How to measure viscosity with a hand mixer

Viscosity can be determined using an electric hand mixer by measuring the stress through the electric power and strain rate through the rotational velocity. All that is needed is a hand mixer, an electric power meter and a cell phone.

Mats Stading, RISE Research Institutes of Sweden and Chalmers University of Technology

Systemic Rheology is a method for extracting rheological data using geometries such as stirrers. It requires calibration by a Newtonian and a non-Newtonian fluid with known properties.

Start by selecting the two calibration fluids, in this example a Newtonian syrup and a shear thinning jam. The Newtonian viscosity of the syrup η_{syrup} and the Power Law parameters K_{jam} and n_{jam} were determined using a rheometer.

Equations

Strain (or rate) constant: $F_{\dot{\gamma}}=\dot{\gamma}/\Omega$
Stress constant: $F_{\sigma}=\sigma/P$
Ratio: $F_m = F_{\sigma} / F_{\dot{\gamma}}$
where $\dot{\gamma}$ denotes shear rate, σ shear stress, P electrical power and Ω angular velocity.

Step 1: Determine F_m

Measure electrical power for each speed without a sample and note this empty power. Measure electrical power for the **Newtonian calibration fluid** and subtract the empty power for each step. Determine the angular velocity from a slow-motion recording for each step, one revolution is 2π radians. Plot P vs. Ω. The slope will be slope = η_{syrup}/F_m as $F_m = F_{\sigma} / F_{\dot{\gamma}} = \sigma/ \dot{\gamma}\ \Omega/P = \eta_{syrup}\ \Omega/P$

Step 2: Determine F_{σ} and $F_{\dot{\gamma}}$

Measure electrical power for the **shear-thinning calibration fluid** and subtract the empty power, and determine the angular velocity . Select a point (P_1, Ω_1) and use F_m to calculate $\eta_1 = F_m P_1/\Omega_1$.
Then use the known Power Law parameters to calculate $\dot{\gamma}_1$ from $\eta_1=K_{jam}\dot{\gamma}_1^{n_{jam}-1}$.
Finally calculate $F_{\dot{\gamma}} = \dot{\gamma}_1/\Omega_1$, and $F_{\sigma} = F_m/F_{\dot{\gamma}}$

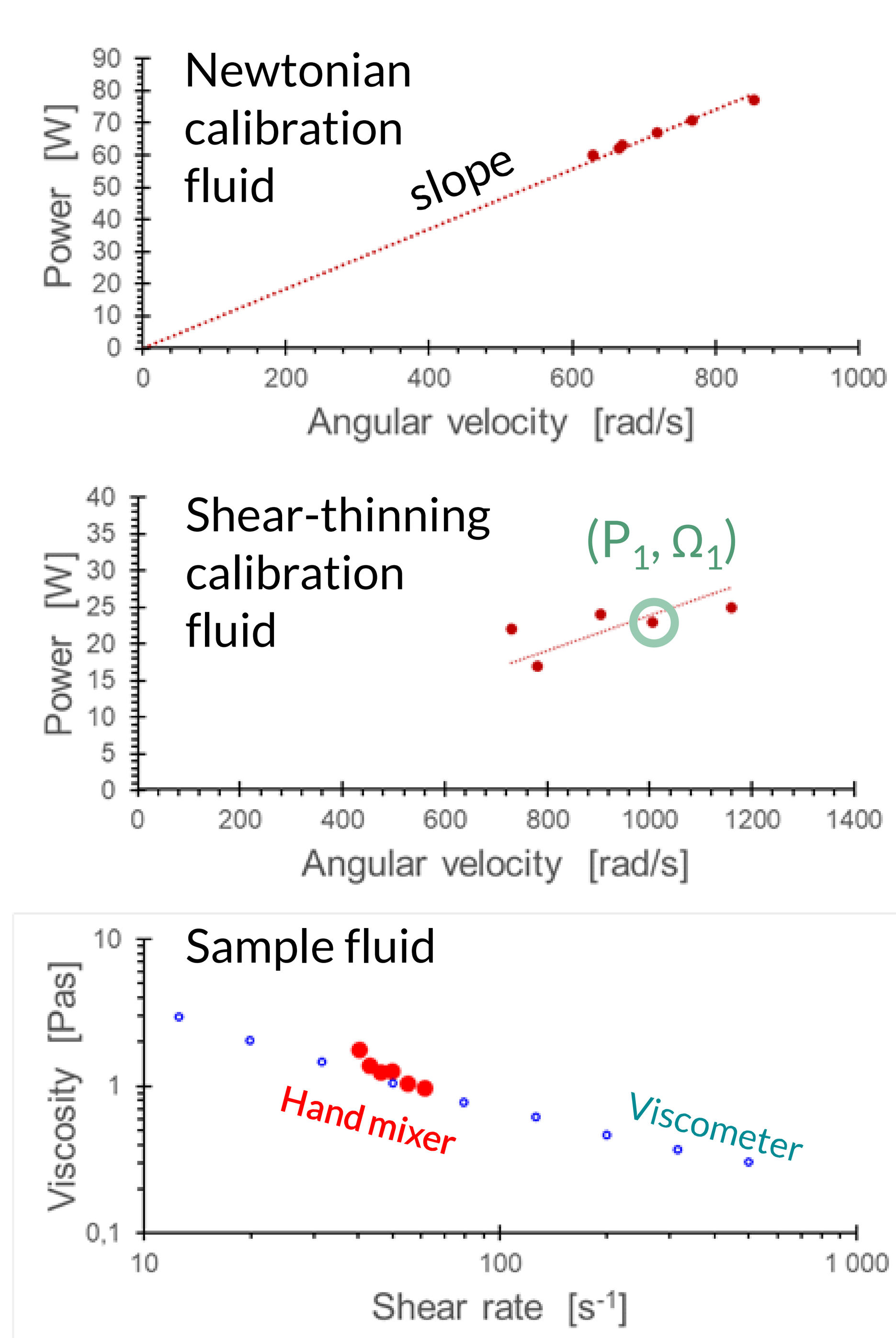
Step 3: Measure viscosity of your sample

Measure electrical power for the **sample fluid** and subtract the empty power, and determine the angular velocity . Use $F_{\dot{\gamma}}$ to calculate shear rate from angular velocity and F_{σ} to calculate stress from power.

Improvements

A dimmer can be added to reach lower velocity and a standard bike velocimeter can be attached to measure rotational velocity.

Setup for measuring viscosity using an electric hand mixer and an electric power meter.



Step 1-3 for determining viscosity. Top: Newtonian fluid. Centre: Shear-thinning fluid. Bottom: Sample fluid data from the hand mixer and a viscometer as reference.

CONCLUSIONS

The hand mixer setup is capable of determining viscosity of viscous fluids. Accuracy increases with viscosity, and with a narrow gap between the mixer and the beaker.

The bottom line is that this proof-of-concept shows how useful Systemic Rheology can be in an industrial setting for mixers, characterization of inhomogeneous fluids as well as for monitoring reactions.

References

Systemic rheology is developed and well described by Professor L. Choplin. See e.g.
L. Choplin and P. Marchal, (2010) "Mixer-type Rheomety" in EOLSS, *Rheology Volume 2*, EOLSS Publishers Co. Ltd., www.eolss.net

RISE Research Institutes of Sweden
www.ri.se / info@ri.se

CONTACT
Mats Stading
Mail: mats.stading@ri.se
Phone: +46 10 516 6637