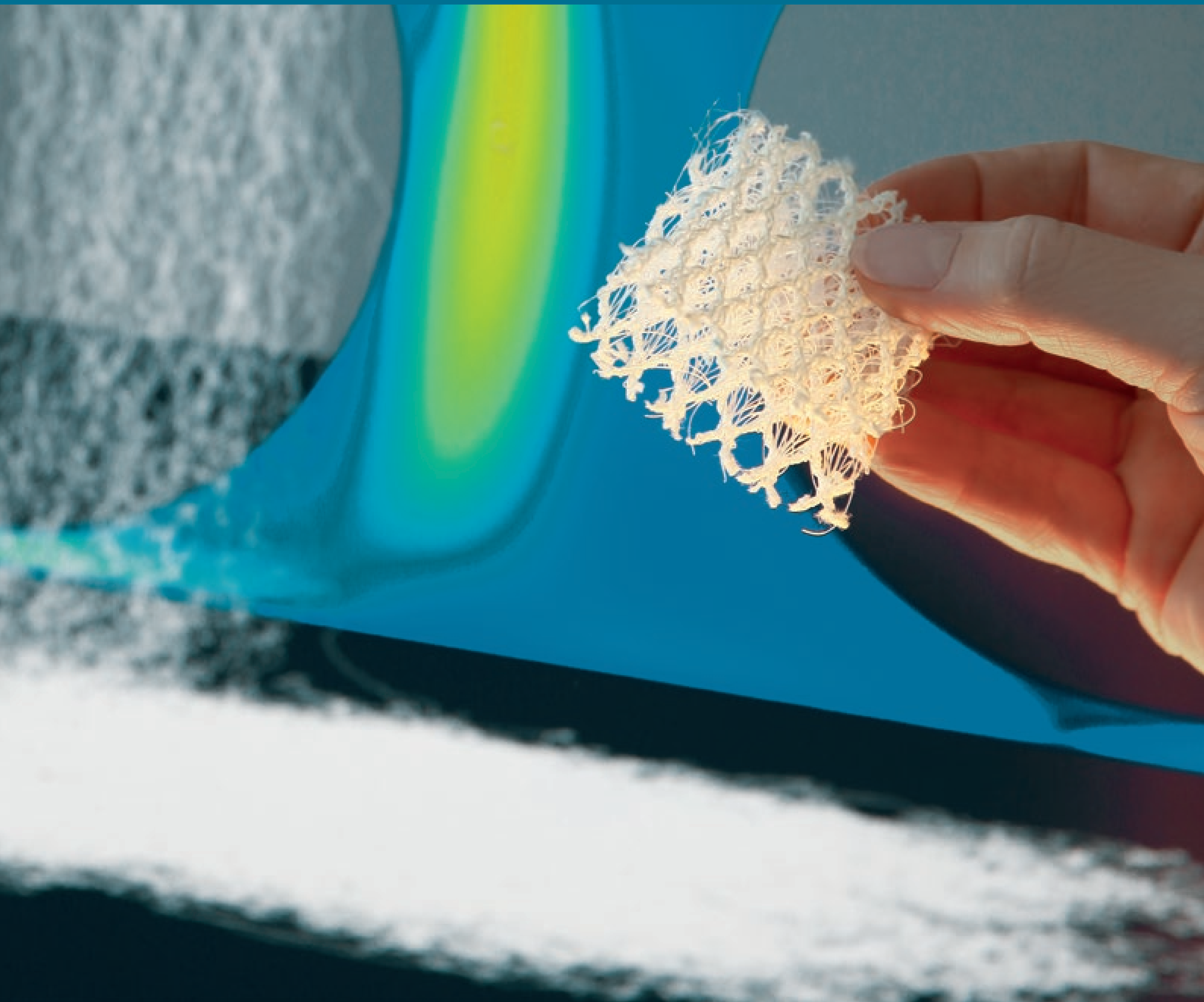
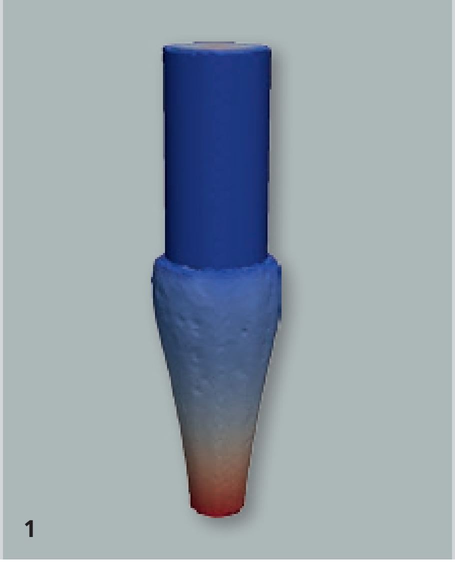
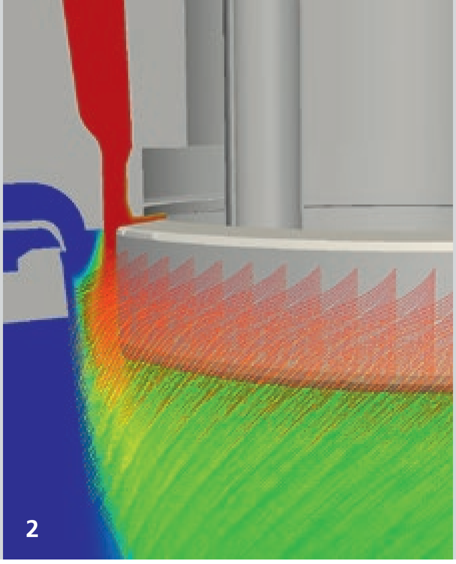
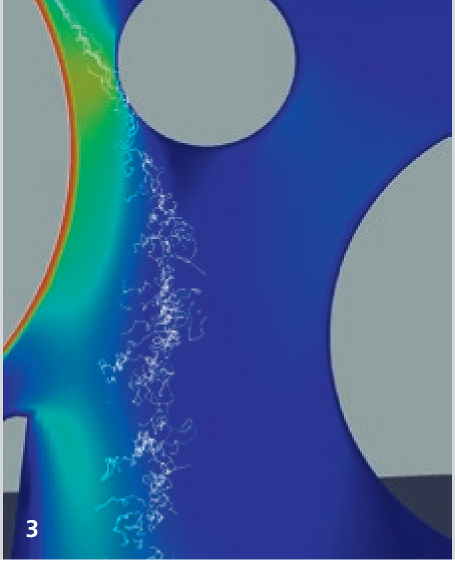
FRAUNHOFER INSTITUTE FOR INDUSTRIAL MATHEMATICS ITWM

COMPUTERIZED OPTIMIZATION OF FIBERS, NONWOVENS AND TECHNICAL TEXTILES









1 Polymer extrusion with 3D simulation of die swell

2 Coupled simulation of filaments and hot gas flow in rotational spinning process for glass wool

3 Simulation of fiber dynamics for airlay nonwoven process (Autefa)

Modeling, simulation and optimization of fiber and nonwovens processes

The modeling and simulation of fiber and nonwovens processes enable new insights and development perspectives. Process optimization can be performed on basis of this type of simulations. Typical aspects to be modeled, simulated and optimized are:

- homogeneity of melt distribution
- residence time of melt in spin pack
- cooling of filaments in quench unit
- filament stretching in spinning process
- filament dynamics in laydown process
- staple fiber laydown and web forming
- uniformity of base weight distribution
- fiber orientation in web structure

Fraunhofer ITWM has developed for all these topics specific models and efficient algorithms for numerical simulations of industrial problems with unique properties:

- effective numerical simulation of melt flow by parametric inclusion of local results on filters and capillaries
- effective optimization of distributors based on homogeneous level of wall shear stress
- effective simulation of spinning processes based on continuation method for boundary value problems
- effective simulation of fiber and filament dynamics by using Cosserat rod models for slender body asymptotic
- effective model for stochastic forces acting by local fluctuations in turbulent flow onto fibers or filaments

With the help of these models and algorithms several software tools have been developed:

- **Meltop:** Analysis and optimization of melt flow in spin packs with respect to residence time and wall shear stress
- **VisFID:** Simulation and optimization of filament spinning processes fully coupled with surrounding fluid flow
- **FIDYST:** Simulation of filament and fiber dynamics in turbulent flow coupled with surrounding fluid flow
- **SURRO:** Fast generation of complete nonwoven web structures based on FIDYST results for laydown behavior

These tools are often used for simulation and optimization in joint projects with industrial partners. Furthermore licensing for direct usage by engineers is possible.

Typical application fields are:

- spin pack design
- spinning processes: filament or centrifugal spinning, BCF, glass fibers, bico fibers
- nonwoven processes: spunbond, meltblown, staple fibers
- optimization of components: spinneret, hole pattern design, quench air unit, funnel, suction box
- optimization of operational conditions
- design of new processes

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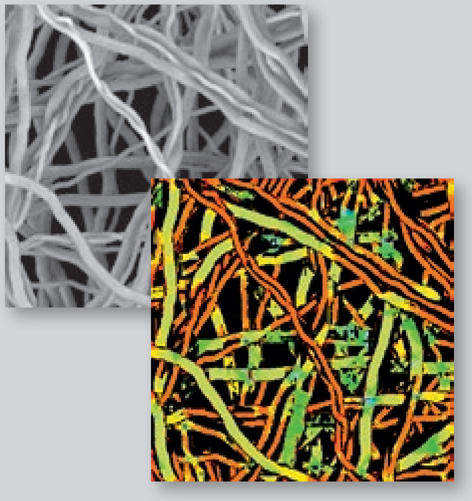
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Image processing for analysis, characterization, and quality management

For all kinds of technical textiles
- woven fabrics
- laid webs, braidings, knittings
- nonwovens

during production, as semi-finished or final products

Applicable
- **inline** as an automatic inspection system for complete control
- **offline** for objective, repeatable quantitative analysis in your quality assurance lab
- **remotely** for feasibility studies or detailed (micro)structural analysis

Quality assessment and characterization

Image analysis finds faults like flaws in woven structures, inclusions, impurities, or holes. Inhomogeneities like thin or thick spots, formation or calender errors or exceeding fuzziness can not only be detected but also measured objectively. Fiber distribution, orientation, and thickness can be analyzed quantitatively in two and three dimensions. Accuracy of patterns and colors can be assessed, too. Model based analysis and machine learning approaches allow to solve further particular problems.

Moreover, we fit texture or geometry models based on image data. These models can serve as realistic starting point for product development via virtual material design.

Imaging methods

Our inspection systems are based on optical light. The optimal combination of light sources, optics, and camera is determined in our well equipped image processing lab. For (micro)structural analysis we offer micro computed tomography. Our software products for quantitative image analysis are also dedicated to SEM, CSLM, and various nano-tomographic methods.

Software products

MAVIfiber2d
- for microscopic images, lab analysis
- fiber thickness
- fiber orientation
- homogeneity (fuzziness)

MAVI
- microstructural analysis
- 2D or 3D image data
- fiber orientation in 3D
- 2nd order orientation tensors
- volume fractions
- connectivity and pore space analysis

ToolIP
- graphical algorithm design tool
- create your own image analysis solution
- analyze a large amount of image data automatically

MASC
- custom made surface inspection
- production integrated inline solutions

4 *Inhomogeneous nonwoven sample*

5 *Inline inspection systems: camera and detected flaw*

6 *SEM image and color coded fiber thickness map*

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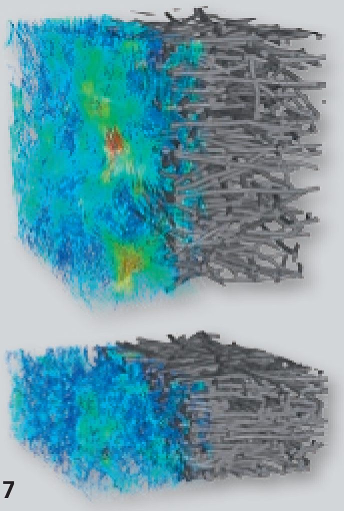

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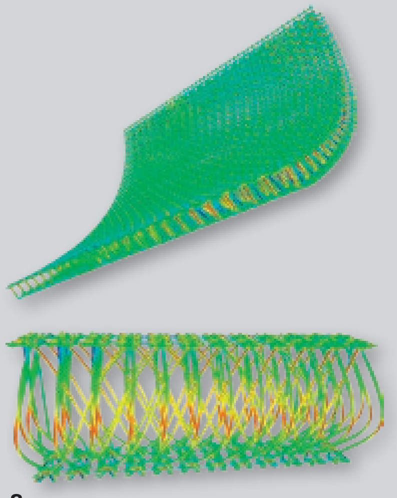

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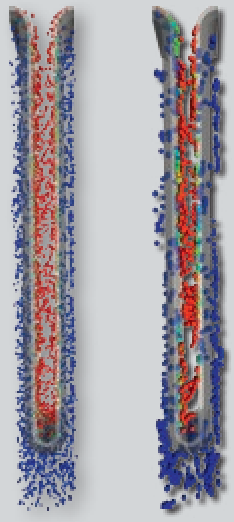

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7 *Manufacturing effects on permeability: Flow simulation for a nonwoven microstructure in original configuration (left) and after compression (right)*

8 *Flexural properties of a spacer fabric: Locale axial stresses. Red indicates tension, blue stands for compression*

9 *Prediction of product performance: Filtering efficiency of a pleat with two different media layers, concentration distribution of small (left) and large (right) particles*

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Prediction of product properties and performance

Combining the information about the materials involved and the manufacturing method with the observations from the quality checks, suitable simulation tools can be used to compute key properties such as

- flow resistance
- mechanical strength (e.g. effective stiffness)
- wettability, capillarity, saturation
- filtration efficiency

Therefore, a computer-aided optimization loop can be done at a very early stage in the production process in order to

- identify the optimal basic materials
- optimize the structure and
- find possible improvements for the manufacturing method.

In addition, the simulation software enables users to transfer the obtained results to subsequent stages of the processing chain and/or the final application. Examples for this are

- deformations (draping, induced by the fluid flow)
- filtering efficiency and evolution of flow resistivity on the filter element scale (e.g. after pleating)

The computer-aided what-if studies connect both several steps of the production and several length scales with each other. Following the combined simulation approach, developers are able to reduce the number of prototypes, shorten developmental cycles and eventually, accelerate product innovation.

The following software tools assist product designers in the optimization of nonwovens, textiles and related products:

- **FeelMath**: Fast simulation tool for the computation of effective mechanical properties and heat conductivity for 3D microstructures
- **FiltEST**: Filter Element Simulation Toolbox for the prediction of flow and filtration processes in layered media, pleats and filter elements
- **FLUID**: Flow simulation tool specialized in the computation of multiphase and non-Newtonian flows (e.g. fiber suspensions and polymers)
- **TexMath**: Textile Material Simulation and Homogenisation for the computation of mechanical properties in woven, knitted or spacer fabrics

In addition, we offer services such as

- consulting
- on-site licensing and training for our simulation tools
- customization of the simulation software.

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