Fluid flow process simulation and material property simulations with FlowDict

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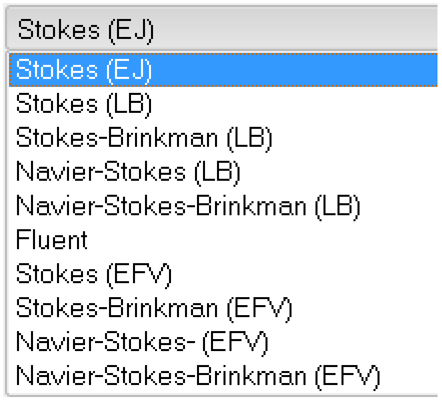
FlowDict computes incompressible, stationary and Newtonian flows

Incompressible means not too large pressure differences.
True for most liquid applications, not all gas applications.

Stationary means the flow field does not vary with time –
for example, no turbulence is modeled

Newtonian means the fluid behaves like water and not like honey

- **Navier-Stokes-Brinkman** describe regimes
- **EJ**, **LB**, **EFV** and **Fluent** are different solvers – they perform differently for the different settings!



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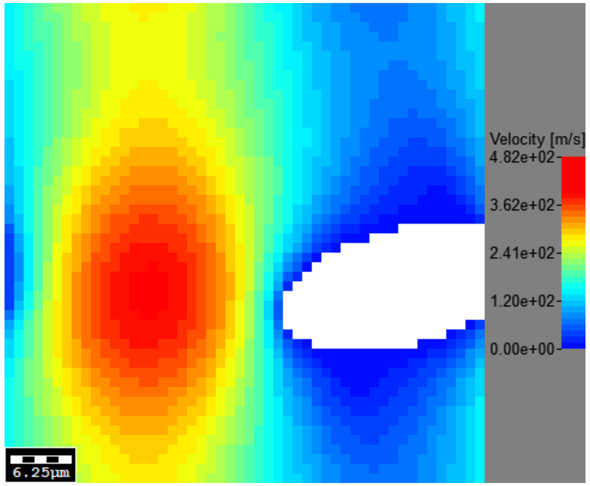
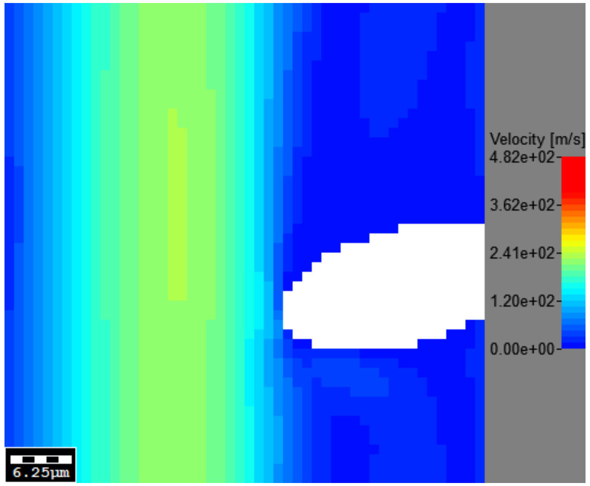
Velocity; Flow from bottom to top

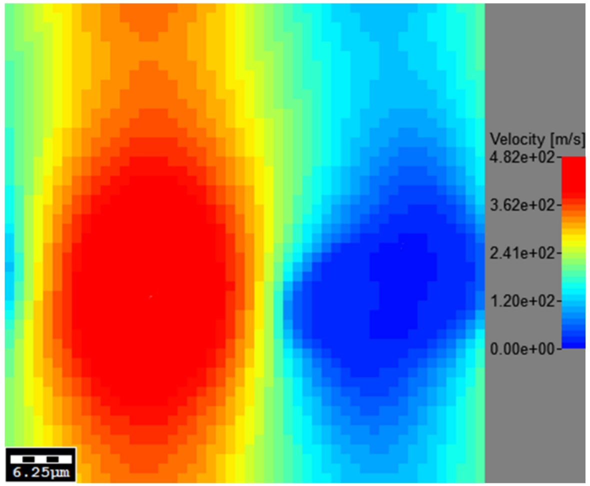
Stokes
solid
obstacle:
slower



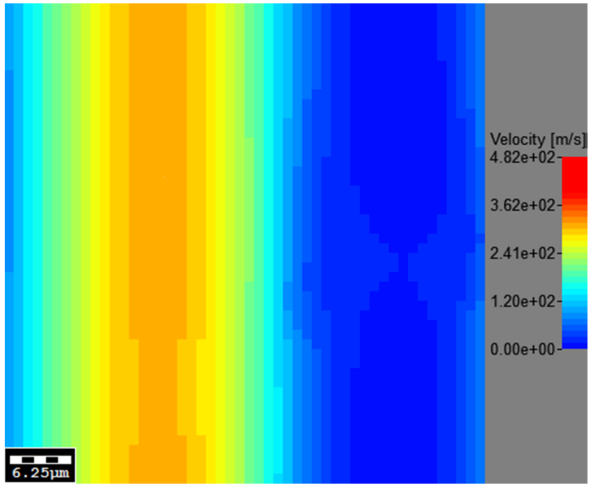
Navier-Stokes
solid
obstacle:
slowest



Stokes – Brinkman
permeable
obstacle
κ=1e-12:
fastest



Navier-Stokes-Brinkman
permeable
obstacle
κ=1e-12:
slower



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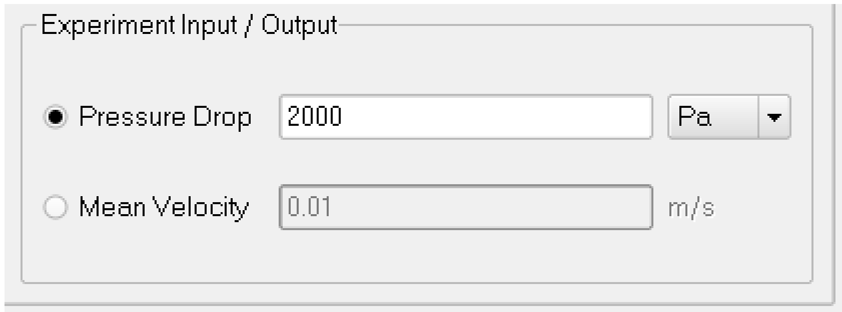
Process Simulation or Material property simulation?

Two experiments are typical:

- Measure mass flow rate for applied pressure drop
- Measure pressure drop for given mass flow rate

But only for EFV and Fluent both can be specified,



EJ and LB work only for prescribed pressure drop.

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Process Simulation or Material property simulation?

All flow solvers always compute the complete velocity field and pressure distribution in the whole computational domain.

I.e., the process / the experiment is always computed.

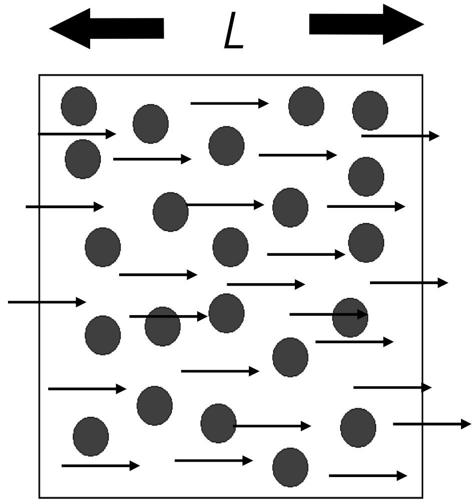
Sometimes the material property ***permeability*** is sought.

Computing the permeability

$\overline{\mathbf{u}}$: Macroscopic flow velocity

$\mathbf{K}$: Permeability tensor

$\Delta\mathbf{p}$: Pressure drop



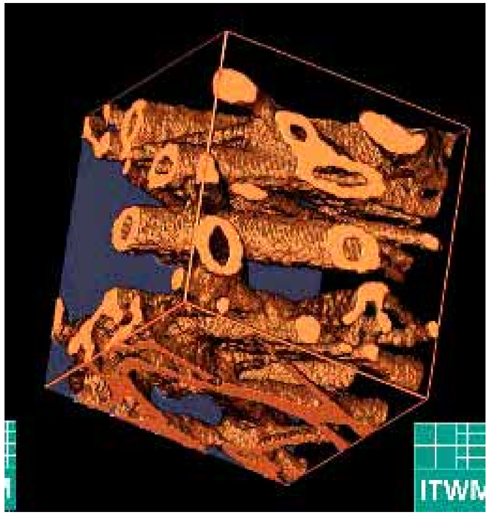
Flow solver finds microscopic flow field.
Averaging yields $\overline{\mathbf{u}}$

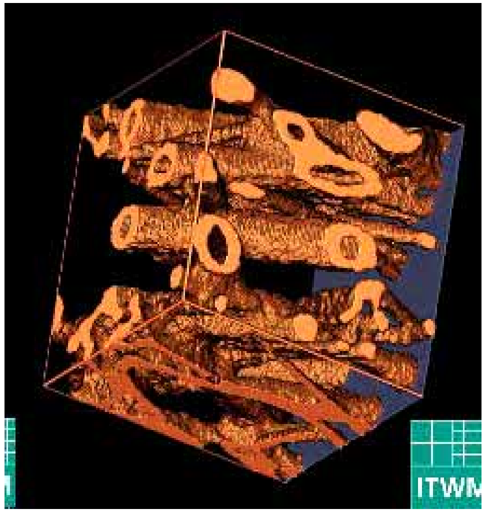
Darcy-Law: $\overline{\mathbf{u}} = \frac{\mu}{L}\mathbf{K} \cdot \Delta\mathbf{p}$

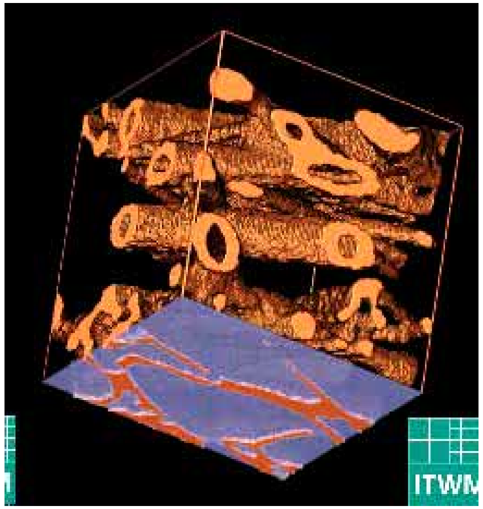
Clear: permeability is independent of viscosity and velocity
in linear regime, i.e. for Stokes flow

Computing the permeability tensor

Permeability tensor: $\mathbf{K} = \begin{pmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{32} & k_{32} & k_{33} \end{pmatrix}$ → Computation of anisotropic material properties







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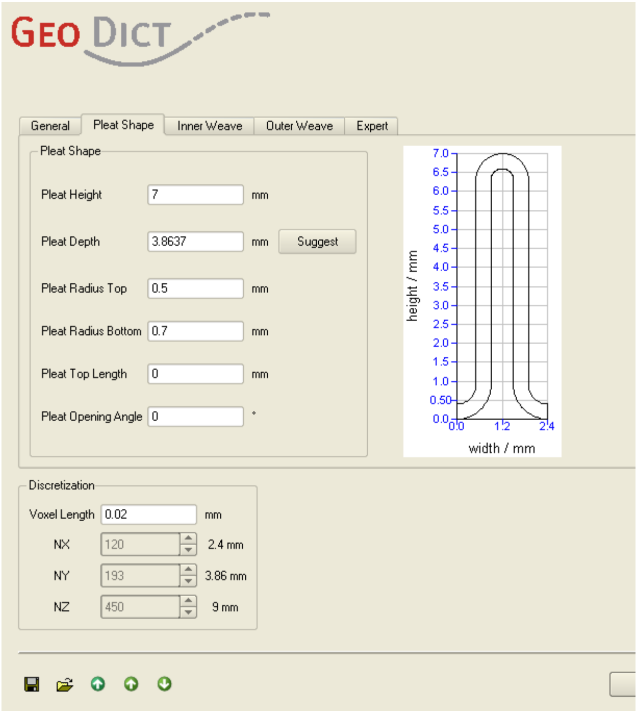
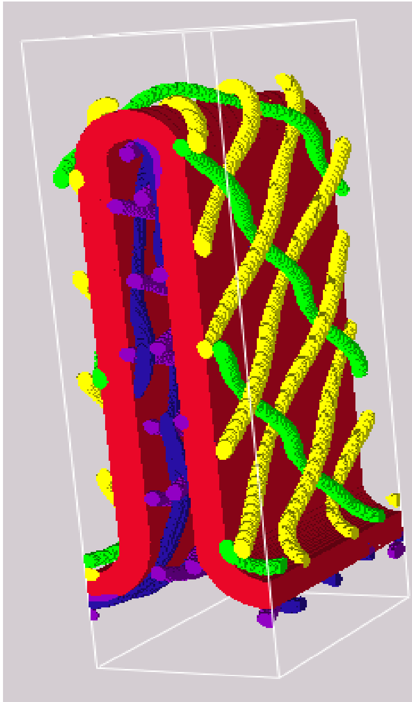
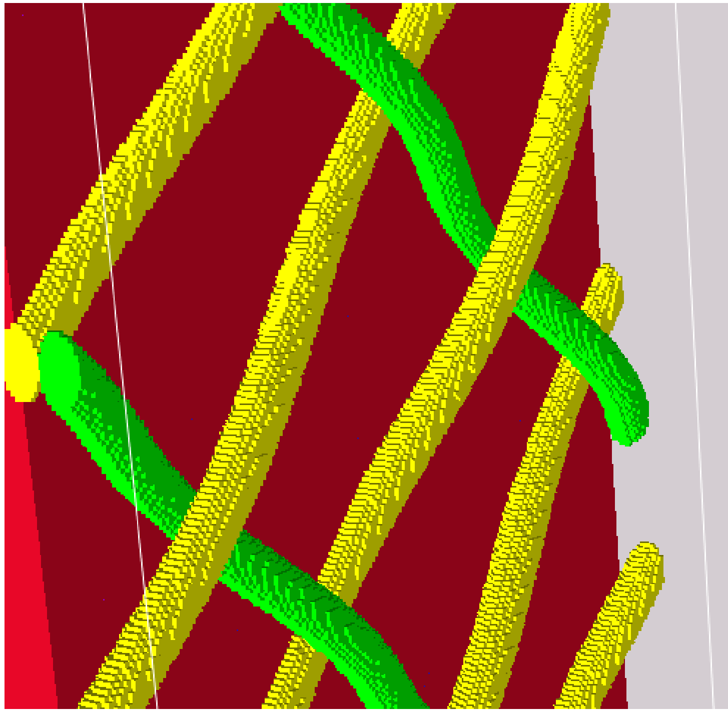
The PleatGeo Tool







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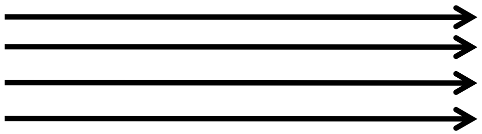
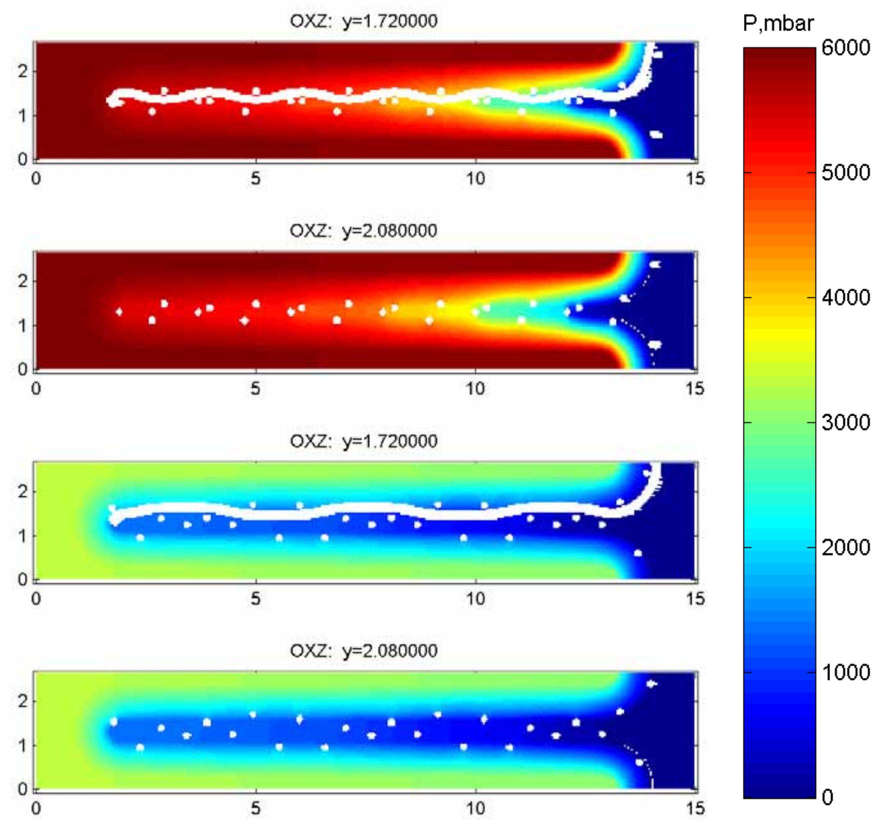
The effect of plain vs twill 2/2

Plain weave, 6 bar

flow



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



Work lead to patent by ARGO HYTOS