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Modeling a Nozzle in a Borehole

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Introduction

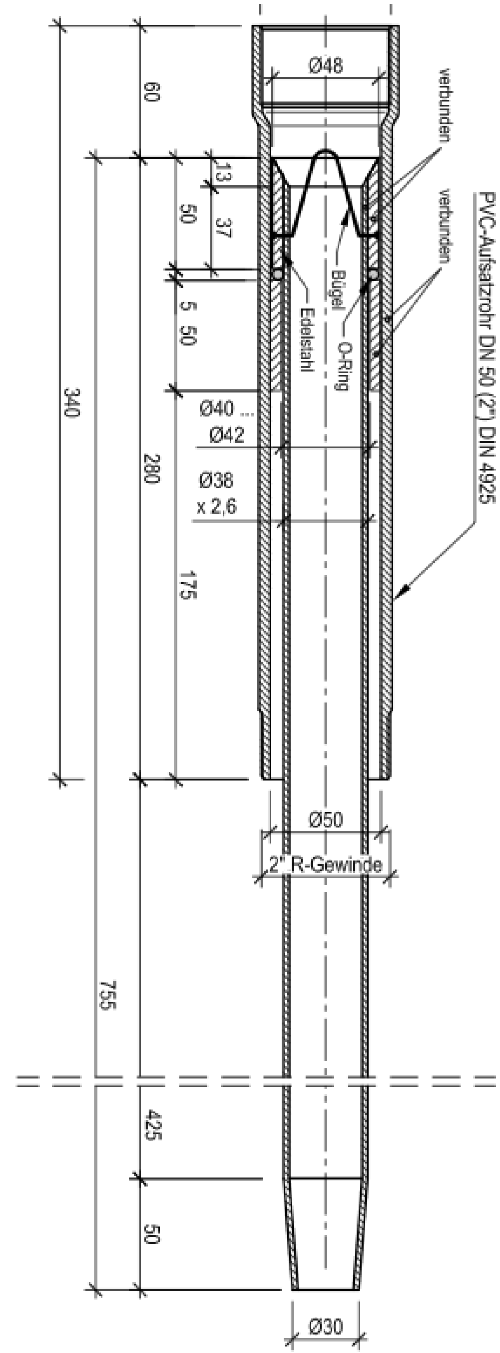
In several geo-technological applications water has to be infiltrated into the subsurface. We are investigating the DSI-method to enhance infiltration volume and speed.

A nozzle, installed in an injecting borehole, can enhance the infiltration rate into the subsurface porous medium significantly. Using Finite-Element simulations of turbulent flow we examine the effect of the nozzle and screen geometry on the flow field within the borehole. In a second step free flow in the borehole is coupled with porous media flow in the surrounding.

Nozzle 2“

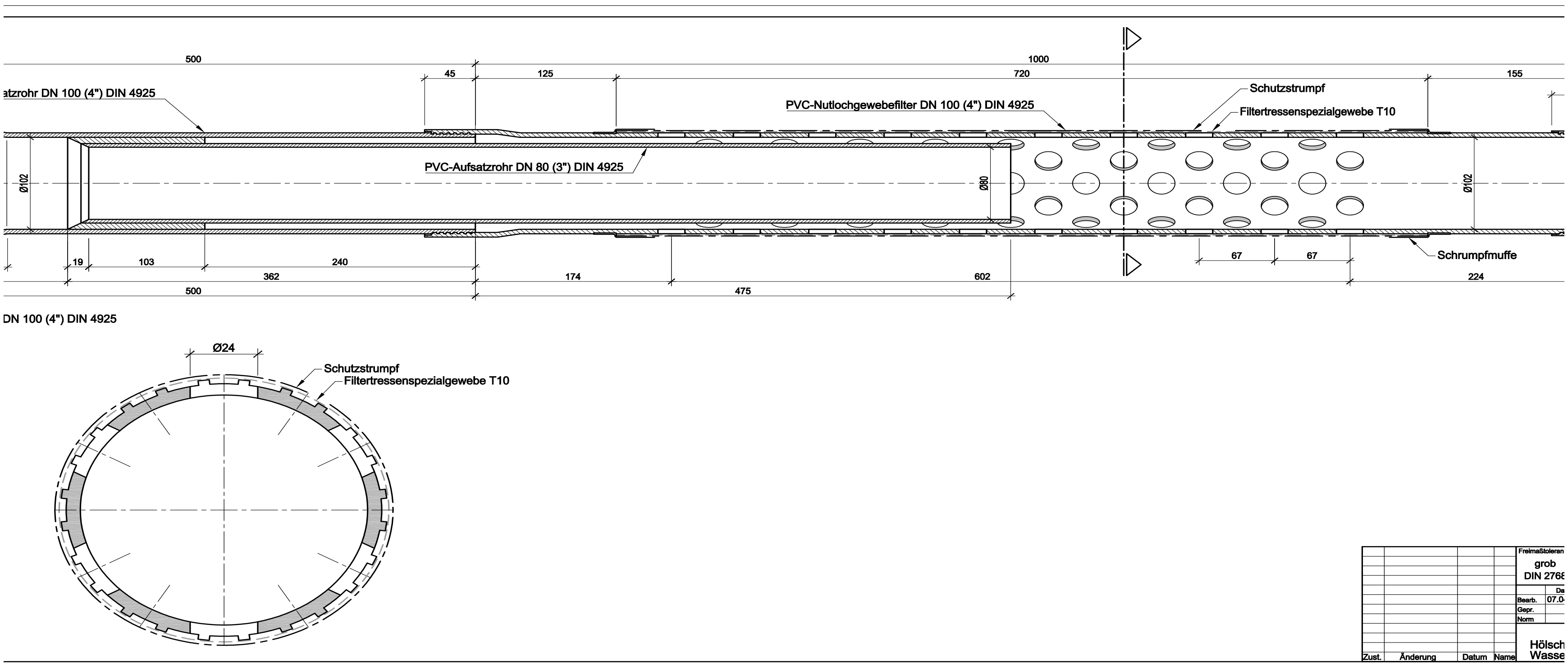
Flow from top to bottom

Without filters



Nozzle with Filter

(4“, horizontal)



Model Set-up

- **Parameters:**
- L 15[m] length comp1
- rp 0.08[m] pipe radius
- Qp 15[m^3/h] flow rate
- vp Qp/pi/rp/rp mean velocity
- Lp 0.5[m] pipe length before nozzle
- Ln 0.05[m] nozzle length
- rn 0.04[m] nozzle radius
- Le 0.5[m] length behind nozzle
- Lout 0.05[m] length below outlets
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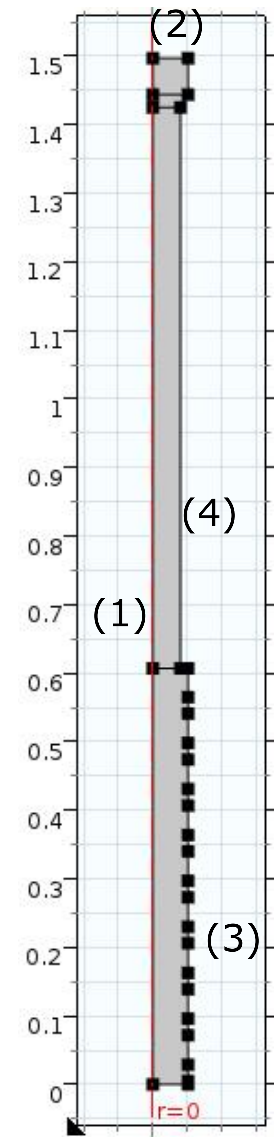
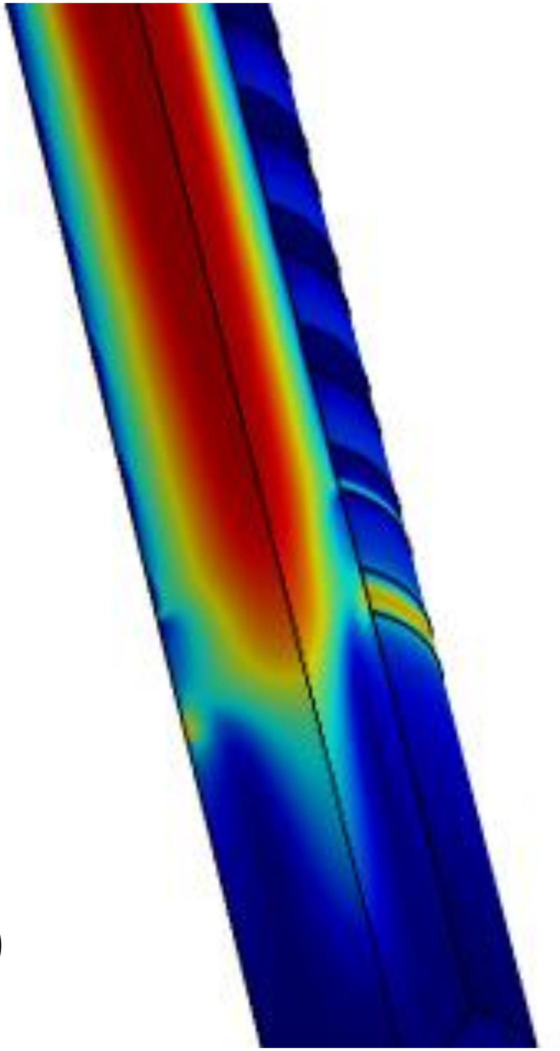
- **2D Radial Geometry**
- **k-epsilon, k-omega Modes**
- **Components Comp1:**
- Geometry: Rectangle, length L, radius rp
- Material: Water
- Fluid properties: from material (20° C)
- Initial values: p=0, v=w=0, kinit, epinit
- Boundary conditions:
- Axial symmetry (1)
- Wall (4): wall functions
- Inlet (2): velocity vp, turbulent intensity 0.05, turbulent length scale 0.01 m
- Outlet (3): p=0, suppress backflow



Model Sequence

Model	Geometry	Dimen-sion	Outlet	Porous medium
1	Simple	2D	bottom	no
2	2“ nozzle	„	„	„
3	„	3D	„	„
4	„	2D	rings	„
5	„	„	„	yes

Result Velocity Magnitude



Model 4

Velocity magnitude

High (red), low (blue)

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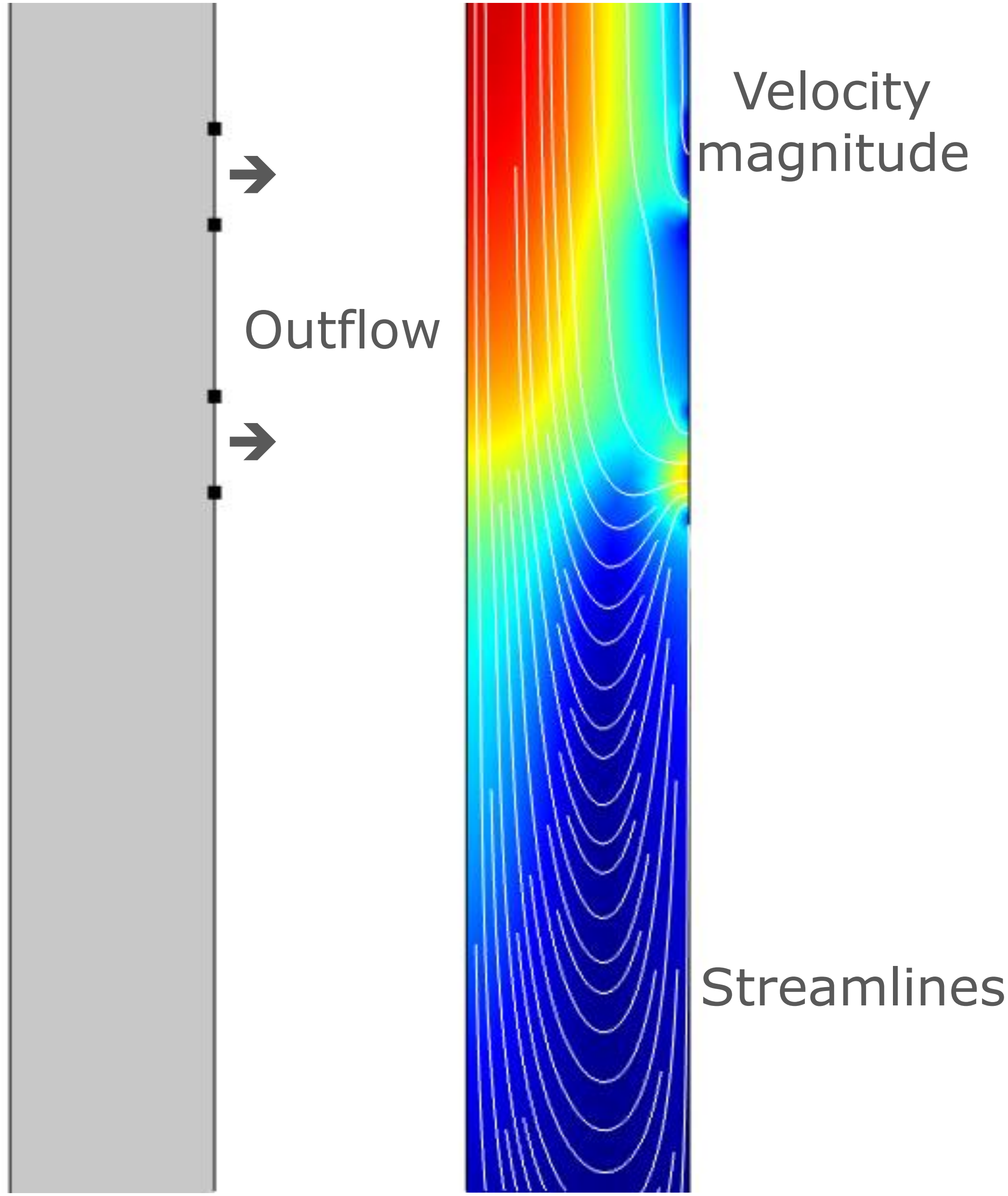
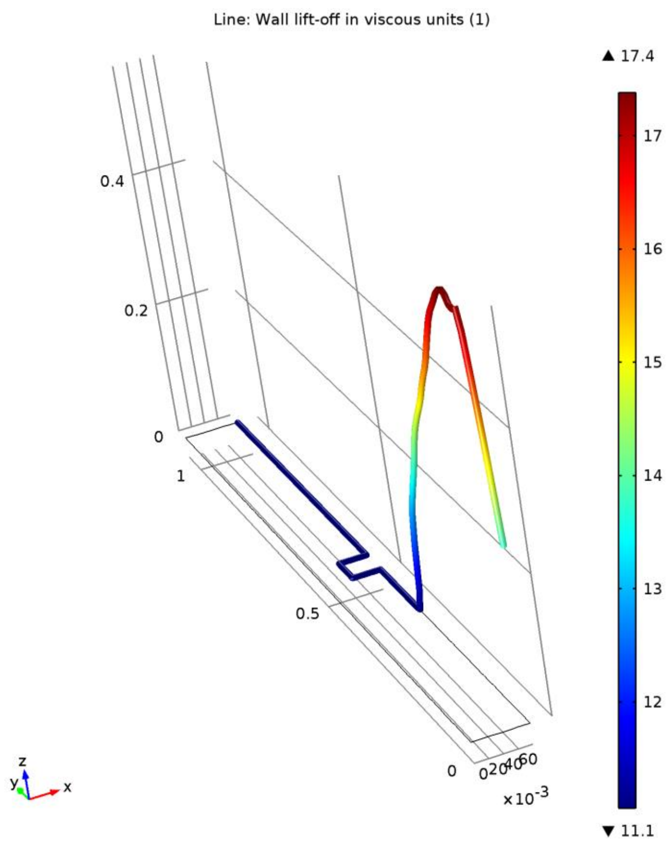
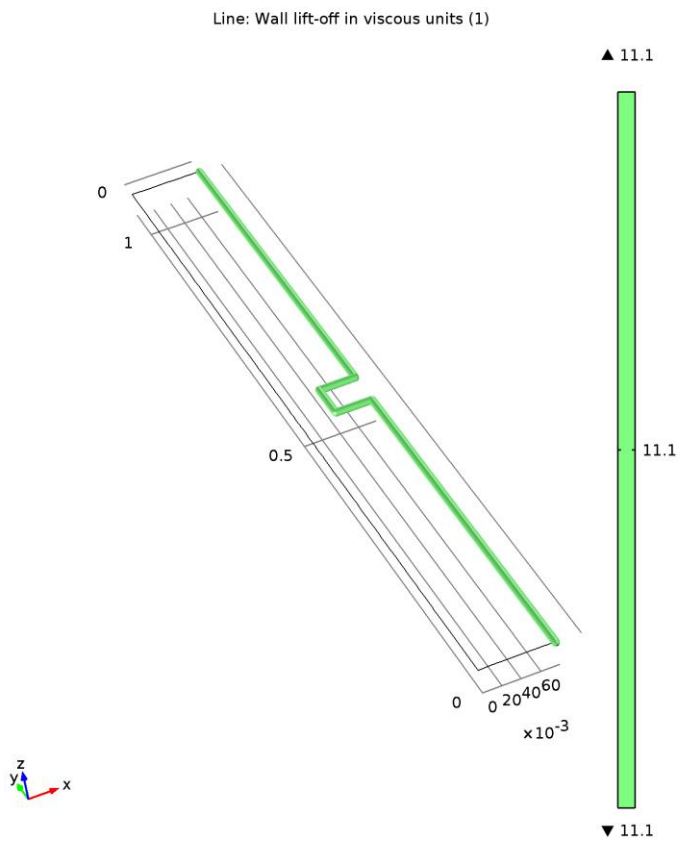
Result Streamlines



Model 4

+ # Turbulence Modes



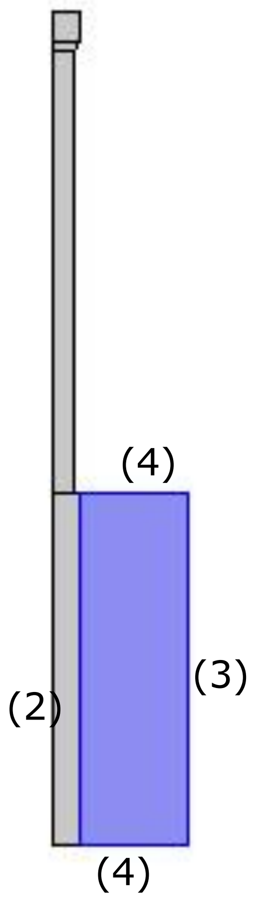


Wall lift-off, depending on turbulent closure; left: *k-ε*, right: *k-ω*

Coupling with Porous Medium

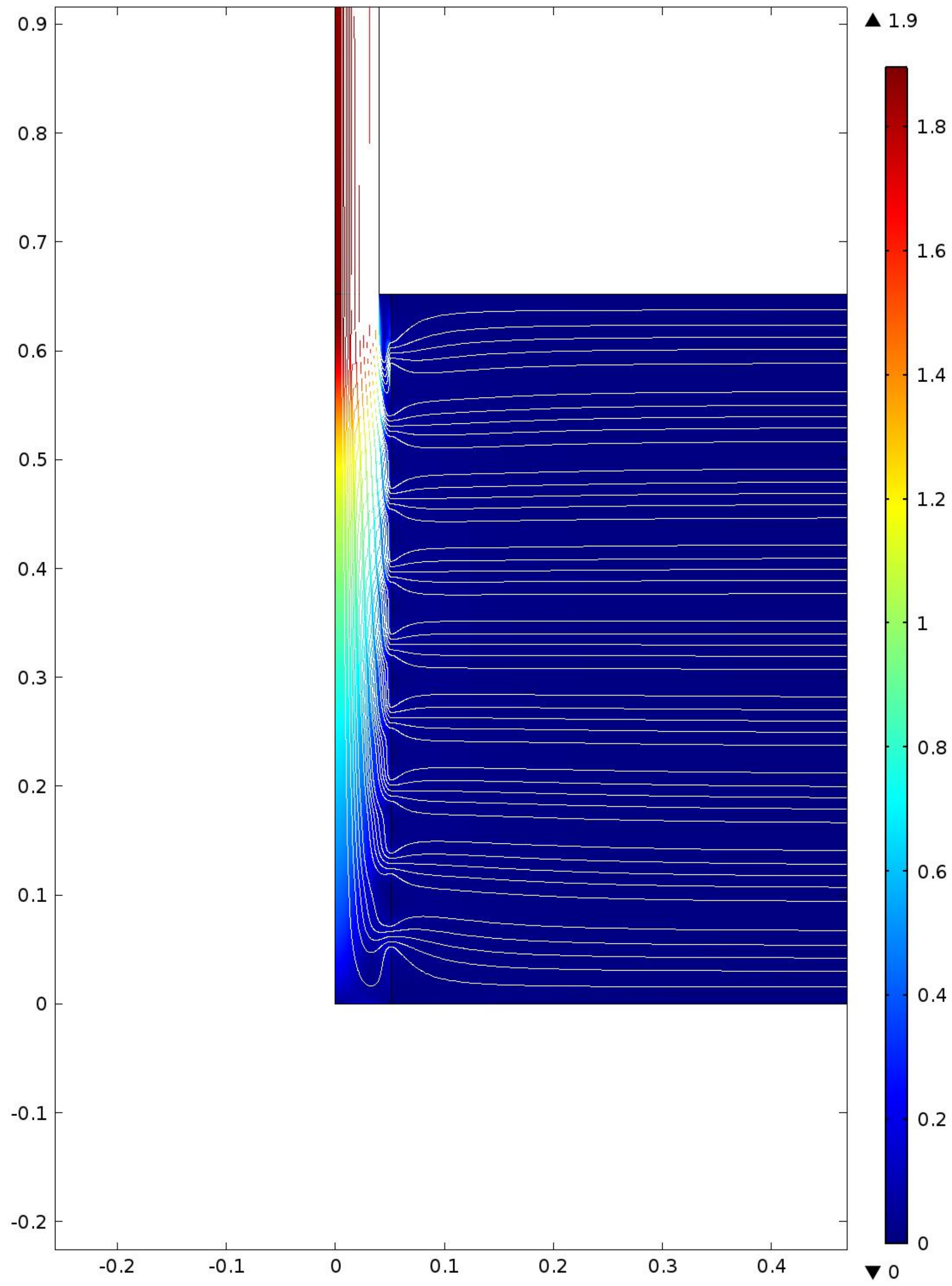
Parameters:
Lt 0.65[m] thickness
rpm 0.20[m] horizontal extension

2D Radial Geometry
Free and Porous Media Mode
Components Comp1:
Geometry: rectangle, length Lt, extension rpm
Material: Water
Fluid properties: from material (20° C)
Porosity: 0.25
Permeability: 10^{-10} m^2
Forchheimer drag: with/without
Initial values: p=0, v=w=0
Boundary conditions:
Wall (4): no slip
Inlet (2): velocity from free fluid model
Outlet (3): p=0



Result

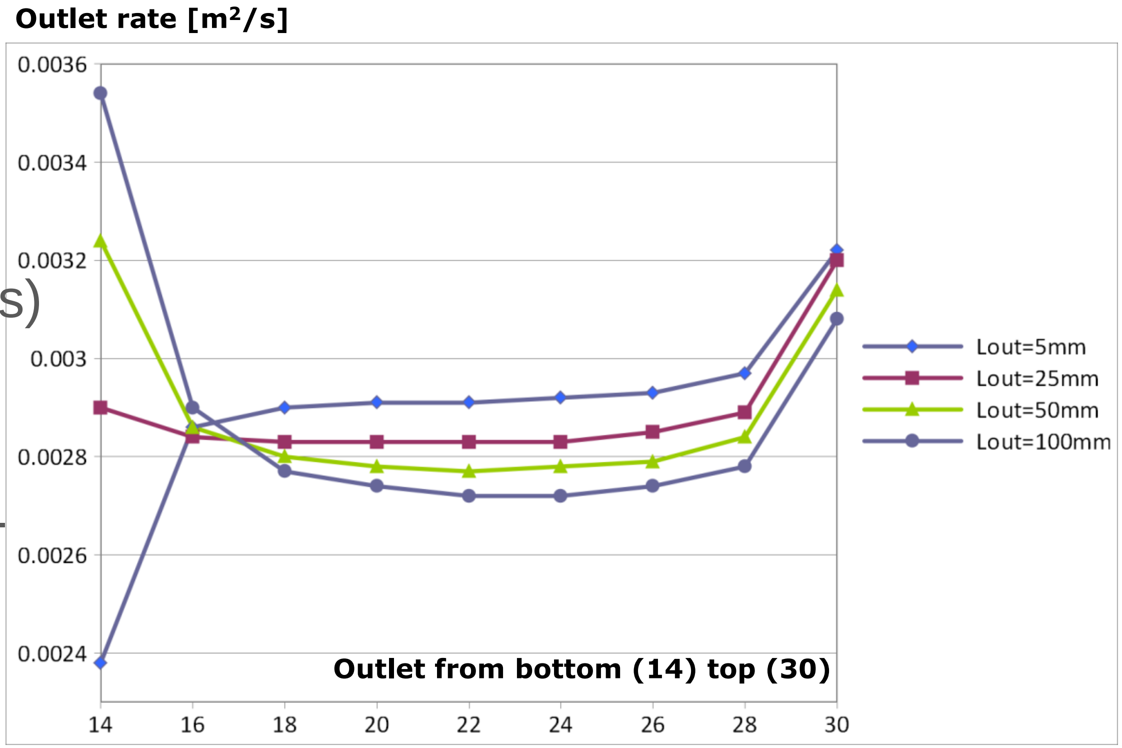
- Surface plot of velocity magnitude [m/s]
- Streamlines



Sensitivity

Examined, due to

- Permeability
- Porosity
- Lout (length below outlets)
- Friction coefficient
- Extension of porous sub-domain
- Pumping rates
- Forchheimer term



Conclusions

- Free laminar or turbulent flow in one sub-domain can be coupled with porous media flow in a connected sub-domain
- In free and porous media mode inertial terms and nonlinear Forchheimer terms can be considered as extensions of the linear Darcy-approach
- For slightly turbulent flow nonlinear terms have small effects only, and can be neglected
- Relatively small extension of porous media sub-domain (20 cm) already does not provide any disturbances from the outflow boundary condition
- Turbulence closure using k-ω works better than k-ε

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