GeoDict
The Digital Material Laboratory

Jahrestreffen der ProcessNet-Fachgruppen Mechanische Flüssigkeitsabtrennung, Trocknungstechnik und Grenzflächenbestimmte Systeme und Prozesse
26. - 28. Februar 2018 Radisson Blu Hotel / Ständehaus, Merseburg

Modeling and simulation of a pressure filtration process based on VDI guideline 2762

Authors:

Mehdi Azimian, Jürgen Becker, Andreas Wiegmann

Modeling and simulation on the resolved scale (micro-strcuture of filter media):

- Preparation of 3D µ-CT scan of the filter media
- Geometric analysis and fluid flow simulation through the clean filter media
- Evaluation of filter media initial resistance
- Particulate flow simulation through the filter media
- Evaluation of filtration characteristics of the resolved media

Modeling and simulation on the unresolved scale (Filter cake formation based on VDI guideline 2762 [1]):

- Modeling the filter paper as a porous plate
- Modeling the cake formation on top of the filter paper
- Evaluation of the specific filter cake resistance
- Simulation of washing and drying processes using the pore morphology method

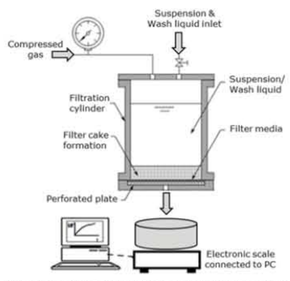

Fig. 1: Schematic figure of the pressure filtration apparatus

Principle & analysis:

- Constant pressure difference
- Recording of the filtrate amount as f(t)
- Cake evaluation (Height, moist cake weight, …)
- Analysis of gas permeation point (filtration end)
- Evaluation using the Darcy equation

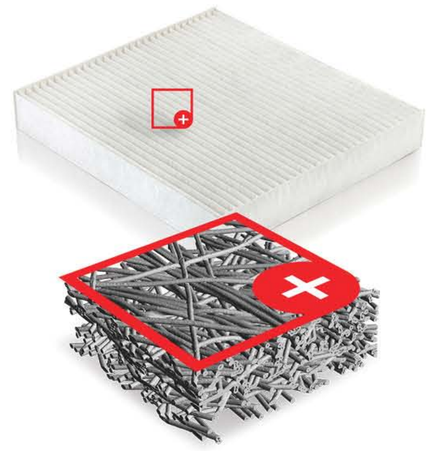

Fig. 2: Sample preparation from the filter media to conduct µ-CT scans

Fig. 3: Micro computer tomography (µ-CT) scan of the filter media

Modeling, simulation and analysis of a filter media micro-structure

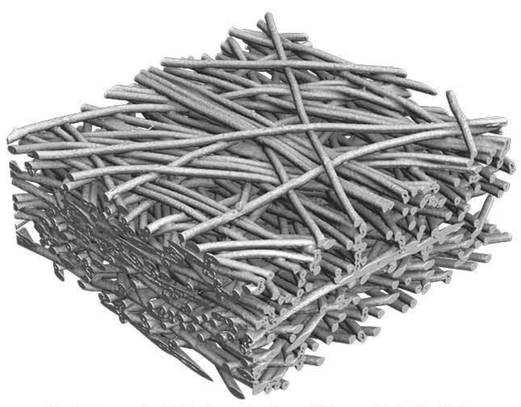

Fig. 4: Segmented 3-D micro-structure of filter media in GeoDict

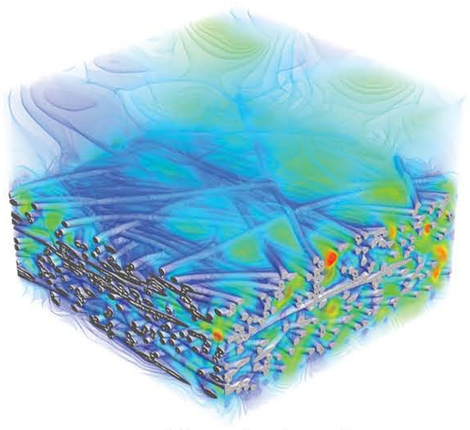

Fig. 5: Calculation and visualization of flow field through the filter media

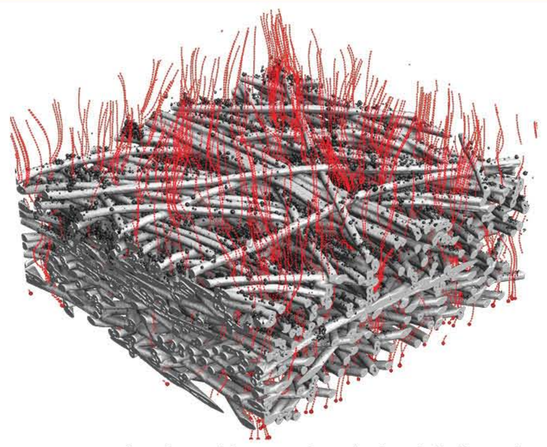

Fig. 6: Particle tracking and deposition of particles through the filter media

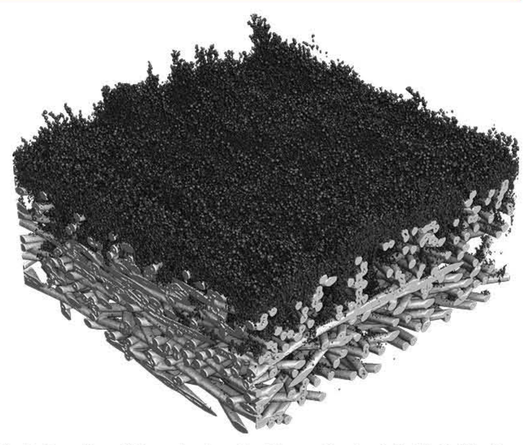

Fig. 7: Formation of filter cake above the filter media after initial depth filtration

Geometric analysis:

- Porosity: 81%
- Mean fiber diameter 15 µm with standard deviation 7.6 µm
- Pore size distribution, D_{10}: 31 µm, D_{50}: 87 µm, D_{90}: 154 µm
- Bubble point: 548 pa (Max. through pore diameter: 92 µm)

Flow simulation results:

- Pressure drop is 416.9 Pa at mean flow velocity 0.1 m/s
- Volume flow rate: 100 l/s per unit area
- Flow resistivity: 6.86e+06 kg/(m³s)
- Permeability: 1.45e-10 m²

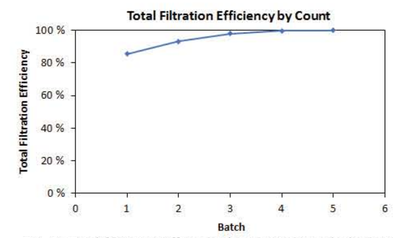

Fig. 8: Total filtration efficiency by count through the batches

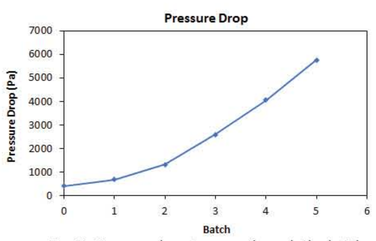

Fig. 9: Pressure drop increase through the batches

Modeling and simulation of filter cake formation based on VDI guideline 2762

Particles:
Glass beads
Density: 2450 kg/m3
Particle shape: Spherical
Particle size distribution:

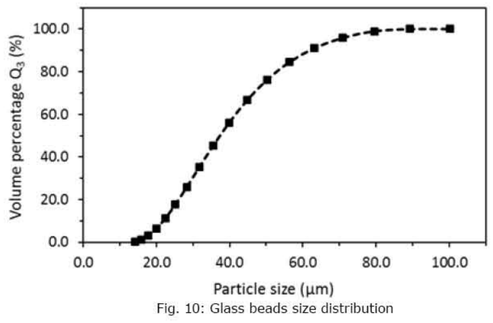

Fig. 10: Glass beads size distribution

Darcy equation: $v = \frac{\dot{V}}{A_0} = \frac{\Delta p}{\mu_L \cdot (\alpha \cdot h_c + \beta)}$

α [m^{-2}]: Specific filter cake resistance

β [m^{-1}]: Filter media (initial) resistance

h_c [m]: Filter cake height

Fluid flow: Brine & Water at 20°C

Filter media:
Assumed as a porous plate with isotropic permeability of 1.45e-10 m²

Collision model: Sieving

Simulation tool:
GeoDict software using FlowDict, FilterDict & SatuDict modules

Solver:
LIR-Stokes solver [2] using adaptive grids to solve the Stokes equations

Flow resistivity: 1.22e+08 kg/(m³s)

Permeability: 8.12e-12 m²

Specific cake resistance: 1.23e+11 m⁻²

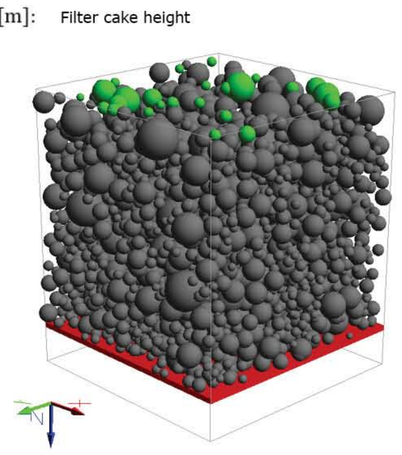

Fig. 11: Filter cake formation above the filter media (modeled as a porous plate)

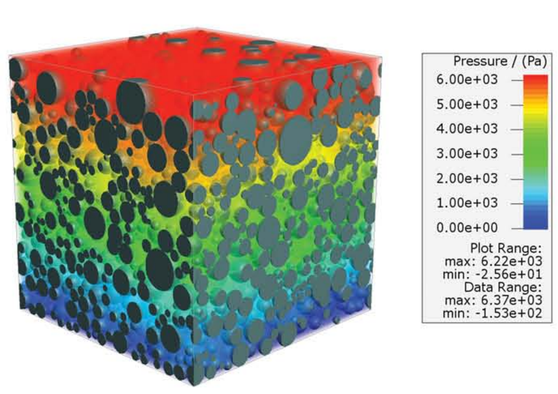

Fig. 12: Flow simulation through the filter cake to calculate the specific cake resistance

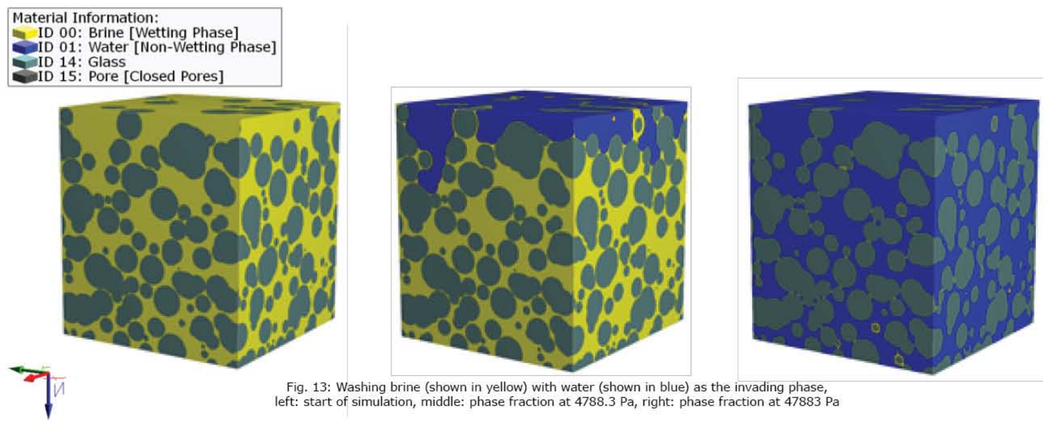

Fig. 13: Washing brine (shown in yellow) with water (shown in blue) as the invading phase, left: start of simulation, middle: phase fraction at 4788.3 Pa, right: phase fraction at 47883 Pa

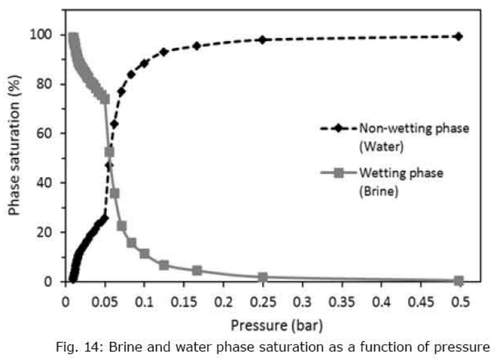

Fig. 14: Brine and water phase saturation as a function of pressure

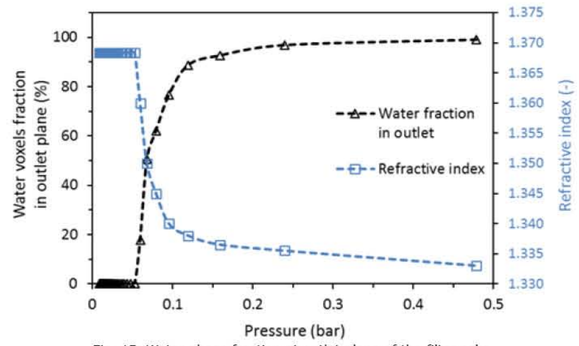

Fig. 15: Water phase fraction at outlet plane of the filter cake

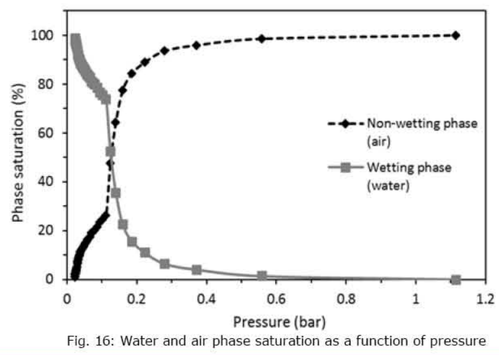

Fig. 16: Water and air phase saturation as a function of pressure

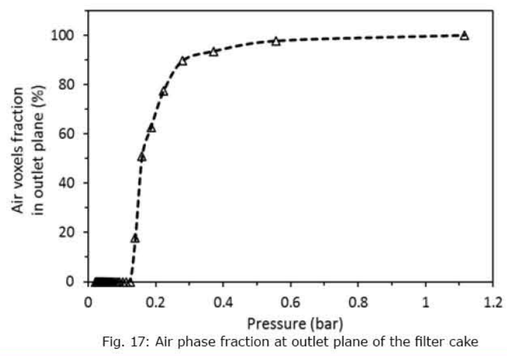

Fig. 17: Air phase fraction at outlet plane of the filter cake

Conclusions

Modeling, simulation and analysis of a filter media micro-structure

- µ-CT scan of the media to evaluate the geometrical characteristics was analysed.
- Flow field characteristics such as velocity and pressure fields were evalauted.
- Clean filter initial pressure drop was evaluated.
- Filtration as a single pass test was simulated.
- The initial filter media resistance was evaluated.
- Pressure-drop evolution and filtration efficiency were evaluated.

Modeling and simulation of filter cake formation

- Simulation of filtration behavior based on VDI-Guideline 2762 was carried out.
- Cake filter formation on a permeable plate was modeled.
- Filtering, washing & drying steps were successfully simulated using GeoDict.
- Permeability of cake filter & the specific cake resistance were computed.
- Optimal pressure for washing & drying processes were predicted.
- Outlook: Optimization in wash liquid amount and washing/drying process time.

Find the poster online:

References:

[1]. VDI-Richtlinie 2762, Filtrierbarkeit von Suspensionen – Bestimmung des Filterkuchenwiderstandes, 1997, Beuth-Verlag, Berlin.
[2]. S. Linden, A. Wiegmann and H. Hagen, "The LIR Space Partitioning System applied to the Stokes Equations," Graphical Models, vol. 8, pp. 58-66, 2015.

Math2Market GmbH | Richard-Wagner-Straße 1 | 67655 Kaiserslautern, Germany

+49 631 205 605 27 +49 631 205 605 99 info@math2market.de

www.math2market.de

MATH 2 MARKET