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Lecture no.25

Mass transfer

Fundamental of Mass Transfer

1. Fundamental of Mass Transfer

When a system contains two or more components whose concentration vary from point to point, there is a natural tendency for mass to be transferred, minimizing the concentration differences within the system. The transport of one constituent from a region of higher concentration to that of lower concentration is called *mass transfer*. A common example of mass transfer is drying of a wet surface exposed to unsaturated air. Refrigeration and air conditioning deal with processes that involve mass transfer. Some basic laws of mass transfer relevant to refrigeration and air conditioning are discussed below.

(a) Fick's Law of diffusion

This law deals with transfer of mass within a medium due to difference in concentration between various parts of it. This is very similar to Fourier's law of heat conduction as the mass transport is also by molecular diffusion processes. According to this law, rate of diffusion of component A $\dot{m}_A$ (kg/s) is proportional to the concentration gradient and the area of mass transfer, i.e.

$$\dot{m}_A = -D_{AB} A \frac{dc_A}{dx} \qquad (1)$$

where, D_{AB} is called diffusion coefficient for component A through component B, and it has the units of m^2/s just like those of thermal diffusivity α and the kinematic viscosity of fluid ν for momentum transfer.

(b) Convective mass transfer

Mass transfer due to convection involves transfer of mass between a moving fluid and a surface or between two relatively immiscible moving fluids. Similar to convective heat transfer, this mode of mass transfer depends on the transport properties as well as the dynamic characteristics of the flow field. Similar to Newton's law for convective heat transfer, he convective mass transfer equation can be written as:

$$\dot{m} = h_m A \Delta c_A \qquad (2)$$

where h_m is the convective mass transfer coefficient and Δc_A is the difference between the boundary surface concentration and the average concentration of fluid stream of the diffusing species A.

Similar to convective heat transfer, convective mass transfer coefficient depends on the type of flow, i.e., laminar or turbulent and forced or free. In general the mass transfer coefficient is a function of the system geometry, fluid and flow properties and

the concentration difference. Similar to momentum and heat transfers, concentration boundary layers develop whenever mass transfer takes place between a surface and a fluid. This suggests analogies between mass, momentum and energy transfers. In convective mass transfer the non-dimensional numbers corresponding to Prandtl and Nusselt numbers of convective heat transfer are called as Schmidt and Sherwood numbers. These are defined as:

$$\text{Sherwood number, } Sh_L = \frac{h_m L}{D} \tag{3}$$

$$\text{Schmidt number, } Sc = \frac{\nu}{D} \tag{4}$$

where h_m is the convective mass transfer coefficient, D is the diffusivity and ν is the kinematic viscosity.

The general convective mass transfer correlations relate the Sherwood number to Reynolds and Schmidt number.