Lab #3
Viscometry
Outline

• Goals of lab
• Flow behavior curve for time-independent fluids
• Rotational viscometer (Newtonian fluid)
• Rotational viscometer (non-Newtonian fluid)
• Flow behavior for a shear thinning fluid
Goals of Lab

- Determine the viscosity of a Newtonian fluid
- Determine the rheological properties of a non-Newtonian fluid
Flow Behavior for Time-Independent Fluids
(Herschel-Bulkley Model for Shear Stress vs. Shear Rate)

\[ \sigma = \sigma_0 + K(\dot{\gamma})^n \]

\( \sigma = \) Shear stress (Pa)
\( \sigma_0 = \) Yield stress (Pa)
\( \dot{\gamma} = \) Shear rate (s\(^{-1}\))
\( K = \) Consistency coeff. (Pa s\(^n\))
\( n = \) Flow behavior index

*Newtonian*
\( \sigma_0 = 0, \ n = 1 \)
Then, \( K = \mu \)

Herschel-Bulkley Model: \( \sigma = \sigma_0 + K(\dot{\gamma})^n \)
Power-law Model: \( \sigma = K(\dot{\gamma})^n \)
Rotational Viscometer (Newtonian Fluid)

• Principle
  – Measure torque [a measure of shear stress ($\sigma$) in Pa] versus rpm [a measure of shear rate ($\dot{\gamma}$) in s$^{-1}$]
  – Use equation below to calculate viscosity

$$
\mu = \frac{T}{8\pi^2 NL \left( \frac{1}{R_i^2} - \frac{1}{R_o^2} \right)}
$$

T: Torque (N$\cdot$m)
N: Revolutions per second (s$^{-1}$)
L: Spindle length (m)
$R_i$, $R_o$: Radius of spindle, cup resp. (m)

Plot “T” on y-axis versus “N” on x-axis. The slope of this graph is “$8\pi^2 L \mu/[1/R_i^2 - 1/R_o^2]$”. Obtain $\mu$ from this.
Rotational Viscometer (Non-Newtonian Fluid)

**Principle**

- Sophisticated viscometers can be used to determine shear stress [(\(\sigma\)) in Pa] versus shear rate [(\(\dot{\gamma}\)) in s\(^{-1}\)]

- Basic viscometers yield only torque versus rpm data

- From shear stress and shear rate values, the Herschel-Bulkely model (\(\sigma = \sigma_0 + K \dot{\gamma}^n\)) can be used to determine the rheological parameters (\(\sigma_0, K,\) and \(n\))
Flow Behavior for a Shear Thinning Fluid

This graph shows the shear-thinning behavior:

\[ \sigma = K \dot{\gamma}^n \]

\[ \ln(\sigma) = \ln(K) + n \ln(\dot{\gamma}) \]

Plot \(\ln(\sigma)\) on y-axis versus \(\ln(\dot{\gamma})\) on x-axis.

- Slope = \(n\)
- Intercept = \(\ln(K)\)

This graph can be used to determine ‘\(K\)’ and ‘\(n\)’:

\[ n = \text{Slope} \]

\[ K = e^{\text{Intercept}} \]