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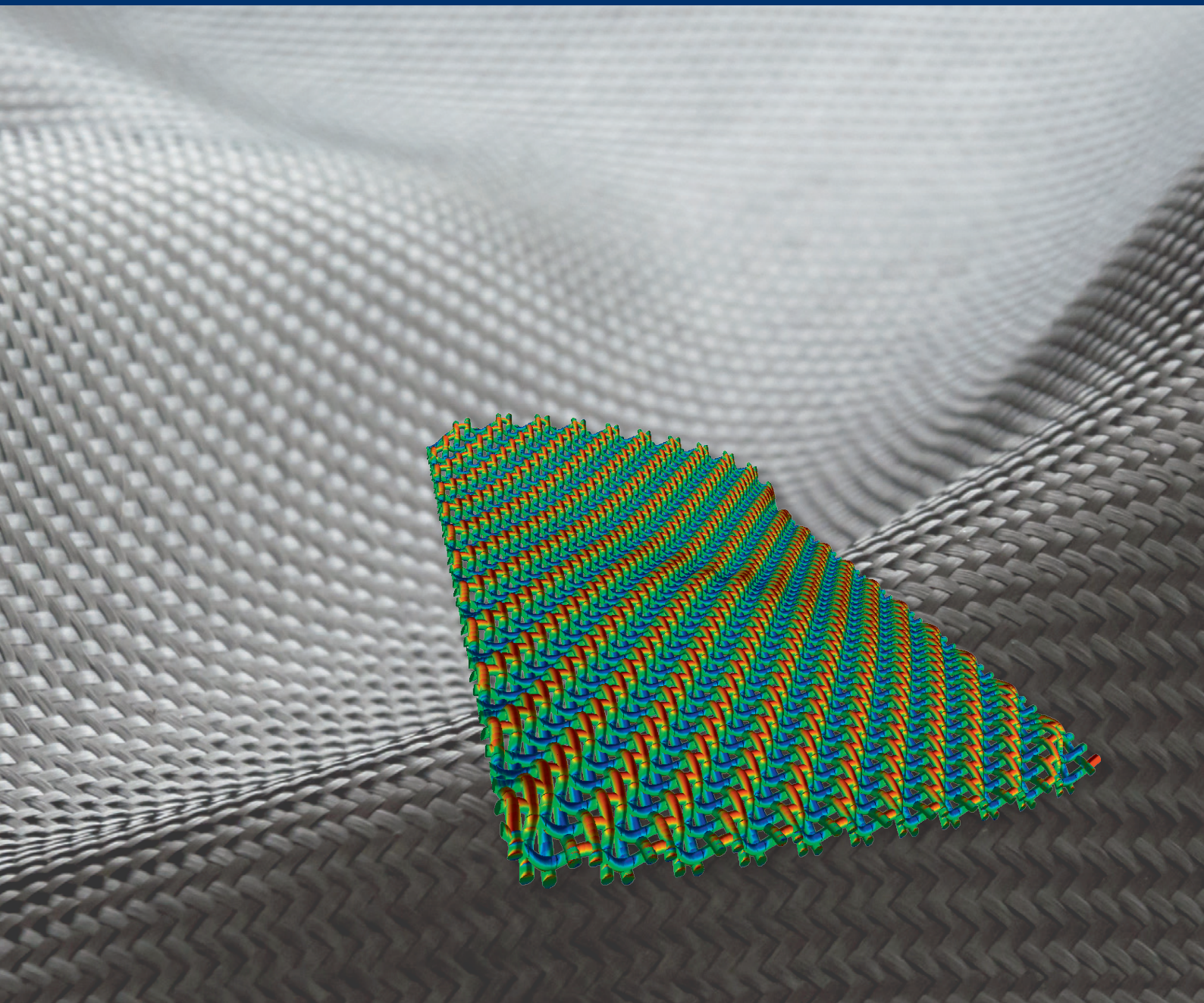
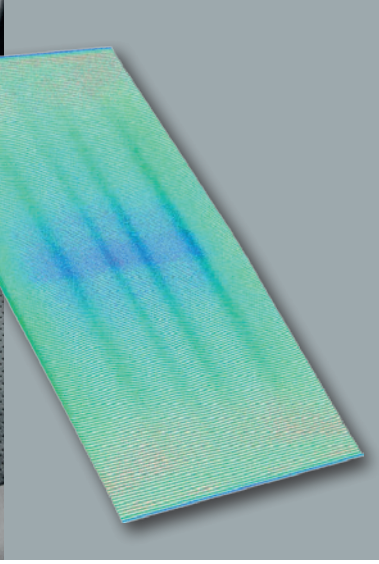
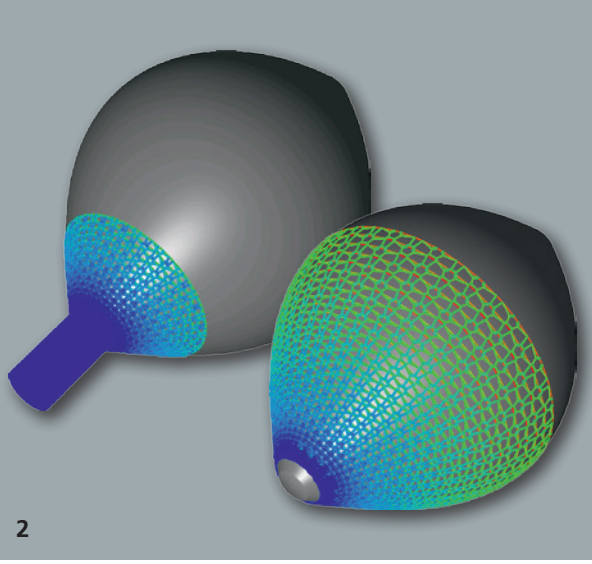
TexMath – SIMULATION AND OPTIMIZATION OF EFFECTIVE TEXTILE PROPERTIES







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1 *Dressing of surfaces, application in automotive industry*

2 *Large stretched knitted textile, modeled and simulated with our software TexMath*

Simulation of effective textile material properties

We are developing and applying methods and software tools which are necessary for the analysis, modeling, simulation, verification and optimization of the effective material properties of textiles, especially

- bending and torsion
- tensional stiffness and strength
- critical shear angles, start of wrinkles
- critical tension load for the cross buckling of belts

Typical applications are woven, non-woven, knitted technical, spacer fabrics, medical, sport and geo-textiles. The focus is on simulation methods that enable efficient predictions of the textile behavior, of wrinkling, of buckling or its production process, e. g. outcome form a knitting machine. Important parameters are

- stress-strain curves and thickness of the individual weaving yarns and
- a weaving or knitting pattern.

Our technology

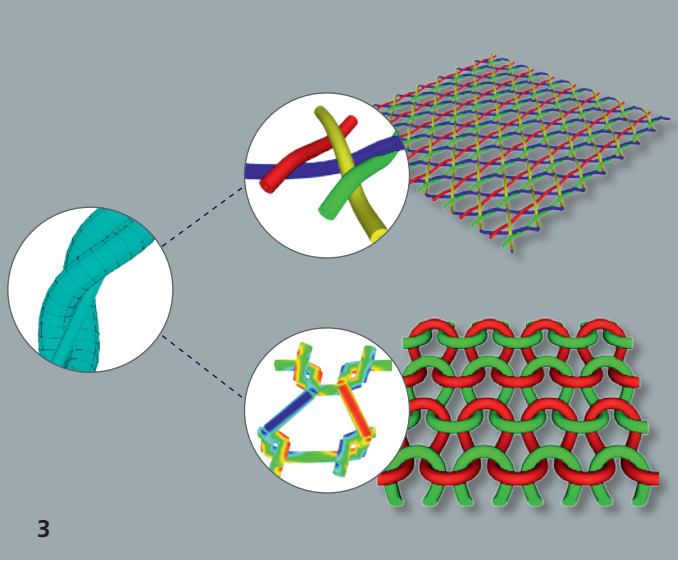
A direct computation of mechanical properties and effects on the macroscale is mostly impossible due to the enormous efforts, for accounting the exact microstructure. To overcome these difficulties we use our own multiscale methods, as homogenization and dimension reduction.

With these mathematical methods we can effectively model and simulate structures for arbitrary textile microstructures and material laws. Our approach allow to classify the textile structures in advance to take a correct model under applied loading range related to the structural parameters and sizes. Generally, the work does not end with a specific textile product, rather more in the advanced development of appropriate algorithms and simulation tools that the customer then uses to run various simulations – with changing materials or geometric parameters.

Optimization of textile materials

Besides the evaluation of a specific textile design by simulation, the tools also enable the optimization of the performance characteristics for different design variants. Corresponding computational algorithms are implemented based on the beam Finite Element method, extended to the contact and friction of fibers. In addition to calculating the effective mechanical material properties for a variety of existing woven and knitted fabrics, the approach also has the potential for the optimal design of innovative textiles having a prescribed mechanical properties profile.

Furthermore, the developed approach for textiles can simulate and analyze different surface treatments. In this way, it is possible to determine in advance the quality of the resulting fabric surface in order to prevent the formation of wrinkles and other visual inhomogeneous features.



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MeshUp generates woven and knitted structures

Knitted, woven and spacer fabrics are produced using knitting and weaving machines. Each fabric has a basic interloop or weave, which is defined in advance and entered in the machine parameters to produce a special textile product.

MeshUp is one of the TexMath software components and is used to generate textile patterns with all the details of the interlooping, contact, connectivity and cross-sections of yarns. It creates a graphic visualization and translates Finite Element structures with the corresponding thread label for the subsequent FISFT and FiberFEM simulations into corresponding input formats, including the contact information. Moreover, MeshUp prepares the geometry in volume data format (voxel format) for simulation with the GeoDict and FeelMath tools. Also an export to Abaqus is possible.

FiberFEM computes the effective mechanical properties of a textile

FiberFEM is a tool for calculating and optimizing the mechanical material parameters of textiles. In addition to the tension and shear properties, a special feature of FiberFEM is the ability to simulate effective bending and torsion properties of textiles and spacer weaves on the basis of their textile structure and the properties of the yarns or fibers.

Furthermore, the relaxation times of the textile can be easily determined from the structural designs and relaxation time of fibres in case of low friction. Also the friction coefficient between fibres is included directly in the simulation of the effective properties. FiberFEM has both numeric and symbolic solvers, which enables the optimization of the textile structure or the specific binding cartridge for the required textile properties.

As the input variables, besides the description of the micro-structure or via a connecting cartridge of the textile, FiberFEM requires the cross section geometry and the mechanical parameters of the yarn, like tensile stiffness and friction. The effective mechanical textile properties and ratios are returned as output.

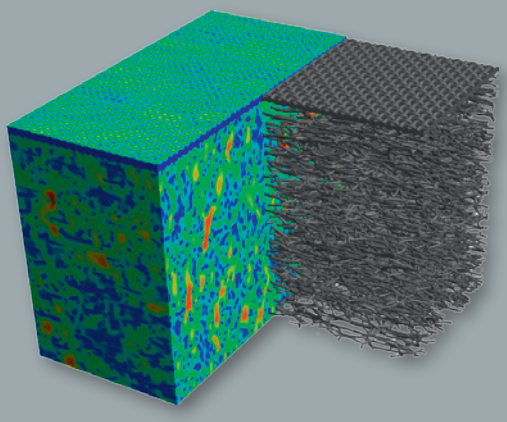
FISFT is a tool for textiles with hyperplastic yarns and frictional sliding between nodes

The FISFT model is specially designed for the dynamic simulation of knitted fabrics, very elastic weaves, and knitwear. It can simulate the knitting process as well as compute the removal from the knitting machine, the shrinkage of the "relaxed" textile, and even the internal forces when putting it on.

A key unique feature of FISFT is the special technology for associating multiple element to specific threads and their arrangement on the thread and at the same time the sliding contact to a million knot points. In this way, FISFT enables multi-scale simulation of measures of knitted and woven shell components while accounting for the local textile structure.

3 *Modeling and simulation of woven and knitted textiles with TexMath*

4 *Optimization of the production process considering hysteresis*



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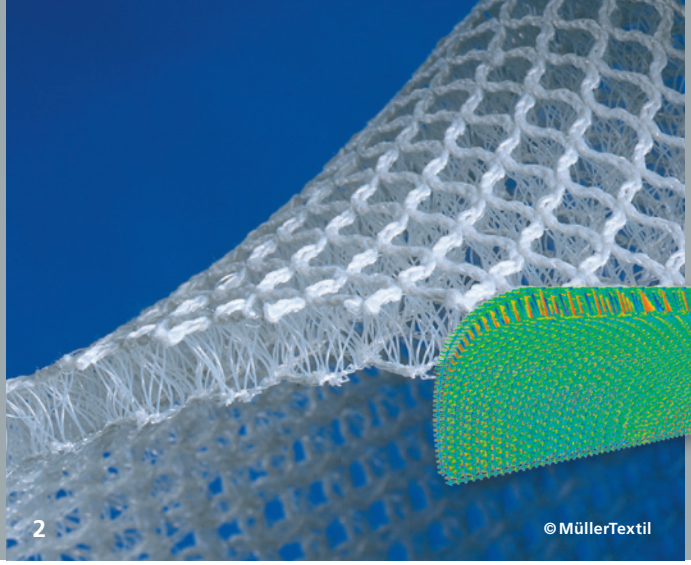

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1 *Multi-layered textile with flow simulation*

2 *Spacer fabric and geometry created with our structure generator*

TexMath is a modular software program which enables simulations of multi-scale problems of 3D woven, non-woven and knitted textiles. Tools are based on algorithms for dimension reduction and homogenization. Periodic textile structures with complex bonds can be created with the structure generator **MeshUp**. Another component called **FiberFEM** then computes the effective mechanical properties of recurring structures under infinitesimal strains.

Alternatively, the **FISFT** component can be used for long stretching and is ideal for simulations of complex load scenarios on textiles or even while in production, such as knitting.

TexMath contains

- contact with sliding and friction
- collision detection
- large deformations
- stochastic modeling
- structure optimization.
- input
  - geometry of the fiber's cross-section
  - stiffness of each yarn or fiber
  - microstructure or pattern
- output
  - effective properties of the textile: bending, torsion, shear, critical shear angles, critical for the cross-buckling tensional load
  - optimal textile structure for specific application

Application examples

- Woven: Protection, sportswear, belts, preforms, draping
- Non-woven: Geo-textiles, drainages, hygienic materials
- Knitted: bandages, compressive wear, vascular stents, sportswear, dressing.

We offer

- consulting, simulation and software tools for
  - efficient computation of effective properties like bending and torsion
  - stretching, visco-elastic and strength properties
  - prediction of wrinkling and buckling loads
  - insulation material properties: heat conduction and acoustic absorption
  - flow properties: permeability, flow resistance, filtration efficiency,
  - wettability, capillarity saturation

- structure and shape optimization of
  - knitted, woven and non-woven textiles, 3D spacer fabrics
  - optimization of the weaving and knitting process considering hysteresis effects

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