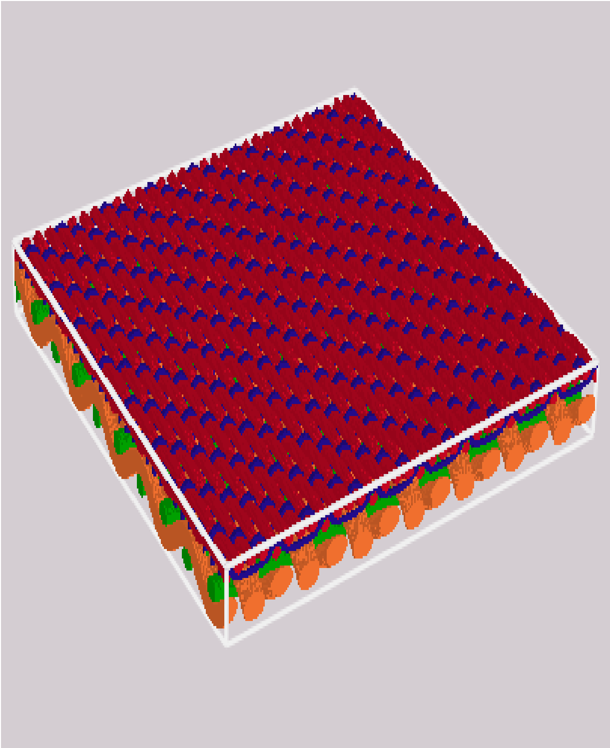
Analysis and Optimization of Paper Machine Clothings by Computer Simulation



Dr. Stefan Rief

Fraunhofer Institute for Industrial Mathematics (ITWM)

Kaiserslautern, Germany

Papermaking Research Symposium 2009

Department of Physics, University of Kuopio

June 2, 2009

Finland

Outline

1. **Introduction**
   - Fraunhofer Society
   - Institute for Industrial Mathematics (ITWM), Kaiserslautern
   - GeoDict
2. **Virtual Structure Generation**
   - Nonwoven, Woven, Sintered Materials, Fabrics and Felts
3. **Structure Characterization**
   - Pore Size Distribution, Bubble Points, Permeability by CFD
4. **Summary and more**

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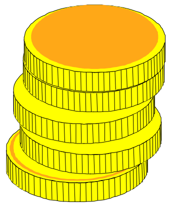
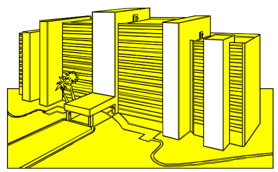
Fraunhofer-Society

13.000
Employees



1,3 Billion €
Budget

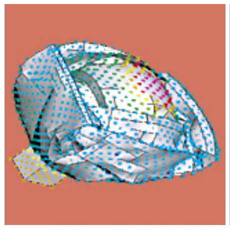
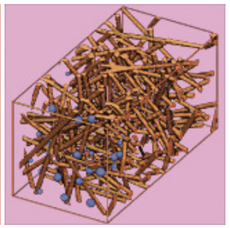
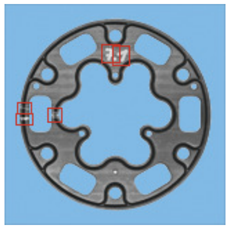


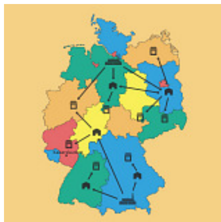
57 Institutes

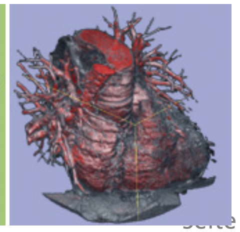
Applied Research Institutes

- **Mechanical Engineering**
- **Experimental Physics**
- **Computer Science**
- **Life Science**
- **Applied Mathematics**
- **…**

Fraunhofer Institute for Industrial Mathematics Kaiserslautern

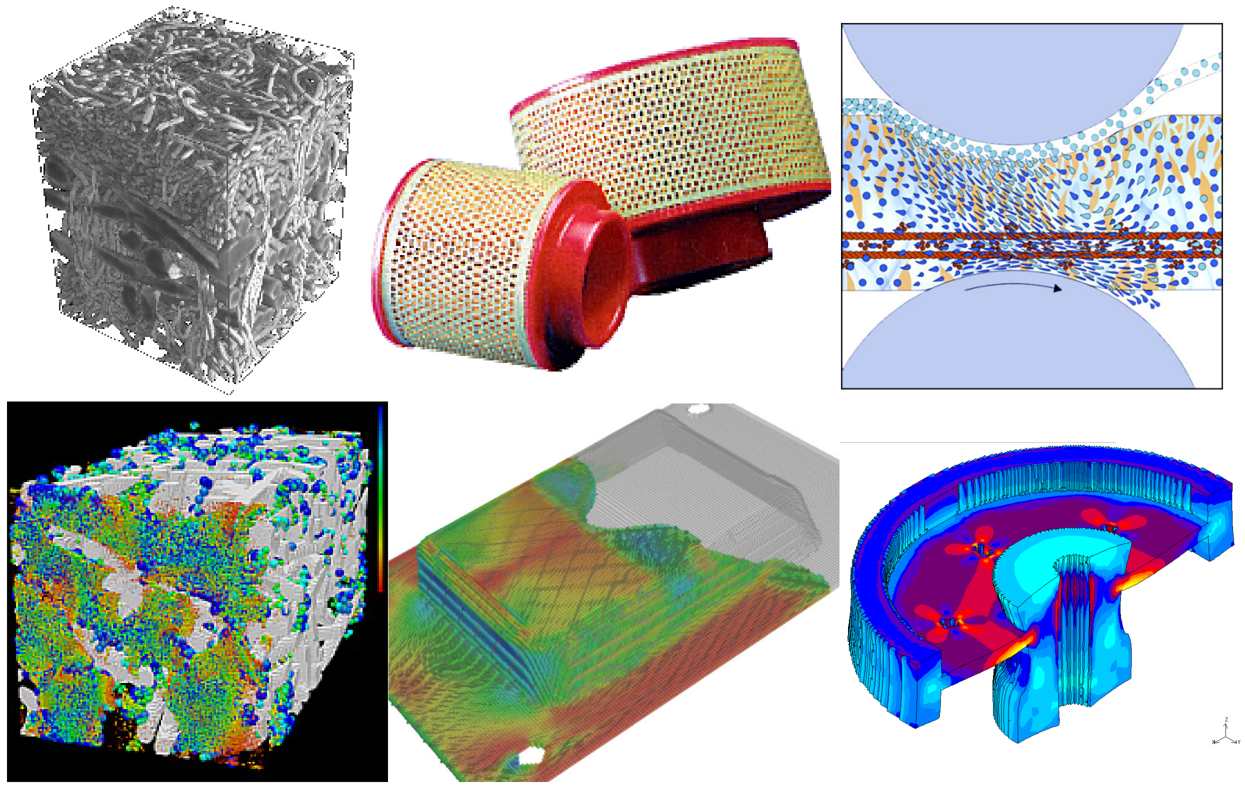


Department *Flow and Material Simulation*

GEO DICT

Subdivisions

- Hydrodynamics and CFD
- Complex Fluids
- Micro-structure simulation and virtual material design
- Structure optimization in mechanics and acoustics



Research Topics

- Efficient numerics for large complex systems
- Multi-scale simulation

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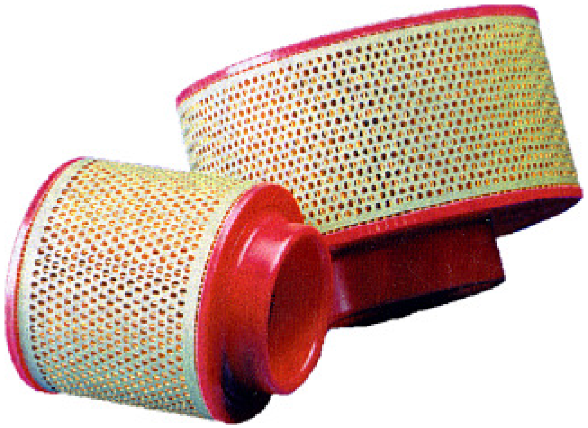
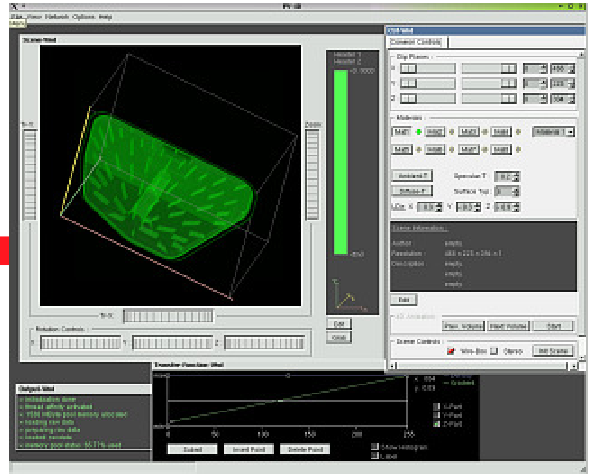
Virtual Material Design Cycle

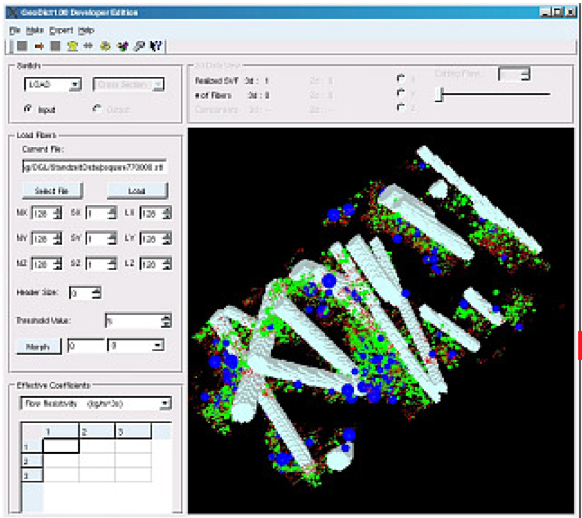
Property Requirements Fulfilled?





Virtual Design Cycle

Selection of Media Types, Dimensions, etc.



Computation of Macroscopic Properties of the Filter

Computation of Microscopic Properties of the Filter Medium

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PRS

Software

GEO DICT

Virtual Structure Generation

(Geometry)

Structure Characterization

(Prediction)

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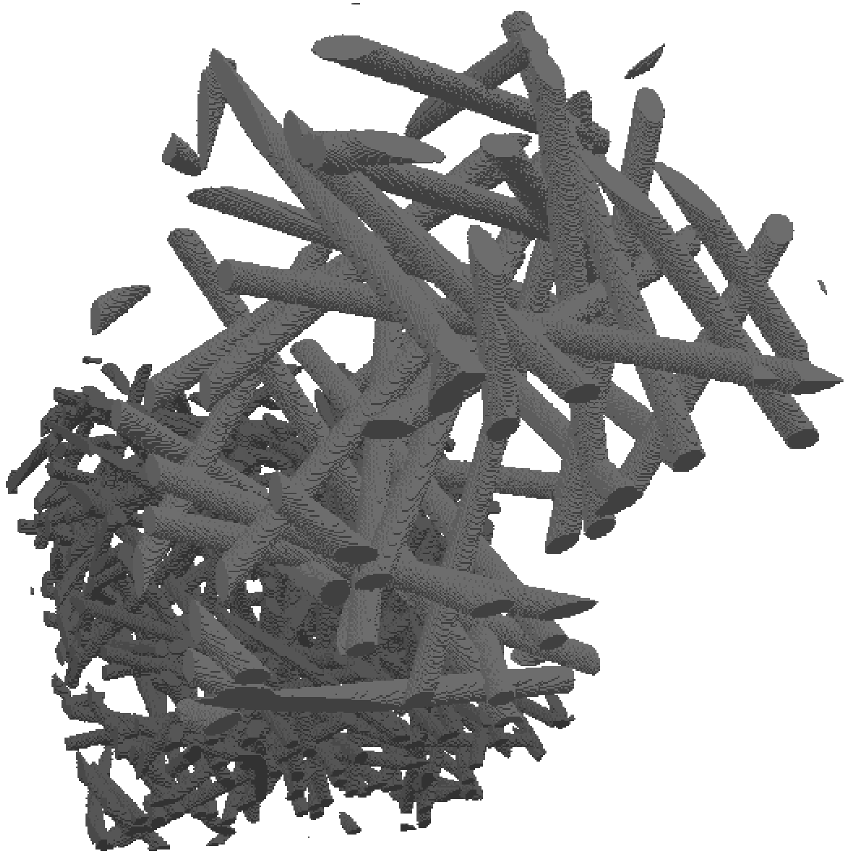
Virtual Structure Generation

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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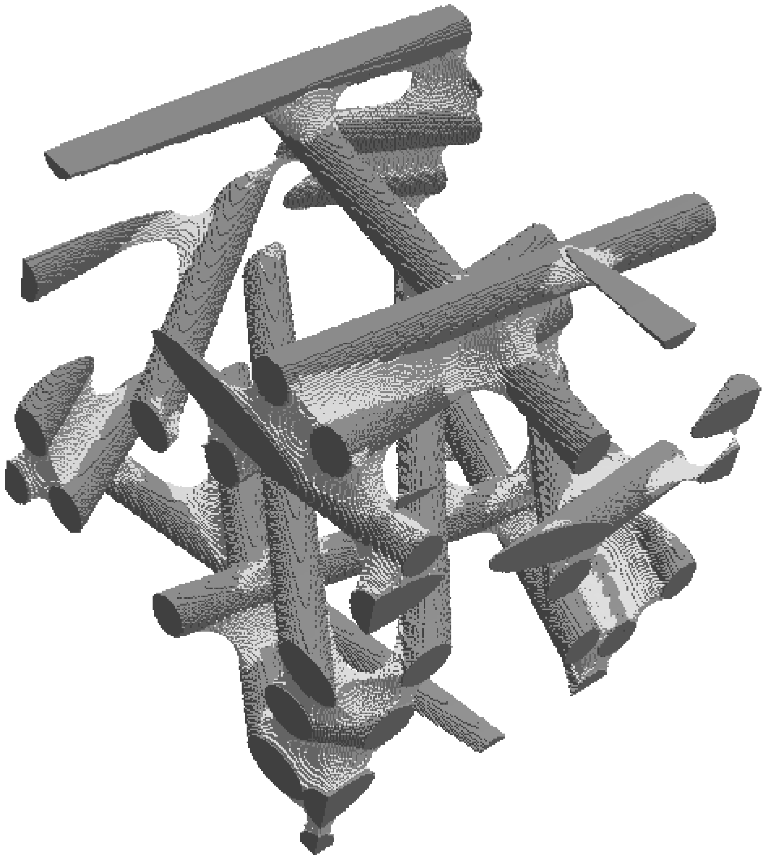
Virtual Structure Generation

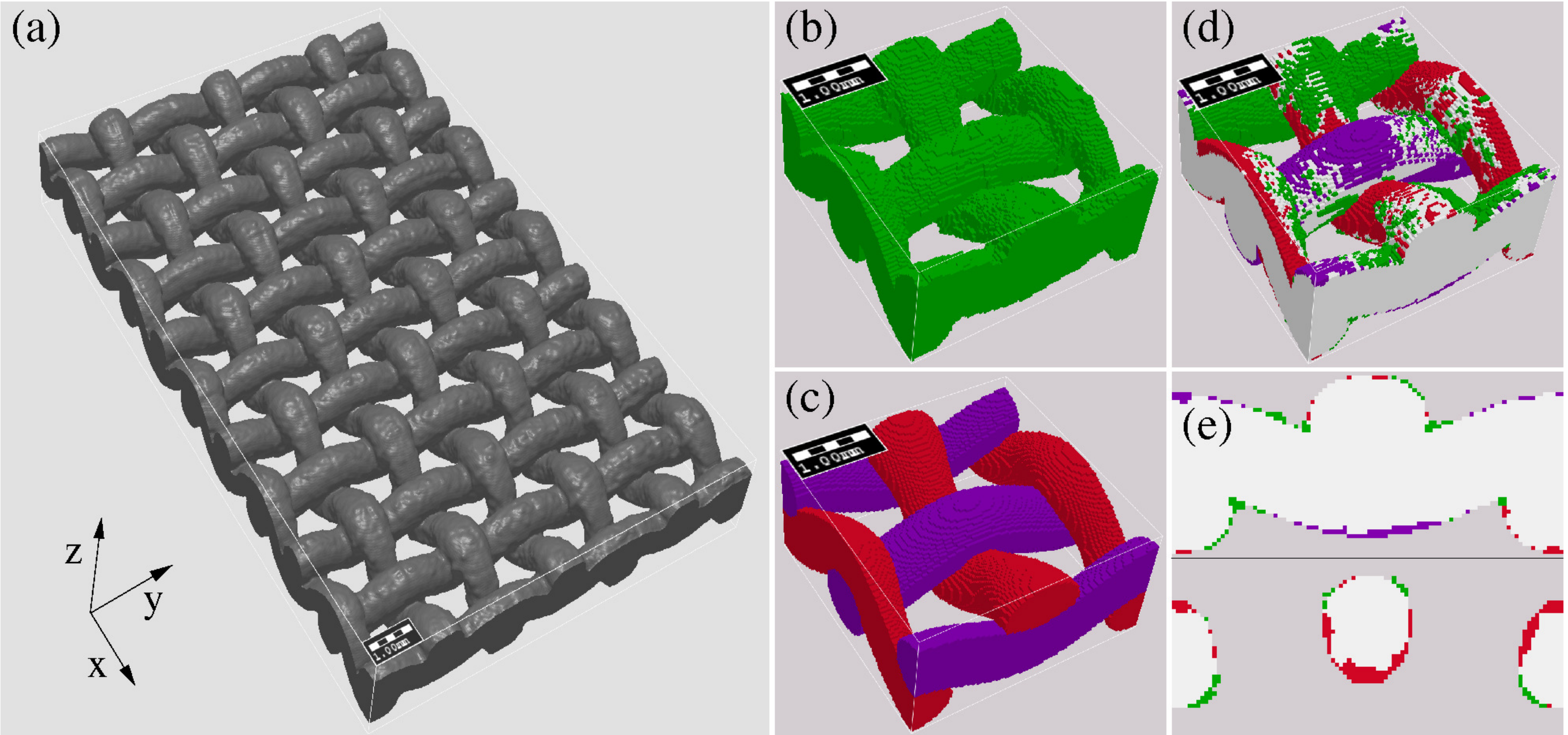
Virtual Nonwoven with Binder Material

- 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



Virtual Structure Generation

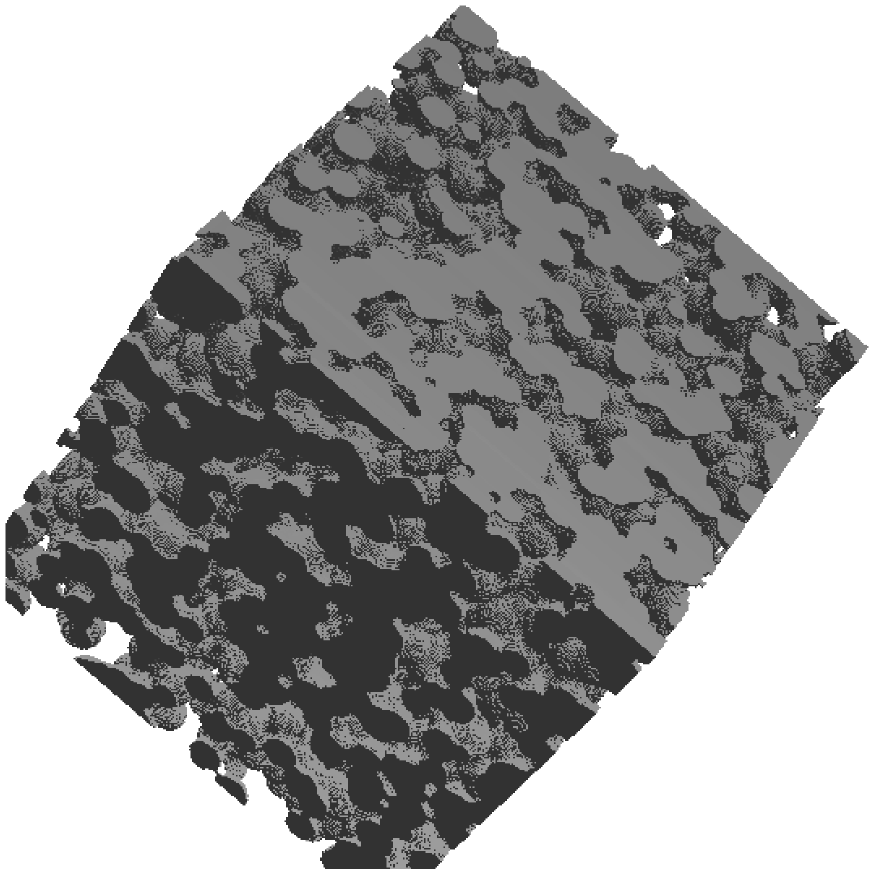
Virtual Woven



Virtual Structure Generation

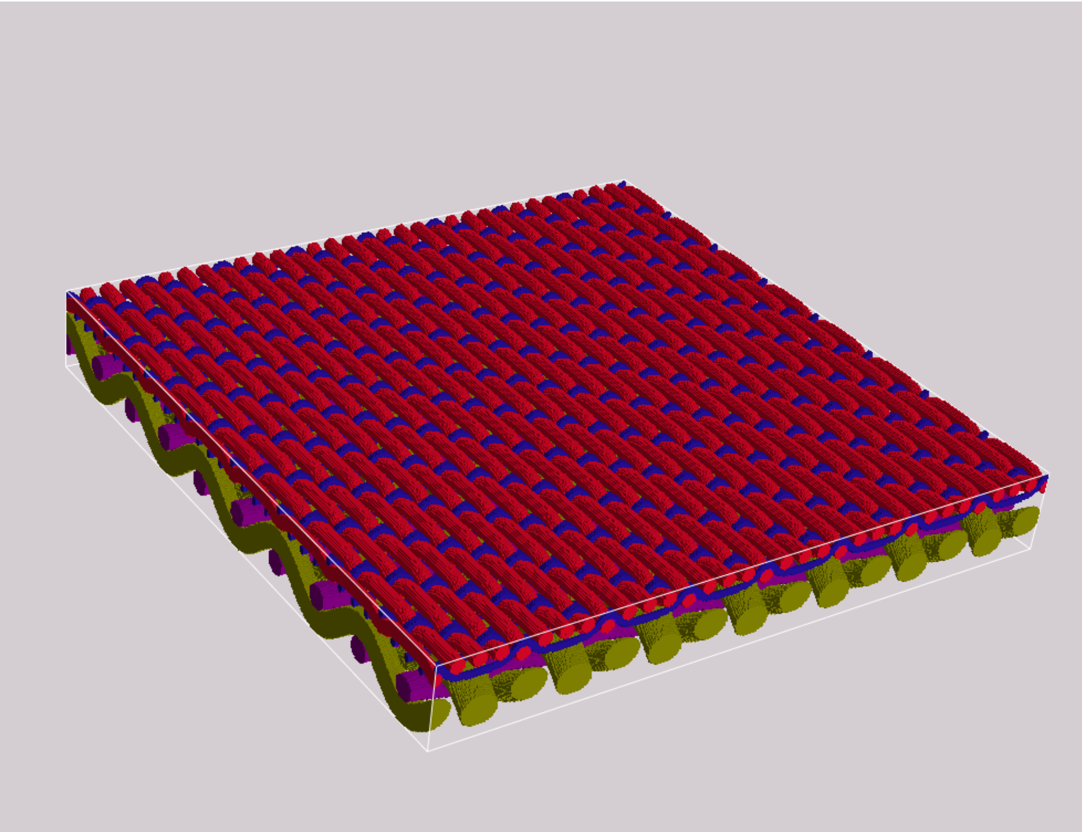
Virtual Sinter Structure

- 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

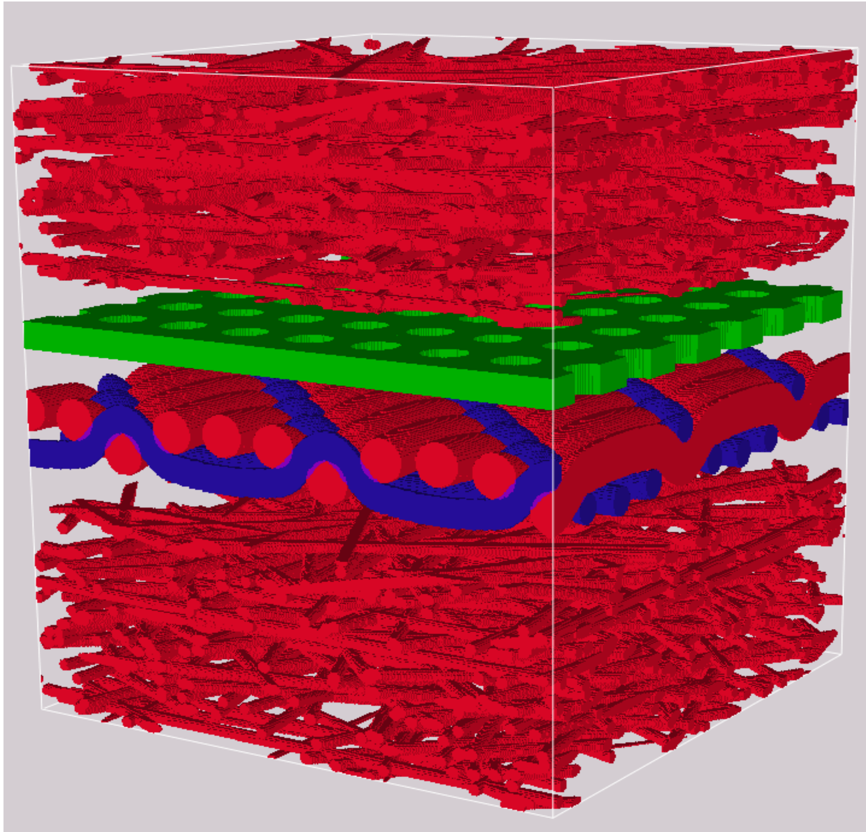


Virtual Structure Generation

Virtual Fabric



Virtual Felt

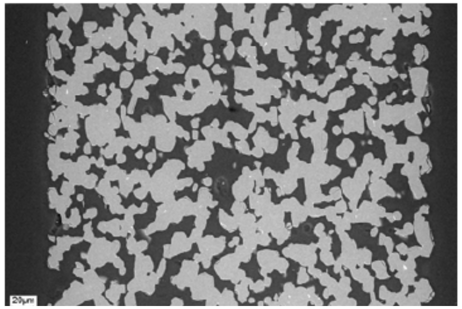


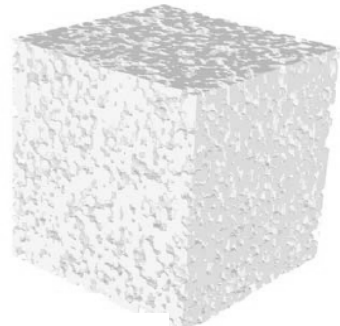
Virtual Structure Generation

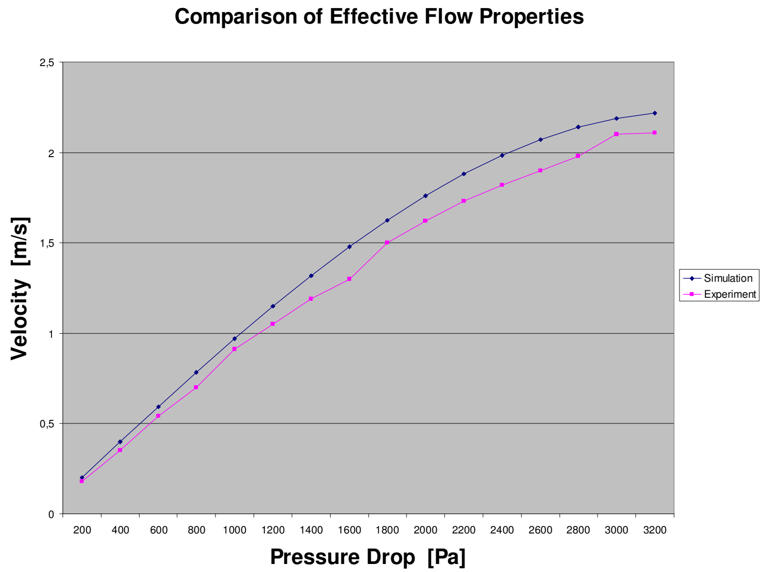
GeoDict

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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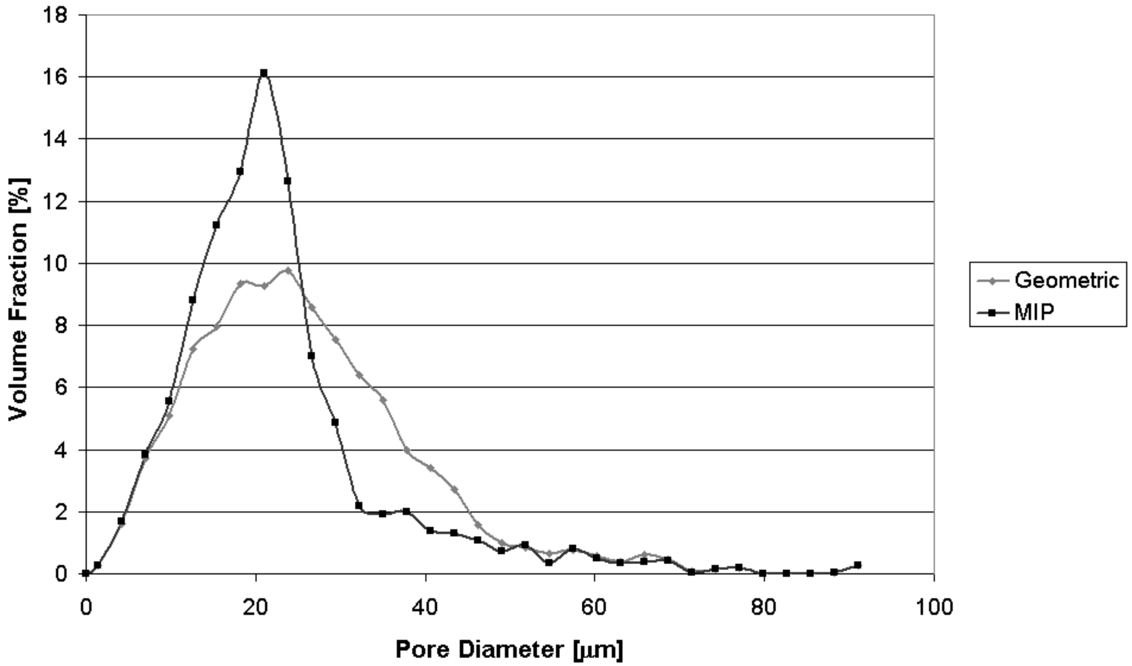
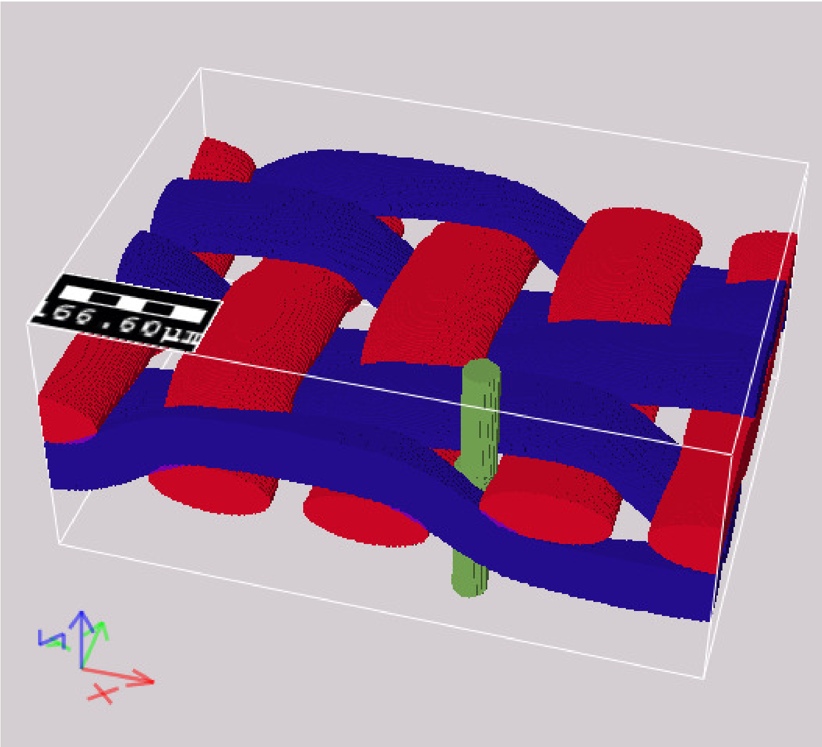
Simulation of Pore Size Distributions

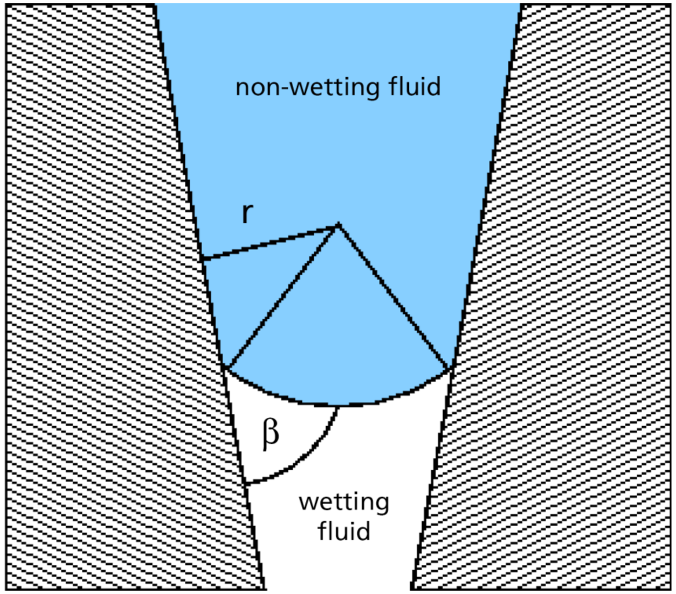


Structure Characterization

Maximum Through Pore → Young-Laplace Equation → Bubble Point



$$p_c = \frac{2\sigma}{r}\cos\beta$$



Structure Characterization

Flow Solver is based on Navier-Stokes-Brinkmann equations

$$
\begin{aligned}
-\mu\Delta\vec{u} + \nabla\vec{u}\cdot\vec{u} + \kappa^{-1}\vec{u} + \nabla p &= \vec{\mathrm{f}}, \qquad \text{(momentum balance)}\\
\nabla\cdot\vec{u} &= 0, \qquad \text{(continuity)}
\end{aligned}
$$

$+$ boundary conditions,

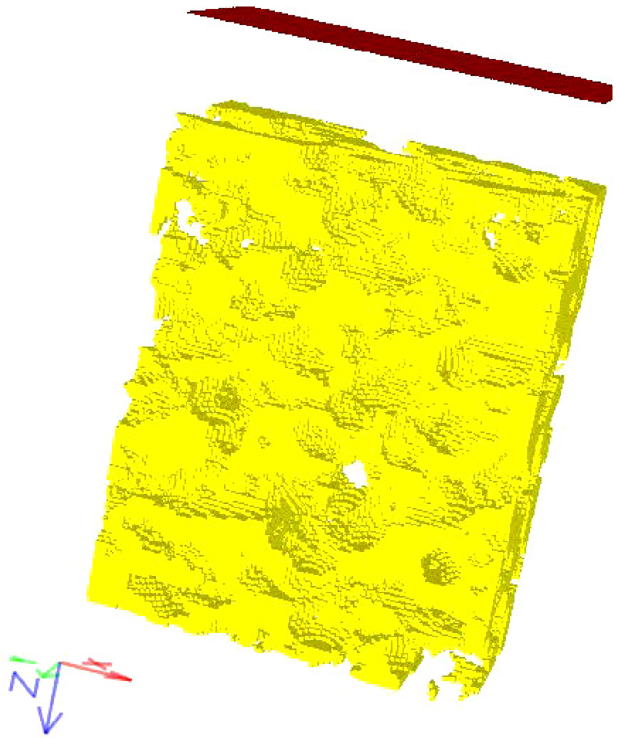
$\vec{u}$: velocity

p : pressure

$\vec{\mathrm{f}}$: force (density)

μ : fluid viscosity

κ : permeability of porous voxel



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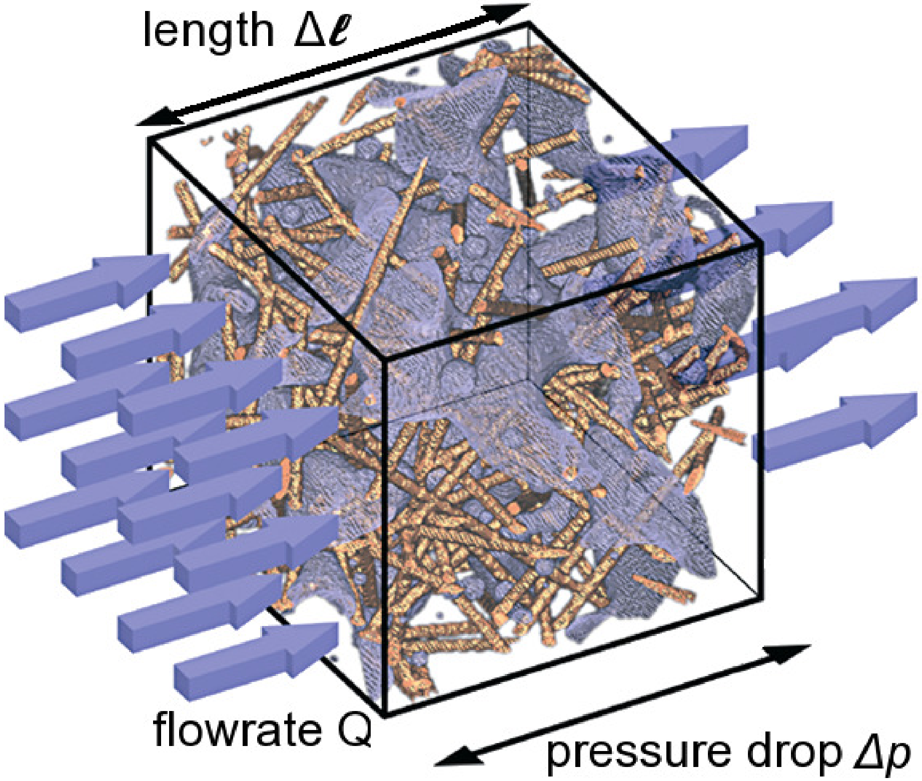
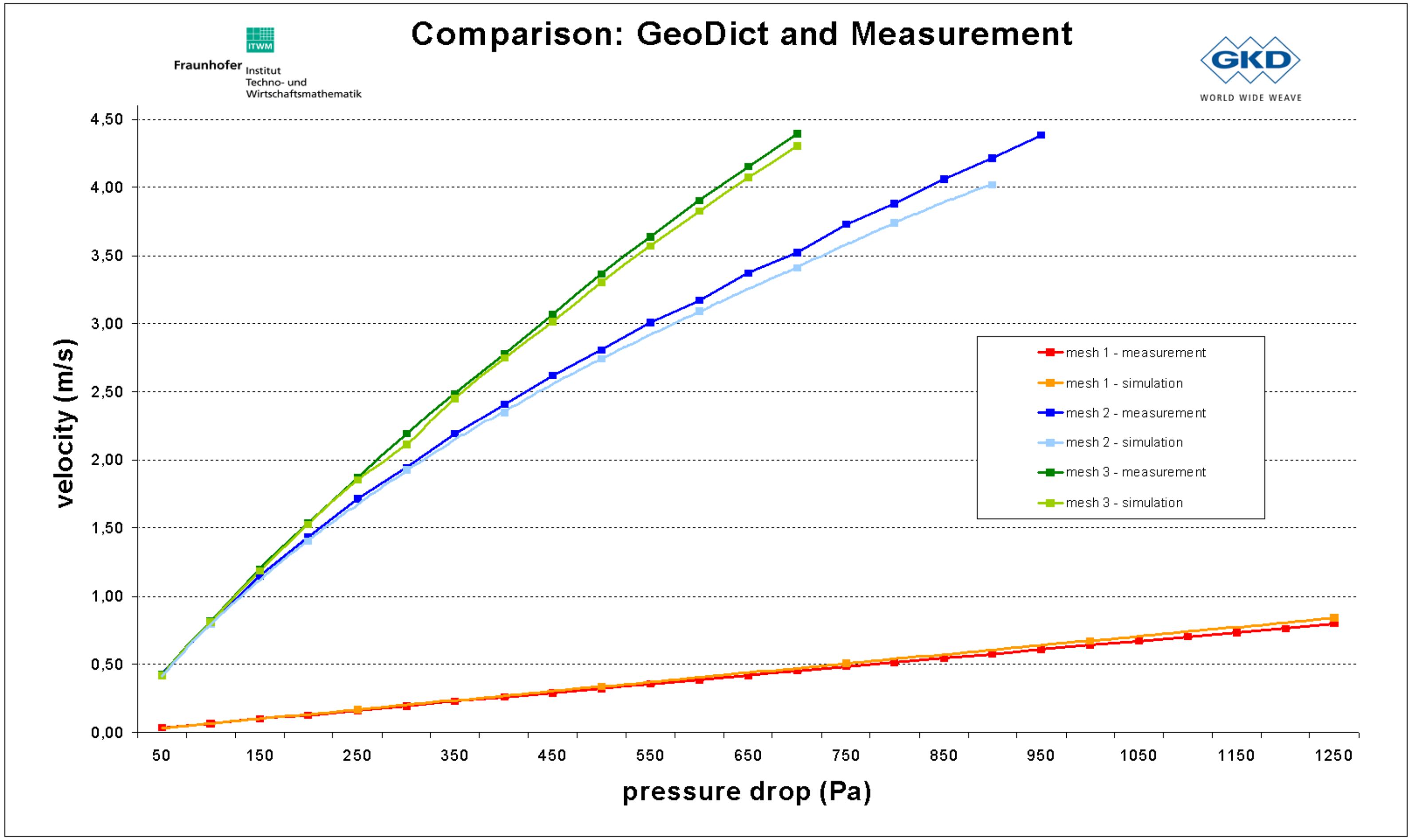
Air / Water Permeability

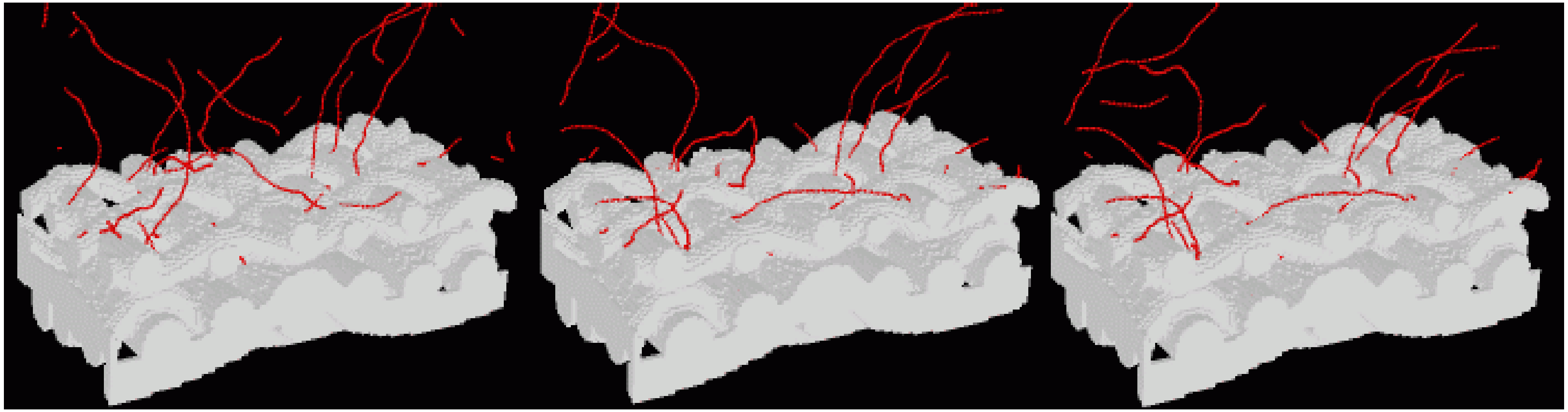
Darcy's law: $$Q = \frac{K}{\mu} \cdot \frac{\Delta p}{\Delta l}$$



Structure Characterization



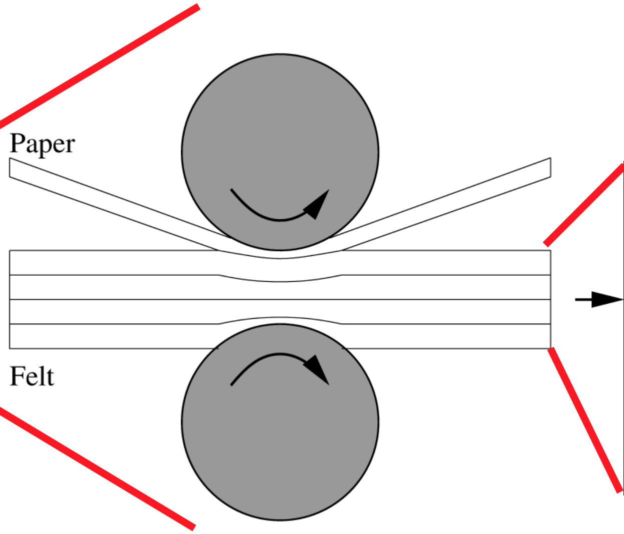
Paper Forming

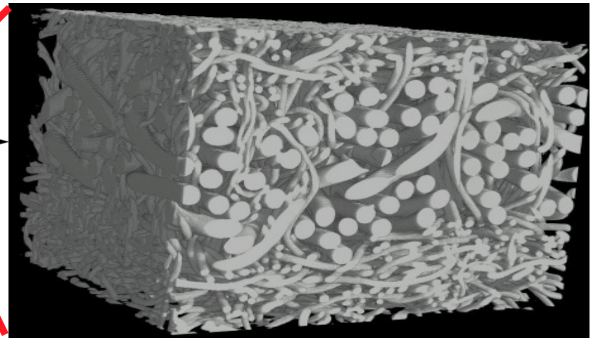


R. Rundqvist: Microstructure simulations of early paperforming (PRS 2009)

Press Nip Simulation

Paper Machine	Press Section	Tomography



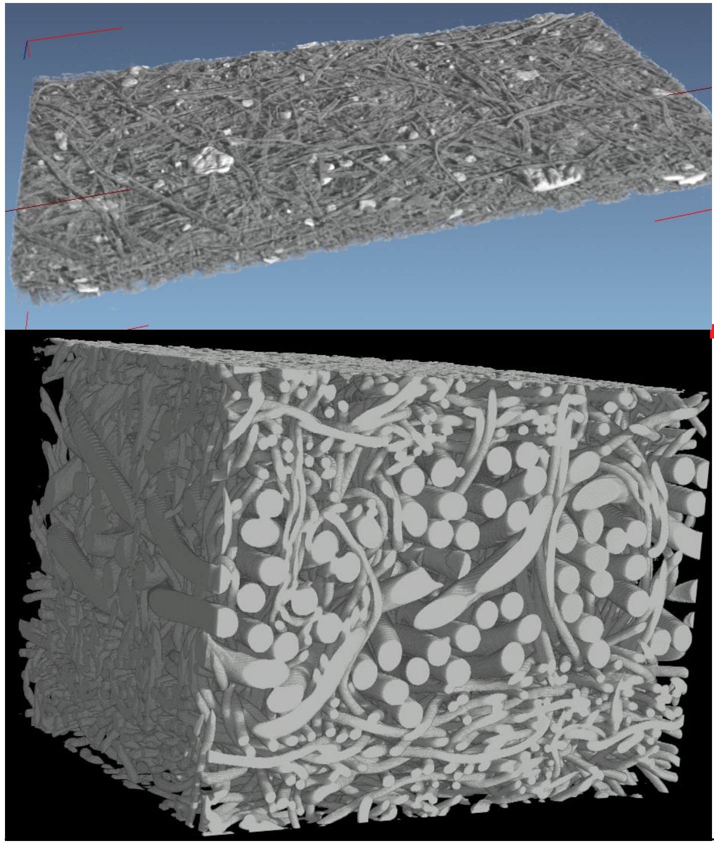


100µm

30 cm

Press Nip Simulation

Modeling and Simulation of the Pressing Section of a Paper Machine



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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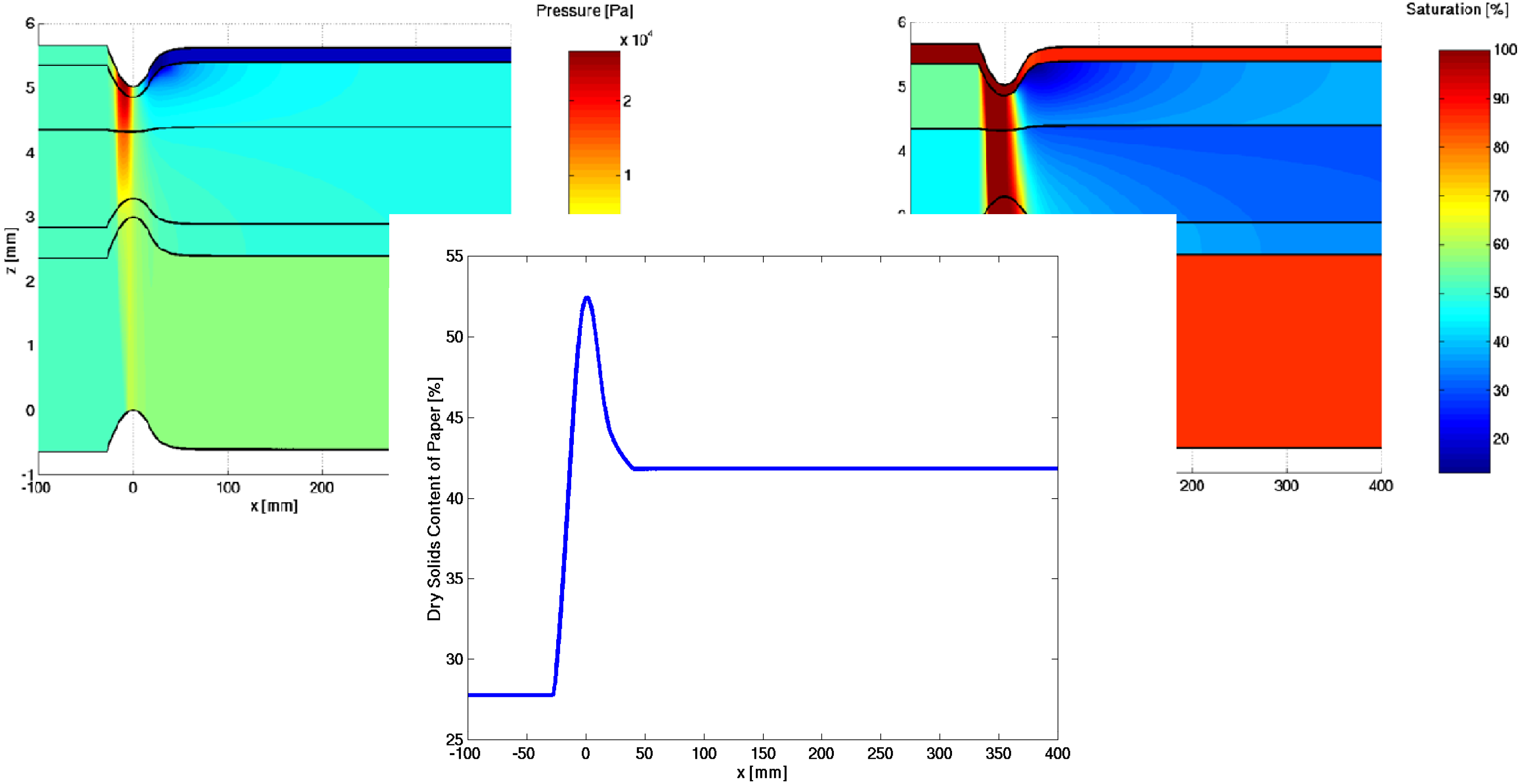
Press Nip Simulation



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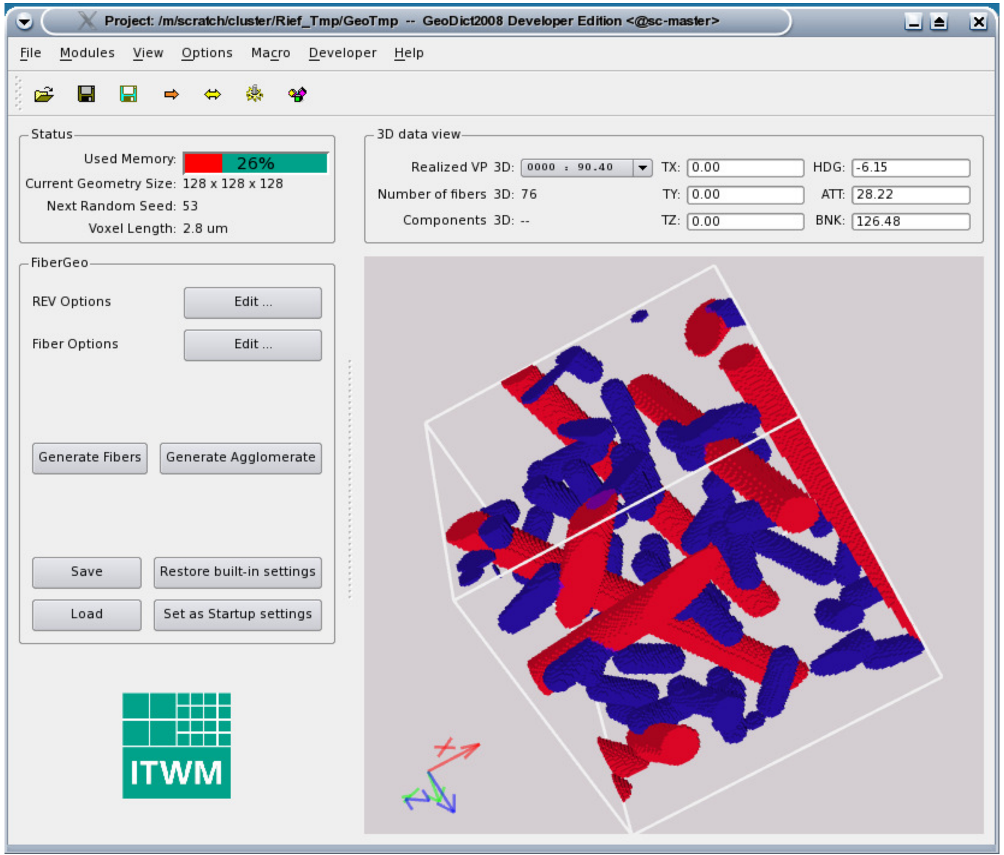
4. Summary and more

- 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
Andreas Wiegmann
Jürgen Becker
Kilian Schmidt
Heiko Andrä
Ashok Kumar Vaikuntam
Rolf Westerteiger
Christian Wagner
Mohammed Alam
Jianping Shen

The PoroDict Team
Andreas Wiegmann
Jürgen Becker
Rolf Westerteiger

The PleatDict Team
Andreas Wiegmann
Oleg Iliev
Stefan Rief

The FilterDict Team
Stefan Rief
Kilian Schmidt
Arnulf Latz
Andreas Wiegmann
Christian Wagner
Rolf Westerteiger

The SatuDict Team
Jürgen Becker
Volker Schulz
Andreas Wiegmann
Rolf Westerteiger

The RenderGeo Teams
Carsten Lojewski
Rolf Westerteiger
Matthias Groß

The FiberGeo Team
Andreas Wiegmann
Katja Schladitz
Joachim Ohser
Hans-Karl Hummel
Petra Baumann

WeaveGeo & PleatGeo
Andreas Wiegmann

The SinterGeo Team
Kilian Schmidt
Norman Ettrich

The ElastoDict Team
Heiko Andrä
Dimiter Stoyanov
Andreas Wiegmann
Vita Rutka
Donatas Elvikis

GridGeo & PackGeo
Andreas Wiegmann

FlowDict Lattice Boltzmann Team
Dirk Kehrwald
Peter Klein
Dirk Merten
Konrad Steiner
Irina Ginzburg
Doris Reinel-Bitzer

FlowDict EJ Solver Team
Andreas Wiegmann
Liping Cheng
Aivars Zemitis
Donatas Elvikis
Vita Rutka
Qing Zhang

Software for Generation, Simulation, Visualization:

GEO DICT

www.geodict.com

Thank You Very Much for Your Attention !

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