Physics for the Life Sciemces

Experiment 23

Viscosity

Purpose

To determine the coefficient of viscosity of oil.

Apparatus

Several small copper or lead spheres (about lmm in diameter)
100 mL graduated cylinder
Micrometer
Stopwatch
Ruler
Oil (10W30 Engine oil)
Balance

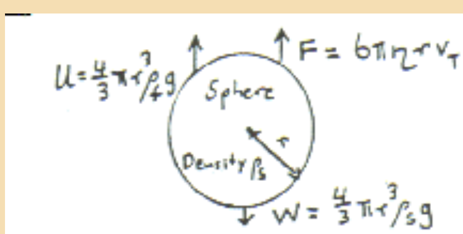
Theory

In order to cause motion of a fluid, a stress must be applied to it. Resistance to motion varies considerably from liquid to liquid and is very much greater than for gases. Some liquids such as glycerin or syrup, offer considerable resistance. These are called viscous liquids. Others, such as water and alcohol, are much less viscous.
It is found experimentally that for any given liquid, provided that laminar or streamline flow exists, the stress exerted on the liquid is directly proportional to the velocity gradient that it causes in it. In the case of fluid flow in a tube, the velocity gradient is the velocity at the center of the tube divided by the radius of the tube, v/r.

The coefficient of viscosity, η, is defined by the relation

$$\text{Stress} = \eta\, v/r \quad\text{...(1)}$$

The units of η are Ns/m^2 (also called the Poiseuille, symbol Pl). In the cgs system, the unit is the Poise (P).
1 P = 0.1 Ns/m^2. Typical values of h are 1 to 5 P for oil, 1 cP for water, and 0.02 cP for air.
When a body moves with constant velocity through a fluid, it experiences a frictional drag force which opposes its motion. For a sphere of radius r when moving with velocity v in a fluid of viscosity η, this frictional force is equal to $6\pi\eta r v$.
Let us consider a sphere of radius r and density ρ_s falling at a constant terminal speed v_T in a fluid of density ρ_f and coefficient of viscosity η. Since the sphere is moving at constant velocity, the forces acting on it are in equilibrium. A force diagram is shown below.



F is the frictional force
U is the bouyancy force
W is the weight of the sphere
r is the radius of the sphere
ϱ_s is the density of the sphere
v_T is the terminal speed of the sphere
ϱ_f is the density of the fluid
η is the coefficient of viscosity of the fluid

For equilibrium, U + F = W, so that $(4/3)\pi r^3\varrho_f g + 6\pi\eta r v_T = (4/3)\pi r^3\varrho_s g$.
Hence, the coefficient of viscosity is given by

$$\eta =(2/9)(r^2/v_T)(\varrho_s - \varrho_f)g \quad \text{.......................................(2)}$$

Procedure

1. **Weigh the graduated cylinder empty.**
2. **Fill it to the 100 mL mark with oil and reweigh.**
3. **Add some more oil until the oil level is about 1 cm above the 100 mL graduation mark.**
4. **Measure the distance between the lowest and highest graduation marks on the cylinder (h) in cm.**
5. **Make three determinations or the diameter of one of the small spheres using the micrometer. Release the sphere from just above the surface of the oil and measure the time that it takes to travel the distance between the two graduations on the cylinder that you measured in procedure (4)**
6. **Repeat procedure (5) for four other spheres.**
7. **Measure the room temperature and record it in the table.**

Calculations

1. **Determine the density of the oil in kg/m^3 using the relation density = (mass in grams)/(volume in mL) x 1000**
2. **Calculate the average diameter for each sphere in mm and the corresponding values of the radius in mm.**
3. **Calculate the terminal velocity of each sphere in m/s from $v_T = h/t$.**
4. **Calculate the coefficient of viscosity for each set of data using Equation (2).**
5. **Determine an average value for the coefficient of viscosity of oil at room temperature.**

Data

Mass of measuring cylinder empty....................................________ g
Mass of measuring cylinder + 100 mL of oil.....................________ g
Mass of 100 mL of oil...________ g
Density of oil (ϱ_f) ....________ kg/m^3
Density of metal spheres (ϱ_s)...________ kg/m^3
Difference in densities(ϱ_s - ϱ_f)..________ kg/m^3
Room teperature...________ ^{o}C
Distance between graduations on measuring cylinder (h) ________ cm

Diameter of spheres in mm	Average diameter of spheres in mm	Radius of spheres in mm	Time of fall in seconds	Terminal velocity $v_T = h/t$ in m/s	Coefficient of viscosity η in Ns/m^2
1.					
2.					
3.					
4.					
5.					

Average value of viscosity of oil at ________ ^oC = ________ Ns/m^2.

Questions

1. **How does your average value of the viscosity of oil compare with the typical range of 0.1 to 0.5 Ns/m^2?**
2. **Why is it important that the motion of the spheres through the oil be streamlined? How was this accomplished in this experiment?**
3. **How does the coefficient of viscosity of liquids vary with temperature? Why is this so? Write a general equation for the variation with temperature.**
4. **Show that Reynold's number, $\varrho vd/\eta$ is dimensionless.**

Last updated on Thursday 25th March, 2010