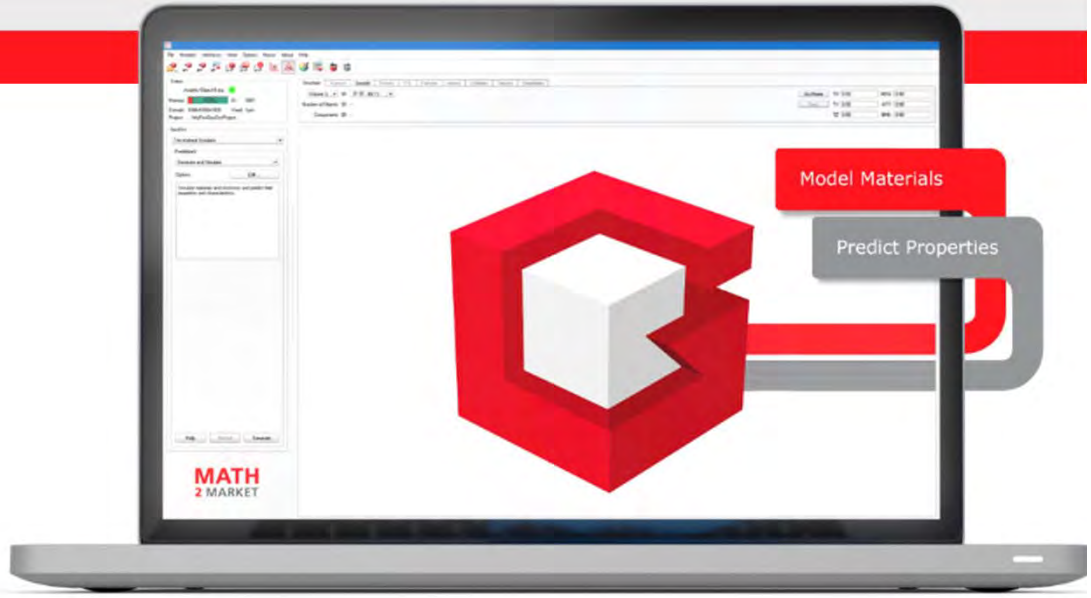
The Economic Attraction in Using Pore Scale Computer Modelling for the Design of Filter Media

- Andreas Wiegmann
- Christian Wagner
- Mehdi Azimian
- Jürgen Becker
- Liping Cheng
- Sven Linden



GEODICT

MATH 2 MARKET

Math2Market …

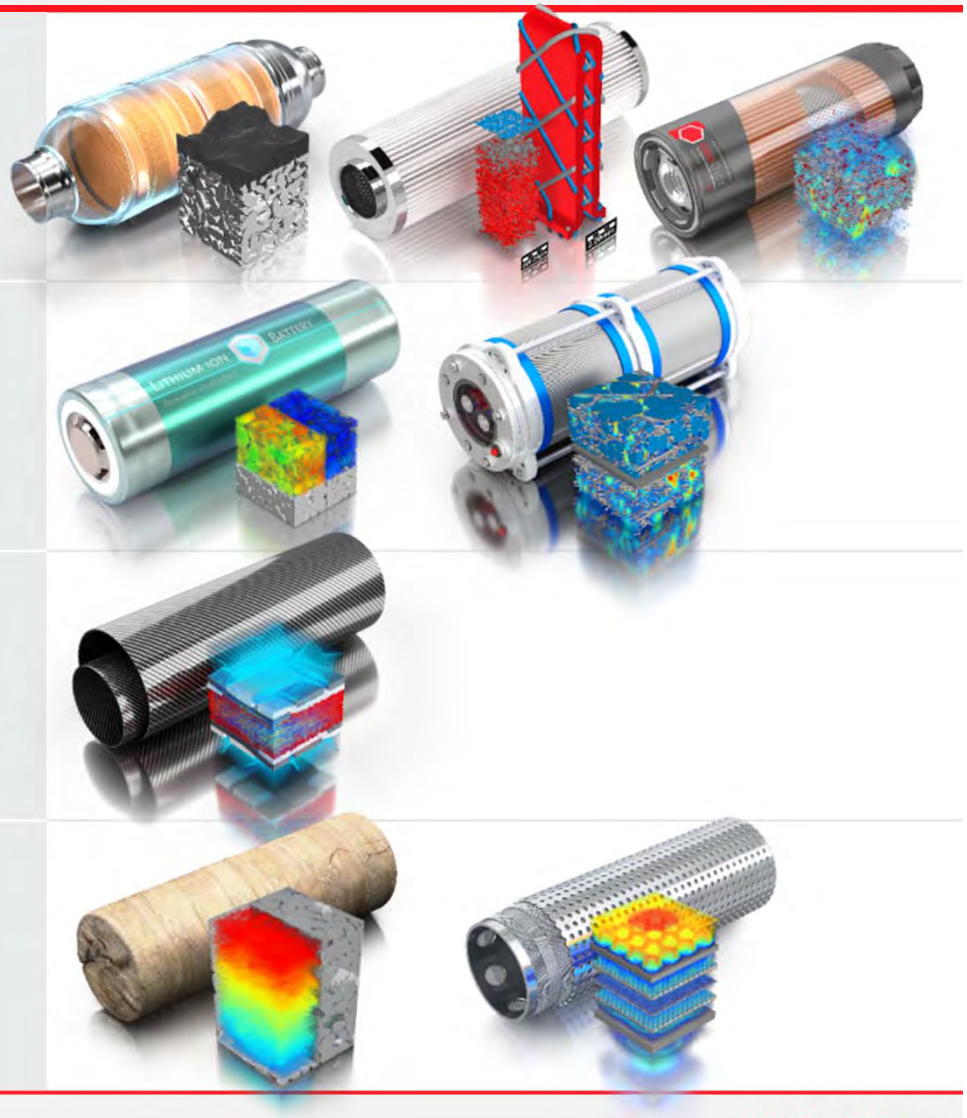
- is 6 years old, spun off after 11 years at Fraunhofer ITWM
- is based in Kaiserslautern, south west Germany
- has currently 35 people
- has more than 150 clients worldwide
- has ca. 30% of their business in “true” filtration applications
- makes & sells software GeoDict with dedicated module FilterDict
- provides consulting around the software

Math2Market GmbH
Employees

- 40% female employees
- 14% foreign employees
- inhouse employees: 32
- external employees: 3

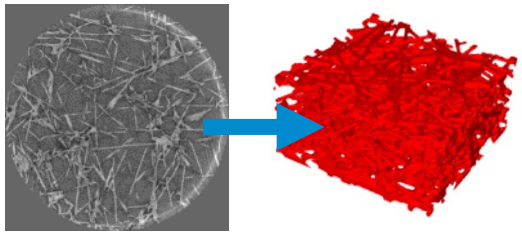
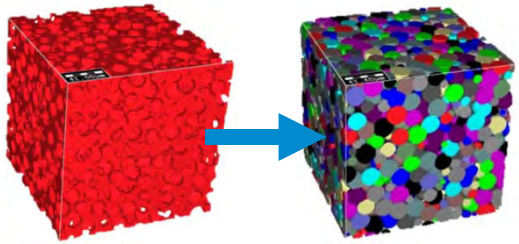
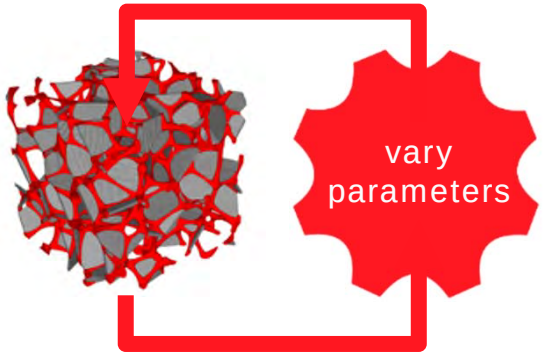
GeoDict The Digital Material Laboratory

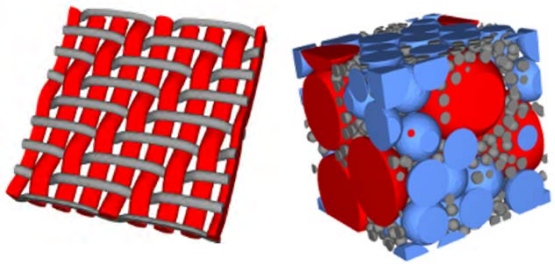
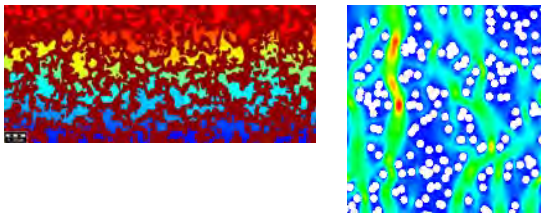
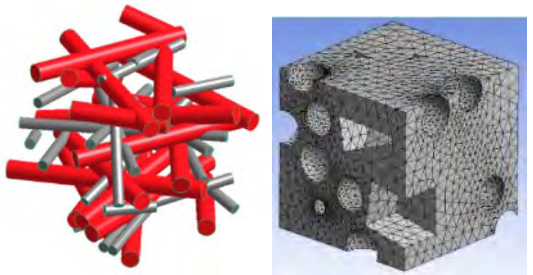
Filtration	Mostly automotive, filter media & filters for water, sludge, oil, air and fuel
Electrochemistry	Fuel cell media & battery materials, catalyst materials
Composites	CFRP, GFRP, mostly automotive, lightweight materials
Oil and Gas	Digital rock physics, digital sand control



GeoDict introduction

With GeoDict you can…

µCT & FIB-SEM Import	Analyse Materials	Optimize Materials
		

Model Materials	Analyse Properties	Export Materials
		

The idea of digital filter media design

1. Represent existing filter media in the computer
    1. From images (µCT, FIBSEM), then as model
2. Perform pore size analysis in the computer
    1. Porometry, bubble point, geometric pore size, etc.
3. Compute flow, get flow rate & pressure drop (Delta P)
4. Compute filter efficiency, eta or beta
5. Compute filter life time, dust holding capacity (DHC)
6. Vary model parameters and repeat 2.-5.
7. Transfer the improved filter media design to production

Use simulation for technological and marketing benefits!

3 examples of this approach

1. Development of metal wire mesh media
2. Development of a gradient structure in synthetic media
3. Development of a new filter media by MANN+HUMMEL

Metal wire mesh

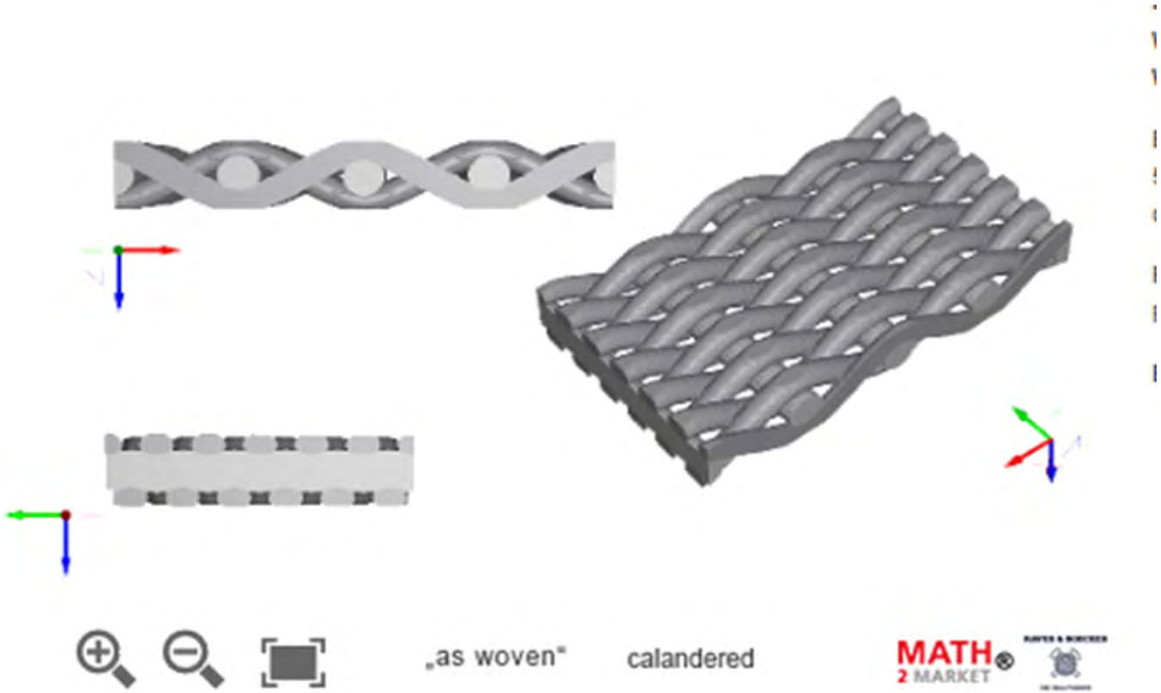
- Metal wire mesh can be geometrically modelled with WeaveGeo (fibrous media with FiberGeo, foams with FoamGeo, pleats with PleatGeo, ceramics with SinterGeo – you get the gist…)
- Geometric pore size can be found with PoroDict
- Flow rate / pressure drop can be found with FlowDict
- Filter efficiency can be found with FilterDict
- Dust holding capacity can be found with FilterDict
- Calendering can be modelled with ElastoDict
- Export for printing / CAE can be done with ExportGeo-CAD
- Abrasion can be done with GeoLab

Enlarged models in Showroom – from GKD web site

- Metal Small wire diameters are hard to see in reality
- Enlarged WeaveGeo models can be presented to clients using 3D printing technology

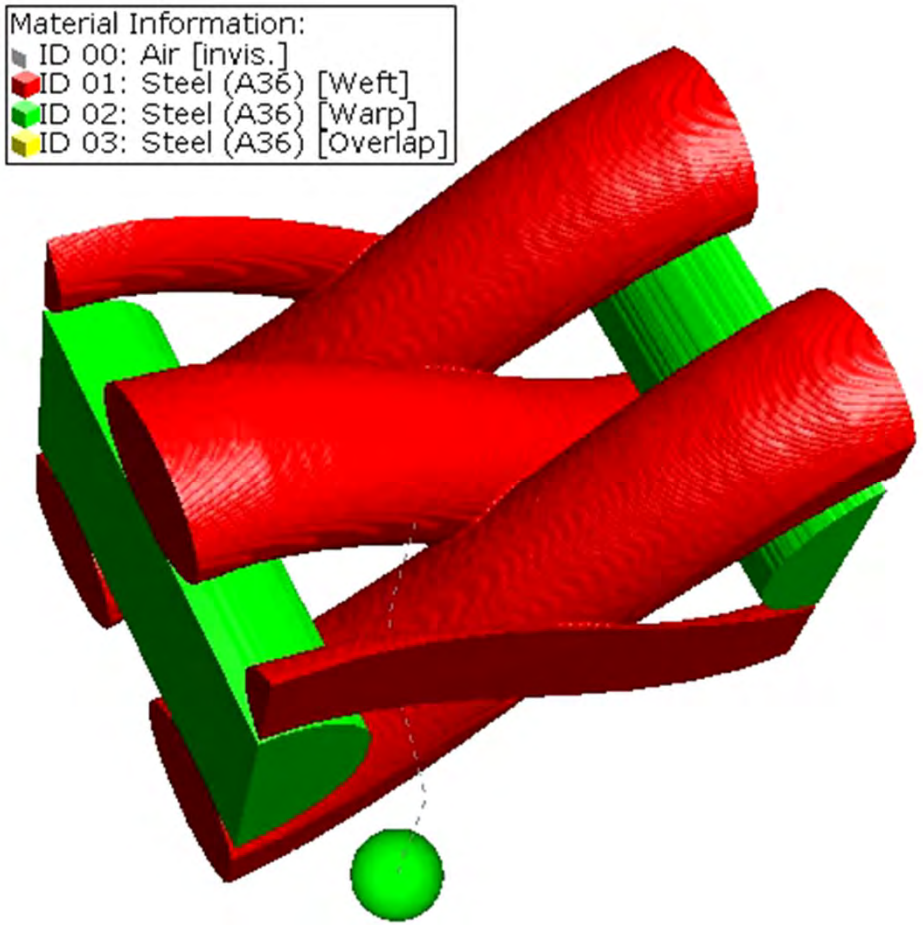
Calendering – from Haver & Boecker web site

- Weaves are often modified to smaller pore sizes by calendering
- This can be modelled using ElastoDict



Determination of largest penetrating particle…

- Agrees very well with Whitehouse Scientifics challenge tests…
- … when the meshes are woven with superb quality and all pores are close to the ideal

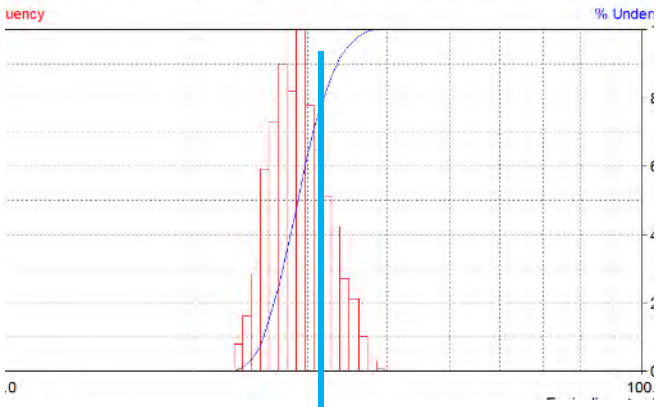


Challenge Test Procedure

30 micron woven stainless steel mesh

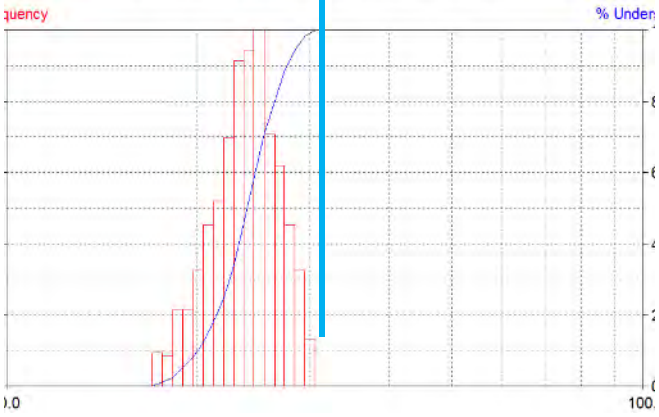
Filter standard (24 – 35 microns)

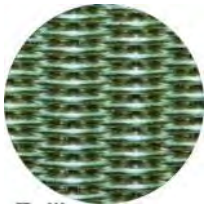
ndersize	3.0	5.0	10.0	25.0	50.0	75.0	90.0	95.0	97.0
/µm	24.47	24.91	25.73	27.05	28.94	31.12	33.40	34.81	35.4

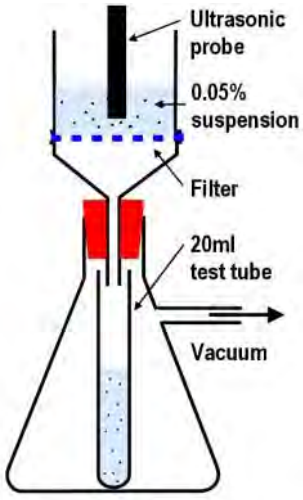


After passing mesh

ndersize	3.0	5.0	10.0	25.0	50.0	75.0	90.0	95.0	97.0
/µm	18.42	18.91	20.11	27.96	23.95	25.75	27.65	28.64	29.0







Top end of the distribution removed
Cut point (D97) = 29 microns

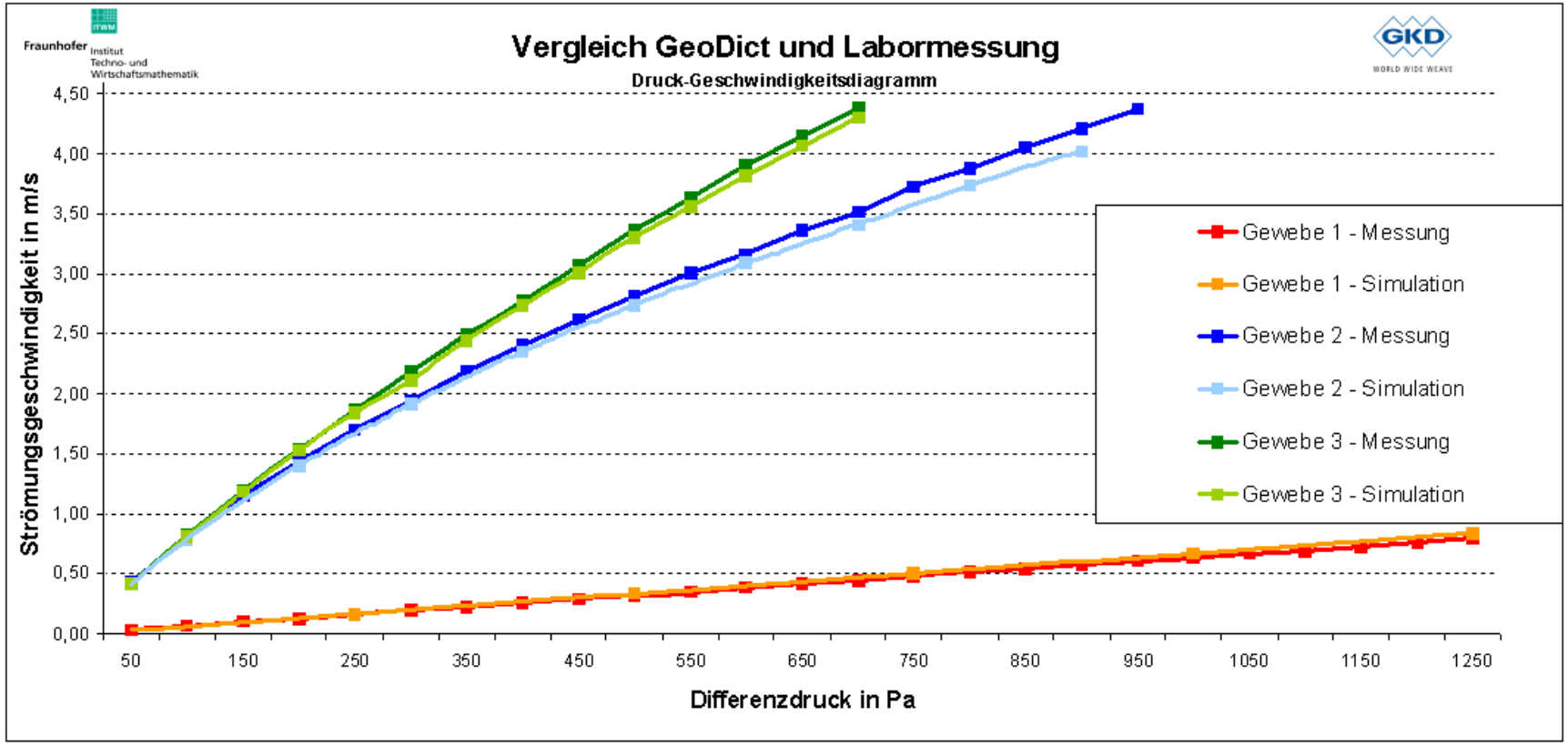
Thankfully permitted by Graham Rideal
Whitehouse Scientific

Mesh Design with GeoDict
Example

- High efficiency
- High flow rates

With permission by
Friedrich Edelmeier,
Haver & Boecker

Measured & FlowDict pressure drop for metal wire meshes

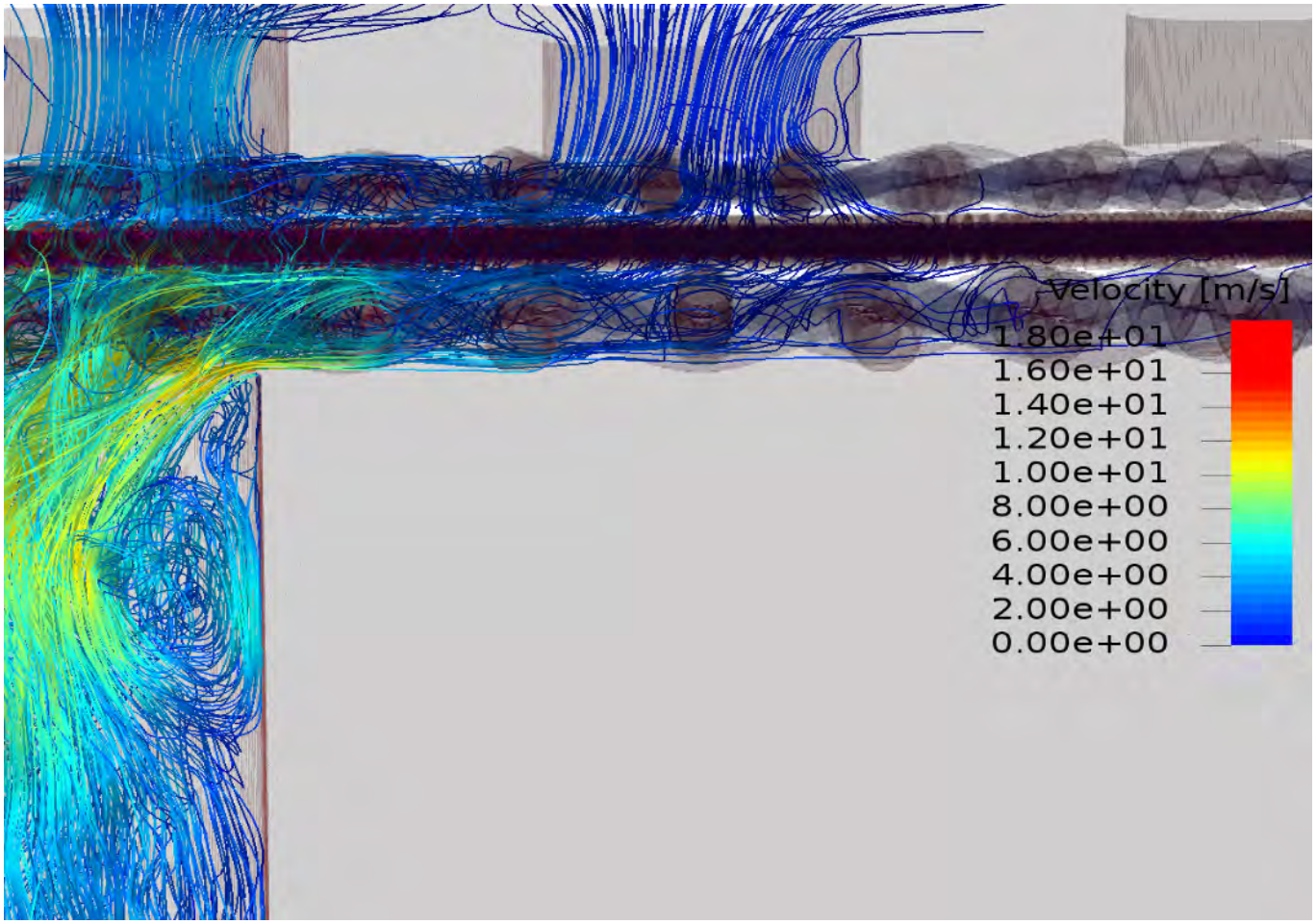


E. Glatt, S. Rief, A. Wiegmann, M. Knefel and E. Wegenke, *Structure and pressure drop of real and virtual metal wire meshes*, Bericht des Fraunhofer ITWM, Nr. 157, 2009.

Deviation of simulation and experiment independently confirmed to lie within 3% over all differential pressures by A. Mantler and M. Theiß of Haver & Boecker, 2017.

Turbulent flows and mesh abrasion is modelled with GeoLab (work by L. Cheng, Math2Market and D. Dreschers, GKD)

- Sand control screens are complex multilayered structures
- Local pore velocity can be vastly different from the average
- Abrasion by sand particles can lead to hot spots



Last but not least…

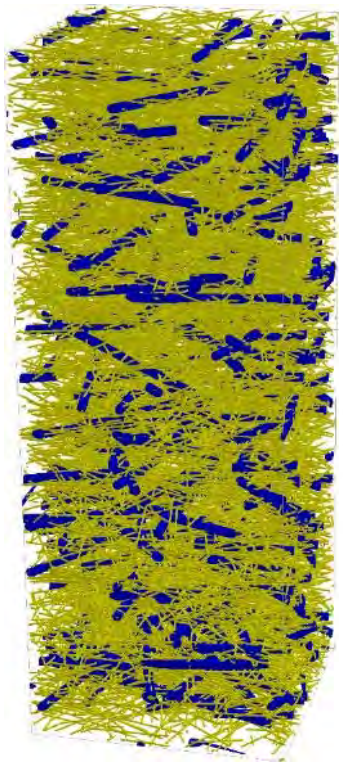
Article in Filtration 17(3) 2017 by Dominik Herper of GKD explains how mesh models and pore size determination together with 2-phase flow simulations can be used to obtain proper correction factors for bubble point determination of geometric pore size.

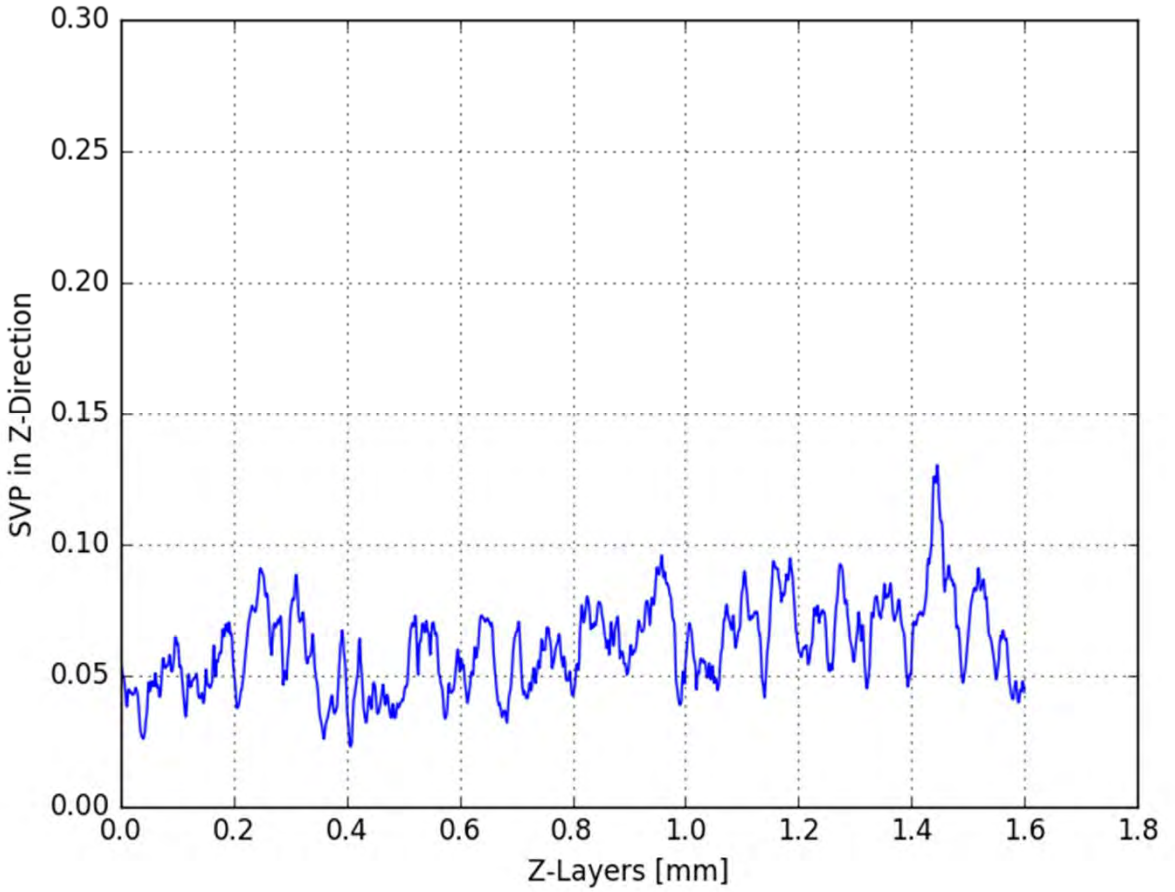
Example 2 – what can be achieved by changing a homogeneous media to an inhomogeneous one?

- Following a presentation by Maxim Silin of Hollingsworth and Vose at Filtech 2015,
- Mehdi Azimian and Christopher Kühnle of Math2Market considered 3 materials with two types of fibers that all have the same initial pressure drop and beta-rating:

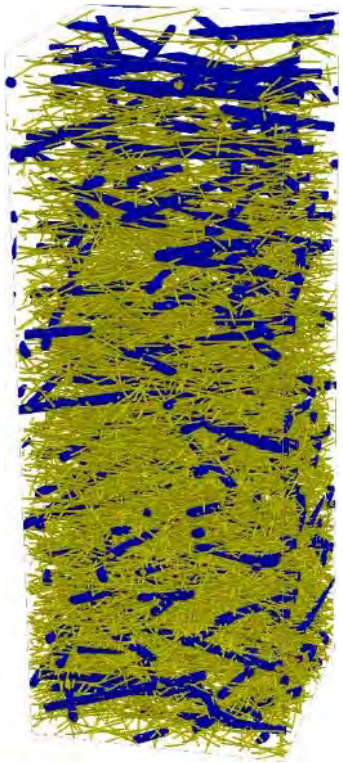
1. Homogeneously distributed of coarser and finer fibers
2. Linear distribution of finer fibers, homogeneous coarser fibers
3. Exponential distribution of finer fibers, homogeneous coarser fibers

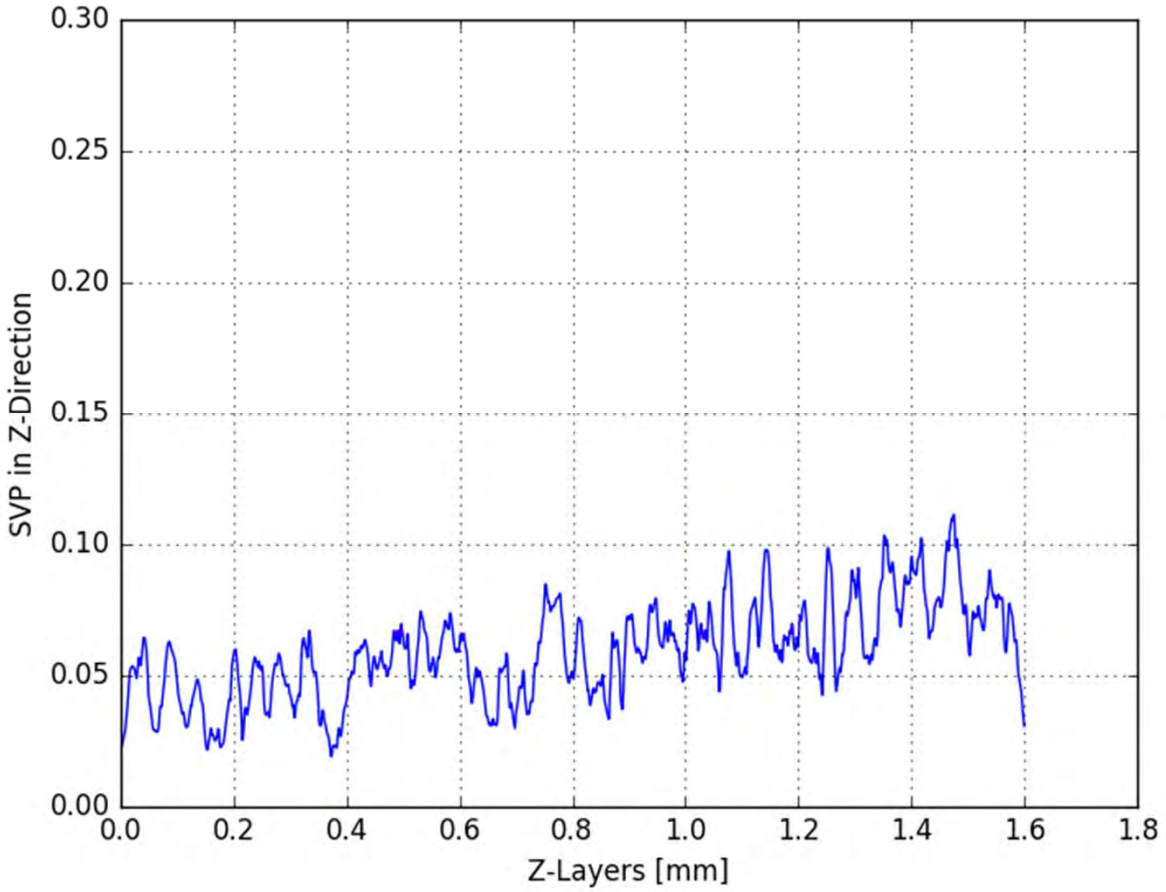
Homogeneous



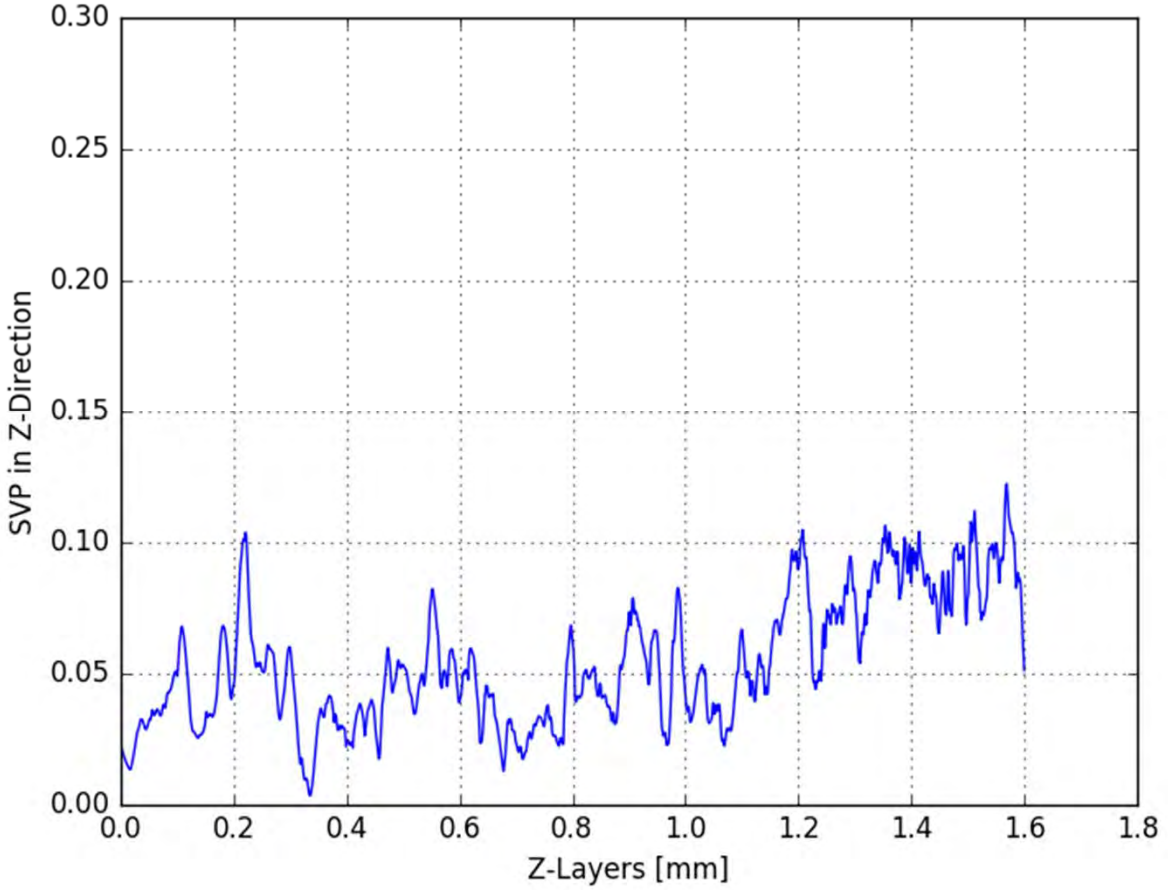


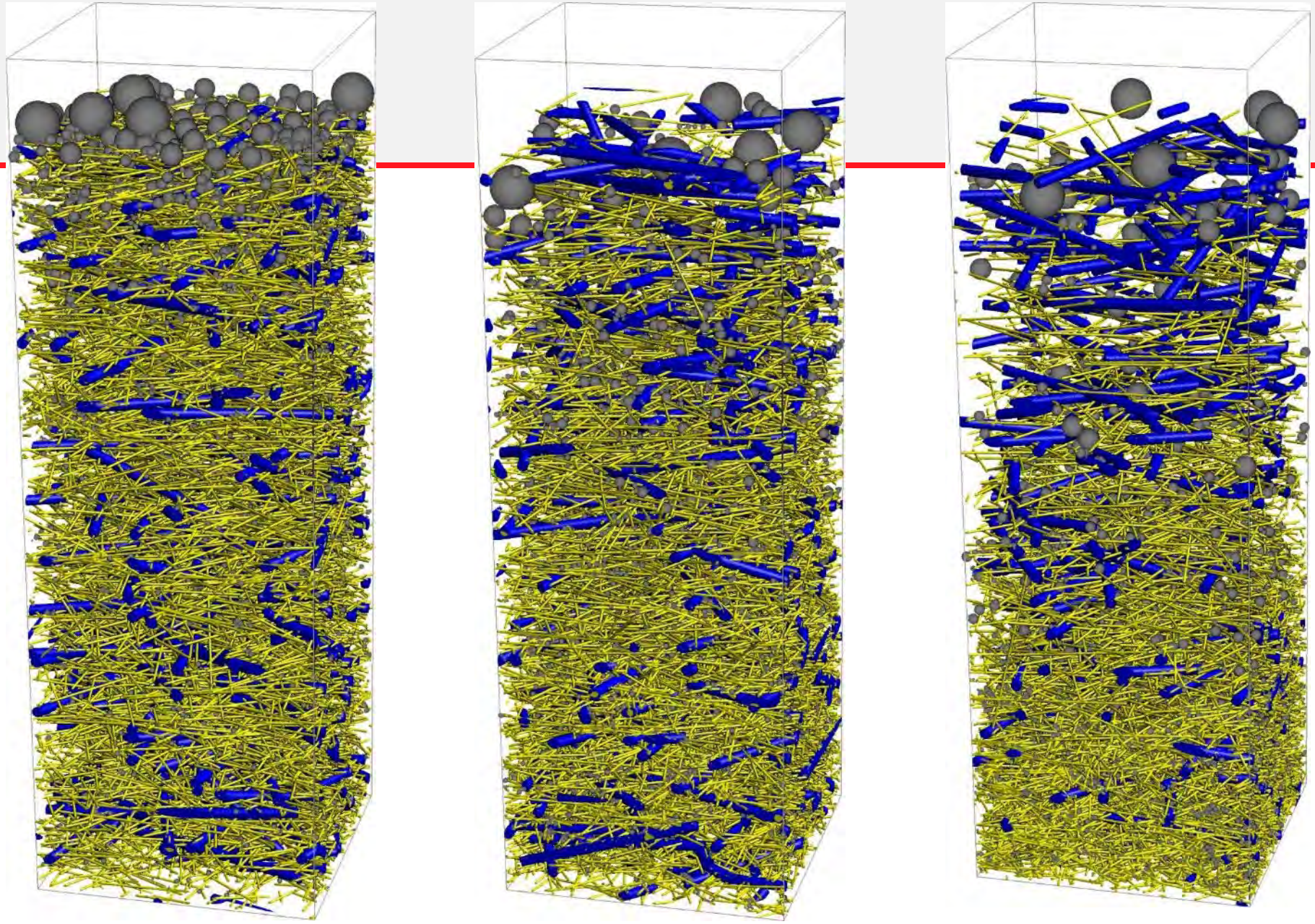
Linear

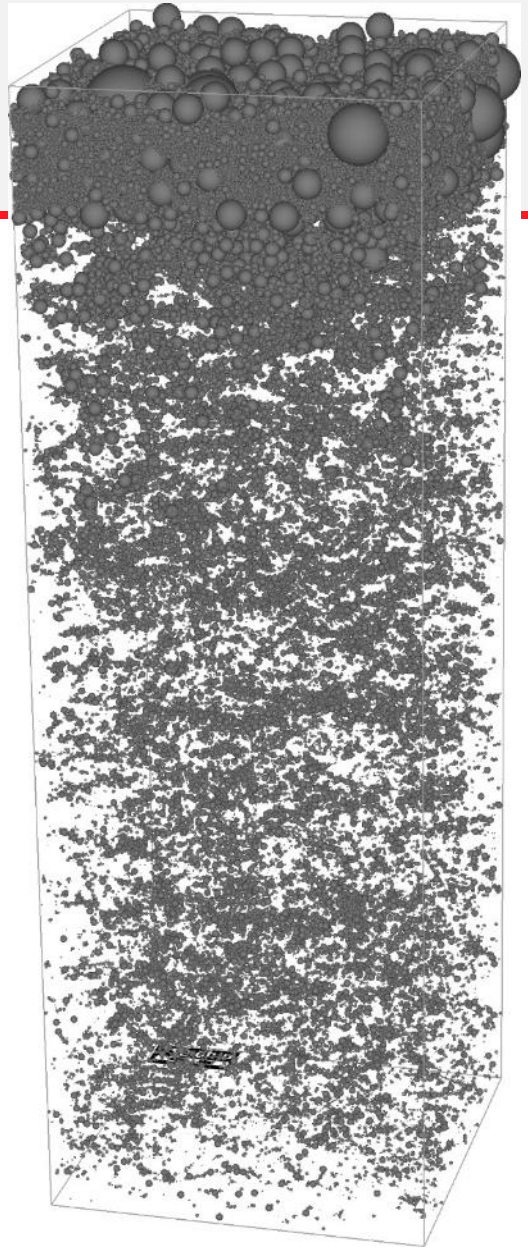


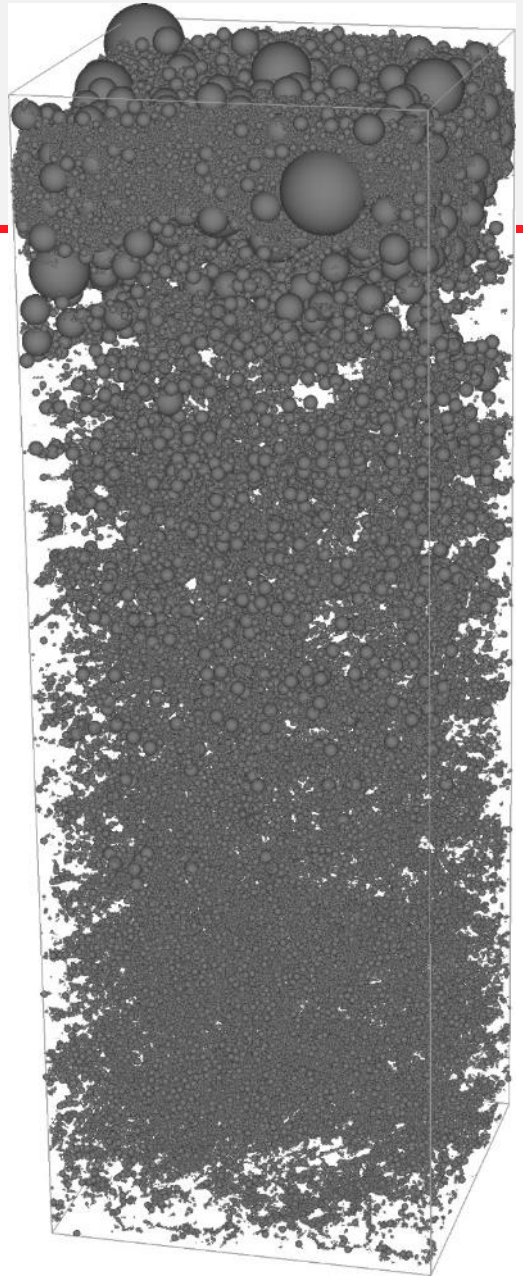


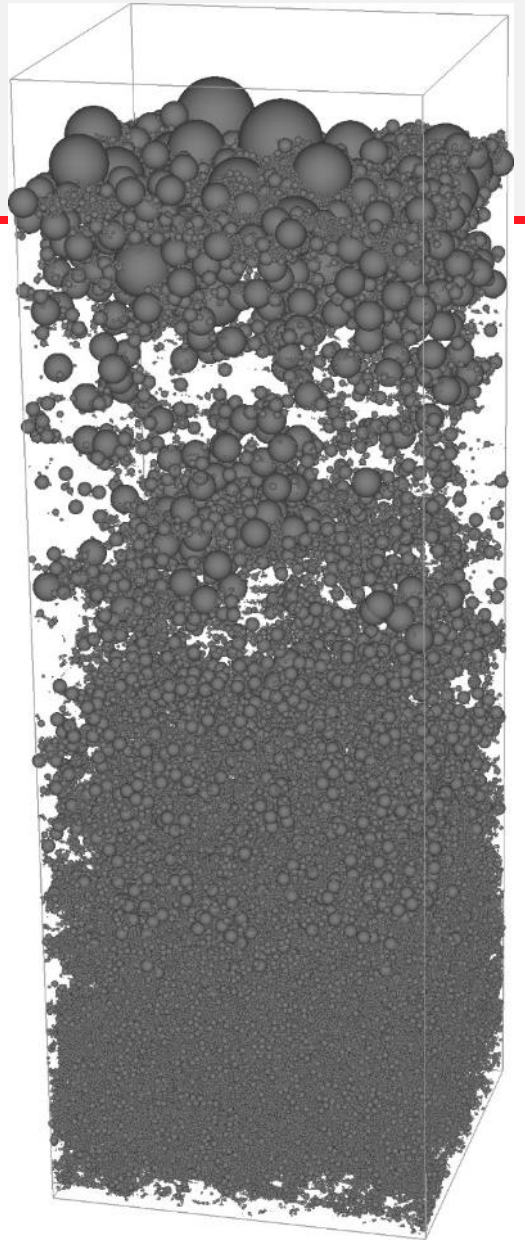
Exponential



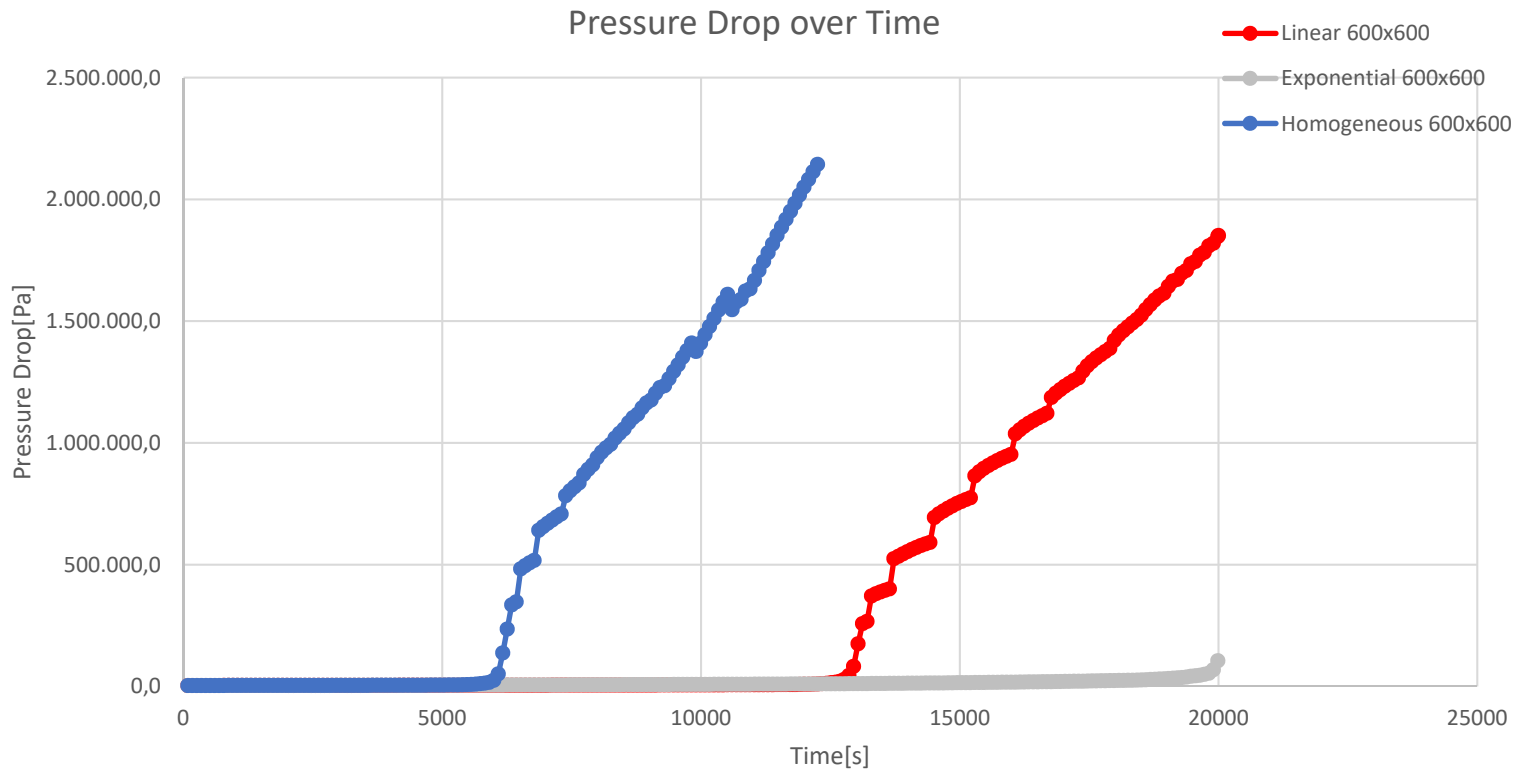




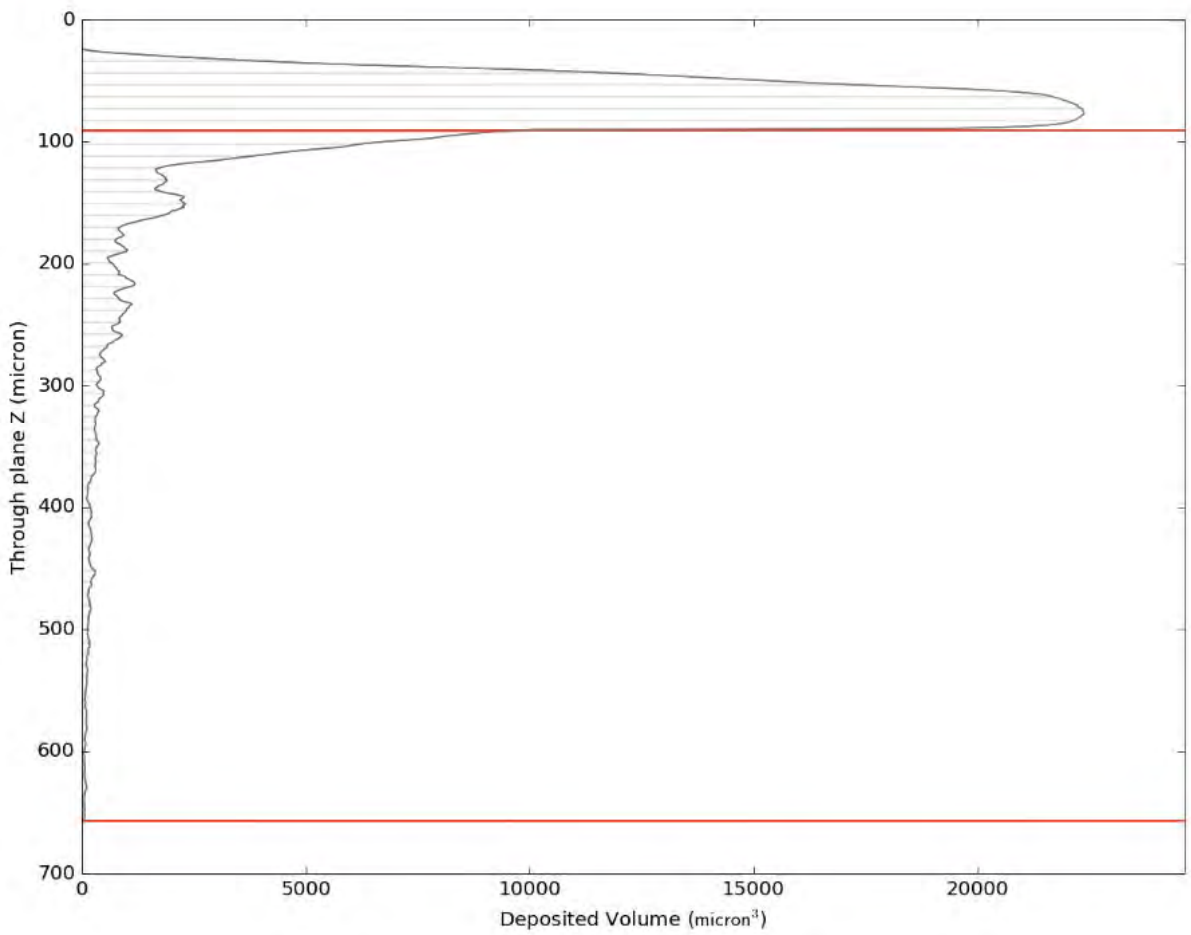




Results for 600x600 structures



Spatial particles deposition over depth



Thank you for your attention.