COMPUTER MODELING OF NON-WOVEN ACOUSTICAL TRIM

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Outline

- **Introduction**
- **Forward Simulation**
  - Microstructure Generation
  - Flow Simulation
  - Absorption Simulation
- **Inverse Simulation**
  - AutoSEA2 Computing of a Data Base
  - Solution of the Constraint Minimization Problem
- **Summary**

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Introduction: Problem

Acoustical trim for the interior of the car:
Ceiling treatment lay-up made of fleece

Optimization of the microstructure of non-woven acoustical trim

Objectives:

- Optimal acoustic absorption spectrum
- High mechanical stiffness
- Light weight
- Easily recyclable material
- Low material and manufacturing costs
- Desired haptics/optics of the product

Application:

Interior of vehicles,
e.g. ceiling treatment lay-up

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Introduction: Requirements

- Upcoming laws of the EU on end-of life vehicles require at least 85% of an automobile´s weight to be recycled.
- However, the acoustic trim of vehicles is currently produced from composite materials which are difficult to separate.

- The goal of the "Integrated Product Policy" (IPP) project at the Fraunhofer ITWM and its partners Audi, Sandler, and Faurecia is to develop improved acoustic trim, which is made of **single materials,** by using **innovative computer simulations**.
- Parameters used in the simulations are calibrated with acoustic measurements on real trims.

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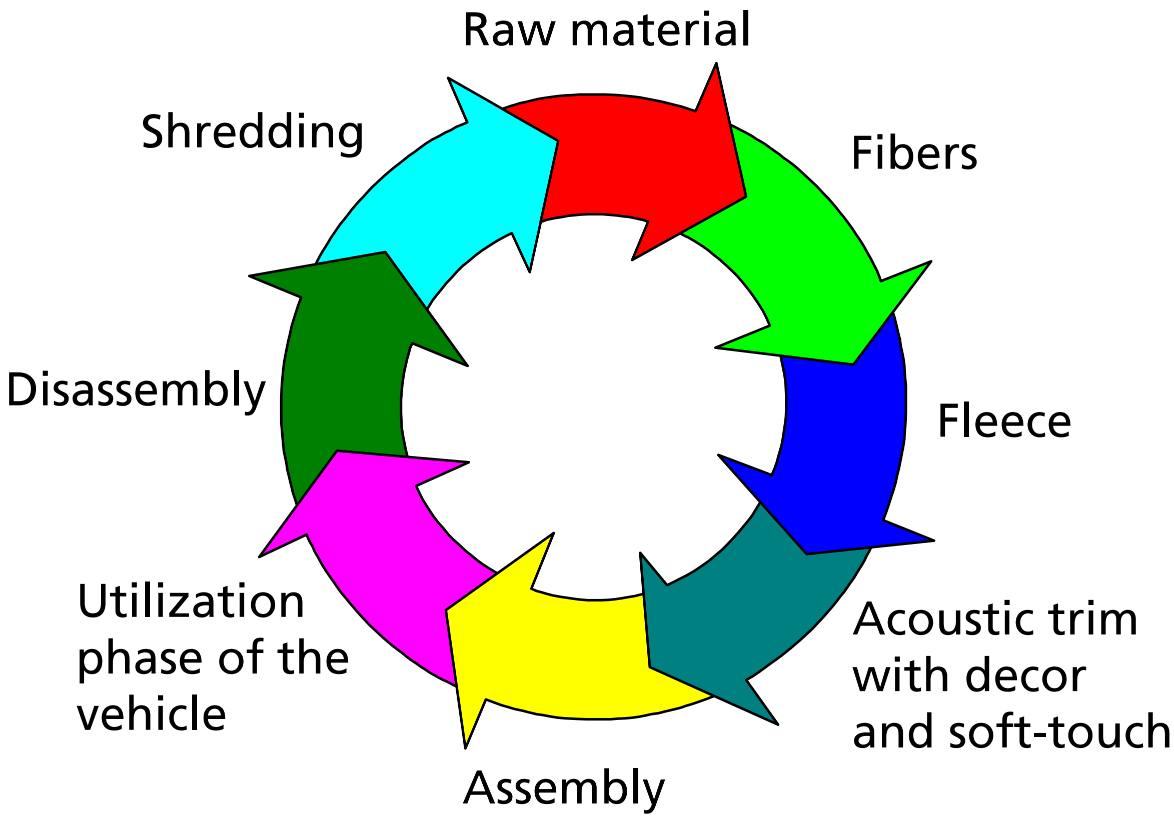
Introduction: IPP

Integrated Product Policy (IPP)

The entire life cycle of a product from its production up to its recycling is considered.

The effects on the environment during the entire life of the product are taken into account additionally.



Closed product life cycle

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Direct and Inverse Simulation

Direct Simulation

Given:
- Averaged geometric properties of the microstructure
- Geometry of the product (in an AutoSEA2 model)

Find:
- Absorption spectrum for the interior of the vehicle

Simulation steps:
- Stochastic geometry of microstructure
- Fluid dynamics in the microstructure
- Acoustic absorption 1D (material)
- Acoustic absorption 3D (product)

Inverse Simulation

Given:
- Desired absorption spectrum
- Desired geometry of the product (in an AutoSEA2 model)

Find:
- Optimal material and its microstructure

Solution steps:
- Precomputing a database for varying material properties by direct simulation
- Find the best fitting materials from the database (by using interpolation)

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Direct Simulation: Geodict

Geodict

- generates stochastic microstructures (as input for computational fluid dynamics) interactively
- generates 3d surface data for microstructures in STL and VRML format

GUI with cross section of the generated microstructure

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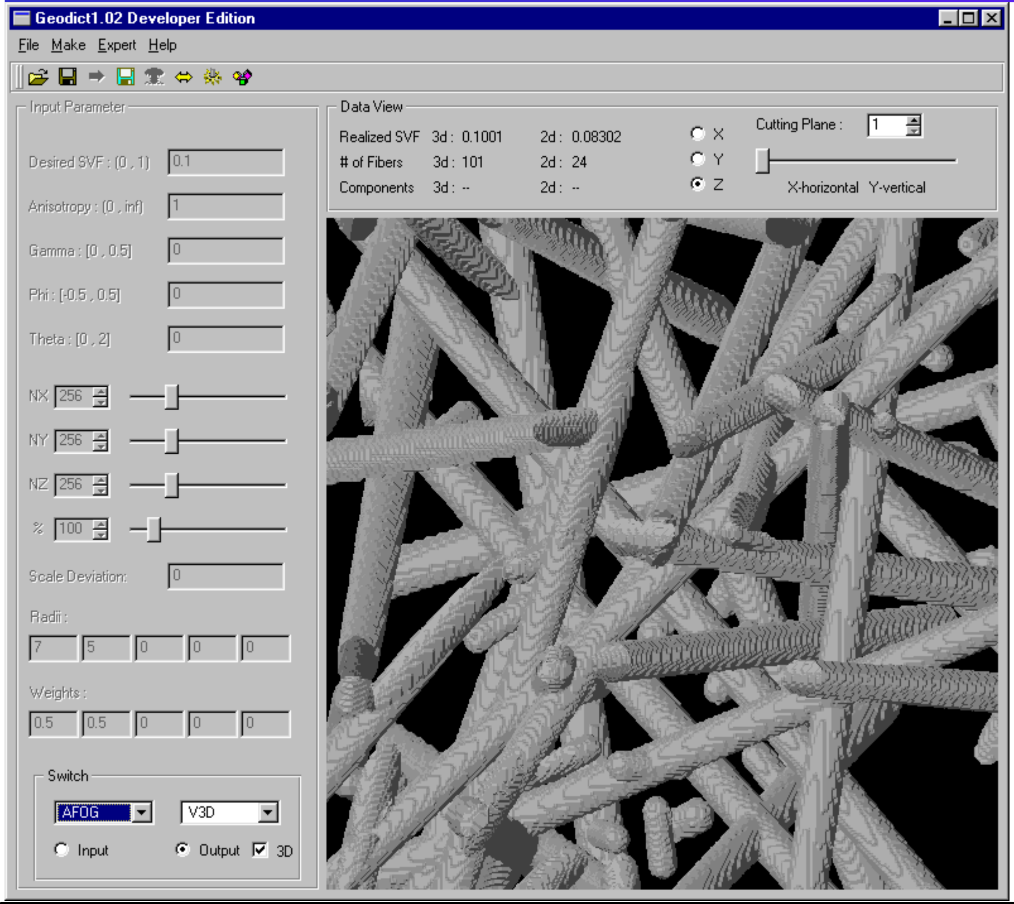
Direct Simulation: Geodict



Input parameters for the microstructure

- solid volume fraction
- anisotropy model and directions
- up to 5 different fiber radii with weighting factors
- fiber length and cross section
- overlapping or non-overlapping objects
- resolution in x-, y-, z-direction

GUI with 3D view on the generated microstructure

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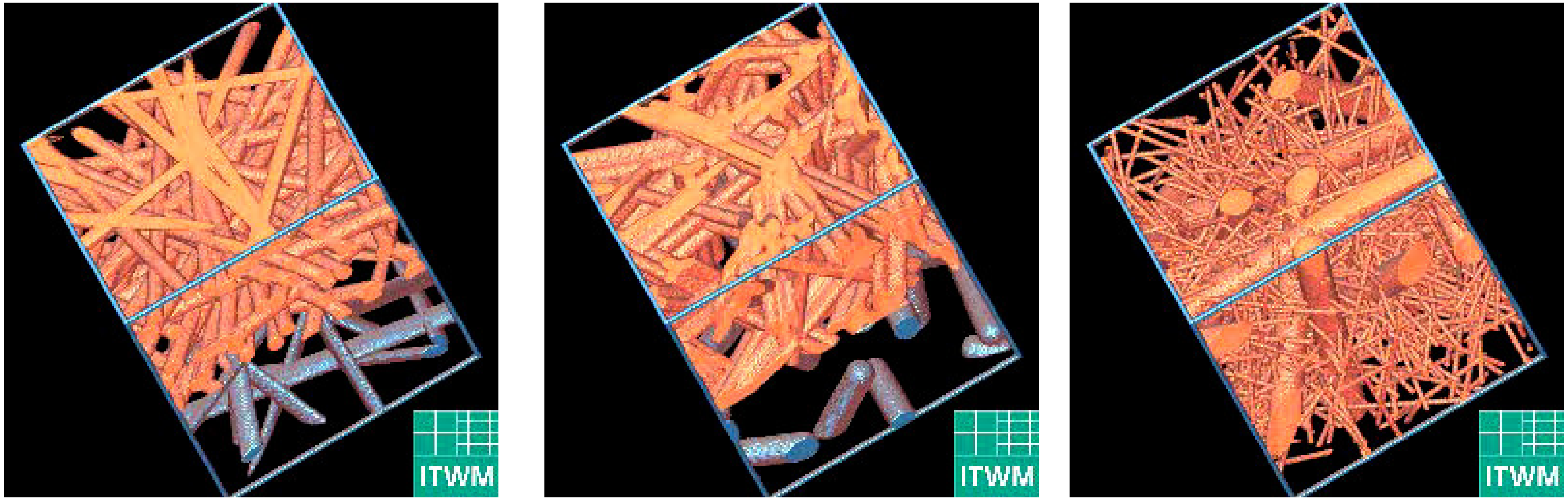
Direct Simulation: Geodict



Examples of microstructures generated by Geodict

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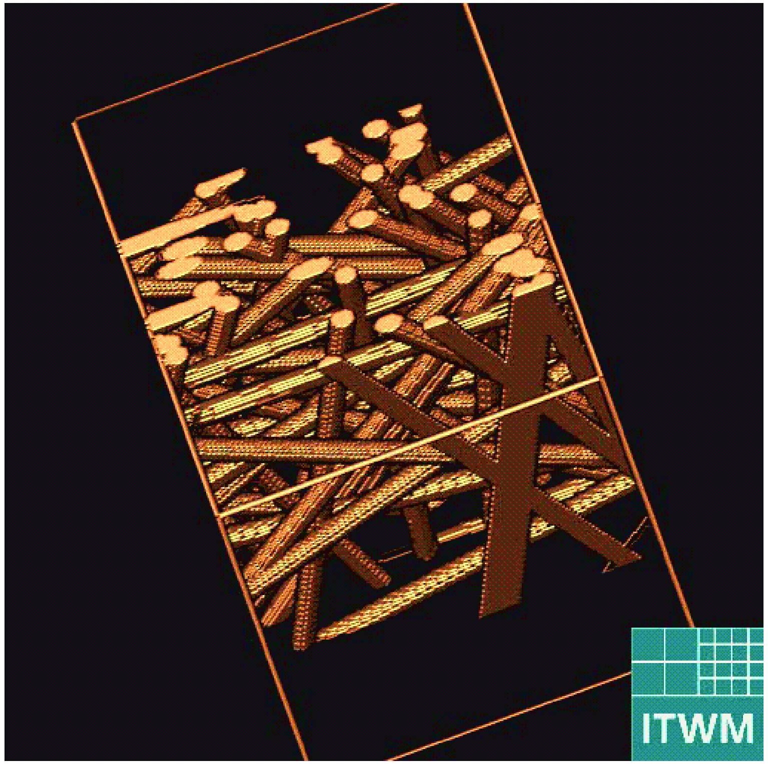
Direct Simulation: Fluid Flow



Free flow through thin fleece of cylindrical fibers

Input: Stochastic geometry model of the microstructure from Geodict
(and further material parameters)

Solution of the (Navier-)Stokes equations

Algorithm: Lattice Boltzmann Method (LBM)

Software: PARPAC (Fraunhofer ITWM)

Result: Flow Resistivity

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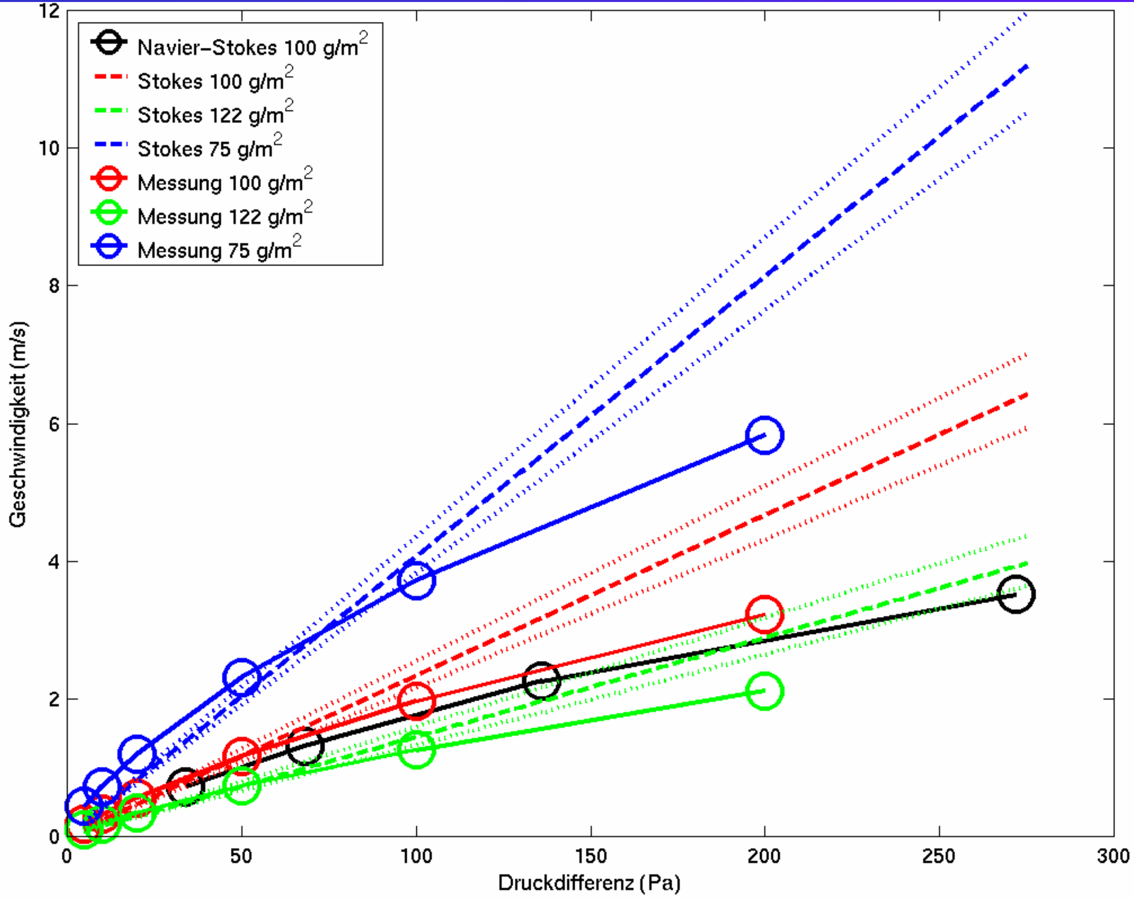
Direct Simulation: Fluid Flow



Comparison between Stokes/Navier-Stokes computations and measurements

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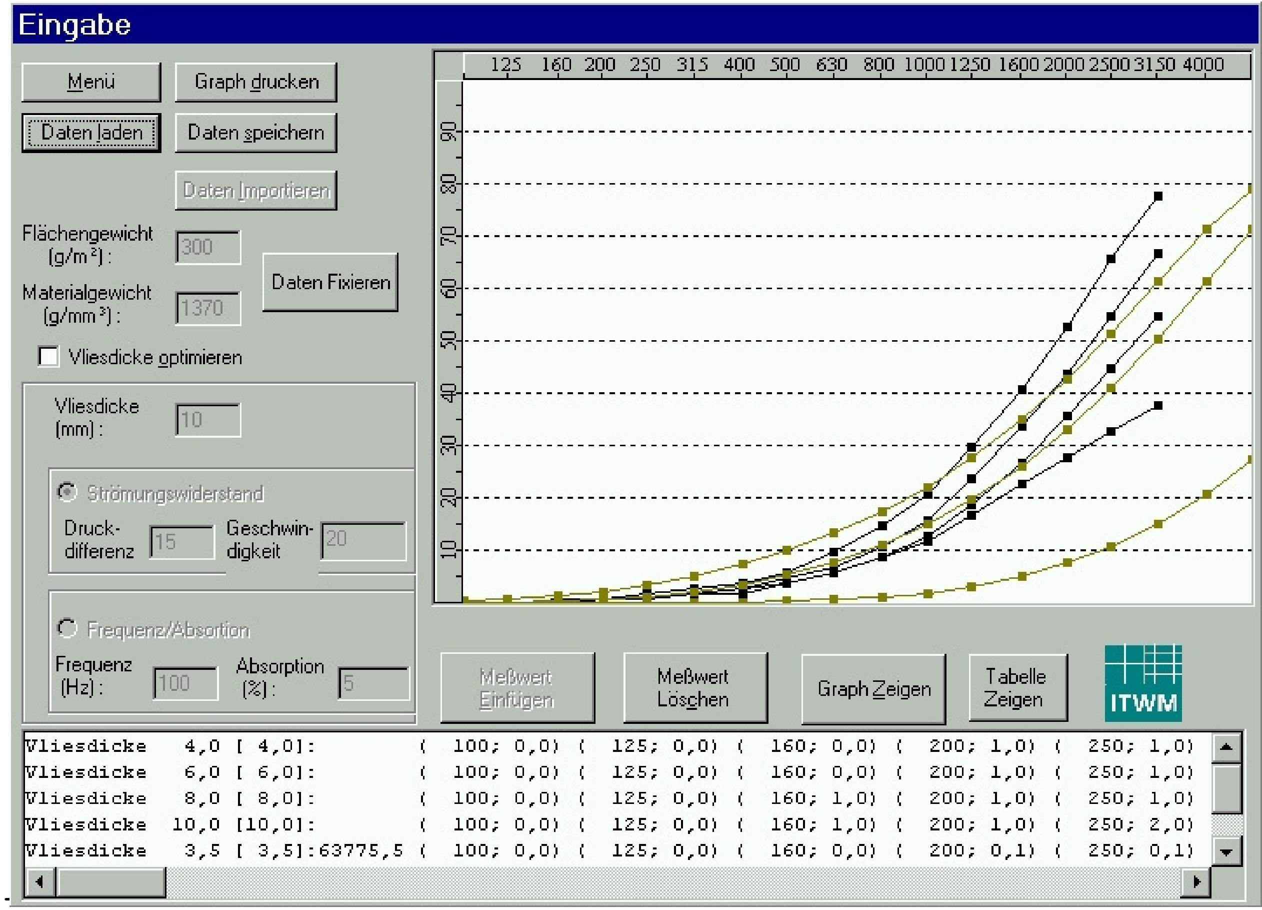
Direct Simulation: Akudict



Akudict is a tool for the prediction of that acoustical absorption, which is measured in the impedance tube, for non-wovens.

Input form for the flow resistivity and measurements in the impedance tube

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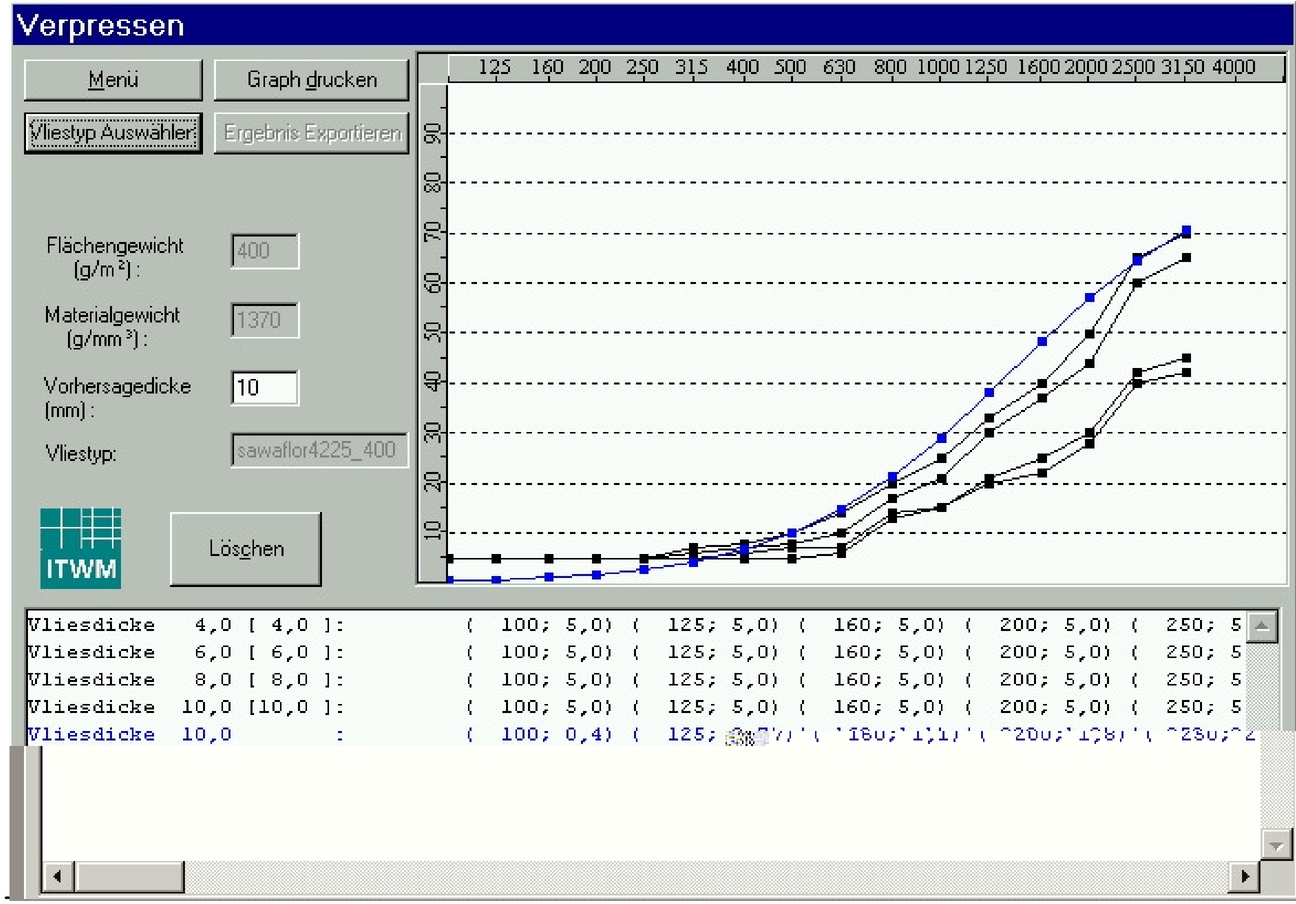
Direct Simulation: Akudict



Prediction for a new compression value

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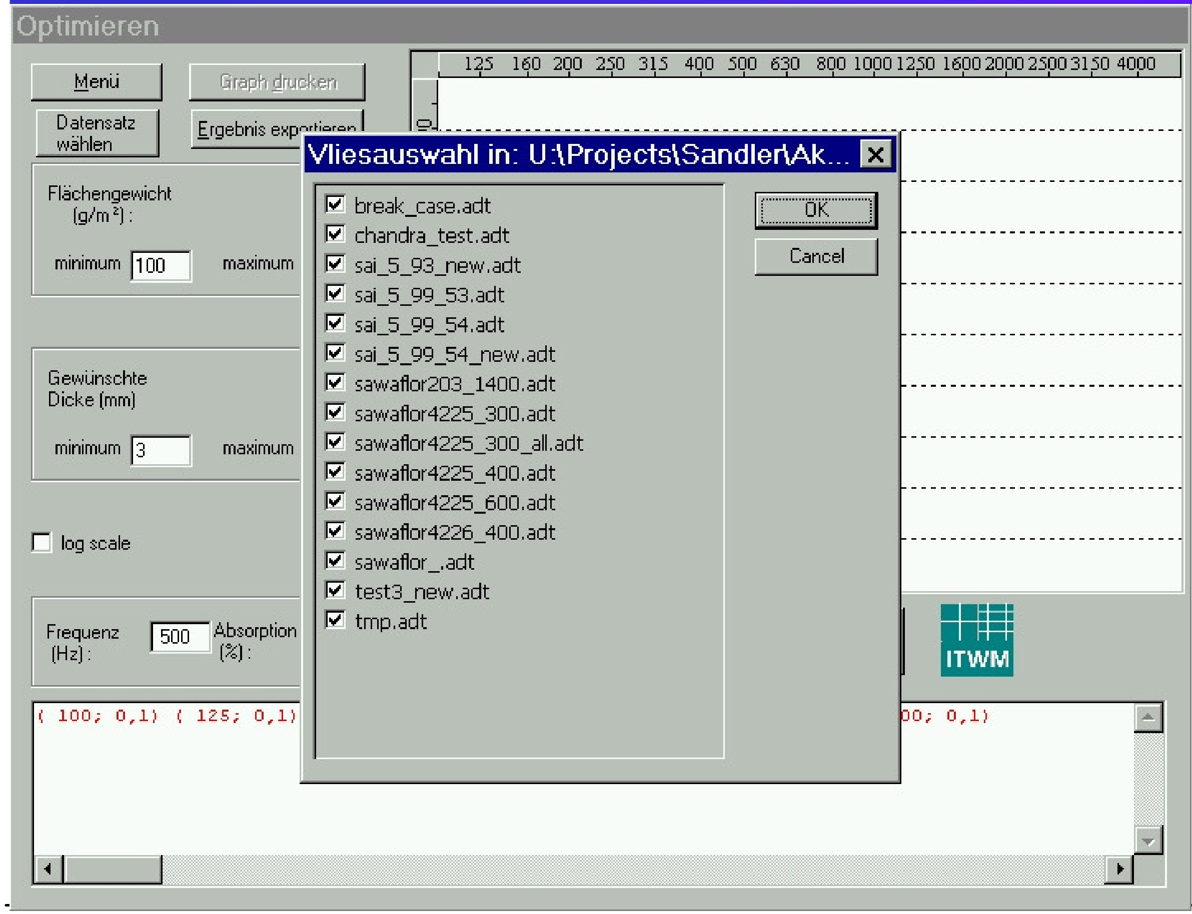
Direct Simulation: Akudict



Input form for data sets from the fleece data base

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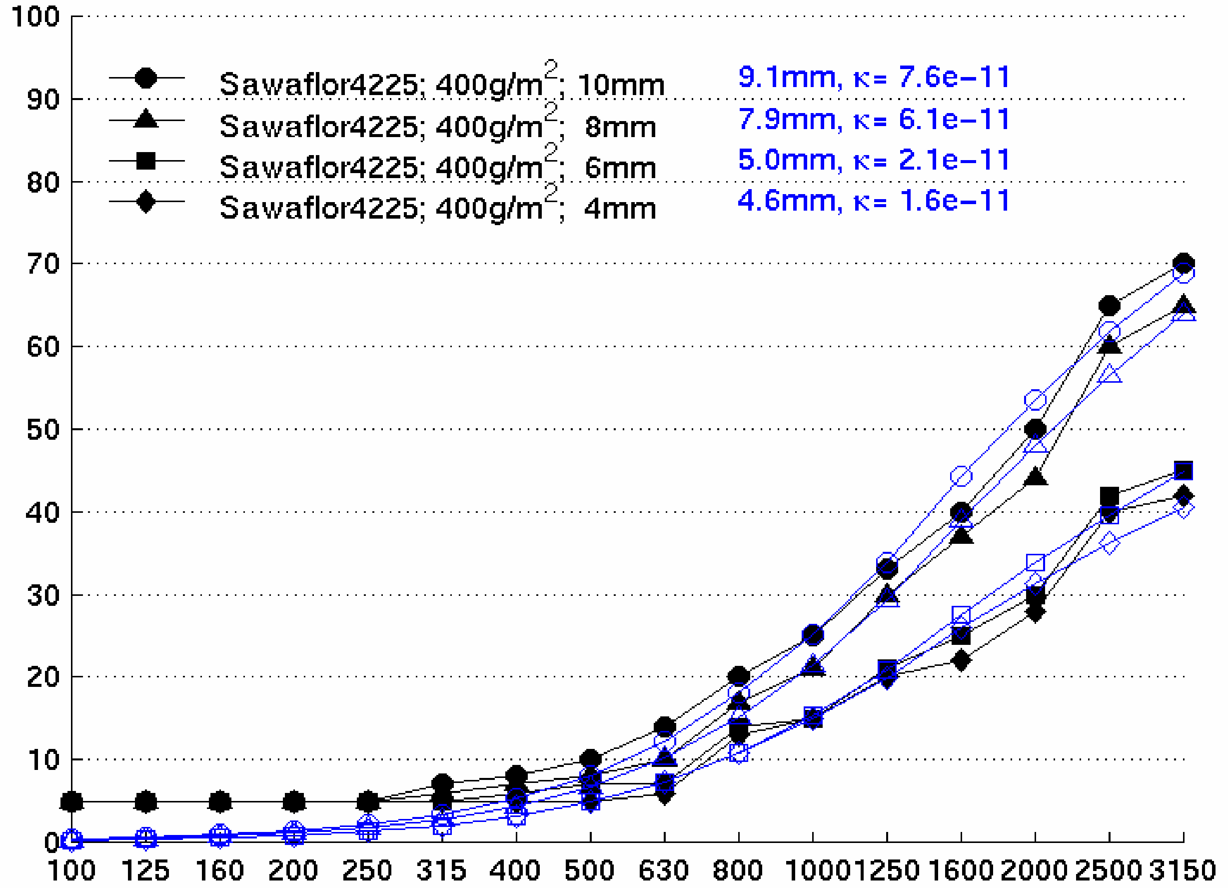
Direct Simulation: Akudict



Comparison of measurements (black) and simulations (blue)

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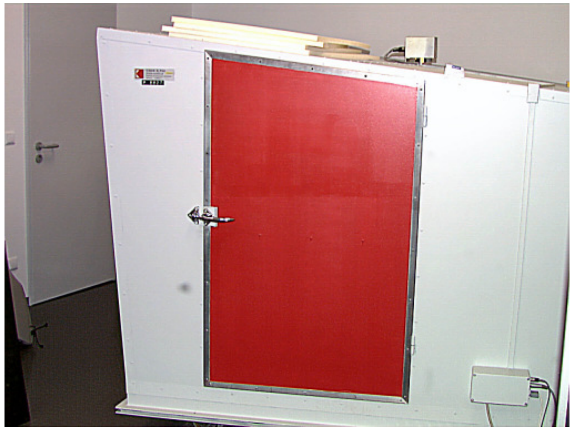
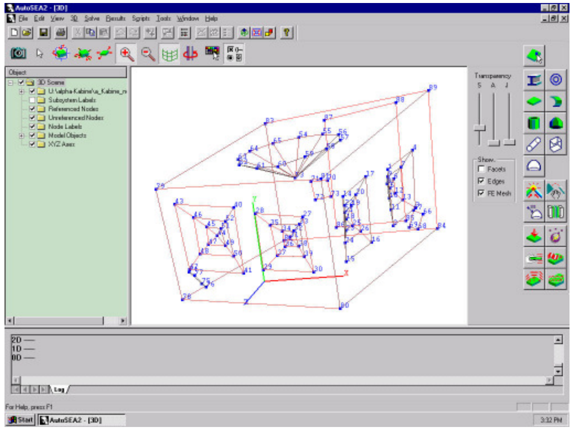
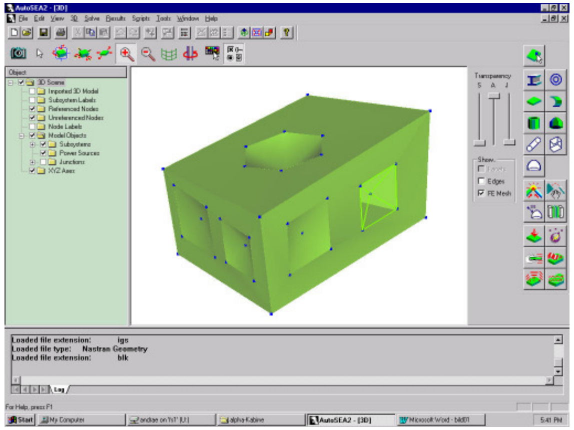
Direct Simulation: Alphadict





Measurements in the Alpha Cabin are used to calibrate the absorption of the acoustical trim in the diffusive field.



An simple SEA model of the Alpha Cabin was implemented.

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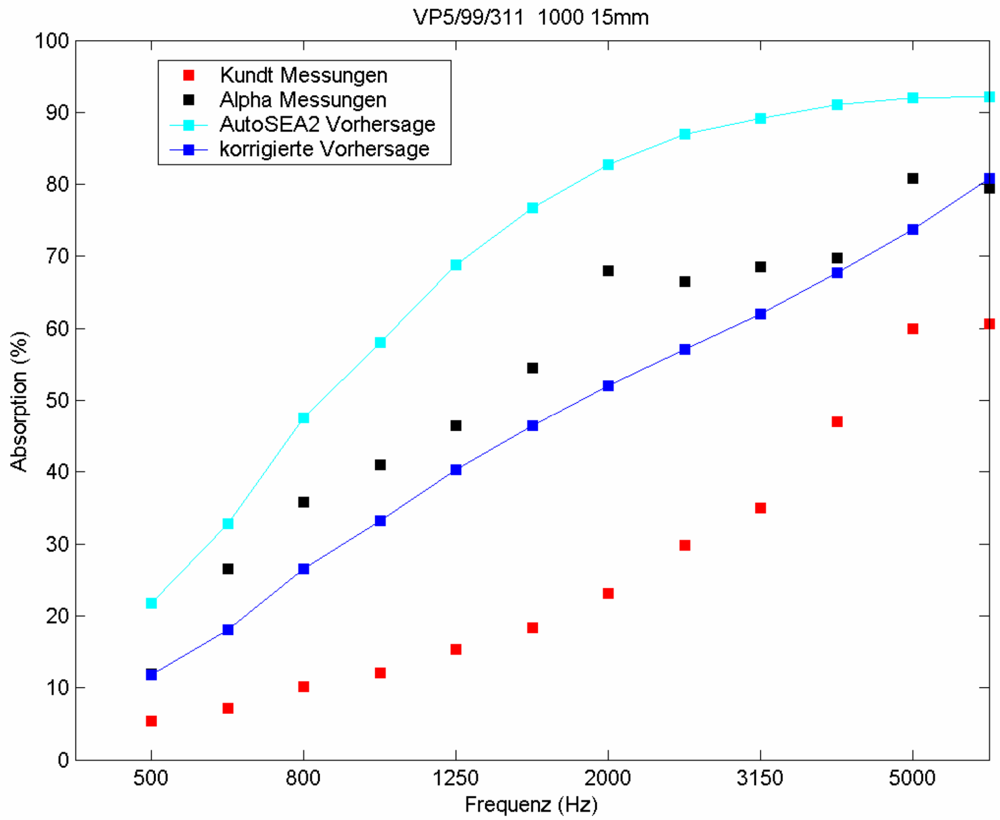
Direct Simulation: Alphadict



Red — Measurements: Impedance Tube

Black — Measurements: Alpha Cabin

Light Blue — Simulation: AutoSEA2

Blue — Simulation: Corrected Simulation with 2 parameters

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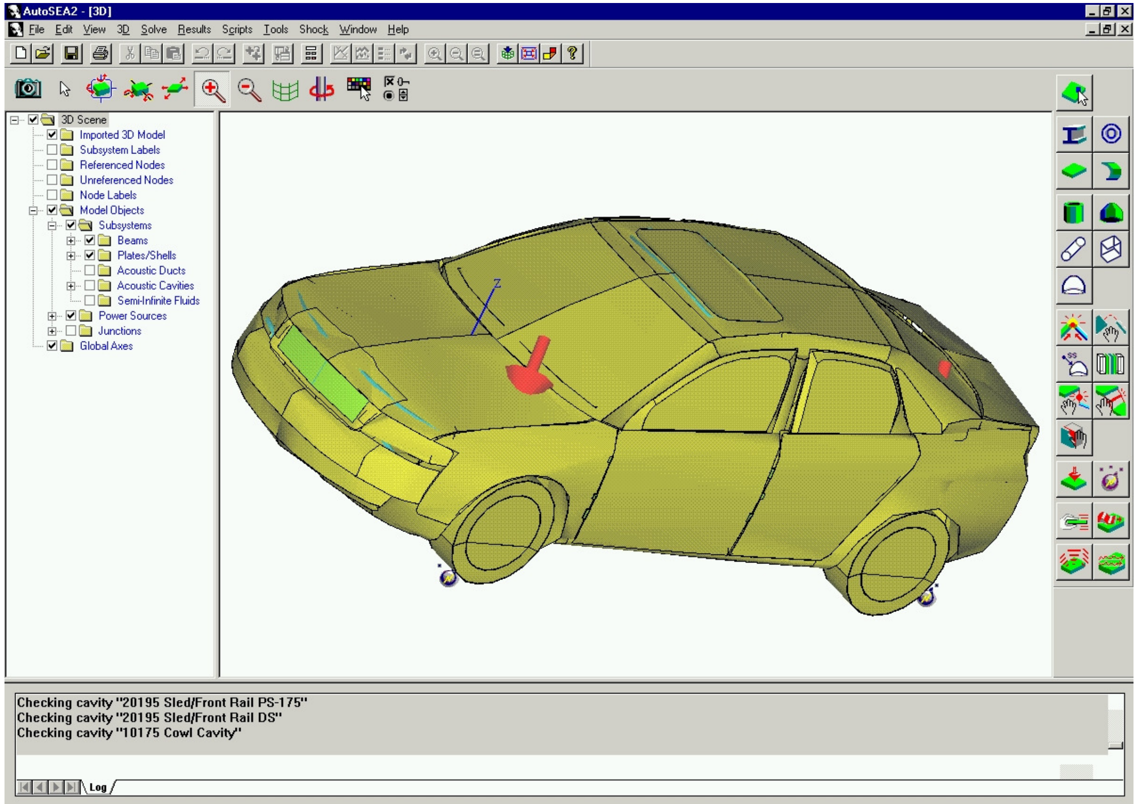
Direct Simulation: AutoSEA2



AutoSEA2 model from Audi/MSXI

The influence of the acoustical trim part on the acoustical absorption of the passenger cabin is modeled by SEA.

A fixed number of acoustic experiments is considered.

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Inverse Simulation

The computational effort for the direct simulation (especially for the fluid flow simulation) is very high.

The solution of the inverse problem requires several direct simulations.

Therefore, we compute a database, which contains for varying material parameters the corresponding absorption spectra in the vehicle, in previous.

By using this database, the solution of the inverse simulation is computed in few seconds.

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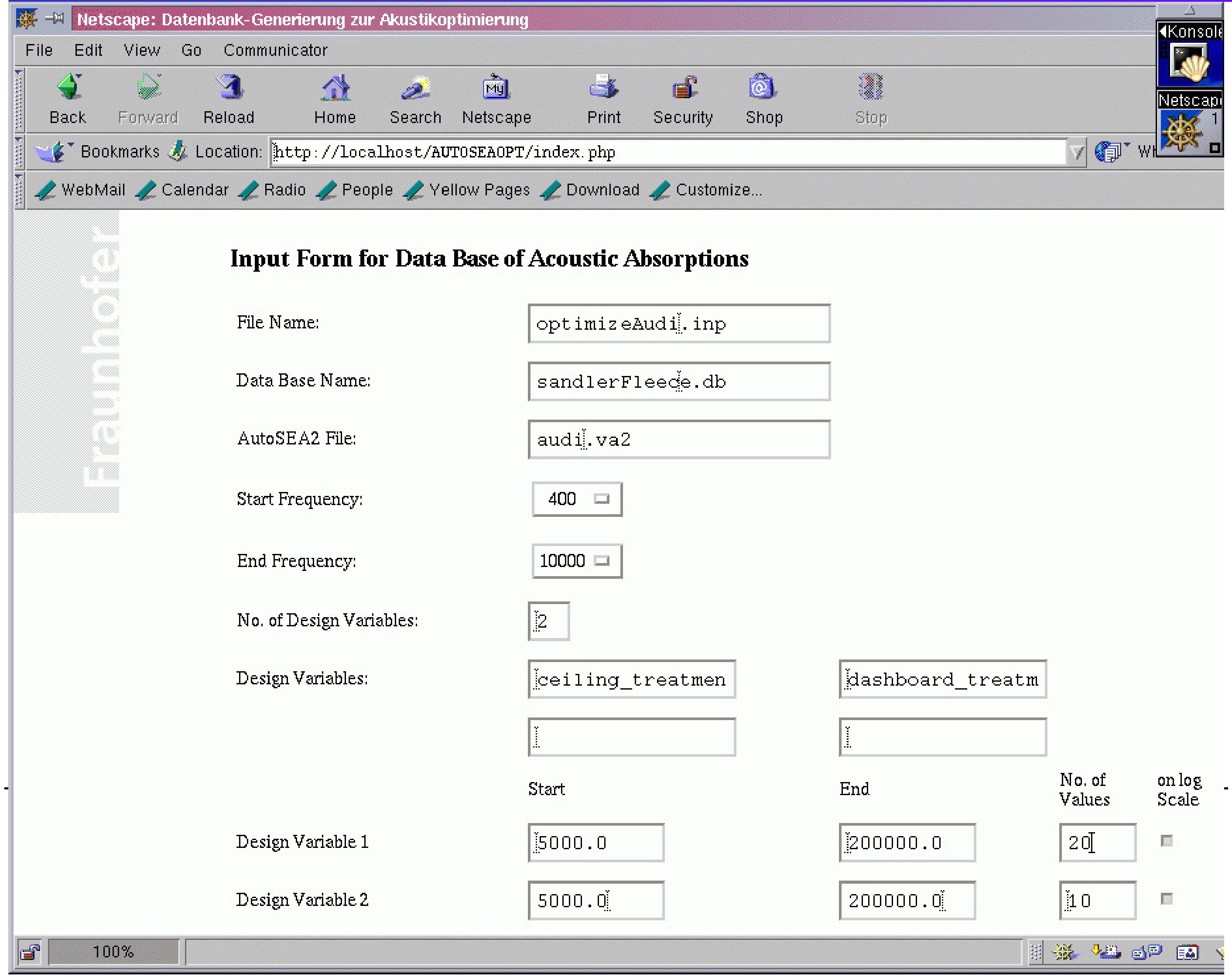
Inverse Simulation: Database

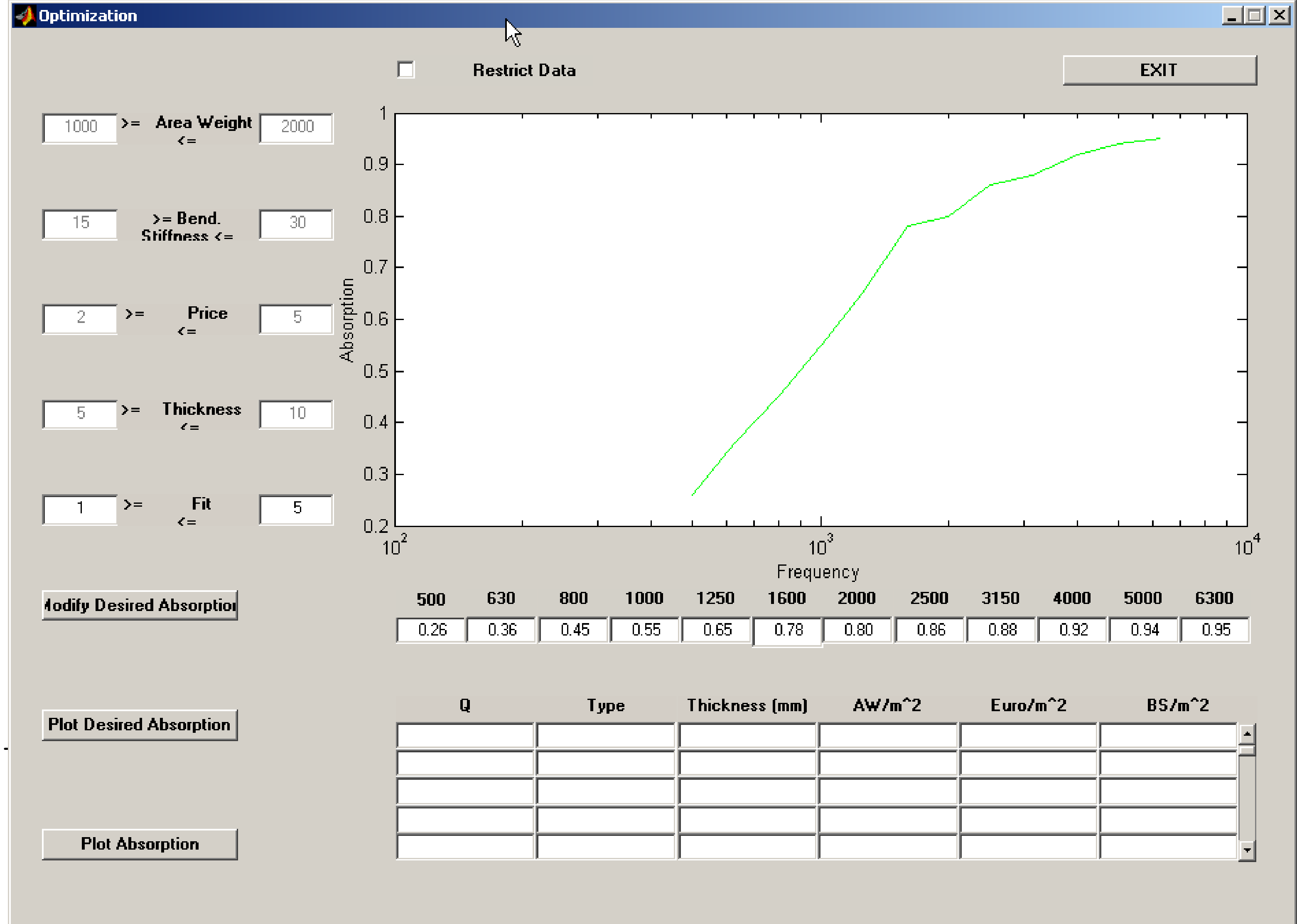


The Absorption spectrum is precomputed for varying material para-meters (design variables) and for fixed experiments.

WW and Matlab interfaces are used for SEA-simulations.

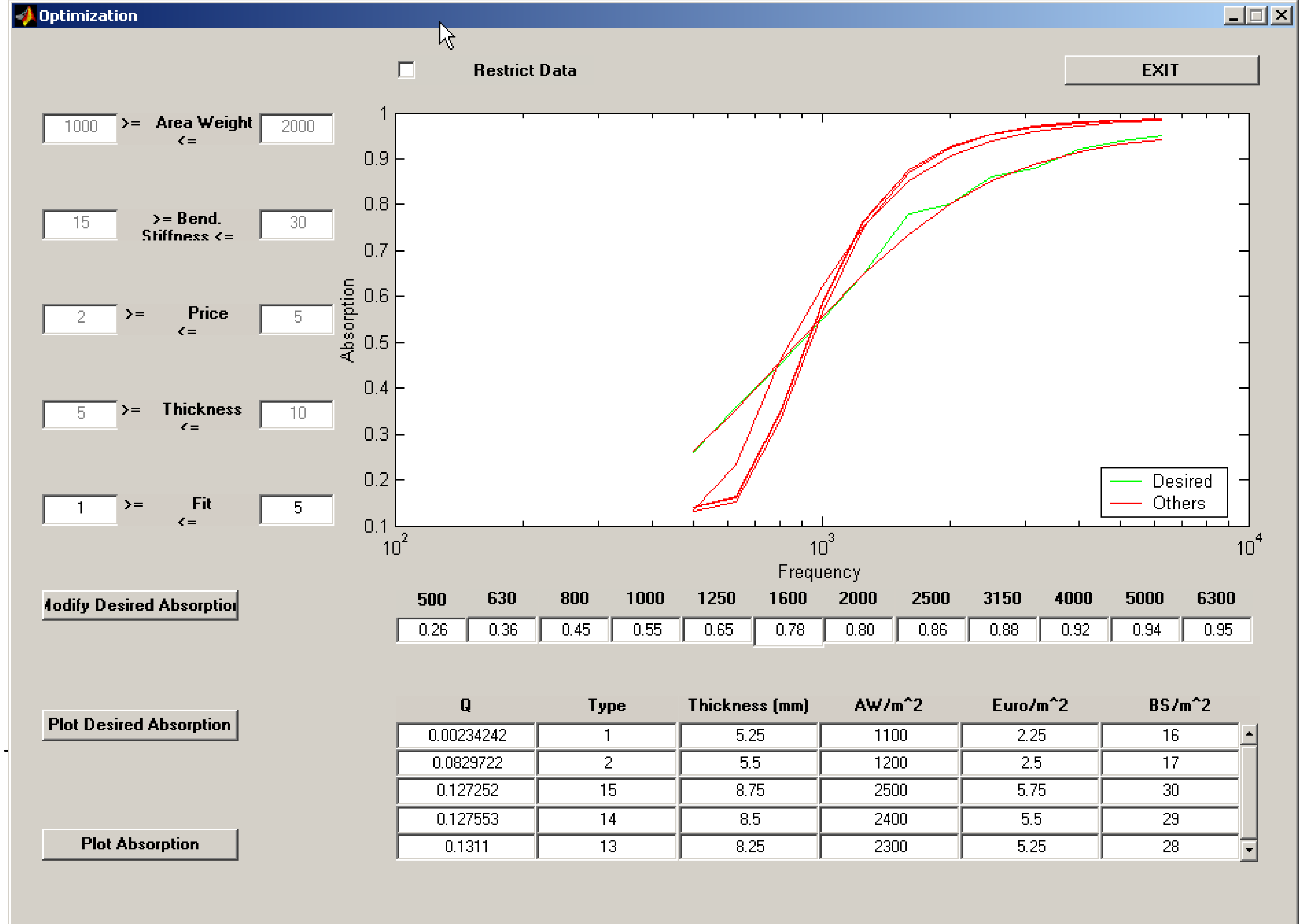
WWW interface for the database generation

Inverse Simulation: CMP



GUI for the solution of the Constraint Minimization Problem (CMP)

Inverse Simulation: CMP



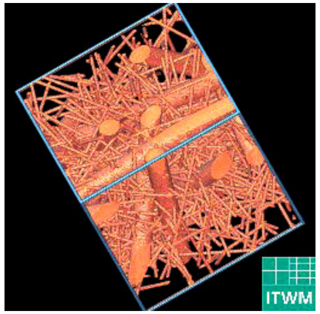
GUI for the solution of the Constraint Minimization Problem (CMP)

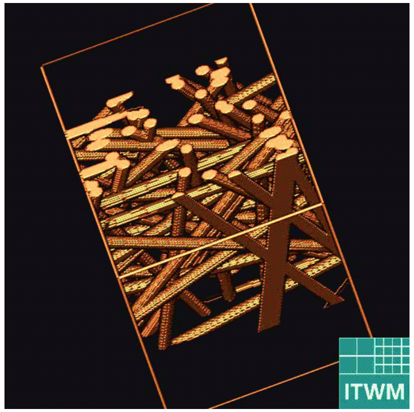
Summary

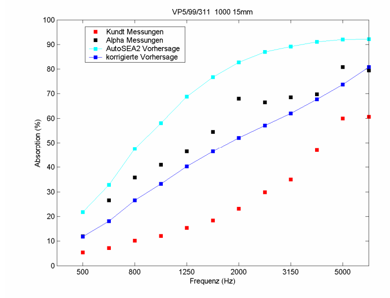
Simulation of the microstructure

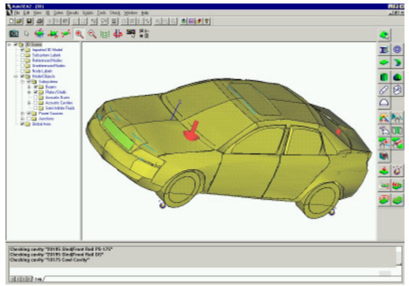
Fluid flow simulation

Simulation of the material absorption









Extracting parameters from micrograph

Searching for optimal fleece

Simulation of the acoustical trim

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