NUMERICAL SIMULATIONS OF STOKES-BRINKMAN EQUATIONS FOR PEARMEABILITY PREDICTION OF DUAL-SCALE FIBROUS POROUS MEDIA

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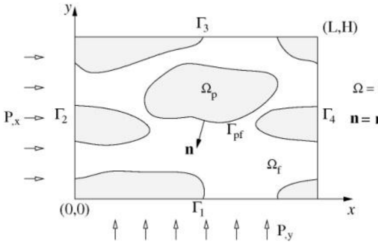
STOKES-BRINKMAN COUPLING

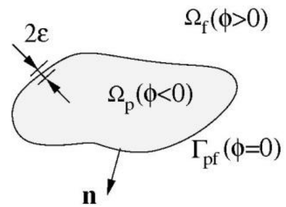


- ♦ Flow in a porous media with surrounding fluid
  - Need a unified approach for entire domain with proper interfacial condition
- ♦ Dual-scale flow problem in fibrous porous media
  - Stokes flow for surrounding (inter-tow) flows
  - Brinkman equation for porous media (intra-tow)
  - General interface condition between two media
  - Bi-periodic simulation (meso-scale)

EQUIVALENT MOMENTUM EQN

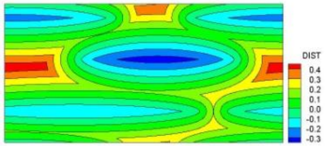
- ♦ Following a formalism of CSF (continuous surface force) scheme in two phase flow
  - A single momentum equation for both porous and fluid domains with inclusion of 'diffuse' interfacial stress jump

$$\nabla \cdot \boldsymbol{\sigma}^* - \alpha \frac{\eta_f}{K_p} \boldsymbol{u}^* + \frac{\eta_f}{\sqrt{K_p}} \boldsymbol{T} \cdot \boldsymbol{u}^* \delta(\phi(\boldsymbol{x})) = \mathbf{0}.$$



NUMERICAL METHODS

- ♦ Finite element formulation
  - Standard velocity pressure formulation
  - Level-set description for the porous media for easy treatment of complex geometry and interfacial conditions

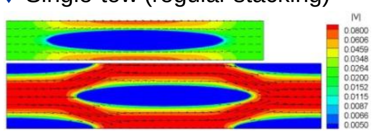


  - Matrix equations

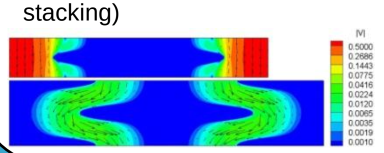
$$\begin{bmatrix} (K + M_D + M_J) & Q^T & \Lambda_H^T & \Lambda_V^T \\ Q & 0 & 0 & 0 \\ \Lambda_H & 0 & 0 & 0 \\ \Lambda_V & 0 & 0 & 0 \end{bmatrix} \begin{Bmatrix} \tilde{u} \\ \tilde{p} \\ \tilde{\lambda}^h \\ \tilde{\lambda}^v \end{Bmatrix} = \begin{Bmatrix} \tilde{f} \\ 0 \\ 0 \\ 0 \end{Bmatrix}.$$

FLOW IN DUAL-SCALE FIBROUS MEDIA

- ♦ Single-tow (regular stacking)

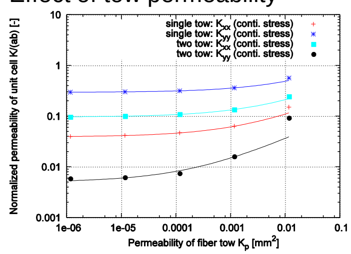


- ♦ Two-tow (squeezed hexagonal stacking)



EFFECTIVE PERMEABILITY

- ♦ Effect of tow permeability



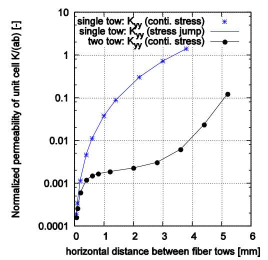
- ♦ Simple modeling

$Q_{slip} \,\square\, \sqrt{K_p}$ $Q_D \,\square\, K_p$ $\sqrt{K_p} \,\square\, K_p$

$$K \approx C_1 + C_2 \sqrt{K_p},$$

TOW ARRANGEMENT

- ♦ Considerable effect of distance between tows on the effective permeability is predicted.



CONCLUSIONS

- ♦ A new FEM scheme developed for rigorous flow simulation of dual-scale porous media
- ♦ In the future, we plan to apply particle deposition and filtration in dual scale porous media

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