First Year CBEE Engineering Orientation   Fall 2016

Fluid Flow -- The HOW and WHY of SHOWERING

INTRODUCTION

The flow of a fluid out of a pipe is one of the most common daily occurrences which demonstrate a engineering principle. Brushing our teeth, taking a shower, pouring a cup of coffee or juice, are just a few examples that relate to the study of ***fluid mechanics*.**

We all know that the rate at which a fluid flows from a pipe is related to a number of factors such as *fluid properties*, *external conditions* and *geometry*. Take the simple example of your morning shower. If you turn on the shower and there is almost no flow of water, your initial thought is that the *water pressure* is low. If the stream of water from the shower head is not to your liking, you adjust the shower head to control the size of the holes through which the water is exiting -- you are changing the flow rate of the water by changing the *geometry* of the shower head. In many cases, the stream exiting from the shower head can be adjusted from a "fine", fast flowing stream which might "pinch" your skin (*turbulent flow*) to a "thick", slow flowing stream which is inadequate for removal of shampoo from your hair (*laminar flow*). If you are out in the wilderness camping you might use one of those portable showers marketed by REI, Inc. in which the *time* and *quality* of your shower are dictated by the *capacity* of the plastic bag holding the water, the *diameter* of the tube delivering the water to the shower head, the *height* of the tree limb from which the plastic bag is hung, and how long the sun has been heating the water!

From these simple observations of flow in everyday life, one can begin to establish a relationship between flow rate and various fluid and physical parameters.

TERMINOLOGY and UNITS

Fundamental Dimensions: mass (M), length (L), time (t), temperature (T)

UNIT Systems

SI: Kilogram (kg), Meter (m), second (s)
CGS: gram (g), centimeter (cm), second (s)
ENGINEERING: pounds-mass (lbm), feet (ft), second (s)

Flow rate (Q) = Q (pressure, geometry, fluid properties)   or   Q = Q (P_h, d, l, μ, ρ)

Q = volumetric flow rate (L^3/t),
d = pipe diameter (L) ,   r = pipe radius (L)
l = pipe length (L)
P = pressure (force/area, M/Lt^2) ,
P_h = pressure head (fluid column height, L)
μ = fluid viscosity (M/Lt)
ρ = fluid density (M/L^3).

Fluid Parameters: WATER

fluid viscosity (μ) = 0.01 poise (g/cm-s) = 0.001 Pa-s (kg/m-s) = 1.0 mPa-s

fluid density (ρ) = 1 g/cm^3 = 1000 kg/m^3

relative viscosity (μ_{rel}) = fluid viscosity/water viscosity (@same temp and fluid height)

EXPERIMENT: The $1 (or less) Fluid Viscometer!

1) Design and build a flow apparatus to measure fluid viscosity with the given materials – Jamba Juice 20oz styrofoam cup, straws of varying diameter (small and large internal diameter (i.d.)) and Silly Putty.
   Q1. Why should you use straws of different internal diameter?
      Hint: Look at Re,and Q equations.

2) ***Fluid: WATER***
Use the flow apparatus to measure the **flow rate (Q_{exp})** as a function of **pressure head (P_H)**
- Use a minimum of **THREE (3) pressure heads** (heights = 6 cm, 9cm, 12cm)
- Perform a minimum of **THREE (3) runs at each pressure head** to check reproducibility**.**
- Use at **two (2) straws** of known (measured) diameter **(small striped & med black)**

• **Total Experimental Runs** (minimum) = (3 heads) x (3 runs/head) x (2 straws) = 18 runs

NOTE: Water will be your *calibration fluid* for the ***relative viscosity*** calculation.

3) ***Fluid: Unknown RED FLUID***
- Pick your FAVORITE straw to repeat experiments in #2 with RED FLUID.
- Use a minimum of **THREE (3) pressure heads** (heights = 6 cm, 9cm, 12cm)
- Perform a minimum of **THREE (3) runs at each pressure head** to check reproducibility**.**

FUNDAMENTAL EQUATIONS for PIPE FLOW
Reynolds Number (Re): $Re = \rho v d/\mu$

Laminar flow (Re < 2100): $f = 16/Re$

Turbulent flow (Re > 2300): $f = 0.0791Re^{-0.25}$

Flow Rate vs Pressure Head (ρgh**):** $Q = \pi R^4(\rho gh)/8\mu l$ [r = pipe radius; l = pipe length]

Velocity (v) = flow rate/cross-sectional pipe area = $Q/\pi r^2$

EXPERIMENTAL DATA WORKSHEET

NOTE: EXCEL WORKSHEET available in the Week #4 Fluid Lab folder on CANVAS **(CBEE101F16_FluidLabDataSheet#1.xlsx**).

RAW DATA (required)
Straw i.d.(cm), Straw length(cm), Fluid Head(cm), Volume(ml), time(sec)

Fluid Flow Lab ---- Key Concepts

Concepts

1) Fundamental Dimensions (M,L, t) and Unit systems (SI, CGS, Engineering)
2) Physical parameters: fluid viscosity, density, and specific gravity.
3) Fluid Pressure Head
4) Process Variables: volume and mass flow rate; velocity
5) Dimensionless groups – Reynolds Number
6) Laminar and Turbulent Pipe Flow – phenomenological description