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LAMY RHEOLOGY INSTRUMENTS

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VISCOMETERS
RHEOMETERS
TEXTURE ANALYZER
TEMPERATURE CONTROL
MEASURING GEOMETRIES

Catalogue 2015-2016

Tactile instruments

RHEOLOGY KNOWLEDGE

Dynamic viscosity: η (Eta)

It is defined by the NEWTON equation: and quantify measurement of internal friction of fluid.
His determination needs to apply to the fluid a Shear rate (D), and to measure the resistant Shear stress (τ) to this rotation.

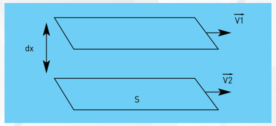
$\tau = \eta * D$ in **Pa.s**

For memory:
1 Pa.s = 10 Poises or
1 mPa.s = 1 cPoises

Shear rate: D (γ)

is the shearing which subjected by the product in the application. It is known for measurement geometries with small gap. It is not the speed of rotation of the bob (in rpm !).

Either a sheared fluid, by a laminar move (dV), between two parallel plates with a surface (S) and separate by a distance dx.



$D = dV / dx$ **in s** $^{-1}$

Shear stress: τ (Tau)

There is the shearing force (F), with which the sample answers to the shear rate (D), divided by the contact surface (S).

$\tau = F / S$ **in Pa** (N / m2)

Rheology:

There is the « science » of « flow ».

Associated physical measurements, realised with the hand of Rheometers, enables the visualisation of the behaviour of the product in various flow , temperature and time conditions .

Rheograms:

displayed curves of the flow behaviour of a fluid.

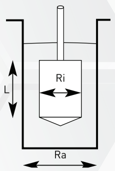
The curves $\tau = f(D)$ enables, by adapted fitting, the access to direct related parameters with the application.

Rotating viscometer:

a - With coaxial cylinders

The fluid is sheared between two coaxial cylinders, with radius Ri and Ra and a length L, by a laminar move which are breaking down in multi-layer with different angular speed from 0 (for the layer in contact with the fixed cylinder) to ω_0 (for the layer in contact with the rotating bob). The relative move of layers towards others give, a shear rate D and one Shear stress τ.

By imposing ω_0 and measuring M, the resisting torque to this rotation, we calculate D and τ according :



$\delta = Ra / Ri$ $\quad$ $Ri / Ra \rightarrow 0.92$

Shear stress:

$T_{rep} = (1+\delta^2 / 2\ \delta^2) * (M / 2\pi L Ri^2)$

Shear rate:

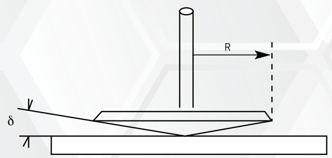
$D_{rep} = \omega * (1+ \delta 2) / (\delta 2 - 1)$

Rq : The determination of D is possible only if the gap is small.
(i.e. DIN / ISO 3219 Standard).

b- With Cone-Plate :

The fluid is placed between a Plate and a Cone with angle δ (< 3°).

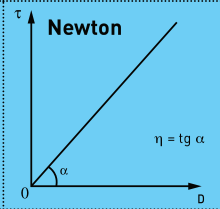
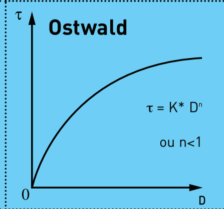
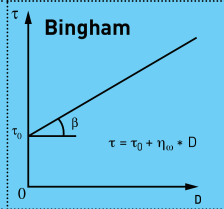
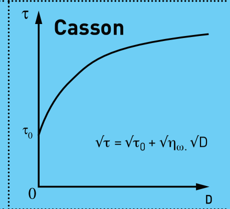
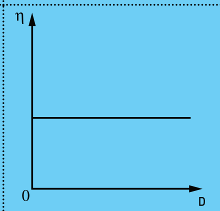
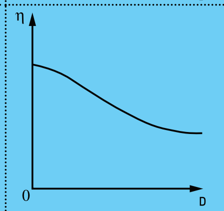
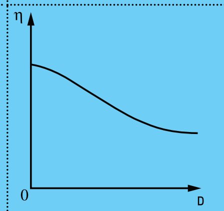
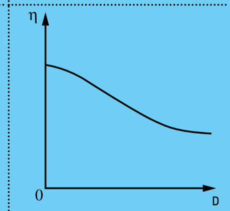
The cone, maintained to a constant speed induce a laminar shearing move. In those conditions, τ and D are constant in the gap, according :



Shear stress / Shear rate
$T = 3M / 2\pi R^3$ / $D = \omega / arc\ \delta$

Rq : You would be vigilant on the sample volume including in the gap, because the great influence of the radius R on the τ value !

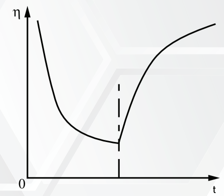
Study of different rheological behaviours

TYPE	NEWTONIAN	PSEUDO-PLASTIC	PLASTIC	
Description	A sample is named newtonian when his viscosity stay constant, whatever the shear rate is. Iit is not necessary to define exactly the shear rate for the measurement. Just the temperature is important.	One pseudo-plastic sample has a viscosity which decrease when the shear rate increase: This flow behaviour is due to the molecules form and to their internal structure.	One sample presents a plastic behaviour, when his viscosity decrease when the shear rate increase, but from one original shear stress upper than 0, called YIELD VALUE (Tau 0), shear stress under which the product doesn't flow. It behave like a solid body.	
Rheogram	Newton  $\eta = tg\ \alpha$	Ostwald  $\tau = K* D^n$ ou n<1	Bingham  $\tau = \tau_0 + \eta_\omega * D$	Casson  $\sqrt{\tau} = \sqrt{\tau_0} + \sqrt{\eta_\omega}.\sqrt{D}$
Viscosity				
Examples	• Water: 1 mPa.s to 20° C • Oils: 150 to 400 mPa.s (motor) 300 to 800 mPa.s (gears) • Mercury: 1,5 mPa.s • Gas: 0,01 to 0, 02 mPa.s	• Coating, • Varnish, • Cosmetics, • Mineral Suspensions....	• Toothpaste, • Ointment, • Grease, • All very concentrated suspensions....	

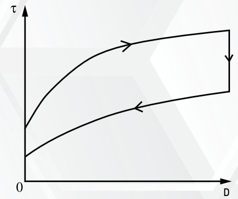
The thixotropy

One thixotropic product is a sample for which the variation of viscosity in function of shear rate is associated to a variation trough the time.

Owe talk about Thixotropy or Rheopexy, with the condition of REVERSIBLE Transformations: frozen or solidification.



Time of shearing $\quad$ Rest Time



Rheogram of thixotropic sample

Causes of thixotropy :

- Molecular structure
- « Château de cartes » with layers
- Particules mixing
- Ball loose Package...

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GLOSSARY

Adhesiveness: is the sticky power of a product. It is measured during a tension phase in texture analysis, by the negative force measured and also by the surface under the base line.

ASTM: American Society of Testing Materials. American organisation in charge of creating ASTM standards.

BINGHAM: model of rheological flow behaviour, characteristic of plastic products (shear-thinning with yield stress).

CASSON: model of rheological flow behaviour, allows the precise determination of non-linear plastic product's yield stress.

Centipoise (cP): measuring unit of dynamic viscosity in the MKSA system; equivalent to mPa·s in the SI system.

Coaxial cylinders: one cylinder with cap contains the product (cup) and one cylinder of a smaller size and another cylinder rotates inside (measuring bob) and imposes shear rate (D) known in the sample. (see DIN Standard).

Cone-plate: measuring geometry composed of one plate on which the product to be measured is placed and a low-angle cone (2° max), which shears the sample.

Consistency: notion of force with which a product resists compression. Quantified in texture analysis by Maximum Force that is measured during a compression phase.

Couette principle: principle of rheometer function in which the cup or the lower plate turns or oscillates, and the measuring bob or cot or upper plate measures torque. This principle lets you separate the part deforming the sample from the part that measures.

D (or $\dot{\gamma}$): shear rate actually subject to the fluid to be measured, expressed as s-1.

Dilatancy: increase of viscosity with the effect of rotation speed.

DIN: German Original Standard, specifying measuring geometries at a defined shear rate. Became ISO 3219.

Elasticity: Ability of a sample to recover its initial state after having been deformed. Inversely proportional to the relaxation % in texture analysis tests.

ETA (η, Dynamic Viscosity): quantifies a fluid's internal frictions; determined by the rotating principle: torque resistant to rotation; expressed in Pa·s.

K: consistency coefficient according to the Ostwald model; it shows a product's viscosity at 1 s-1.

KREBBS Unit: viscosity measuring unit obtained with a KU110 measuring bob, at 200 rpm.

M (mNm): measured torque in response to the rotation of the measuring bob, based on the product's viscosity.

Measuring bob (spindle): element immersed in fluid which rotates and measures the resistant torque of a product, according to the Searle principle.

Measuring geometry: set of spindles and cups or cones and plates used to measure viscosity. It enables, if well defined, to control the shear rate (D) subjected by the product.

N: rotation speed of motor, in rpm, which generates a shear rate (D) which depends on the measuring geometry used.

n: behaviour index of the Ostwald model; shows shear-thinning character of a product.

NEWTON: model of rheological behaviour model, characterising fluids for which only temperature has an influence on viscosity.

OSTWALD: model of rheological behaviour, characterising pseudo-plastic products: shear-thinning without yield stress

Pa·s: official measuring unit, in the SI system, of dynamic viscosity (Eta). For fluid products, mPa·s (=cP) is used. i.e.: Water viscosity at 20°C = 1 mPa·s. Peltier (effect): electric thermostatisation system through a quick exchange of calories between two plate elements.

Plastic: for a fluid with a viscosity that decreases linearly or not under the effect of increasing speed, and that has a non-zero yield rate.

Plate-plate: measuring geometry composed of a plate on which the product to be measured is placed and another upper rotative plate, which shears the sample, inserted into an adjustable gap (h).

Poise (P): measuring unit of dynamic viscosity in the MKSA system; equivalent to 0.1 Pa·s in the SI system.

Pseudo-plastic: for a fluid with a viscosity that decreases under the effect of increasing speed, and that does not have a non-zero yield rate (flows with gravity).

PT100: temperature sensor, indicating a sample's temperature.

Rheogram: flow curve obtained by a continuous ramp (or steps) of shear rates, it allows you to see a fluid's rheological behaviour.

Rheology: science of flow studying the deformation properties of fluids under various factors.

Rheometer: a measuring instrument for studying a fluid's flow behaviour.

Rheopexy: increase of viscosity over time, independent of speed.

s-1: unit of shear rate (D) that the sample is subject to in a defined geometry.

Sensorial analysis: series of sensorial tests: touch, taste and visual tests carried out by a panel of people who state the texture of a product and its acceptability according to predefined criteria.

Tau (τ, Shear stress): force by unit of surface with which the fluid responds to rotations; directly comes from measured torque and from the surface of the measuring bob used; express in Pa.

Texture: set of physical properties of a solid or pasty product, qualitatively characterised by sensorial analysis; mainly covers the notions of consistency, elasticity and adhesiveness.

Thermostatisation: maintenance of and setting of a sample's temperature; requires accessories such as baths, cryostats, thermostating cells.

Thixotropy: reversible decrease in viscosity, dependant on shear time and not on speed.

Viscometer: rotating measuring instrument that enables dynamic viscosity (Eta) to be measured, at one rotation speed (N) or a defined shear rate (D).

ν (Kinematic Viscosity): measure of internal resistance of a fluid; determined by flow principle. It includes the gravity of fluid, expressed in Stokes or cSt.

Yield stress (τ_0): minimum force under which the fluid has a solid behaviour.

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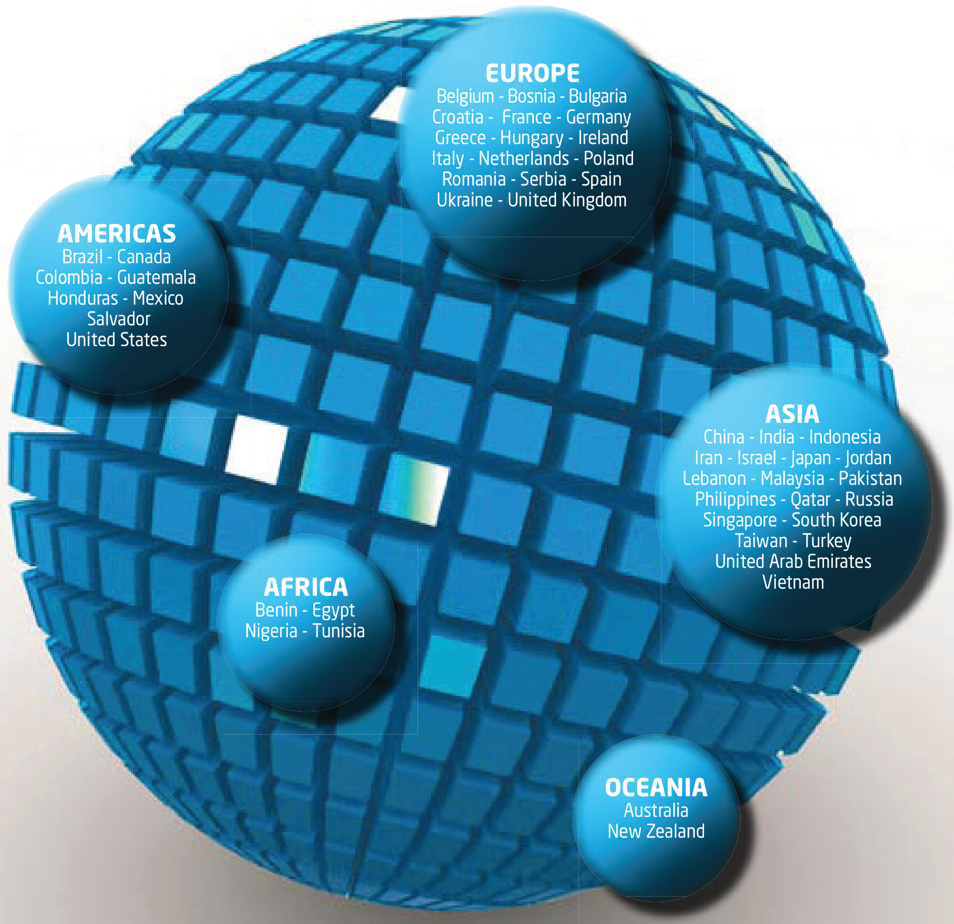

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