International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 3, Issue 8, August 2016)

Summary of Investigations on Mass Transfer Coefficients with Emphasis on Inter phase Mass Transfer

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***Abstract*— The mass transfer coefficient is defined as the moles transferred per unit area per unit time per unit driving force. The driving force for inter phase mass transfer can be expressed as concentration difference or difference in mole fractions. For gases usually it is expresses as pressure difference. In inter phase mass transfer; the mass transfer is defined in terms of overall and individual mass transfer coefficients. The inverse of mass transfer coefficient is resistance. For the gas liquid operation, packed or tray columns can be used. Other equipments such as pulse column, spray column and ventury scrubbers can also be used for liquid dispersed mode of mass transfer. The mass transfer depends largely on solubility of gas in liquid, mass transfer area, temperature and pressure. Many investigators have carried out experiments to study effect of various parameters on mass transfer coefficients, their modeling and analysis. Current review provides summery of important investigations carried out on mass transfer coefficients.**

***Index Terms*: Volumetric mass transfer coefficient, liquid side mass transfer coefficient, resistance, diffusivity.**

I. Introduction

Mass transfer is one of the most important areas in chemical engineering. Diffusion and mass transfer coefficients are basic parameters in mass transfer. The mass transfer coefficients include convective mass transfer. The local and overall mass transfer coefficients can be estimated experimentally. The inter phase mass transfer includes liquid solid and liquid gas mass transfer. Mass transfer coefficients are integral part of many reaction mechanisms. Investigations are reported on many important mass transfer operations such as distillation, adsorption, absorption and drying. Also the advanced methods such as reactive adsorption, reactive distillation, reactive adsorption are finding wide applications[1,2,3,4,5,6]. Synthesis of various chemicals and compounds is being tried by new methods and new raw materials for cost effectiveness [7,8,9,10]. All these developments calls for in depth studies on mass transfer coefficients for different operating conditions, different packings. Developing suitable model is also an integral part of these mass transfer studies [11,12,13,14,15]. Current review summarizes research and studies on mass transfer coefficients in inter phase mass transfer.

II. MASS TRANSFER COEFFICIENTS: AN INSIGHT INTO RESEARCH AND STUDIES

Phadatare and Verma carried out an investigation on heat and mass transfer coefficients in a plastic solar still[16]. They studied the effect of cover materials on heat and mass transfer coefficient. They constructed two plastic stills having similar geometrical features. They used two different materials for two stills, one was acrylic and other glass. They found that for 10 cm water depth, glass cover produced 30–35% more output than the plastic solar still with Plexiglas cover. They also found that the evaporative heat transfer coefficient for the glass cover still was 57% more than that for the still with the plastic cover. Sobieszuk et.al. carried out investigation on liquid and gas-side mass transfer coefficients[17]. According to them, the data about gas-side mass transfer coefficients are practically nonexistent. They investigated effect of factors like the gas diffusivity, gas viscosity, channel diameter, bubble length and gas bubble velocity on mass transfer coefficients. They observed that, in many cases, the mass transfer resistances in both phases were comparable and the gas-side resistance was significant.

Moutafchieva et.al. investigated the sensitivity of the dynamic methods and the steady-state method for estimation the overall volumetric oxygen mass transfer coefficient[18]. In their extensive research, they used dynamic gassing-out method for measuring the volumetric mass transfer coefficient. They carried out an investigation with three types of reactors namely stirred tanks, bubble columns and airlift. According to these studies, the dynamic oxygen method was suitable for large scale bioreactors with errors less than 10 %. Also they found that for stirred vessels, the response methods were also satisfactory. Yue et.al. investigated hydrodynamics and mass transfer characteristics in gas–liquid flow[19]. They carried out investigation for flow through a rectangular micro channel. They measured liquid side volumetric mass transfer coefficients by absorbing pure CO_2 into water and a 0.3M $NaHCO_3$ / 0.3M Na_2CO_3 buffer solution. According to their investigation, two-phase frictional pressure drop in the micro channel can be well predicted by the Lockhart–Martinelli method. For this, it was necessary to use a new correlation of *C* value in the Chisholm's equation. They found that liquid side volumetric mass transfer coefficient increases with the increasing superficial liquid or gas velocity. Kim and Deshusses carried out investigation on mass transfer

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coefficients for packing materials used in biofilters and biotrickling filters for air pollution control[20].They presented correlations for determination of gas film mass transfer coefficients and liquid film mass transfer coefficients for packing materials used in biofilters and biotrickling filters for air pollution control. According to them, each packing had a different functionality with gas and liquid velocity and different wetting property. It was very obvious that different correlation equations were needed for the different packing materials.

According to studies carried out by Brito and Melo, there was no dependence between bulk flow and internal mass transport rates for in anaerobic reactors used for wastewater treatment[21]. They measured internal mass transfer coefficients during biofilm formation under liquid velocities of 1.5 and 13.2 m/h. According to their discussion, periodic changes in the bulk fluid velocity can be used as a tool to increase the transport of soluble substrates.Tamas et.al. carried out experimental investigation on determination of mass transfer coefficients for dissolution processes[22]. They studied influence of several parameters like substance nature, hydrodynamic conditions, temperature, compacting pressure on dissolution processes. They used substances such as acetylsalicylic acid, citric acid, sodium benzoate, sodium chloride, Penicillin G-potassium salt, and pentaerythriol in their investigation. They observed that the increase in stirring rate has a favorable effect over the dissolution process. Also it was observed that compacting degree doesn’t influence the amount of dissolved substance. They found that total mass transfer coefficient increased significantly with the increase in temperature. Beenackers and Swaaij carried out review on mass transfer coefficient in slurry reactors[23]. According to them, there is considerable progress in the investigation on the influence of solids on the volumetric mass transfer coefficient in slurry reactors. According to them, there is necessity of experiments in industrial reactors of sufficient scale to confirm the predictions under practical circumstances.

Alves et.al. investigated gas-liquid mass transfer coefficient in stirred tanks[24]. They used tap water, electrolyte solutions and water with controlled addition of tensioactive material as liquid media. They observed that bubbles in tap water are the closest to Higbie’s line. Also they found that bubbles in PEG solution behave as rigid bubbles. Vaddella et.al. investigated mass transfer coefficients of ammonia for liquid dairy manure[25]. According to their studies the overall NH_3 mass transfer coefficient (K_{OL}) is an important component of any NH_3 emission process-based model. They observed that the mass transfer coefficient was affected by the parameters namely liquid manure temperature, ambient air temperature, wind or air velocity, and total solids concentration in descending order. They also observed that the value of mass transfer coefficient increased with an increase in liquid temperature and an increase in air velocity, but decreased with an increase in air temperature.

Olujic and Seibert investigated the liquid phase mass transfer coefficients of structured packings[26]. They carried out total reflux distillation tests using the chlorobenzene/ethylbenzene system at two operating pressures. In their investigations, they observed large difference between different correlations. This difference was with respect to both, the absolute values of mass transfer coefficients and the fraction of liquid phase based resistance. Al-Malah carried out an investigation on mass transfer coefficient of gas absorption into falling liquid film[27]. In his study, he presented the analytic, open-form solution for the steady-state, 2-dimensinal partial differential equation. This partial differential equation was designed for the concentration profile for the gas solute in a falling liquid film flowing under a steady-state laminar condition. He tested the overall mass transfer coefficient k, for a binary diffusion system, in light of the analytic solution and also tested it for oxygen absorption into falling water film. He also compared convective mass transfer with predicted mass transfer. He observed about 10 percent error in the results.

Fatemeh et.al. compared The performance of a forced-liquid vertical tubular loop bioreactor (VTLB), a forced-liquid horizontal tubular loop bioreactor (HTLB) and a gas-induced external airlift loop bioreactor (EALB)[28]. They carried out studies on production of biomass from natural gas. They determined hydrodynamic characteristics and mass transfer coefficients. Studies were also carried out on energy consumption for different gas and liquid flow rates. It was observed that vertical tubular loop bioreactor (VTLB) was the best for biomass production. Mohebbi and Behbahani investigated mass transfer coefficients of natural gas mixture[29]. They conducted this measurement during gas hydrate formation. They assumed that that the transport of gas molecules from gas phases to aqueous phase was dominant among other resistances. In their experimentation, they observed that MTC was a function of pressure and temperature during hydrate growth stage.

Kim and Deshusses investigated mass transfer coefficients for packing materials[30]. They carried out investigation for packing materials used in biofilters and biotrickling filters for air pollution control. They used the packing materials such as lava rock, polyurethane foam cube (PUF), pall ring, porous ceramic beads, porous ceramic raschig rings and compost–woodchips mixtures. They observed that all compost mixtures exhibited a greater gas film mass transfer coefficient than lava rock or other synthetic materials. They found that packing method also influenced the mass transfer coefficient considerably. It was found to be directly proportional to the surface area of the bulking agents added. Feroz and Prasad presented experimental results for the mass transfer coefficients in the radial direction from the stagnation point of a multi-jet flow[31]. With variation in nozzle hole and disc distributor, cell size, and height of the disc distributor, the mass transfer coefficients in this region showed similar trends of stagnation point from the target surface. Ibusuki and Aneja investigated mass transfer of NH_3 into water[32].They carried out the studies in a two-phase flow reactor. They observed that the overall mass transfer coefficient (K) was more dependent on the hydrodynamics of the gas phase than that of the liquid phase. They found that k_g value was about two

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orders greater than the k_l value. Their results also supported some of the theoretical or semiempirical assumptions for estimating the mass transfer coefficient.

Anwar carried out investigation on estimation of mass transfer coefficients using air-liquid interfacial area in porous media[33]. According him, air-liquid interfacial area plays a significant role in mass transfer during the remediation of contaminated soil in unsaturated zone. In his work, he estimated inter phase mass transfer coefficients separately using the air-liquid interfacial area based on soil characteristics curve. He observed that the mass transfer coefficient increases with pore gas velocities and grain sizes. Also mass transfer changed linearly with pore gas velocity. Mostaedi and Safdari estimated the volumetric overall mass transfer coefficients in a pulsed packed extraction column[34]. They used diffusion model for two different liquid-liquid systems. They studied the effects of operational variables such as pulsation intensity and dispersed and continuous phase flow rates on mass transfer. In their experiments, it was also found that the effects of phase flow rates were less pronounced than those of pulsation intensity and interfacial tension.

III. Conclusion

Mass transfer coefficients are integral part of many reaction mechanisms. Investigations are reported on many important mass transfer operations such as distillation, adsorption, absorption and drying. Also the advanced methods such as reactive adsorption, reactive distillation, and reactive adsorption are finding wide applications. Manufacture of various chemicals and compounds is being tried by new methods and new raw materials for cost effectiveness. suitable model is also an integral part of these mass transfer studies. All these developments call for in depth studies on mass transfer coefficients at different operating conditions, with different packing materials.

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