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Short communication

Measurements of mass transfer rates in a rectangular liquid fluidised bed using LCDT

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Abstract

Ionic mass transfer from electrolyte to a plate cathode in liquid fluidised bed filled with spherical inert particles has been experimentally studied. The mass transfer rates were measured by using the limiting current diffusion technique (LCDT) in ferri- and ferrocyanide electrolyte systems. The effects of bed height and electrode location from the bottom of test chamber in different electrolyte concentrations and flow velocities on mass transfer coefficient were evaluated. Ranges of the variables used in the study are as follows: Reynolds number=78–300, Galileo number=282,000–298,000, density number=0.335–0.370 and Schmidt number=1831–1995. Experimental data are correlated as follows, by non-linear regression using Statistica Package Program:

$$Sh = 0.199 Re_{\mathrm{p}}^{\frac{3}{5}} Ga^{\frac{1}{10}} Mv^{\frac{7}{2}} Sc^{\frac{1}{3}} \left(\frac{d_{\mathrm{eq}}}{E_{\mathrm{L}}}\right)^{\frac{3}{10}} \left(\frac{d_{\mathrm{eq}}}{L_{\mathrm{Y}}}\right)^{\frac{-3}{4}}.$$

A comparison between the present data and related several literature correlation's has been achieved by calculating absolute (σ_{A}) and relative (σ_{R}) deviations. The deviations in present study are less than those in the literature cited.

Keywords: Fluidised bed; Mass transfer; Electrochemical technique

1. Introduction

The enhancement of transfer rates in process equipment by using certain techniques has been of vital importance because of the necessity for energy and material savings [1]. The application of any augmentative technique, though making the system more complicated, offers tremendous improvement in transfer coefficients [2]. Dissolution, adsorption, sedimentation, crystallisation, leaching, ion exchange, wastewater treatment, etc. can be performed either in a fixed bed or in a stirred vessel or in a fluidised bed [3–8].

When comparing these three major processes, it appears that:

- Achievement of solid particles flow in a fluidised bed is an important advantage when compared with a fixed situation. It enables to organise continuous treatments of the solid particles.
- Because the liquid in a fluidised bed is approximately in plug flow, the mean driving force for mass transfer is higher than in a well mixed stirred vessel; attrition of the solid particles is also less violent.

Despite its advantages, it must be kept in mind that liquid fluidised beds are rarely used in industrial operations such as food technology, hydrometallurgy, biochemical reactors, electrochemical processing, water treatment, etc. [5,8–11].

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Table 1
Physical properties of the electrolyte (20 °C)

Fluid	0.005M–0.05 M ferricyanide
ρ (kg m^{-3})	1022–1049
ν (m^2 s^{-1})	1.112×10^{-6}–1.143×10^{-6}
D (m^2 s^{-1})	6.07×10^{-10}–5.73×10^{-10}
Sc (–)	1831–1995

Fluidised bed is usually associated with two- or three-phase systems, in which solid particles are fluidised by a liquid or gas stream flowing in the direction opposite to that of gravity [12]. In fluidised systems, the solid particles have a higher density than those of the fluidizing liquid and/or gas, and the bed is expanded by the upward flow of the continuous fluid [13].

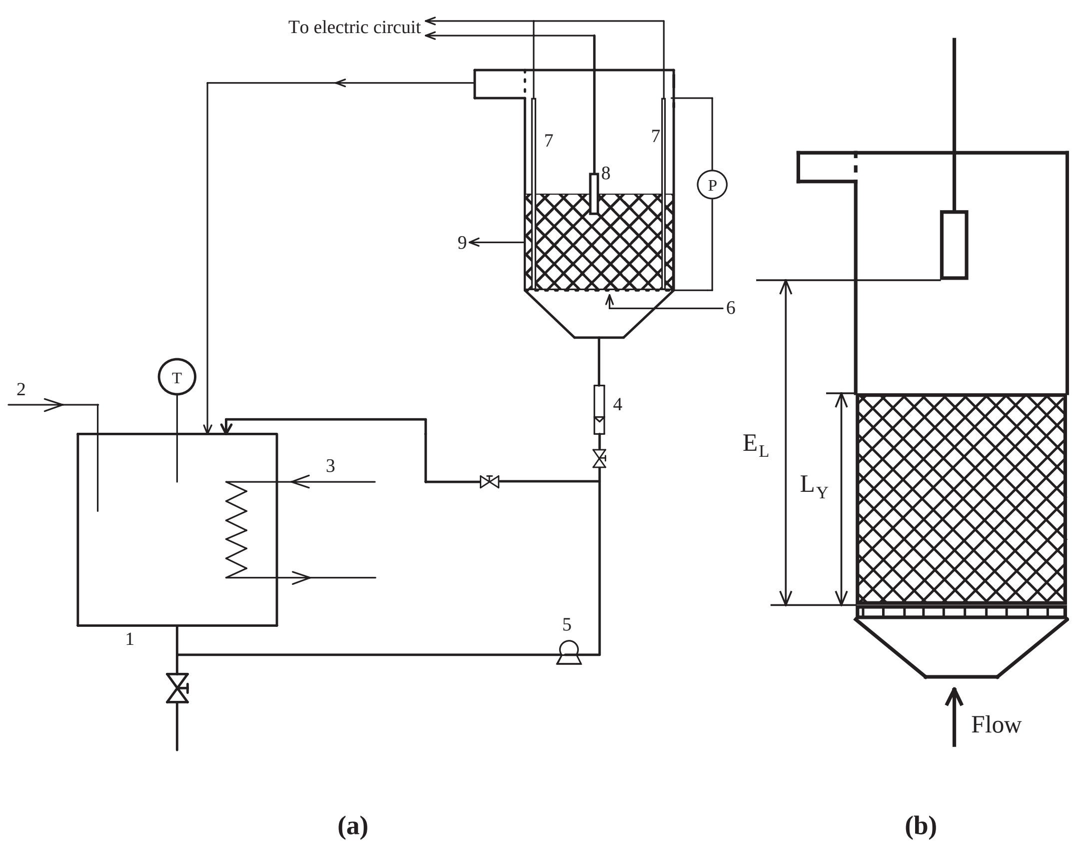
Three different kinds of measurements of mass transfer rates are used in fluidised bed process, as follows: dissolution, adsorption and electrochemical. Several authors [14–19] have extensively studied dissolution and adsorption methods by measuring the rate of dissolution of suitable solids into a liquid or adsorption to solid particles. However in last few decades, the mass transfer rates with electrochemical method in solid–liquid fluidised beds have been investigated by Riba et al., Nikov et al. and Latha et al. [5,20–22]. Some of the correlations of these studies are shown in Table 1.

In all the above-mentioned references, the correlation of experimental results is not compatible with each other, because of different physical properties of liquids, geometries of beds and solid–liquid hydrodynamic conditions of these systems.

The first objective of the present study was to investigate the effects of bed height and electrode location from the bottom of test chamber on mass transfer rate in different electrolyte concentrations and superficial velocities, using a rectangular fluidised bed. The second objective was to discuss in light of the results of this study and the literature and develop a correlation to predict from electrolyte to a plate cathode mass transfer in a two-phase fluidised bed.

2. Experimental and method

Apparatus used in the experiments is shown in Fig. 1(a). It essentially consists of an electrolyte tank, a centrifugal pump, a flowmeter, a test chamber, multimeters and a power



1. Electrolyte tank, 2. Nitrogen inlet, 3. Water cooling, 4. Flowmeter, 5. Centrifugal pump, 6. Distributor, 7. Anode, 8. Cathode, 9. Fluidized bed

E_L*10^2 = 5, 8, 11 and 14 m and L_Y*10^2 = 2, 4, 8 and 16 m

Fig. 1. Experimental aparatus.