TRANSPORT PROCESSES

The company Dilo from Eberbach develops and produces innovative plants for the nonwovens industry. The picture shows the formation of the nonwoven in a carding line before it is bonded by needling. Our institute supports Dilo in the development of new needling technologies.

MATHEMATICAL MODELING, SIMULATION, AND OPTIMIZATION OF TRANSPORT PROCESSES

The Transport Processes department models complex industrial problems and develops efficient algorithms for their numerical solution (simulations). The specific tasks are primarily within the context of the technical-natural sciences (fluid dynamics, radiative transport, optics, structural mechanics, etc.). When modeled, these tasks lead to partial differential equations that are mainly characterized as transport equations.

From the perspective of our industrial customers, such problems typically concern product optimization or the design of production processes. The expertise includes collaboration with the engineering-oriented R&D departments of our partner companies, design and optimization studies, as well as software development for individual modules or complete tools.

The year 2017 was a successful one, both scientifically and economically. Our chosen strategy, which also encourages revenue generation from software licensing, is producing first major successes. One notable example is a VW Group license issued for FPM, the mesh-free flow simulator.

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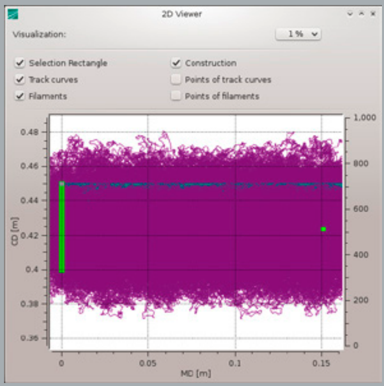
MAIN TOPICS

- Flexible Structures
- Fluid Dynamical Process Design
- Grid-free Methods
- Energy Transport Networks and Model Reduction



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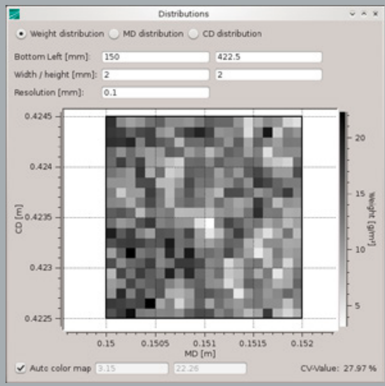

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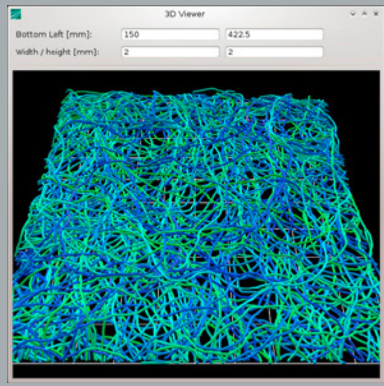

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VIRTUAL PRODUCTION OF NONWOVEN FABRICS

1 *2D view of the virtual nonwoven in SURRO*

2 *Weight distribution of a sample at 0.1 mm resolution*

3 *3D view of the sample*

The production of nonwoven fabrics involves spinning, entangling, and layering a multitude of thin fibers to form a nonwoven web structure. For many years, our department has been collaborating with a wide range of industry customers to advance the virtualization of this process.

We face many mathematical challenges that cannot be solved with standard simulations because of the complexity and differences in scale. We develop special methods and tools to support the design and control of several key aspects of the technical textile production process with efficient simulations.

SURRO software generates virtual nonwoven structures

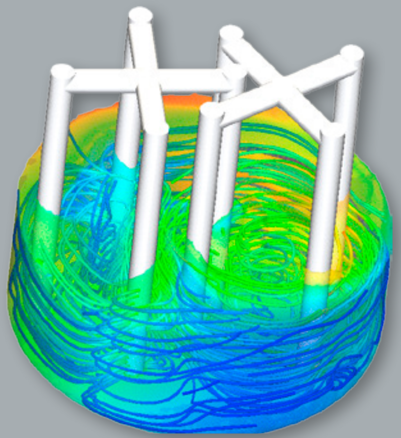
In recent years, we have developed sophisticated methods to generate virtual, large-scale, nonwoven structures. The resulting software SURRO (Surrogate Model) is based on a stochastic surrogate model for the simulation of filaments, which is mathematically described by a stochastic differential equation (SDE).

The input parameters of this process are obtained by first performing physically-based simulations of a few individual filaments using FIDYST (Fiber Dynamics Simulation Tool) software. By means of an identification process, the complex behavior of the filaments is reduced to a few stochastic parameters characterizing the resulting nonwoven structure.

Analyzing nonwovens production processes with SURRO and FIDYST

In comparison to a full physical simulation, fibers can be computed extremely fast with the SURRO surrogate model. It is possible to produce a very detailed resolution of microstructures in the range of several centimeters edge length. The virtual nonwoven structure is then analyzed for weight distribution and homogeneity on different scales. The homogeneity is essential for the quality of the nonwoven fabric and is a criterion for optimizing the manufacturing process.

Furthermore, tensile strength tests can be carried out by means of interfaces to standard software such as Abaqus. We successfully use the microstructure generator SURRO together with the FIDYST simulation software to analyze and optimize the production processes for nonwoven fabrics.



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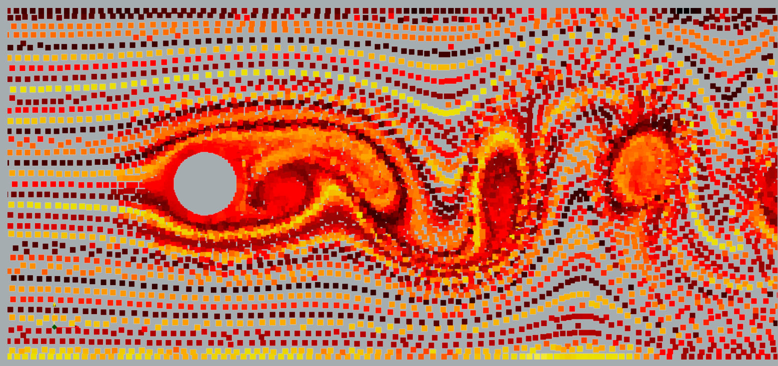

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SIMULATIONS WITH MESHFREE

MESHFREE is an innovative software tool in fluid and continuum mechanics developed in cooperation with Fraunhofer SCAI and to be released in 2018. It joins the expertise in meshfree simulations and scientific computations of the two institutes.

Goodbye, meshes!

The software MESHFREE combines the Finite Pointset Method (FPM) for solving the conservation equations of mass, momentum, and energy with efficient algorithms for solving linear systems of equations. The underlying method is based on a cloud of numerical points without explicit neighborhood information of a mesh, so the need for costly meshing and re-meshing disappears.

The geometry can be exported directly from CAD tools and used for the simulation. Due to the complete absence of a mesh, MESHFREE is highly flexible regarding the discretization of the computational domain in highly dynamic processes, such as flows with free surfaces or fast moving geometry elements.

The world is neither solid nor fluid

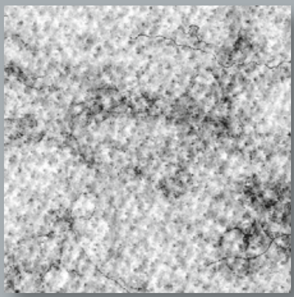
MESHFREE uses a general material model, which allows to simulate complex materials (non-Newtonian fluids, foams or viscoelastic materials) with the same numerical method. The medium does not need to be declared as fluid or solid a priori to choose an appropriate numerical solver. Instead, only material properties such as viscosity or shear modulus are required to predict the material behavior.

On the shoulders of giants

With MESHFREE, the user benefits from extensive experience and expertise of the two Fraunhofer Institutes ITWM and SCAI in simulations of complex physical processes. The product is a synthesis of two software tools (FPM and SAMG) that have been successfully applied in many different industry sectors independently for over 15 years and are both being continuously developed.

1 *Simulation of a stirring process*

2 *In fluid dynamics, a Kármán vortex street is a repeating pattern of swirling vortices in a flow around an obstacle. The illustration shows a simulation of such a vortex street using adaptive refinement dependent on the gradient of the velocity.*



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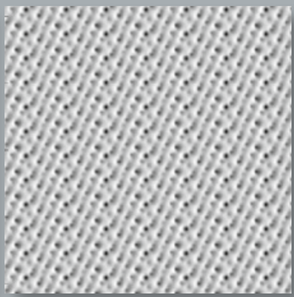

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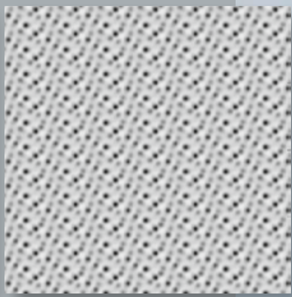

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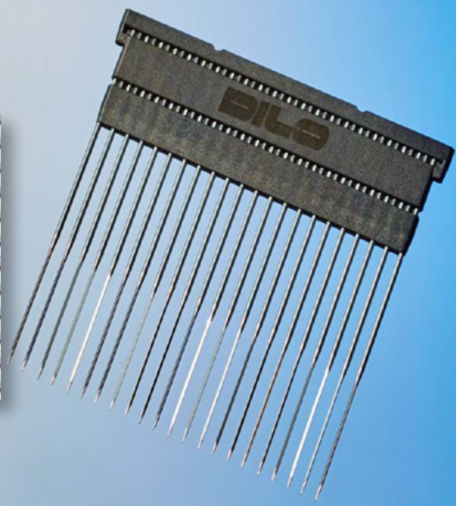

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ADAPTIVE NEEDLE LOOMS

1 Needled nonwoven fabric

2 Penetration pattern after image processing

3 Simulated penetration pattern

4 Needle modules

The Dilo Group in Eberbach, Germany develops and produces innovative systems for the nonwoven materials industry. Needle punch systems used for mechanical bonding of nonwoven fabrics play a major role in their business. We assist Dilo in the development of Variopunch, a needle punch technology that will contribute to a more uniform penetration pattern. The process is described below.

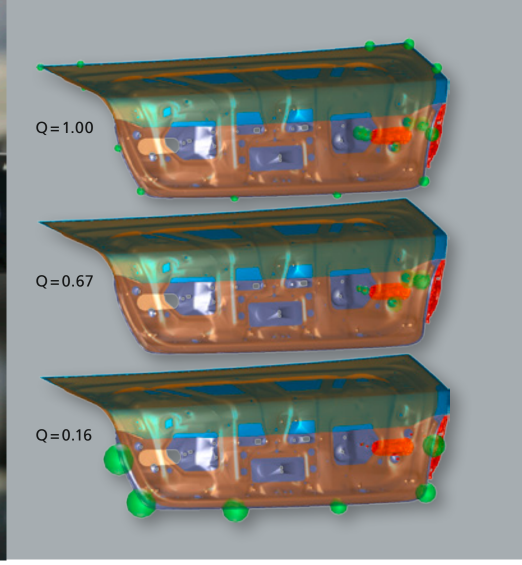
Dilo-Variopunch – adaptive needle punch technology

A large number of needles are arranged in a repeating pattern on a needle board. The needle board continuously moves vertically in and out as the nonwoven material is transported underneath. As a result, the individual fibers are locked together giving the fabric strength. Besides strength, the optical impression also plays a crucial role for many applications because the needle punch inevitably leaves a pattern.

The needles have traditionally been positioned at fixed points on the needle board. The new Variopunch technology being developed at Dilo enables adaptive needle positioning. In a typical line of needle looms, several machines are placed in succession and operate in a sequence of decreasing intensity so as to produce a pattern that is as homogeneous and streak-free as possible. A significant increase in quality is achieved by placing a Variopunch machine with variable positionable needles at the end of such a line, which corrects previously occurring errors through adaptive needling.

Image processing, simulation, and optimization

Our institute supports the development of the Dilo Variopunch, especially in the algorithmic implementation. We use techniques from the fields of image processing, simulation, and optimization. An optical sensor located at the front of the machine scans the incoming fabric. The resulting images are processed algorithmically and the pattern is extracted. By means of simulations we can compute the resulting pattern for any possible positioning of needles in the Variopunch board. Optimization methods are then applied to determine the optimal punch positions and, accordingly, use them to adapt the needle board.



RoMI – ROOT CAUSE ANALYSIS OF MEASUREMENT ISSUES

Systematic studies of deviating measurements in the manufacturing process have yet to provide a way to predict the causal aberrations of components and joints. Although historical trends in the deviations between target and actual dimensions can be detected by statistical process controls, the cause analysis is still missing. While traditional tolerance analysis helps to explain how typical component and joint failure results in measurement deviations, we examine the opposite problem in the Central Innovation Program for SMEs (ZIM).

1 *Tactile measurement*

2 *Cause analysis for measurement deviations at the surface of the rear end of a car (green balls: component and joint faults, RoMI quotient Q: probability of error source)*

The ITWM component of RoMI

In the project RoMI (Root Cause Analysis of Measurement Issues), we have developed an algorithm and implemented the associated software to analyze potential root causes of aberrations in components or joints. Surface measurements, which have been taken during the production process, allow us to automatically detect defective assemblies and error sources in the joining process. In particular, we can reveal an installation error at a spot that is inaccessible and can no longer be measured after final assembly.

The software is able to simulate different assemblies of the parts. Our algorithm selects the most likely assembly from all the potential combinations of component or joint deviations matching the surface measurements. This selection is achieved by solving a non-linear optimization problem. A special effort is made to ensure that the components are not pervasive. Starting with a set of measurements, the appropriate configuration is found.

This is basically an inverse problem, i. e., from an observed effect on the system, we want to identify the underlying cause. Since there are usually many more failure parameters than measurements, identification usually relies on solving a stochastic optimization problem.

Embedding in eMMA

The new RoMI module is embedded in the eMMA software supplied by project partner Q-DAS (formerly Kronion). Many suppliers from the fields of automobile, shipbuilding, and mechanical engineering have chosen to use this product. This integration ensures the responsible managers are informed in a timely manner before any real problems can emerge from the trends identified.

NEWS

NEW AiF PROJECT STARTS – VIRTUAL BOBBIN DYEING AND OPTIMIZATION

Faulty dyeing in the German textile and clothing industry results in costs of 8.8 million euros, which the industry can no longer accept in light of the increasing price competition from East Asia. The aim of a multidisciplinary project called DensiSpul at the German Federation of Industrial Research Associations – AiF (Arbeitsgemeinschaft industrieller Forschungsvereinigungen) is to reduce the rejection rate of poorly colored bobbins by at least 15 percent through the use of simulation. The success of the project could mean annual savings of approximately 1.3 million euros in Germany. Our institute is collaborating on the project with the Institute for Textile Technology (ITA) at RWTH Aachen University and the Society for the Advancement of Applied Computer Science (GFaI).

One of the aims of DensiSpul is to develop a system that generates recommended settings for the winding machines on the basis of a simulation. Together with the other project partners, we are developing an algorithm to simulate a virtual bobbin based on the machine setup parameters. We then calculate an optimized density of the virtually wound bobbin for the subsequent dyeing process. The CT imaging of actual wound bobbins is always a priority focus for the validation of the material models. Ultimately, from the optimized virtual bobbin, the recommended setup parameters for the winder can be determined.

FROM PhD CANDIDATE TO PERMANENT STAFF

Since its establishment, our institute has continually offered scholarships for PhD candidates in cooperation with TU Kaiserslautern and other universities, which can lead to the award of a PhD in just over three years. Because of the close relationships to the supervisors, this program strengthens the research orientation of our department. In addition, the program provides excellent job opportunities for the doctoral candidates while representing a potential source of outstanding qualified employees for the department. The two new staff members for 2017, Jaroslaw Wlazlo and Tobias Seifarth, successfully completed their doctorates in Kaiserslautern and Kassel.

Front, left to right: Dr. Tobias Seifarth, Dr. Walter Arne, Dr. Timo Wächtler, Dr. Simone Gramsch, Dr. Almut Eisenträger, Dr. Raimund Wegener, Dr. Dietmar Hietel, Matthias Eimer, Jens Bender, Dr. Jaroslaw Wlazlo, Dr. Robert Feßler, Dominik Linn, Raphael Hohmann, Manuel Wieland, Dr. Andre Schmeißer, Dr. Jan Mohring, Johannes Schnebele, Dr. Simon Schröder, Markus Rein, Dr. Jörg Kuhnert