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RESEARCH PAPER

Turbulent mass transfer of Al_2O_3 and TiO_2 electrolyte nanofluids in circular tube

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Abstract Experimental study was performed to investigate turbulent mass transfer in straight circular tube. Electrochemical limiting diffusion current technique was used to measure the mass transfer coefficient in fully developed hydrodynamics and under developed mass transfer region. TiO_2 and γ-Al_2O_3 nanoparticles were added into the electrolyte solution (ES) to make electrolyte nanofluids (ENF). Measurements revealed that enhancement in mass transfer reaches 10 % in a 0.01 vol% γ-Al_2O_3/electrolyte nanofluid while 18 % in a 0.015 vol% TiO_2/electrolyte nanofluid relative to the base ES. Mass transfer coefficients increased with nanoparticles concentration up to an optimum concentration (0.01 % in γ-Al_2O_3/electrolyte nanofluid and 0.015 % in TiO_2/electrolyte nanofluid) while decreased by increasing nanoparticles concentration further. Enhancement ratio which is the ratio of the mass transfer coefficient of nanofluid to that of the base fluid was a function of nanoparticle concentration and was independent of Reynolds number. The mechanisms of nanoparticles Brownian motion and nanoparticles clustering were used to describe the behavior of the enhancement ratio in ENF.

Keywords Electrolyte nanofluids · Mass transfer coefficient · Electrochemical limiting diffusion current technique · Turbulent flow

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1 Introduction

The idea of addition of inert particles to working fluids for improving heat and mass transfer in liquids was suggested more than 100 years ago (Wang and Mujumdar 2007). Addition of milli and micro meter sized particles to base liquids showed disadvantages such as agglomeration, sedimentation and increment of pumping power (de Ficquelmont-Loizos et al. 1988; Caprani 1988; Sonneveld et al. 1990; Goel et al. 1994). The manufacture of the nano-sized particles resolved many of the mentioned disadvantages. Fluids in which nanometer-sized particles are suspended are called nanofluids. Most of the studies have reported that nanofluids provide heat transfer enhancement relative to their base fluids (Fotukian and Nasr Esfahany 2010a, b; Murshed et al. 2005, 2008; Kakaç and Pramuanjaroenkij 2009; Heris et al. 2007). Considering the analogy between mass and heat transfer, nanoparticles may also influence the mass transfer favorably. Published reports on the effects of nanoparticles on mass transfer are scarce. Table 1 summarizes the results of the previous investigations. Olle et al. (2006) observed that Fe_3O_4 nanoparticles improved oxygen absorption remarkably at nanoparticles volume fractions below 1 %. Nagy et al. (2007) demonstrated that the solubility of oxygen in nanofluids was 2.2-fold of the base liquid. Zhu et al. (2008) indicated that mesoporous silica (MCM41) nanoparticles showed higher volumetric mass transfer coefficients relative to large silica particles (1.4 and 7 μm). The effect of the nanoparticles on absorption in binary nanofluids was investigated showing that both heat and mass transfer were improved (Kim et al. 2006; Kang et al. 2008; Ma et al. 2009; Yang et al. 2011a, b). Using electrochemical limiting diffusion current (ELDC) technique, Sara et al. (2011) showed that CuO nanoparticles increased mass transfer of ferricyanide ions