Group-Meeting

(Photo)Rheology

Quentin Bauerlin

April 24, 2025

Introduction

Part 1 – Generalities and characterisation in rheology

I. Photorheometer : HAAKE MARS 60

II. Choice of geometry

III. Choice of operating mode

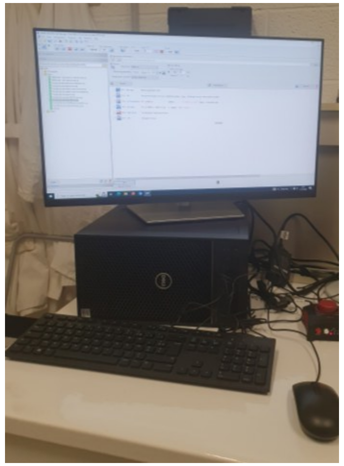
IV. Choice of shear rate

V. Possibilities and results

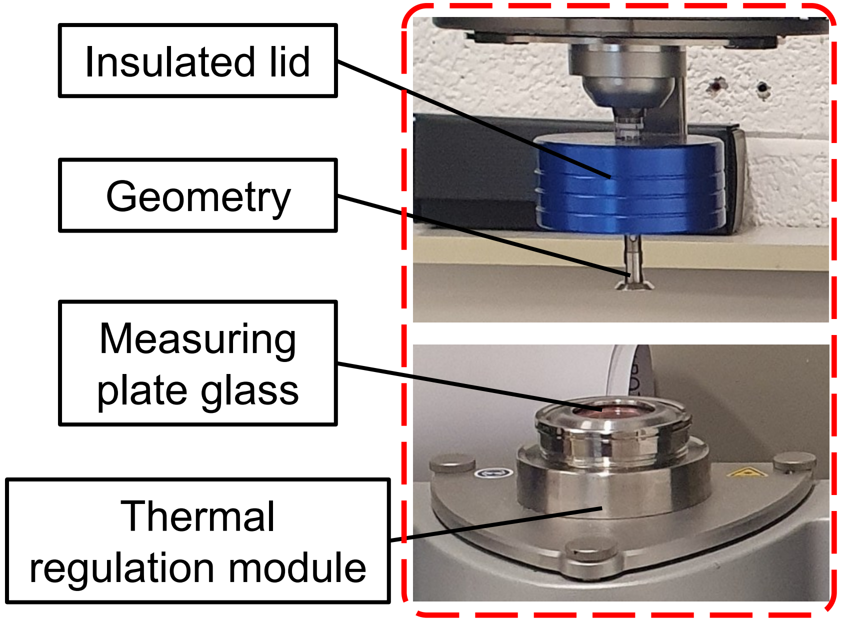
VI. Conclusion-Perspectives

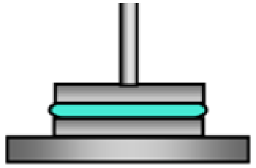
Part 2 – Next Group Meeting

Photorheometer : HAAKE MARS 60



Computer

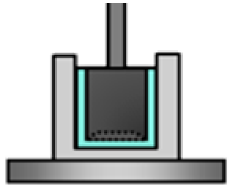




Parallel plate

Pure de-ionized water : **0 to 180°C**

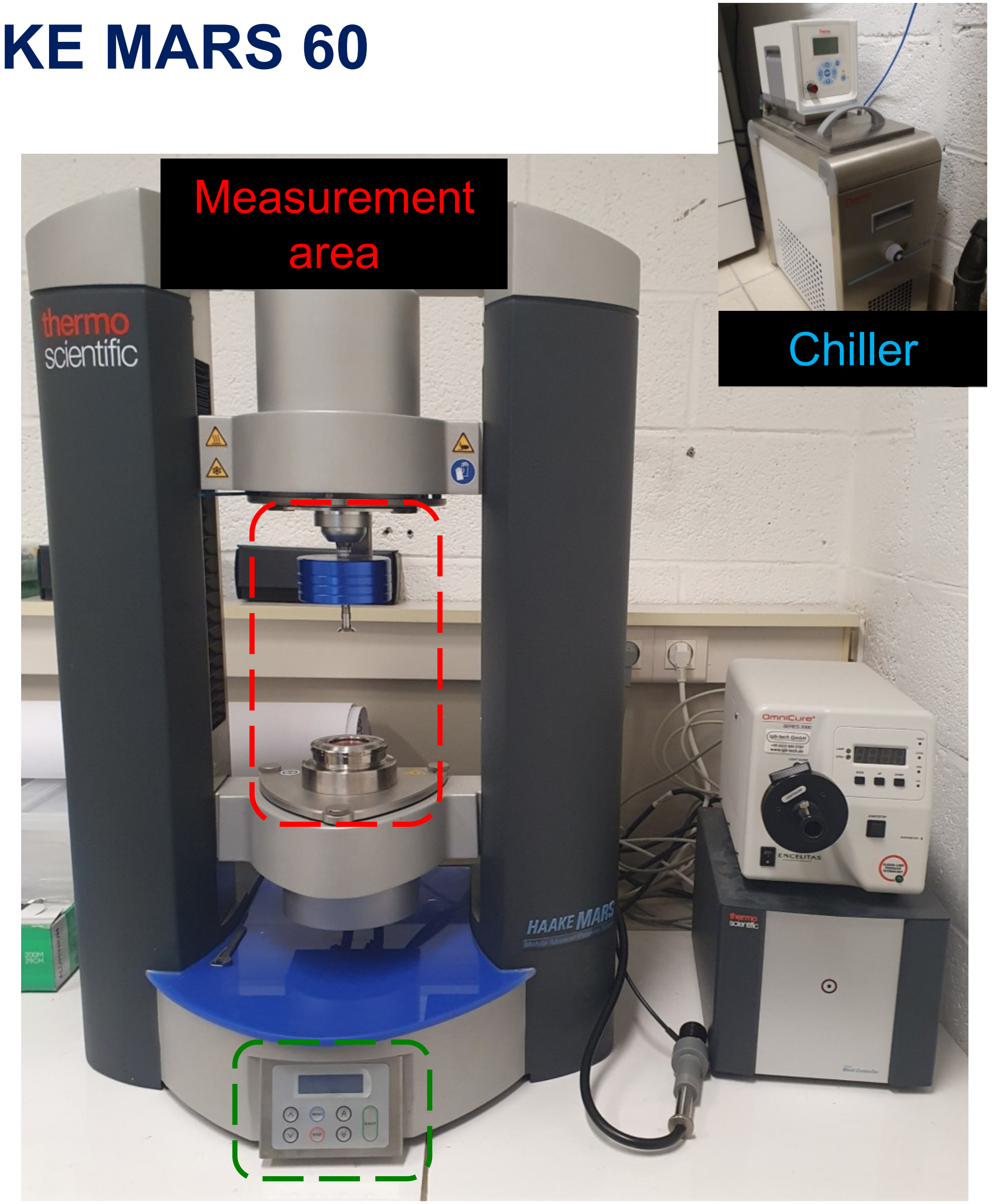
Water with anti-freeze : **-40 to 180°C**



Concentric Cylinders

Pure de-ionized water : **0 to 200°C**

Water with anti-freeze : **-20 to 200°C**



Control panel

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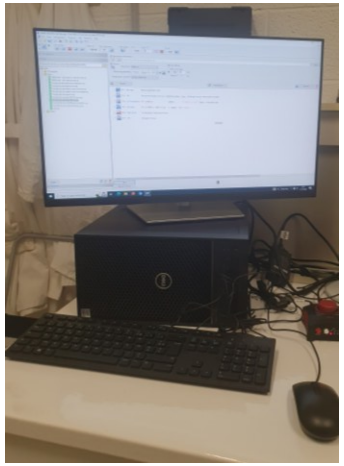
Photorheometer : HAAKE MARS 60



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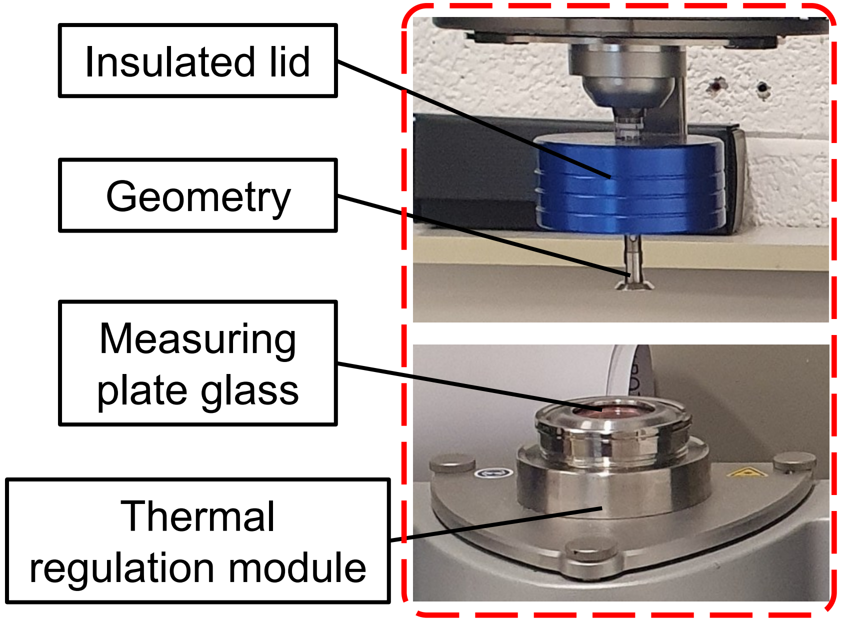

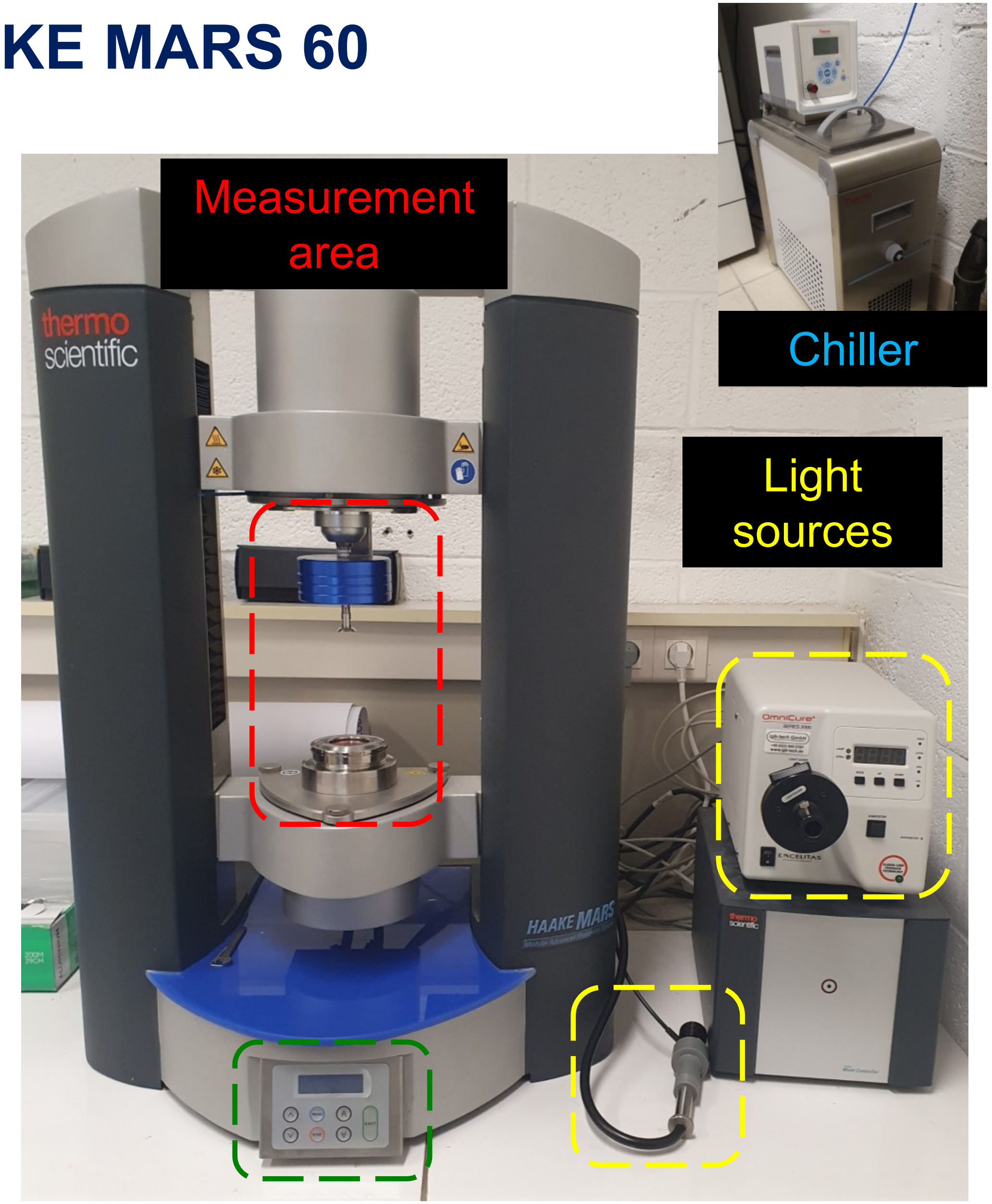

Control panel

Light with manual control
405 - 470 - 530 nm

Automatic light at
365 nm

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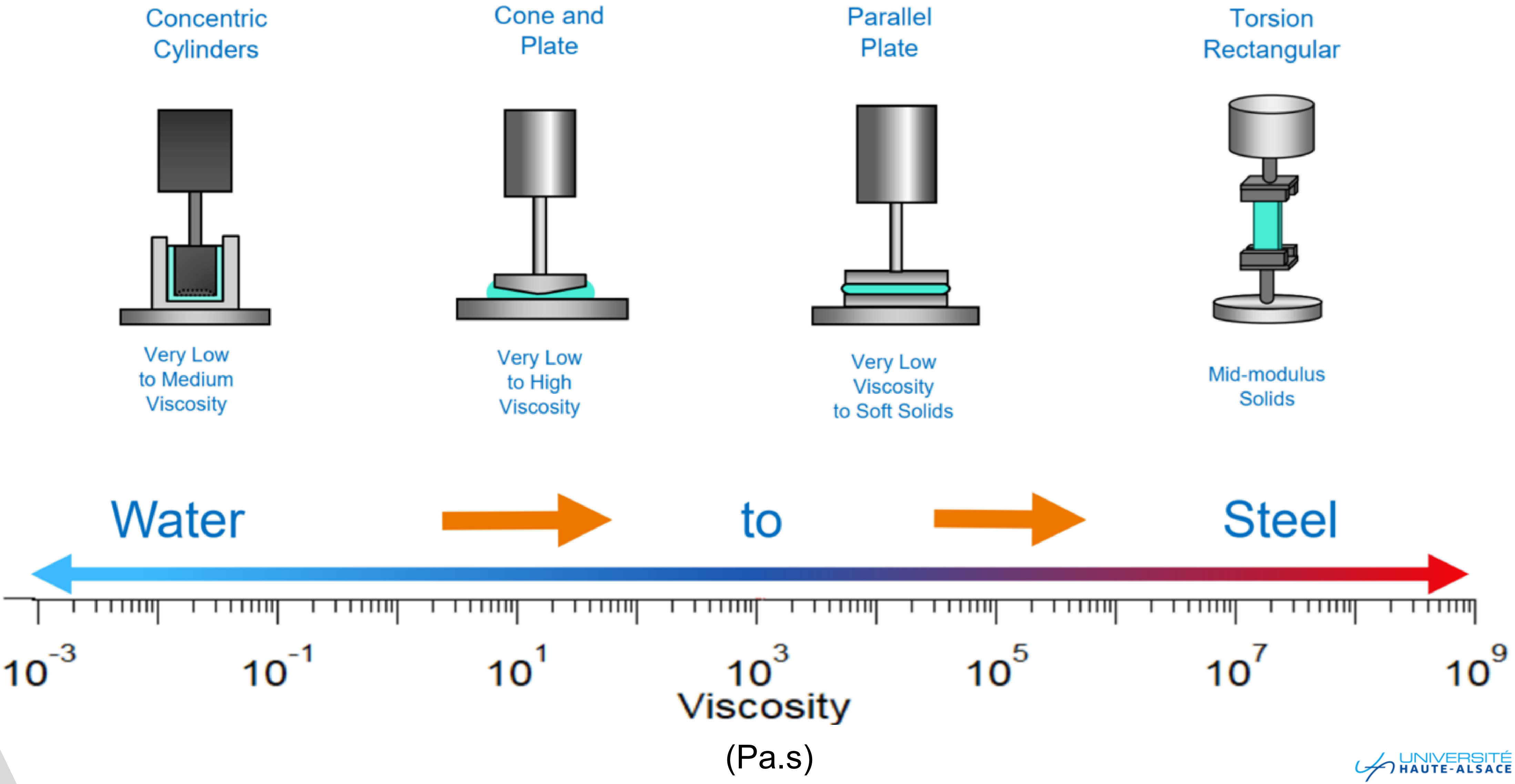
Choice of geometry



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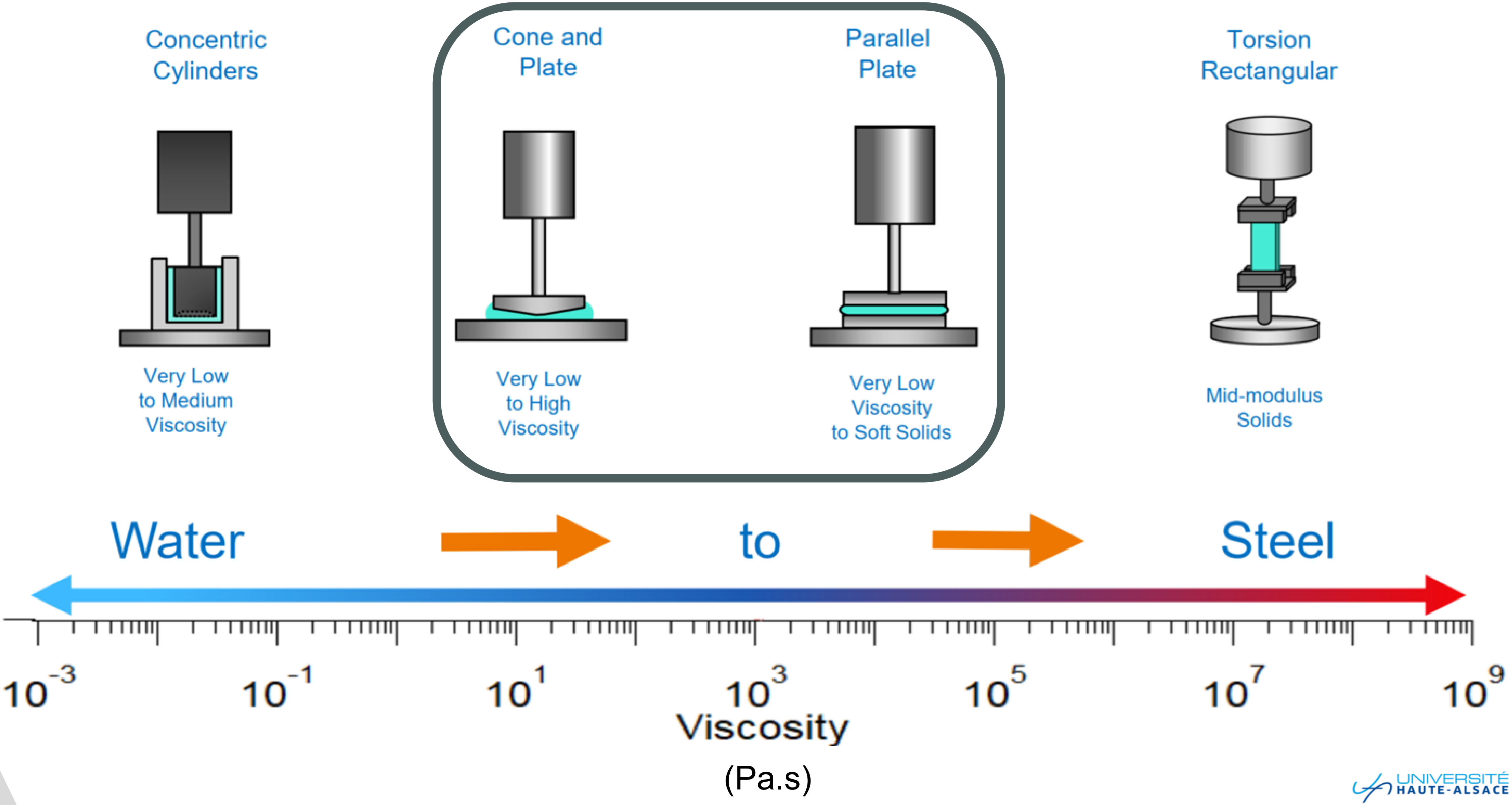


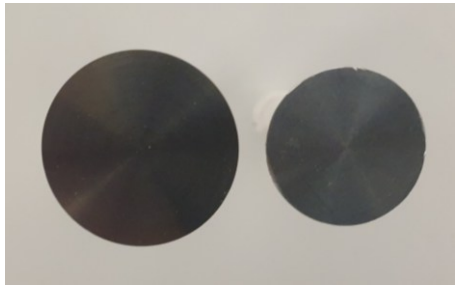
Choice of geometry

C25 1°/Ti

Fixed gap = 0.054 mm

P3 adapter and
P20-CTC/Al inserts

Variable gap = 0.1 - 2.5 mm

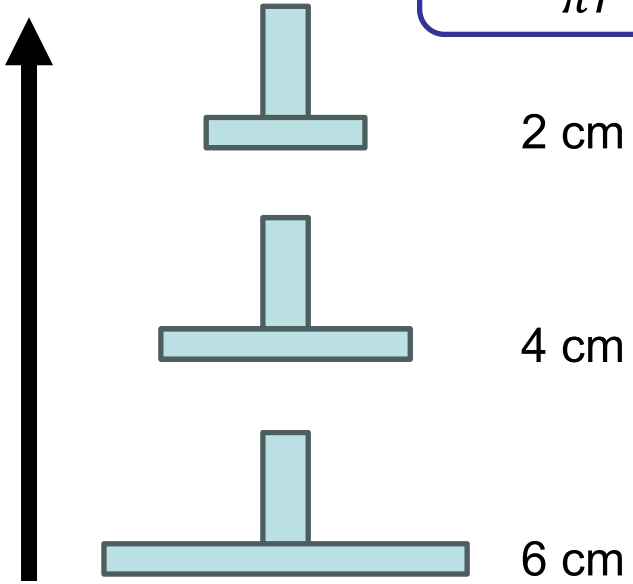


ø = 2.5 cm   ø = 2 cm

Advised gap
0.1 - 0.5 mm

Shear Stress

$$\tau = \frac{2M}{\pi r^3}$$



Shear rate

$$\dot{\gamma} = \frac{\omega \times r}{h}$$

τ = shear stress (Pa)
M = applied torque (N.m)
$\dot{\gamma}$ = shear rate (s^{-1})
ω = angular plate speed (rad/s)
r = plate radius (m)
h = gap (m)

Choice of geometry

C25 1°/Ti

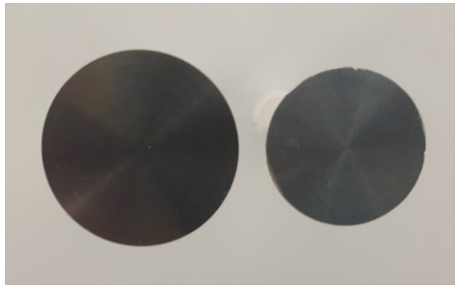
Viscosity test

Fixed gap = 0.054 mm

P3 adapter and P20-CTC/Al inserts

Photorheology test

Variable gap = 0.1 - 2.5 mm



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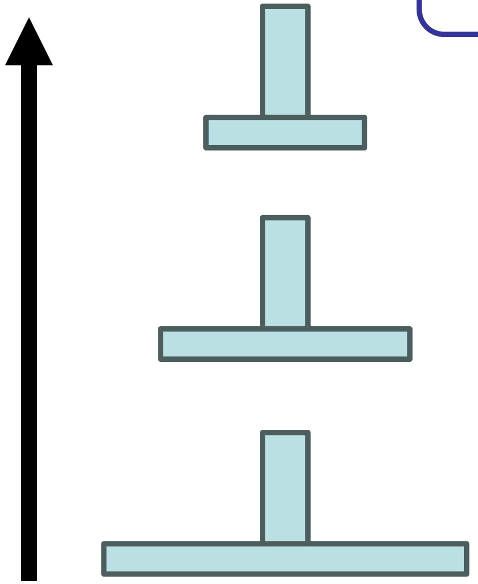

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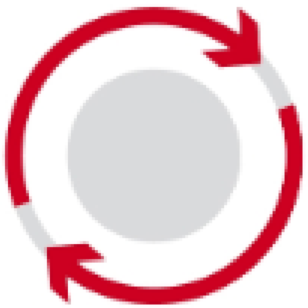
Choice of operating mode

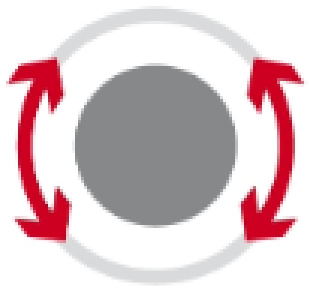
Continuous rotation

Type of analysis
Flow (fluid)

Parameters measured
Viscosity, shear stress, shear rate

Example of use
Painting, extrusion, pumping





Rotary oscillation

Type of analysis
Viscoelasticity (solid + fluid)

Measured parameters
G', G'', δ, etc.

Example of use
Gels, creams, foams, polymers

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Choice of operating mode

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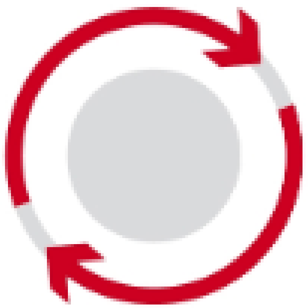

Rotary oscillation

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Viscosity test

Photorheology test

cnrs

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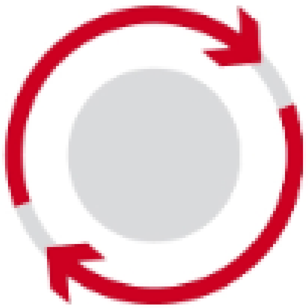
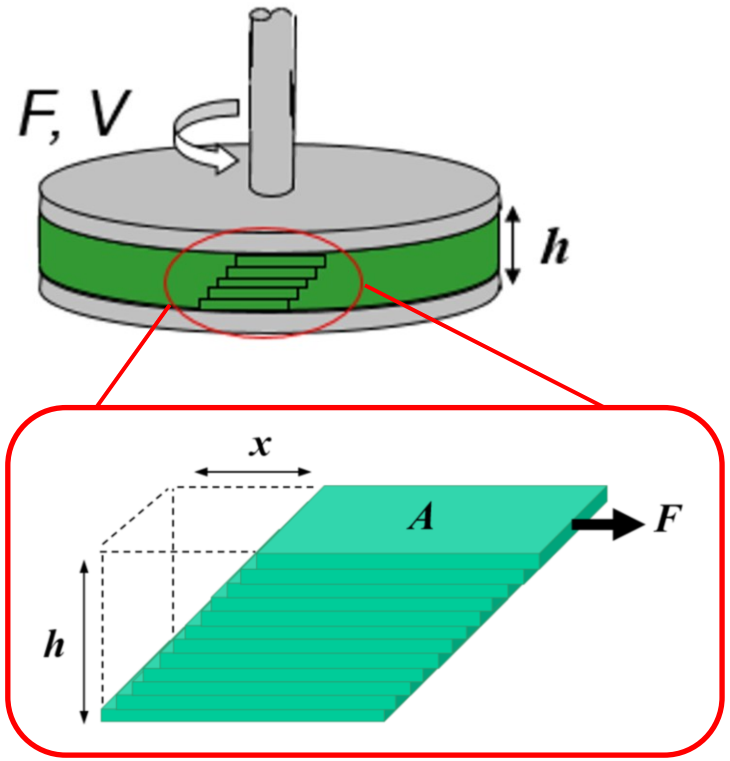
Choice of operating mode



Continuous rotation : Viscosity test



$$\tau = \frac{F}{A}$$

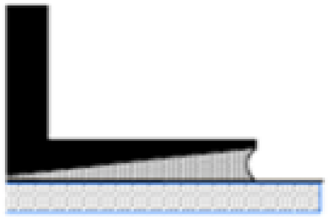
$$\gamma = \frac{x}{h}$$

$$\dot{\gamma} = \frac{d\gamma}{dt}$$

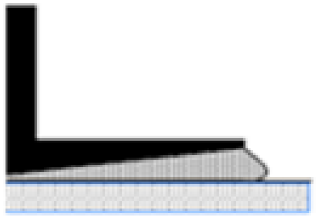
$$\boxed{\eta = \frac{\tau}{\dot{\gamma}}}$$

F = Force (N)
A = Aire (m^2)
x = travel distance (m)
h = Gap (m)
τ = shear stress (Pa)
$\dot{\gamma}$ = shear rate (s^{-1})
η = dynamic viscosity (Pa.s)

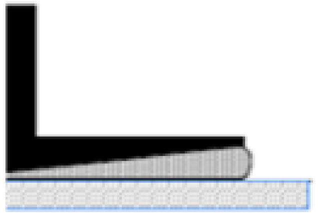
Appropriate amount of material is essential



under loading



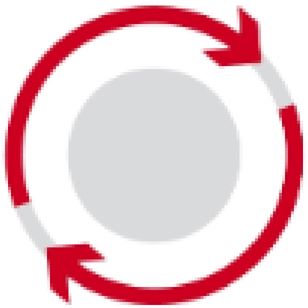
overloading



correct loading

Measures the <u>push</u> (stress) needed to get the material to move a certain speed (shear rate) and vice versa.

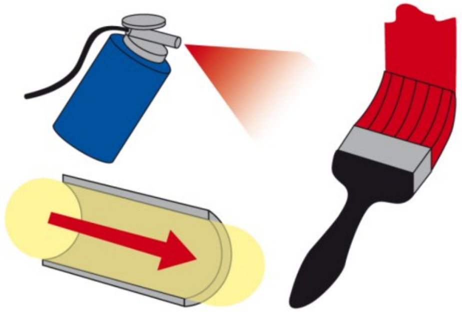
Choice of operating mode



To obtain the viscosity, it is necessary to define a shear rate or a shear stress.

Controlled shear rate (CSR or CR)

Controlled shear stress (CSS or CS)



$$\boxed{\eta = \frac{\tau}{\dot{\gamma}}}$$

η = dynamic viscosity (Pa.s)
τ = shear stress (Pa)
$\dot{\gamma}$ = shear rate (s^{-1})

Paints, creams and lotions, liquid resins, oils

Ketchup, toothpaste, thick cosmetic creams, thick inks

•**CSR** mode: Deformation is imposed (variable shear rates) and the force required to cause it is measured.
Suitable for fluids, where deformation depends on the speed applied.

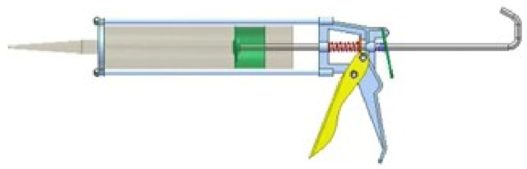
•**CSS** mode: The force is imposed, and the deformation of the material is observed.
Suitable for viscoelastic or plastic materials, where flow begins above a stress threshold.

Choice of shear rate

Situation	Typical Shear Rate Range (s^{-1})	Application
Sedimentation of fine powders in suspensions	$10^{-6} – 10^{-4}$	Pharmaceutical products, paints
Leveling due to surface tension	$10^{-2} – 10^{-1}$	Paints, printing inks
Gravity-driven drainage	$10^{0} – 10^{1}$	Paints and coatings, rinsing layers
Extruders	$10^{0} – 10^{2}$	Polymers
Chewing gums	$10^{1} – 10^{2}$	Food products
Coating applied by dipping	$10^{1} – 10^{2}$	Paints, confectionery
Mixing and agitation	$10^{0} – 10^{3}$	Industrial liquids

Situation	Typical Shear Rate Range (s^{-1})	Application
Flow in pipes	$10^{0} – 10^{3}$	Pumping, blood flow
Spraying and equipment application	$10^{3} – 10^{4}$	Spraying, paints, fuel atomization
Rubbing	$10^{4} – 10^{5}$	Application of creams and lotions on the skin
Grinding pigments in fluid bases	$10^{3} – 10^{5}$	Paints, printing inks
High-speed coating	$10^{5} – 10^{6}$	Paper
Lubrication	$10^{3} – 10^{7}$	Engines

Silicone gun pressure

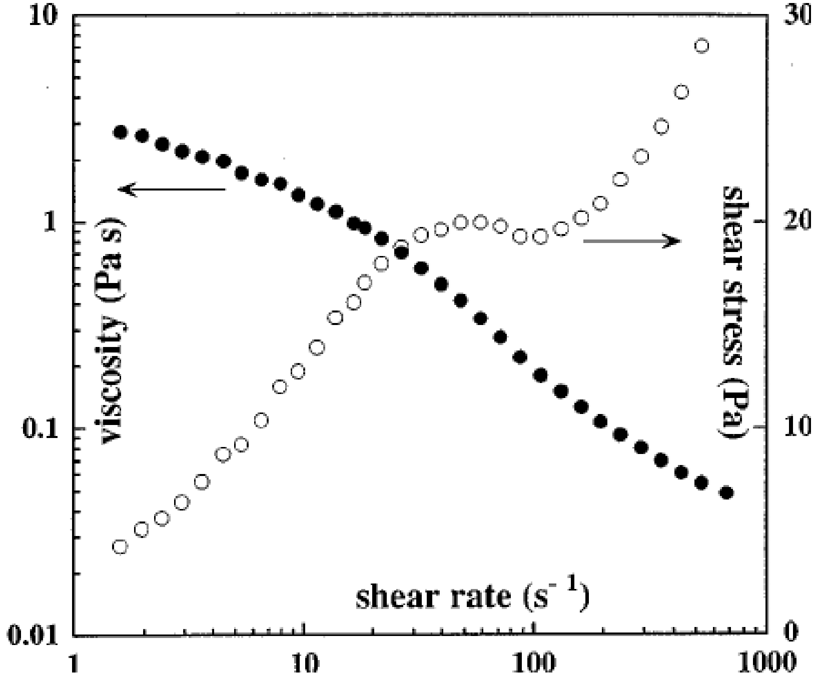


Application of a cream

Possibilities and results

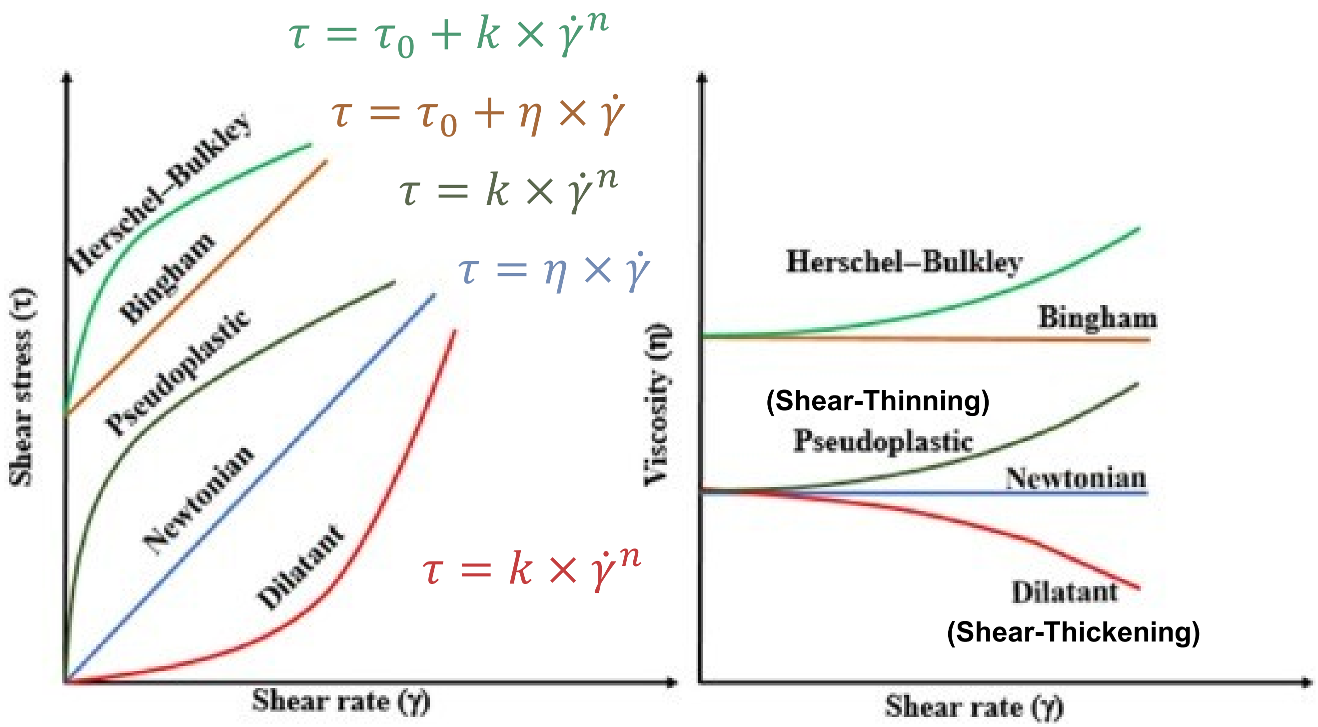
Important: When presenting a viscosity value, it is essential to specify the measurement parameters, such as temperature, shear rate, geometry used and gap .

Viscosity curve



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

Rheologicals behaviours



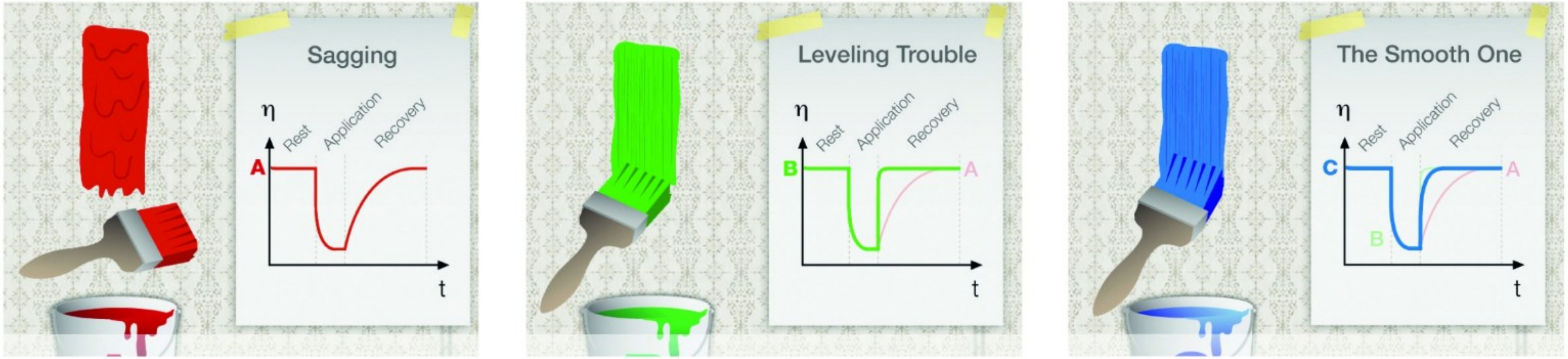
τ = shear stress (Pa)
τ_0 = threshold stress (Pa)
$\dot{\gamma}$ = shear rate (s^{-1})
η = dynamic viscosity (Pa.s)

k = Consistency index ($Pa.s^{-1}$)
n = Flow index (a.u.)
Dilatant n >1
Pseudo-plastique 0 < n < 1

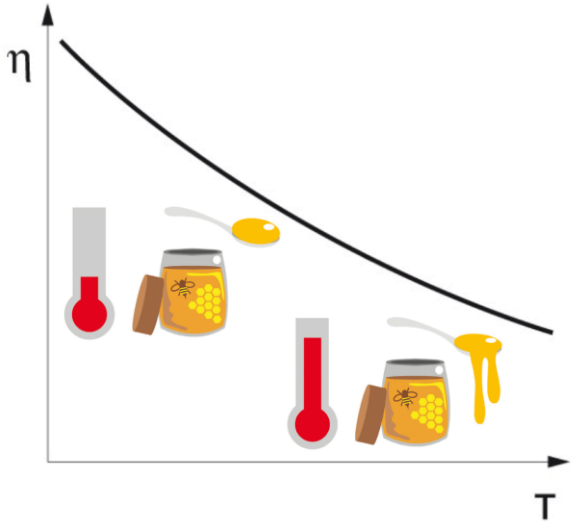
Possibilities and results

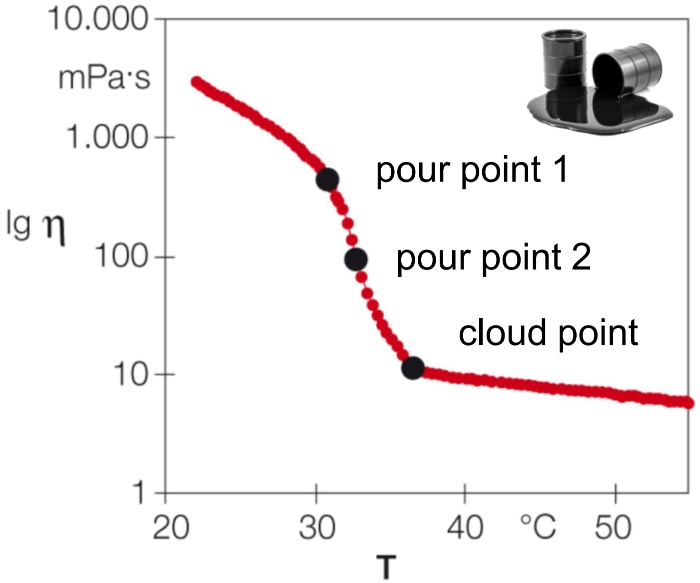
Viscosity vs time curve

Thixotropic behaviour of a paint



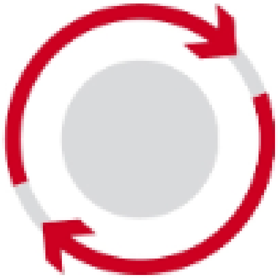
Viscosity vs temperature curve





- Cloud point (fuel becomes cloudy – initial crystallization of waxes and paraffins)
- Pour point 1: Turning point of the viscosity curve
- Pour point 2: Bend where the viscosity curve becomes flatter

Conclusion

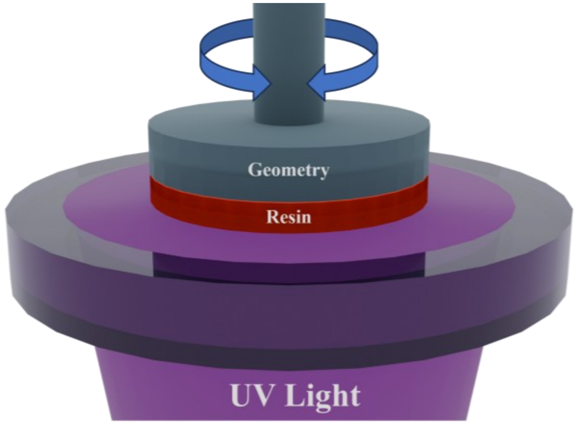


Continuous rotation mode

Important: When presenting a viscosity value, it is essential to specify the measurement parameters, such as temperature, shear rate, geometry used and gap .

Perspectives

Rotary oscillation mode



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Thank you for your attention !

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