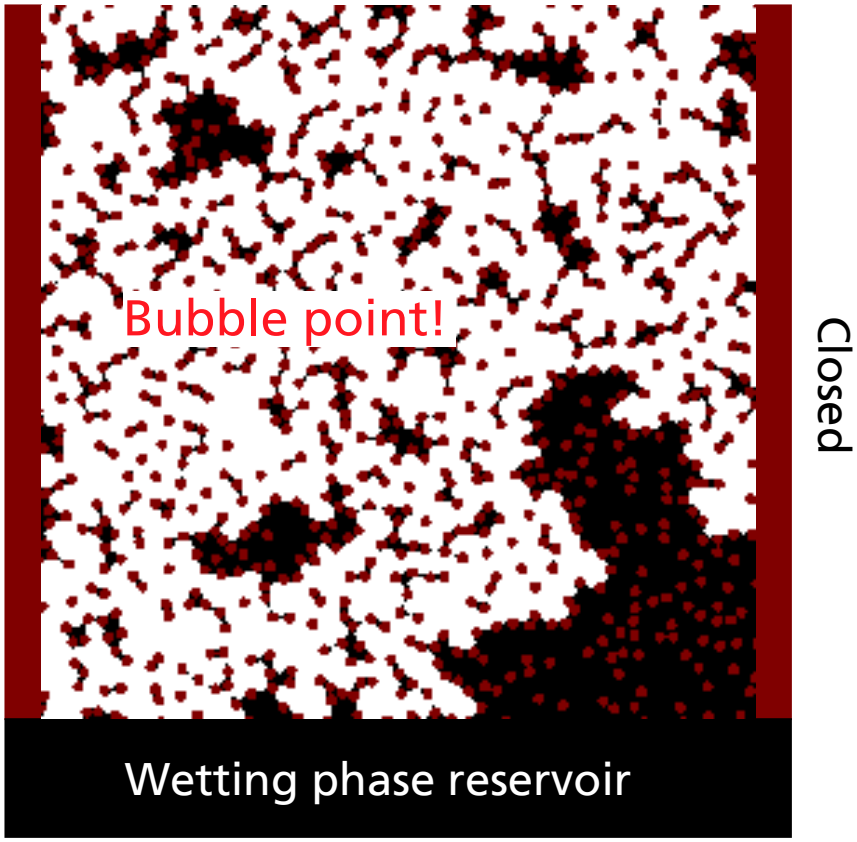
3. Simulation of Structural Properties

Bubble Point Simulation by the Pore Morphology Method

- Young-Laplace equation: $p_c = \frac{2\sigma}{r}\cos\beta$
- Pore filled by fluid, if $p_c \geq \frac{2\sigma}{r}\cos\beta$



Non-wetting phase reservoir



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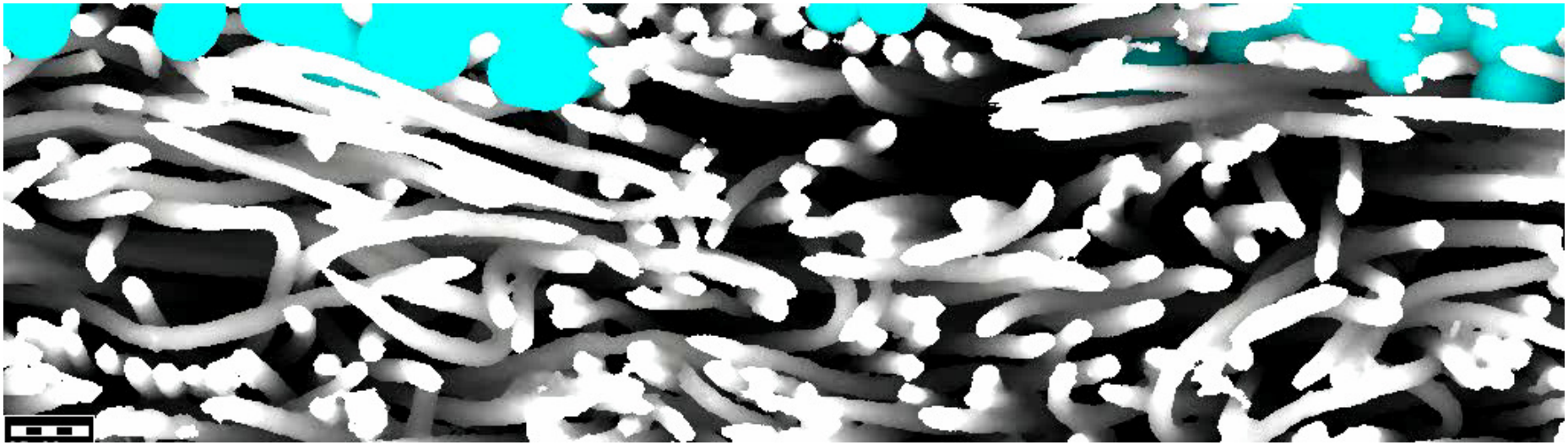
3. Simulation of Structural Properties

Gas Diffusion Layer: Fluid Distribution at the Bubble Point

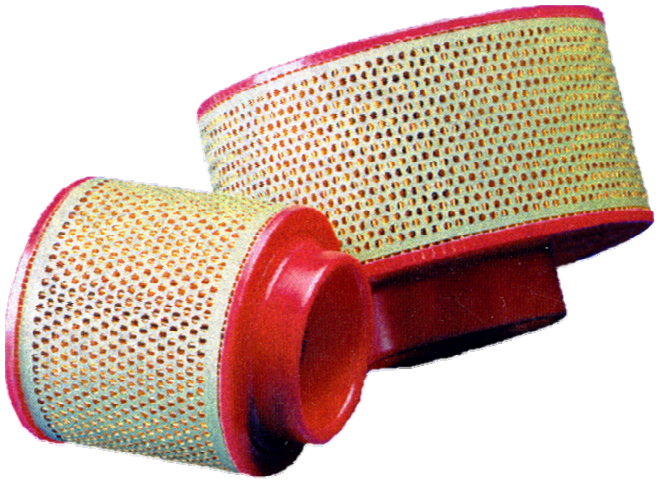


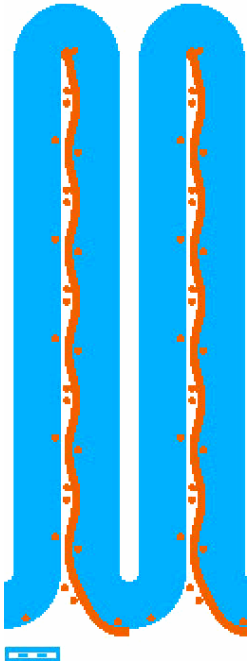
3. Simulation of Structural Properties

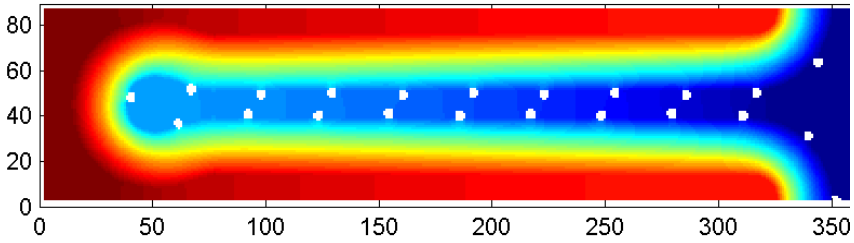
GEO DICT

Simulation of Pleated Oil Filters

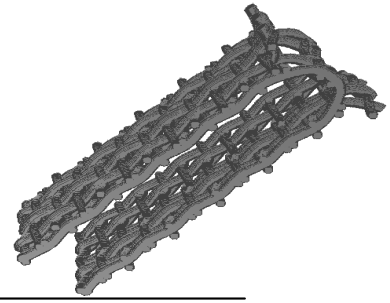
- Navier-Stokes-Brinkmann equation handles free and porous flow
- Permeability of the filter media is computed by „micro CFD“
- Study of pressure drop dependence on wire-cloth structure







Pressure



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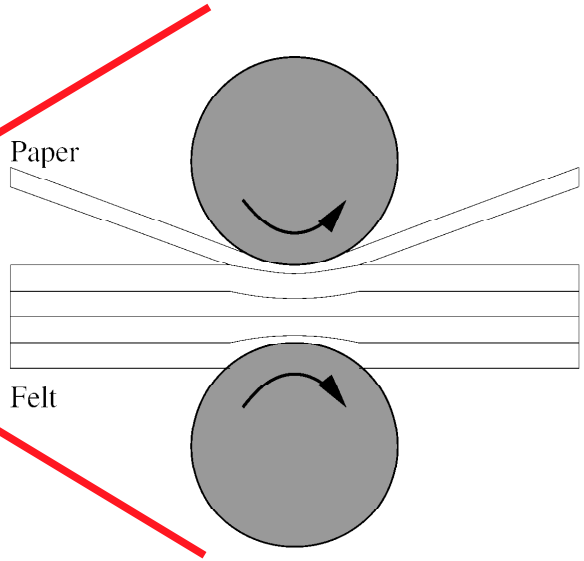
3. Simulation of Structural Properties

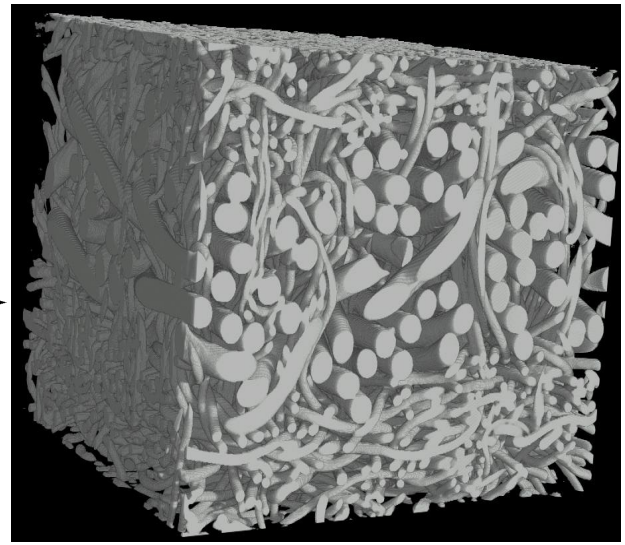
Modeling and Simulation of the Pressing Section of a Paper Machine

Paper machine

Press nip



Press felt



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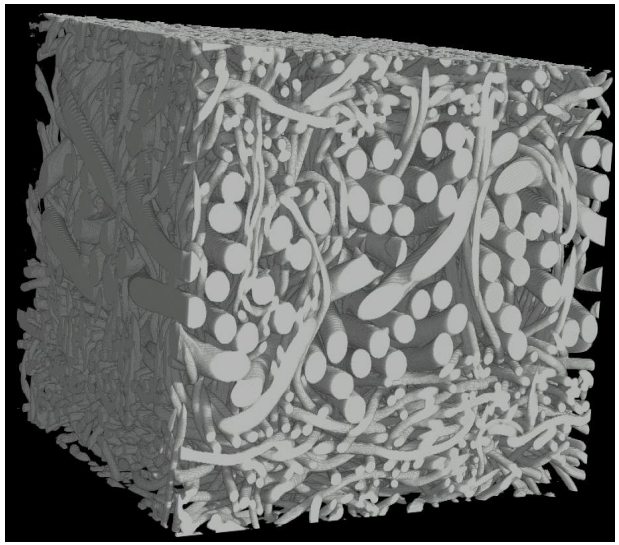
3. Simulation of Structural Properties

Modeling and Simulation of the Pressing Section of a Paper Machine

Tomography



GeoDict provides input parameters for macro simulations:

- Image processing (filters, cut-outs)
- Analysis of porosity distribution
- Computation of layer wise permeability
- Porosity and permeability variations under virtual compression
- Pressure-saturation curves by pore morphology method

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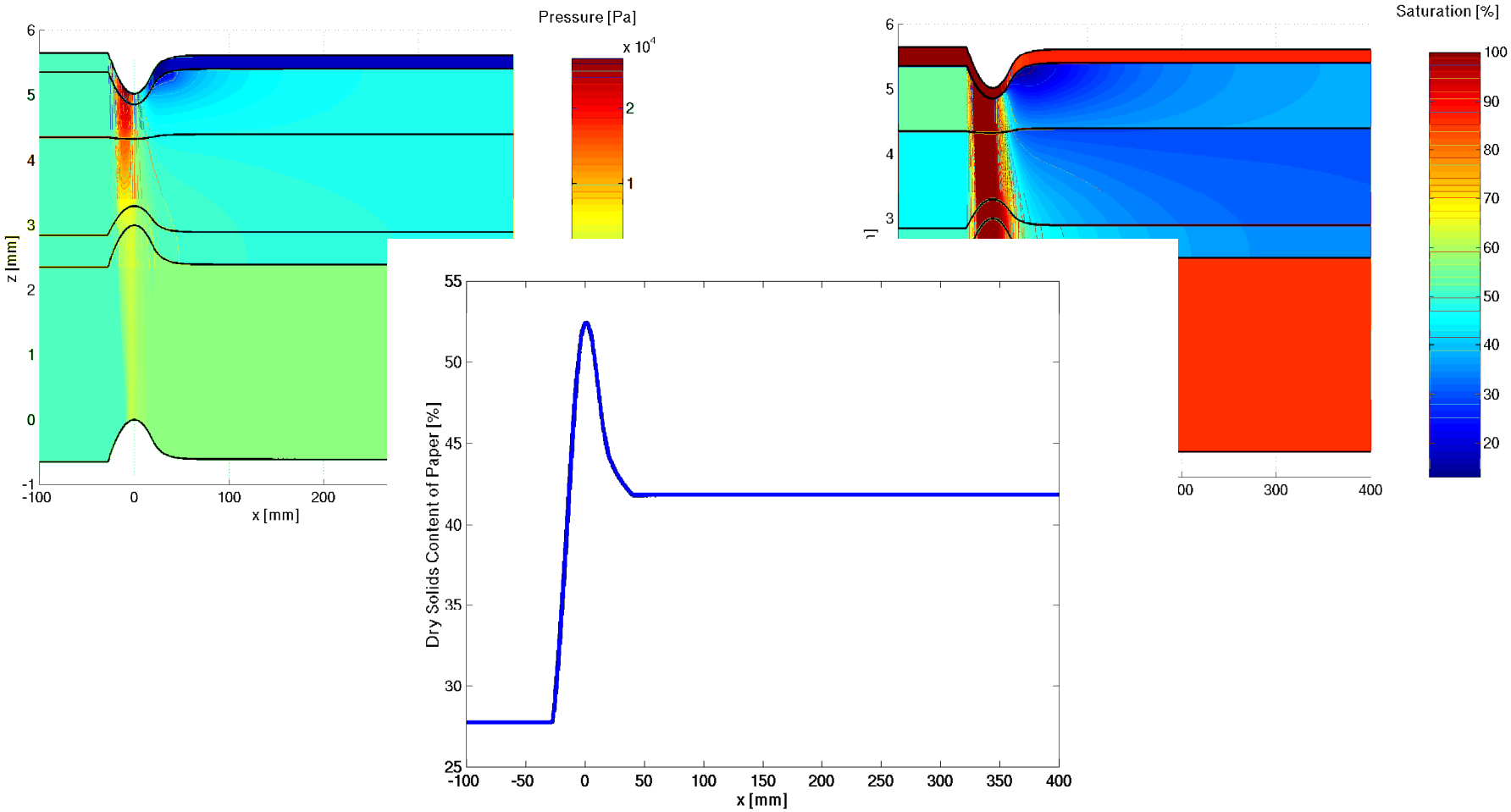
3. Simulation of Structural Properties



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3. Simulation of Structural Properties

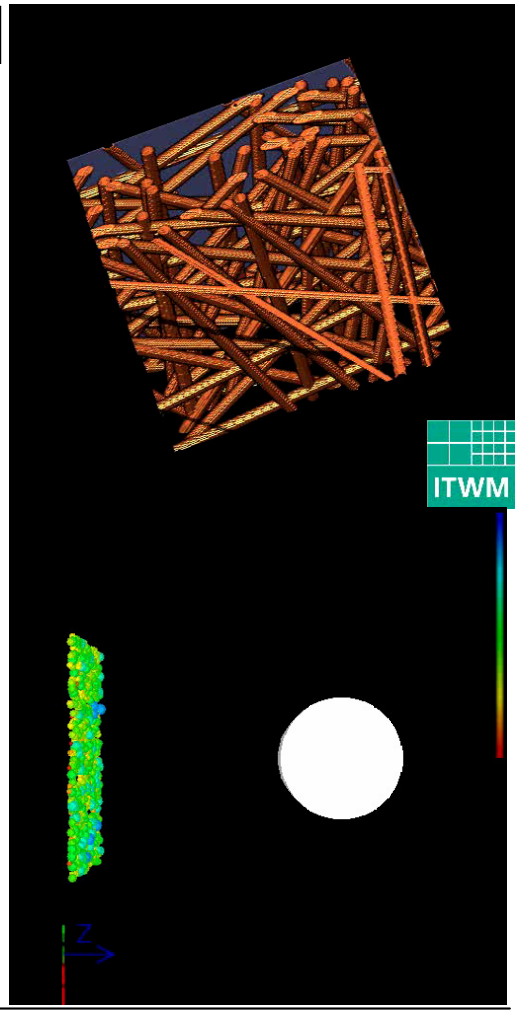
Simulation of Filtration Processes

OPTIMIZATION

1. Choose initial structural parameters
2. Generate / modify structure
3. Solve CFD problem
4. Compute particle transport and deposition
5. Compute filtration efficiency and pressure drop
6. Choose new material parameters

LIFETIME

Flow



Single Fiber Simulation

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3. Simulation of Structural Properties

GEO DICT

Implemented Separation Mechanisms

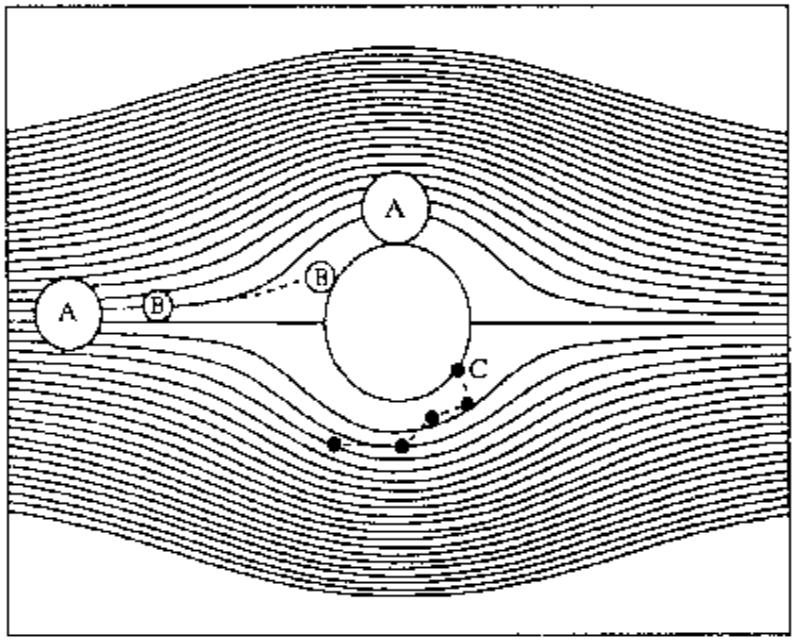
A) Interception

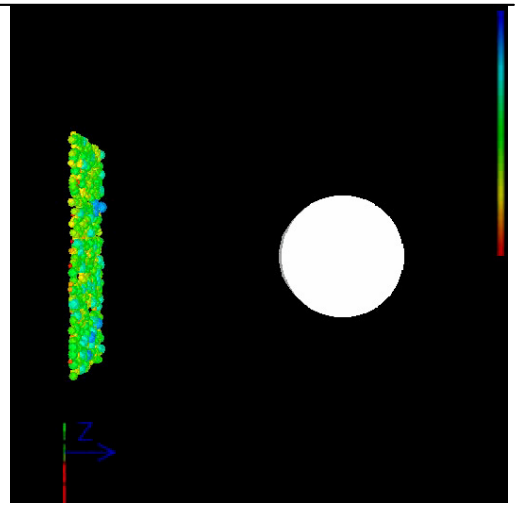
B) Inertia

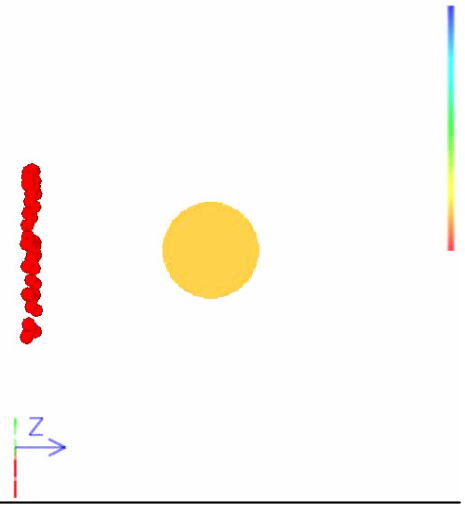
C) Brownian Motion

D) Sieving

E) Electrostatic effects







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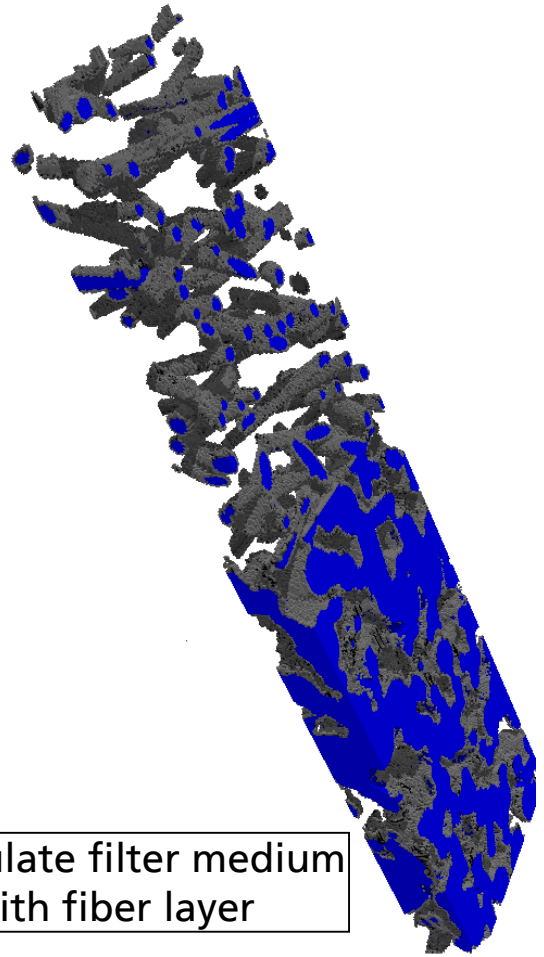
3. Simulation of Structural Properties

GEO DICT

Design Study of a Diesel Particulate Filter

- What is the effect of an additional fibrous layer on top of a sintered substrate ?
- Soot particles (~80nm) are much smaller than voxels (1µm) -> porous deposition model
- Navier-Stokes-Brinkmann model to handle free and porous flow
- Permeability and maximum degree of filling of porous voxels are determined by high resolution single fiber experiments
- Several hundreds of millions of particles are needed for a lifetime computation



Particulate filter medium with fiber layer

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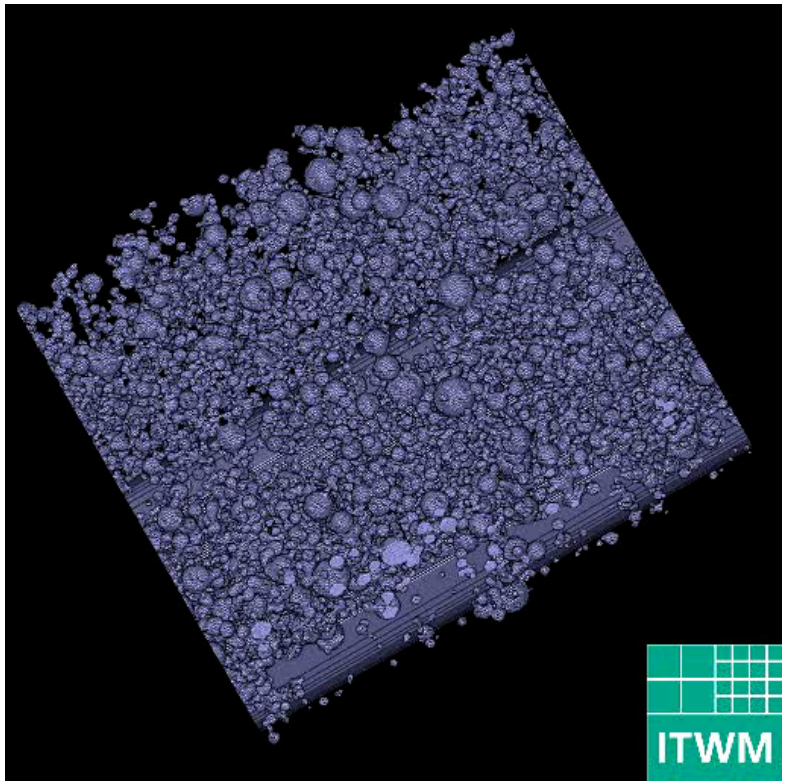
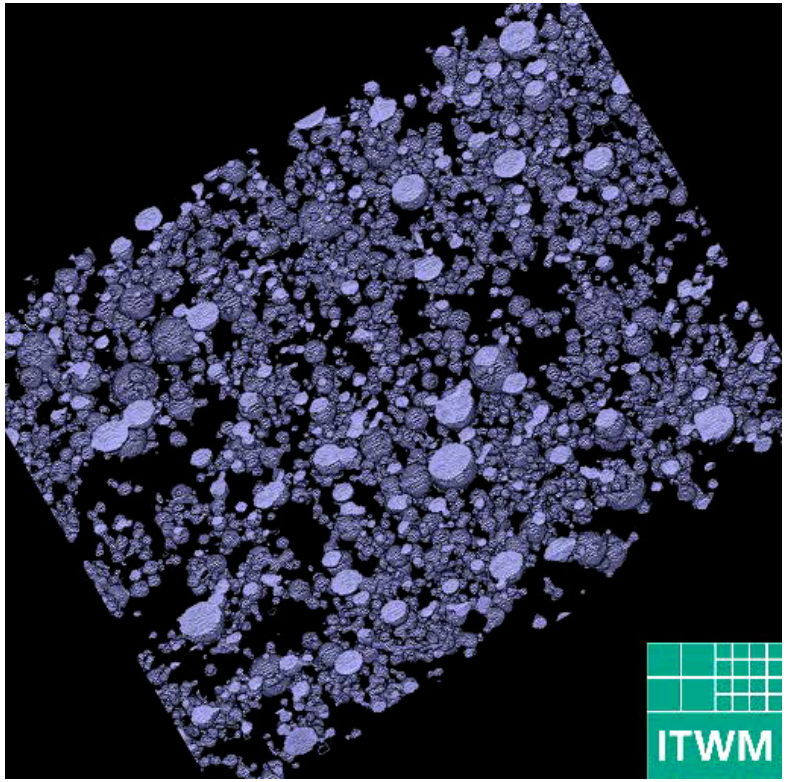
3. Simulation of Structural Properties

GEO DICT

Single Fiber Simulation



Cut-Out of Soot Layer



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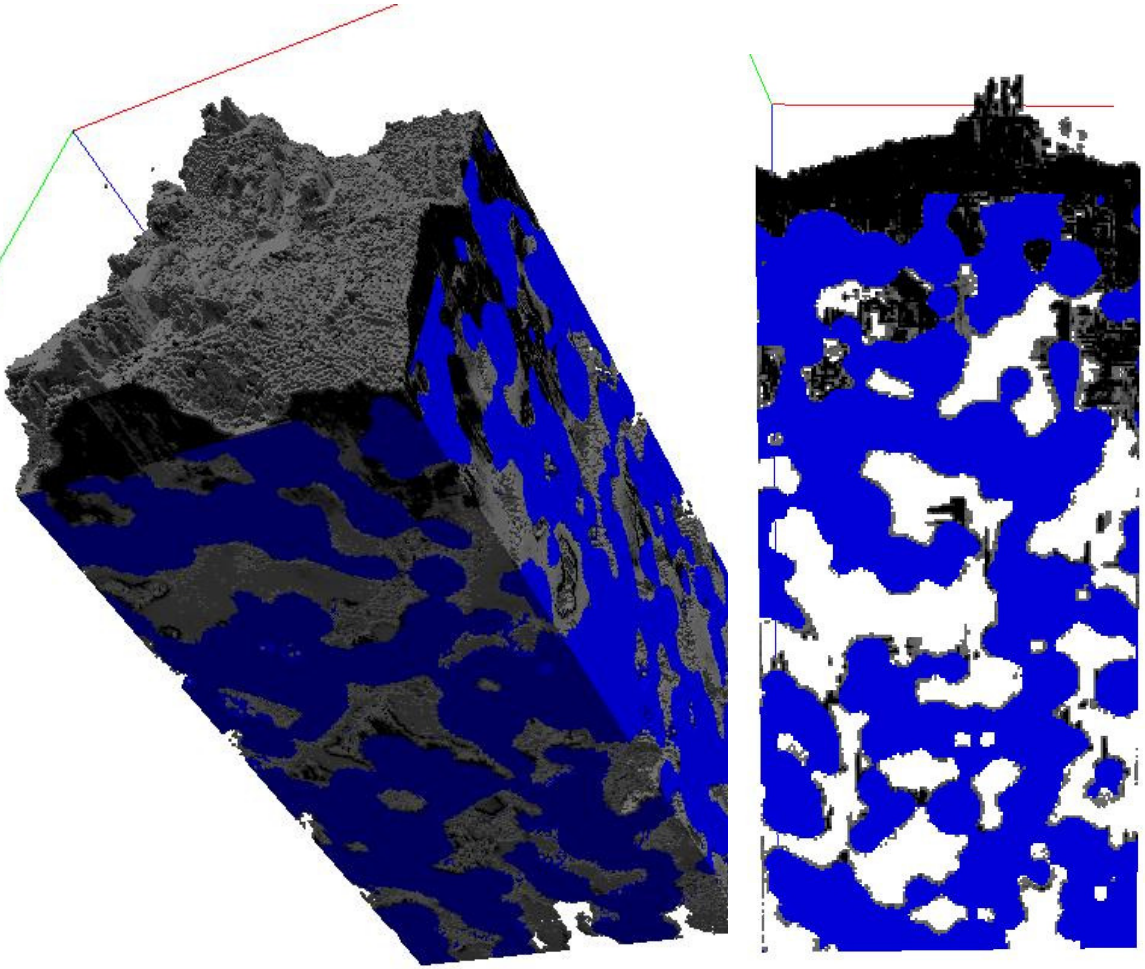

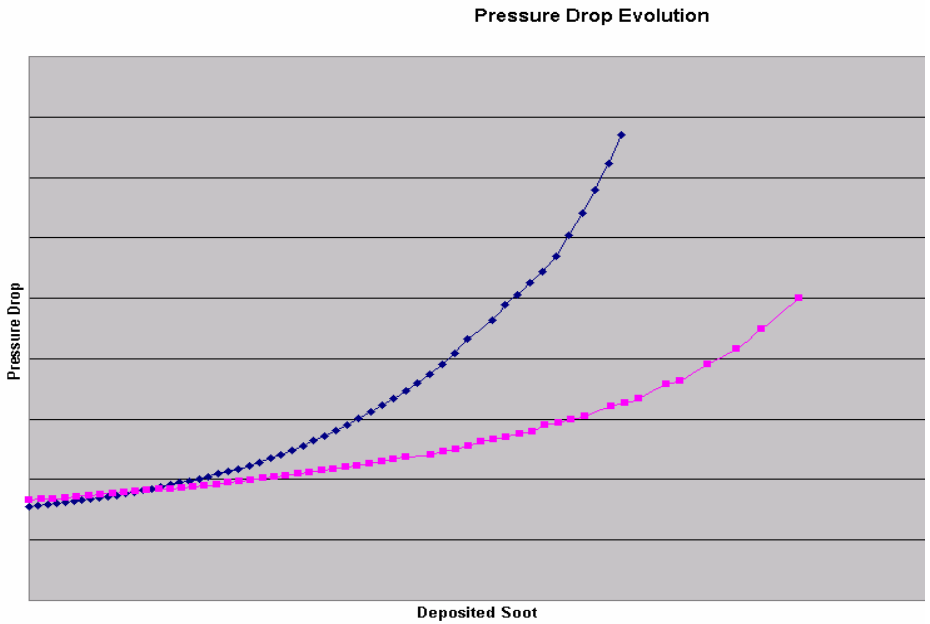

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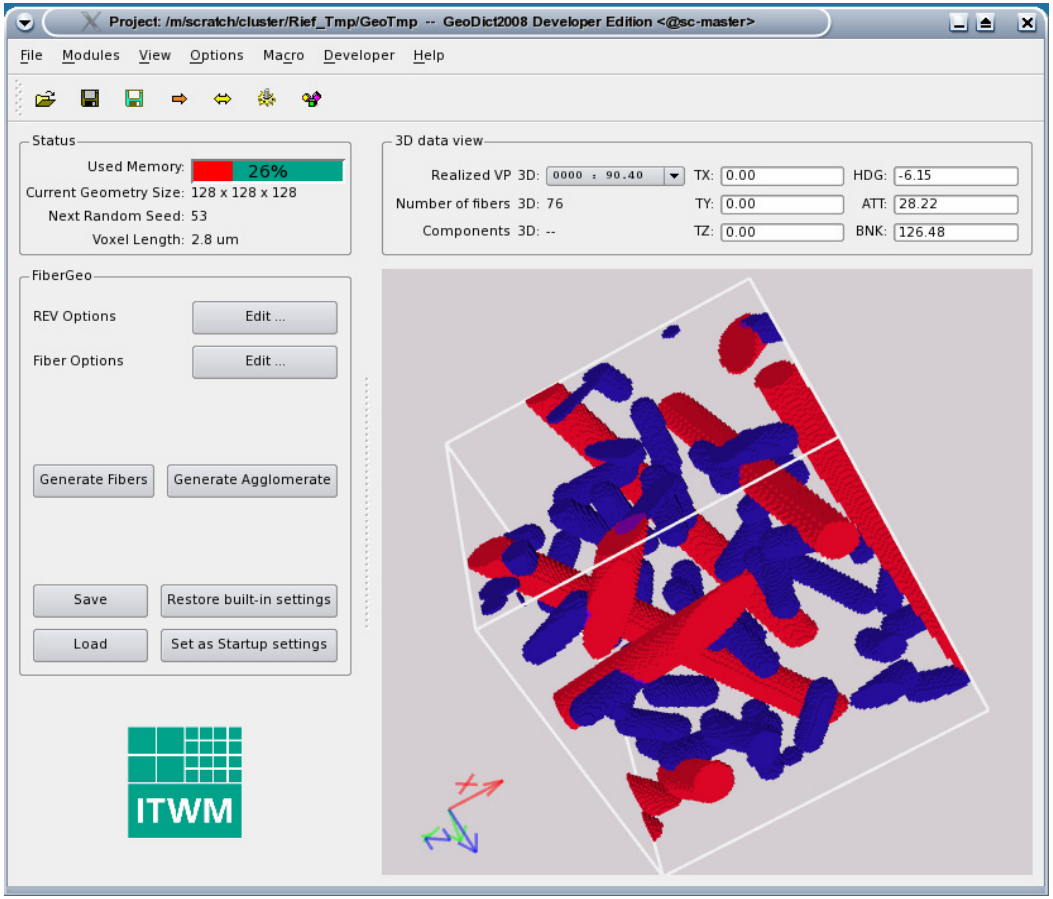
4. Summary (and more …)

- FiberGeo, SinterGeo, WeaveGeo, GridGeo, PackGeo (Structure generation)
- ProcessGeo (3d image processing)
- LayerGeo (building media stacks)
- ImportGeo (Tomography, STL, etc.)
- ExportGeo (Fluent, Abaqus)
- FlowDict (Flow properties)
- ElastoDict (Effective elasticity)
- ThermoDict (Heat conductivity)
- DiffuDict (Effective diffusion)
- FilterDict (Filtration)
- SatuDict (Capillary pressure curves)
- PoroDict (Pore size analysis)
- AcoustoDict (acoustic absorption properties)



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GeoDict Development Teams

The GeoDict Team
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The PleatDict Team
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The FilterDict Team
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Christian Wagner
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Software for Generation, Simulation, Visualization:

GEO DICT

www.geodict.com

Thank You Very Much for Your Attention !

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