6. Determination of the liquid viscosity by Stoke's Law

1. Objectives: Understand the concept of fuild viscosity and dimension sion less parametres, determination of Reynolds number

2. Theory Viscosity is a property that provides an indication of the resistance to shear within a fluid

Newton's Law for viscous fluid; $F_d = (\mu du/dy)$

S; S - area; of contact Drag force;

$F_d = 6\pi\mu v r$;

μ - fluid dynamic velocity

v - velocity of the sphere clotive to fluid

r - R of the sphere

There are 3 forces action to sphere into a fuild; F_d, F_b, and mg.

by summing them we have;

$F_b + F_d = mg$

$F = \frac{4}{3}\pi R^2 g \rho$ fuild

$F_b + F_d = mg$

$\frac{4}{3}\pi r^3 g \rho + 6\pi\mu v r = mg$

Reynold's number: $R_E = \rho v d / \mu$

The buoyant force is defined by Archimedes principle: $P_1 = \frac{4}{3} \pi r^3 \rho g$

ρ - density of liquid

By Newton's second law we have:

$$m(dv/dt) = P_1 - P - F_d$$

Terminal velocity: $V_0 = \frac{2}{9}(\rho_1 - \rho)\, g r^2 / \eta$;

if we compare R(of vessel) with r;

$$F_c = 6 r v \pi \eta [1 + 2{,}4(r/R)]$$

$$\text{Then} \Rightarrow V_0 = \frac{2}{9} g r^2 (\rho_1 - \rho) g r^2 / \eta [1 + 2{,}4 r/R]$$

By substitution all formulas we determined the final formula of liquid viscosity

$$\eta = \frac{2}{9} g r^2 (\rho_1 - \rho) g r^2 / V_0 [1 + 2{,}4(r/R)]$$

Stoke's Law valid for $R_E < 0{,}5$;

where $R_e = 2 V_0 r g / \eta$

3 Equipment: Two transparent vessels with castor oil and glycerin. For measurement we'll use steel spheres.

4. Experimental procedure:

N	1	2	3	4	5
D_1	1,52	1,58	1,16	1,45	1,54
D_2	1,51	1,63	1,17	1,46	1,56
D_3	1,5	1,59	1,175	1,48	1,54
D_4	1,49	1,61	1,113	1,51	1,57
D_5	1,52	1,6	1,116	1,49	1,56
D_6	1,512	1,62	1,14	1,47	1,55
D_7	1,492	1,61	1,183	1,495	1,55
$t_{,5}$	25,14	21,25	50,79	28,35	26,48

Table 1
D in mm

N	1	2	3	4	5
$\langle r \rangle$	0,7531	0,8028	0,5755	0,7396	0,7764
Δr	0,0069	0,0128	0,0045	0,0146	0,0039
v_0	0,0174	0,0207	0,0086	0,0155	0,0166
η	0,5402	0,5188	0,6258	0,584	0,6033

Table 2.
$\langle r \rangle$ and Δr in mm
v_0 in m/s
η in Pa·s

$\langle r_n \rangle = \frac{\langle D_n \rangle}{2}$; $\Delta r = (\langle r \rangle - r_i)$; $l = 44$ cm

$\langle r_n \rangle = \frac{\sum D_n}{14}$; $v_0 = \frac{l}{t}$; $\eta = \frac{2}{9} g r^2 \frac{\rho_1 - \rho}{v_0}\left[1 + 2{,}4 \frac{r}{R}\right]$

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$R = 2$ cm
$\rho_1 = 7{,}8$ g/cm³
$\rho = 0{,}96$ g/cm³

$$\langle D \rangle = \frac{0{,}5402 + 0{,}5188 + 0{,}6258 + 0{,}584 + 0{,}6033}{5} =$$
$0{,}57442 \ P_a \cdot S$

Now we need to work out Reynold's number!

$$R_E = \frac{2 V_0 r \cdot \rho}{D}$$

$$R_{E_1} = \frac{2 \cdot 0{,}174 \cdot 0{,}7531 \cdot 10^{-3} \cdot 960}{0{,}5402} = 0{,}0465$$

$$R_{E_2} = \frac{2 \cdot 0{,}0207 \cdot 0{,}8028 \cdot 10^{-3} \cdot 960}{0{,}5188} = 0{,}0615$$

$$R_{E_3} = \frac{2 \cdot 0{,}0086 \cdot 0{,}5755 \cdot 10^{-3} \cdot 960}{0{,}6258} = 0{,}0151$$

$$R_{E_4} = \frac{2 \cdot 0{,}0155 \cdot 0{,}7396 \cdot 10^{-3} \cdot 960}{0{,}584} = 0{,}0376$$

$$R_{E_5} = \frac{2 \cdot 0{,}0166 \cdot 0{,}7764 \cdot 10^{-3} \cdot 966}{0{,}6033} = 0{,}041$$

5. Conclusion: In this Laboratory work, have determined the liquid viscosity by Stoke's law. Finally i get average value as 0,57442 from 5 measuring. Then, calculated the Reynold's number to finish the experiment. if we'll compare my result with $D = 0{,}985$ $P_a \cdot S$, had got much smaller value. They differ by 70 % per cent from each other.