Computer aided development of hydraulic filter elements

-From theory to patent and products-

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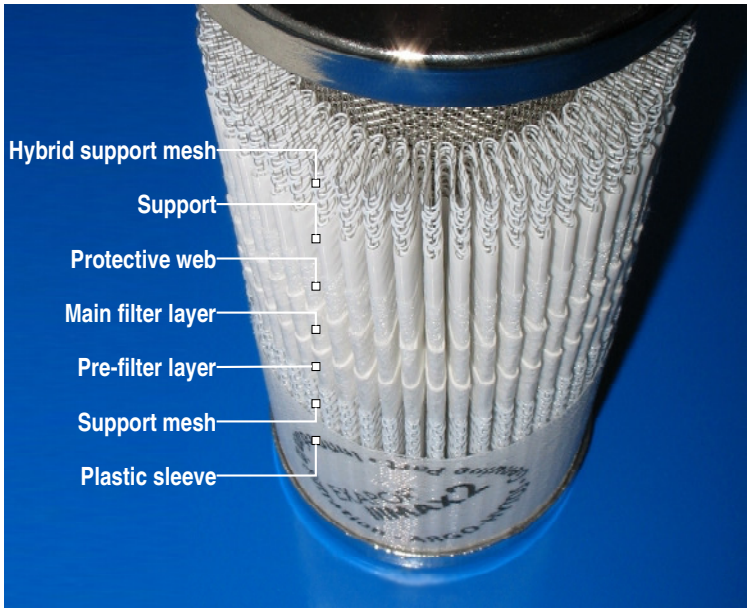
What does a hydraulic filter element do?

- Oil flows from outside to inside
- Out through perpendicular center region
- Oil passes through layered filter media
- Filter media removes dirt particles from the oil



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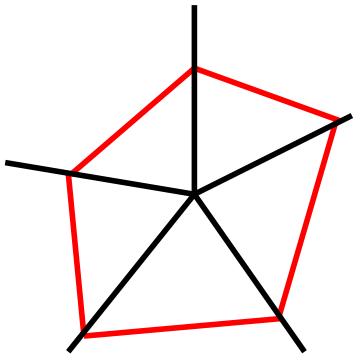
Parameters for a hydraulic filter element

Disposal cost

Operating cost:
Pressure Drop

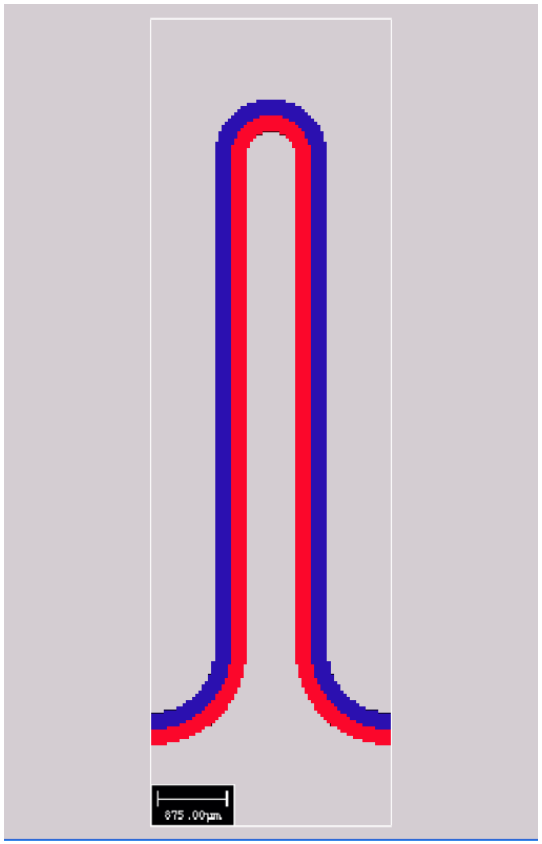


Protective function:
Filter efficiency

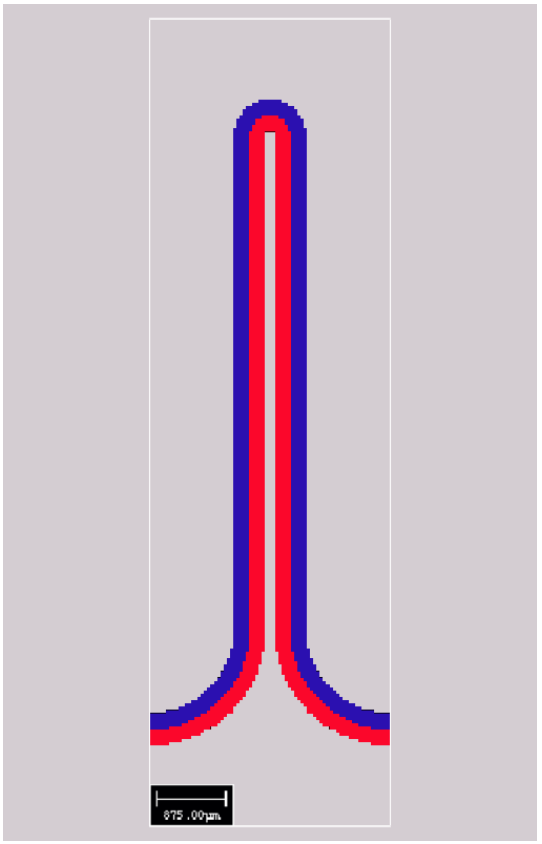
Operating cost:
Dirt-holding capacity

Acquisition cost

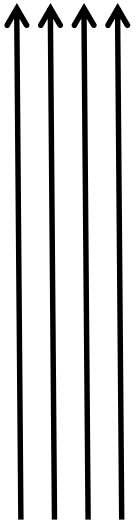
Consider pressure drop over a single pleat



Without support mesh, 2d model suffices



flow



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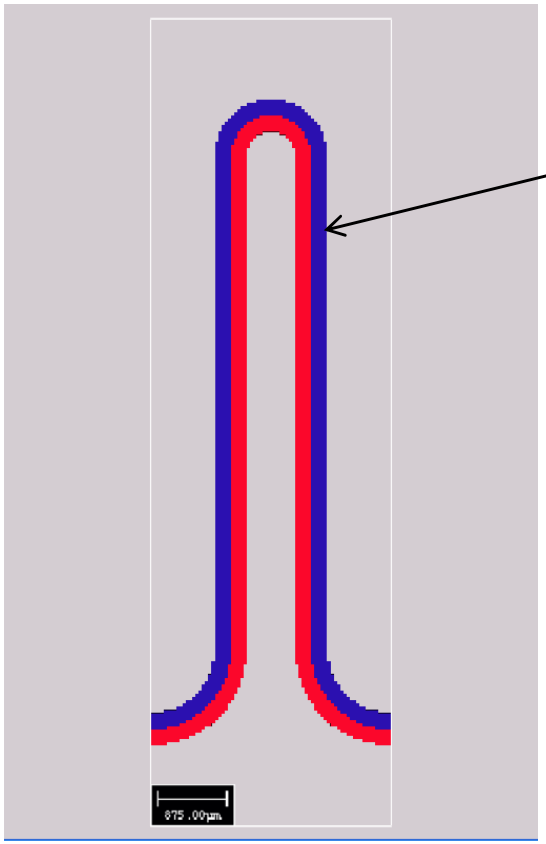
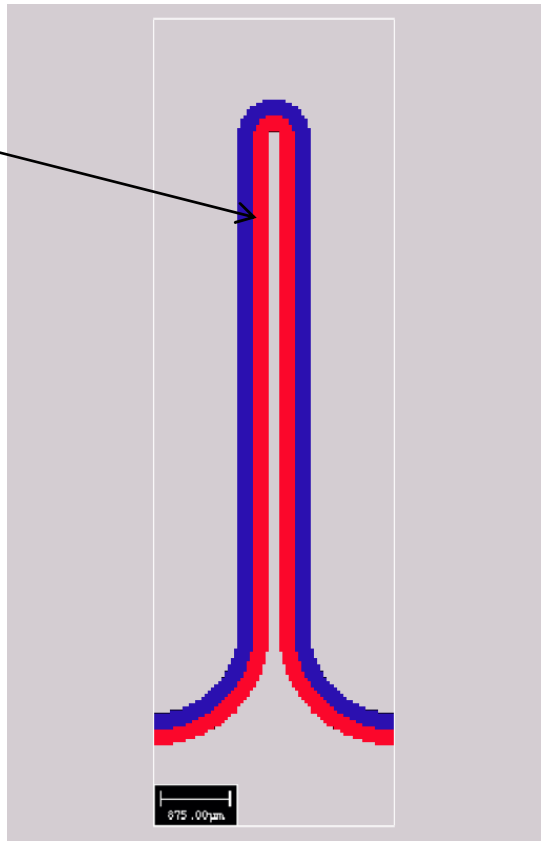
Consider pressure drop over a single pleat

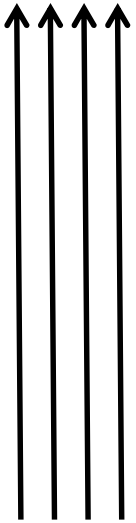


2 layered permeable filter media

Without support mesh, 2d model suffices



flow



The Navier-Stokes-Brinkman equations for fluid flow

$$
\begin{aligned}
-\mu\Delta\vec{v} + \nabla\vec{u}\cdot\vec{u} + \kappa^{-1}\vec{u} + \nabla p &= \vec{f} \text{ (momentum balance)} \\
\nabla\cdot\vec{u} &= 0 \text{ (mass conservation)} \\
\vec{u} &= 0 \text{ on } \Gamma \text{ (no-slip on fiber surfaces)}
\end{aligned}
$$

$\vec{f} = (0, 0, f)$: force in flow(z)-direction,

κ : porous voxel permeability,

$\vec{u}$: velocity,

μ : fluid viscosity,

p : pressure and

Γ : surfaces of fibers or deposited particles.

The flow can be solved with periodic boundary conditions if the cutout is large enough and empty space is added in front.

O. Iliev, V. Laptev: *On Numerical Simulation of Flow through Oil Filters*, J. Computers and Visualization in Science, vol. 6, 2004.139-146.

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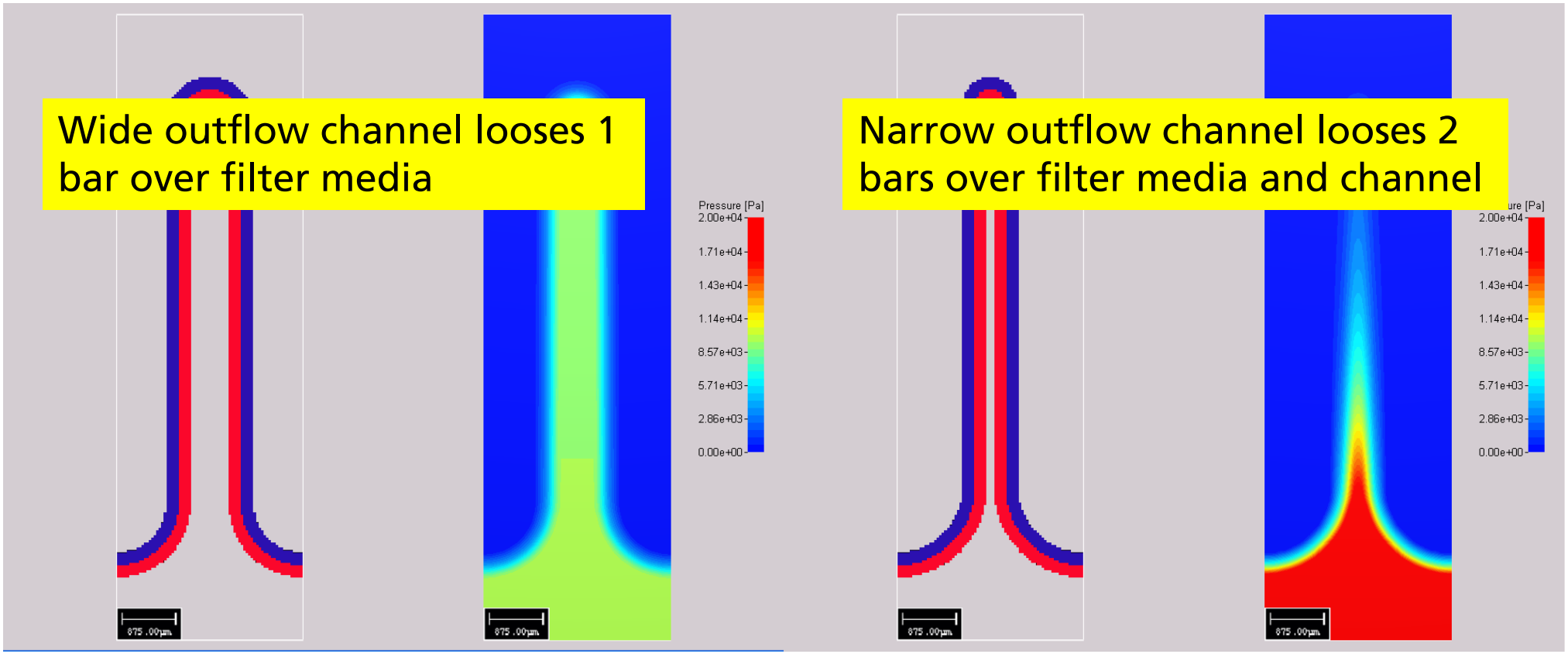
Oil pressure collapses pleats, this increases pressure drop



Pressure at 0.01 m/s

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How to prevent the collapse?

- Use support structure in outflow channel
- Need 3d pleat model for flow simulations
- 3d plain weave model in outflow channel

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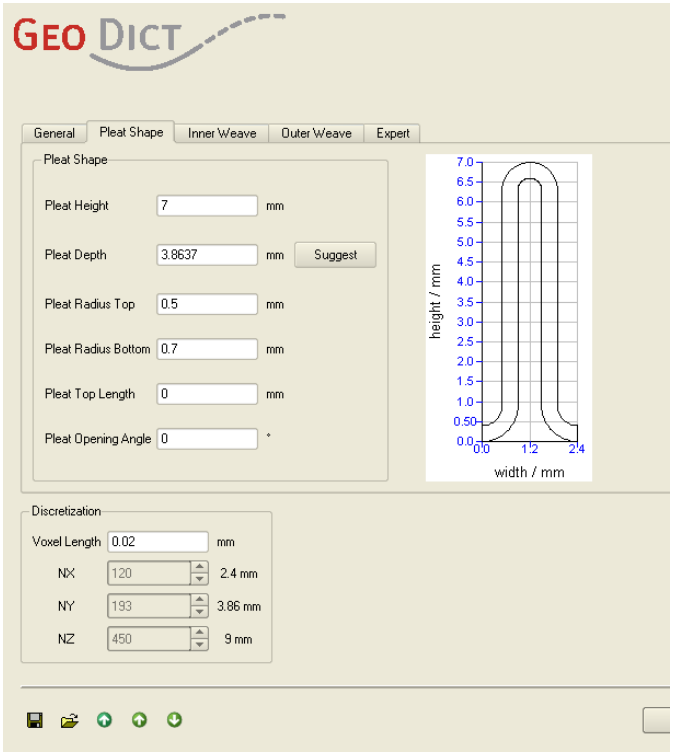
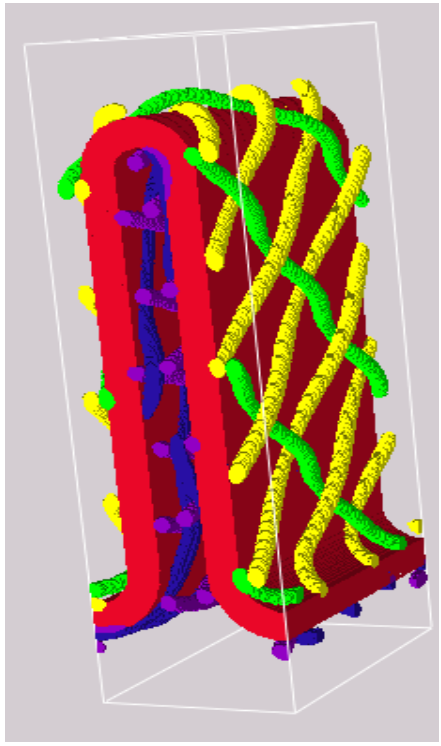
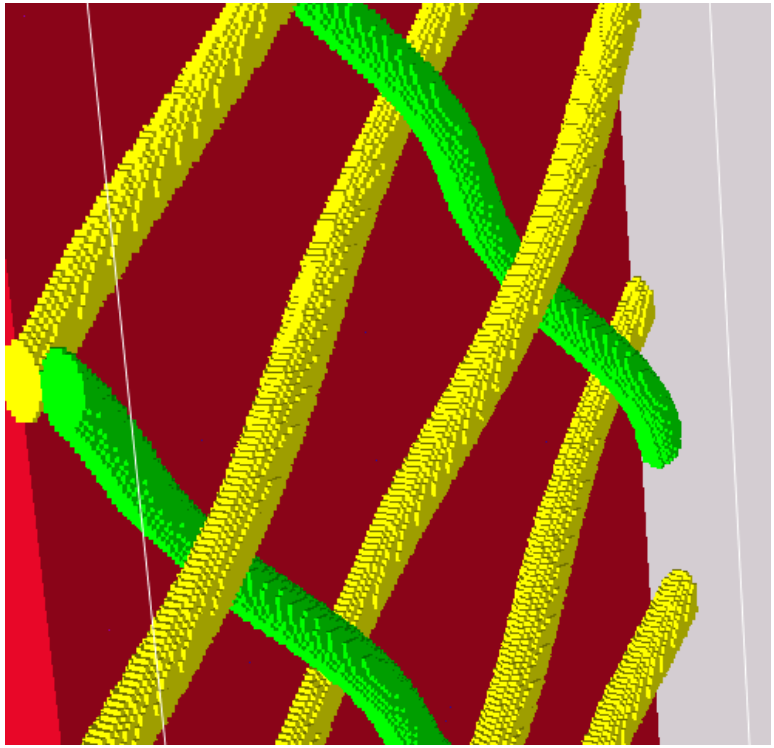
The PleatGeo Tool







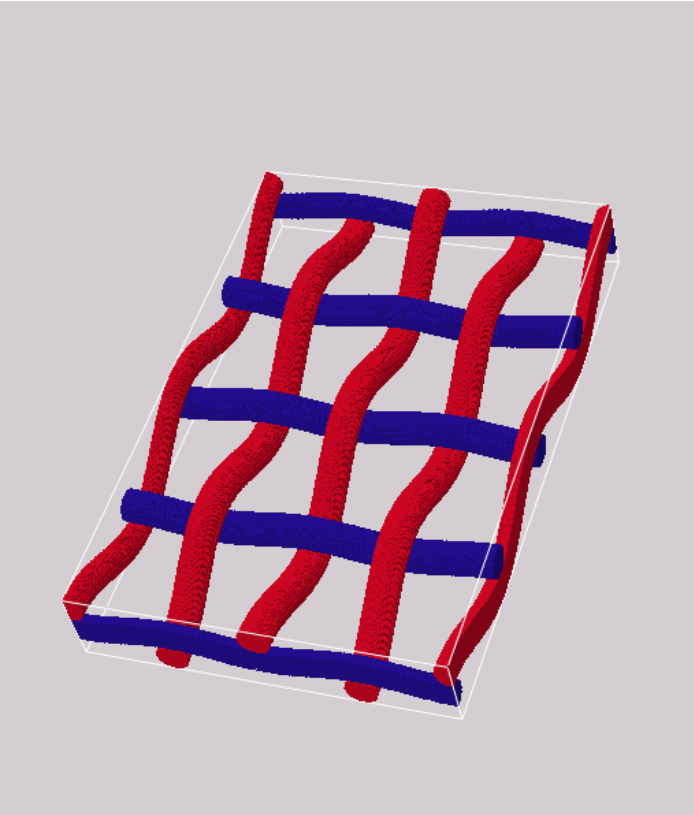
Calibration?

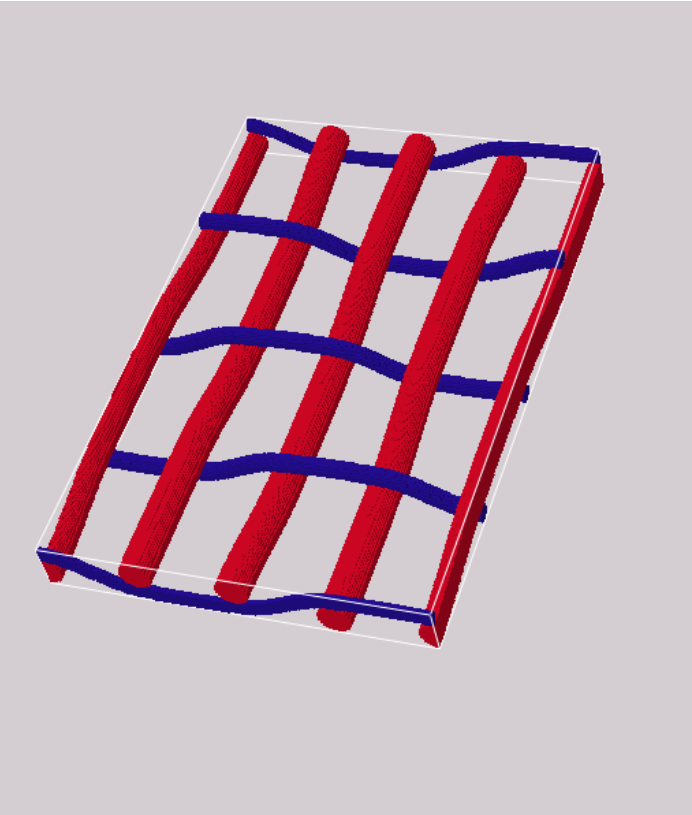
- Permeability for plain media
- Indentation of wires into media
- Found parameters to match experimental pressure drop for plain weave up to 10%.
- …

The idea!

- Change of weave pattern in the outflow channel makes outflow channel wider

Plain weave vs Twil 2/2





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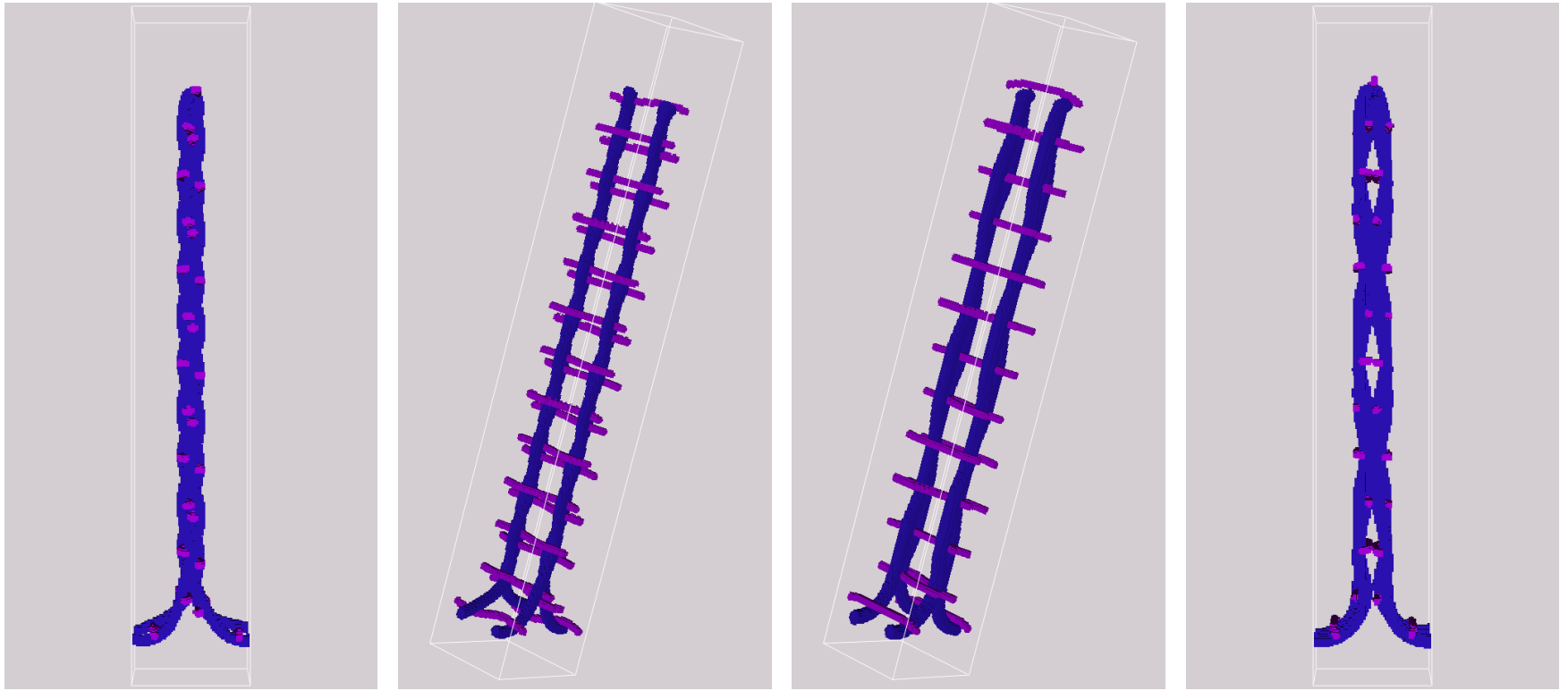
Plain weave creates a narrower outflow channel than twill 2/2



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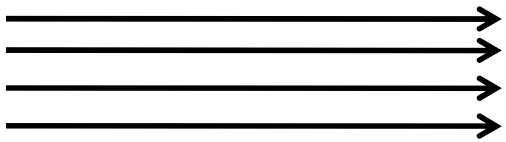
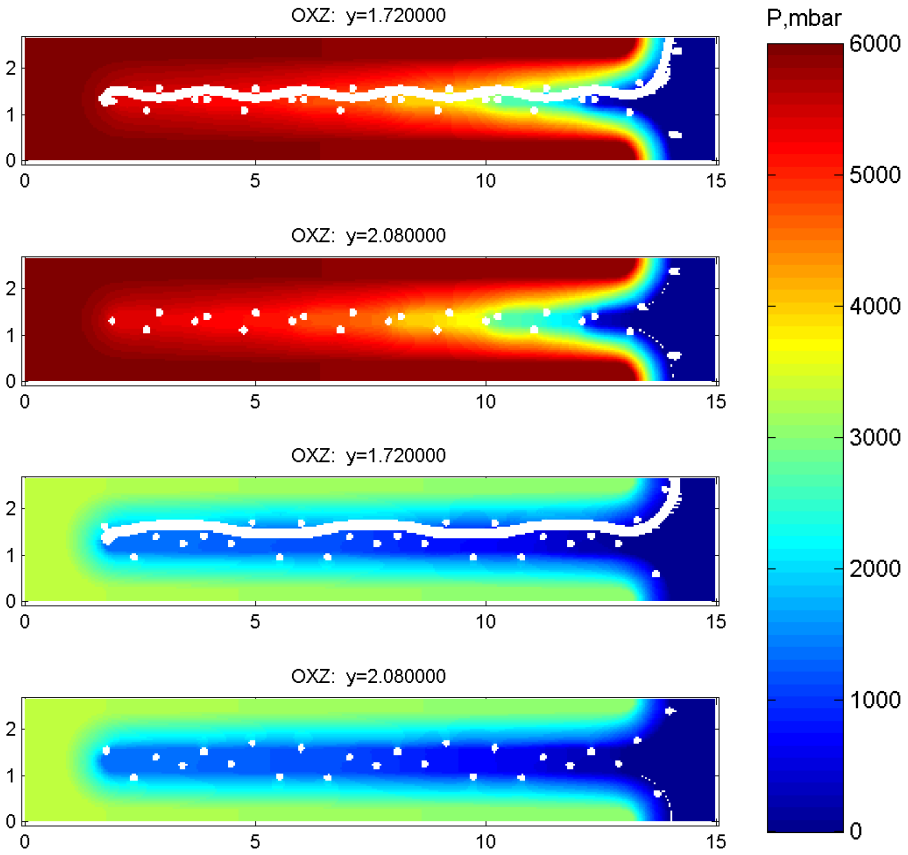
The effect of plain vs twill 2/2

Plain weave, 6 bar

flow



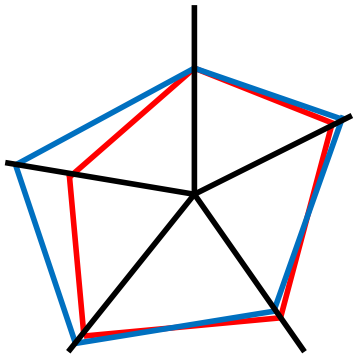
Twill 2/2, 4 bar
(35% lower pressure drop)



Improved Parameters for a hydraulic filter element

Disposal cost

Operating cost:
Pressure Drop



Protective function:
Filter efficiency

Operating cost:
Dirt-holding capacity

Acquisition cost

What happened afterwards?

- Argo-Hytos filed a patent on the new filter element design
- Argo-Hytos sells next generation filter element EXAPOR®MAX 2
- Fraunhofer ITWM developed general software PleatGeo for pleat design and PleatDict for pressure drop simulation for GeoDict software suite
- Fraunhofer ITWM has several new customers for these 2 new modules

Conclusions and Outlook

- Simulations can prove an idea before building prototypes
- Simulations require validation and calibration with experimental data for existing objects before predicting quantitatively correctly new objects
- Collaboration between industry and research institute gives sustainable results if IPR is handled well.
- Work now focused on filter efficiency and dirt-holding capacity

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Find out more:

www.itwm.fhg.de

www.geodict.com

www.argo-hytos.com