SIMULATION SOFTWARE TEXMATH – SIMULATING TECHNICAL TEXTILES REALISTICALLY

Fraunhofer ITWM
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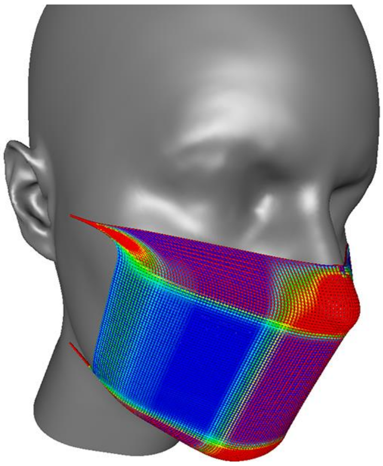
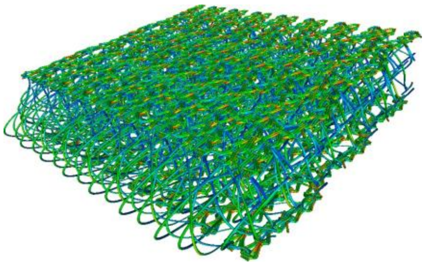
From high-performance textiles to compression and sportswear: The modular software program »TexMath« of the Fraunhofer Institute for Industrial Mathematics ITWM enables both the simulation of mechanical material properties and the optimization of textile products.



Accelerated development and optimized design of technical textiles while reducing experiments? The demand for techniques that can realize this is especially high in areas such as the sports, medical, and clothing industries. The »Technical Textiles« team of the »Flow and Material Simulation« department at Fraunhofer ITWM has taken up this challenge and is developing simulation methods that allow efficient prediction of textile behavior under stretching, shear, bending, torsion, or compression. It is also possible to simulate wrinkling under stretching as well as shrinkage of yarns or critical shear angles throughout the manufacturing process.

The »TexMath« simulation software they developed ensures that process chains in production can be adapted to new materials in advance. Complicated patterns and layers can be mapped with the help of the software and a direct connection to the textile machine can be made. Desired woven, knitted and warp-knitted products are accurately simulated with the software and their material properties computed. In addition to evaluating a particular textile design using simulation, the tools also provide optimization of performance characteristics for different design variations. The goal of the software, according to team leader Dr. Julia Orlik, is to »realize the design according to product properties and target criteria.«

TexMath consists of several components: »MeshUp«, »FibreFEM« and »FIFST«. Each of the components included in TexMath has its specific field of application. In addition, the tools have interfaces to each other as well as connections to the software »GeoDict®« of the Fraunhofer spin-off Math2Market, which can be used, for example, to perform fluid mechanical simulations on the textiles.

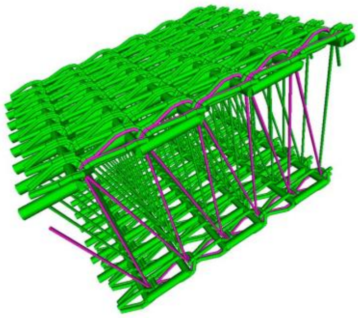


Generating structures with MeshUp

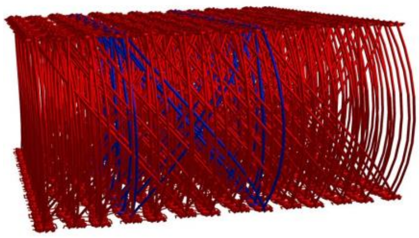
One area of application for the TexMath software is the optimization of compression textiles for the medical sector or for sports. For optimal effectiveness, the fit of the material is particularly important. For example, the knitting process can be simulated with TexMath to create a bandage with predefined compression properties and thus design the optimal knitted fabric. This virtual bandage is then loaded in another simulation and put on a virtual arm or leg. Thanks to TexMath, the calculated pressure profile makes it possible to evaluate the compression properties of the bandage in advance and also to directly control the knitting machine according to the optimal design.

»TexMath can also be used to design spacer textiles, such as those used for the upper material of sports shoes and for the production of high-performance textiles, and to optimize them in advance in terms of structure and fluid mechanics,« say Dr. Julia Orlik and department head Dr. Konrad Steiner, naming further areas of application for the software.

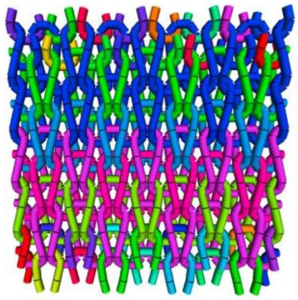
The newly developed input interface is particularly user-friendly. The textile class (i.e. knitted, warp-knitted, woven and spacer fabrics) can be easily set. The new graphic interface allows simple and fast configuration.



Further 3D spacer fabric in initial state



3D spacer fabric with marked mono-filament fibre in slightly drawn conditi-on



Multi-layer knitted fabric. Different yarns colour coded

MeshUp for Structure Generation of Woven Patterns and Stitches

Knitted and woven fabrics are produced with the aid of knitting or weaving machines. Each textile is based on a looping diagramm, which is read into the machine or is firmly pre-defined in the machi-ne. MeshUp is the software module of TexMath, in which looping diagramm for various woven and knitted fabrics with different types of binding, the yarn path and all contact points between different yarns are created, graphically displayed and translated into the corresponding input formats for further simulations in TexMath with FISFT and FiberFEM. In addition, MeshUp also provides the geometry as volume data (voxel format) for calculation tools such as GeoDict and FeelMath.

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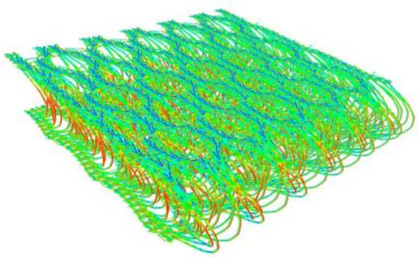
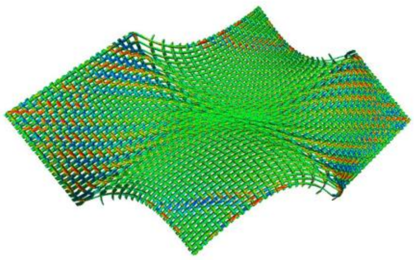
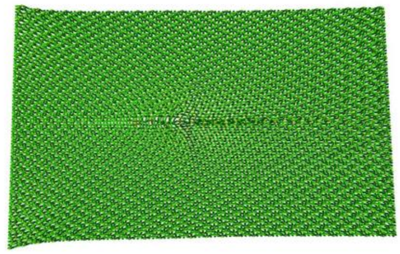


Compression of a spacer fabric.



Wrinkle formation in a fabric.



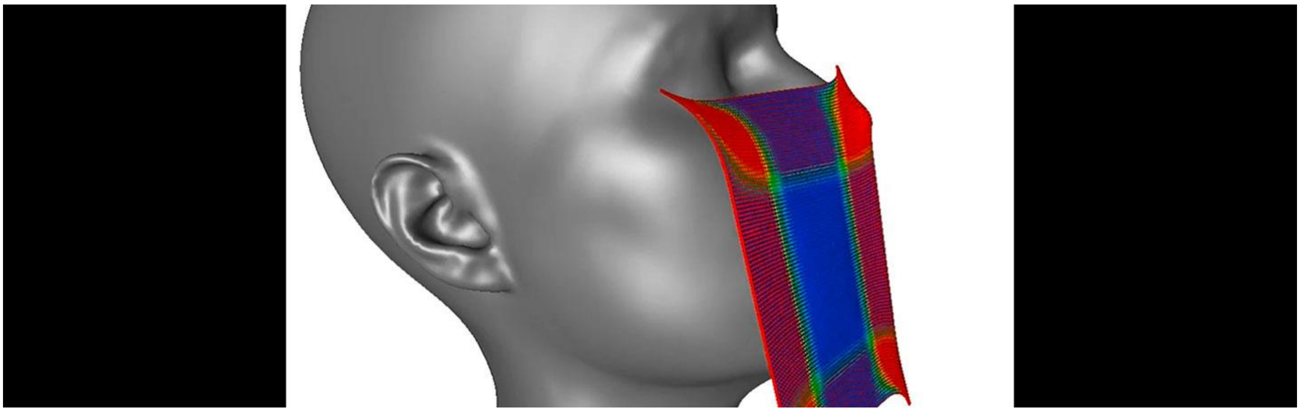
Simulation of a continuous damage in a fabric.

FiberFEM to Calculate Effective Mechanical Properties of a Periodic Textile Structure

With FiberFEM, woven and braided textiles, spacer fabrics, scrims and trusses can be calculated and optimized regarding their effective mechanical material properties. A special feature of FiberFEM is that, in addition to tensile and shear properties, effective bending and torsional properties of textiles can also be determined based on their textile structure and yarn properties.

As input variables FiberFEM requires the microstructure description from MeshUp, the fiber cross-section geometry, as well as mechanical fiber properties such as tensile stiffness and friction. As output the effective mechanical textile quantities are calculated. Besides the calculation of the effective mechanical material properties for already existing woven or knitted textiles for technical and medical applications, the approach also offers the potential for the targeted design and optimization of new textiles with a given mechanical property profile.

For example, the relaxation behavior of a textile can be determined from the weave or knit pattern and the yarn relaxation times for viscoelastic yarns. Coefficients of friction between the yarns are also taken into account and are directly included in the simulation of the effective properties or identified from the experimental validation with the fabric.



FIFST to Calculate the Deformation and Load of Textiles

The tool FIFST is specialized for dynamic simulations of stretchable knitted fabrics and teir production. For example, the knitting process can be simulated, the pull-off from the knitting machine, the shrinkage to a relaxed textile and also the further deformation during tightening can be calculated. This means that the design of the knitted fabric can also be adapted to predefined tension profiles and individualized machine control is possible for the production of personalized textiles or product-specific designs.

The numerical implementation uses the finite element method with non-linear truss elements, which has been extended for contact problems by an additional internal variable - the sliding of threads at contact nodes. The friction law is implemented with the Euler-Eutelwein model, which was extended by an additional adhesion term. Adhesion thus allows different pre-strains in the respective meshes. The elastic energy is calculated directly from the yarn force-elongation curves.

One of the most important unique selling points of FIFST is the special technology of assigning several elements to specific threads and their arrangement in the thread as well as the simultaneous contact sliding at millions of nodes. Thus FIFST enables multi-scale simulation of large knitted or woven shell components, taking into account the local textile structure.

Another functionality of the software is to virtually drag textiles over a surface triangulation given in STL format. In the video, woven mask (knitted is also possible) is extended in the plane at 6 points and pulled against the face surface. Its knots are projected onto the face and continue to slide on the surface until the mask is fully in place. If you know frictional properties of yarns on the face, you can investigate further folding formation and also influence it specifically. As a further potential for optimization, FIFST allows to minimize pore sizes of dressed textiles on particularly curved surface areas. This can be achieved by increasing the pre-tension in yarns or by modifying the lapping diagram or the binding cartridge.

Source: Fraunhofer Institute for Industrial Mathematics ITWM