International Communications in Heat and Mass Transfer 38 (2011) 493–498

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

Mass transfer behavior at horizontal cylinder in cross flow under different flow conditions ☆

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ARTICLE INFO

Available online 8 January 2011

Keywords:
Mass transfer
Heat transfer
Horizontal cylinder
Gas sparging
Two phase flow
Limiting Current

ABSTRACT

The rate of liquid–solid mass transfer at a horizontal cylinder placed in a cylindrical vertical column under different hydronamic conditions including gas sparging, single phase liquid flow, and two phase (gas–liquid) flow was studied experimentally by using the electrochemical technique which involves measuring the limiting current of the cathodic reduction of $K_3Fe(CN)_6$ using a solution containing 0.01 M $K_3Fe(CN)_6$ and 0.1 M $K_4Fe(CN)_6$ and a large excess of NaOH as supporting electrolyte. Variables studied were: liquid and gas superficial velocities, cylinder diameter, and solution physical properties. For gas sparging: the data were correlated for the conditions $0.2<(Re.Fr)<8.7$, and $1253<Sc<2778$ by the equation:

$$j = 0.11(\mathrm{Re}.Fr)^{-0.247}.$$

For single phase liquid flow: the data were correlated for the conditions $1253<Sc<2778$, and $14<Re<516$ by the equation:

$$Sh = 19Sc^{0.33}\mathrm{Re}^{0.47}\left(\frac{d_t}{d_c}\right)^{0.9}.$$

For two phase flow: the data were correlated for the conditions $1253<Sc<2778$, $21<Re_L<181$, and $139<Re_g<781$ by the equation:

$$Sh = 6.34Sc^{0.33}\mathrm{Re}_L^{0.1}\mathrm{Re}_g^{0.26}.$$

The possibility of using the present data in the area of heat transfer was noted.

1. Introduction

Single or array of horizontal cylinders placed in vertical cylindrical chemical reactors and bioreactors are frequently used as heat exchanger to control the reactor temperature [1]. Sometimes they are also used to serve as a catalyst support e.g. immobilized enzyme besides acting as heat exchanger. Knowledge of the heat and mass transfer coefficient at such tubes under different hydrodynamic conditions would make it possible to design chemical reactors and bioreactors employing horizontal tubes on a rational basis. The aim of the present work is to study the rate of mass transfer at a horizontal tube surrounded by a vertical cylindrical container under single phase flow, gas sparging, and two phase flow. To this end an electrochemical technique which involves measuring the limiting current of the cathodic reduction of $K_3Fe(CN)_6$ in a large excess of NaOH supporting electrolyte was used. Elimination of electrical migration of the reactant ion by using large excess of NaOH makes the technique suitable for measuring heat and mass transfer as confirmed by Mizushina [2] under different flow conditions. Previous studies on horizontal cylinders have concentrated on cylinders placed in infinite medium [3–6] under single phase flow.

2. Experimental technique

Fig. 1 shows the experimental setup used in the present study. It consisted mainly of a vertical cylindrical column, flow circuit and electrical circuit. The column consisted of a plexiglass cylinder of 20 cm outside diameter and 70 cm height, divided into three sections namely: the inlet section, the working section, and the outlet section. The inlet section which was packed with plexiglass spheres of 1.2 cm diameter had a height of 30 cm which was sufficient to calm the flow [7–9]. The bottom of the inlet section was a uniformly perforated

☆ Communicated by W.J. Minkowycz.

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doi:10.1016/j.icheatmasstransfer.2010.12.032