Two Phase Flows

(28082)

By: Prof. M. H. Saidi

Center of Excellence in Energy Conversion

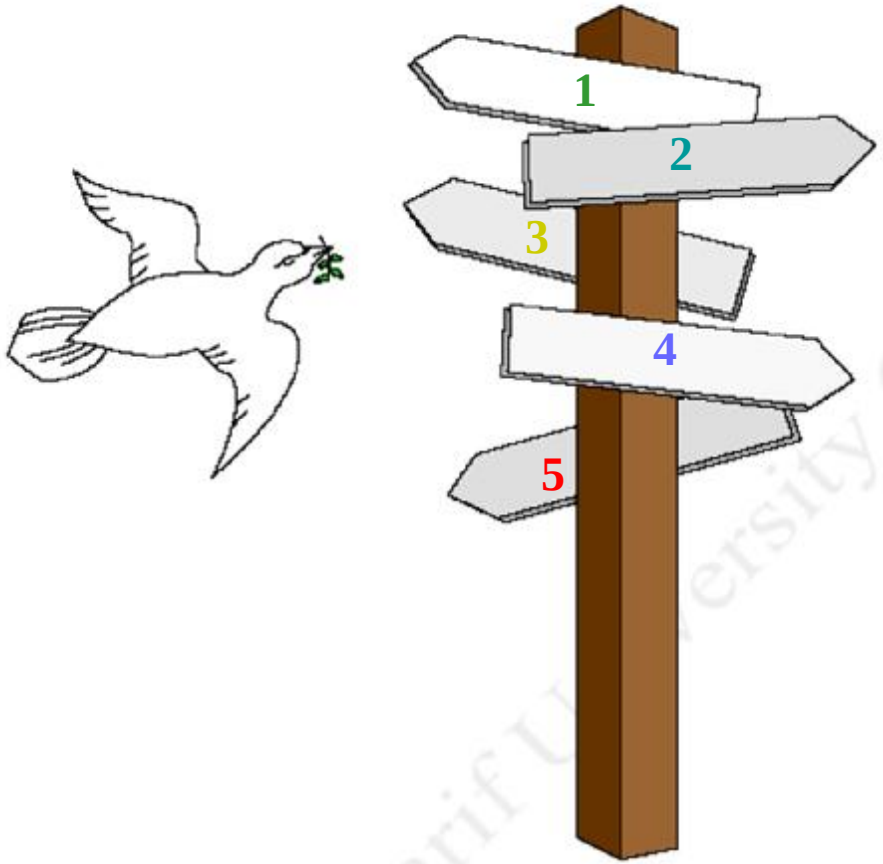
School of Mechanical Engineering

Sharif University of Technology

Outline of Course

- Introduction, Fundamental concepts and definition
- Principle Model of Two phase Flow (Method of Analysis)
- Experimental Model of Two phase Flow
- Pool Boiling
- Heat Transfer in Sub cooled Boiling
- Void Fraction and Pressure Lost
- Heat Transfer in Saturated Boiling

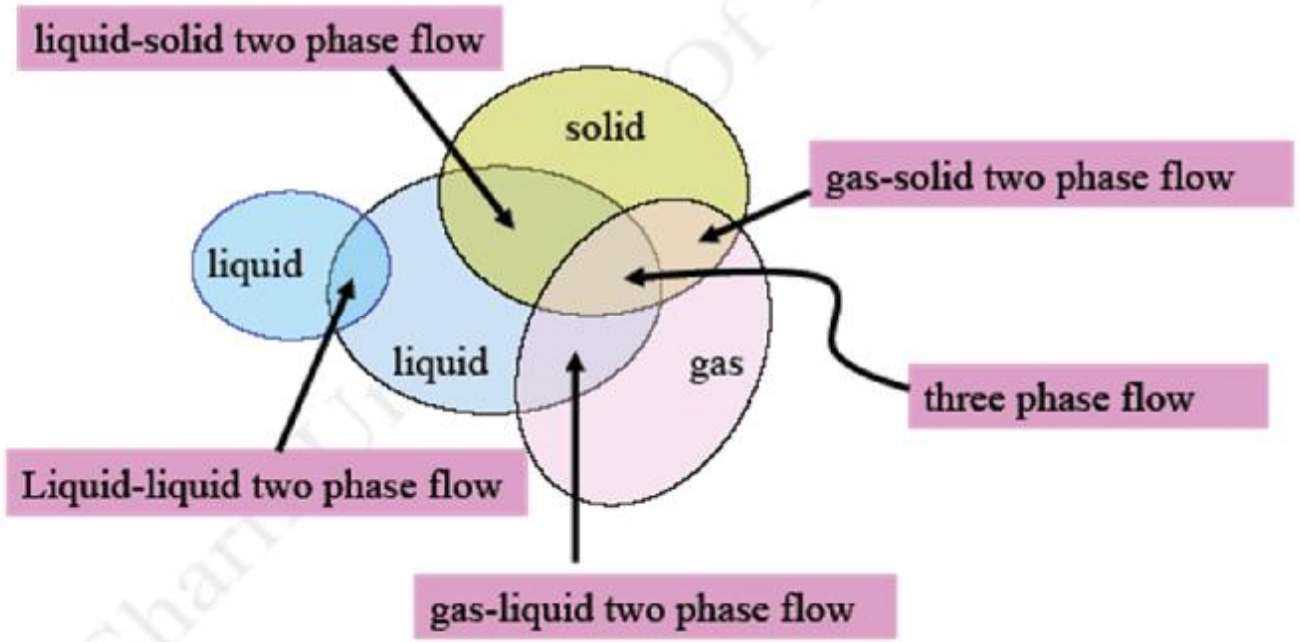
Example of Multiphase Flow



1. **Liquid- Solid Two Phase Flow**
2. **Gas- Liquid Two Phase Flow**
3. **Liquid- Liquid Two Phase Flow**
4. **Gas- Solid Two phase Flow**
5. **Three- Phase Flow**

Multiphase Flow

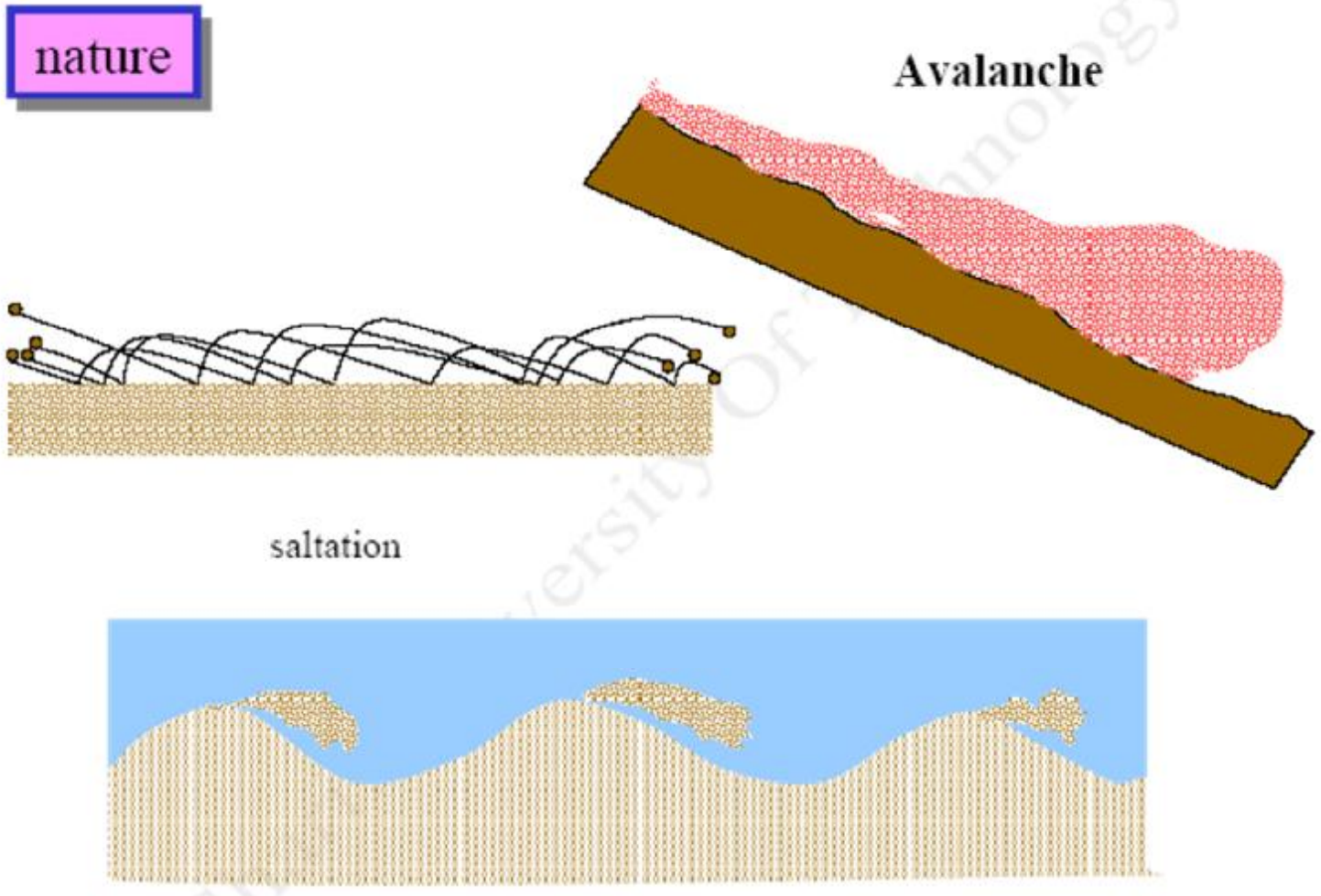
Multiphase Flow { gas, liquid, solid



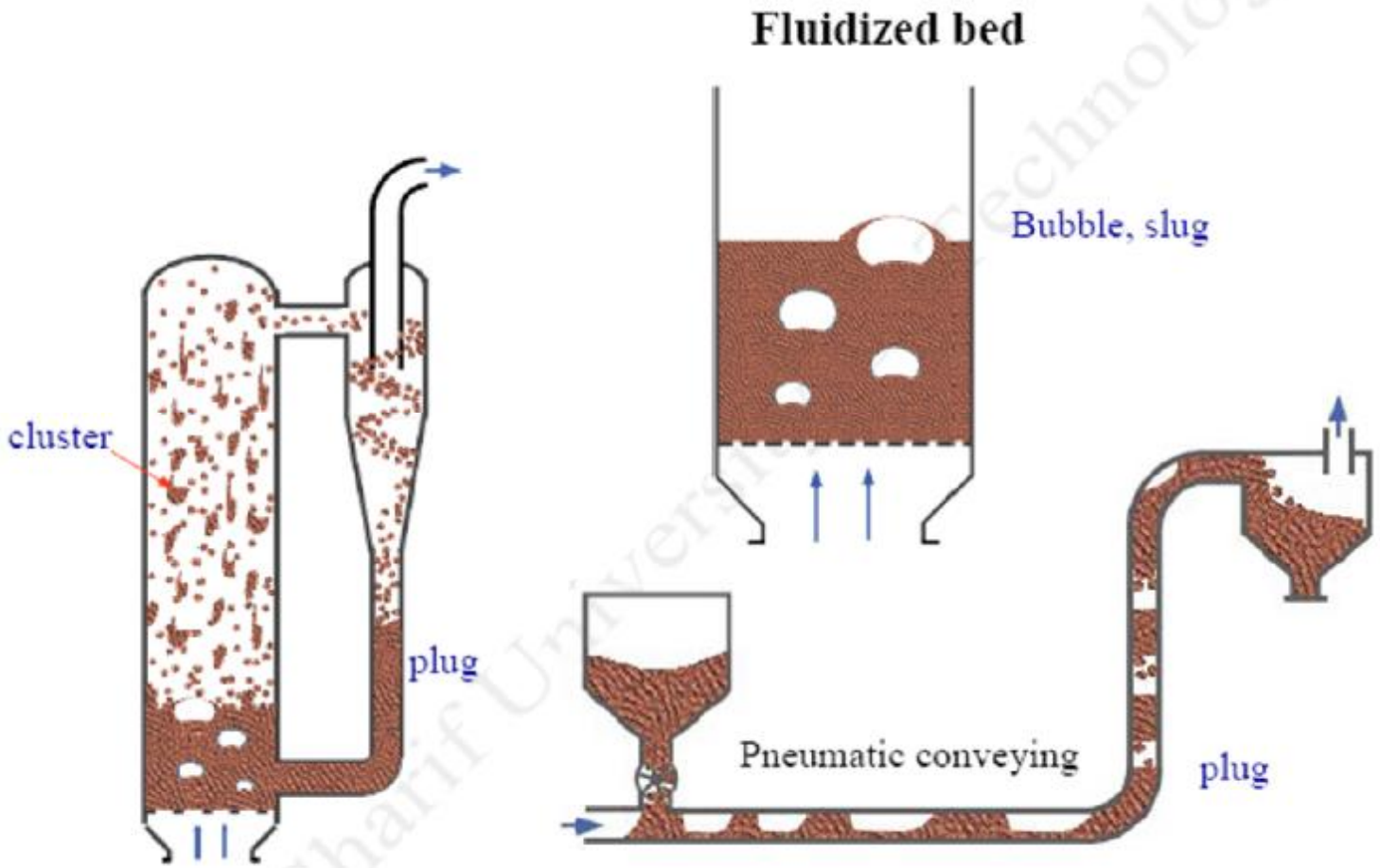
Example of Multiphase Flow

Gas- Solid	Nature	Sand Storm . Volcano . Avalanche
	Living Body	Aerosol
	Industries	Pneumatic Conveying. Dust Collector. Fluidized Bed Solid Propellant Rocket. Spray Drying. Spray Casting
Solid- Liquid	Nature	Motion Of Sand In Rivers And Sea. Mud Flow Debris Flow. Ice Berge
	Living Body	Blood Flow
	Industries	Slurry Transport. Flotation Fluidized Bed. Water Jet Cutting
Liquid- Gas	Nature	Rain. Mist
	Industries	Nuclear reactor. Boiler
Liquid- Liquid	Industries	Emulsion
Three Phase Flow	Industries	Airlift Pump

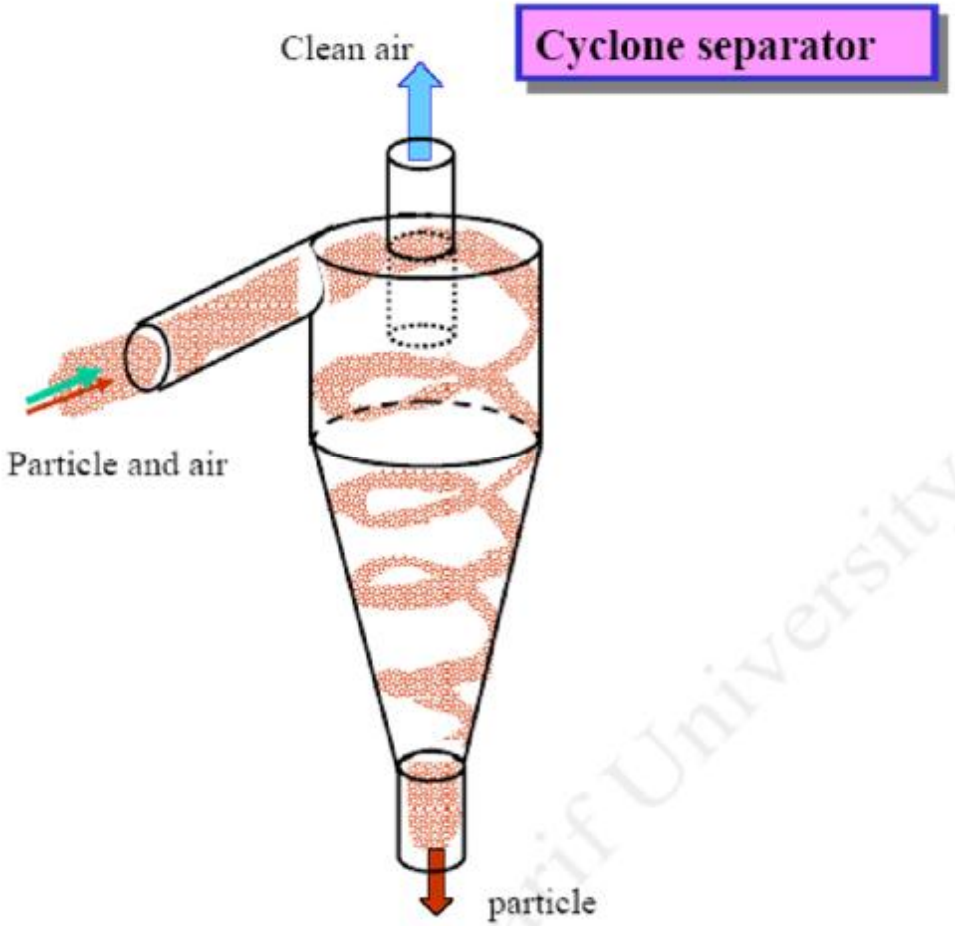
Natural Application of Gas- Solid Two Phase Flow

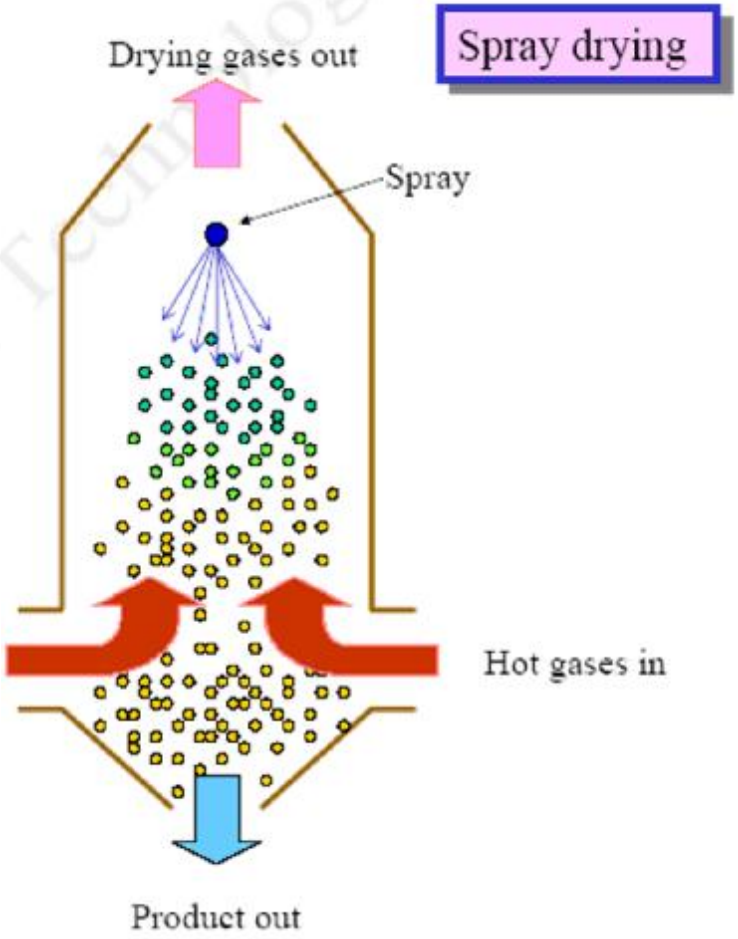


Industrial Application of Gas- Solid Two Phase Flow



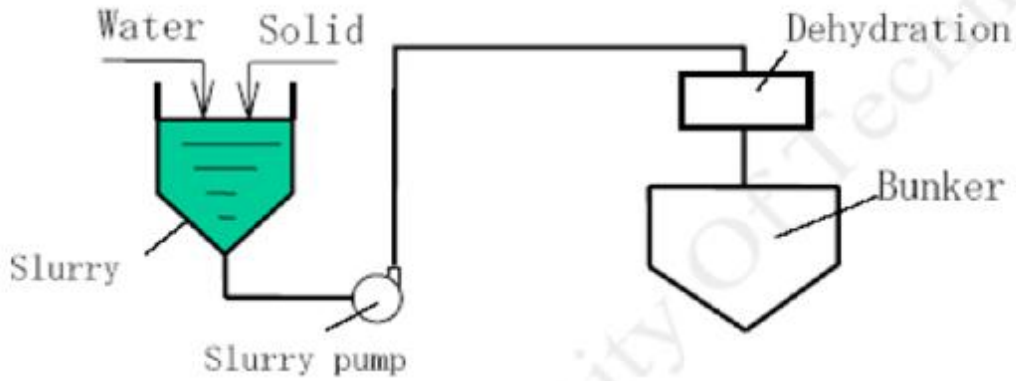
Application of Gas- Solid Two Phase Flow



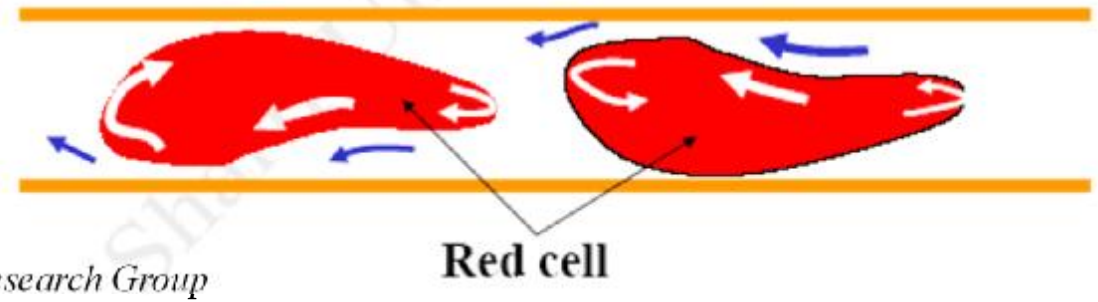


Application of Solid- Liquid Two Phase Flow

Slurry Transportation

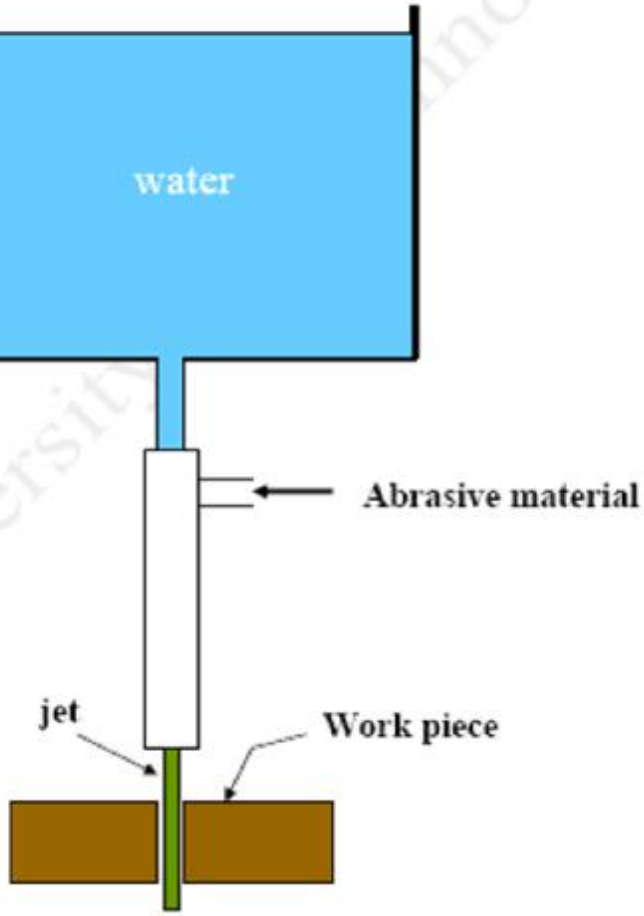


Blood flow in capillary tube



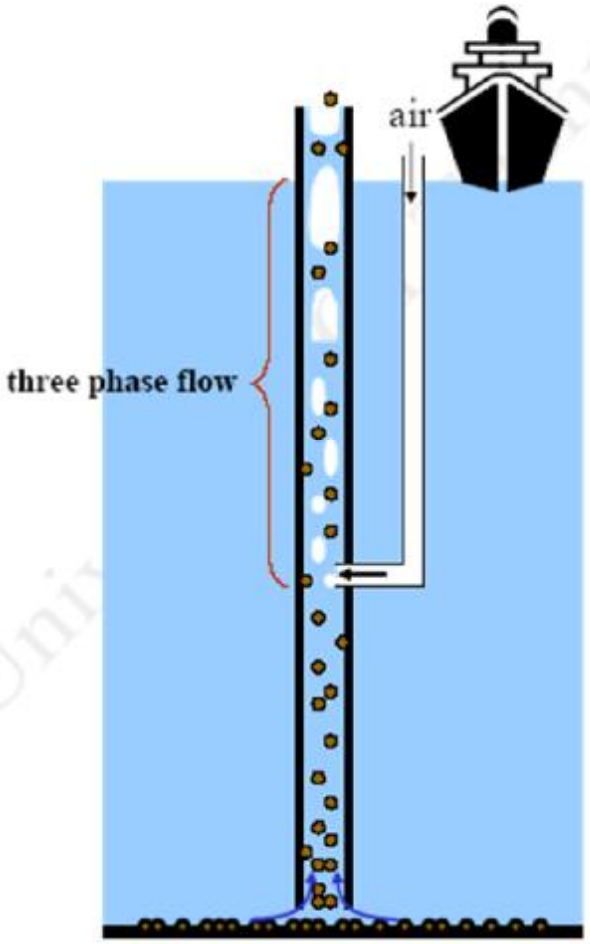
Industrial Application of Solid- Liquid Two Phase Flow

Water-jet cutting



Industrial Application of Three Phase Flow

Air lift pump



Introduction

- Multiphase flow occurs in many industrial processes
  - Petroleum, power and manufacturing processes (food, drug)
- Major goal of this course is to provide a basic working knowledge of multiphase flow and where to learn more
- Expected outcomes for this course:
  - Ability to develop a conceptual picture of multiphase flow
  - Familiarity with definitions and nomenclature
  - Familiarity with basic balances and correlations
  - Understand when to use more complex approaches
  - Recommendations are made for particular situations

Method Of Two Phase Flow Analysis

- Homogeneous Model (HM)

equal velocity, pressure, temperature

- Separated Model (SM)

non-equal velocities => emp. correlation

- Flow Pattern Model (FPM)

non-equal velocity and temperature

  - Balance equations for each fluid and interface coupling relations describing interfacial momentum and heat transfer

Definition

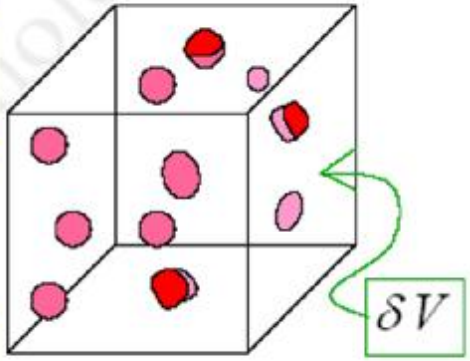
Volume fraction

$$\alpha_c = \lim_{\delta V \to \delta V_0} \frac{\delta V_c}{\delta V} \quad \text{...Continuous phase}$$

δV_c : volume of continuous phase

$$\alpha_d = \lim_{\delta V \to \delta V_0} \frac{\delta V_d}{\delta V} \quad \text{...Dispersed phase}$$

δV_d : volume of dispersed phase



Void Fraction for Gas- Liquid Two Phase Flow

$$\delta V = \delta V_c + \delta V_d \quad \Rightarrow \quad \alpha_d + \alpha_c = 1$$

$$a = \frac{A_g}{A}, (1-a) = \frac{A_f}{A}$$

Definition

Mass Quality

quality $= \dfrac{\text{mass flow rate of gas}}{\text{total mass flow rate}}$ or $= \dfrac{\text{mass of gas}}{\text{total mass}}$

$$x = \frac{W_g}{W_g + W_f} \quad , \quad (1-x) = \frac{W_f}{W_g + W_f}$$

mass flow quality | **mass quality**

Mass velocity

$$G = \frac{W}{A} = r\,u = \frac{u}{u}$$

$$W_g = GAx \quad , \quad W_f = GA(1-x)$$

$$u_g = \frac{W_g}{r_g A_g}, \quad u_f = \frac{W_f}{r_f A_f}$$

$$u_g = \frac{Q_g}{A_g}, \quad u_f = \frac{Q_f}{A_f}$$

$$u_g = \frac{Gx}{r_g a}, \quad u_f = \frac{G(1-x)}{r_f (1-a)}$$

Definitions

Volumetric Quality

$$b = \frac{Q_g}{Q_g + Q_f}, \quad (1-b) = \frac{Q_f}{Q_g + Q_f}$$

Superficial Velocity

$$j = \frac{Q}{A}, \qquad j_g = \frac{Q_g}{A}, \qquad j_f = \frac{Q_f}{A}$$

$$j_g = a\,u_g = b\,j = \frac{Gx}{r_g}, \qquad j_f = (1-a)u_f = (1-b)\,j = \frac{G(1-x)}{r_f}$$

$$G_g = r_g J_g = Gx, \qquad G_f = r_f\, j_f = G(1-x), G = G_g + G_f$$

Slip Ratio

$$\frac{u_g}{u_f} = \frac{r_f A_f W_g}{r_g A_g W_f} = \left(\frac{x}{1-x}\right)\left(\frac{r_f}{r_g}\right)\left(\frac{1-a}{a}\right)$$

Measurement Classification

	Principal		Measured Quantity
METHOD	1. Optical	attenuation reflection/refraction interference diffraction image sensor PIV LDV	Particle velocity
	2. Mechanical	pressure resistance/impact rotation weight	Particle density
	3. Electrical	Resistance charging capacitance	Particle flow rate
	4. Radiation	Attenuation tracer tracking	Fluid velocity
	5. Acoustic	ultra-sonic noise	Particle size
	6. Thermal	hot wire (film) thermal response	
	7. Electrochemical	electrolyte	Flow Structure
	8. Other	Microwave MRI	