CL 232 Chemical Engineering Lab

Experiment Code	FM 202
Title	Nature of Flow

Sub-Group Code	

Date of Experiment	
Date of Report Submission	

Roll Number	Name	Responsibility Owned

(*for use by Examiners only*)

Criterion	TA Grade	Faculty assigned Grade
Data Analysis		
Graphical Plots		
Inference		
Report Quality		
Bonus Marks (Y|N)		
Initials with dates		

R&P TA initials with date		

Objective:

- To visually observe laminar and turbulent flow patterns.
- To determine the critical Reynolds number for transition from laminar to turbulent flow and vice versa.
- To calculate the pressure drop Δp between the two tanks and understand the relation between this and volume flow rate Q.
- To calculate the experimental and theoretical friction factor.

Theory:

Types of Flow:

Laminar Flow – When each layer of fluid moves parallel to each other. There is no intermixing between layers. Fluid particle do translational motion without any lateral movement. This type of flow occurs at very low velocity of fluid.

Turbulent Flow- Highly disorganized motion of fluid particle. Eddies formed which causes lateral mixing of fluid particle. This type of flow occurs at high velocity of fluid.

The types of flow is determined by a dimensionless parameter called Reynolds Number (N_{Re}).

Reynold's Number is given by:

$$N_{\mathrm{Re}} = \frac{\rho V D}{\mu}$$

This can be written as:

$$N_{\mathrm{Re}} = \frac{\rho Q D}{A\mu} = \frac{m D}{A\mu}$$

Where;

ρ: Density of fluid (kg/m^3)

V: Velocity of fluid (m/s)

D: Diameter of pipe (m)

μ: Viscosity of fluid (kg/m.s)

Q: Volumetric flow rate (m^3/s)

m: Mass flow rate (kg/s)

A: Cross-sectional area (m^2)

(All are in SI unit)

When the velocity of a fluid increases, the Reynolds Numbers also increases and after a certain value the flow changes from Laminar to Turbulent. This value of N_{Re} is called ''Upper *Critical Reynolds Number''*.

Similarly when the velocity of a fast moving fluid decreases, after a certain value of N_{Re} the flow changes from Turbulent to Laminar. This value is called "Lower critical Reynolds number".

Another factor which is useful in the study of flow is called *"Friction factor"* (*f*) which is defined as the ratio of wall shear stress to the product of density and velocity head.

$$f = \frac{\Delta p D}{2\rho L V^2}$$

Where Δp the pressure drop and L is length of the pipe.

$f = 16/N_{Re}$ for laminar flow and

For turbulent flow;

$f = 0.046\, {N_{Re}}^{-0.2}$ for $50000 < N_{Re} < 10^6$

$f = 0.0014 + 0.125 {N_{Re}}^{-0.32}$ for $3000 < N_{Re} < 3\times10^6$

Procedure:

- The equipment was filled with water and the flow rate was adjusted to the minimum value.
- The flow rate of dye solution was adjusted such that it matches the velocity of water.
- For each flow rate the heights of the two tank was measured and the flow pattern was observed by the dye solution.
- The volumetric flow rate of water was measured by collecting it in a measuring cylinder and a stopwatch was used to note the time it has taken.
- Similar steps were carried out by increasing the flow rate gradually and the flow pattern was observed from laminar to turbulent.
- The flow pattern was observed from turbulent to laminar by decreasing the flow rate with small decrement and by similar steps as above.

Raw Data:

Diameter of pipe: 25mm

Length of pipe: 1.65m

Viscosity of water: 8.9×10^{-4} Pa.s

Density of water: 1000 kg/m^3

Cross sectional area of pipe: 4.908×10^{-4} m^2

Least Count:

1. Stopwatch: 0.01s
2. Measuring Cylinder:
   a. For 1000ml: 10ml
   b. For 2000ml: 20ml

Height of water in the tank 1 at inlet and tank at the outlet of the pipe with no flowing water:

Height of water in the tank 2 at inlet and tank at the outlet of the pipe with no flowing water:

Difference between the above two heights is **zero error**.

Water level in the tank		Volume (m^3)	Time (s)	Velocity (m/s)	Reynold's No. (N_{Re})	Nature of flow observed visibly
Inlet (H_1 mm)	Outlet (H_2 mm)					

(Table 1)

Correction for zero error for manual fixing of the datum:

H_1=

H_2=

$H_{correction}$ =

H_1 (mm)	H_2 (mm)	H_2 corrected (mm) = H2 + H_{corr}	ΔH corrected (mm) = H_2 corrected - H_1

(Table 2)

Sample Calculation: (with Random data)

Experimental value:

Reynolds number calculation:

For example:

Q=volumetric flow rate= volume/time

Q= A×V=> V= Q/A = 0.003×10^{-3} (m^3/s)/ (4.908×10^{-4} m^2) = 6.1×10^{-3} m/s

$$N_{\mathrm{Re}} = \frac{\rho V D}{\mu} = \frac{1000\frac{kg}{m^3}\times 6.1\times10^{-3}\ \frac{m}{s}\times(25\times10^{-3})m}{8.9\times10^{-4}\frac{kg}{m.s}} = 171.34$$

Pressure drop calculation:

From table 2 let's say the value for $\Delta H_{corrected}$ = 2mm

$$\Delta p = \rho g\ \Delta H = 1000\ \frac{kg}{m^3}\ \times 9.81\ \frac{m}{s^2}\ \times (2\times10^{-3})\,m = 19.62\ N/m^2\ (Pascal)$$

Friction factor calculation:

$$f = \frac{\Delta p D}{2\rho L V^2} = \frac{19.62\frac{N}{m^2}(25\times10^{-3})m}{2\times1000\frac{kg}{m^3}\times 1.65m\times\left(6.1\times10^{-3}\ \frac{m}{s}\right)^2} = 3.99$$

Theoretical value:

Calculate friction factor (f) by using the relation f=16/Re (for laminar)

For turbulent flow;

$f = 0.046\ N_{Re}^{-0.2}$ for $50000 < N_{\mathrm{Re}} < 10^6$

$f = 0.0014+0.125 N_{Re}^{-0.32}$ for $3000 < N_{\mathrm{Re}} < 3\times10^6$

(Note: *Use table 1 for Reynolds number data*)

By substituting the value for (f) in the equation below;

$$f = \frac{\Delta p D}{2\rho L V^2}$$

Calculate Velocity (V). And from the relation;

$$Q = A \times V$$

Calculate Q.

Derived data for ΔP and f:

(Note: The experimental value)

ΔH corrected (mm)	**ΔP (Pa)**

(Table 3)

ΔP (Pa)	Q=vol/t (L/s)	V=Q/A (m/s)	f (Experimental)	f (calculated)	$Velocity^2$ (calculated)	Velocity (calculated)	Q (calculated)

(Table 4)

Plots:

(ΔP vs Q graph)

(Q experimental vs Q calculated)

Error Analysis:

Least count:

L.C of millimeter screw gauge: 0.01mm (ΔH)

L.C of stopwatch: 0.01s (ΔT)

L.C of measuring cylinder: (ΔV)

(Note: Use the least count for 1L measuring cylinder i.e. use ΔV=10ml)

a) for 1L: 10ml

b) for 2L: 20ml

- *Error in N_{Re}:*

By using $Q=V/T$

$$\frac{\Delta Q}{Q} = \frac{\Delta V}{V} + \frac{\Delta T}{T};$$

$$N_{\mathrm{Re}} = \frac{\rho V D}{\mu} = \frac{\rho Q D}{A\mu}; \quad \text{Hence,} \quad \frac{\Delta N_{Re}}{N_{Re}} = \frac{\Delta Q}{Q}$$

$$\frac{\Delta N_{Re}}{N_{Re}} = \frac{\Delta Q}{Q} = \frac{\Delta V}{V} + \frac{\Delta T}{T}$$

- *Error in Δp:*

$$\Delta p = \rho g\, \Delta H$$

Error in height difference $\Delta H = \Delta\,(\Delta H)$

$= \Delta\ (h_2\text{-}h_1) / \Delta H$

$= (0.01+0.01) / \Delta H$

Error in pressure difference $\Delta\ (\Delta p) = 0.02 / \Delta H$

- *Error in friction factor (f):*

$$f = \frac{\Delta p D}{2\rho L V^2}$$

$\Delta f/f = \Delta(\Delta P) / \Delta P + 2\ \Delta V/V$
{Since $V=Q/A \rightarrow (\Delta V/V = \Delta Q/Q)$}
Hence, $\Delta f/f = \Delta(\Delta P) / \Delta P + 2\ \Delta Q/Q$

Percentage relative error:

Error ΔH	Error in V	Error in T	Error ΔP	Error Q (Experimental)	Error f (Calculated)	Error Re

(Table 5)

Results:

Predict the flow behavior at different Reynolds number value you got.

Hypothesis:

Explain your logic behind the error in experimental and theoretical value. And the effect you think might have caused the error.