CHEMICAL ENGINEERING RESEARCH AND DESIGN 90 (2012) 985–997

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Research and Design

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

Measurement of drop size characteristics in annular centrifugal extractors using phase Doppler particle analyzer (PDPA)

T.V. Tamhane[a], J.B. Joshi[a,b,*], Kamachi Mudali[c], R. Natarajan[c], R.N. Patil[d]

[a] Department of Chemical Engineering, Institute of Chemical Technology, Matunga, Mumbai 400019, India
[b] Homi Bhabha National Institute, Anushakti Nagar, Mumbai 400094, India
[c] Indira Gandhi Centre for Atomic Research, Kalpakkam 603 102, Tamil Nadu, India
[d] Techno-Force Pvt. Ltd., Ambad D-34, Nashik 422010, India

ABSTRACT

Drop size distributions have been measured in a 39 mm annular centrifugal extractor using phase Doppler particle analyzer (PDPA). The power consumption and the interfacial tension have been varied in the range of 10–450 kW/m^3 and 13–33 mN/m, respectively. The two liquid phases have been selected with different density and viscosity ratios. The results have been analyzed using Rosin–Rammler distribution function. A correlation has been developed for the drop size distribution. The same has been compared with the correlations in the literature.

Keywords: Taylor–Couette flow; Annular centrifugal extractor; Liquid–liquid extraction; Power consumption; Drop size distribution; PDPA

1. Introduction

Annular centrifugal extractors (ACE) find wide applications in chemical process industries involving liquid–liquid extractions. The principle of these extractors is based on Taylor–Couette flow. It consists of a stationary outer cylinder, concentric to which is a rotating inner cylinder. The annular gap between the two cylinders is kept small. The inner cylinder is rotated at a high speed. The motion of the inner cylinder is quantified by a dimensionless number, known as Taylor number (*Ta*), which is the ratio of centrifugal force to the viscous force. At low speeds of rotation, the flow is purely circumferential and occurs at $Ta < 1708$ and is simply called as circular Couette flow (CCF). When *Ta* exceeds a certain critical value, Ta_{Cr} (1708), the centrifugal instability gives rise to Taylor vortex flow (TVF). In TVF, there occurs a sequence of counter rotating vortices stacked along the annulus which is a characteristic feature of this type of flow. At high Taylor numbers ($Ta > 1000 Ta_{Cr}$) the flow becomes turbulent and is called turbulent Taylor vortex flow (TTVF). Above this point, the vortex boundaries become difficult to discern.

Annular centrifugal extractors offer various advantages over conventional mixer-settlers, which include high mass transfer coefficients, high interfacial areas, low residence times and a clear separation after extraction. Low hold-up volumes and flexible phase ratios are a few more in this list. Owing to these features of annular centrifugal extractors, they find wide applications in nuclear fuel processing (where safety is the main concern) (Schlea et al., 1963; Roth, 1969; Bernstein et al., 1973), biological operations (where facilitated settling is important) (Tsao et al., 1994; Joshi et al., 1996) and polymerization (Imamura et al., 1993; Kataoka et al., 1995), etc. Also, excellent mixing, mass and heat transfer can be achieved between wall and fluid. This finds particular applications in the chemical reactors (Joshi et al., 1980; Pandit and Joshi, 1983, 1986; Cohen and Maron, 1983; Ranade and Joshi, 1989, 1990a, 1990b; Ranade et al., 1989, 1991, 1992). Synthesis of monodisperse silica particles has been shown by Ogihara et al. (1995).

* *Corresponding author at*: Department of Chemical Engineering, Institute of Chemical Technology, Matunga, Mumbai 400019, India. Tel.: +91 22 33332106/25597625; fax: +91 22 33611020.
E-mail addresses: jbjoshi@gmail.com, jb.joshi@ictmumbai.edu.in (J.B. Joshi).
Received 14 June 2011; Received in revised form 3 November 2011; Accepted 6 November 2011
0263-8762/$ – see front matter
doi:10.1016/j.cherd.2011.11.007