Viscometer

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Introduction

Viscosity is a measure of response of a fluid under shear stress, τ.

$\tau = \eta \mathbf{D}$ (Newton's law of viscosity)
η viscosity coefficient.
D = dV/dy
D is shear rate.

Unit
SI unit **Pascal.second [Pa•s]**
CGS **poise [P]**

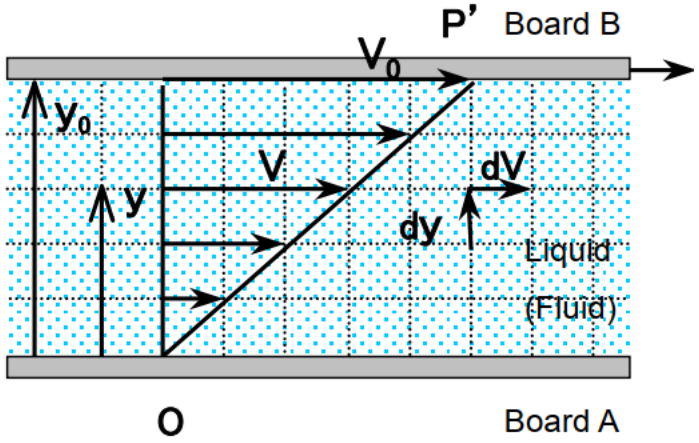


Figure 2 Couette Flow
(Newtonian Fluid)

Curved line ② shows a **dilatant fluid**
Curved line ③ shows a **pseudo plastic fluid**
Straight line ④ and curved line ④’ show called a **plastic fluid**
line ④, it is called a **Bingham fluid**
Curved line ④, it is called a **Bingham fluid**
Curved line ⑤ shows what is called **thixotropy**
Sol state (colloidal sol) (flow) <-> gel (rest)

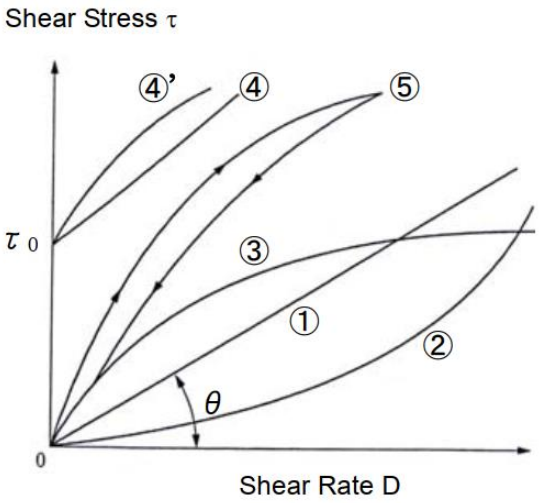


Figure 3 Newtonian Fluid and Non-Newtonian Fluid (Yutaka Matsuyama,

Table 1 Typical examples of fluid type

Type of fluid	Typical example
①Newtonian fluid:	Water, sugar solution, salt solution, alcohol, solvent, glycerin, silicon oil, oil-based (water-based) cosmetics, mercury
②Dilatant fluid:	Starch solution, moist sand (quick sand), suspension (high concentration), clay slurry, paint, chocolate (buttermilk)
③Pseudo plastic fluid:	Colloidal solution, polymer solution, emulsion, lacquer varnish, paint/dye, mayonnaise, sauces, juice, evaporated milk
④Plastic fluid (Bingham fluid) :	Margarine, tomato ketchup, egg white (foam), toothpaste, cream (cosmetics), various slurries (cloudy liquid with solid particle)
(Non-Bingham fluid) :	Print ink, paint, coating, mayonnaise, refined flour of alimentary yam paste, asphalt, blood
⑤Thixotropy:	Solder paste, grease, print ink, clay suspension, tomato ketchup, cocoa, cream (cosmetics)

Types of Viscometer

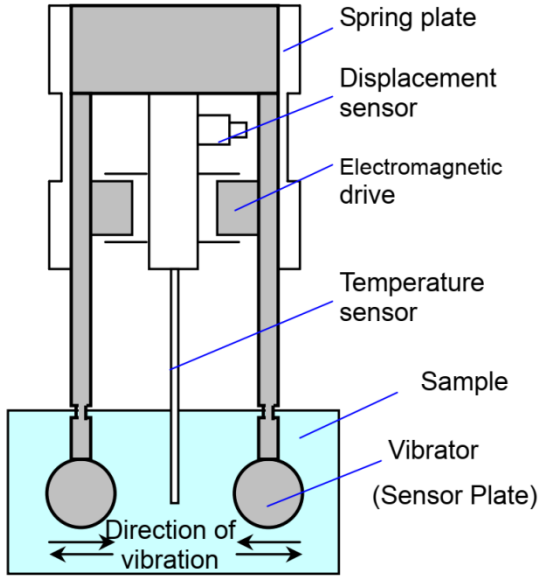
1	**Vibro viscometer**	Measures viscosity by controlling the amplitude of the sensor plates immersed in a sample and measuring the electric current to drive the sensor plates.
2	**Rotational viscometer**	Measures viscosity by measuring the running torque of the cylindrical rotors immersed in a sample.
3	**Capillary viscometer**	Obtains viscosity by letting a sample flow inside the capillary and measuring the difference in pressures between both ends of the capillary.
4	**Falling-ball viscometer**	Obtains viscosity by measuring the time of a cylindrical or spherical object falling through a sample over a specific distance.
5	**Cup-type viscometer**	Obtains viscosity by measuring the time taken by a sample to flow out of the opening in a container.

Vibro Viscometer

For a fixed frequency and amplitude the driving electric current (driving power) is also directly proportional to the product of viscosity and density of each sample.

Current ∝ viscosity x density

Advantage
Can measure over wide range
Take continuous measurement



Rotational Viscometer

Measures torque

Based on
Torque ∝ Viscosity

Limitation
Continuity – Requires several type of rotors to wide range of viscosity .

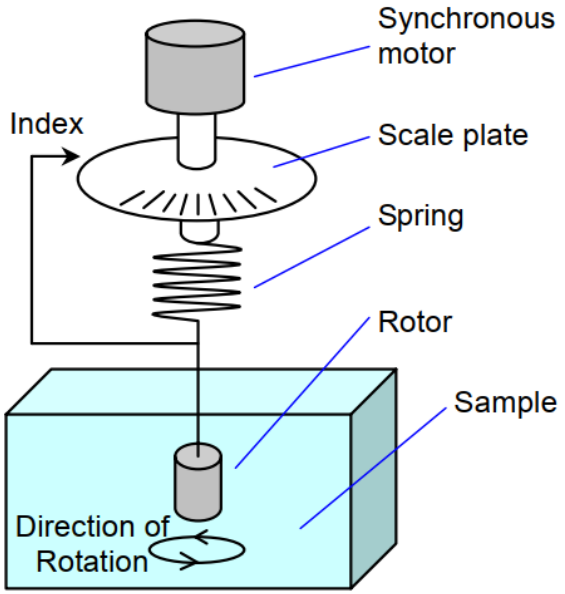


Figure 6 Principle of Rotational Viscometer

Capillary Viscometer

$$\eta = \frac{\pi r^4}{8L}\frac{\Delta P}{Q}$$

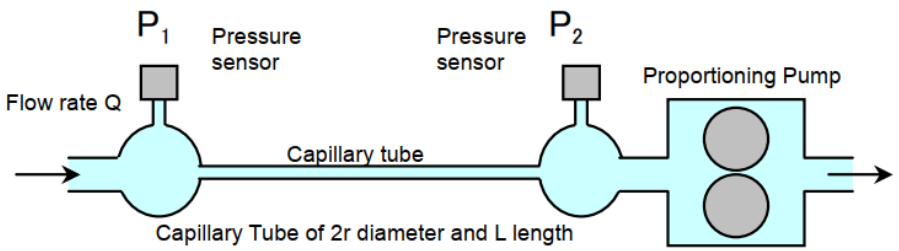


Figure 7 Principle of Capillary Viscometer

Measures kinetic viscosity ,ν from the time t taken by a certain amount of sample to flow by free-fall through the capillary tube

Limitation

- Can take continuous measurement
- glass can expand/contract under the influence of temperature

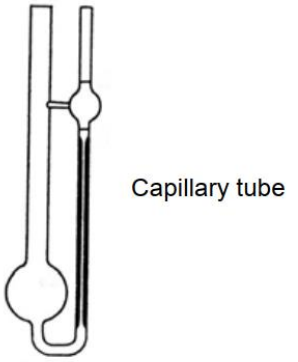


Figure 8 Capillary Viscometer (Free-fall)

Falling-ball Viscometer

A sphere or column with known dimension and density is dropped into the medium.

Time taken to travel a specified distance under free fall ∝ Viscosity

Limitation
Continuous measurement

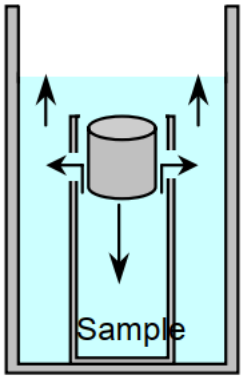


Figure 9 Principle of Falling-ball Viscometer

Cup Type Viscometer

When measuring the viscosity of paint or ink cup type viscometer are used.
Time taken a sample flow from the opening of the cup gives a measure of viscosity.

Limitation

Continuous measurement

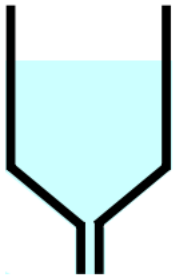


Figure 10 Cup-type Viscometer

THANK YOU