

# **Multiple Phase Flow**

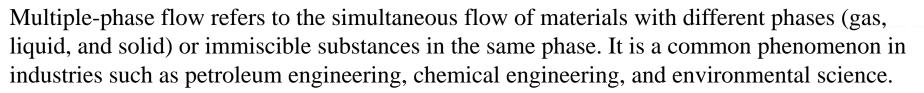
# Burhan S Abdulrazak, Ph.D. Chemical Engineering Department

كلية الهندسة - COLLEGE OF ENGINEERING

جامعة تكريت - Tikrit University

### **Lecture Notes: Multiple Phase Flow**

#### Introduction



#### **1. Definition of Multiple Phase Flow**

- Single-phase flow: Involves only one phase, e.g., water in a pipe.
- Multiple-phase flow: Involves two or more phases flowing simultaneously.
- 2. Importance of Studying Multiple Phase Flow
- Industrial Applications: Oil and gas extraction, chemical reactors, and cooling systems.
- Natural Processes: Lava flows, ocean currents, and groundwater flow.
- Challenges: Complex flow regimes, phase interactions, and varying properties.

#### كلية الهندسة - COLLEGE OF ENGINEERING

جامعة تكريت - Tikrit University





# **3.** Classification of Multiple Phase Flows

# **1. Phase Combinations:**

- Gas-liquid
- Liquid-liquid
- Gas-solid
- Liquid-solid
- Gas-liquid-solid
- 2. Flow Regimes:
  - **Bubbly flow**: Gas dispersed as bubbles in a liquid.
  - **Slug flow**: Alternating large bubbles and liquid slugs.
  - **Stratified flow**: Separate layers of fluids.
  - Annular flow: Liquid flows as a film on the wall with gas in the core.
  - **Dispersed flow**: One phase finely dispersed within another.

### كلبة الهندسة - COLLEGE OF ENGINEERING

جامعة تكريت - Tikrit University



#### **Governing Equations**

معنية المعنية الم معنية المعنية الم معنية المعنية ال

- 1. Conservation Laws:
- Mass Conservation:

 $rac{\partial}{\partial t}(
ho lpha_k) + 
abla \cdot (
ho lpha_k \mathbf{u}_k) = \dot{m}_k$ 

Where  $\rho$ : density,  $\alpha_k$ : volume fraction,  $\mathbf{u}_k$ : velocity, and  $\dot{m}_k$ : source term for mass transfer.

• Momentum Conservation:

 $rac{\partial}{\partial t}(
ho lpha_k \mathbf{u}_k) + 
abla \cdot (
ho lpha_k \mathbf{u}_k \mathbf{u}_k) = lpha_k \mathbf{F}_k - 
abla p_k$ 

• Energy Conservation:

$$rac{\partial}{\partial t}(
ho lpha_k e_k) + 
abla \cdot (
ho lpha_k e_k \mathbf{u}_k) = \mathbf{q}_k + \mathbf{w}_k$$

COLLEGE OF ENGINEERING - كلبة المندسة Tikrit University جامعة تكريت

#### 2. Interphase Interaction:

• Drag forces, heat transfer, and mass transfer across phases.

#### **Analytical and Experimental Tools**

#### 1. Analytical Models:

- Homogeneous flow model.
- Drift-flux model.
- Two-fluid model.

### 2. Experimental Techniques:

- Particle image velocimetry (PIV).
- X-ray computed tomography.
- High-speed photography.

#### كلبة الهندسة - COLLEGE OF ENGINEERING

جامعة تكريت - Tikrit University



# Applications

# 1. Oil and Gas Industry

- Transportation of oil, gas, and water through pipelines.
- Wellbore flows during extraction.

# 2. Chemical Engineering

- Bubble column reactors.
- Distillation and extraction processes.

### 3. Environmental Engineering

- Sediment transport in rivers.
- Erosion and deposition studies.

# 4. Power Generation

- Boiling in nuclear reactors.
- Condensation in heat exchangers.

# كلبة الهندسة - COLLEGE OF ENGINEERING

جامعة تكريت - Tikrit University



### **Challenges in Multiple Phase Flow**

- 1. Non-linear and coupled governing equations.
- 2. Measurement difficulties due to opacity of multiphase systems.
- 3. Scale-up from lab models to industrial applications.
- 4. Developing predictive models for complex flow regimes.

# Conclusion

Understanding multiple-phase flow is critical for optimizing industrial processes, predicting natural phenomena, and advancing engineering solutions. Continuous research in modeling techniques, experimental validation, and computational fluid dynamics (CFD) contributes to advancements in this field.

### كلية الهندسة - COLLEGE OF ENGINEERING

جامعة تكريت - Tikrit University



#### **References for Further Reading**



- 1. Crowe, C. T., Sommerfeld, M., & Tsuji, Y. (1998). *Multiphase Flows with Droples* and Particles. CRC Press.
- 2. Wallis, G. B. (1969). One-Dimensional Two-Phase Flow. McGraw-Hill.
- 3. Brennen, C. E. (2005). *Fundamentals of Multiphase Flow*. Cambridge University Press.

#### كلبة الهندسة - COLLEGE OF ENGINEERING

جامعة تكريت - Tikrit University