

ChE 345 Fluid Mechanics

Momentum transfer - fluid mechanics

Heat transfer

Mass transfer

+ reaction engineering

Chapter 1 Introduction

1.1

Fluid – a fluid is a substance that deforms continuously when acted on by a shearing stress of any magnitude

Gas (highly compressible)

Liquid

Supercritical fluid

1.2 Dimensions

Two systems:

FLT (force-length-time)

MLT (mass-length-time)

Newton's second law $F=ma$ gives $F = MLT^{-2}$

Temperature is denoted θ (extra property, not covered by FLT or MLT).

All theoretically derived equations are dimensionally homogenous.

Empirical correlations not included.

System of Units

International system (SI)

British Gravitational (BG) system

1.4

$$\text{Density } \rho = \frac{m}{V} = \frac{\text{mass}}{\text{vol.}}$$

Specific weight $\gamma = \rho g$ where $g = 9.81 \text{ m/s}^2$

$$\text{Specific gravity } SG = \frac{\rho}{\rho(\text{H}_2\text{O @ } 4^\circ\text{C})} = \frac{\rho}{1000 \text{ kg/m}^3}$$

1.5 Ideal gas law

$$pV = nRT$$

n = number of moles

R = universal gas constant ($8.314 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$)

If we convert R to $\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$ which depends on MW, we have

$$pV = mRT$$

or $p = \rho RT$

Example: H_2 gas

$$R = \frac{8.314 \text{ J}}{2.02 \times 10^{-3} \text{ kg} \cdot \text{K}} = 4.12 \times 10^3 \text{ J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$$

Chapter 7 – Similitude, Dimensional Analysis, and Modeling

Similitude – similarity between small and large objects of similar nature (used for scale-up)

7.1 Dimensional Analysis

It can greatly simplify correlations and experiments

Example: $\Delta p_1 = f(D, \rho, \mu, V)$

7.2 Buckingham Pi Theorem

If an equation involving k variables is dimensionally homogeneous, it can be reduced to a relationship among $k-r$ independent dimensionless products (groups), where r is the minimum number of reference dimensions required to describe the variables.

$$u_1 = f(u_2, u_3, \dots, u_k) \quad (u_1, u_2, u_3, u_k \text{ are } k \text{ variables})$$

reduces to

$$\Pi_1 = \Phi(\Pi_2, \Pi_3, \dots, \Pi_{k-r})$$

7.3 How to obtain pi terms (p. 243)

Step 1 – List all the variables that are involved in the problem

Step 2 – Express each of the variables in terms of basic dimensions

Step 3 – Determine the required number of pi terms

Step 4 - Select a number of repeating variables.

Step 5 – Form a pi term by multiplying one of the nonrepeating variables by the product of the repeating variables, each raised to an exponent that will make the combination dimensionless

Step 6 – Repeat Step 5 for each of the remaining nonrepeating variables

Step 7 – Check all the resulting pi terms to make sure they are dimensionless

Step 8 – Express the final form as a relationship among the pi terms and think about what it means, e.g., $\Pi_1 = \Phi(\Pi_2, \Pi_3, \dots, \Pi_{k-r})$