# THEORETICAL INTRODUCTION

## Rheology

Rheology, by definition, is the study of the flow and deformation of materials.

BASIC TERMS

*The stress* is the internal force acting on the area. Unit of stress is the pascal Pa

*Normal stress* $\sigma$ is penperdicular stress to a plane and *shear stress* $\tau$ is tangential to a plane.

*Strain* is the relative deformation of a material in response to a stress, extent of deformation. Symbol is $\gamma$, and has no units.

*Shear rate* *D* is velocity gradient dv/dx that is caused in liquids during the flow. Unit is reciprocal seconds.

*Definition of viscosity (EuPh 10.0):*

*The dynamic viscosity* or *coefficient* $\eta$ is the tangential force per unit surface, known as shearing stress $\tau$ and expressed in pascals, necessary to move, parallel to the sliding plane, a layer of liquid of 1 square metre at a rate (v) 1 metre per second relative to a parallel layer at a distance (x) of 1 metre.

The ratio dv/dx is a speed gradient giving the rate of shear D expressed in reciprocal seconds ($s^{-1}$), so that $\eta = \tau / D$.

*The kinematic viscosity* ν, expressed in square metres per second, is obtained by dividing the dynamic viscosity $\eta$ by the density $\rho$ expressed in kilograms per cubic metre, of the liquid measured at the same temperature, i.e. $\nu = \eta / \rho$. The kinematic viscosity is usually expressed in square millimetres per second.

*Rheogram* is a graph of shear stress against shear rate.

*Tabule 1:* The units of the basic rheological quantity

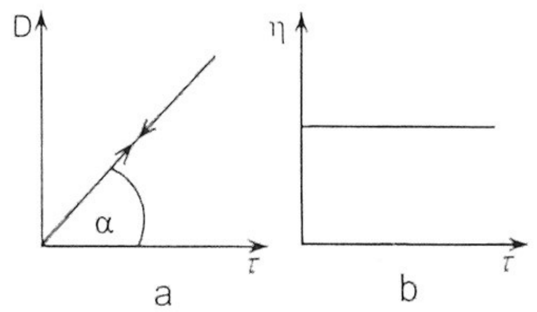
| Quantity | Unit in SI units | Unit in CGS units | Transliteration |
|---|---|---|---|
| Shear stress $\tau$ | $N/m^2$ | $dyn/cm^2$ | $1\ dyn/cm^2 = 0{,}1\ N/m^2$ |
| Shear rate $D$ | $s^{-1}$ | $s^{-1}$ | |
| Dynamic viscosity $\eta$ | Pa·s<br>mPa s | dyne·s/cm²<br>P (Poise) | $1\ dyn{\cdot}s/cm^2 = 1P = 0{,}1\ N{\cdot}s/m^2$<br>1cP = 1 mPa·s |
| Kinematic viscosity $\nu$ | $m^2/s$<br>$mm^2/s$ | $cm^2/s$<br>cSt | $cSt = 10^{-6}\ m^2/s$ |

## NEWTONIAN LIQUIDS

Newton´s equation for ideal viscous liquids:

$$\tau = \eta \cdot \frac{dv}{dx} \qquad D = \frac{dv}{dx} \quad \left[s^{-1}\right] \qquad \tau = \eta \cdot D \quad \left[Pa{\cdot}s\right]$$

- direct proportionality between shear stress and shear rate
- reogram is staight line going through the origin with the value of its slope *1/η* (*η=cotg α)*
- viscosity is constant
- gases, water, mineral and vegetable oils, alcohols, glycerin, and true solutions

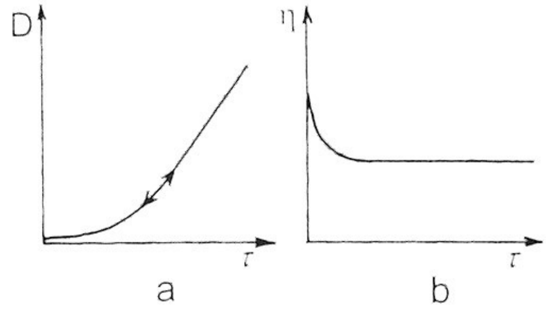


reogram curve of viscosity

# NONNEWTONIAN LIQUIDS

Pseudoplastic liquid

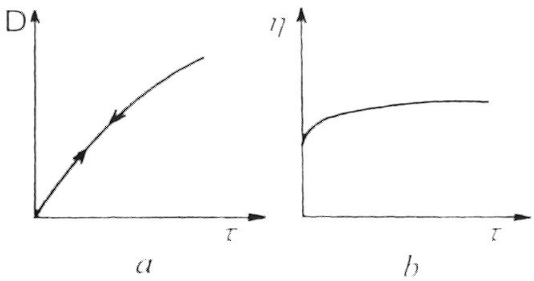
- rheogram passes through the origin
- apparent dynamic viscosity decreases continuously with increasing shear rate
- diluted water solutions of polymers, diluted suspensions, emulsions




reogram curve of viscosity

Dilatant liquid

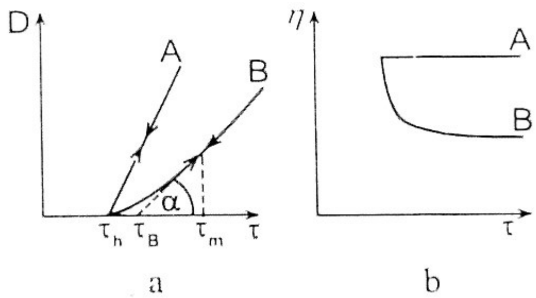
- rheogram passes through the origin
- apparent dynamic viscosity increases continuously with increasing shear rate
- concentrated suspensions (susp of ZnO)




reogram curve of viscosity

Plastic liquid

- rheogram does not pass through the origin
- yield point
- at shear stresses greater then yield point is possible newtonian flow (A) or nonnewtonian flow (B)
- oitments, creams, gels




reogram curve of viscosity