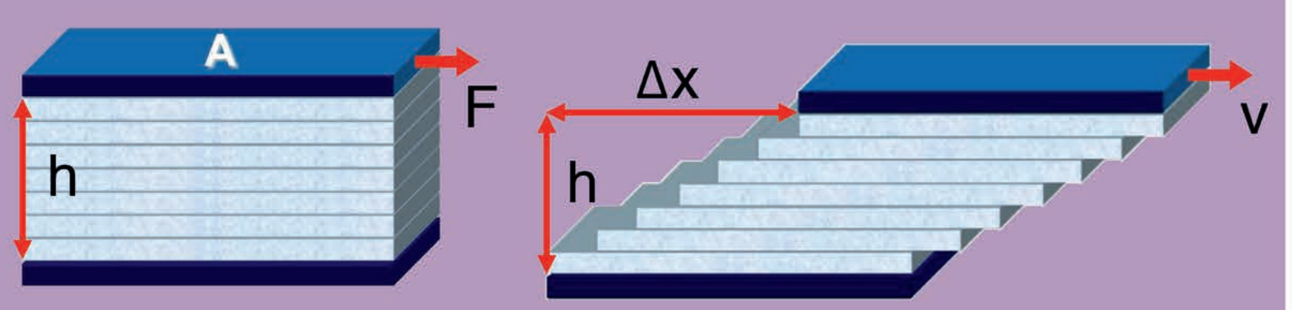
The Basics of Rheology

The study of flow and deformation of matter

ROTATIONAL TESTS

Basic Terms



Shear Stress

$$\tau = \frac{\text{Force}}{\text{Area}} = \frac{F}{A} \qquad \text{Unit: } \frac{N}{m^2} = Pa$$

Deformation (Strain)

$$\gamma = \frac{\text{Displacement}}{\text{Height}} = \frac{\Delta x}{h} \qquad \text{Unit: } \frac{m}{m} = 1$$

Shear Rate

$$\dot{\gamma} = \frac{\text{Change in Deformation}}{\text{Change in Time}} = \frac{d\gamma}{dt} \qquad \text{Unit: } \frac{1}{s}$$

Shear Viscosity

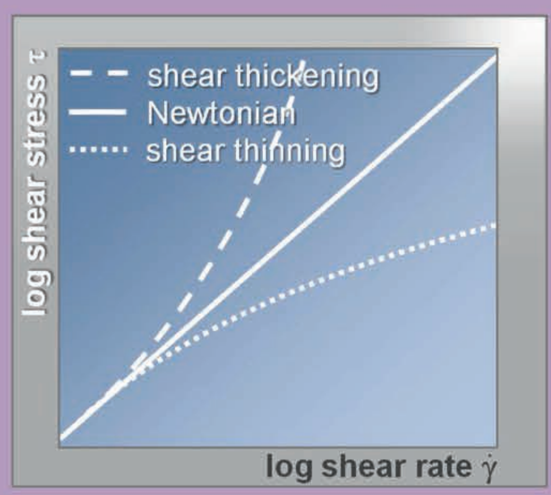
$$\eta = \frac{\text{Shear Stress}}{\text{Shear Rate}} = \frac{\tau}{\dot{\gamma}} \qquad \text{Unit: } \frac{Pa}{1/s} = Pa\cdot s$$

Compliance

$$J = \frac{\text{Deformation}}{\text{Shear Stress}} = \frac{\gamma}{\tau} \qquad \text{Unit: } \frac{1}{Pa}$$

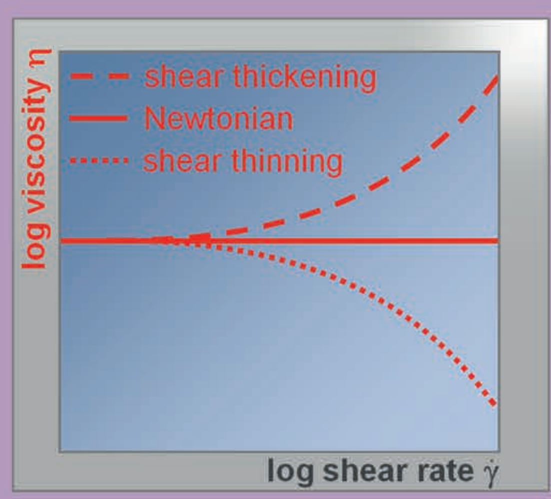
Flow Curve

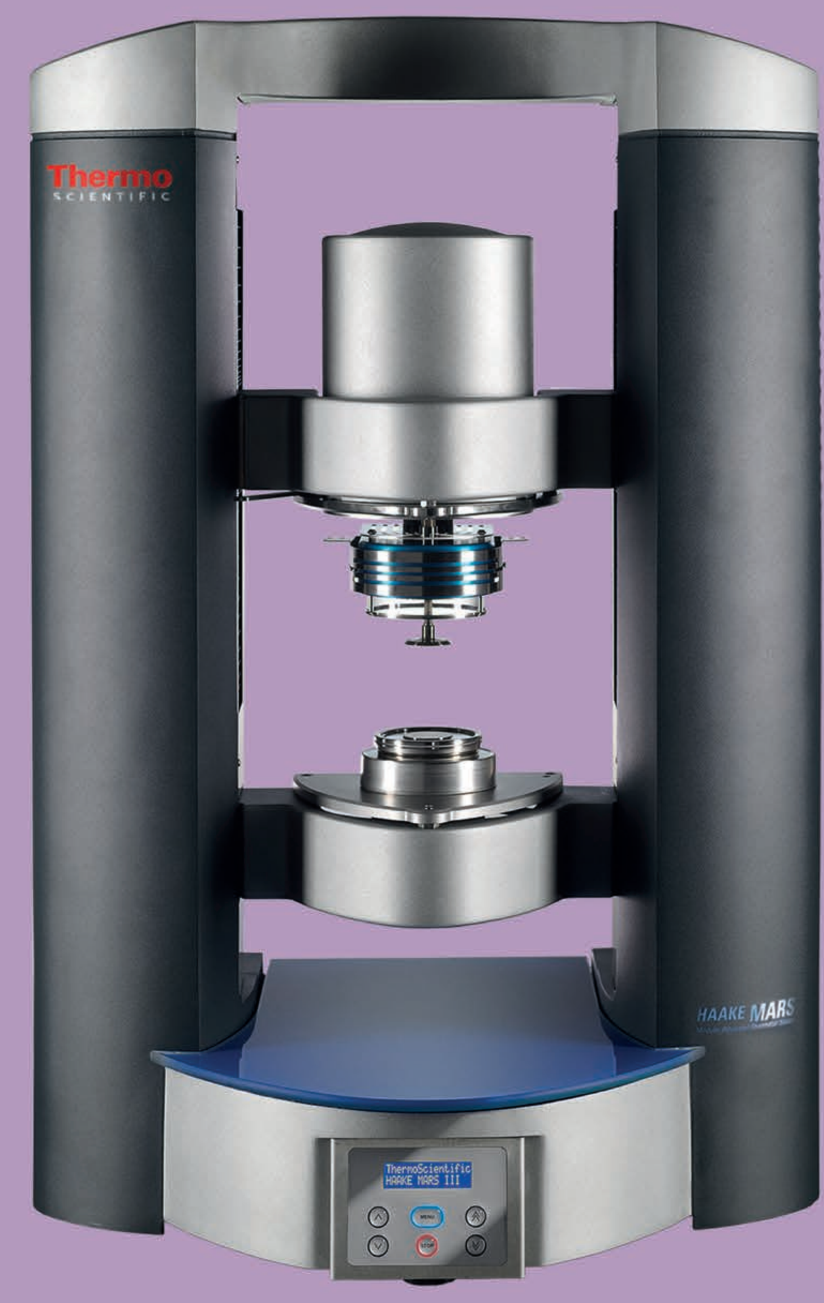
Shear stress as a function of shear rate



Viscosity Curve

Viscosity as a function of shear rate

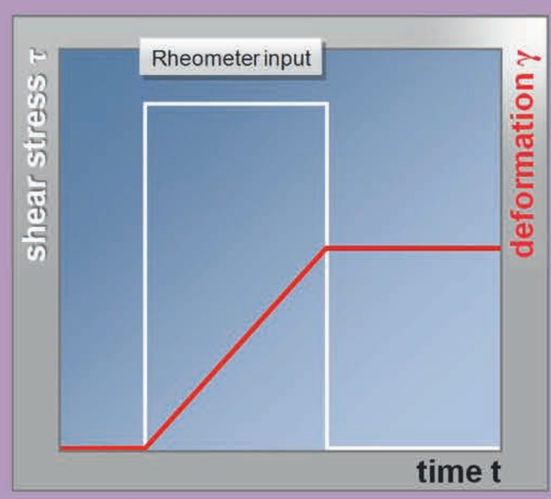




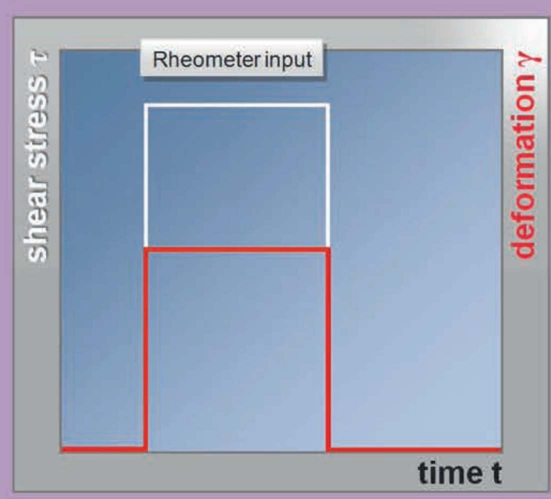
HAAKE MARS High End Rheometer Platform

Creep and Recovery

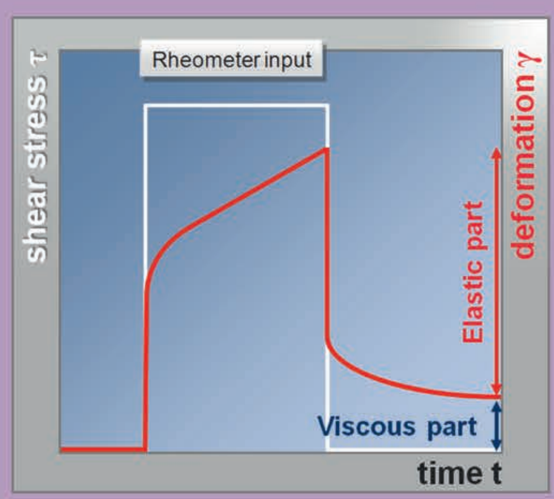
Sample deformation as a response to an applied shear stress and release



Viscous sample



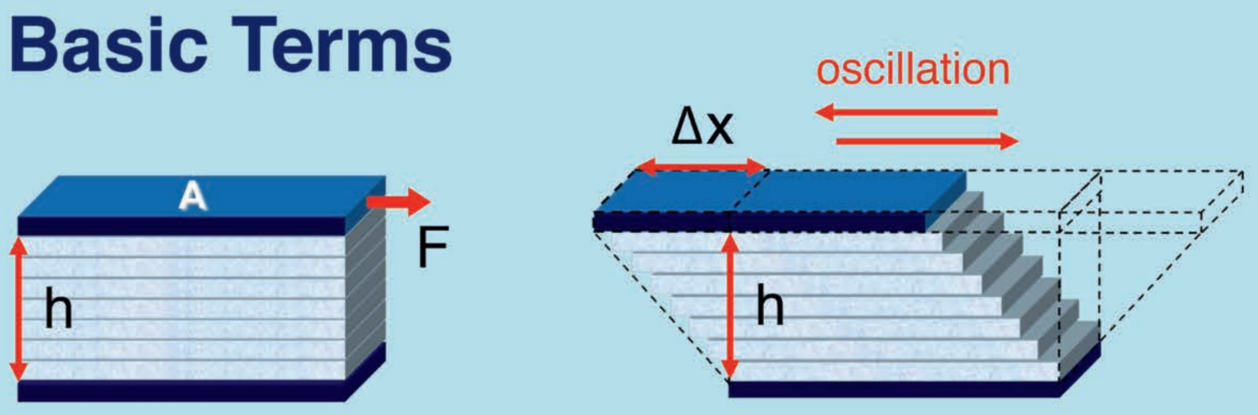
Elastic sample



Visco-elastic sample

OSCILLATORY TESTS

Basic Terms



Frequency

f Frequency — Unit: Hz

ω Angular frequency $\omega = 2\pi f$ — Unit: rad/s

Phase angle

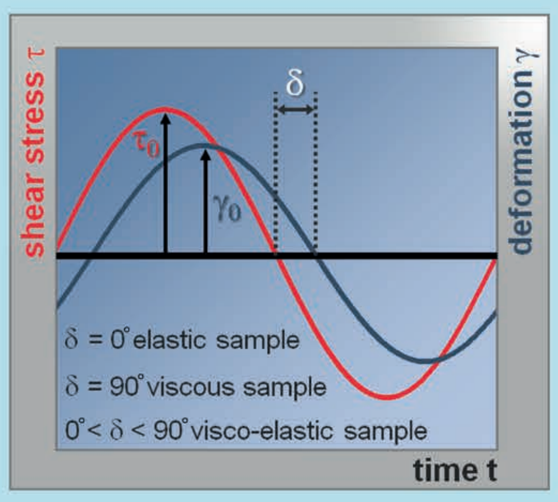
δ Phase angle — Unit: rad or °

Shear stress

$$\tau(t) = \tau_0 \cdot \sin(\omega t)$$

Deformation (Strain)

$$\gamma(t) = \gamma_0 \cdot \sin(\omega t - \delta)$$



Modulus

$$|G^*| = \frac{\tau_0}{\gamma_0} \qquad \text{Complex modulus} \qquad \text{Unit: Pa}$$

$$|G^*| = \sqrt{(G')^2 + (G'')^2}$$

G‘ Storage modulus (elastic part) — Unit: Pa

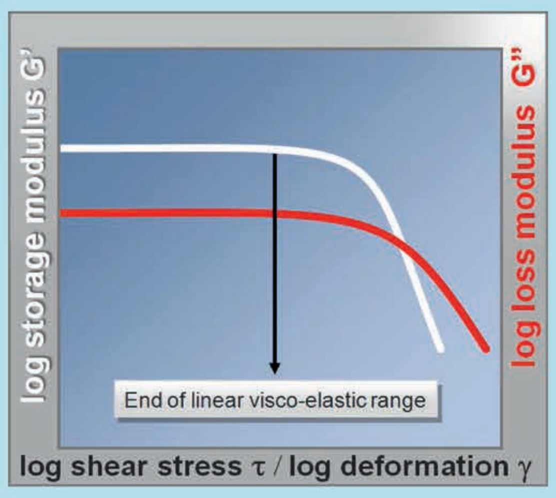
G“ Loss modulus (viscous part) — Unit: Pa

Complex viscosity

$$|\eta^*| = \frac{|G^*|}{\omega} \qquad \text{Unit: } Pa\cdot s$$

Amplitude Sweep

Increasing shear stress τ or deformation γ at a constant frequency ω or f

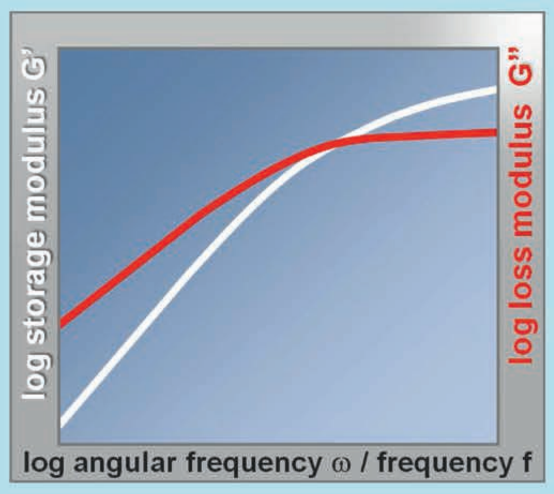


Determination of the linear visco-elastic range

Stability test for samples with gel-character

Frequency Sweep

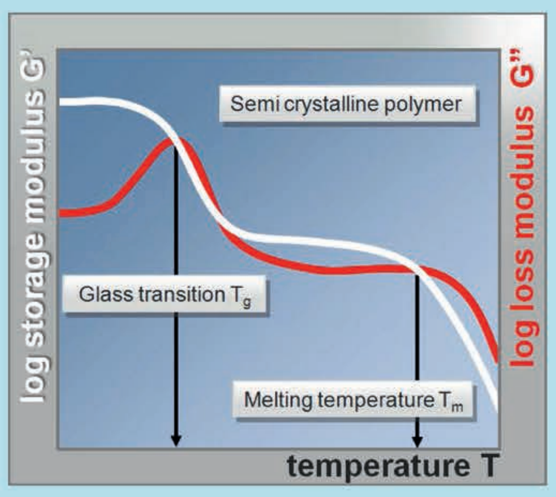
Variation of frequency ω or f with constant shear stress τ or deformation γ



Determination of the material’s structure

Temperature Sweep

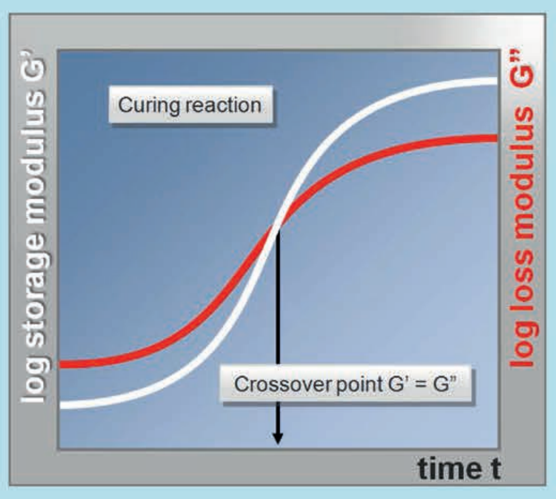
Variation of temperature with constant shear stress τ or deformation γ and frequency ω or f



Determination of material changes like glass transition or melting

Time Sweep

Time experiment with constant shear stress τ or deformation γ and frequency ω or f



Determination of time depending material changes or chemical reactions

www.thermoscientific.com/mc

Thermo SCIENTIFIC

623-2130