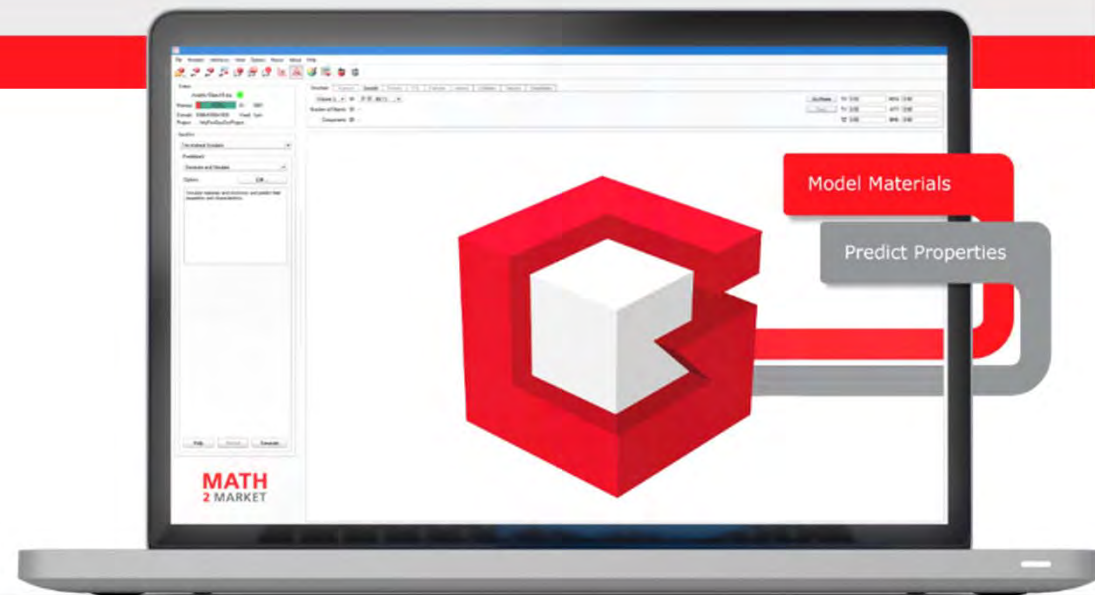


# The Economic Attraction in Using Pore Scale Computer Modelling for the Design of Filter Media

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



## Math2Market ...

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- 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



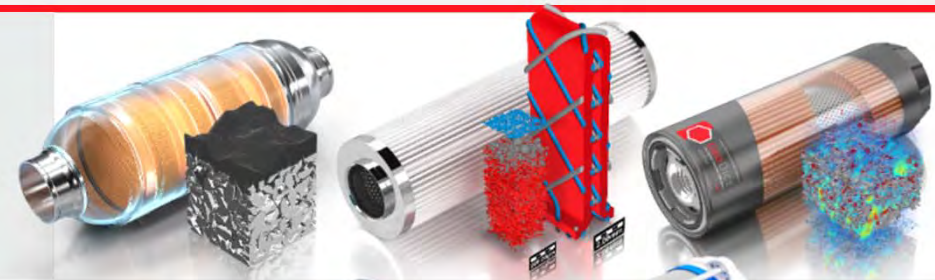
- 40% female employees
- 14% foreign employees

- inhouse employees: 32
- external employees: 3

# GeoDict The Digital Material Laboratory

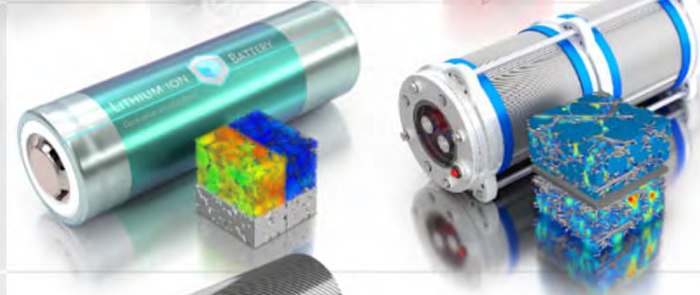
## Filtration

Mostly automotive,  
filter media & filters  
for water, sludge, oil,  
air and fuel



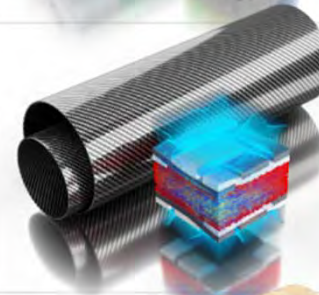
## Electrochemistry

Fuel cell media &  
battery materials,  
catalyst materials



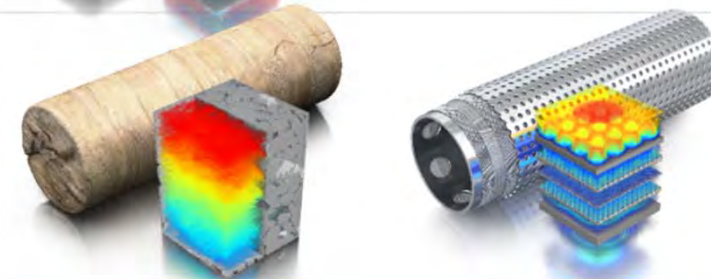
## Composites

CFRP, GFRP,  
mostly automotive,  
lightweight materials



## Oil and Gas

Digital rock physics,  
digital sand control

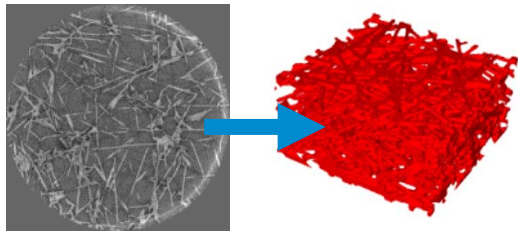




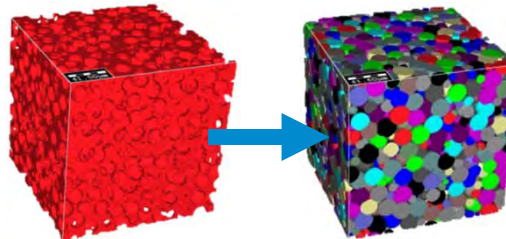
# GeoDict introduction

With GeoDict you can...

$\mu$ CT & FIB-SEM Import



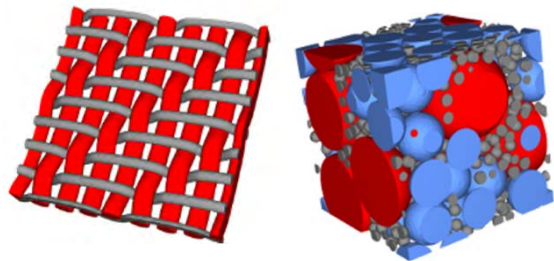
Analyse Materials



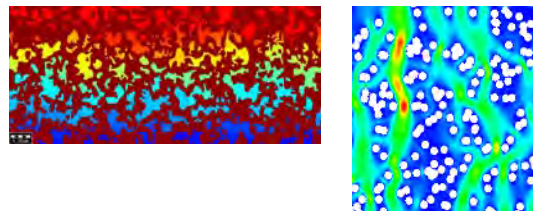
Optimize Materials



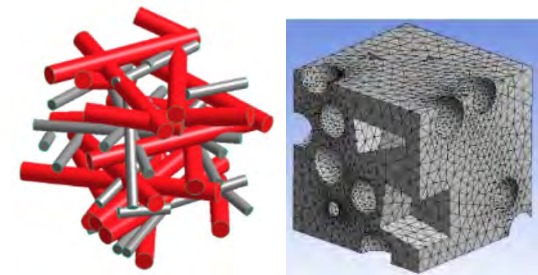
Model Materials



Analyse Properties



Export Materials



# The idea of digital filter media design

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1. Represent existing filter media in the computer
  1. From images ( $\mu$ CT, 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

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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

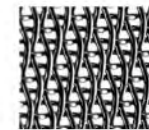
- Metal wire mesh can be geometrically modelled with **WeaveGeo** (fibrous media with **FiberGeo**, foams with **FoamGeo**, pleats with **PleatGeo**, ceramics with **SinterGeo** – you get the gist...)
- Geometric pore size can be found with **PoroDict**
- Flow rate / pressure drop can be found with **FlowDict**
- 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**



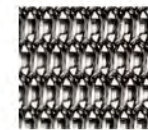
# Enlarged models in Showroom – from GKD web site



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



LLA mesh



KZ Mandur mesh



Circular filter in process specific design

Our filter media are considered especially efficient and economical – regardless of whether they are intended for universally deployable products, components for series manufacturing or complex individual solutions. With our own simulation methods and testing techniques, we integrate these filter media seamlessly into the customer's process.

Our developments are acknowledged across all industries as standards for many industrial applications. Electronics manufacturers use our filters in inkjet printers or as shielding against electromagnetic radiation. The automotive industry uses our meshes for diesel particulate filtration, in exhaust gas aftertreatment and in hydraulic systems. Ship chandlers use them for ballast water filtration. In the aerospace industry, our meshes are used in lightning protection applications or for noise insulation of jet engines.

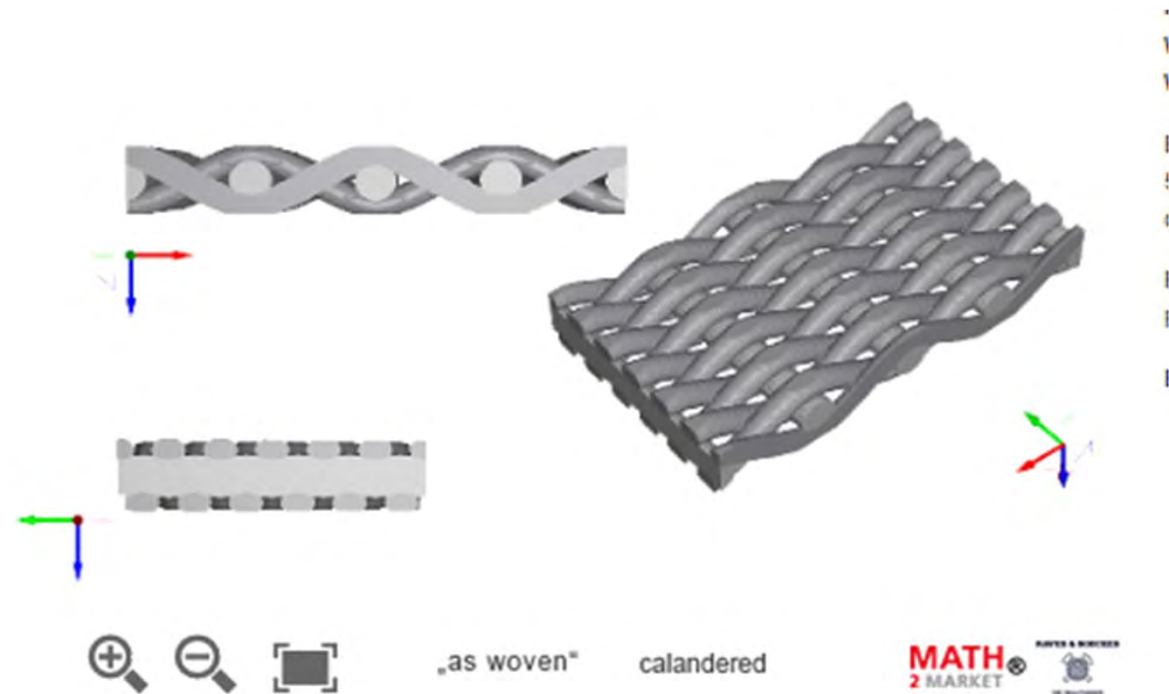
The chemical, pharmaceutical, plastics and foodstuffs industries place their trust in our meshes for demanding filtration tasks. And in the energy and environmental technology sectors, too, they have become successfully established.

## SOLIDWEAVE AT A GLANCE

- INNOVATIVE RANGE OF MATERIALS
- PRECISION MESH
- COMPLEX FILTER SYSTEMS
- UNIVERSAL PRODUCTS
- STANDARDS ACROSS ALL INDUSTRIES
- CUSTOMER SPECIFIC SOLUTIONS
- LEADING MANUFACTURING EXPERTISE
- THE LATEST SIMULATION AND TESTING METHODS
- CONTINUOUSLY CERTIFIED QUALITY

## Calendering – from Haver & Boecker web site

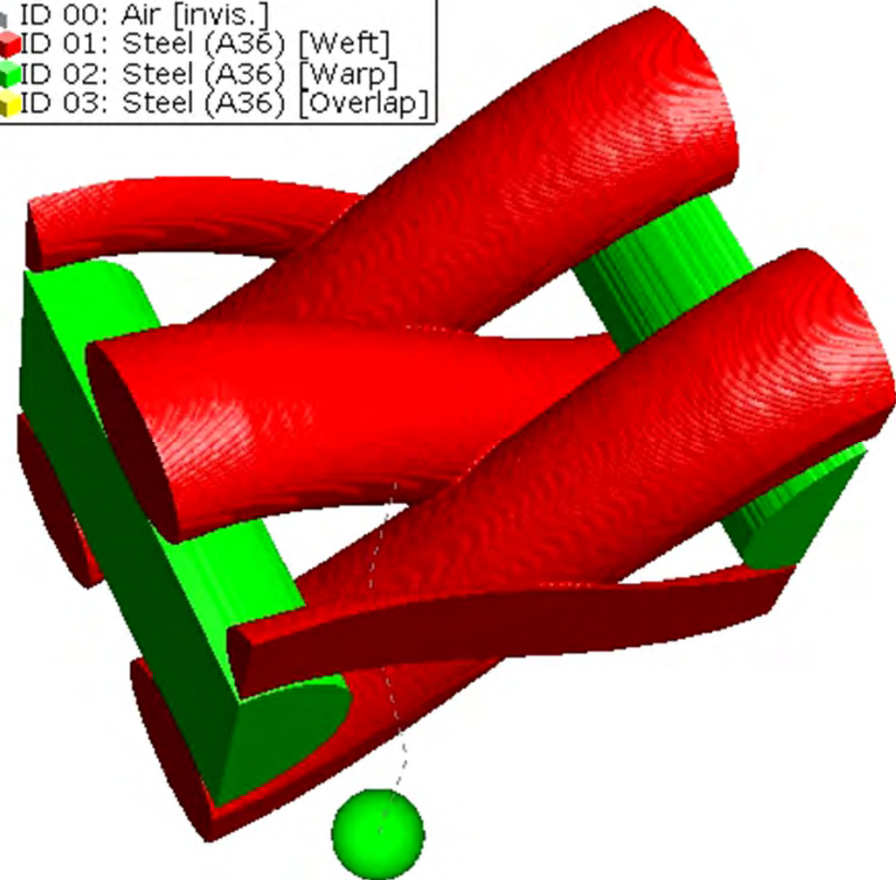
- Weaves are often modified to smaller pore sizes by calendering
- This can be modelled using **ElastoDict**



## 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

Material Information:  
ID 00: Air [invis.]  
ID 01: Steel (A36) [Weft]  
ID 02: Steel (A36) [Warp]  
ID 03: Steel (A36) [Overlap]

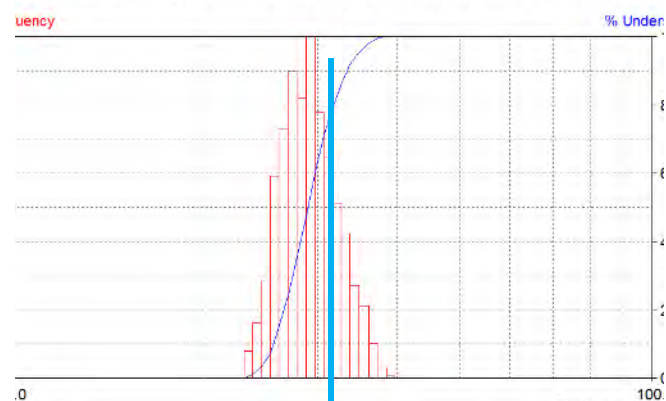


# Challenge Test Procedure

30 micron woven stainless steel mesh

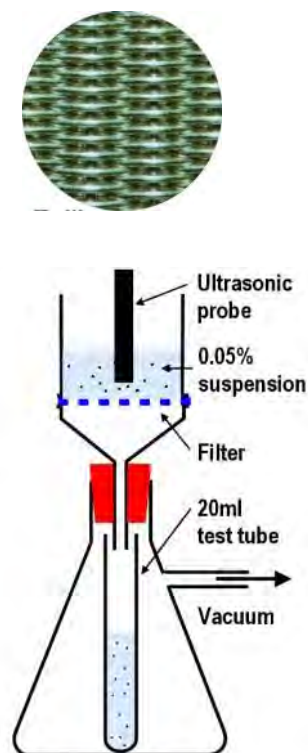
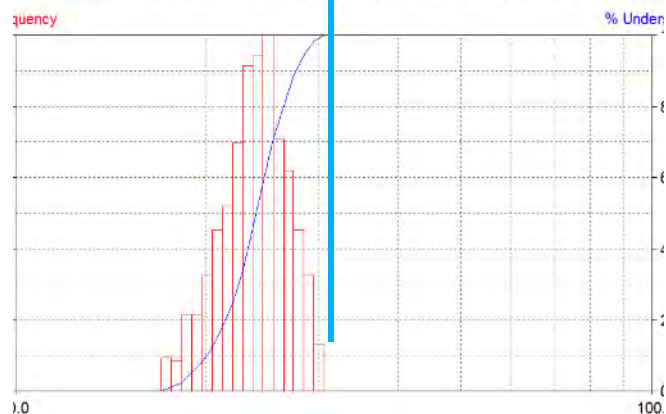
Filter standard (24 – 35 microns)

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



After passing mesh

Standard size	3.0	5.0	10.0	25.0	50.0	75.0	90.0	95.0	97.0
Size /µm	18.42	18.91	20.11	21.96	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

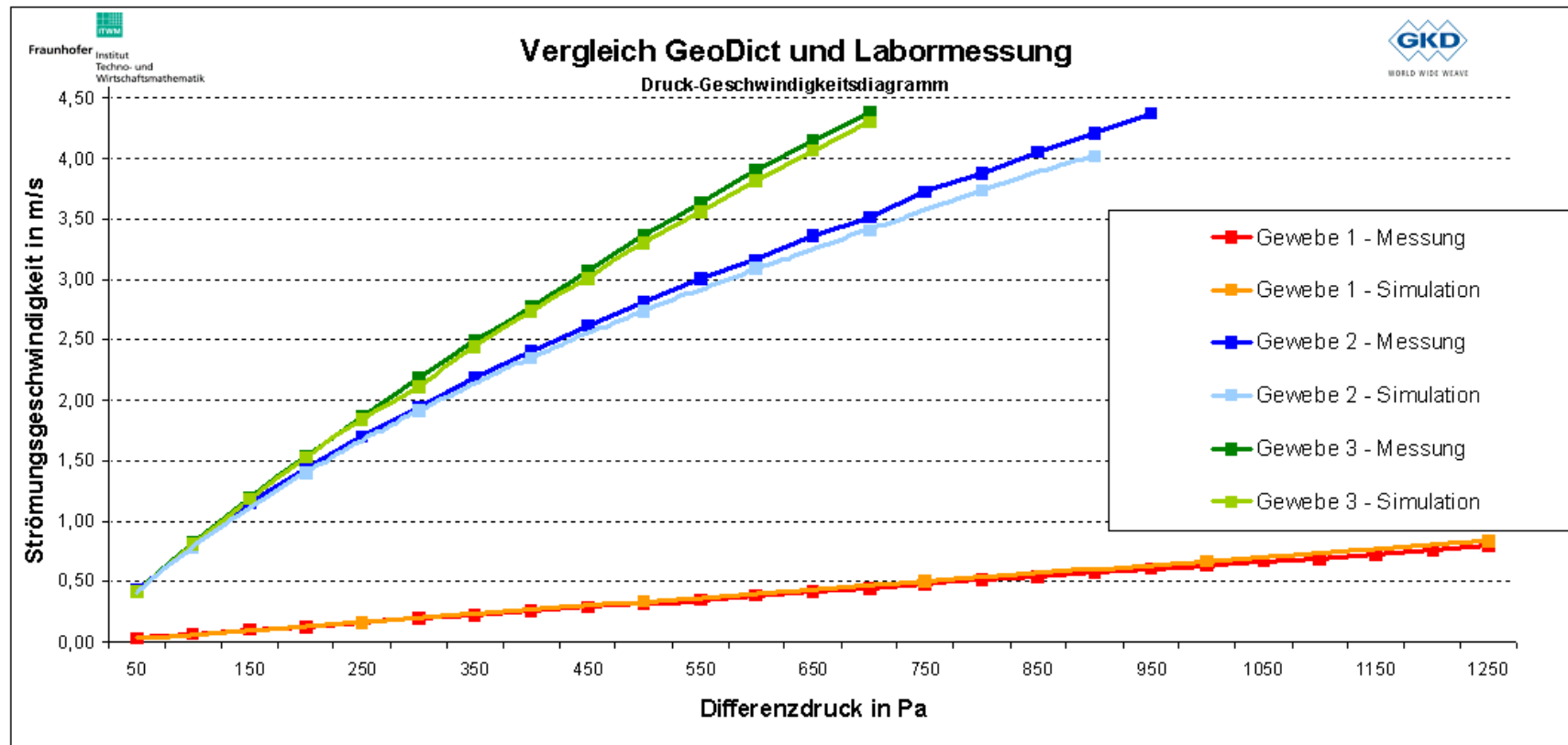


- High efficiency
- High flow rates

With permission by  
Friedrich Edelmeier,  
Haver & Boecker



# Measured & FlowDict pressure drop for metal wire meshes

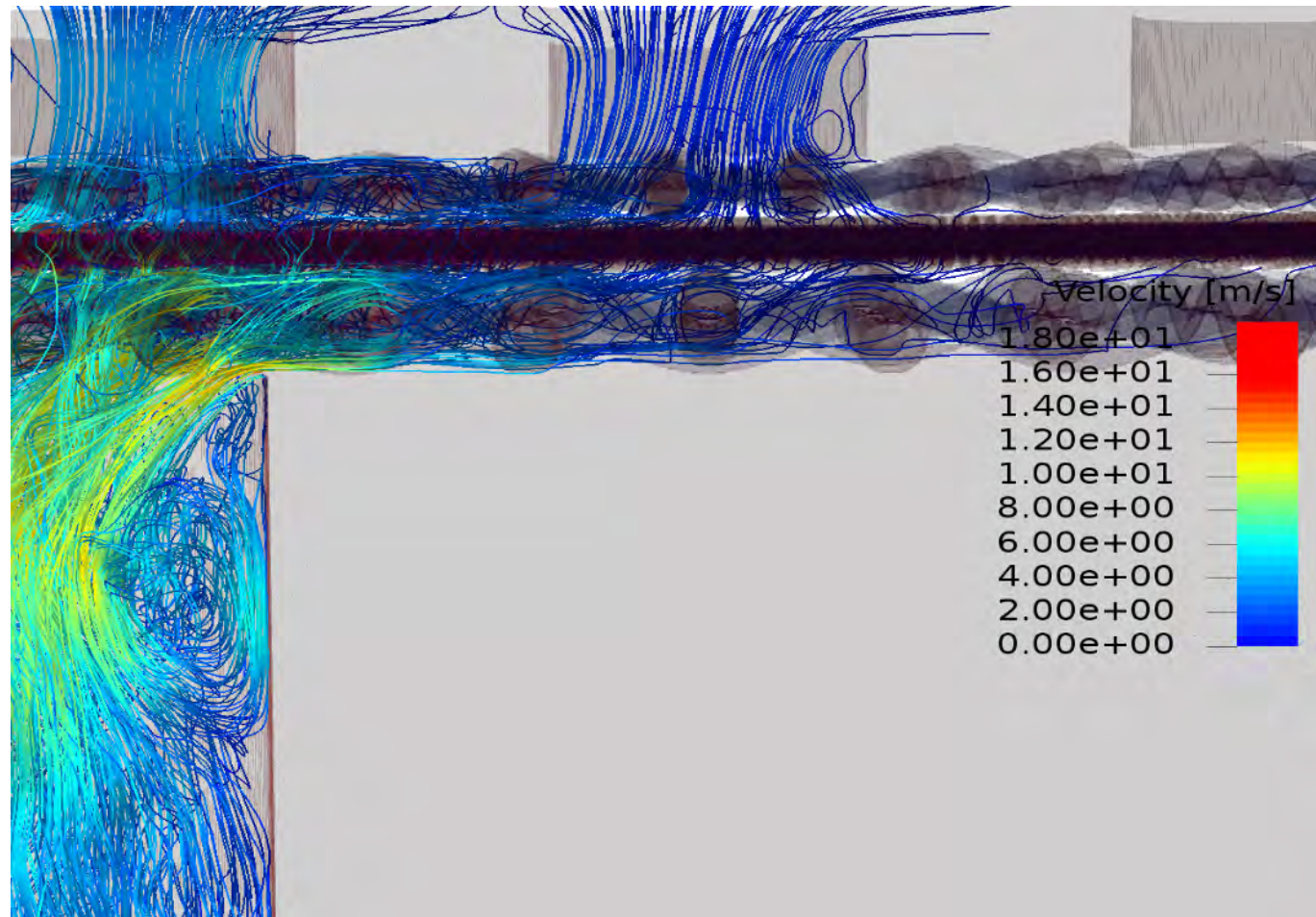


E. Glatt, S. Rief, A. Wiegmann, M. Knäfel and E. Wegenke, *Structure and pressure drop of real and virtual metal wire meshes*, Bericht des Fraunhofer ITWM, Nr. 157, 2009.

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...

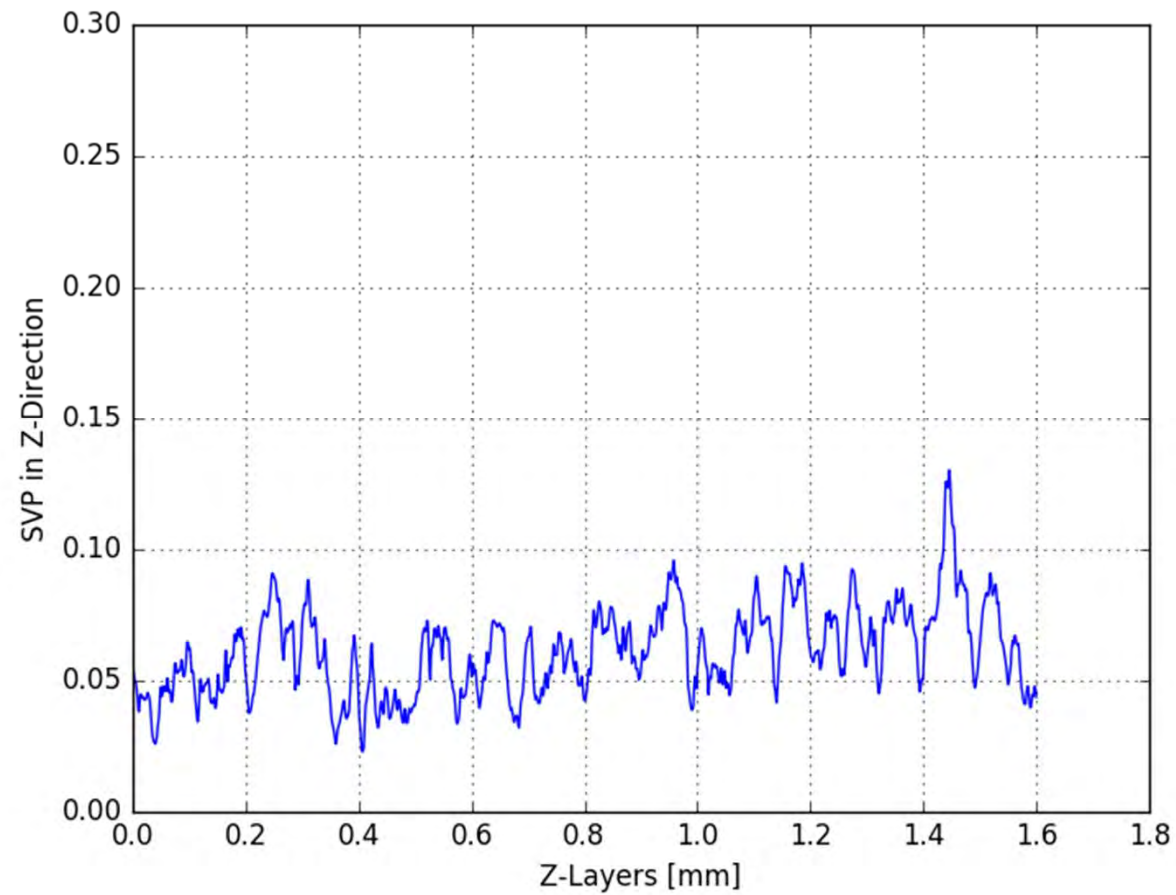
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Article in Filtration 17(3) 2017 by Dominik Herper of GKD explains how mesh models and pore size determination together with 2-phase flow simulations can be used to obtain proper correction factors for bubble point determination of geometric pore size.

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

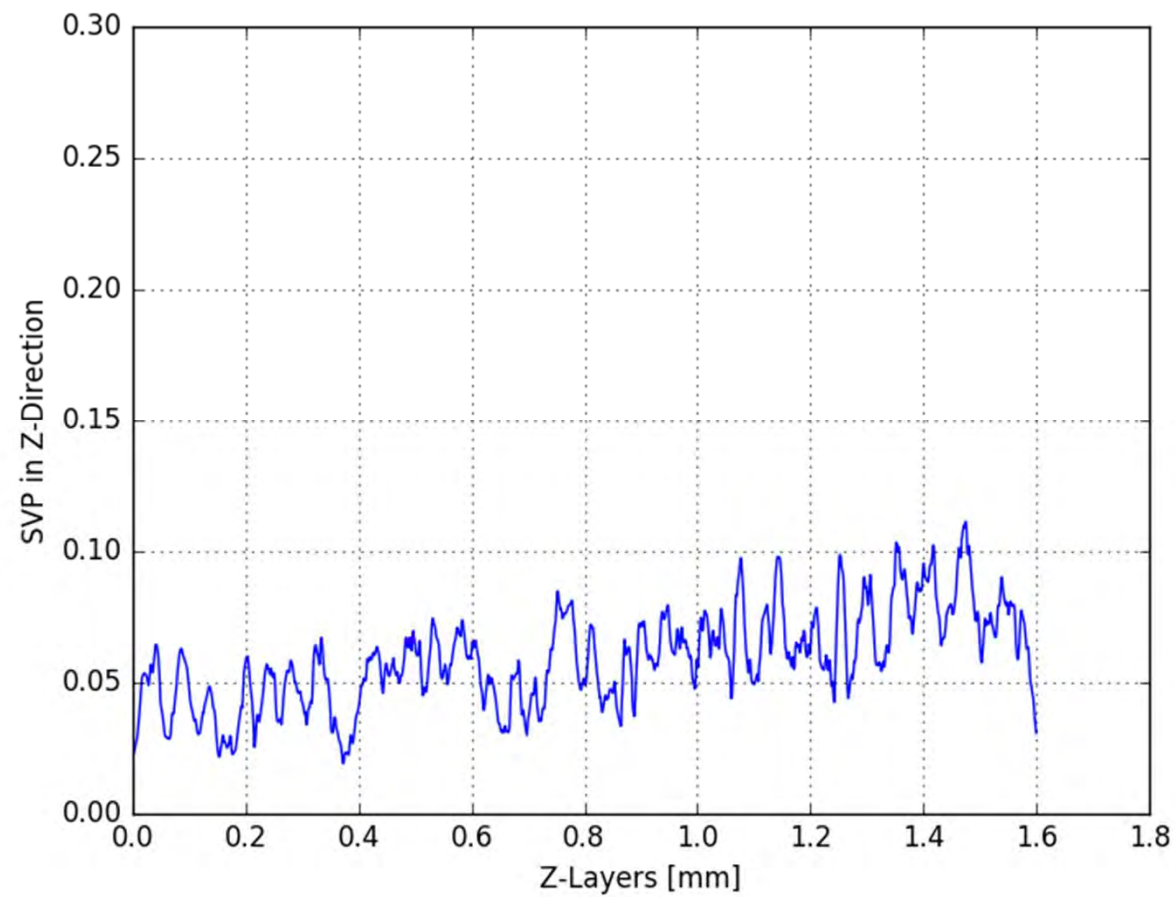
- Following a presentation by Maxim Silin of Hollingsworth and Vose at Filtech 2015,
- Mehdi Azimian and Christopher Kühnle of Math2Market considered 3 materials with two types of fibers that all have the same initial pressure drop and beta-rating:
  1. Homogeneously distributed of coarser and finer fibers
  2. Linear distribution of finer fibers, homogeneous coarser fibers
  3. Exponential distribution of finer fibers, homogeneous coarser fibers

# Homogeneous

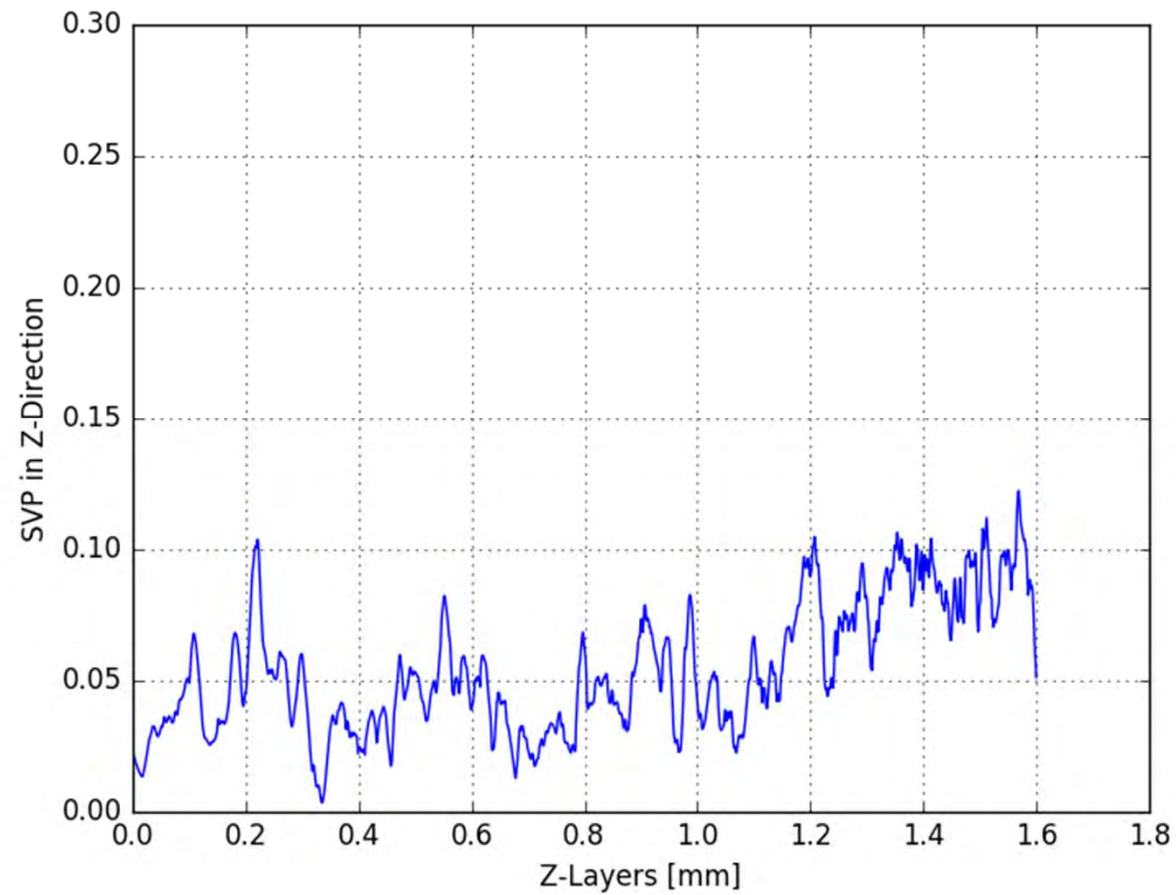
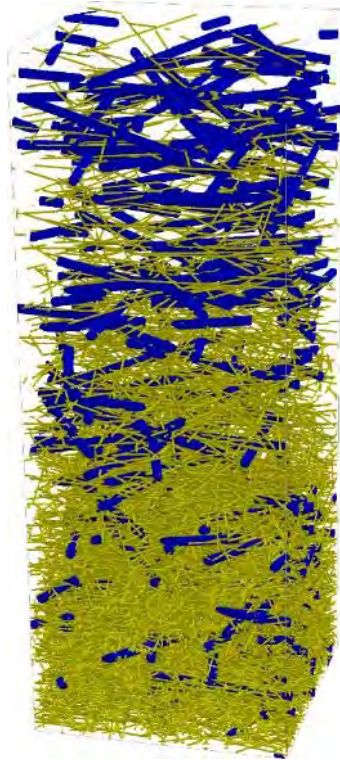




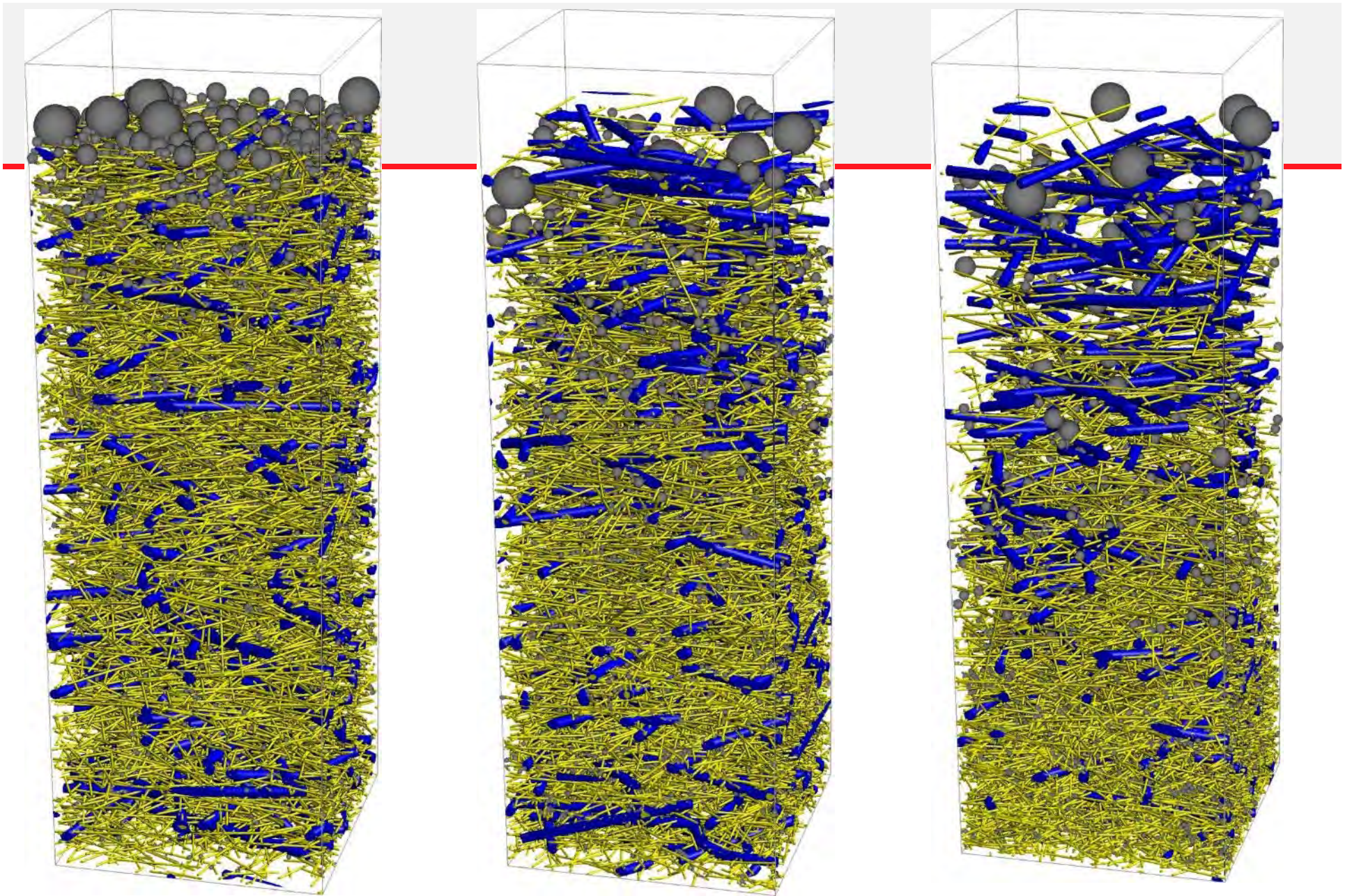
# Linear



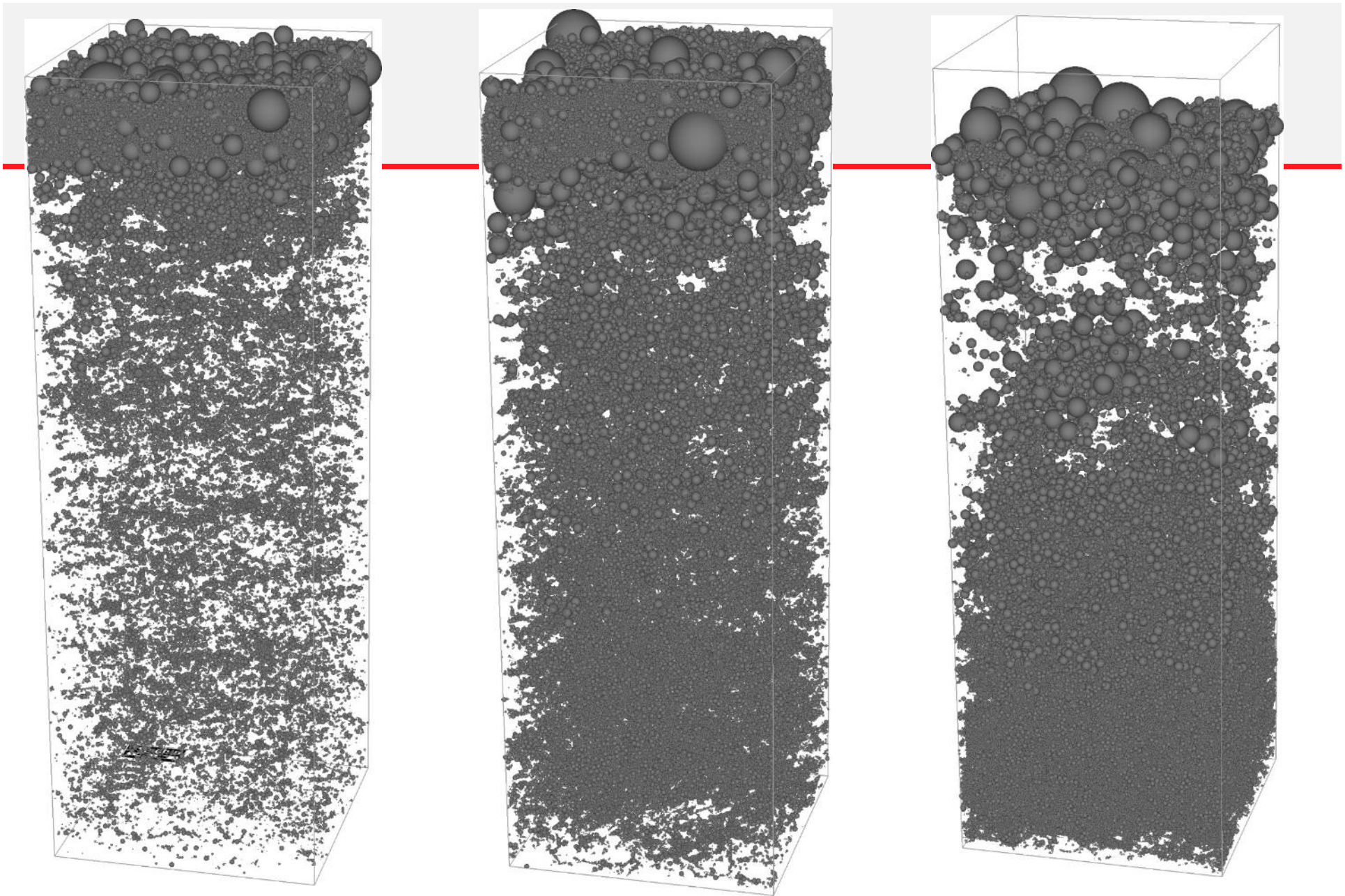
# Exponential



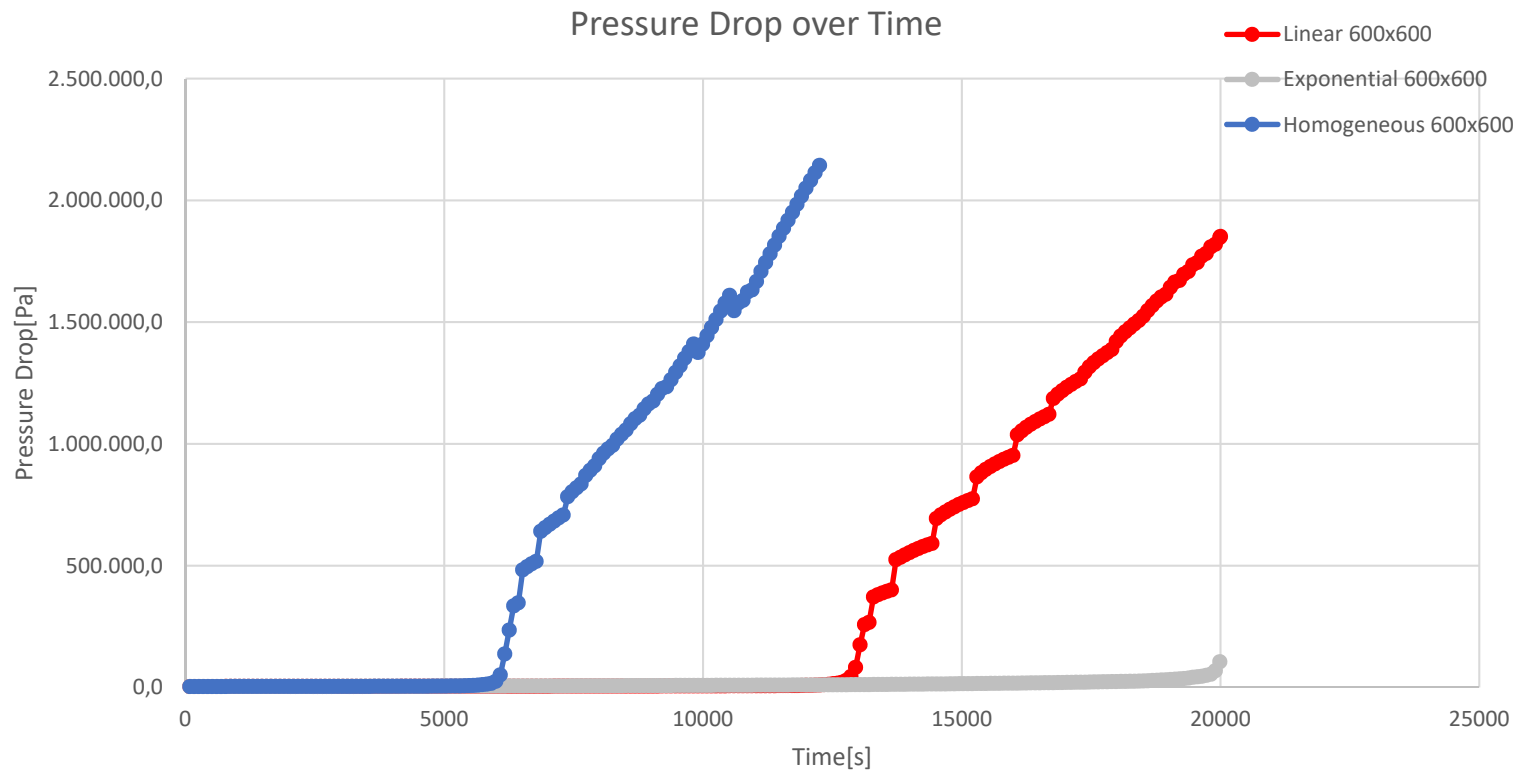






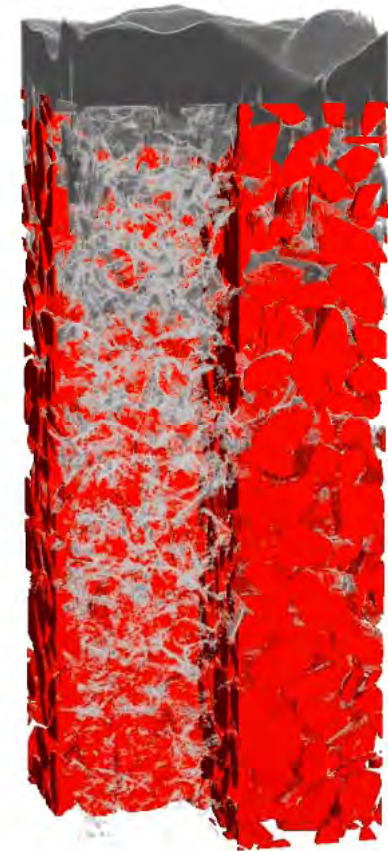
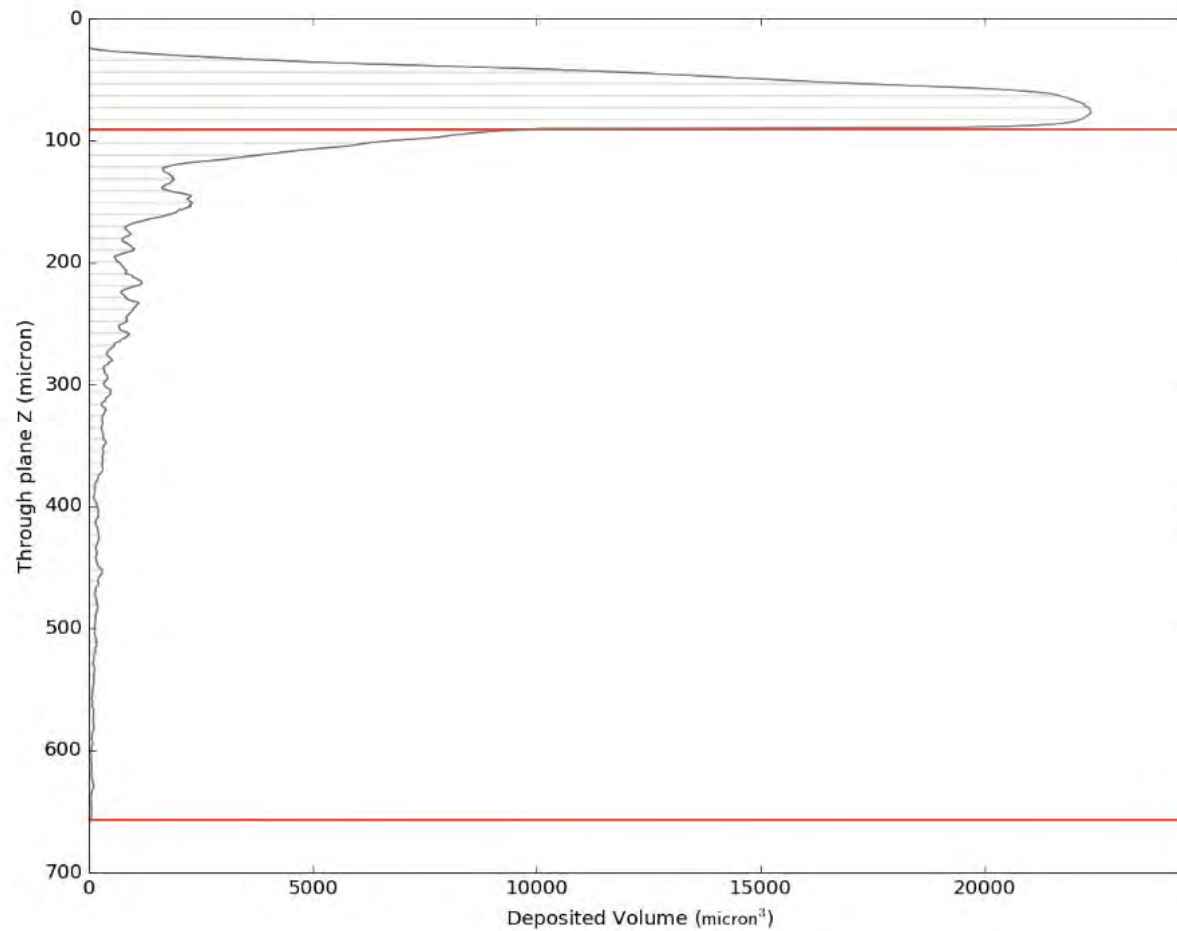


## Results for 600x600 structures





# Spatial particles deposition over depth



# Thank you for your attention.

