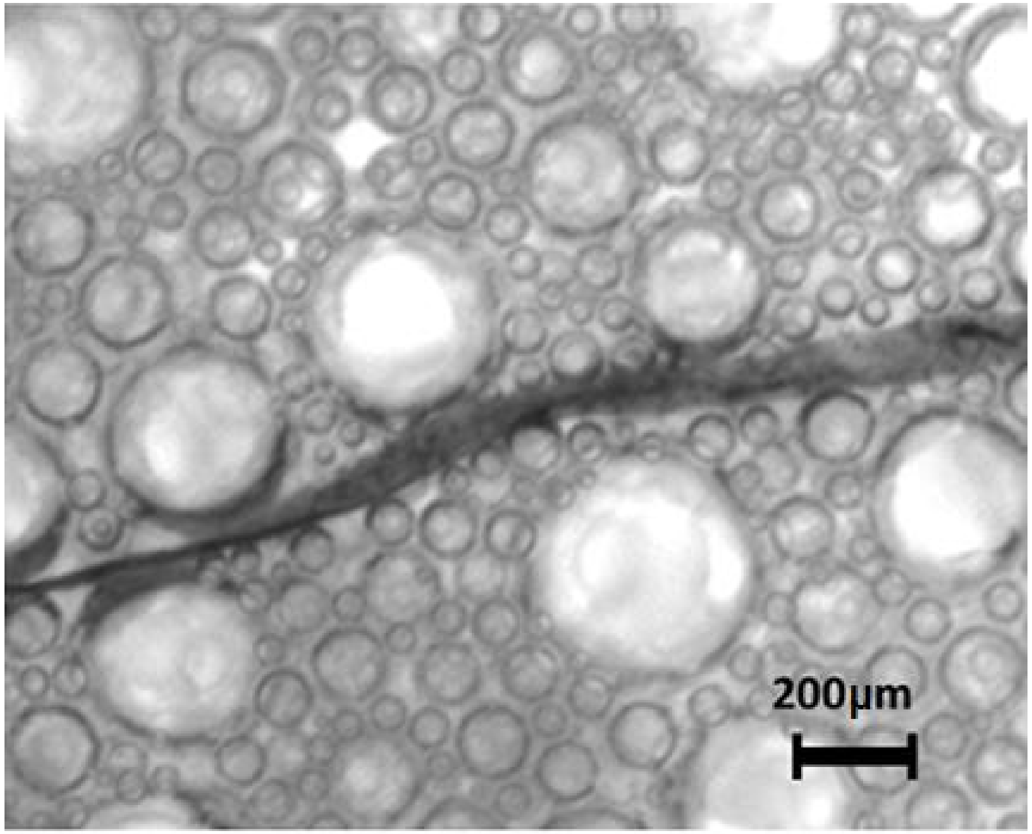


Direct measurements of rheology of fiber foams

Ari Jäsberg
Pasi Selenius
Antti Koponen
VTT Technical Research Centre of Finland

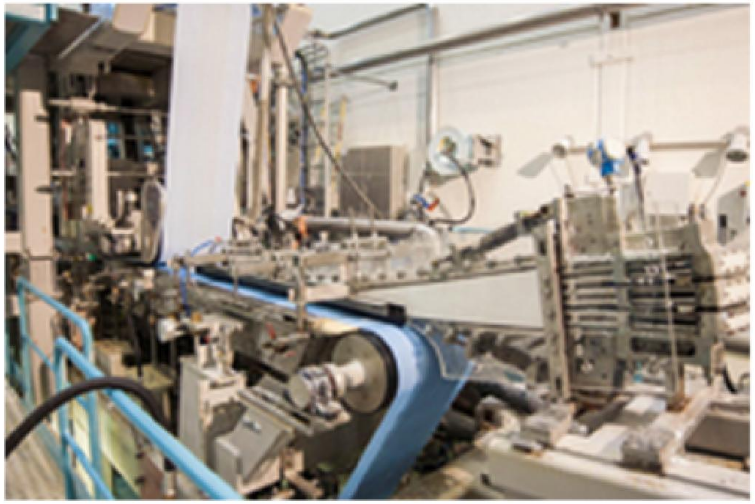
WORKING GROUP 1, EXPERIMENTAL METHODS

cost
Project supported by COST - European Cooperation in Science and Technology

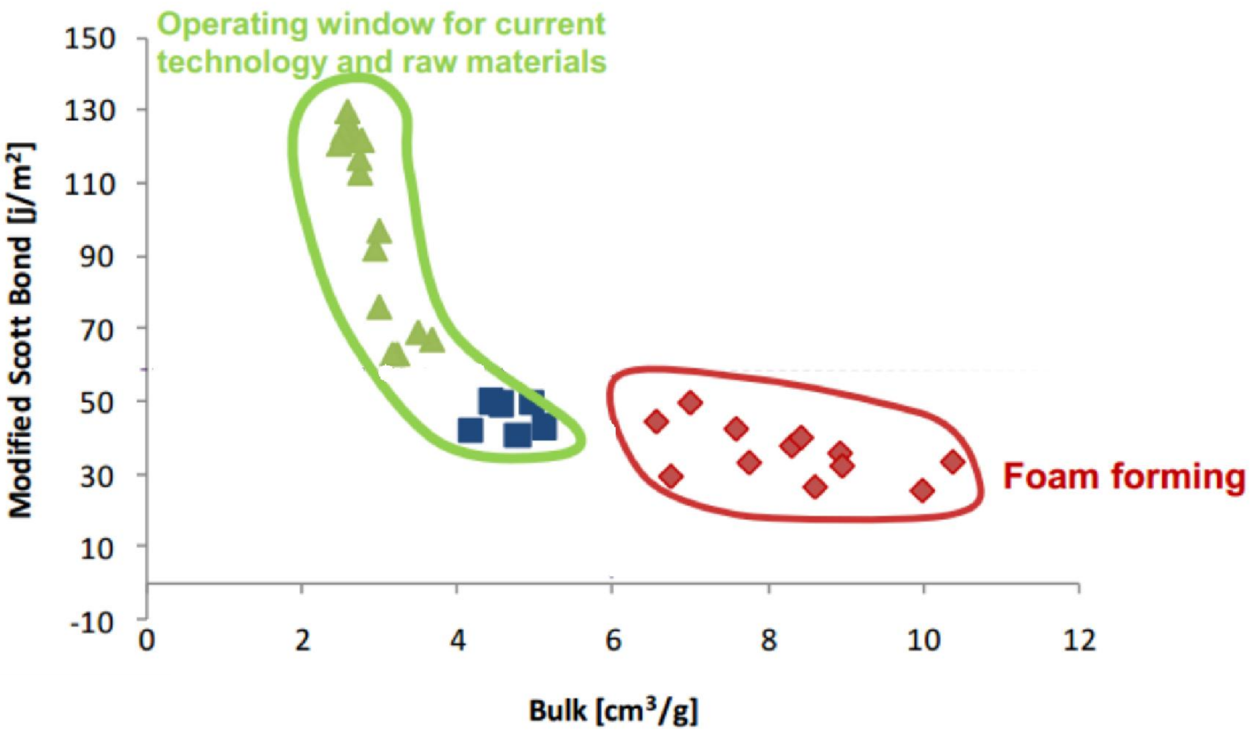
COST FP1005 "Fibre Suspension Flow Modelling"

Motivation:

Foam forming

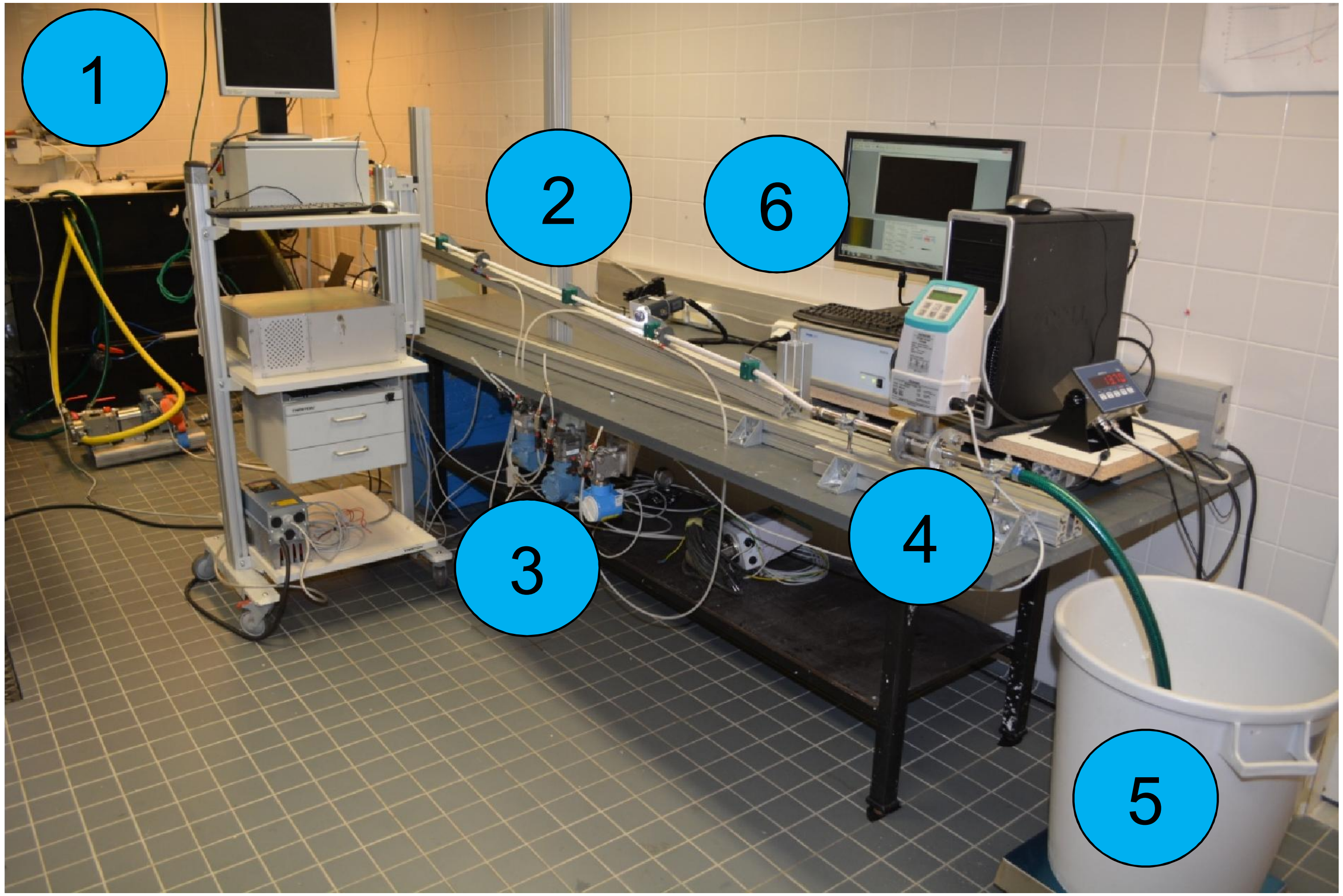


Foam forming can be used for marked expansion of the selection of natural fibre-based, recyclable and lighter products, and the achievement of substantial savings in production costs. The world's first industrial-scale foam forming research environment will be constructed for VTT to support the product development of companies.



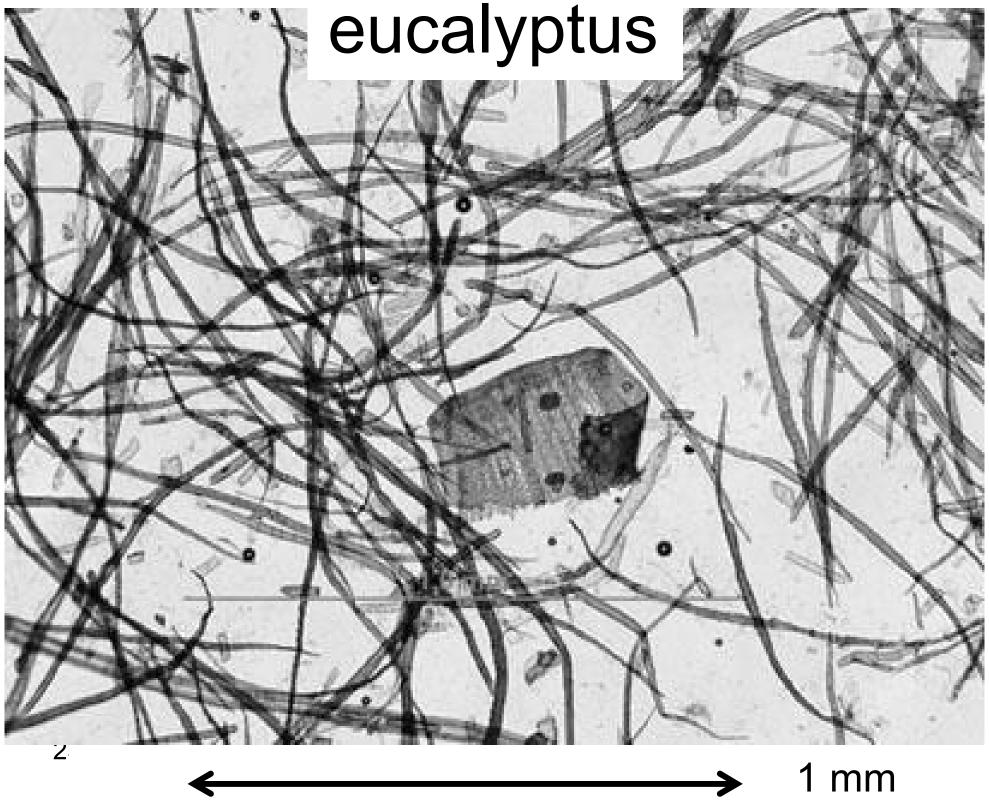
Measurement setup

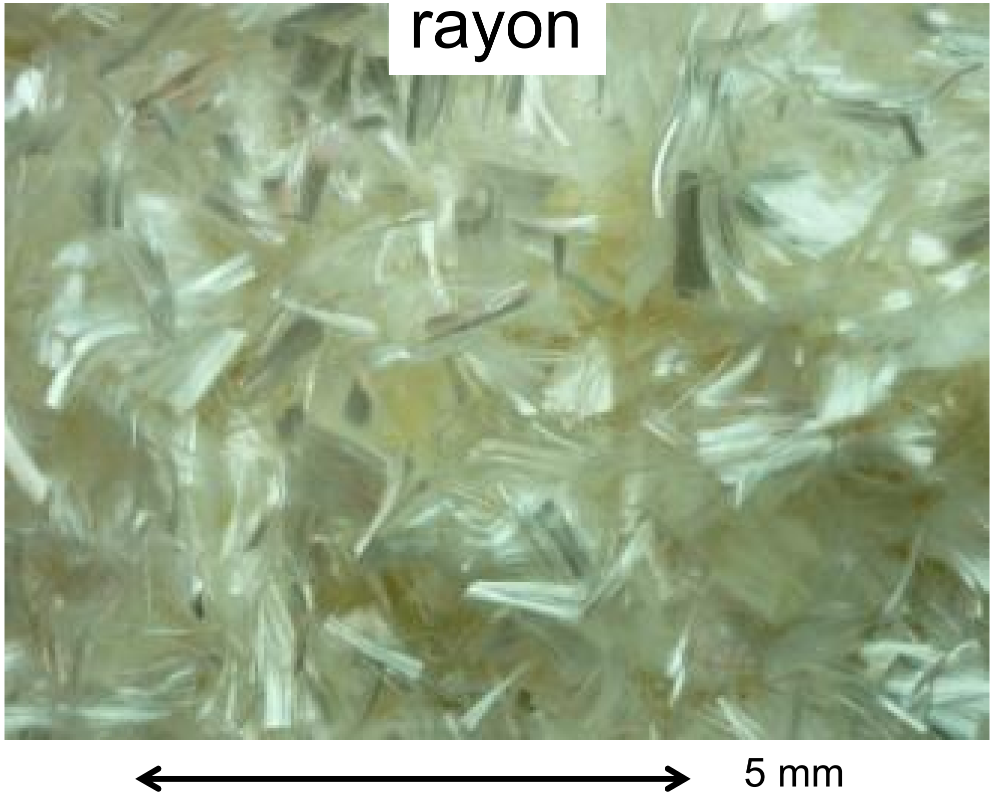
1. Foam generation with **temperature control**
2. Flow pipe, D = 15 mm
3. Pressure drop and pressure level
4. Flow rate
5. Mass flow rate
6. High speed video -> **slip velocity at the wall**



Materials

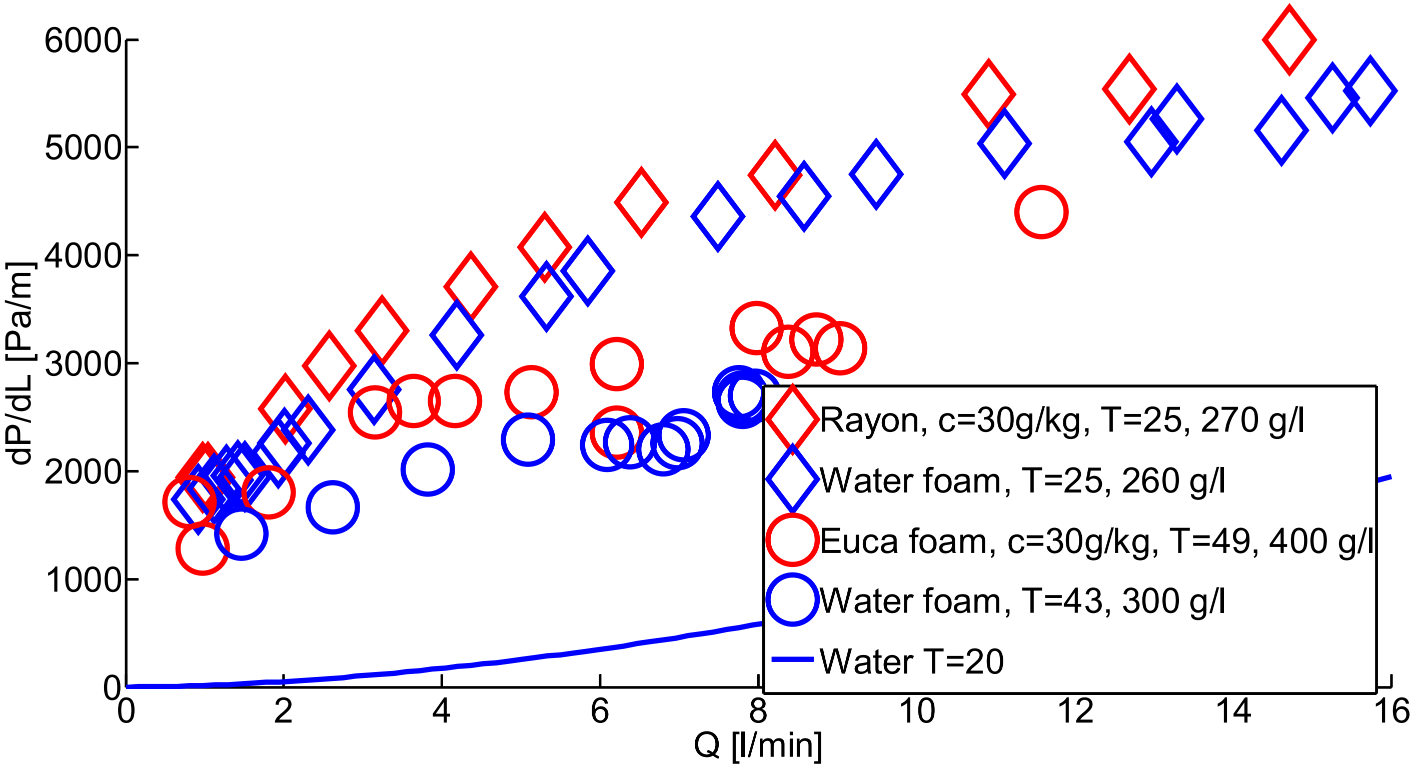
- Water foam: solution of water and sodium dodecyl sulfate (SDS), concentration 2.5 g/kg, target value for the foam density 250 - 300 g/l, bubble size is ca. 40 μm.
- Eucalyptus fibres, c_{max} = 30 g/kg
- Rayon fibres, c_{max} = 72 g/kg (length close to the mean length of euca fibres, ca.1 mm)





Pressure loss measurements

Loss data: euca & rayon

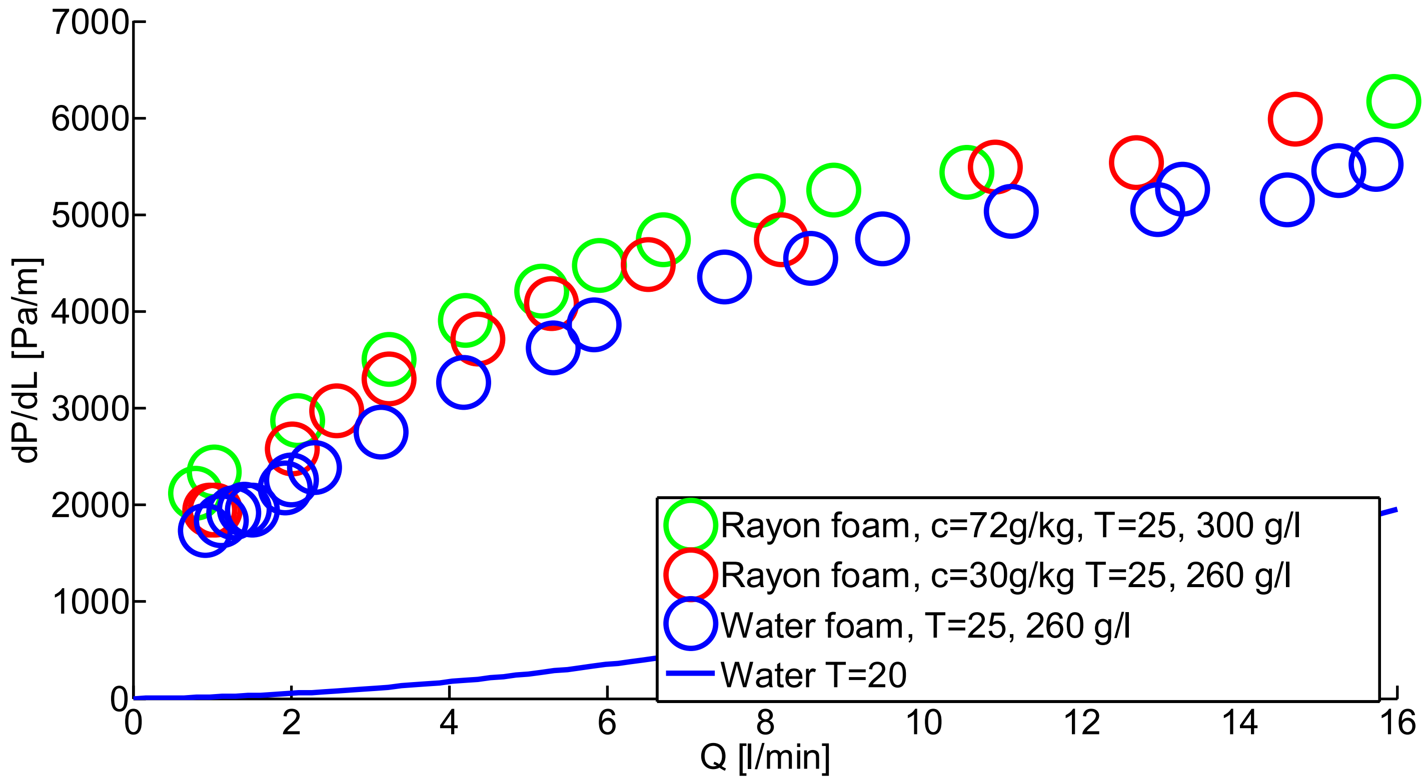


Pressure losses much higher than for pure water.

Fibers increase the pressure loss.

Temperature control obligatory.

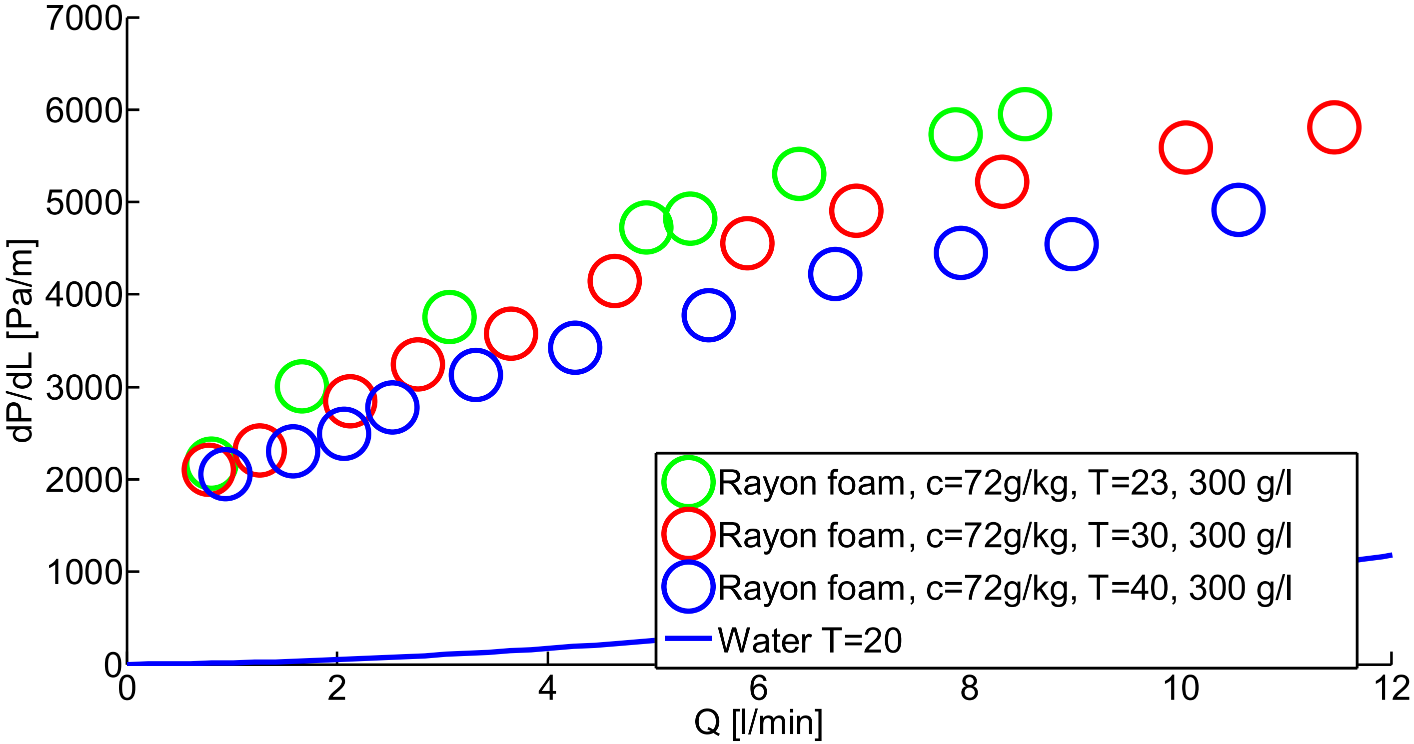
Loss data: rayon, effect of consistency



Addition of 72 g/kg of rayon fibres gives an increase of 500-1000 Pa/m in the pressure gradient,

Clearly smaller effect than with 30g/kg of euca fibres.

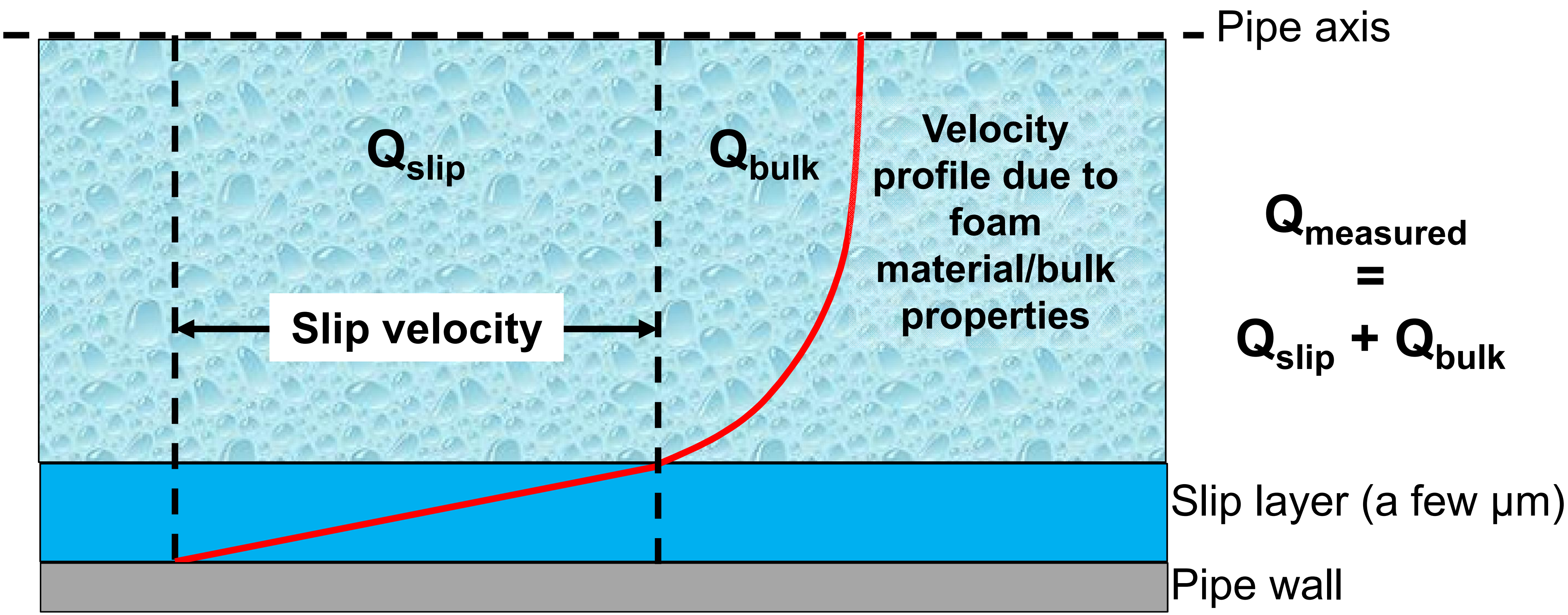
Loss data: rayon, effect of temperature



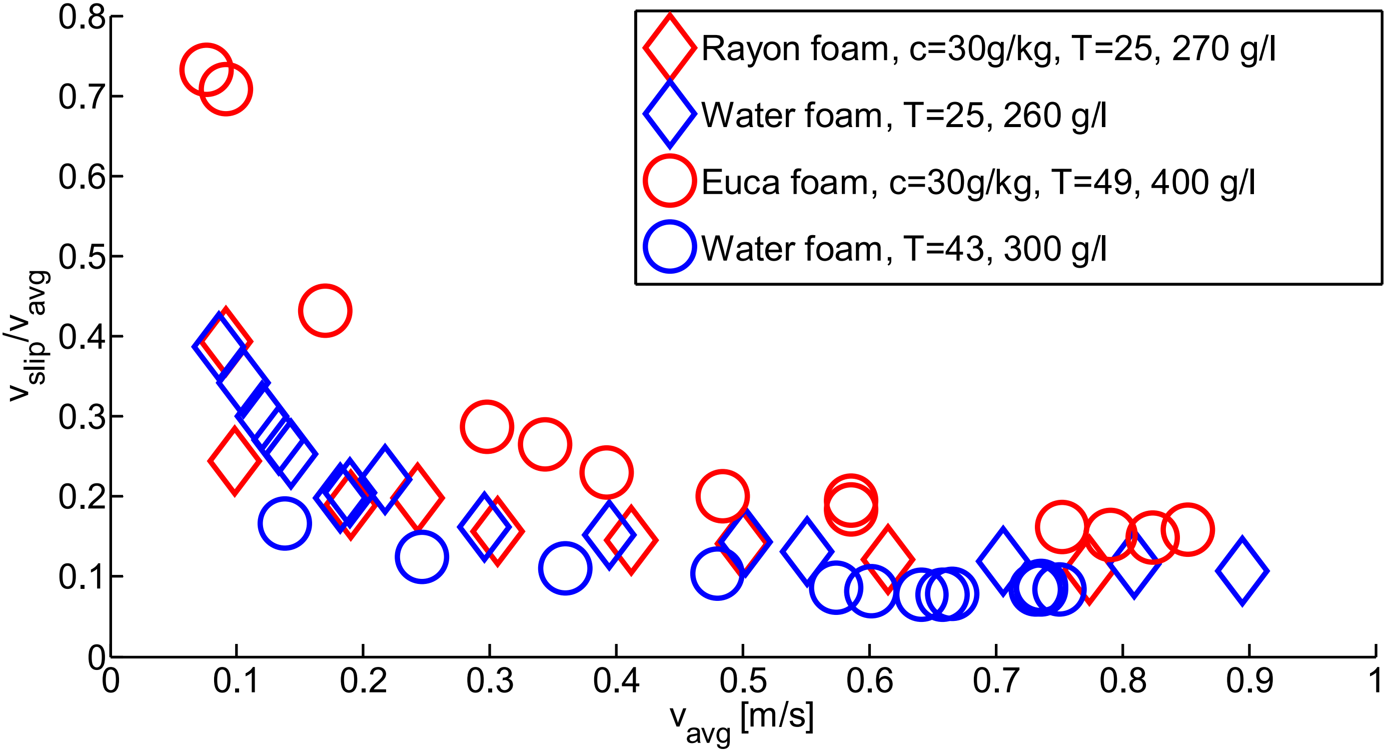
Loss decreases with increasing temperature.

Wall slip

Slip layer & material/bulk properties



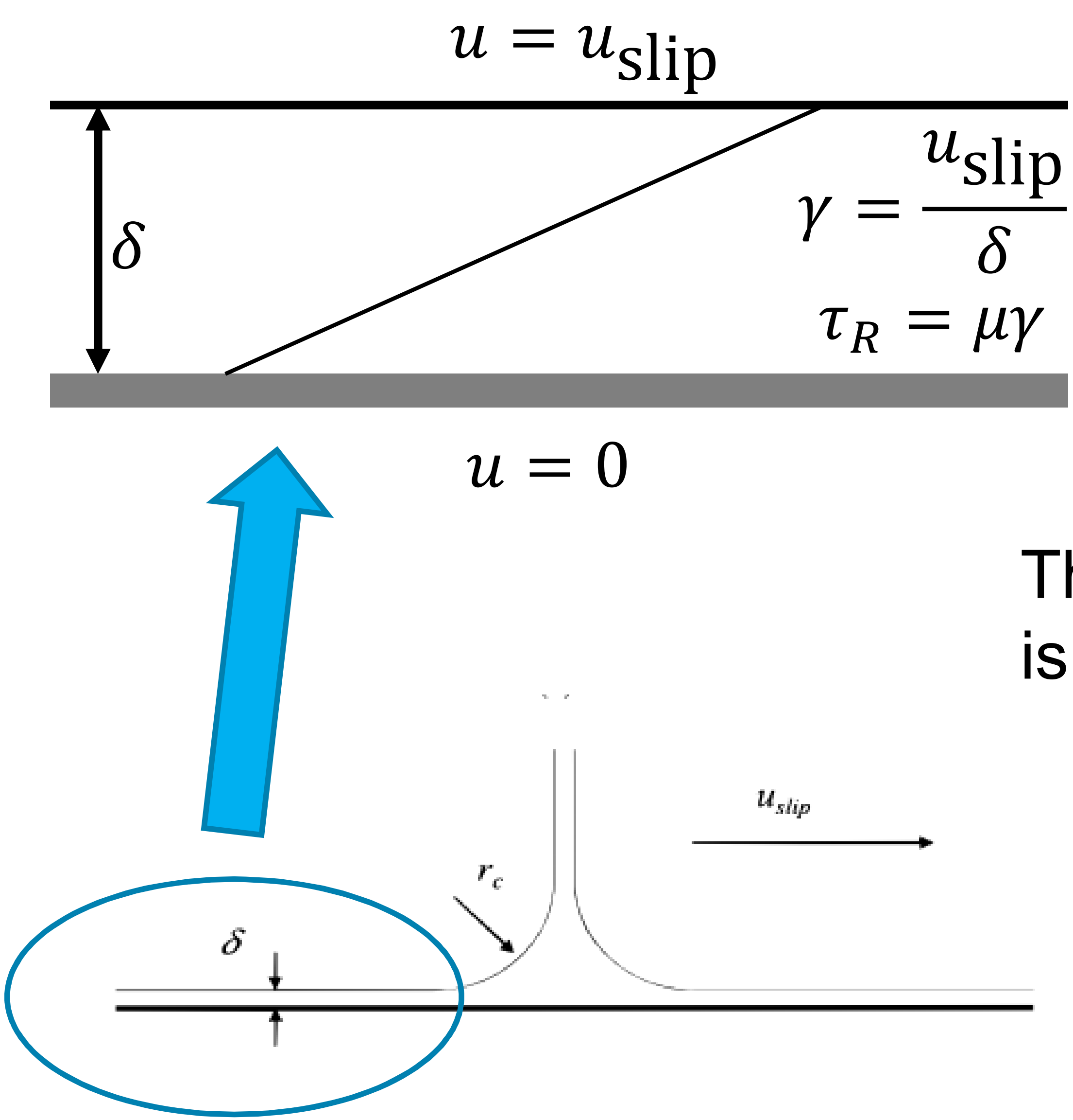
Slip velocity: euca & rayon 30g/kg



Euca
- large slip
- low shear in the bulk

Rayon
- small effect on slip / shear

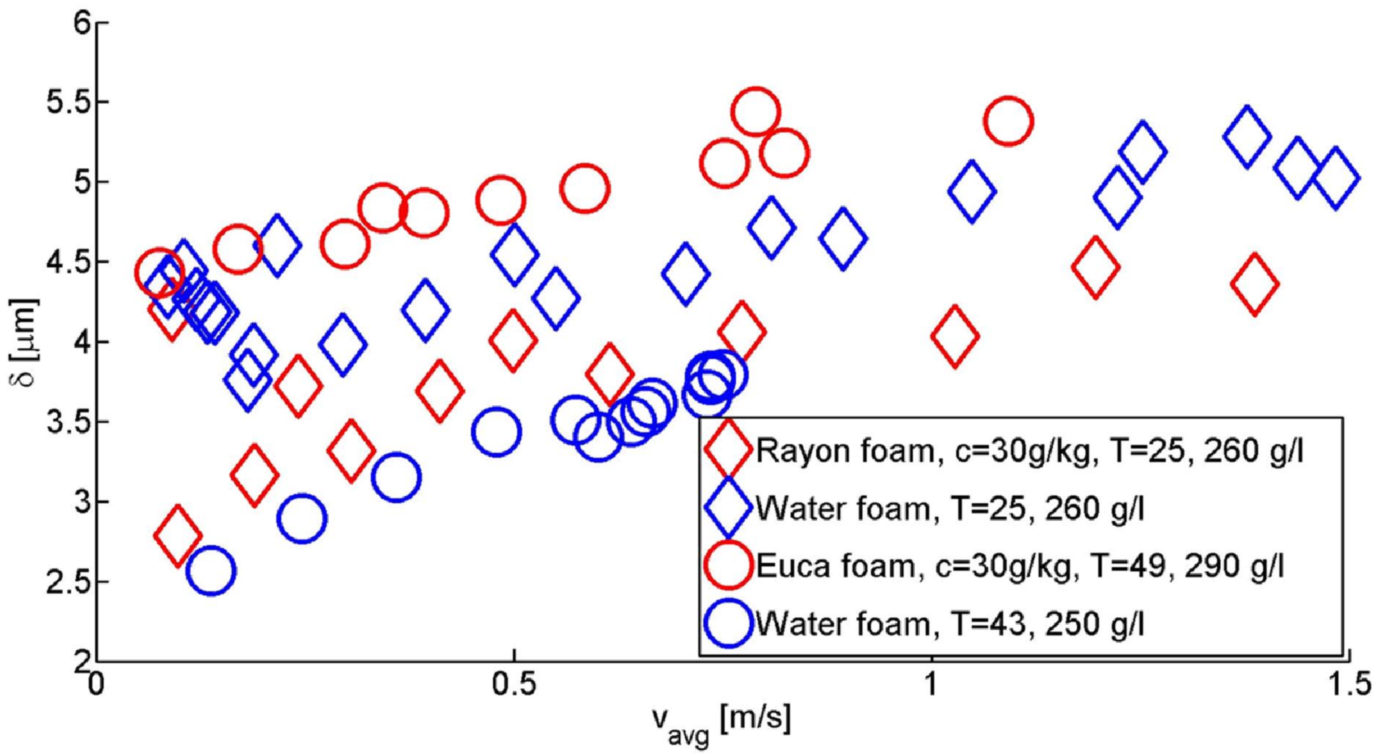
Thickness of the slip layer



$$\delta = \frac{\mu u_{\text{slip}}}{\tau_R}$$

The viscosity μ of the SDS solution is very close to that of water.

Slip layer: euca & rayon 30 g/kg



The calculated thickness of the slip layer for water foams is consistent with the literature.

Rheology

Rheology analysis

- Subtract the slip velocity from the mean velocity: $\tilde{v} = v - v_{\mathrm{slip}}$
- Calculate the *apparent shear rate* at the pipe wall

$$\dot{\gamma}_a = \frac{8\tilde{v}}{D}$$

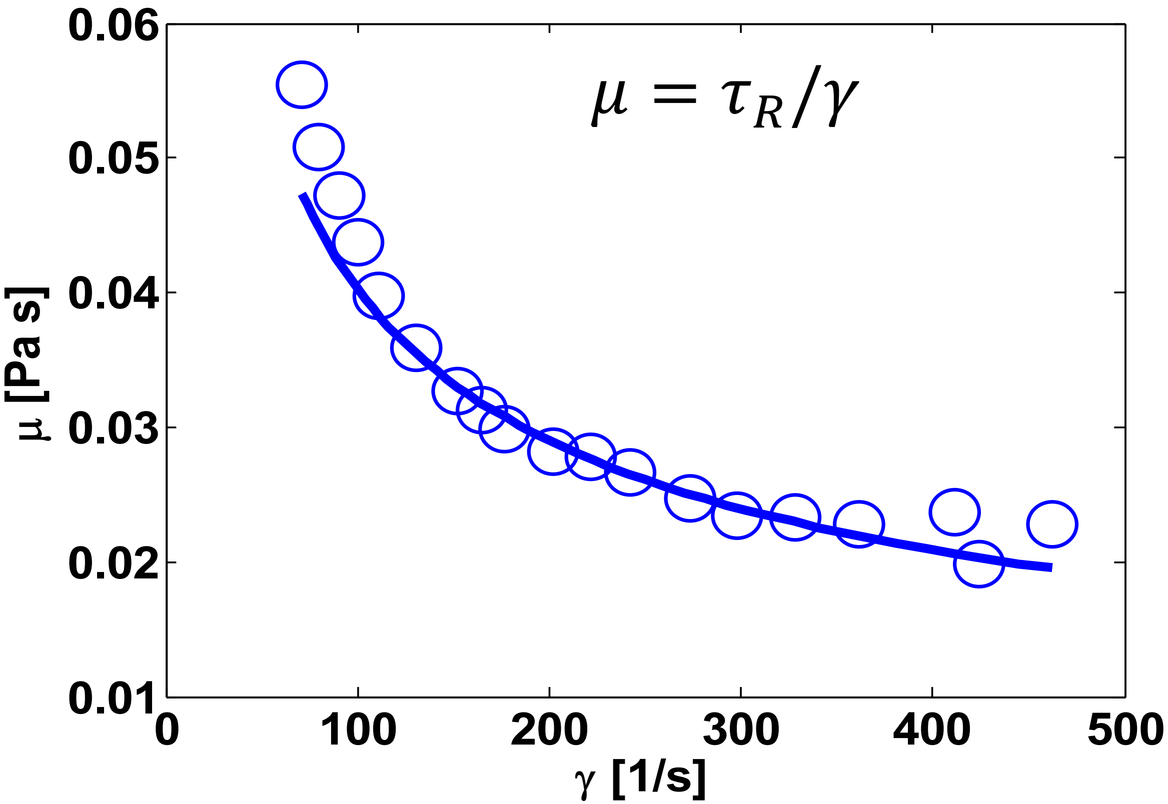
- *Weissenberg-Rabinowitsch correction* gives now the real shear rate at the pipe wall

$$\dot{\gamma} = \dot{\gamma}_a \times \frac{1}{4}\left(3 + \frac{d\ln\dot{\gamma}_a}{d\ln\tau_R}\right)$$

- Viscosity: $\mu(\dot{\gamma}) = \tau_R/\dot{\gamma}$ (REAL, not apparent!)

No need to use several pipe sizes. No velocity profiling needed!

Viscosity of pure foam



Power – law viscosity

$$\mu(\dot{\gamma}) = k\dot{\gamma}^{n-1}$$

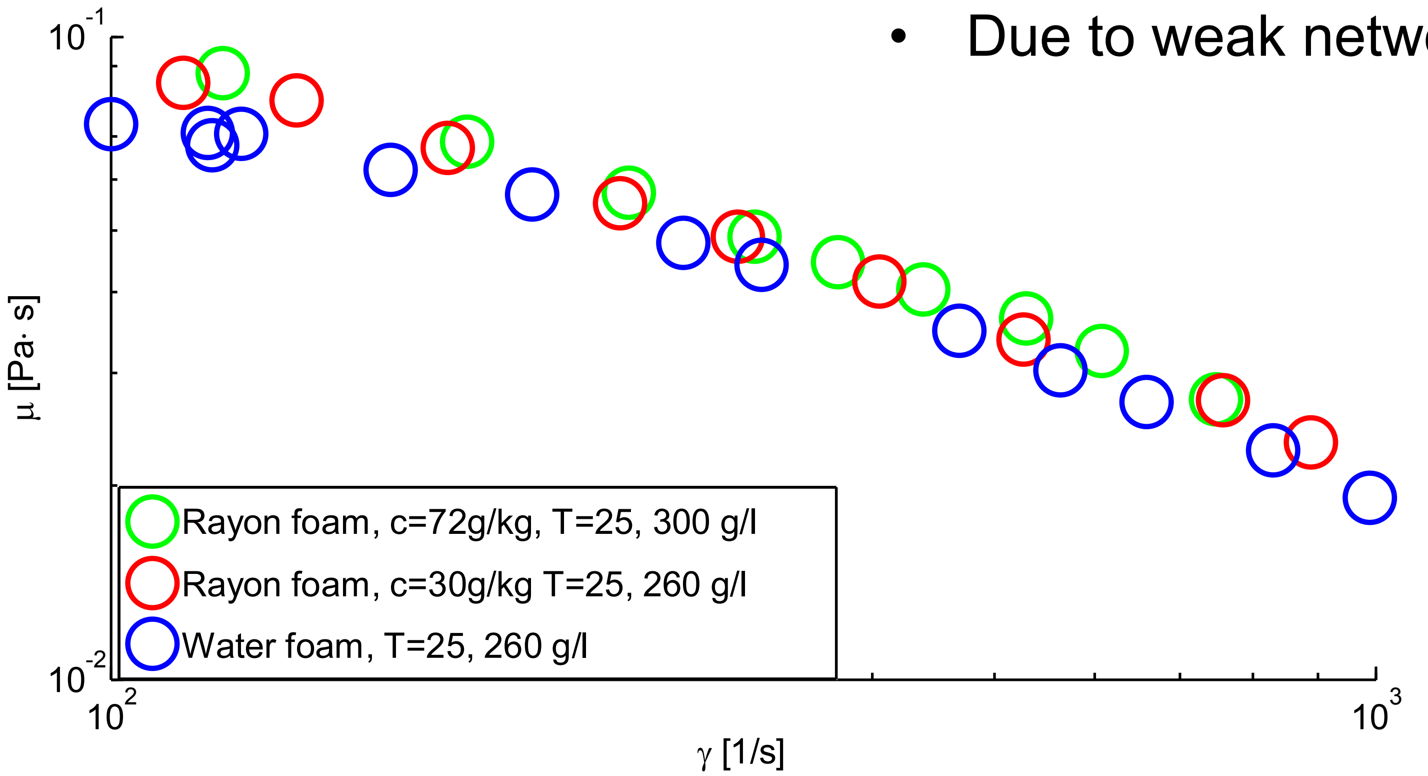
Least-squares fit:

- $k = 350\ \mathrm{mPa \cdot s}$
- $n = 0.53$

The exponent *n* is in the same range as the values reported in the literature for the given density.

Viscosity: rayon, effect of consistency

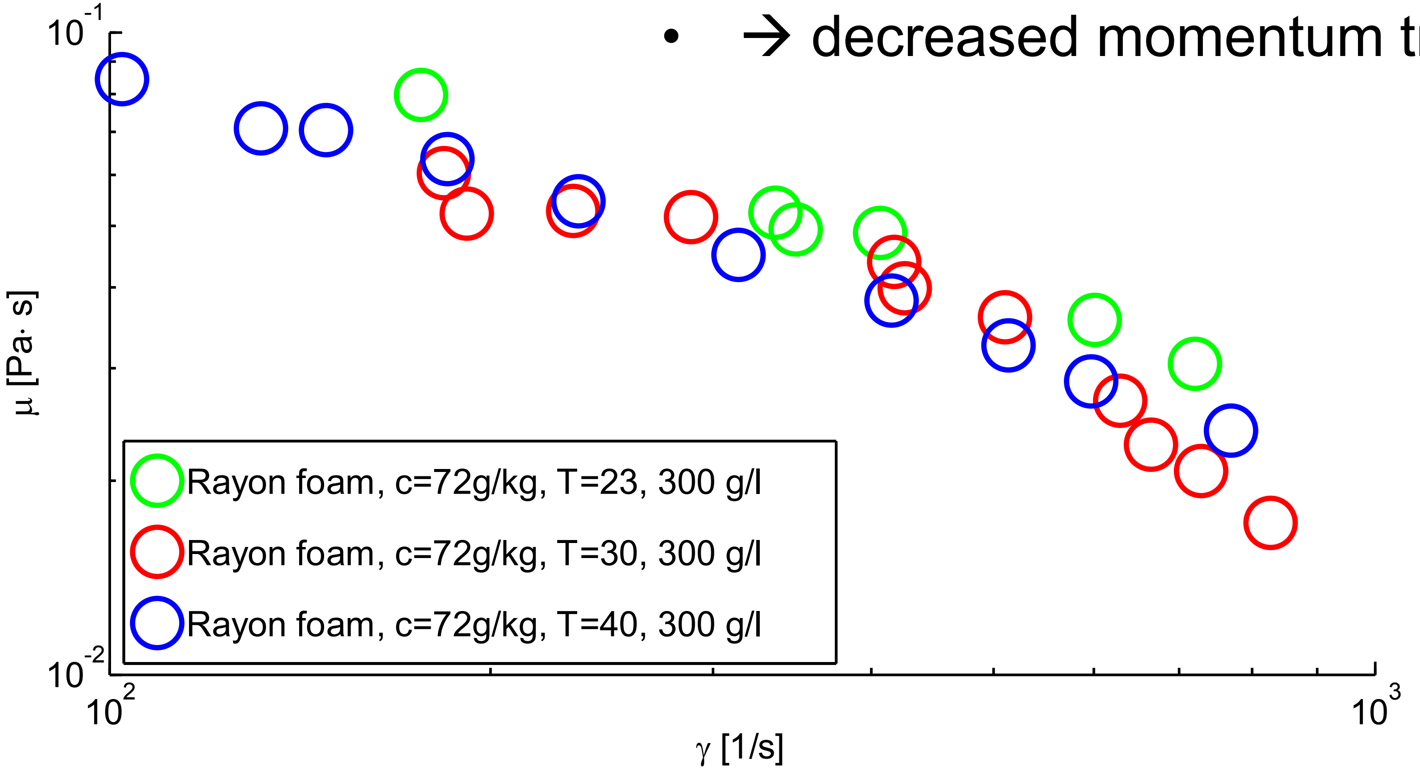
- Shear thinning behaviour, close to power-law.
- The effect of ryon fibres is small even at the highest concentration (effect bigger with euca)
  - Due to weak networking of fibres.



Viscosity: rayon, effect of temperature

Foam viscosity decreases with increasing temperature.

- SDS+water - viscosity decreases
- SDS+water - surface tension decreases
- → decreased momentum transfer



Conclusions

- The slip velocity can have a high impact on the flow properties of fibre foams.
- By applying the methodology described here one can calculate real material properties on the data measured with only one pipe diameter that are independent of boundary effects like slip velocity.
- Fibre foams exhibit strong shear thinning behaviour.
- Fibre type has a big effect on the viscosity of the fibre foam.


TECHNOLOGY FOR BUSINESS