Determination of Fluid Viscosity with Falling Ball Viscometer

Introduction

Viscosity is a fundamental characteristic property of all liquids. Viscosity is a measure of the frictional properties of the fluid (occurs between the molecules of that fluid). When a liquid flows, it has an internal resistance to flow. Viscosity is a measure of this resistance to flow or shear. Viscosity is a function of temperature and pressure. Although the viscosities of both liquids and gases change with temperature and pressure, they affect the viscosity in a different manner. In this test, we will deal only with viscosity of liquids and its change with temperature.

Viscosity is expressed in two distinct forms:

a. Dynamic viscosity (also called absolute or shear viscosity)

b. Kinematic viscosity

Dynamic viscosity is the tangential force per unit area required to slide one layer of a fluid against another to the velocity gradient perpendicular to the direction of flow. Kinematic viscosity requires knowledge of density of the liquid at that temperature and pressure.

In the SI System the dynamic viscosity units are N•s/m^2, Pa•s or kg/m•s. The kinematic viscosity is expressed as m^2/s or Stokes (St), where 1 St = 10^{-4} m^2/s.

Purpose

To determine the viscosity of a fluid with falling ball viscometer.

Apparatus

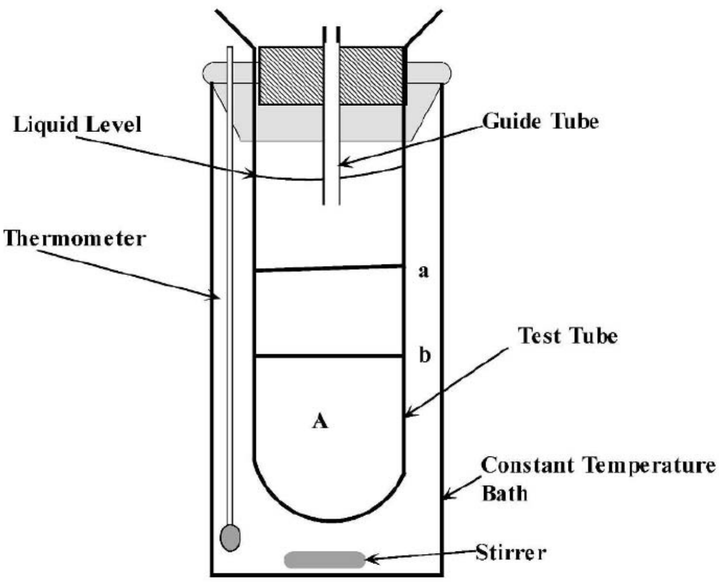

Fig.1 Falling ball viscometer (Viswanath *et al*, 2007).

Theory

In falling ball viscometers, a solid body is allowed to fall under gravity through a viscous medium. After a period of initial acceleration, the solid body attains a uniform terminal velocity when the gravitational force is balanced by the viscous resistance of the fluid. By measuring the terminal velocity of the falling body, the viscosity can be determined. Under this condition and assuming that the fluid medium has an infinite extension, the viscous resistance to the motion of the sphere moving with a velocity v is equal to the driving force due to the difference in density between the sphere and the fluid. This is known as the Stokes' law and is given by

$$6\pi\eta r v = \frac{4}{3}\pi r^3 g(\rho_s - \rho_f) \qquad (1)$$

where

η is the dynamic viscosity, r is the radius of sphere, v is the velocity of the sphere, ρ_s and ρ_f are the density of sphere and fluid respectively and g is the acceleration due to gravity.

Equation 1 can be rewritten as follows to obtain the dynamic viscosity

$$\eta = \frac{2gr^2(\rho_s - \rho_f)}{9v} \qquad (2)$$

The Kinematic viscosity υ is obtained from

$$\upsilon = \frac{\eta}{\rho_f} \qquad (3)$$

Procedure

1. Consider the system shown in Fig. 1, a sphere (any other shape and size can be used) is left to fall through a homogeneous fluid. If the motion of the sphere is sufficiently slow, the inertia terms become negligible.
2. The tube A, closed at the bottom, is filled with the sample to be tested. The tube A is placed inside a constant temperature bath, that could be maintained within ± 0.1oC, for about 1 hr.
3. The sphere is introduced into the tube along the axis by means of a guide tube.
4. The position of the sphere is followed and the time at which it passes the reference marks a and b is noted.
5. The density of both the liquid and the sphere at the test temperature should be determined as accurately as possible.
6. Dynamic and kinematic viscosities at a given temperature are then calculated from Equations 2 & 3 respectively.

Data source: Viswanath D.S, Ghosh T.K., Prasad D.H. L., Dutt N.K. and Rani K.Y., (2007), "*Viscosity of Liquids: Theory, Estimation, Experiment, and Data*", Springer, P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

Questions to guide discussions

Why viscosity gets affected by temperature variation? What does 'ideal fluid' mean? What is the viscosity of ideal fluid? Are viscosity, cohesion, and adhesion related? Explain.

