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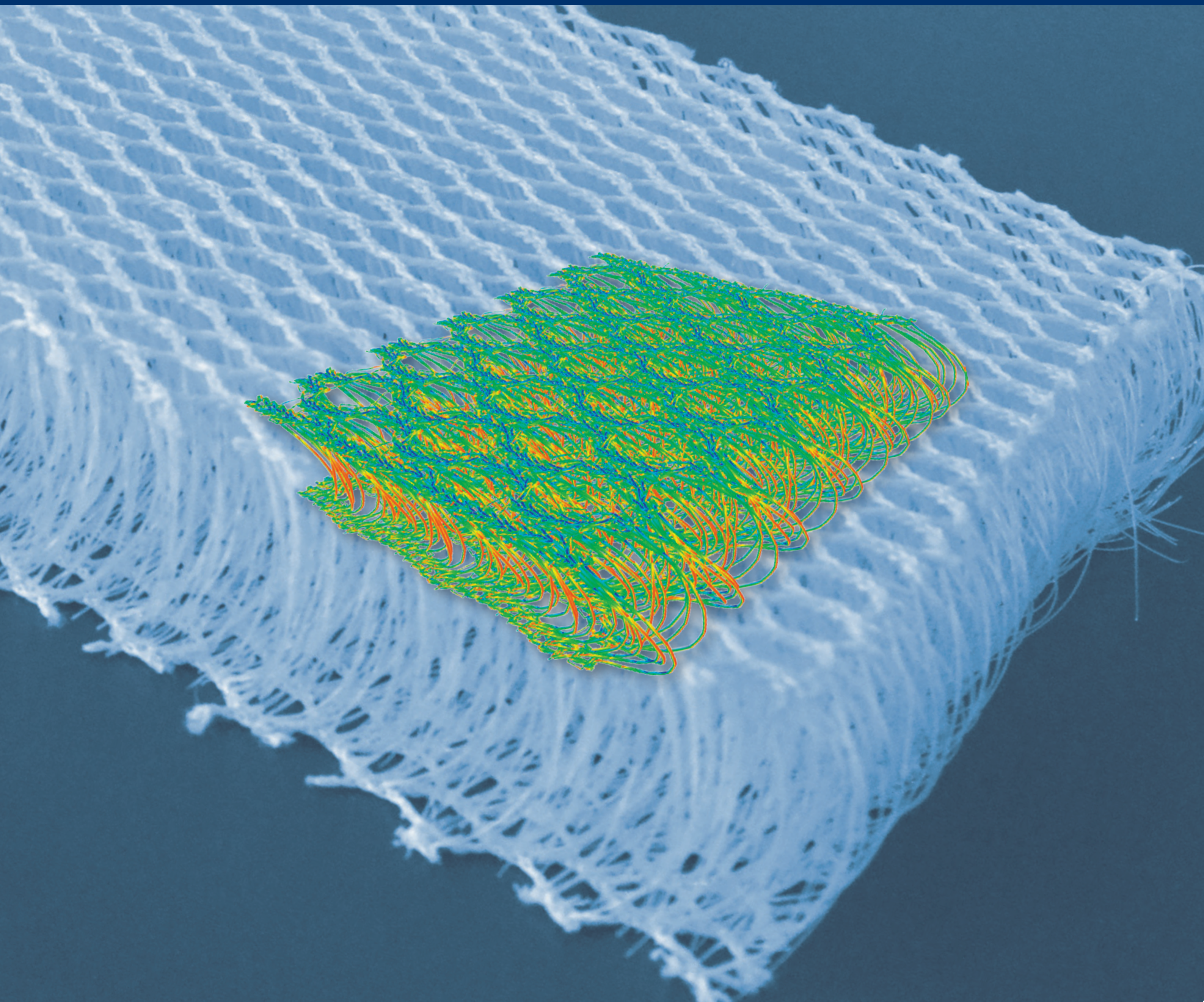
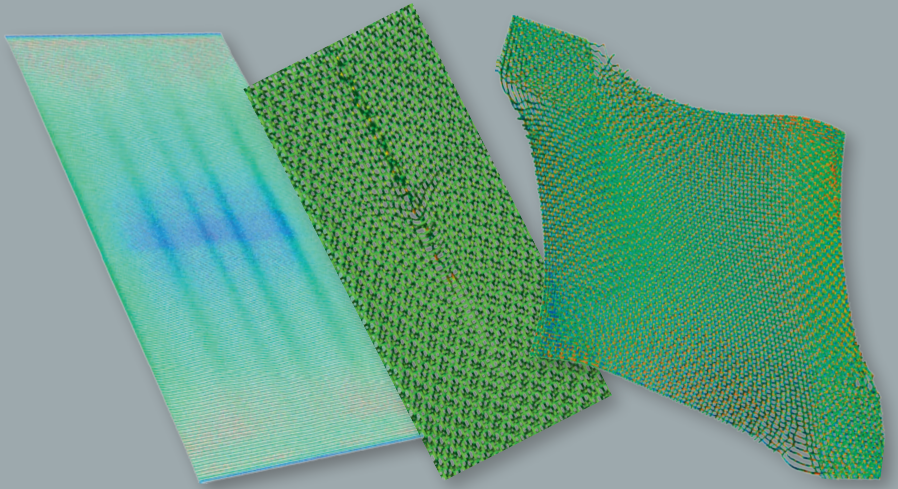
SMART TEXTILE DESIGN





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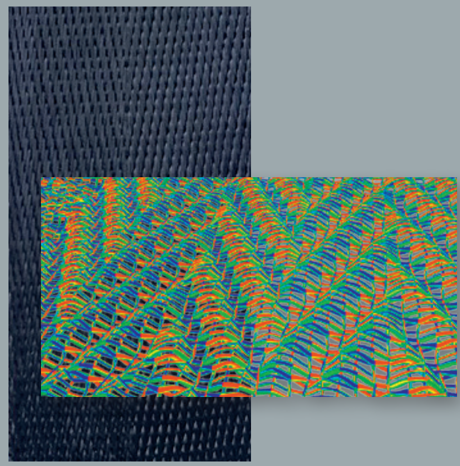

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1 Simulation of hyper-elastic knitted textile; damage under stretching due to an obstacle in a twill woven; simulation of a 45°-tension test of a plane woven fabric

2 Simulation of straps and belts: influence of the yarn thickness

Quantitative design rules for the draping and wrinkling of textiles

It is well known, that different material properties can be designed by the structuring of textiles using different weaving or knitting patterns and special yarn properties.

With the use of our sophisticated mathematical methods (asymptotic analysis and homogenization) and specific simulation tools (TexMath) we can classify quantitatively the resulting material behavior of textiles with respect to wrinkling.

As it is known, the textile structure, i. e. weave or knitting pattern, and the yarn properties (i. e. friction, elongation) determine the resulting textile property together with the applied forces.

With our Know How, we are able to determine the critical for the wrinkling loading and can predict the critical shear angle for textile wrinkling as well as critical tension for cross-buckling of belts and thin sheets.

Typical examples are:

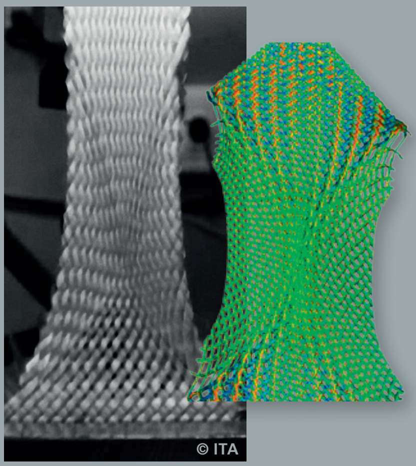
- buckling of belts under tension
- wrinkling under shear in preforms
- wrinkling under the in-plane tension (e. g. thermal, electric, etc.) or under shrinkage of yarns or matrix

Buckling behavior of carrying straps and optimal load design

For safety or carrying straps, or other textiles under the in-plane tension, we can predict the buckling loading from the weaving kind and yarn properties. This enables to optimal design the weave patterns to minimize or maximize the buckling.

Then, it is also possible to find a critical strain, critical temperature, or critical electric charge for smart textiles to jump-wise change the textile shape.

This critical loading can be increased by the structural optimization. Also a buckling or wrinkling shape can be optimized by a heterogeneous design of textiles.



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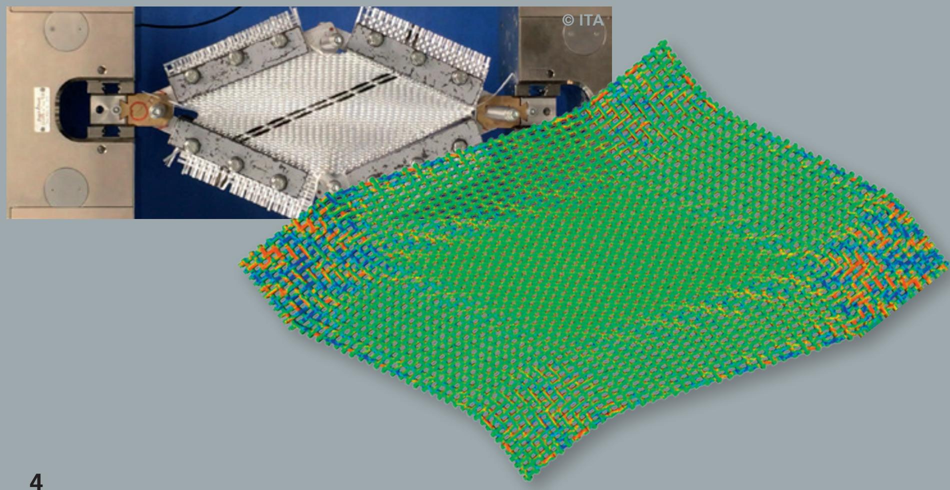

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Determination of critical shear angle and optimal design of draping

The draping quality of a reinforcing textile after the preforming process is evaluated by the draping effects occurring in the final preform. A high preform quality means that the reinforcing fibers are present in the locally required fiber orientation. Undesired draping effects (e. g. wrinkles) cause internal defects in the component which severely restrict its mechanical performance. In the production of complex geometries, the draping process is carried out by experienced specialists who manually correct the wrinkles. Due to the lack of standards and objective criteria, this procedure is technically and economically inadequate.

Various scrims and fabrics can be classified according to roving materials and cross sections, as well as the type of weave. By the use of our simulation tool **TexMath** the effective tensile, shear and bending properties are pre-calculated. The main result is the critical shear deformations, at which the drapery of the textile begins.

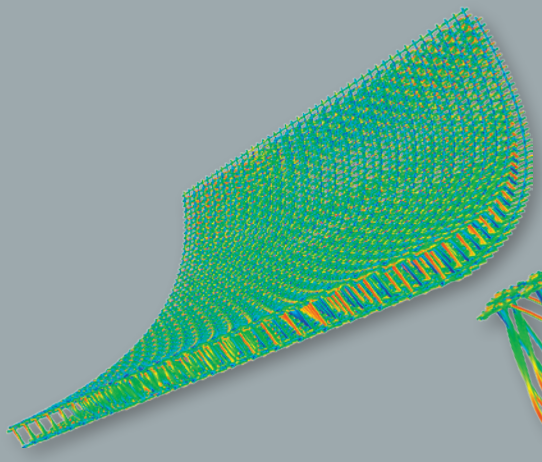
By use of an extensive mathematical analysis, we have developed a quite simple predictive effective model for the determination of critical shear angles for selected textiles at which drapery begins. These angles are calculated from the contact data obtained from the experiments carried out for each rowing pair, from bond type and rowing thickness, related to the textile thickness. Further parameters to be varied are different rowing's cross-sections, distances between the bonding points and different dislocations in the bond.

For validation, we created with **TexMath** a set of computer models of textiles with carbon and glass rowings with different widths and heights of cross sections, different types of weave, 90°-, 45°-layers, canvas and tress fabrics with different offsets. We calculated the effective tensile, shear and bending properties of the textile semi-finished products with a very high degree of detail on the roving level. The simulations were validated with the experimental results performed at the Institut für Textiltechnik (ITA) of RWTH Aachen University.

In contrast to the experiment, the simulation allows a virtual material design in which the rowing cross-sections, materials, distances between the bonding points, etc. are varied. Thus the experimental catalogue could be completed. At the same time, the dependence of the respective macroscopic stiffness on these geometric design parameters was represented in the form of curves, thus allowing an optimal textile design depending on the application.

3 Critical shear angle experiment performed by ITA and simulation of wrinkling

4 45°-tension test of a woven fabric with fixed frame performed by ITA and corresponding simulation



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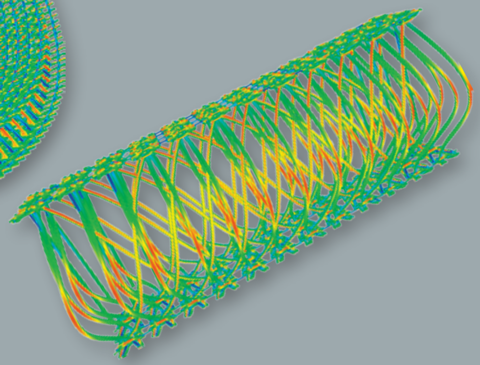

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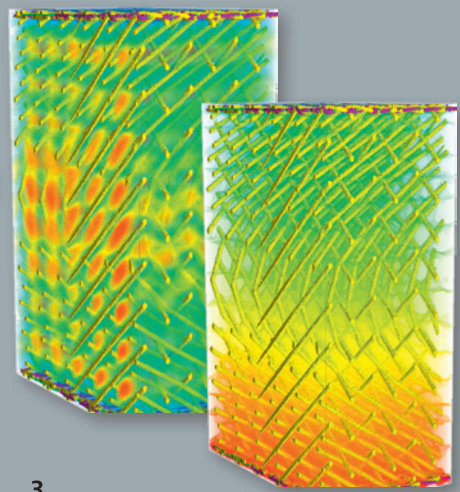

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Simulation of a spacer fabric

1 *Bending*

2 *Compression*

3 *Flow: velocity and pressure*

Stability analysis and optimal design of auxetic materials and spaces fabrics

One advantage of spacer fabrics is their superior decompression. This means these materials are highly resilient, flexible, and strong when subjected to an external pressure load. In the automatic structure modeling process, we first map the complex structure of the spacer fabric, following all the bonds of the spacer fibers. We construct the elements of different layers and then connect them sequentially.

Then, we simulate the tensile, shear, compression and bending properties using our TexMath software which we developed for modeling and analyzing textile fabrics. The effective properties are generated from the knitting pattern and the yarn's known force-elongation curve, cross section, and frictional properties. We analyze the textile spatial variations of porosity caused by unequal compression of the structure.

We compute permeability of spacer fabrics in different compression stages and analyze its dependence on the compressive deformation.

Depending on the design of spacer fabrics, its macroscopic behavior will be stable for one range and unstable for another range of the applied loading. The stability critical force depends on the thickness of fibers related to their unsupported length as well as of the fiber structure design.

The generated models allow to continuously vary all design parameters and thus to optimally design the spacer textile.

Additionally, we can design auxetic textiles and structures, i.e. to obtain a negative macroscopic Poisson's ratio or to loose stability under a certain critical load.

Services

We can assist you in the optimal design of your technical textiles.

- Consulting to analyze your textiles
  - Textile stability under different load conditions
  - Buckling of straps and weaves
  - Wrinkling of weaves
- Development of customized software for your textile design
- Simulation to optimize your textiles
  - Draping of weaves including prediction of critical shear angle
  - Optimal weave or knitting patterns
  - Resilience and stability of 3D spacers
  - Design of auxetic and smart material behavior

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