ChE 3400 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

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

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

Specific gravity $SG=\frac{\rho}{\rho(H_2O @ 4^\circ C)} = \frac{\rho}{1000 kg/m^3}$

1.5 Ideal gas law

$pV=nRT$

n = number of moles

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

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

$pV = mRT$

or $p=\rho RT$

Example: H_2 gas

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

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

Many momentum transfer/heat transfer/mass transfer correlations have their roots in a dimensional analysis.

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.

$u_1=f(u_2, u_3,\ldots,u_k)$ (u_1, u_2, u_3, u_k are k variables)

reduces to

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

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