SYNOPSIS

Studies on the 'Interfacial Resistance' in a gas-liquid interface have of late drawn much attention because of its fundamental importance in mass-transfer operations. When a gas comes in contact with a liquid which is unsaturated with respect to the gas, a finite time is necessary to saturate the liquid surface. The gas molecules strike the interface at a finite rate and are continuously transferred from the interface into the bulk of the liquid till the equilibrium is established. During this time the interface remains unsaturated and the non-equilibrium that exists at the interface gives rise to an extra resistance to the mass-transfer which is known as interfacial resistance. In case of liquid-liquid system this non-equilibrium at the interface may be due to an extra diffusional resistance which leads to interfacial resistance.

Several experimental techniques like rotating drum, moving band, wetted wall column, laminar liquid jet etc. have been developed for measuring interfacial resistance in a gas-liquid interface. Among all these, laminar liquid-jet technique seems to posses several advantages over other types. A particular advantage of the jet is the wide range of contact time down to a few milliseconds can be achieved, which is necessary in the measurement of interfacial resistance. Researchers working in this field using this technique, obtained conflicting results and concluded that the interfacial resistance shown for a particular system may also be due to the hydrodynamics of the system.

In most cases laminar liquid jet is formed by ejecting fluid from an orifice or nozzle. The fluid leaves the nozzle tip with fully developed parabolic velocity profile, and if the ejection is into an inviscid medium such as air or any other gas, the profile is free to relax to uniformity. The relaxation process gives rise to the following effects:

1. Jet diameter continuously reduces.

2. Surface velocity which is zero at the nozzle tip starts gaining velocity as it leaves the nozzle tip and is different from the bulk average velocity till it assumes plug flow profile.

Both these effects are of prime importance in the measurement of interfacial resistance in gas-liquid interface. Firstly, due to combined effect of viscous drag and gravitational acceleration, continuous reduction in jet diameter along the jet length occurs. Since contact area between gas-liquid interface in mass transfer operation must be known accurately, it is imperative that the variation in jet diameter should be recognized. Secondly, since the surface velocity differs from the average velocity of the fluid, the actual surface age or in other words the actual time of contact will be different from the age obtained by using average velocity. This surface age is also an important parameter and must be known accurately in order to predict the absorption rate at the interface.

The present investigation is undertaken with the object of studying the hydrodynamics of a laminar liquid jet and to predict correlations for surface velocity and diameter variation along the axis of the jet as a function of different variables, like dynamic and physical properties of the fluid. The validity of these equations are then tested in a highly soluble gas-liquid contacting system where hydrodynamics of the system is playing an important role and the interfacial resistance is not significant.

The present thesis is presented in three chapters:

In Chapter I, an attempt has been made to discuss the significance of interfacial resistance and different techniques used for its measurement. The scope of the present work has been discussed.

Chapter II presents a comprehensive literature survey on the hydrodynamics of laminar liquid jet. A critical analysis of the problem has been made.

This also presents a detail discussion on the experimental set-up designed and experimental technique employed.

Next, the experimental data, correlations, and discussions on the hydrodynamic study of laminar liquid-jet has been presented.

When a laminar jet is formed by ejecting fluid through a nozzle there exists two distinct zones in the jet, the viscous zone and the gravity zone. In the viscous zone both viscous and gravity forces are effective in the relaxation of velocity profile whereas in the gravity zone only gravity force is effective.

From a critical analysis of the experimental data it is concluded that the profile relaxation is complete in the viscous zone and the relaxation length is represented by

$$\left[\frac{Z_f^3 \rho^2 g}{\mu^2}\right] = 1.452 \times \left[\frac{\rho\sigma^3}{g\mu^4}\right]^{0.14} \times \left[\frac{\bar{V}_o^3 \rho}{g\mu}\right]^{1.376} \qquad \text{(i)}$$

It also deals with the correlation for the variation of jet diameter along the jet length which is represented by

$$\frac{d_j}{d_o} = 0.8308 \times \left[\frac{\rho\sigma^3}{g\mu^4}\right]^{0.0047} \times \left[\frac{\bar{V}_o^3 \rho}{g\mu}\right]^{0.046} \times \left[\frac{Z^3 \rho^2 g}{\mu^2}\right]^{-0.0334} \qquad \text{(ii)}$$

Finally, it deals with the prediction of surface velocity as a function of different variables. The method of calculation of surface velocity at any point in the surface is based on the proportionate loss of maximum shear stress at the nozzle exit. This progressively approaches zero as it travels through the relaxation length with a corresponding gain in surface velocity. The velocity thus calculated is checked back with the velocity obtained from the difference in average velocity existing at that cross-section of the jet due to free fall and due to maximum shear stress. Both these results are in good agreement, the deviation being $\pm$ 1 per cent. In this way the surface velocity at different axial distances for all the liquid systems studied are calculated using all nozzles and different average velocities at the nozzle tip. These surface velocities are then correlated with the system variables and is represented by

$$\frac{v_s}{\bar{V}_o} = 1.683 \times \left[\frac{\rho\sigma^3}{g\mu^4}\right]^{-0.0223} \times \left[\frac{\bar{V}_o{}^3\rho}{g\mu}\right]^{-0.38} \times \left[\frac{Z^3\rho^2 g}{\mu^2}\right]^{0.236} \qquad \text{(iii)}$$

Chapter III presents absorption studies in gas-liquid interface. A critical review of literature survey on interfacial resistance in gas-liquid and liquid-liquid interface has been presented.

It consists of detail description of the experimental set-up and the technique employed for the measurement of mass transfer rate in gas-liquid interface.

Next, the results and discussions have been presented. A highly soluble system is chosen for which interfacial resistance may be assumed negligible. The main idea of choosing such a system is to test the validity of the Equations (ii) and (iii). The calculations for the mass-transfer rate is made from the recommendations of previous investigators and the plot of average mass transfer rate against the reciprocal of root of contact time shows deviation from the theoretical curve. After correcting for actual contact area and actual contact time with the help of Equations (ii) and (iii), it is observed that the deviation shifts towards the theoretical line and ends up with good agreement between the theoretical value and observed data.

Appendix A presents an approximate mathematical analysis for the prediction of jet diameter as a function of axial distance. The analysis leads to a non-linear differential equation which is solved for boundary conditions obtained from experimental data and is found to be in good agreement.