April 8, 2005: Wrap up porous media, Deformation processing

Porous media: calculating K_1 starting with single tube average velocity:

$$u_{av} = \frac{Q}{A_{xs}} = \frac{\Delta P R^2}{8\mu L}. \tag{4.103}$$

Definitions:

- ω is pore volume fraction (so $1-\omega$ is solid volume fraction)
- S=area/vol
- S_0=area/solid vol=$S/(1-\omega)$
- R_h=hydraulic radius=fluid volume/wetting area $V_h/A_w = \omega/S_0(1-\omega)$.

Then said average fluid velocity in pores (fluid phase) is like tube flow:

$$\bar{V} = K_1 \frac{\Delta P' R_h^2}{L\mu};\ V_0 = K_1 \frac{\Delta P' R_h^2 \omega}{L\mu} = K_1 \frac{\nabla P' \omega}{L\mu} \frac{\omega^2}{S_0^2(1-\omega)^2}. \tag{4.104}$$

So set $\bar{V}$ equal to u_{av}:

$$K_1 \frac{\Delta P' R_h^2}{L\mu} = \frac{(P_1 - P_2)R^2}{8\mu L} \tag{4.105}$$

$$K_1 \left(\frac{R}{2}\right)^2 = \frac{R^2}{8} \tag{4.106}$$

$$K_1 = \frac{1}{2}. \tag{4.107}$$

For a packed bed of spheres, around 1/4.2 or 1/5, differences in literature.

This works for Stokes flow (laminar in tubes); how to define Reynolds number?

$$\mathrm{Re} = \frac{\rho \bar{V} R_h}{\mu} = \frac{\rho V_0}{\mu(1-\omega)S_0}, \tag{4.108}$$

For a friction factor, we get:

$$f_c = \frac{F_d}{KA} = \frac{\Delta P' \cdot A_{xs}\omega}{\rho \bar{V}^2 \cdot A_w} = \frac{\Delta P' V}{L} \frac{\omega^3}{\rho V_0^2 S_0 (1-\omega) V} = \frac{\Delta P' \omega^3}{L \rho V_0^2 S_0 (1-\omega)}. \tag{4.109}$$

For slow flow, substitute V_0 expressions to get $f_c = 4.2/\mathrm{Re}$; higher velocities get Ergun equation whose dimensionless version is:

$$f_c = \frac{4.2}{\mathrm{Re}} + 0.292. \tag{4.110}$$

Deformation Processing

- Non-Newtonian fluids, Viscoelasticity
- Deformation mechanisms: metals, polymers
- Stress-strain, sheet forming, stability
- Consolidation processes and mechanisms: sintering, HIP, compression molding