Hydrodynamics of Jet-driven Liquid-liquid Inverse Droplet Flow and Its Application for Separation of Organic Contaminants

THESIS

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ABSTRACT

Over the years, the research on the liquid-liquid plunging jet extraction column has drawn significant interest among the scientific fraternity because of its numerous applications, including fine chemical synthesis, recovery of fuel in nuclear plants, acid mixing, ink-jet, and liquid metal transfer (Asadollahzadeh et al., 2016; Gao et al., 2016; Hu et al., 2009; Tadrist et al., 1991). Various researchers have used different columns for the liquid-liquid extraction process such as Kühni column, rotating disc contactor, static mixer, and jet extraction column. Jet mixers have several advantages compared to mechanical mixers because they have low maintenance, low cost, low energy consumption, and shorter mixing time. The jet system has a higher liquid mixing and mass-transfer operation for mixing the liquid-liquid phase. For the past years, the jet device has been employed for wastewater treatment and acid extraction, but the studies were found to be limited. The jet device was used to extract copper ions, and it was discovered that the rate of copper extraction was 7 to 8 times higher than in the CSTR (Dehkordi, 2002a). Suresh et al. (2005) used liquid-liquid jet extraction system and separated uranium and thorium. They have stated that the ejector-type jet device can provide a high extraction efficiency. The various parameters such as liquid-liquid entrainment, drop size and its distribution, axial dispersion coefficient, extraction efficiency, and overall mass transfer play a significant role in designing and modeling of liquid-liquid extraction column. These parameters have an immense impact on selectivity and conversion in chemical engineering applications. Based on the literature, the jet-driven extraction column is gaining popularity for generating interfacial area, intense mass-transfer operations such as gas adsorption, liquid-liquid extraction, etc. However, there is a scarcity of studies on hydrodynamics and mass transfer for specific applications correlating the hydrodynamics in the jet-driven mixing column. The present work aims to enunciate hydrodynamics and its application in a jet-driven

liquid-liquid extraction column. As per the literature review and scope of the research, the following aims are framed under this main objective as:

- Entrainment characteristics of liquid-liquid dispersion
- Drop size distribution and drop aspect ratio
- Dispersion characteristics and its analysis
- Extraction efficiency and overall mass transfer in jet-driven extraction column

Chapter 2 presents the experimental investigation of the effects of the plunging of continuous liquid jets on a liquid-liquid dispersion of a two-phase system in a mixing column. The impact of various operating variables such as continuous liquid jets velocity, liquid jet lengths, mixture density, viscosity, and different dispersed phase volumes on immiscible liquid penetration heights were discussed. A mechanistic model was developed using the shell momentum balance and validated with the experimental data. A general correlation is developed based on the dimensional analysis to predict the penetration height at different operating variables.

Chapter 3 reports the study of drop size distribution, drop aspect ratio, and interfacial area in a liquid-liquid jet-driven column. Drop size distribution is found to follow the Log-logistic drop size distribution function. Empirical correlation is developed to predict Sauter mean drop diameter, drop aspect ratio, distribution function parameters, and interfacial area based on the operating variables and physical properties.

Chapter 4 focuses on studying the degree of liquid-liquid axial dispersion in a jet-driven mixing column. The effects of jet velocity and dispersed phase volume on mixing characteristics were studied. A general correlation was developed to predict the axial dispersion coefficient based on various operating variables. A mechanistic model was used to interpret dispersion due to turbulence and phase circulation inside the jet-driven mixing column. Based on the velocity distribution model, the velocity characteristic factor and the dispersion factor of drop motion were also enunciated.

Chapter 5 studied the liquid-liquid extraction using solvents such as kerosene, diesel, 1-decanol, and paraffin in a jet-driven extraction column. The influence of jet velocity dispersed phase volume and physical properties on extraction efficiencies and mass transfer were studied. The overall mass transfer coefficient (K_La) range was found to be 0.73 to 8.49 s^{-1} and 1.23 to 9.42 s^{-1}. A correlation is established based on the operating variables and physical parameters to predict the overall mass transfer coefficient.