Computer aided development of hydraulic filter elements

-From theory to patent and products-

Andreas Wiegmann
Oleg Iliev
Andreas Schindelin

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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
Parameters for a hydraulic filter element

- Operating cost: Pressure Drop
- Operating cost: Dirt-holding capacity
- Protective function: Filter efficiency
- Disposal cost
- Acquisition cost
Consider pressure drop over a single pleat

Without support mesh, 2d model suffices
Consider pressure drop over a single pleat

Without support mesh, 2d model suffices
The Navier-Stokes-Brinkman equations for fluid flow

\[-\mu \Delta \vec{u} + \nabla \vec{u} \cdot \vec{u} + \kappa^{-1} \vec{u} + \nabla p = \vec{f} \text{ (momentum balance)}\]
\[\nabla \cdot \vec{u} = 0 \text{ (mass conservation)}\]
\[\vec{u} = 0 \text{ on } \Gamma \text{ (no-slip on fiber surfaces)}\]

\[\vec{f} = (0, 0, f) : \text{ force in flow(z)-direction,}\]
\[\kappa : \text{ porous voxel permeability,}\]
\[\vec{u} : \text{ velocity,}\]
\[\mu : \text{ fluid viscosity,}\]
\[p : \text{ pressure and}\]
\[\Gamma : \text{ surfaces of fibers or deposited particles.}\]

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

Oil pressure collapses pleats, this increases pressure drop

Wide outflow channel looses 1 bar over filter media

Narrow outflow channel looses 2 bars over filter media and channel

Pressure at 0.01 m/s
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
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
Plain weave creates a narrower outflow channel than twill 2/2
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

Operating cost: Pressure Drop

Operating cost: Dirt-holding capacity

Disposal cost

Protective function: Filter efficiency

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
Find out more:

www.itwm.fhg.de
www.geodict.com
www.argo-hytos.com