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 $F \doteq MLT^{-2}$

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) (I-19 in Arizona is metric)

British Gravitational (BG) system (used by Myanmar, Liberia and USA)

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

$$R = \frac{8.314 J}{2.02x10^{-3} kg \cdot K} = 4.12x10^{3} J \cdot kg^{-1} K^{-1}$$

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