Viscosity is a representation of the resistance of a fluid to flow and higher is the viscosity greater is the resistance. On the basis of flow and deformation, material can be classified mainly to category

1. Newtonian flow
2. Non-Newtonian flow

Newtonian flow

Fluids which follow Newton's law of flow is known as fluid having Newtonian flow. It states that 'the rate of shear is directly proportional to the shearing stress'. Let us consider a block as shown in Fig. 4.2. If bottom layer is considered to be fixed and top plane of liquid is moved at a constant velocity. The rate of shear is directly proportional to the distance from the stationary bottom layer.

Velocity gradient or rate of shear = dv/dr

where, dv is velocity between two planes of liquids, dr is very small distance between two planes.

The force per unit area required to bring about flow is called the shearing stress.

$$\text{Shearing stress} = \text{Force/Area} = F'/A$$

According to Newtonian law

$$\text{Shearing stress} \propto \text{rate of shear}$$
$$F'/A \propto dv/dr$$
$$F'/A = \eta\, dv/dr$$

where η is called as coefficient of viscosity. It is generally represented in term viscosity. Viscosity or internal friction is the resistance to the relative motion of adjacent layer of liquid.

If use, $F'/A = F$ and $dv/dr = G$ Then $\eta = F/G$

If plot a graph between F & G it shows a Straight line which passes through origin

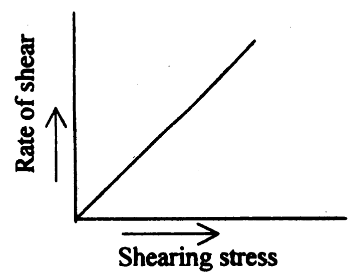

Fig. 4.2. Newtonian flow

Units and dimension of viscosity

Unit is in CGS unit- poise, small unit centipoise (10^{-2} poise).

Dimension of viscosity $[ML^{-1}T^{-1}]$

Fluidity : It is reciprocal of the viscosity

$\phi = 1/\eta$ where, ϕ is the fluidity

Poiseuille's equation

$$\eta = \frac{\pi r^4 \, t\, h\, d\, g}{81\, V}$$

If instrumental constant

$$K = \frac{\pi r4\, h\, g}{81\, V}$$

Then $\eta = K\, t\, d$

It is not necessary to evaluate K. If two liquid A and B are considered having viscosities η_1 & η_2 and density d_1 and d_2 and time taken by them to flow between two fixed points is t1& t_2 respectively then it can be expressed as equation.

$$\eta_1 = K\, t_1\, d_1 \quad \text{(i)} \qquad\qquad \eta_2 = K\, t_2\, d_2 \quad \text{(ii)}$$

Equation (i) is divided by (ii)

$$\frac{\eta_1}{\eta_2} = \frac{t_1\, d_1}{t_2\, d_2} \quad \text{or} \quad \boxed{\eta_1 = \frac{t_1\, d_1\, \eta_2}{t_2\, d_2}}$$

A range of glass capillary viscometer with different diameter are available for liquid of different viscosity.

Precautions

1. Instrument should be completely cleaned using chromic acid solution and if necessary then organic solvents like methanol or acetone.
2. Capillary diameter should be selected on the basis of viscosity of liquid.
3. For accuracy, take readings in triplicate.
4. A range of shear rates can be covered when external pressure is applied to force a viscous liquid through a narrow capillary.

Falling sphere viscometer

This type of viscometer consists of a glass tube & steel ball rolls. It moves vertically in the glass tube containing the test liquid at a control temperature. The rate of ball at which it moves in a fixed diameter tube is inversely proportional to the viscosity of liquids. If the viscosity of the liquids is high, ball is moved slowly in the liquid.

It is based on the principle that resistance offered by a liquid to falling ball is equal to its viscosity. Thus, velocity of the ball is inversely proportional to the viscosity. It consists of a ball placed in the inner glass tube which has the homogeneous temperature maintained by constant water jacket. The time for the ball to fall between two fixed points is accurately measured and experiment is repeated for several times. The viscosity of the liquid is calculated by the following equation

EXERCISE NO 4.8

To study the effect of temperature on viscosity

Purpose

- To learn the effect of temperature on viscosity.

Requirements

Chemicals/reagents

- Sucrose syrup
- or glycerin & Distilled water

Equipment /glasswares

Same as exercise no. 4.1

Procedure

1. Prepare saturated solution of sucrose in purified water if necessary, filter it without warming the sucrose solution.
2. Arrange the assembly.
3. Before setting the assembly, thoroughly clean the glasswares as well as, equipment required in experiment.
4. After cleaning the viscometer, dry it completely using the current of hot air or dry in the oven.
5. Determine the density of suspension using pycnometer as exercise no. 4.1
6. Report time taken to flow for purified water and sucrose solution under the same conditions between two points, at different temperature.

Observation

(a) Weight of pycnometer or density bottle at room temperature = W_1 g
(b) Weight of pycnometer or density bottle with water represent by = W_w
(c) Weight of pycnometer or density bottle with sucrose solution represent by = W_s

Observation table A

Weight of pycnometer (solutions)	Weight in g					
	Temperature (°C)					
	RT	37	45	55	75	85
W_w W_s						

(a) Force (F_1) due to surface tension, raising the liquid column upward

$$F_1 = \text{inside circumference of capillary} \times \text{surface tension of liquid}$$

$$F_1 = 2\pi r\gamma$$

(b) Force (F_2) of gravity pulling the liquid downward

$$F_2 = \text{weight of liquid in the column pulled downward due to gravity}$$

$$F_2 = mg$$

if, $m = \rho V$ and V (volume of liquid inside the tube) $= \pi r^2 \times h$

Hence,

$$F_2 = \pi r^2 \times h\rho g = \pi r^2 . h\rho g$$

At the equilibrium state both forces are equal

$$F_1 = F_2$$

or

$$2\pi r\gamma = \pi r^2 \times h\rho g$$

or

$$\boxed{\gamma = \tfrac{1}{2}\, rh\rho g} \qquad \text{-- (5.12)}$$

If the liquid has poor wetting power or wetting is not pertect, in this condition contact angle (θ) between glass and liquid is not zero.

Hence,

$$F_1 = 2\pi r\gamma \cos\theta$$

Now equation (5.12) is

$$\boxed{\gamma = rh\rho g/2\cos\theta} \qquad \text{--- (5.13)}$$

DuNouy Tensiometer

DuNouy tensiometer is commonly used for determination of surface tension and interfacial tensions. It is very convenient, rapid and require small amount of sample. The principle of the instrument depends on the fact that the force required to detach a platinum-iridium ring immersed at the surface or interface is proportional to the surface tension or interfacial tension. The force which is necessary to dettach the ring in this manner that is provided by a torsion wire and is recorded in dynes on a calibration dial. The instrument is shown in the Fig. 5.4. The surface tension of liquid is determined by the following equation.

$$\boxed{\gamma = \frac{\text{Dial reading in dynes}}{2 \times \text{ring circumference}} \times \text{correction factor}}$$