GeoDict

The Digital Material Laboratory

USER MEETING 2021 & WORKSHOPS

4 - 8 Oktober 2021

Information | Innovation | Inspiration

MATH 2 MARKET

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Foreword

All of us at Math2Market welcome our clients, partners, and friends to this second online GeoDict User Meeting. The Covid-19 pandemic has changed our way of working at M2M. Only about 1/3rd of us are back to work in the office regularly and mobile office works well for us. Fortunately, you are all willing to communicate with us via video conferencing and E-Mails, and business has picked up for us instead of slowing down. We feel fortunate and thank you for your continued trust!

For the second year in a row, we must go online and provide all presentations as videos, rather than live talks. I thank all presenters and our organizers for the great effort that went into preparing these materials. All sessions will take place twice, to accommodate our participants from the earlier time zones in Asia, and the Pacific and Australia, as well as those from the later time zones in the Americas. Most presentations and all our workshops will be available on YouTube after the meeting. If you wish to watch a presentation again, or could not do it due to other obligations, we hope you will find this service useful.

To get started, please check the User Meeting and Workshops Program for a full listing of all presentations and other pertinent information. The Workshops that were a successful format in the last years are again organized online. They take place after the corresponding User Meeting blocks and, this year, there are again 8 to choose from: **Filtration**, **Digital Material R&D**, **Batteries** and **Fuel Cells**, **Digital Rock Physics & Digital Core Analysis**, **Image Processing & Image Analysis**, **GeoPy-Beginners** and **GeoPy-Advanced** for automation and scripting, and **Visualization** with GeoDict.

Math2Market's growth has picked up during the pandemic and this year a new Consulting and Projects Team was formed, led by Dr. Mathias Fingerle. Within the team, we continued to participate in several advanced research projects with renowned scientific institutions. Details on these projects can be found on our webpage, but it is worth mentioning them here.

We thank the German Federal Ministry for Economic Affairs and Energy for funding of the structur.e project that is led by Volkswagen and joint with DLR, Fraunhofer ITWM, ZSW Ulm, FH Aalen, SGL Carbon, Preci-Point, Porsche, and Trumpf.

We thank the Eurostars program of the European Union for funding of the SOLVED! Project together with ETH Zurich.

Andreas Wiegmann, PhD., CEA, Math2Market GmbH

We thank the ZIM program of German Federal Ministry for Economic Affairs and Energy and AiF GmbH for funding of the DamageDict project with the Leibniz-Institute for Composite Materials GmbH in Kaiserslautern, and for funding the BiGOFil project with Fraunhofer ITWM, RWTH Aachen, Hochschule Heilbronn, Junker Filter and Ahlstrom-Munksjö.

The German government also helps us with a tax break for internal research projects under the new "Forschungszulagengesetz" and we very much appreciate this new option.

A highlight like every year is the release of our newest edition of the GeoDict software. In this GeoDict 2022 release, you will find vast improvements illustrated in the presentations from Math2Market and in the hands-on Workshops that take place right after the presentations of the User Meeting.

Many attendees are joining us this year from Japan, South Korea, China, the United States of America, Argentina, Brazil, Colombia, Australia, United Arab Emirates, and the Russian Federation. As every year, we particularly welcome former colleagues and acknowledge very fruitful collaborations with Fraunhofer ITWM and the Leibniz-Institut für Verbundwerkstoffe GmbH in Kaiserslautern.

I very much thank our guest speakers for their willingness to prepare and share their work with us. Math2-Market just turned 10 years old in September 2021 and so this is a good moment to also thank those of you who are repeat attendants to this event for your continued interest and collaboration with us. We hope you will enjoy your online time with us and feel as welcome as previous years!

MORNING - for CEST and East from CEST

User Meeting	Monday Oct 4, 2021	Tuesday Oct 5, 2021	Wednesday Oct 6, 2021	Thursday Oct 7, 2021	Friday Oct 8, 2021
	Image Processing & Image Analysis	Digital Rock Physics & Digital Core Analysis	Digital Material R&D	Batteries & Fuel cells	Filtration
8:00-8:05	Welcome & Introduction	Welcome & Introduction	Welcome & Introduction	Welcome & Introduction	Welcome & Introduction
8:05-8:25	Technology highlights in GeoDict 2022 *(Math2Market GmbH)*	Digital Core Analysis in GeoDict 2022 – Latest & greatest *(Math2Market GmbH)*	Technology highlights in GeoDict 2022 *(Math2Market GmbH)*	Technology highlights in GeoDict 2022 *(Math2Market GmbH)*	Technology highlights in GeoDict 2022 *(Math2Market GmbH)*
8:25-8:50	Advances in image analysis and AI applications in GeoDict 2022 *(Math2Market GmbH)*	Advances in two-phase and single-phase flows *(Math2Market GmbH)*	Digital Materials R&D with GeoDict 2022 – Latest & greatest *(Math2Market GmbH)*	Battery and fuel cell R&D with GeoDict 2022 – Latest & greatest *(Math2Market GmbH)*	Filtration simulation with GeoDict 2022 – Latest & greatest *(Math2Market GmbH)*
8:50-9:15	GeoCloud: Your personal supercomputer on demand *(Math2Market GmbH)*	An image-based estimation of the mechanical properties of karstified reservoirs *(Petrobras SA)*	Bending simulations of CFRP laminates with ElastoDict *(Fraunhofer ITWM)*	Generation of virtual three-phase structures based on Gaussian random fields: An important option for … *(ZHAW)*	Numerical design of three way catalyzed membrane filter with both high filtration efficiency … *(Tokyo Institute of Technology)*
9:15-9:30	Break	Break	Break	Break	Break
9:30-9:55	Permeability and percolation of sea ice from Digital Rock Physics *(Norwegian University of Science and Technology)*	Computing elastic properties of organic-rich source rocks using digital images *(Aramco Services Company)*	From experiment to model – Dynamic µCT for calibration and validation of mechanical solvers in GeoDict *(TESCAN)*	Numerical characterization of porous transport layers in PEM water electrolyser by means of GeoDict software *(Schaeffler Technologies AG & Co. KG)*	Predicting the 3D elastic-plastic behavior of polymer-based filter media *(MANN+HUMMEL)*
9:55-10:20	GeoApps, a short overview *(cvt engineering)*	GeoDict as a benchmark in new technology development *(Skolkovo Institute of Science and Technology)*	Benchmarking virtual permeability predictions of real unidirectional fibrous microstructure *(École Centrale de Nantes)*	Simulated material properties from multiscale 3-Dimensional Imaging with applications in energy materials research *(ZEISS US)*	Modeling and simulation of coalescence in the context of oil mist filtration using a distance map *(Hochschule Heilbronn (HHN))*
10:20-10:30	Farewell	Farewell	Farewell	Farewell	Farewell
10:30-11:00	Break	Break	Break	Break	Break
Workshops 11:00-13:00	Image Processing & Image Analysis; GeoPy Beginners	Digital Rock Physics & Digital Core Analysis; GeoPy Advanced	Digital Material R&D; Visualization	Batteries & Fuel cells; GeoPy Beginners	Filtration; GeoPy Advanced; Visualization

AFTERNOON - for CEST and West from CEST

User Meeting	Monday Oct 4, 2021	Tuesday Oct 5, 2021	Wednesday Oct 6, 2021	Thursday Oct 7, 2021	Friday Oct 8, 2021
	Image Processing & Image Analysis	Digital Rock Physics & Digital Core Analysis	Batteries & Fuel cells	Filtration	Digital Material R&D
14:00-14:05	Welcome & Introduction	Welcome & Introduction	Welcome & Introduction	Welcome & Introduction	Welcome & Introduction
14:05-14:25	Innovations in GeoDict 2022 *(Math2Market GmbH)*	Digital Core Analysis in GeoDict 2022 – Latest & greatest *(Math2Market GmbH)*	Technology highlights in GeoDict 2022 *(Math2Market GmbH)*	Technology highlights in GeoDict 2022 *(Math2Market GmbH)*	Technology highlights in GeoDict 2022 *(Math2Market GmbH)*
14:25-14:50	Advances in image analysis and AI applications in GeoDict 2022 *(Math2Market GmbH)*	Advances in two-phase and single-phase flows *(Math2Market GmbH)*	Battery & fuel cell R&D with GeoDict 2022 – Latest & greatest *(Math2Market GmbH)*	Filtration simulation with GeoDict 2022 – Latest & greatest *(Math2Market GmbH)*	Digital Materials R&D with GeoDict 2022 – Latest & greatest *(Math2Market GmbH)*
14:50-15:15	GeoCloud: Your personal supercomputer on demand *(Math2Market GmbH)*	An image-based estimation of the mechanical properties of karstified reservoirs *(Petrobras SA)*	Generation of virtual three-phase structures based on Gaussian random fields: An important option for … *(ZHAW)*	Numerical design of three way catalyzed membrane filter with both high filtration efficiency …*(Tokyo Institute of Technology)*	Bending simulations of CFRP laminates with ElastoDict *(Fraunhofer ITWM)*
15:15-15:30	Break	Break	Break	Break	Break
15:30-15:55	Permeability and percolation of sea ice from Digital Rock Physics *(Norwegian University of Science and Technology)*	Computing elastic properties of organic-rich source rocks using digital images *(Aramco Services Company)*	Numerical characterization of porous transport layers in PEM water electrolyser by means of GeoDict *(Schaeffler Technologies AG & Co. KG)*	Predicting the 3D elastic-plastic behavior of polymer-based filter media *(MANN+HUMMEL)*	From experiment to model – Dynamic µCT for calibration and validation of mechanical solvers in GeoDict *(TESCAN)*
15:55-16:20	GeoApps, a short overview *(cvt engineering)*	GeoDict as a benchmark in new technology development *(Skolkovo Institute of Science and Technology)*	Simulated material properties from multiscale 3-Dimensional Imaging with applications in energy materials research *(ZEISS US)*	Modeling and simulation of coalescence in the context of oil mist filtration using a distance map *(Hochschule Heilbronn (HHN))*	Benchmarking virtual permeability predictions of real unidirectional fibrous microstructure *(École Centrale de Nantes)*
16:20-16:30	Farewell	Farewell	Farewell	Farewell	Farewell
16:30-17:00	Break	Break	Break	Break	Break
Workshops 17:00-19:00	Image Processing & Image Analysis; GeoPy Beginners	Digital Rock Physics & Digital Core Analysis; GeoPy Advanced	Batteries & Fuel cells; Visualization	Filtration; GeoPy Beginners	Digital Material R&D; GeoPy Advanced; Visualization

Welcome & Introduction

Author / Speaker: Andreas Wiegmann, Math2Market GmbH

This year marks the 10th anniversary of Math2Market and we welcome over 300 participants from over 25 different countries to our 2021 GeoDict User Meeting and Workshops. Again an online event, it will cover our 5 major topics in 5 days: Image Processing and Image Analysis, Digital Rock Physics & Digital Rock Analysis, Digital Material Research & Development, and Filtration, as well as Batteries & Fuel Cells. The topics repeat as morning and afternoon blocks to accommodate our guests from very different time zones. We hope that this format makes sense for you and fits your needs. We look forward to your feedback regarding all the items in the program: the recorded presentations at the User Meeting, the Workshops after it, and the breaks to chat and answer your questions.

During the online meeting and afterwards, we would like to hear from you regarding software usability, the needs in image processing capabilities, and your modelling and simulation project requirements. Our forum is starting to be filled in and we hope that you will find it useful and add to the content with your own questions and answers. On our web page and YouTube channel, many online resources such as tutorials and workshop videos are becoming available at an ever-increasing rate. The list of publications using GeoDict on our web page has grown to an astonishing 470 entries by now.

At the same time, many, many new features of the newly released GeoDict 2022 will hopefully enchant you, as they do the Math2Market team. As every year, we have important news about many of the current hot topics.

For simulations of battery charging, especially helpful are the speedup by a factor 6-30 and the handling of porous Carbon Black domains, as well as the 15 ways of estimating tortuosity. In Digital Rock Analysis / Physics, the mixed wettability for the full range of contact angles from 0-180° constitutes quite a breakthrough that is applicable also to fuel cells and technical textiles. New is also simulating whole filters and even air purifiers in office spaces, as well as the treatment of coalescence. Three-point bending experiments can now be simulated as well as a multitude of strut-based lattices and user-defined triply periodic minimal surfaces for Additive Manufacturing applications. The capability to train your own neural networks for Artificial Intelligence applications has matured significantly, and the post-processing to determine fiber properties after fiber recognition should not leave any needs unanswered. Also, the import and export into GeoDict and from GeoDict are much improved. And finally, Math2Market also reports much progress in using cloud solutions, both in batch-mode and in interactive mode.

Today, we are extremely happy to announce our latest release, the new GeoDict 2022. Join us online to see for yourself why we are so proud to have created it.

Technology Highlights in GeoDict® 2022

Author / Speaker: Erik Glatt, Math2Market GmbH

As established in previous years, GeoDict 2022 is released on time for the GeoDict User Meeting.

GeoDict 2022 is full of improvements and new features that improve the analysis and engineering of materials. This makes GeoDict the best solution in the market for digital material analysis and design.

In this talk, I shortly present a selection of the technology highlights in GeoDict 2022, such as:

- Computation of 3-point flexural test in ElastoDict
- Tracking of objects and contacts during large deformations
- Strongly improved
  - computation speed for nonlinear mechanics simulations
  - computation speed for Navier-Stokes flow simulations e.g., for complete filters
  - computation speed for battery simulations and porous binder in Battery-LIR
  - 2-phase flow with e.g., constant flow rate and forced imbibition
- Direct half-cell battery simulation and complex charging profiles for batteries
- More accurate computation of the geodesic tortuosity
- Modeling of realistic foams with (tri-)angular struts and specified solid volume percentage
- Generation of grains and fibers with more than one material ID
- Generation of strut bases lattices and triply periodic minimal surfaces for additive manufacturing
- Free adjustment of the units and the style of all result plots
- Improved mouse modes GUI and better distance and angle measure in the 2D view
- New interpolation options for the visualization of volume fields
- Export to Excel via Python also on computers without Excel e.g., on Linux
- Capability to create a 3D image from loaded surface meshes
- GeoDict AI: Training of your own neuronal network for 3D image analysis
- Cloud computation: flexible & unlimited computation power for GeoDict

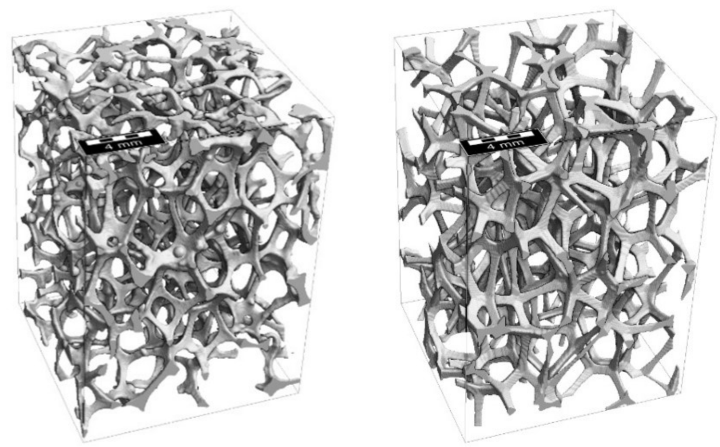


Fig. 1. Open-cell Aluminum foam with angular struts: CT-scan on the left and statistical digital twin on the right (FoamGeo).

Advances in Image Analysis and AI Applications in GeoDict® 2022

Author / Speaker: Andreas Grießer, Math2Market GmbH

3D imaging techniques are a valuable method in material sciences for analysis and design of materials. Using µCT and FIB-SEM devices, it is possible and easy to obtain images at a resolution well suited for micro scale simulations and to investigate the impact of microstructural morphology on material properties.

Even before starting to run simulations (for example, flow or mechanics simulations) on these images, valuable insights can be obtained from the analysis of the geometry of the scanned materials. In GeoDict 2022, the capabilities for geometry analysis have been improved further. For the segmentation of µCT and FIB-SEM images, we extended the trainable AI segmentation of the ImportGeo-VOL module. Now, more data can be labeled for the deep learning-based methods, still keeping the training times at a reasonable range.

Besides this, we added the GeoDict-AI module for easy training of customized neural network from GeoDict generated material models. The training can be aimed to the segmentation of material phases or the labeling of individual objects (e.g., fibers) in µCT-images.

In the recent years, advances in synchrotron and µCT imaging have pushed the times required to take these images down to a time scale where 4D imaging is becoming more and more available. These kinds of image series can be also analyzed with GeoDict, and objects can be tracked over time, with the possibility of close comparison of in-situ experiments and simulations.

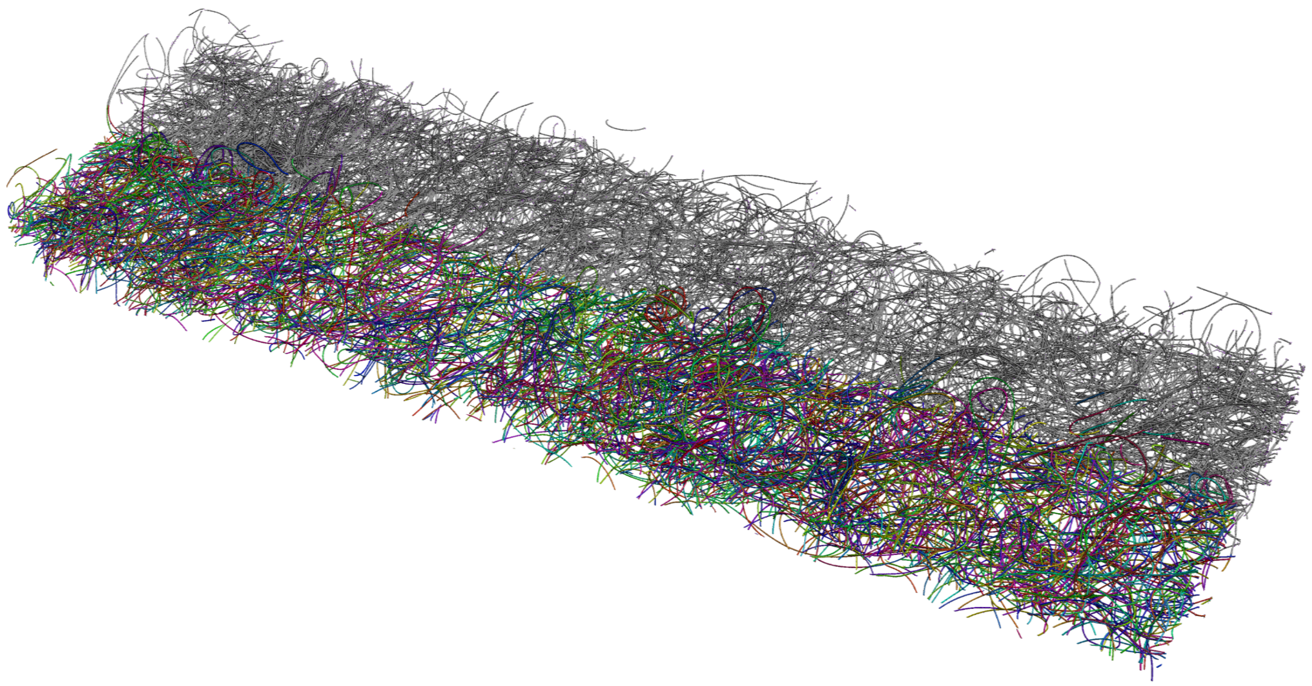


Fig. 1. Image of a Nonwoven Sample (15000x4000x2000 Voxels) with the individual fibers labeled by FiberFind in the front half.

GeoCloud: Your Personal Supercomputer On Demand

Author / Speaker: Rolf Westerteiger, Math2Market GmbH
Co-author: Mathias Fingerle, Andreas Griesser, Sven Linden, Christian Hinz, Jens-Oliver Schwarz, Erik Glatt, Andreas Wiegmann, Math2Market GmbH

In material innovation, more computational resources are often required than are readily available when it comes to reducing time-to-market. The results are unwanted delays and elevated costs for IT acquisition and maintenance. The on-premises approach is also inflexible regarding varying simulation demands: in peak times, limited local computation resources lead to long waiting times, while in off-peak times, the expensive hardware, a depreciating asset, might sit unused.

In 2020, M2M - together with the Swiss company KaleidoSim - started to offer a Software-as-a-Service (SaaS) solution to run GeoDict simulations in the cloud. Through a simple web interface, users can upload simulation cases and run large parameter studies via batch processing in the cloud. Exploiting the practically limitless computational resources of the cloud, extremely large numbers of simulation cases can run in parallel, reducing their total runtime to the time required for a single simulation. Recently, we started offering GPU instances as well, so that the AI capabilities of GeoDict can also be fully utilized (e.g., GeoDict-AI, FiberFind-AI, ImportGeo-VOL).

M2M now offers another solution based on Amazon Web Services (AWS) for use-cases requiring interactive pre-/post-processing or visualization. Here, users start powerful virtual machine instances and connect to a remote desktop session with pre-installed GeoDict - all within 5 minutes - using only a web browser. No expensive hardware or local GeoDict installation is required.

Talking about flexibility: for KaleidoSim batch processing, M2M offers a pre-paid model where users buy virtual CPU (VCPU)-hours upfront. For the interactive AWS solution, M2M offers a pay-per-use or bring-your-own-license (BYOL) model. Between the three options of traditional on-premises installation, cloud batch processing, and interactive GeoDict sessions in the cloud, we aim to address your requirements and help you make more effective use of GeoDict and your time.

Fig. 1. GeoDict in the Cloud.

Permeability and Percolation of Sea Ice from Digital Rock Physics

Author / Speaker: Sönke Maus, Department of Civil and Environmental Engineering, Norwegian University of Science and Technology
Co-author: Martin Schneebeli, WSL Swiss Federal Institute for Snow and Avalanche Research / Andreas Wiegmann, Math2Market GmbH

Finding the permeability-porosity-relationship of porous media is a classical problem in many scientific fields. As the permeability is often difficult to measure, percolation theory has been popular to interpret limited observations. In recent years Digital Rock Physics – to compute the relationship on X-ray microtomographic (XRT) images – has received growing interest. Here we present such an approach for the porous medium sea ice, using GeoDict.

Sea ice consists of brine, solid salts, and air in pore networks and inclusions within a matrix of almost pure ice crystals. This microstructure changes during cooling/warming, when the brine partially freezes/melts in pores to stay in thermodynamic equilibrium. This affects many physical sea ice properties, in particular the permeability, being of high relevance for sea ice in the climate system: By influencing the salinity and pore space evolution of sea ice, the permeability is a key factor for many other properties. E.g., by controlling the drainage of snow melt through sea ice, it has a considerable impact on the ice albedo.

The sea ice permeability has been suggested to exhibit percolation behavior with a critical brine volume fraction of 5 %. So far, this threshold was based on sparse observations. We have analyzed an extensive dataset of XRT images of Arctic Sea ice. Linking characteristic pore scales (PoroDict) to fluid permeability (FlowDict), we propose a percolation-based permeability model with a revised threshold porosity of 2-3%.

The data sets are made available to all researchers in the field and hosted by Math2Market under https://doi.org/10.30423/scandata.scan-2021-01

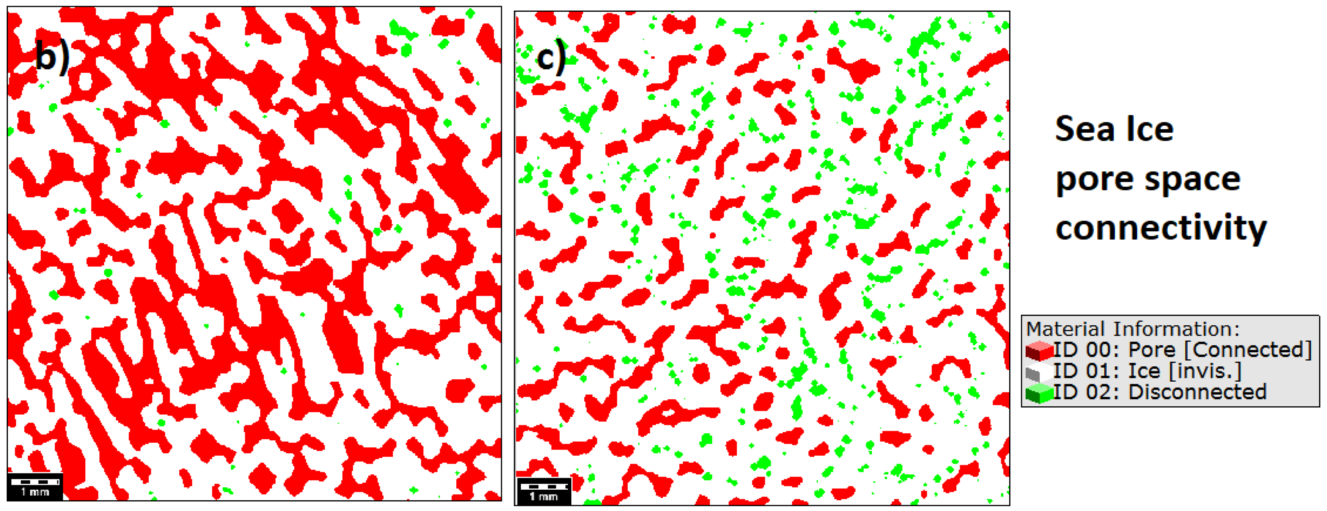


Fig. 1. Horizontal cross section slices of sea ice, contrasting a highly connected (left) versus disconnected (right) sample. Note that the color coding refers to the global 3D connectivity normal to the image plane. From Maus, Schneebeli and Wiegmann (2021, The Cryosphere, 15, 4047-4072. https://doi.org/10.5194/tc-15-4047-2021)

GeoApps, a short Overview

Author / Speaker: Tom Cvjetkovic, cvt engineering

GeoApps are Python macros embedded in the GeoDict User Interface that combine complex workflows with a user friendly interface. GeoDict has a very broad range of applications, for which GeoApps are an easy-to-use way of creating customized and automated workflows. Many of the carried out projects have been automated by using GeoApps. For example, µCT analysis and visualization, filtration simulations through membranes or with polydisperse filter media for water filtration, or in the design of filter media for polymer filtration.

In this talk, the author presents use cases of GeoApps for automation within GeoDict, based on real world examples from one of the projects.

Additionally, several open-source GeoApps are shown and published during the User Meeting.

Contact person:

Tom Cvjetkovic, tc@cvt-engineering.de

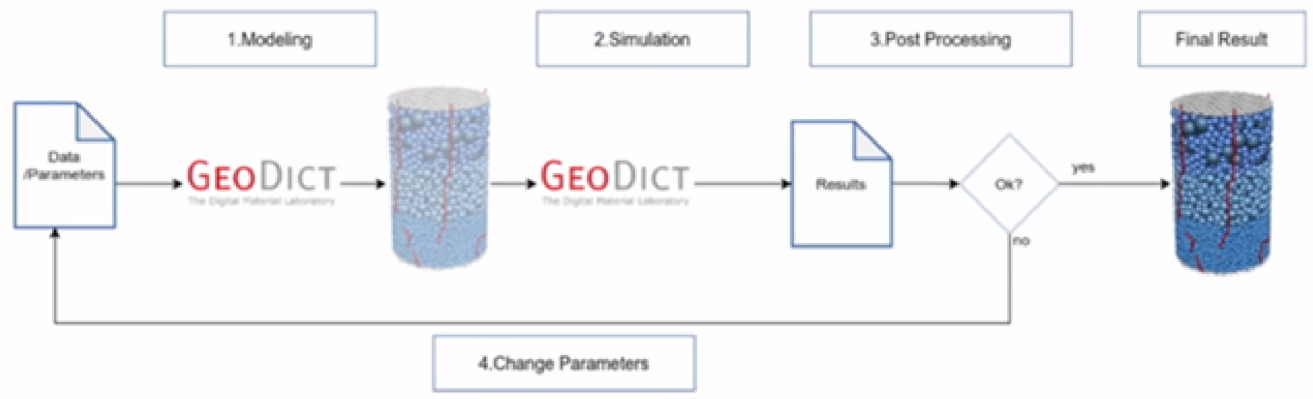


Fig. 1. Workflow of a simulation loop with GeoDict

Digital Core Analysis with GeoDict® 2022 – Latest & Greatest

Author / Speaker: Christian Hinz, Math2Market GmbH
Co-author: Arne Jacob, Sven Linden, Jens-Oliver Schwarz, Math2Market GmbH

In this talk, we provide a general overview of the Digital Core Analysis capabilities of GeoDict 2022. We present the main features for Digital Rock Physics (DRP) workflows, with a focus on GeoDict features for digitalization of the Special Core Analysis (SCAL).

The GeoDict DRP workflow typically begins with 3D image processing and segmentation of 3D gray value images obtained via image acquisition devices. Based on the resulting voxel-based geometry, the geometric properties of digital rocks are determined, including pore analysis, material analysis, and identification of individual pores and grains. For SCAL digitalization, the determination of transport properties in digital reservoir rocks is a key capability available in GeoDict.

Among these properties, GeoDict predicts the absolute permeability of porous and microporous reservoir rocks, computes capillary pressure curves in mixed-wet systems, and determines the relative permeability curve. Further, the GeoDict features for digital reservoir rocks are the determination of electrical properties and of overall mechanical properties, computation of rock deformation and failure, and 3D digital reactive flow experiments.

Significant developments in GeoDict 2022 aim at substantial performance improvements for computation of absolute and relative permeability in challenging domains and an extension of the Pore Morphology Method to cover mixed-wet systems in two-phase flow computation with GeoDict.

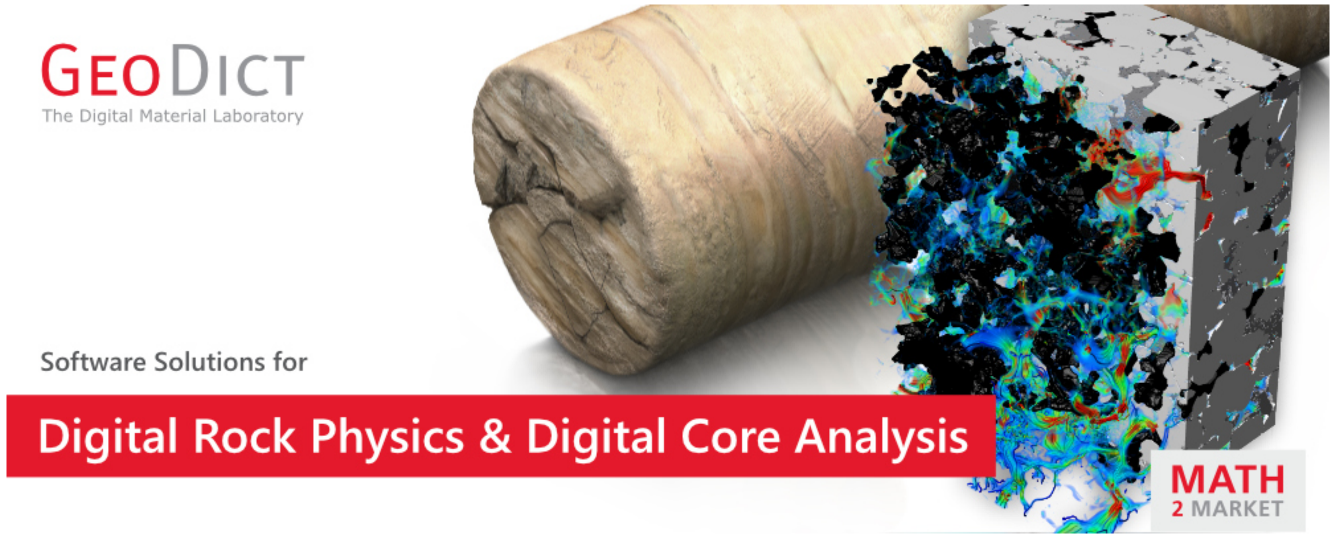


Fig. 1. GeoDict – The Digital Material Laboratory for Digital Core Analysis

Advances in Two-Phase and Single-Phase Flows

Author / Speaker: Sven Linden, Math2Market GmbH
Co-author: Christian Hinz, Arne Jacob, Jens-Oliver Schwarz, Andreas Wiegmann, Math2Market GmbH

The Oil and Gas industry is substantially affected by changes in the worldwide energy market. Particularly for the Exploration & Production sector, the pressure for optimization and productivity increase has intensified over the last years. A key factor to accelerate research and production through digital workflows is the understanding of two-phase and single-phase flows at the pore-scale. With the SatuDict and FlowDict modules of GeoDict, we can predict oil and water distributions and capillary pressure curves, as well as relative and absolute permeability in reservoir rocks.

Here, the Pore Morphology Method (PMM) is used to predict fluid distributions and capillary pressure. The original method can predict spontaneous imbibition and drainage processes for complete water-wet cases. But oil in contact with the rock alters its wettability and causes mixed-wet cases with both water-wet and oil-wet interfaces. Another challenge is the prediction of the relative and absolute permeability in tight or low saturated rocks. The complex pore structure and low porosity are challenging and increase the runtime for all flow solvers significantly.

In this presentation, we show our recent advancements of the PMM which allow to consider mixed wettability. We focus on the validation and compare our simulations with measurements performed in a quasi 2D microstructure. In addition, we demonstrate the latest improvements in the LIR solver to predict absolute and relative permeability much more rapidly.

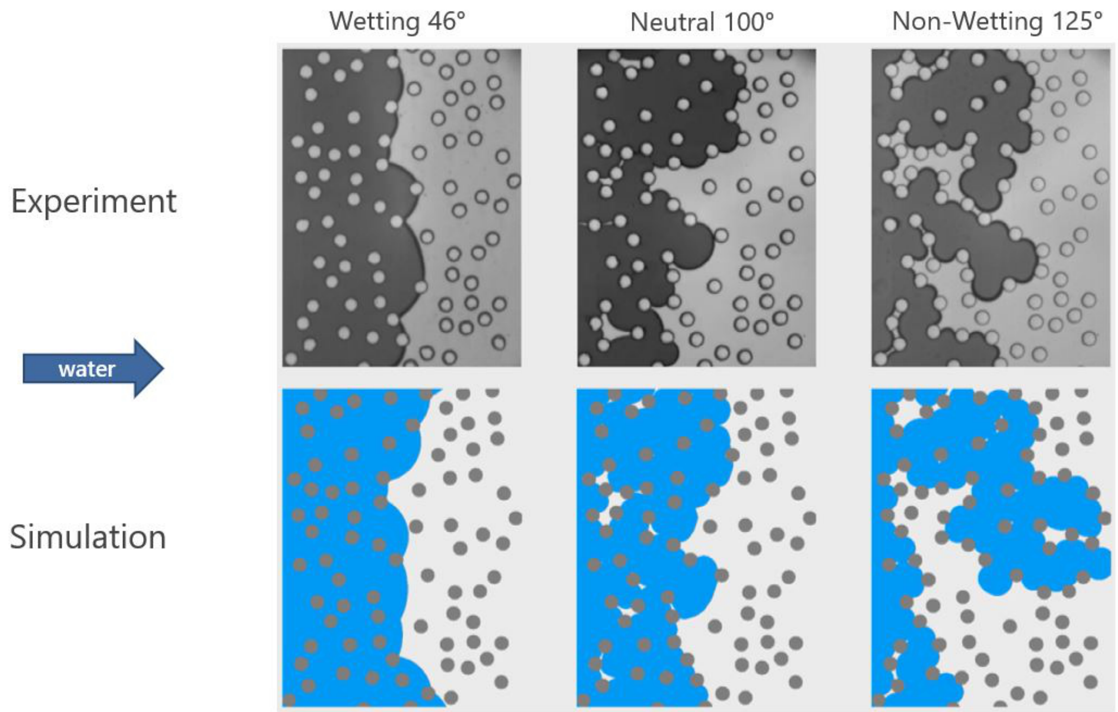


Fig. 1. Comparison of the Pore-Morphology Method in SatuDict with Experiments

An Image-based Estimation of the Mechanical Properties of karstified Reservoirs

Author / Speaker: João Paulo Pereira Nunes, Petrobras SA

Permission for publication not granted

Digital Rock Physics & Digital Core Analysis

Computing Elastic Properties of Organic-rich Source Rocks using Digital Images

Author / Speaker: Mita Sengupta, Aramco Services Company
Co-author: Shannon L. Eichmann, Aramco Services Company

Digital rocks are 3D image-based representations of pore-scale geometries that reside in virtual laboratories. High-resolution 3D images that capture microstructural details of the real rock are used to build a digital rock. The digital rock, which is a data-driven model, is used to simulate physical processes such as fluid flow, heat flow, electricity, and elastic deformation through basic laws of physics and numerical simulations.

Unconventional reservoirs are chemically heterogeneous where the rock matrix is composed of inorganic minerals, and hydrocarbons are held in the pores of thermally matured organic matter, all of which vary spatially at the nanoscale. This nanoscale heterogeneity poses challenges in measuring the petrophysical properties of source rocks and interpreting the data with reference to the changing rock structure. Focused ion beam scanning electron microscopy is a powerful 3D imaging technique used to study source rock structure where significant micro- and nanoscale heterogeneity exists.

Compared to conventional rocks, the imaging resolution required to image source rocks is much higher due to the nanoscale pores, while the field of view becomes smaller. Moreover, pore connectivity and resulting permeability are extremely low, making flow property computations much more challenging than in conventional rocks. Elastic properties of source rocks are significantly more anisotropic than those of conventional reservoirs. However, one advantage of unconventional rocks is that the soft organic matter can be captured at the same imaging resolution as the stiff inorganic matrix, making digital elasticity computations feasible. Experimental measurement of kerogen elastic properties is difficult because of the extremely small sample size. Nano-indentation can yield one elastic modulus, but at least two moduli are needed for the complete characterization of kerogen.

Using digital simulations, we achieve a good theoretical understanding of how the kerogen elastic properties can respond to varying intra-kerogen porosity for the observed pore-structure and geometries.

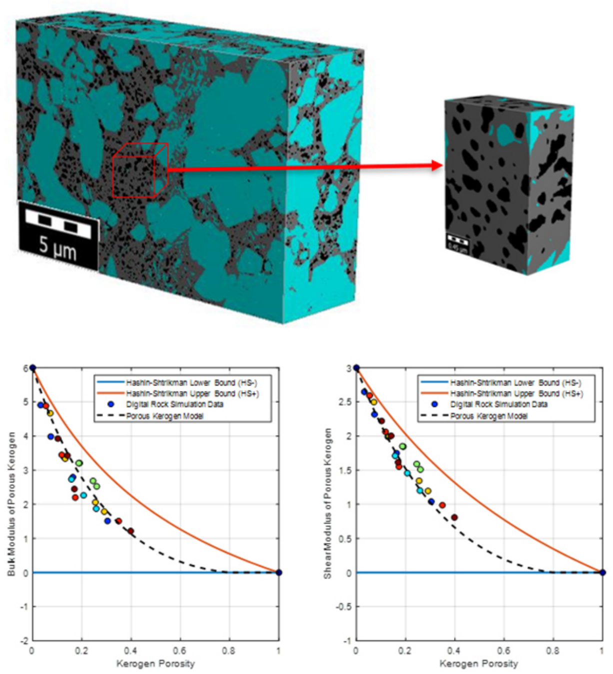


Fig. 1. Subsamples of porous kerogen only were extracted from the larger digital rock samples. The zoomed-in image of the porous kerogen shows pores of varying shapes and sizes within the solid organic matter. Digital simulation data are shown with colored symbols in the cross-plots. Colors represent the different rock samples. Upper Hashin-Shtrikman (HS) bound is plotted in red, and Lower HS bound in blue. Porous Kerogen Model based on digital simulations is shown by the black dashed line.

GeoDict as a Benchmark in New Technology Development

Author / Speaker: Denis Orlov, Skoltech (Skolkovo Institute of Science and Technology)
Co-author: Dmitry Koroteev, Ekaterina Muravleva, Mohammad Ebadi, Skoltech

Digital Rock Physics (DRP) emerged recently as the alternative to conventional laboratory experiments on core samples. For tight reservoir rocks, the usage of DRP is not as straightforward as for higher porosity sandstones. This is due to the inherent trade-off between the spatial resolution of data and the representativeness of the size of the model. For this regime, we developed a new approach to consider porosity from different scales (micro and sub-micro) in a single 3D digital core model.

The new methodology combines information about pore space structure from various sources of data: micro-CT, SEM, and FIB-SEM. The final coarse 3D digital model is a multiclass model that includes 100 classes of porosity to account for the sub-micron scale effects and that covers a large enough portion of the core to be representative.

Our approach was validated with the help of GeoDict in the following ways:

- We built two equivalent models (binary with high resolution and multiclass with low resolution) and calculated absolute permeability solving Stokes equations for the binary and Stokes-Brinkman equations for the multiclass model;
- We developed and tested workflow to assign permeability in porous voxels of the multiclass model for Stokes-Brinkman calculations to obtain permeability relevant to the permeability of high-resolution binary model;
- We performed a sensitivity analysis of different factors (number of porous classes, errors in classification and size of the model) on the resulting permeability of the multiclass model.

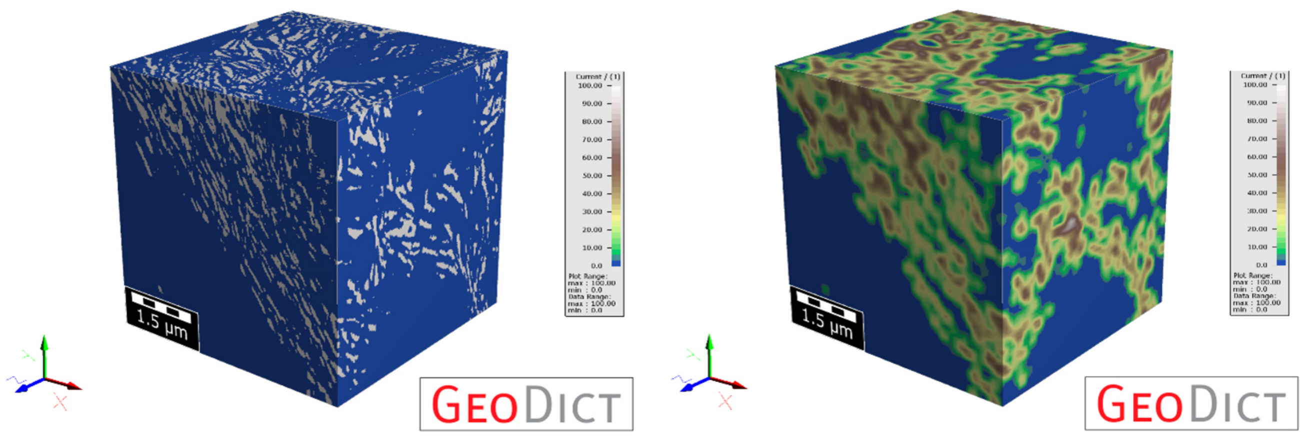


Fig. 1. Binary model from FIB-SEM (left) and Multiclass model with 5 times lower resolution (right)

Digital Materials R&D with GeoDict® 2022 – Latest & Greatest

Author / Speaker: Martina Hümbert, Math2Market GmbH
Co-author: Sebastian Rief, Aaron Widera, Andreas Grießer, Erik Glatt, Math2Market GmbH

GeoDict offers many features for the development of nonwovens, polymer and metal foams, laser sintered materials, composites, and ceramics. In the GeoDict 2022 release, many of these functionalities are greatly improved and those relevant for Digital Materials R&D are presented in this talk.

- The identification of single fibers in an imported µCT-scan is an important step in the analysis of fibrous materials. For this reason, the post-processing of FiberFind-AI has gained power in GeoDict 2022. Now, the fibers can be segmented into batches by their properties, such as diameter, and these batches can be evaluated individually in regard to other properties, such as orientation or curvature.
- In many foams, the struts have a triangular cross-section, but until now FoamGeo generated only round or hollow struts. For this reason, generation of foams with triangular cross-section struts is now available in GeoDict 2022. The modelling of a statistical Digital Twin of a metal foam will be presented.
- More modelling options e. g. for laser sintered materials are now available in GridGeo. This includes a wide range of lattice-based structures and triply periodic minimal surfaces.
- Up to now, only Neumann Series was available as solver method for nonlinearity in the FeelMath solver running under ElastoDict. Now, Conjugate Gradient, which has already been the standard solver for linear problems, can also handle nonlinear simulations. This leads to shorter runtimes and better results, for example in the simulation of damage in composites.

Other important features of GeoDict are presented in the other talks of the Digital Materials R&D session.

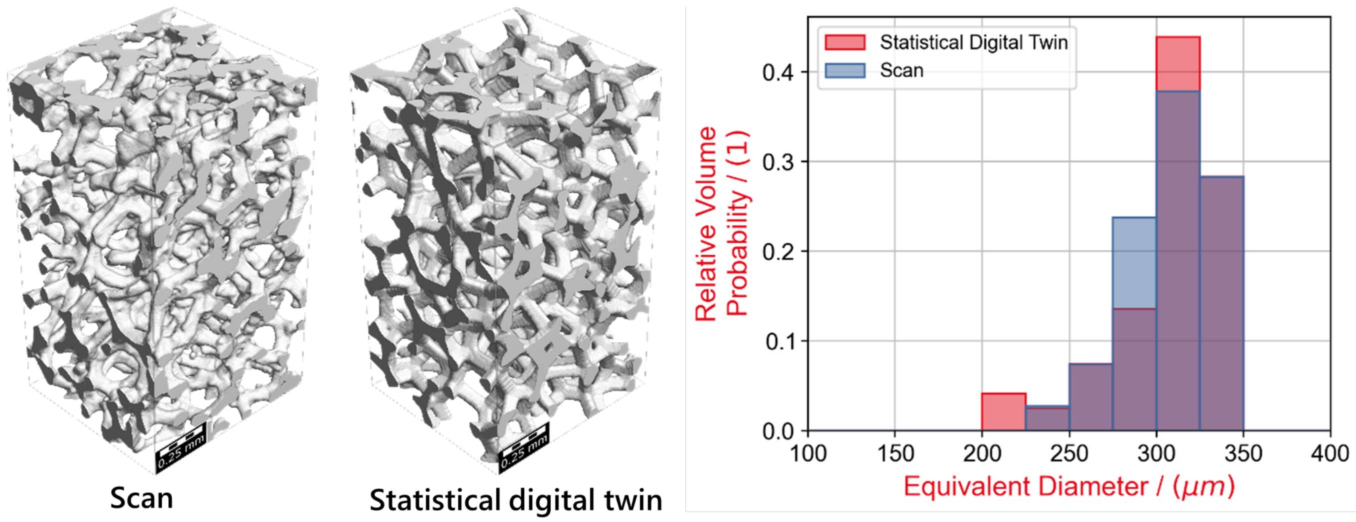


Fig. 1. Scan of a metallic foam and its statistical digital twin modelled in GeoDict (left) and their equivalent diameters (right)

Bending Simulations of CFRP Laminates with ElastoDict

Author / Speaker: Matthias Kabel, Fraunhofer Institute for Industrial Mathematics (ITWM)

Permission for publication not granted

From Experiment to Model - Dynamic µCT for Calibration and Validation of Mechanical Solvers in GeoDict®

Author / Speaker: Wesley de Boever, TESCAN
Co-author: Martina Hümbert, Aaron Widera, Andreas Grießer, Math2Market GmbH

Metal foams play an important role in engineering and are used in a wide range of applications. They are used in crumple zones in vehicles, or to create lightweight structures without compromising on strength. The understanding of the behavior of these metal foams under (increasing) loads is therefore paramount to optimize the design of such lightweight materials.

Traditionally, this behavior is studied with compression tests, where applied force versus displacement is measured. Although this gives excellent values for overall material behavior, it is impossible to gain information on local defects or imperfections, impacting this overall strength. Therefore, we used lab-based dynamic micro-CT to visualize and analyze uninterrupted compression experiments of aluminum foams.

Using a temporal resolution of 20 seconds and 200 consecutive full tomograms we performed on 20 mm tall samples that underwent a compression of about 7 mm. Based on this visualization and the corresponding load curve, the material properties were determined to find correct input parameters for the mechanical FFT based solvers in GeoDict. Once the model matched the experiment, the flow was reversed on a second sample of the same material, to see if it is possible to predict the material behavior using just one static input scan. Again, dynamic micro-CT was used to verify this, leading to excellent results and good correlation between model and experiment, down to single-strut buckling events that were present in both model and real-life experiment.

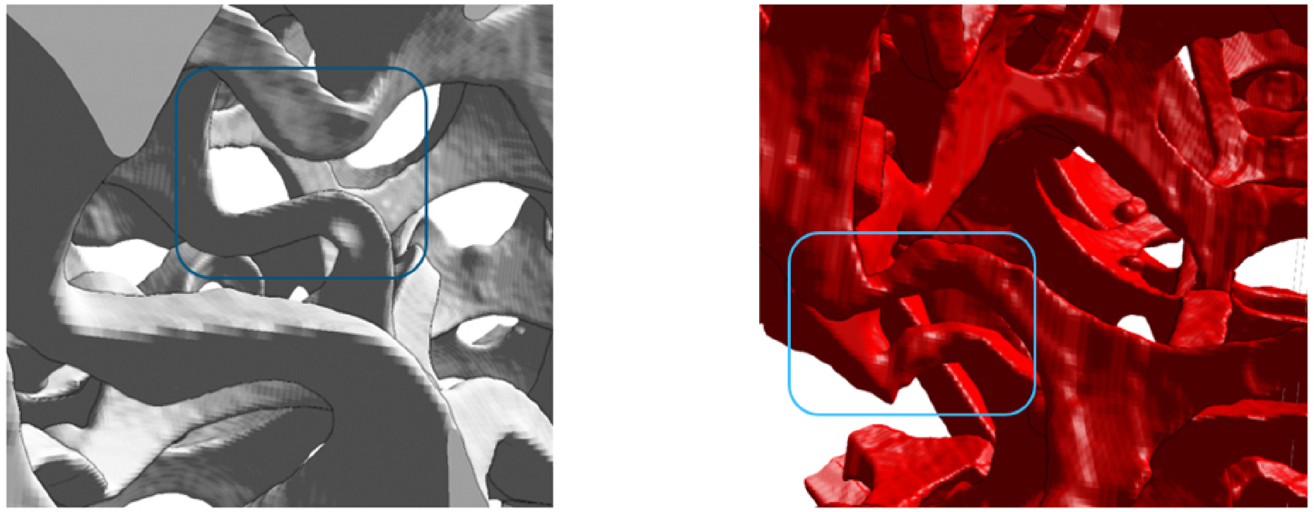


Fig. 1. Buckling events in experiment (left) and model (right), visualized in GeoDict.

Benchmarking Virtual Permeability Predictions of Real Unidirectional Fibrous Microstructure

Author / Speaker: Elena Syerko, Institute of Civil Engineering & Mechanics, Centrale Nantes,

Co-author: Christophe Binetruy, Institute of Civil Engineering & Mechanics, Centrale Nantes / Tim Schmidt, David May, Leibniz-Institut für Verbundwerkstoffe / Luisa Rocha da Silva, High Performance Computing Institute, Centrale Nantes / Stepan Lomov, Department of Materials Engineering, Composite Materials Group, KU Leuven / Suresh Advani, Department of Mechanical Engineering, University of Delaware

Liquid Composite Molding (LCM) is a class of composite manufacturing processes in which a mold cavity with a fibrous preform is injected with liquid resin to fill the volumes between the fibers. At macro-scale, the resin flow is generally described by Darcy's law and characterized by the saturated permeability. This law allows engineers to relate the flow rate to the pressure gradient needed to drive the flow. Permeability is a parameter of practical interest, and its determination is important to predict the flows macro-scale behavior. While the development of experimental methods to measure permeability goes on, a parallel benchmark effort to numerically characterize permeability is being pursued.

The permeability numerical prediction follows a classic workflow: imaging of composites pieces to resolve the inter-fiber pores; processing images to separate pores from fibers; simulating the single-phase pore-scale flow to compute its effective permeability. This upscaling approach has some important aspects that can affect the computed permeability. While it was investigated for various porous media, this benchmark exercise is the first contribution to a real unidirectional fibrous structure.

The approach was to send out segmented images of a real fibrous microstructure to a number of participants, for them to apply their methods for permeability prediction. Results will be presented and discussed to highlight differences between the participants' methods and hence sources of variation.

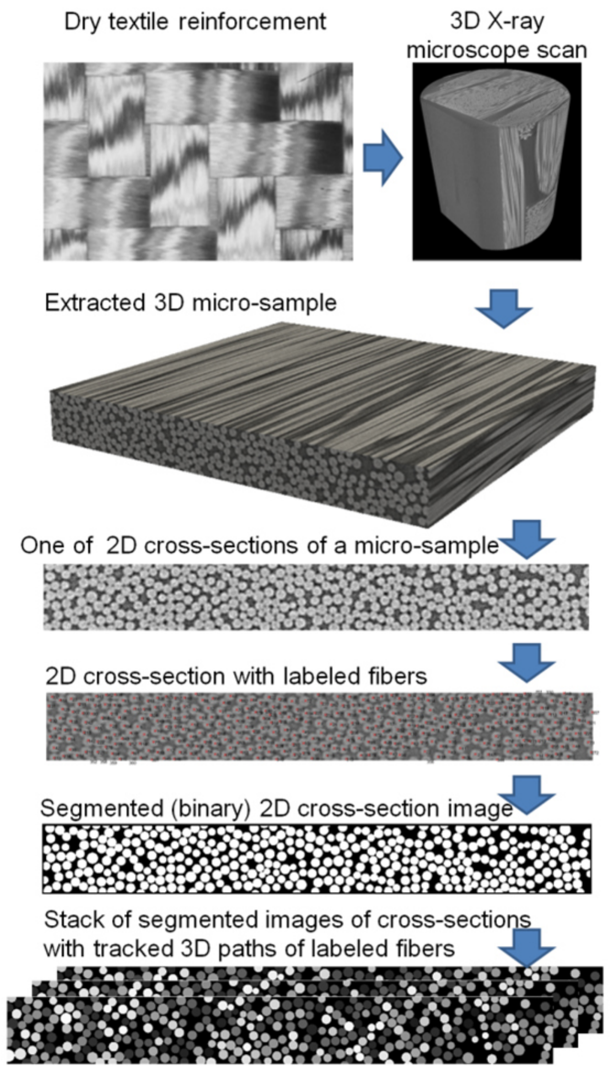


Fig. 1. Procedure for the preparation of the data input for the numerical permeability prediction.

Battery and Fuel Cell R&D with GeoDict® 2022 – Latest & Greatest

Author / Speaker: Ilona Glatt, Math2Market GmbH

Co-author: Mathias Fingerle, Fabian Biebl, Sarah Reeb, Anja Streit, Janine Hilden, Sven Linden, Sebastian Rief, Erik Glatt, Andreas Wiegmann, Franziska Arnold, Barbara Planas, ... and many more, Math2Market GmbH / Jochen Zausch, Jan Lammel, Fraunhofer ITWM,

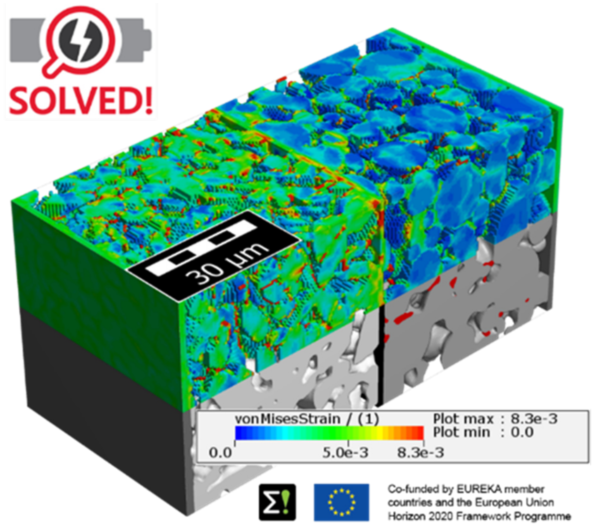
The digital transformation of materials science and the transition to renewable energies is progressing and the state-of-the-art simulation software GeoDict 2022 is capable of processing large representative volumes of complex structures on the microscale, pushing digital material design. The development of next-generation materials for batteries and for fuel cells focuses on optimization on the microscale.

This talk highlights five main topics for battery and fuel cell applications:

- Creation of realistic Statistical Digital Twins for batteries & fuel cells
- Simulation of transport phenomena in batteries & fuel cells
- Quantitative battery charging simulations on large battery microstructures
- Simulation of battery ageing on the microscale
- Easy and fast learning of digital battery development

GeoDict 2022 covers these five topics while providing impressive result visualization capabilities and represents an all-in-one toolbox for R&D of next generation battery and fuel cell materials.

In the next years, Math2Market GmbH will continue the extensive developments in GeoDict and the fruitful collaboration with our partners to remain at the forefront of digital material design.



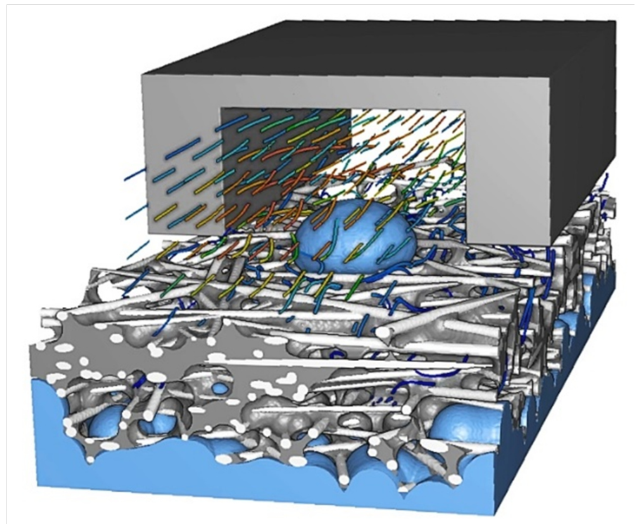


Fig. 1. Visualization of von Mises strain in a battery microstructure due to changes in the local lithium concentration.
Fig. 2. Simulation of gas flow and water transport in a fuel cell gas channel with underlying gas diffusion layer (GDL).

Generation of virtual three-phase Structures based on Gaussian Random Fields: An important Option for Digital Materials Design of Solid Oxide Fuel Cell Electrodes

Author / Speaker: Philip Marmet, Zurich University of Applied Sciences (ZHAW)
Co-author: Lorenz Holzer, Thomas Hocker, Gernot Boiger, Institute of Computational Physics (ICP), ZHAW / Janine Hilden, Sarah Reeb, Mathias Fingerle, Math2Market GmbH

Digital Materials Design (DMD) is a modern approach for model-based material optimization and can be applied to optimize electrodes for solid oxide fuel cells (SOFC). Therefore a combination of stochastic microstructure modelling, virtual testing of 3D microstructures and a multiphysics electrode model provides a good basis for data driven microstructure optimization. The software GeoDict enables studying hundreds of different microstructures in an automated workflow for the generation, simulation and characterization of virtual microstructures.

In this context, an appropriate structure generator is needed, which enables efficient creation of virtual microstructures with realistic properties by means of stochastic parameter variations. SOFC electrodes are typically three phase systems with a pore space and two solid phases like the common Ni-YSZ anodes. Normally, they are strongly sintered, resulting in continuous phase networks and can hardly be represented by sphere or particle packing methods. Those generally yield in a microstructure that keeps the geometry of the initial spheres/particles. The structure generation based on Gaussian random fields is an alternative approach, which provides continuous phase networks from the outset. This approach was introduced for the application of SOFC electrodes by Moussaoui et al [1].

In order to obtain a closed workflow with microstructure generation and characterization, we have now implemented the approach in GeoDict. Thereby, two truncated gaussian random fields are constructed, one for each solid phase. The gaussian random fields are characterized by their covariance function, and can be fitted to covariance functions of 3D tomographs of real samples. Using appropriate threshold operations, the solid volume fractions and the wetting behaviour of the phases can be adjusted. The remaining space is considered as the pore phase. Therewith, many different microstructures can be deduced from one set of two gaussian random fields.

The resulting virtual microstructures can be characterized by numerical transport simulations and morphological analysis using GeoDict. Therewith, it can be ensured, that the virtual structure shows the right characteristics regarding the relevant physical effects. The most relevant microstructure parameters for the common Ni-YSZ fuel electrodes are the relative conductivities of both phases, the specific length of the three phase boundaries and the gas transport in the pore phase. The last one is governed by bulk and Knudsen diffusion.

Using a multiphysics electrode model, the microstructure properties can be linked to the cell performance. If an appropriate digital twin is found, the microstructure parameters can be varied in a realistic way. However, long computing times and the lack of available computational resources usually put strong limitations for extensive parameter sweeps. With the GeoDict Cloud, hundreds of virtual microstructures can be studied in parallel in a very short time using massive simultaneous cloud computing (MSCC) powered by KaleidoSim. The statistical analysis of these results leads to new design guidelines for electrodes with improved properties.

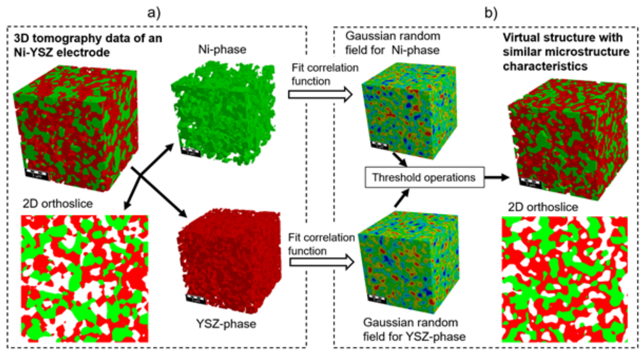


Fig. 1. a) 3D tomography data of a Ni-YSZ anode from Holzer et al. [2]. The 2D orthoslice shows the complex and continuous phases of Ni (green), YSZ (red) and the pore phase (transparent). b) A digital twin of this microstructure can be constructed by two independent gaussian random fields resulting in very similar microstructure properties.

[1] *H. Moussaoui et al., "Stochastic geometrical modeling of solid oxide cells electrodes validated on 3D reconstructions," Comput. Mater. Sci., vol. 143, pp. 262–276, 2018, doi: 10.1016/j.commatsci.2017.11.015.*

[2] *L. Holzer, O. Pecho, T. Hocker, B. Iwanschitz, A. Mai. (2020). FIB-tomography data of Ni-YSZ anodes for Solid Oxide Fuel Cells (SOFC): Comparison of pristine and degraded materials (before/after redox cycling) (Version 1) [3_Rx36_Segmented]. Zenodo. https://doi.org/10.5281/zenodo.4056538*

Numerical Characterization of porous Transport Layers in PEM Water Electrolyser by means of GeoDict® software

Author / Speaker: Pavlo Lyubarskyy, Schaeffler Technologies AG & Co. KG

Porous Transport Layer (PTL) is an important component in the Protone Exchange Membrane Water Electrolyser (PEMWE). It's main purpose is the transport and distribution of water towards a catalytical layer and membrane as well as the transport of generated gases backwards to the flow field. There is a big number of diverse materials and composites that are used in the PEMWE as PTL. PTLs themselves can be an assembly of materials with different physical characteristics like permeability, porosity, thermal and electrical conductivity.

The mechanical properties of the PTL are also considered in the development of the electrolyser. Because of the compression during the stack assembly and the high pressure during the stack operation, elastic and plastic deformation of the PTL affects the mentioned physical characteristics.

In this presentation, we want to show how numerical simulation can assist the development of the PTL materials. We have been using different modules of GeoDict to import and process the µCT-scanned data, analyze the material statistics and estimate the properties of PTL. The results could be incorporated in upscaled CFD simulation with unresolved porous layer coupled with electro-chemical modeling. The derived PTL properties could also be used for their assessment and validation with benchmark testing.

Simulated Material Properties from Multiscale 3-D Imaging with Applications in Energy Materials Research

Author / Speaker: Robin T. White, Carl Zeiss RMS
Co-author: Stephen T. Kelly, Tobias Volkenandt, Benjamin Tordoff, Carl Zeiss RMS / Andreas Griesser, Math2Market

A key aspect in materials science is the ability to generate new material designs with specific characteristics to provide a particular function that improves performance and lifetime in a working device. X-ray Computed Tomography has proven to be a crucial method to properly characterize and understand a huge variety of materials applications.

Due to the non-destructive 3D imaging capabilities, this imaging methodology provides unique insight into material microstructure with comparatively minimal sample processing. This capability is ideal for imaging energy materials, which are often comprised of an interconnected 3-dimensional microstructure spanning orders of magnitude, as well as various material properties that can be difficult to visualize using other imaging methods, such as electron microscopy. By using available lab-based systems, accurate 3-dimensional sample geometry and morphology can be acquired over large volumes and with high resolution. The segmented datasets can be used to perform advanced analysis using computational methods available in GeoDict to enable accurate quantification of the true fabricated material morphology and simulating device performance.

In a combined correlative image acquisition, advanced image processing, and modelling workflow, we present results demonstrating the capabilities for simulating material property performance from real world data for various energy materials technologies including batteries and fuel cells.

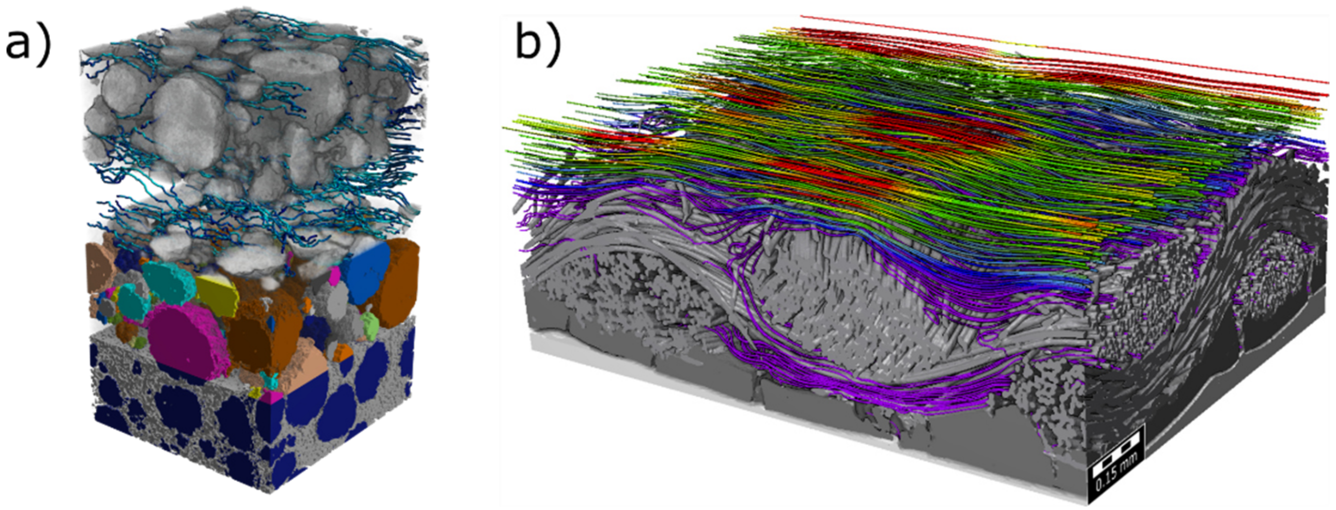


Fig. 1. Visualizations of tomography data used in conductivity and flow simulations. a) Ionic conductivity through carbon binder domain in battery cathode, b) air flow simulation through polymer electrolyte fuel cell channel.

Filtration Simulation with GeoDict® 2022 – Latest & Greatest

Author / Speaker: Mehdi Azimian, Math2Market GmbH
Co-author: Philipp Eichheimer, Andreas Weber, Math2Market GmbH

All the way through the Covid-19 pandemic, Math2-Market has been developing features in the GeoDict software to design, model, simulate and optimize filter media and filter elements at different scales. Many GeoDict users worldwide are pressing towards digital design of modern and optimized filters.

The study of the nano/micro structure of filter media is the starting point to understand, analyze, and optimize a filter. Often, the first simulation step consists of processing of nano/micro CT images of the real media to prepare a 3D nano/micro structure model of the filter media [1]. Alternatively, the 3D digital filter media can be modeled using different modules of GeoDict for structure generation.

The precise simulation of flow through nano fibers was a new feature of GeoDict 2020 based on the implementation of slip length and consideration of tangential slip flow on nano fibers. It enables filter media designers and manufacturers to digitally optimize their filter media. Especially when dealing with multi layers of filter media e.g., for face masks made from micro-fibrous and nano-fibrous layers.

For this presentation, the filtration behavior of a face mask was investigated by the Institute for Flow in Additively Manufactured Porous Structures (ISAPS) of the Heilbronn University of Applied Sciences. The filtration simulation using GeoDict was done under the same conditions as the experiment. A very good agreement was found between simulation results and experimental data. Then, GeoDict was used to optimize the filter media by generating various digital filter media and running and analyzing the filtration simulations.

Another important topic this year is the publicly funded project BiGOFil, aiming to develop coalescer filters with higher efficiency and lower pressure drop. The main focus is on increasing oil droplets coalescence and separation using non-round, profiled bicomponent fibers in a nonwoven medium. For Math2Market, the main task was to implement the computational models into GeoDict to simulate the droplets coalescence and also the detachment of large coalesced droplets through the media. In this presentation, the droplets coalescence on a single fiber and through a filter medium are shown. Further details and technical information will be presented separately by another speaker in the filtration session.

Finally, we present the simulation of the flow and filtration at room scale, e.g., in classrooms using air purifiers. The room CAD geometry, including walls, desks, chairs, shelves, etc. are imported into GeoDict and are voxelized. The CAD geometry of the air purifier is also imported. The effects of air purifiers at different flow rates, and the effect of their location in room, are investigated by running filtration simulations. The time required to minimize the aerosol concentration in room, besides operational and maintenance costs, is a key factor when choosing the right air purifier and the best location.

[1] D. Hoch, M. Azimian, A. Baumann, J. Behringer, J. Niessner, *Comparison of Voxel-Based and Mesh-Based CFD Models for Aerosol Deposition on Complex Fibrous Filters*, Chem. Eng. Technol. 2020, 43, No. 12, 2538–2547.

Numerical Design of three Way catalyzed Membrane Filter with both High Filtration Efficiency and Low Pressure Drop

Author / Speaker: Katsunori Hanamura, Tokyo Institute of Technology

An advanced filter which has a low pressure drop and a high filtration efficiency should be developed for after treatment systems of gasoline engines. In the current study, a membrane filter made of Three Way Catalyst (TWC) particles was proposed and designed by numerical simulation and experiment.

Figure 1 shows results of numerical simulation and an SEM image of cross-sectional view of TWC membrane filter fabricated on the conventional GPF made of cordierite. A stack of GPF pictures were taken using an X-Ray computed tomography method, then were imported into a software of GeoDict. Finally, through image processing, a practical structure of the GPF was successfully reconstructed as a 3D model in a computer software for numerical simulation. It was assumed that TWC particles introduced here have a Gaussian size distribution, a spherical shape, a mean diameter of 1.6 µm, the standard deviation of 0.433 µm, and the distribution width of 1.02 µm. A Hamaker constant relating to the Van der Waals force was used for deposition of TWC particles on the GPF substrate. The numerical result shows a good agreement with the experimental ones as shown in Fig.1. Moreover, both pressure drop increases, in numerical and experimental ones, are much the same with respect to time.

Then, a comparison of soot trapping on the membrane and the conventional GPF was made using a soot particle size range from 50 to 300 nm. Soot particles first trapped on the substrate generating a dendrite structure at the constricted area. Then, flying soot particles accumulated until the bridge structure was completed, which is the same point of 100% filtration efficiency that insisted on the hypothesis from the experiment [1]. On the other hand, it reaches almost 100 % from the beginning of trapping in TWC membrane filter with a low pressure drop.

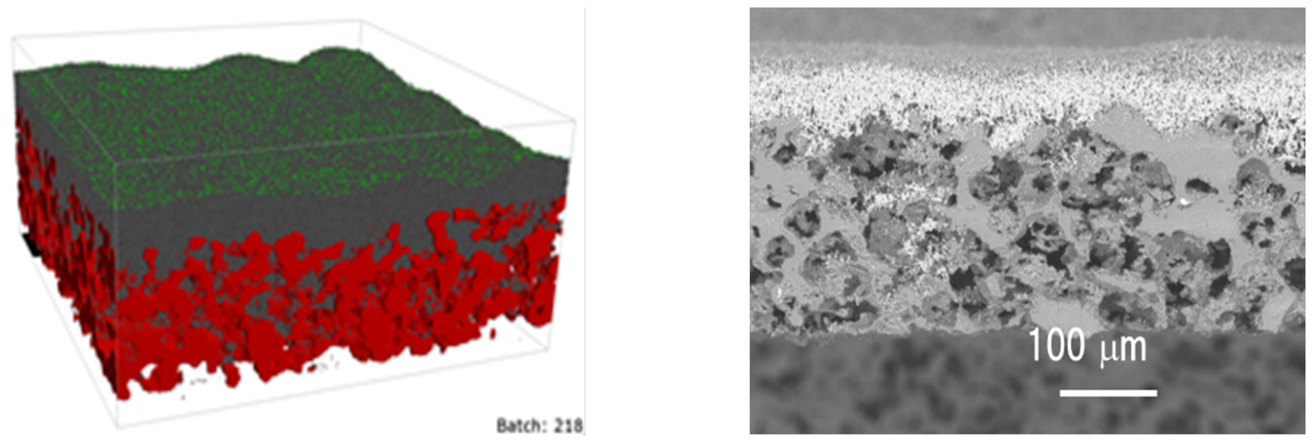


Fig.1. Three way catalyst (TWC) membrane layer fabricated on the conventional GPF made of cordierite. Left: A result of Numerical simulation. Right: An SEM image of cross-secssional view of TWC membrane filter.

[1] *R. Sanui, K. Hanamura. Scanning electron microscopic visualization of bridge formation inside the porous channels of diesel particulate filters, SAE Int. J. Fuels Lubr. 9(3), pp.725-733, 2016.*

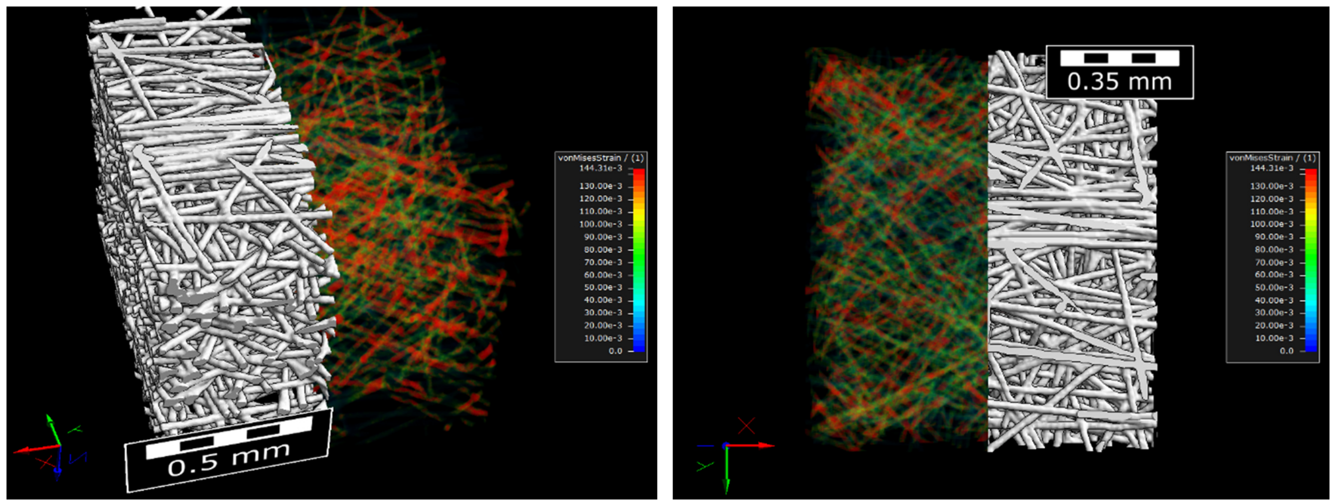
Predicting the 3D elastic-plastic Behavior of polymer-based Filter Media

Author / Speaker: Kai M. Höss, GSaME – University Stuttgart, MANN+HUMMEL GmbH, IMWF – University Stuttgart
Co-author: Florian Keller, MANN+HUMMEL GmbH / Siegfried Schmauder, IMWF – University Stuttgart

The performance level of flat filter media is defined by the three filtration parameters: Dust holding capacity, filtration efficiency, and pressure drop [1]. These parameters directly correlate to the microstructural properties of the nonwoven filter media. Hence, new multi-layered filter media are developed, for example, with gradual fiber densities across the media thickness, to increase filtration performance based on filtration simulations and parameter optimizations [2].

To gain the volumetric flow rate required by the application, it is often necessary to pleat the filter media and achieve the needed filter media area in a given design space. The highly anisotropic material behavior of these nonwovens is challenging. At this point in the design process of the new filter media, the microstructure's effective mechanical properties in the three spatial directions are unknown. The capability to predict these anisotropic mechanical properties of a microstructural design is crucial to assess the new microstructural design's viability for further processing in the manufacturing of filter elements. Hence, a simulation model to virtually test the microstructural design for tension, compression, and shear in all three spatial directions is needed.

This presentation introduces a microstructural simulation model, using the GeoDict-software package, to predict the three-dimensional elastic-plastic behavior of polymer-based nonwovens. Starting from a representative volume element for the material structure based on micro-computed tomography, we characterize and simulate the material's deformation behavior when subjected to tension, compression, and shear loads in the machine direction, cross direction, and z-direction. The simulation results are validated using an extensive 3D material testing program. Finally, the dependency of the effective elastic-plastic deformation behavior on a limited number of selected microstructural parameters is discussed. This dependency forms the basis for the usage of digital twins to predict the deformation behavior of virtual microstructure designs.



[1] 1) *Klein, G.M., Banzhaf, H., Lehmann, M.J., Heininger, T., 2019. "Filtration in Fahrzeugen: Grundlagen und Beispiele zur Luft- Öl-, Kraftstoff- und Innenraumfiltration", Die Bibliothek der Technik, Bd.398, Verlag Moderne Industrie, Munich Germany 2019*
[2] 2) *Gose, T., Kilian, A., Banzhaf, H., Keller, F., Bernewitz, R., 2019. "Augmented filter media development by virtual prototype optimization", FILTECH 2019 – F3 - Advanced Filter Media Developments and Manufacturing Methods, Cologne Germany 2019*

Modeling and Simulation of Coalescence in the Context of Oil Mist Filtration using a Distance Map

Author / Speaker: Dennis Hoch, Institute for Flow in Additively Manufactured Porous Media (ISAPS), Heilbronn University of Applied Sciences

Co-author: Andreas Weber, Math2Market GmbH / Jennifer Niessner, ISAPS, Heilbronn University of Applied Sciences

Today aerosols are produced in many industrial processes like machining or in pneumatic compressors. The harmfulness of these industrially produced droplets often lies in the liquid itself as it can be toxic or cancerous while exhaled natural aerosols can carry viruses or other pathogens. For health protection, the filtration of these aerosols is an important task. The wetting properties of the fibers have a large influence on the filtration efficiency and coalescence of droplets on the fibers. Oleophilic fibers are better in capturing the oil aerosols while the drainage increases with oleophobic fibers. For improved efficiency and drainage properties, a mixed-wet fiber system could therefore be advantageous.

Deposition of droplets and the resulting coalescence is highly complex and extremely dependent on the wetting properties. Describing these processes in filter-scale simulations is computationally extremely demanding, if not unfeasible. We present a new approach for simulating oil mist deposition and droplet coalescence correctly accounting for the wettability of the fibers, especially for mixed-wet filter media. The aim is to gain a more realistic pressure loss of a fibrous filter structure which takes the presence of the filtered phase into account, as well as the coalescence of the liquid phase on the fibers depending on the wettability and the fluid parameters.

Therefore, we model the shape of deposited droplets via weighted distance maps, according to the contact angles. For validation purposes, a volume-of-fluid based simulation was set up using the same droplet-fiber system as a reference to compare the droplet shape and pressure loss in the presence of oil droplets on the fiber surface.

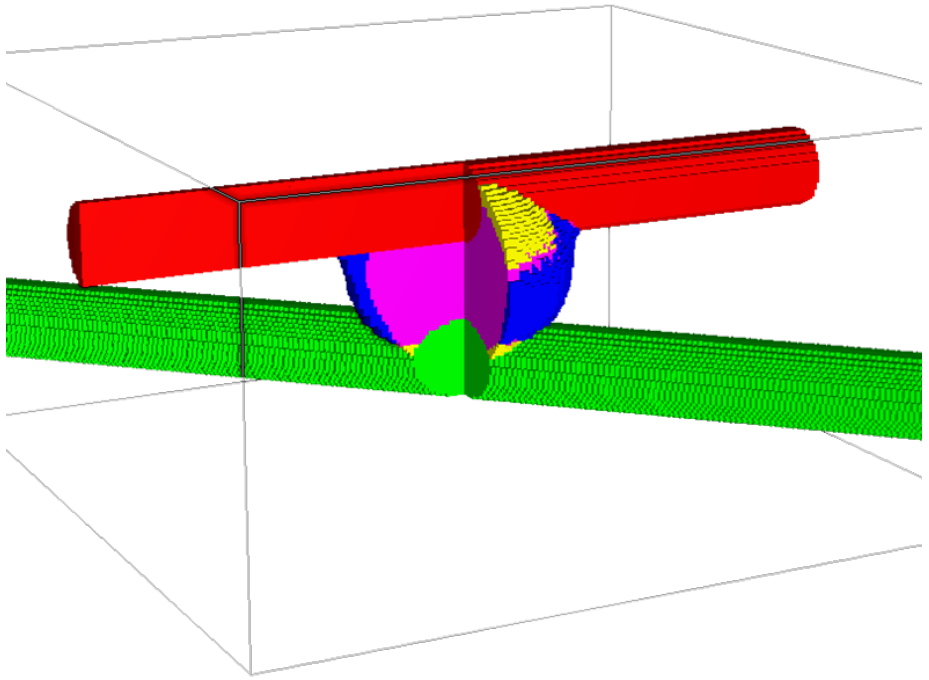


Fig. 1. Droplet shape resulting from the VOF simulation (blue), the weighted distance map (yellow) and overlap of both methods (magenta) on crossed fibers with a 90° contact angle

Conclusion and Farewell

Author / Speaker: Andreas Wiegmann, Math2Market GmbH

We summarize our second online GeoDict User Meeting and give a first glimpse at the future directions of Math2Market and the GeoDict software, particularly regarding the awaited features of the upcoming GeoDict 2023 version.

Maybe it is of interest to you and your institution or company that Math2Market is increasing its efforts in Application Engineering. The new Project and Consulting Team is here to help you develop new materials by establishing workflows at Math2Market, to save you time and start immediately with the right setup of simulations yourself.

Additionally, information on GeoDict in the Cloud, both with GUI and in batch-mode, is available for those who are able to run their own simulations, but might be constrained by their lack of in-house computational power.

For those of you who joined the GeoDict User Meeting for the first time, as well as those that are repeating GeoAddicts, we hope that the 2021 edition of the GeoDict User Meeting met your expectations. Please join us again next year, hopefully in person, and tell your friends and colleagues about your experience.

For those staying on for the workshops after these presentations, we will see you later for the hands-on workshops!

Regardless, make sure to plan to come to Kaiserslautern next year, even maybe present your current work with GeoDict, and tell your colleagues about the GeoDict User Meeting, too.

Thanks to our Speakers at GeoDict® User Meeting 2021

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We look forward to welcoming you again next year for the GeoDict® Usermeeting 2022 & Workshops.

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