The flow of Herschel-Bulkley fluids

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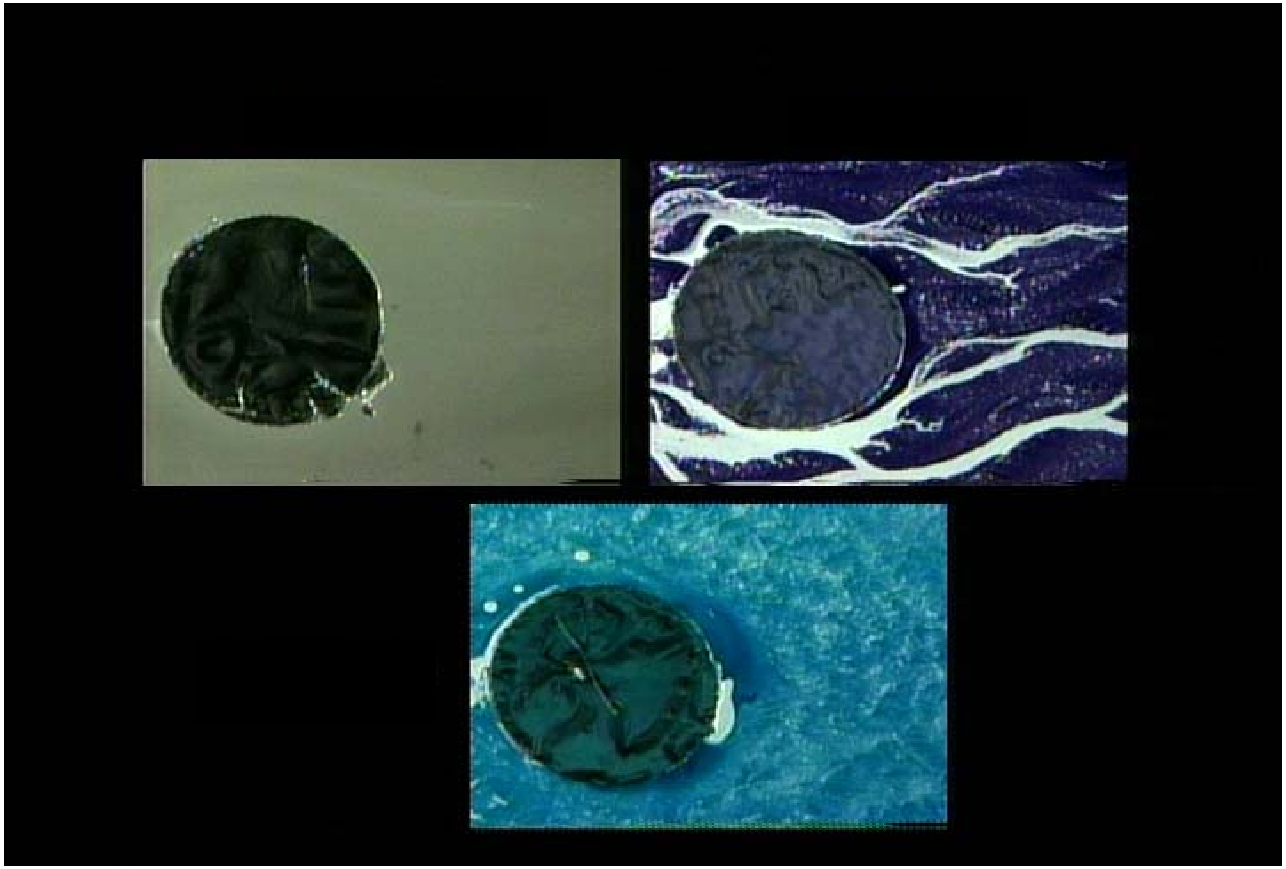
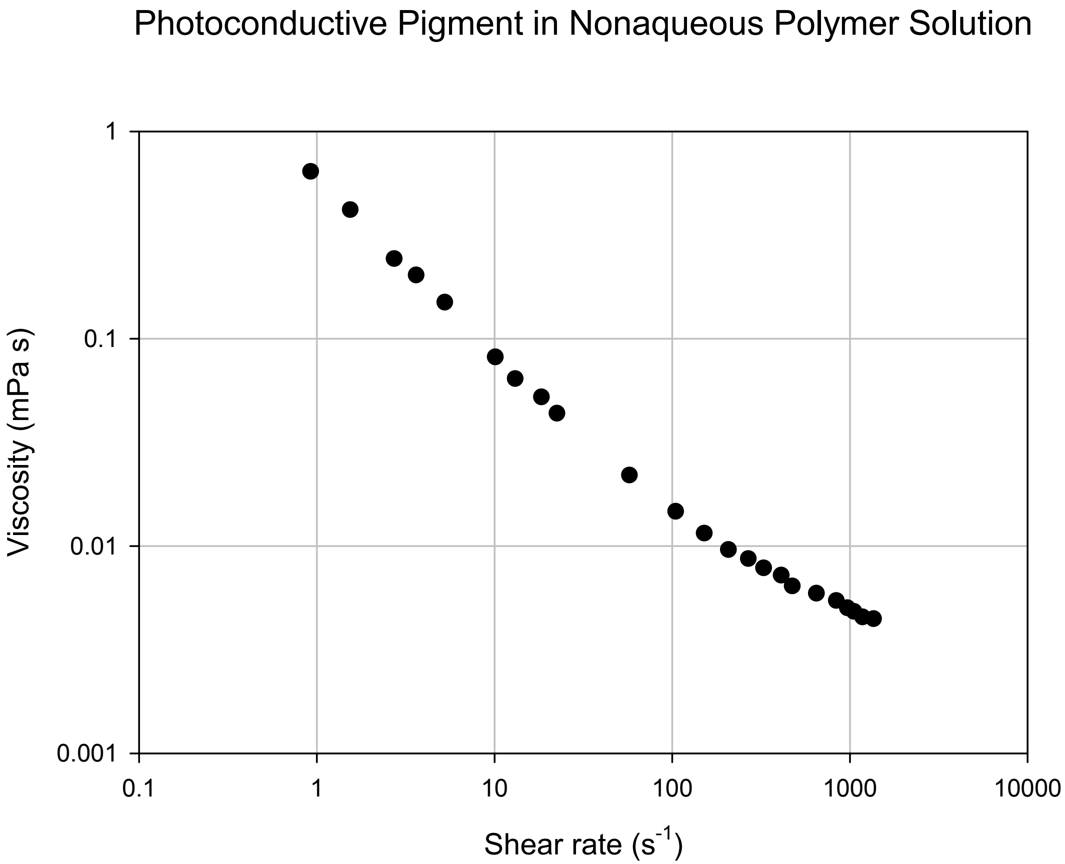
Thin polymer-filled layers coated from dispersions



Typical shear thinning rheogram

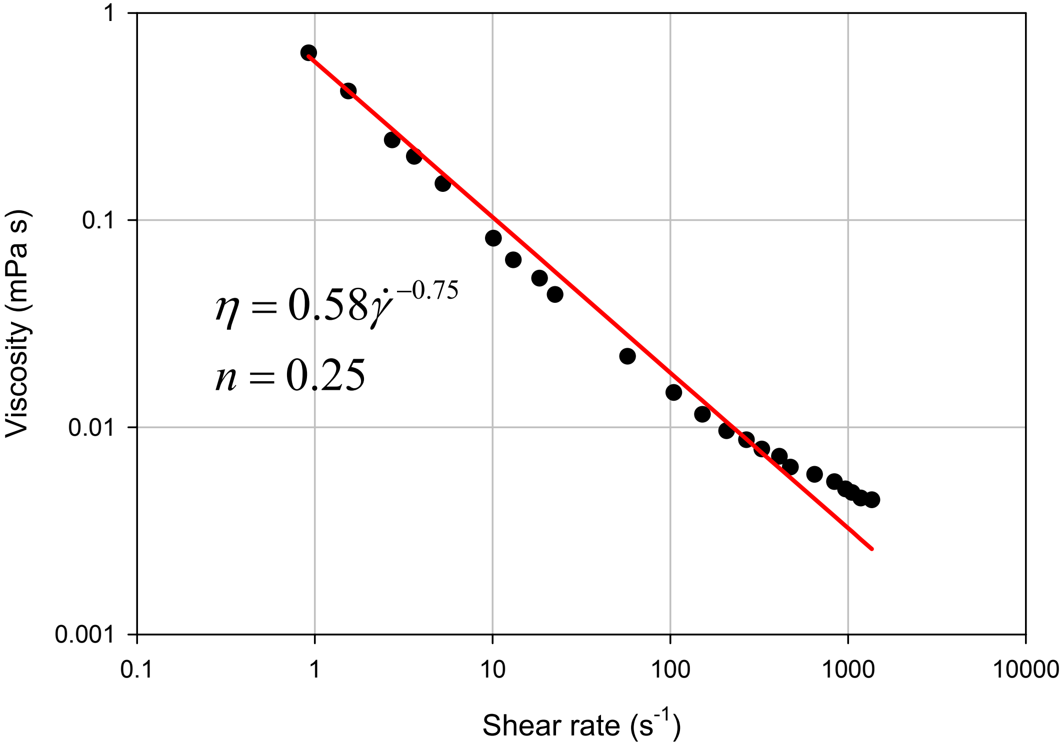


Data is reasonably fitted by a power law

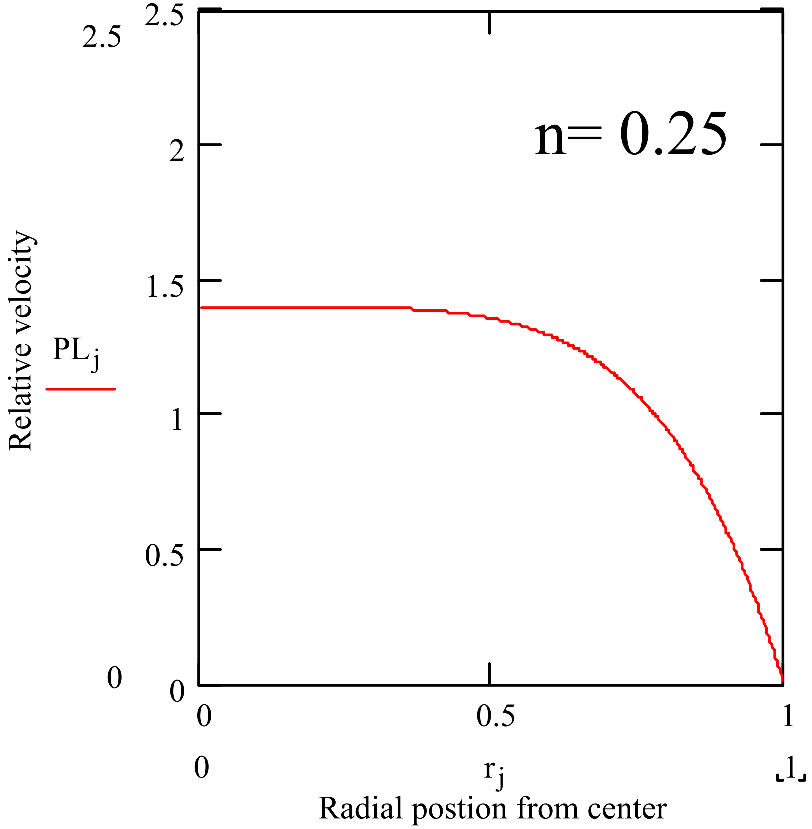
$$\eta = \eta_0 \dot{\gamma}^{n-1}$$

n is the power law index and is one for a Newtonian fluid.

Photoconductive Pigment in Nonaqueous Polymer Solution



The flow of a shear thinning liquid through a pipe

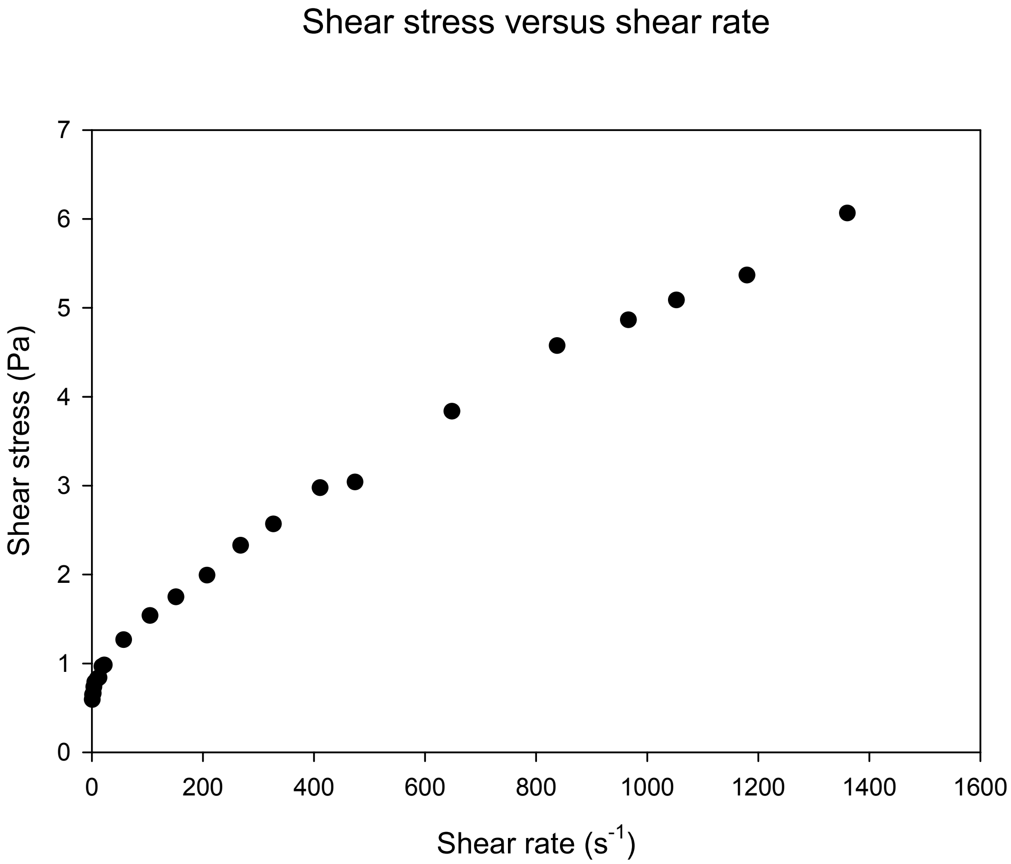


The reduced flow rate of a shear thinning liquid is:

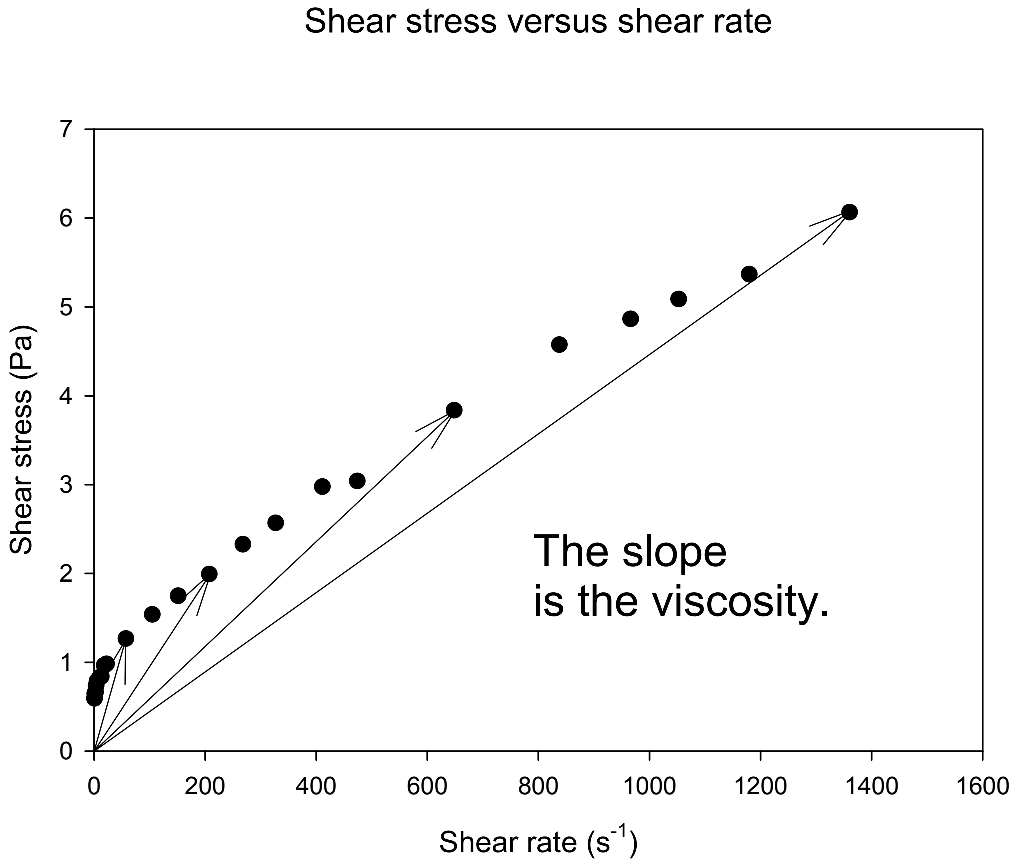
$$\bar{v} = \frac{1+3n}{1+n}\left[1-\left(\frac{r}{R}\right)^{\frac{1}{n}+1}\right]$$

Macosko, *Rheology*, pp. 88-89, 1994.

Same data replotted



How yield points approximate power law flow



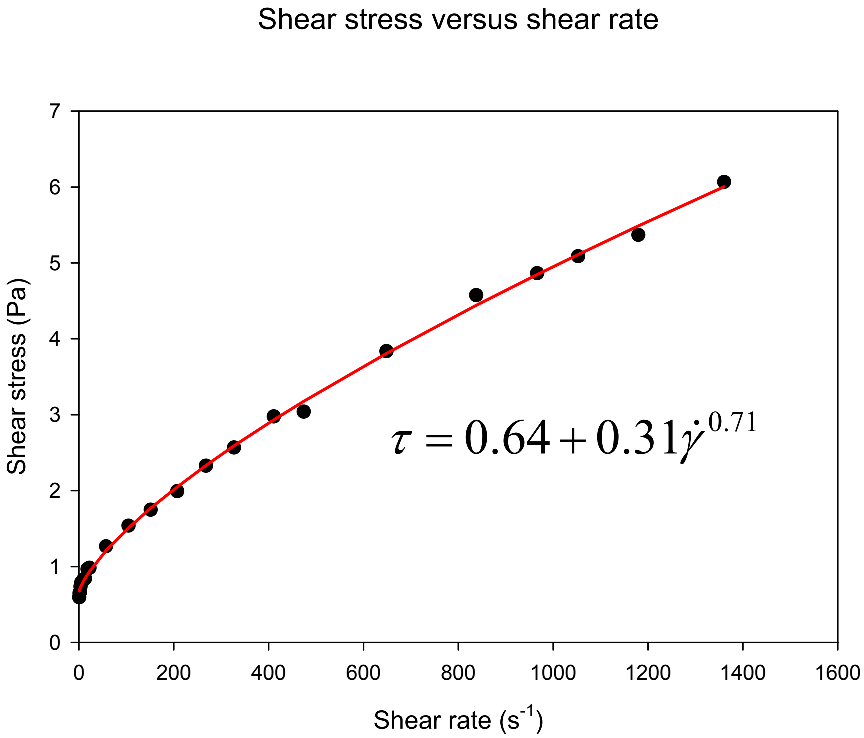
The slope
is the viscosity.

Herschel-Bulkley rheology

Model the flow as shear thinning above some yield point:

$$\tau = \tau_0 + m\dot{\gamma}^n$$

Note the value of "n" is now higher, apparently less shear thinning.



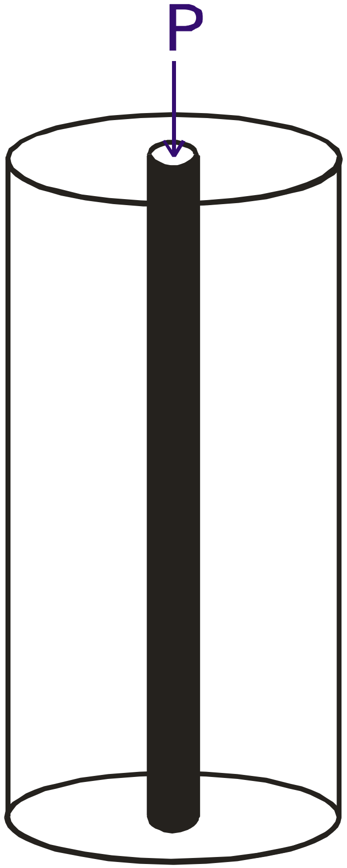
Effect of a yield point on flow

If a fluid has a yield point, τ_0, and is under pressure, *p*, a column of radius *r* and length *L* in the center moves as a plug. The plug radius can be calculated.

$$p = \frac{\tau_0(2\pi r L)}{\pi r^2} \text{ or}$$

$$r = \frac{2\tau_0 L}{p} = \frac{2\tau_0}{P}$$

P is the pressure drop.



Flow of an Herschel-Bulkley fluid through a pipe

$$r > \frac{2\tau_0}{P}$$

$$velocity = \frac{-P^2\left(3n+1\right)(2n+1)R^2((PR-\tau_0)^{-1/n}(\mathrm{Pr}-\tau_0)^{\frac{1+n}{n}} - PR + \tau_0)}{2n^2\tau_0^3 - R^3P^3 + 2n\tau_0^2RP + \tau_0R^2P^2n - 2R^3P^3n^2}$$

$$else$$

$$velocity = \frac{2\left(1-\frac{\tau_0}{RP}\right)^2}{\left(1-\frac{4}{3}\frac{\tau_0}{RP}+\frac{1}{3}\left(\frac{\tau_0}{RP}\right)^4\right)}$$

Flow of Herschel Bulkley fluid

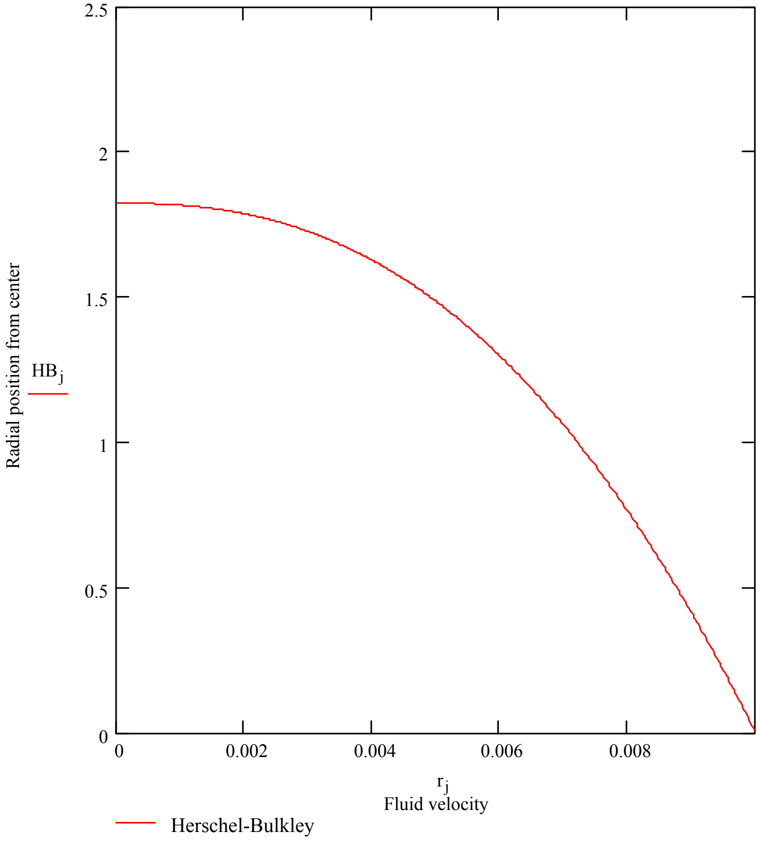
The fitted Herschel-Bulkley parameters:

$n = 0.75$

$\tau = 0.5$ Pa

with a reasonable pressure drop

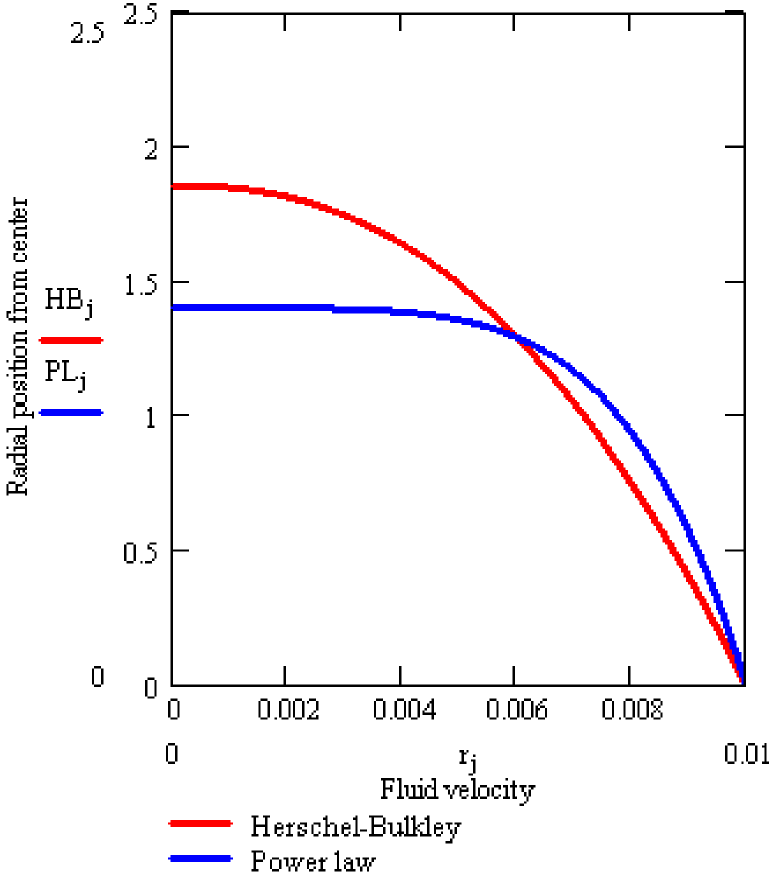
$P = 10^6$ Pa/0.1m



Note: The radius of the plug is:

$$r = \frac{2\ x\ 0.5\ \text{Pa}}{10^5\ \text{Pa}/0.1m} = 1\mu m$$

Comparison of predicted flows: Power law and Herschel-Bulkley



Some Problems Require More Study

Surface Energy Characterization of Fibers, Fillers and Paper

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