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Mass transfer at the confining wall of helically coiled circular tubes in the absence and presence of packed solids☆

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ABSTRACT

Limiting current measurements were made at the electrode surfaces fixed flush with the inner wall of a helically coiled circular tube. The measured limiting current facilitated the computation of wall–liquid mass transfer coefficients. The mass transfer data were obtained for the flow of electrolyte through the helical coil in the absence and presence of packed solids. The mass transfer coefficient was found to decrease with increasing p/D ratio and approached minimum for straight tube case. The mass transfer data were correlated in terms of Colburn factor j_D, expressed as a function of Reynolds number Re and torsion number Tn obtained as $j_D = 0.34\mathrm{Re}^{-0.58}Tn^{0.17}$. Analysis of the experimental data obtained in case of packed coiled tubes of circular cros- section revealed that the effect of p/D ratio on pressure drop was observed to be insignificant. The effect of pitch on mass transfer coefficient in case of packed helical coils was found to be marginal.

1. Introduction

Flow through coiled tubes and pipes commonly occur in chemical process industries. Helically wound circular pipes/tubes are frequently used in heat or mass transfer equipment. The commonly encountered situations are in engineering piping systems, biological systems such as in human body and in bends in piping network. Applications are found in enhancement of heat transfer in compact heat exchangers, coil steam generators, refrigerators, nuclear reactors, cryogenics, boilers, condensers, thermosyphones, exhaust gas ducts of engines, cooling systems for conductors of electric generators, reverse osmosis, coiled membrane blood oxygenerators, fluid mixing, power production, environmental engineering, manufacturing industry, air-conditioning, waste heat recovery, phase separators, chemical reactors, food and pharmaceutical industries.

Advantages of helically coiled tubes are their simplicity, compactness of structure, small residence time distribution and ability to accommodate large heat transfer area in a small space, high efficiency in heat and mass transfer and low pressure loss. These advantages can be attributed to the presence of secondary flows in the coils. When fluid flows through a curved pipe, the presence of curvature generates the centrifugal force that acts right angle to the main flow and results in secondary flow. The strength of the secondary flow depends on the curvature of the flow path. Thus, coiled flow system may be conceived as one of the passive heat and mass transfer augmentation techniques [1].

A comprehensive review of pressure drop studies for flow through helical coils has been presented by Ali [2]. Austin and Seader [3] obtained solutions of the equations of fluid motion for the case of steady state, fully developed, isothermal, incompressible, viscous Newtonian flow with a toroidal type coiled tube geometry. Fully developed pulsed flow in a curved tube was investigated by Hamakiotes and Berger [4]. Flow through a rotating helical pipe with circular cross-section had been investigated by Yamamoto et al. [5]. They also reported visualization of flow in helical pipes [6].

Hameed and Muhammed [7] investigated gas–liquid mass transfer in helical coiled tubes. Absorption of carbon dioxide in water and dilute solutions of ethylene glycol was carried out. The mass transfer coefficient was found to be higher for helical coiled tube than that of straight tube. Anil Kumar et al. [8] studied wall–liquid mass transfer in helical coiled tubes in the presence of fluidizing solids and with two-phase gas–liquid flow. The mass transfer coefficient was found to be influenced by particle diameter and p/D ratio in the presence of fluidizing solids. In case of gas–liquid flow, the effect of liquid velocity and pitch on mass transfer coefficient was not observed.

Although having widespread use, the investigations in helically coiled tubes are relatively less in number. The literature review revealed that studies in helically coiled tubes are mainly focused on hydrodynamics and modeling. Heat transfer studies were very few and mass transfer studies were found to be less in number [9]. Hence an attempt is made to investigate the wall–liquid mass transfer in homogeneous flow and in packed helical coiled tubes. Measurement of mass transfer coefficient was made using limiting current technique. Usage of limiting current technique for determining mass transfer coefficients was

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