MODULE 3: MASS TRANSFER COEFFICIENTS

LECTURE NO. 3

3.4 CORRELATION FOR CONVECTIVE MASS TRANSFER COEFFICIENT

In this section various correlations that are used to estimate the convective mass transfer coefficients for various cases are presented. The various correlations are generally formed in terms of different dimensionless groups associated with the mass transfer. The definitions of mostly useful dimensionless groups associated with the mass transfer are given in Table 3.1 as follows:

Table 3.1: Dimensionless groups for mass transfer:

Name of dimensionless groups	Definition of group	Significance of group
Reynolds number (Re)	$\frac{\rho u l}{\mu}$	Ratio of inertia force to viscous force
Schmidt number (Sc)	$\frac{\mu}{\rho D_{AB}}$	Ratio of molecular diffusivity of momentum to molecular diffusivity of mass transfer
Sherwood number (Sh)	$\frac{k_g p_{BM} RTl}{PD_{AB}}$, $\frac{k_c p_{BM} l}{PD_{AB}}$, $\frac{k_c l}{D_{AB}}$, $\frac{k_y p_{BM} RTl}{PD_{AB}}$, etc.	Ratio of total mass transfer rate to mass transfer by molecular diffusion
Grashof number (Gr_D)	$\frac{gl^3 \rho \Delta\rho}{\mu^2}$	Ratio of product of buoyancy forces and inertia forces to

		square of viscous force
Peclet number (Pe_D)	Re. Sc, $\frac{ul}{D_{AB}}$	Ratio of inertia forces to mass transfer by molecular diffusion
Stanton number (St_D)	Sh/(Re.Sc), Sh/Pe_D	Ratio of total mass transfer rate to inertia forces

3.4.1 Correlation of mass transfer coefficients for a single sphere

3.4.1.1 Mass transfer coefficients for a single sphere in case of natural convection

In presence of natural convection the mass transfer from single sphere were studied by Steinberger and Treybal (1960) and they recommended the mass transfer coefficient as follows:

$$Sh = Sh_{nc} + 0.347(\mathrm{Re}\,Sc^{0.5})^{0.62} \tag{3.34}$$

In the range of $1 \le \mathrm{Re} \le 3\times10^4$ and $0.6 \le \mathrm{Sc} \le 3200$

$$Sh_{nc} = 2.0 + 0.569(Gr_D Sc)^{1/4} \tag{3.35}$$

in the range of $Gr_D Sc < 10^8$

and

$$Sh_{nc} = 2.0 + 0.0254(Gr_D Sc)^{1/3} Sc^{0.244} \tag{3.36}$$

in the range of $Gr_D\,Sc > 10^8$

3.4.1.2 Mass transfer coefficients for a single sphere in case of forced convection

Different investigators have performed the experiment on the mass transport from a single sphere and developed correlations based on mass transfer in the environment of forced convection along with the consideration of mss transfer by molecular diffusion in the general form of:

$$Sh = Sh_0 + m\mathrm{Re}^n Sc^{1/3} \quad (3.37)$$

where m and n are correlating constants. As per Bird et al. (1960), for low Reynolds number, the effects of natural convection is negligible which results Sherwood number theoretically to a value of 2.0. Then the generalized correction becomes:

$$Sh = 2.0 + m\mathrm{Re}^n Sc^{1/3} \quad (3.38)$$

At Reynolds numbers ranging from 2 to 12000 and Schmidt number ranging from 0.6 to 2.7, Froessling (1939) and Evnochides and Thodos (1959) developed the mass transfer coefficient for a single sphere and represented as follows:

$$Sh = 2.0 + 0.552\mathrm{Re}^{1/7} Sc^{1/3} \quad (3.39)$$

3.4.2 Correlation of mass transfer coefficients for flat plates

There are several investigations in literature regarding the evaporation from a free liquid surface or the sublimation from a flat solid surface into air stream under both laminar and turbulent conditions. Wilty et al. (1984) developed correlations for the average mass transfer coefficient during evaporations from a flat solid surface of characteristic length of L under laminar and turbulent conditions as follows:

at laminar condition and Re < 3×10^5

$$Sh = 0.664\mathrm{Re}^{1/2} Sc^{1/3} \quad (3.40)$$

at turbulent condition and Re $\geq 3\times10^5$

$$Sh = 0.036\mathrm{Re}^{4/5} Sc^{1/3} \quad (3.41)$$

The Reynolds number and the Sherwood number are defined based on the characteristic length *l*. The range of Schmidt number for the above correlations is 0.6< Sc < 2500.