RHEOLOGY

Introduction

Rheology is the science that studies **flow** and **deformation** of materials under the effect of an applied force

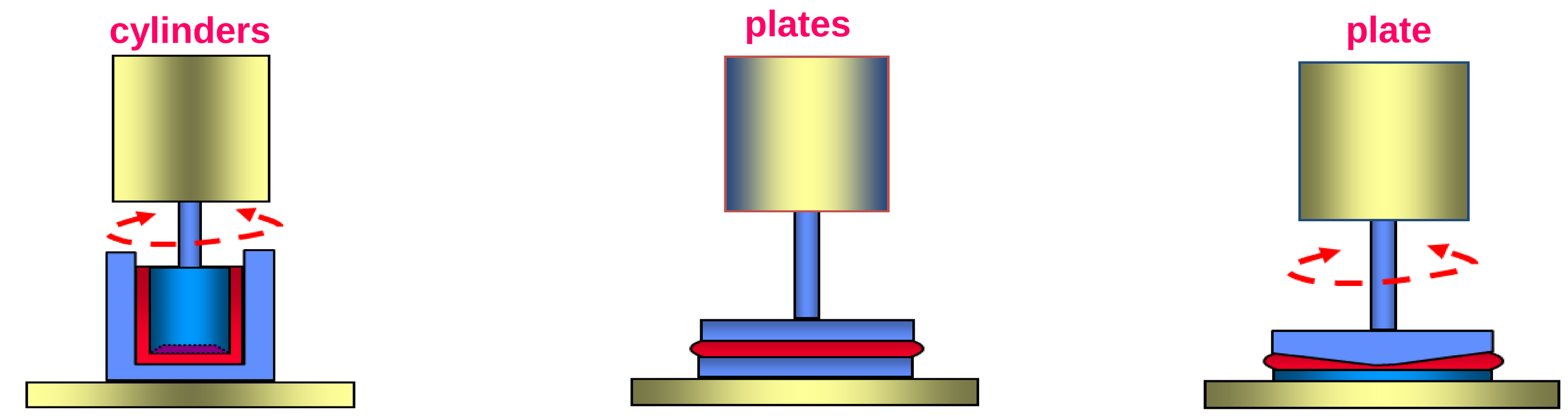
Ideal solids *Deform* reversibly → *The energy required for the deformation is fully recovered when the stresses are removed.*

Ideal liquids *Deform* irreversibly → *They flow. The energy is dissipated in the form of heat.*

Rheology applications

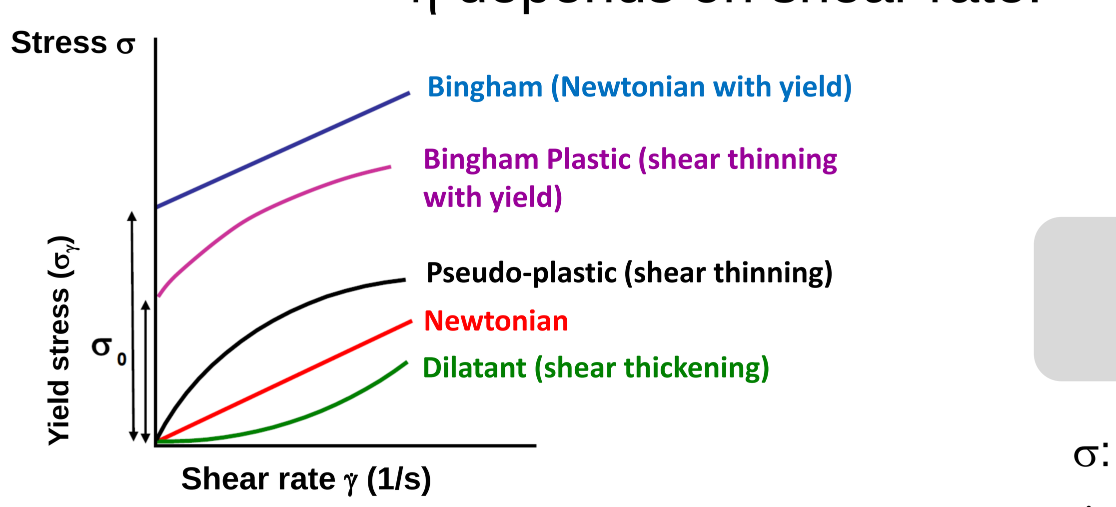
- Quality control of polymers
- Improvement of the processing behaviour
- Optimization of the end product

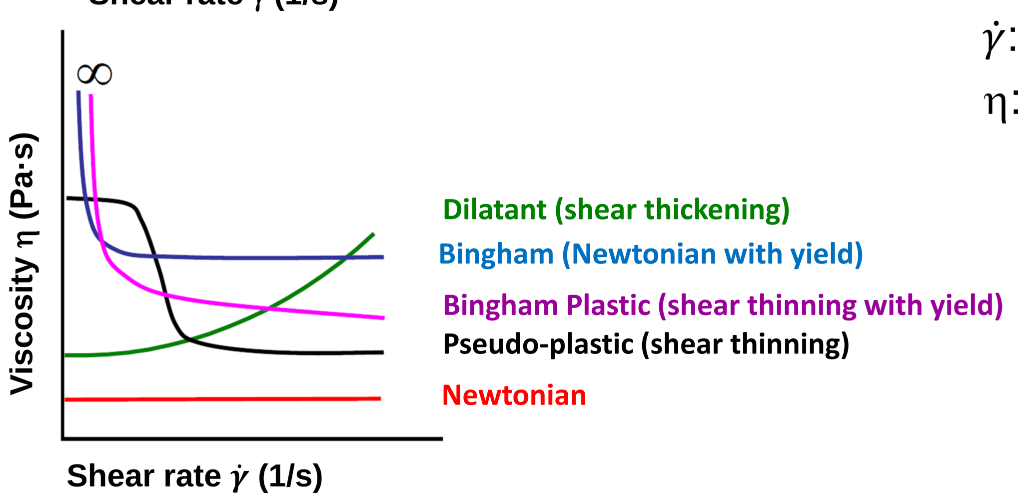
Geometries



Flow

Viscosity (η) is the "**resistance to flow**".
η depends on shear rate.





$$\eta = \frac{\sigma}{\dot{\gamma}}$$

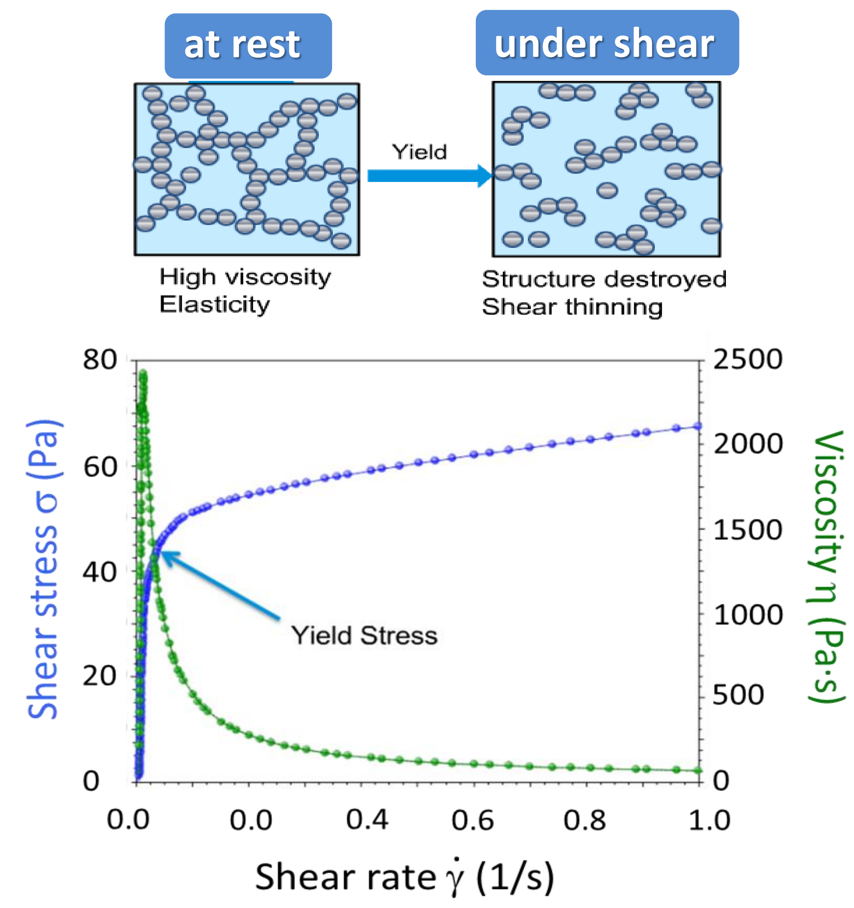
σ: stress (Pa)

$\dot{\gamma}$: shear rate (1/s)

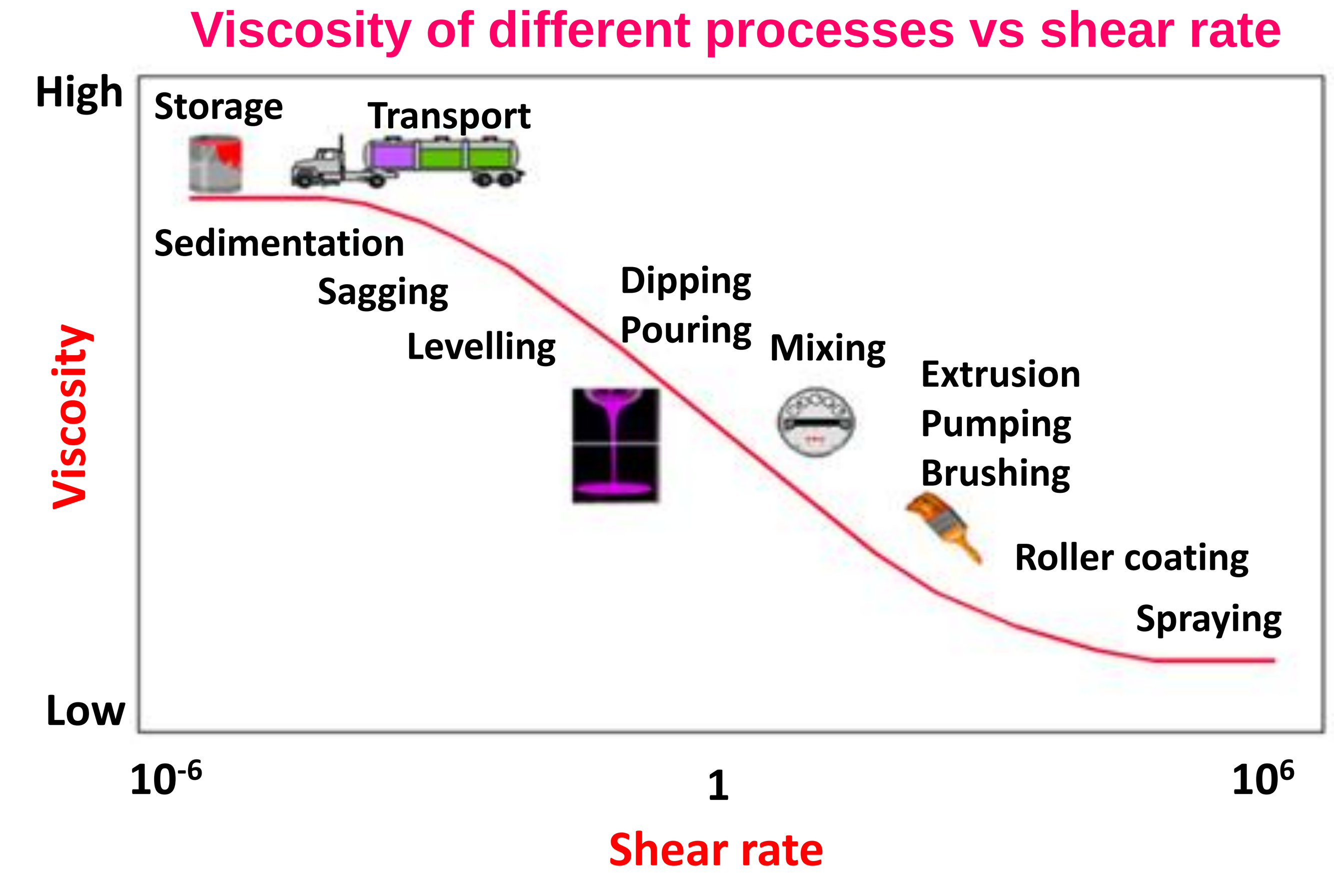
η: Viscosity: (Pa·s)

Yield stress

Some samples require a certain stress to flow.



Viscosity of different processes vs shear rate



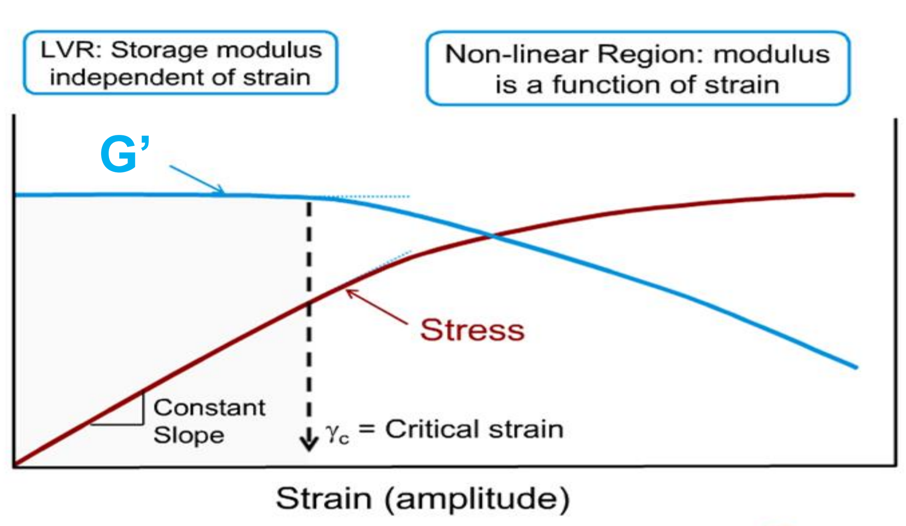
Thixotropy

- **Thixotropy** is a **time-dependent shear thinning** property, which is used to characterize structure change reversibility.

Oscillation

Oscillatory measurements are used to measure the **viscoelastic properties** of a material. A stress or strain is applied and the corresponding response (strain or stress) is measured.

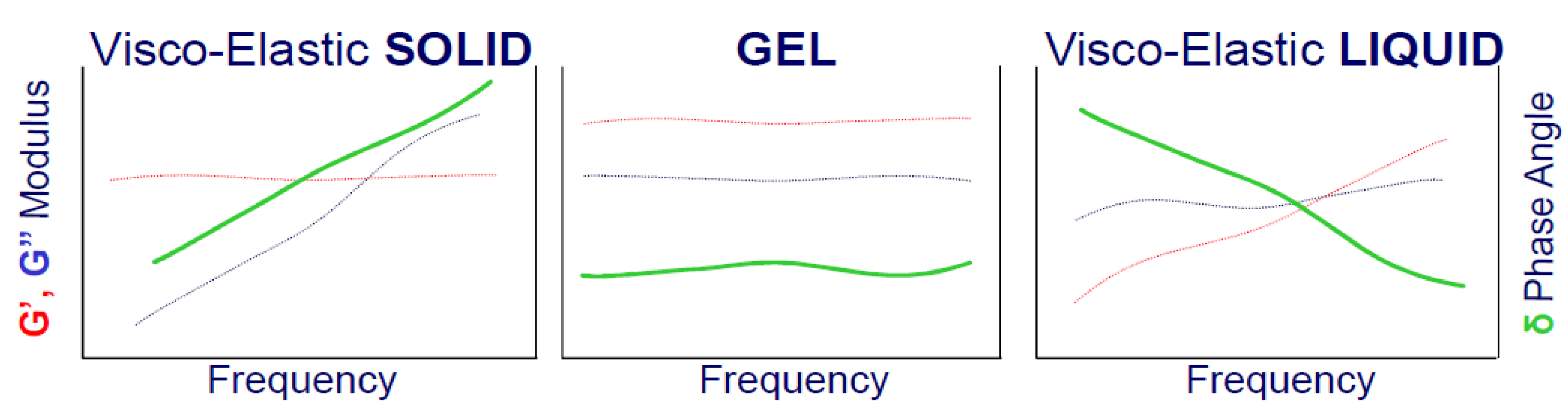
Complex Modulus G*	$G^* = G' + iG''$
Storage Modulus G' (Elastic parameter)	$G' = G^* \cos\delta$
Loss Modulus G" (Viscous parameter)	$G'' = G^* \sin\delta$
tan δ	$\tan\delta = \frac{G''}{G'}$



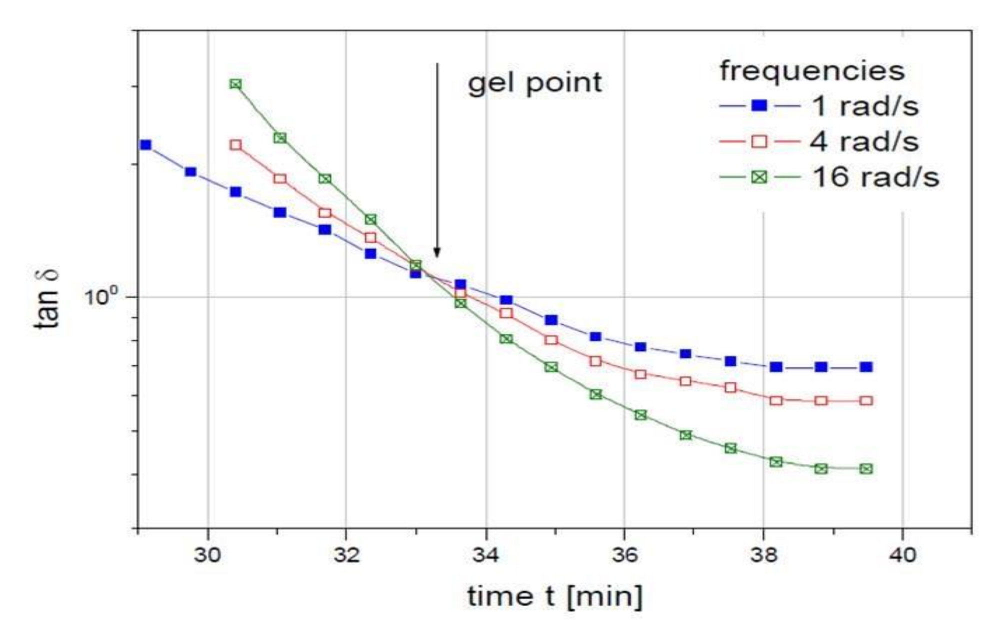
- A **strain sweep** is used to measure the linear viscoelastic region (LVR).
- From a strain sweep **cohesive energy (CE)** can be calculated to determine stability.

$$CE = \frac{1}{2} G' \gamma_c^2$$

The larger the cohesive energy the more stable is the sample.

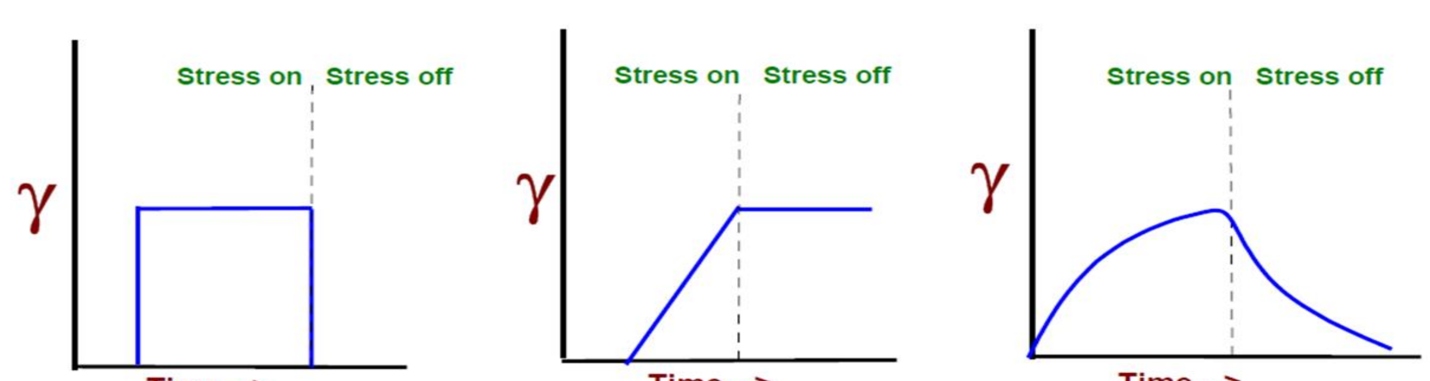


- **Gel point** : represents the point where behaviour changes from viscous (liquid-like) to elastic (solid-like).



Creep and recovery

Creep: **slow deformation** of a material, usually measured **under** a **constant stress**. The creep test gives a measure of elastic, viscoelastic and viscous components.

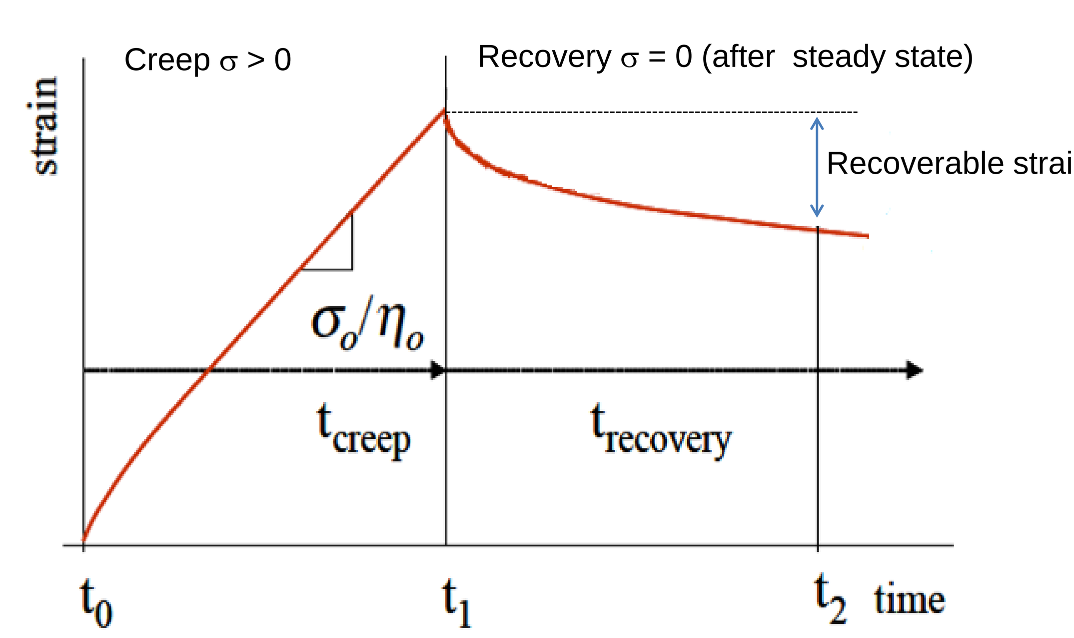


PURE ELASTIC PURE VISCOUS VISCOELASTIC

The **compliance** is defined as the ratio of the strain to the applied stress (J).

$$J = \frac{Steady\ state\ recoverable\ strain}{stress}$$

The greater the compliance the more the material can be strained under the application of a certain shear stress.



References

(1) H.A. Barnes, J. F. Hutton, K. Walters F.R.S., An Introduction to Rheology, Elsevier, Amsterdam, 1993.
(2) F. Chambon, J. Winter, J. Rheol. 3 (8), 683-697, 1987.
(3) www. tainstruments.com.

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