TECHNISCHE UNIVERSITÄT DRESDEN

Faculty Mechanical Engineering, Chair of Magnetofluiddynamics, Measuring and Automation Technology

Weekly task – some solutions:

Experiments with complex fluids

Experiment 1

A shear thickening liquid

Experiment 1: A shear thickening liquid

The starch-water system is a colloidal suspension. In such suspensions particles, suspended in the liquid interact with each other if the suspension is sheared.

In suspensions with a high volume fraction of suspended material this interaction becomes extremely strong – which is not dilatancy (as it is often named in literature). Dilatancy yields shear thickening, but shear thickening can appear without dilatancy!

Adding small amount of water gives rise to a change of volume concentration of suspended material and since viscosity depends highly non linear on volume concentration and in addition hydrodynamic interaction depends non linear on volume concentration too, already a small amount of water can lead to a significant decrease of viscosity.

This nonlinear dependence is technically important since it allows significant reduction of viscosity by small changes of fluid composition!

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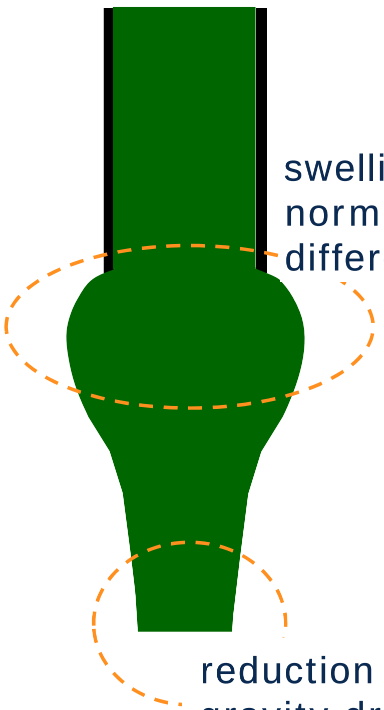
Experiment 2

The shape of a free liquid jet

Experiment 2: The shape of a free liquid jet



swelling due to normal stress differences

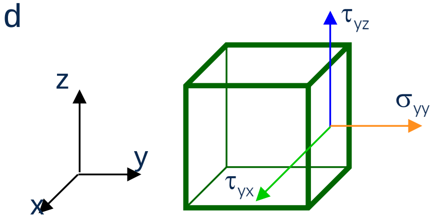
reduction due to gravity driven acceleration

Normal stress differences:

- disappear in a fluid at rest
- due not change with direction of fluid motion
- cause deformation of a volume element of the fluid

$$N_1 = \sigma_{xx} - \sigma_{yy} \qquad N_{i(\dot\gamma)} = \nu_{i(\dot\gamma)}\dot\gamma^2$$

$$N_2 = \sigma_{yy} - \sigma_{zz} \qquad \lim_{\dot\gamma\to 0} \nu_{i(\dot\gamma)} = \nu_{i0} \neq 0$$



Derivation:

- calculate change of impulse at the nozzle due to the action of σ_{zz}
- radial equation of motion provides σ_{zz}

$$\frac{r_0^2}{r_s^2} = \frac{4}{3} - \frac{4\left(2\nu_{10} + \nu_{20}\right)}{\rho r_0^2}$$

r_0: radius of the tube, r_s: maximum radius of jet

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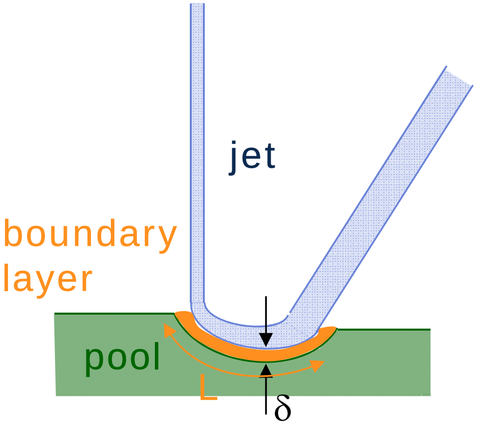
Experiment 3

A bouncing liquid stream

Experiment 3: A bouncing liquid stream



Explanation for the Kaye-effect (given by D. Lohse in 2006):

Strongly shear thinning liquid forms a shear thinning layer between jet and pool
fluid looeses energy here, resulting ina thicker jet emerging from the pool

$$R_{in} = \left(\frac{\dot{m}}{\pi \rho v_{in}}\right)^{1/2} \qquad \dot{\gamma} = \frac{v}{\delta} \qquad \eta_{(\dot{\gamma})} = \eta^{\infty} + \frac{\eta^{*} - \eta^{\infty}}{1 + \left(\frac{\dot{\gamma}}{\dot{\gamma}^{*}}\right)^{n}} = \eta^{\infty} + \eta^{*}\dot{\gamma}^{*}\frac{\delta}{v} \qquad (n=1)$$

Energy balance

dissipation causes change of kinetic energy

critical entrance velocity

$$v_{in} = \left(\frac{\pi}{\rho \dot{m}}\right)^{1/3} \left(\frac{3}{2}\eta^{*}\dot{\gamma}^{*}L\right)^{2/3}$$