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Study of axial mixing, holdup and slip velocity of dispersed phase in a pulsed sieve plate extraction column using radiotracer technique

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ABSTRACT

Axial mixing, holdup and slip velocity of dispersed phase which are parameters of fundamental importance in the design and operation of liquid–liquid extraction pulsed sieve plate columns have been investigated. Experiments for residence time distribution (RTD) analysis have been carried out for a range of pulsation frequency and amplitude in a liquid–liquid extraction pulsed sieve plate column with water as dispersed and kerosene as continuous phase using radiotracer technique. The column was operated in emulsion region and ^{99m}Tc in the form of sodium pertechnetate eluted from a ^{99}Mo/^{99m}Tc generator was used to trace the dispersed phase. Axial dispersed plug flow model with open–open boundary condition and two points measurement method was used to simulate the hydrodynamics of dispersed phase. It has been observed that the axial mixing and holdup of dispersed phase increases with increase in pulsation frequency and amplitude until a maximum value is achieved while slip velocity decreases with increase in pulsation frequency and amplitude until it approaches a minimum value. Short lived and low energy radiotracer ^{99m}Tc in the form of sodium pertechnetate was found to be a good water tracer to study the hydrodynamics of a liquid–liquid extraction pulsed sieve plate column operating with two immiscible liquids, water and kerosene. Axial dispersed plug flow model with open–open boundary condition was found to be a suitable model to describe the hydrodynamics of dispersed phase in the pulsed sieve plate extraction column.

1. Introduction

Liquid–liquid extraction is a process of separation of constituents of a liquid phase by contacting it with another immiscible liquid phase. Petroleum, nuclear, chemical, metallurgical, pharmaceutical, food processing and bio-processing industries are the major beneficiaries of this technology. Column type contactors with agitation are very famous liquid–liquid extraction equipments as they offer large interfacial area, high mass transfer coefficient, high turbulence and minimum radial gradients. Counter current movement of phases in these type of columns provide high concentration gradients for efficient mass transfer but axial mixing in both phases lowers the process efficiency by lowering solute concentration gradients. It has been reported that axial mixing in extraction columns lowers the process efficiency as much as 30% (Li and Ziegler, 1967). The major sources of axial mixing in the extraction columns are geometrical and operating parameters. Therefore, the presence of axial mixing in such kind of equipments is unavoidable and needs special care. A simple approach to represent the hydrodynamics of phases in these kind of columns is the axial dispersion model (ADM) (Levenspiel and Smith, 1957; Levenspiel, 1999) and the concept of residence time distribution (RTD) analysis is an important method for the estimation of axial dispersion in chemical reactors (Danckwerts, 1953). The holdup and slip velocity of dispersed phase are other parameters of fundamental importance that need to be focused in the design and operation of pulsed extraction columns.

Axial mixing in the continuous phase of liquid–liquid extraction columns remained a major focus of many studies. These include studies on spray towers (Hazlebeck and Geankoplis, 1963; Henton and Cavers, 1970; Geankoplis et al., 1982), reciprocating plate extraction columns (Kim and Baird, 1976a, b; Hafez et al., 1979; Parthasarathy et al., 1984) and pulsed sieve plate extraction columns (Kumar and Hartland, 1989). Axial mixing in the dispersed phase of liquid–liquid extraction columns has either been assumed negligible or it has not been estimated. Only a few studies can be found regarding axial dispersion in the dispersed

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phase (Srinikethan et al., 1987) with conventional methods in which a non-radioactive tracer is injected into the system and measurements were made by a conductivity probe. The holdup and slip velocity of the dispersed phase have also been determined by arresting the flow of phases and measuring the fractional dispersed phase volume in the extraction column (Venkatanarasaiah and Varma, 1998). These experimental approaches present some disadvantages including low sensitivity, requirement of phase separation before measurement and poor statistics. Most important of all is that one needs to shutdown the plant to obtain the holdup fraction at each operating parameter resulting in a high plant shutdown.

Radiotracers are being used for industrial process optimization and trouble shooting from decades. They offer state of the art

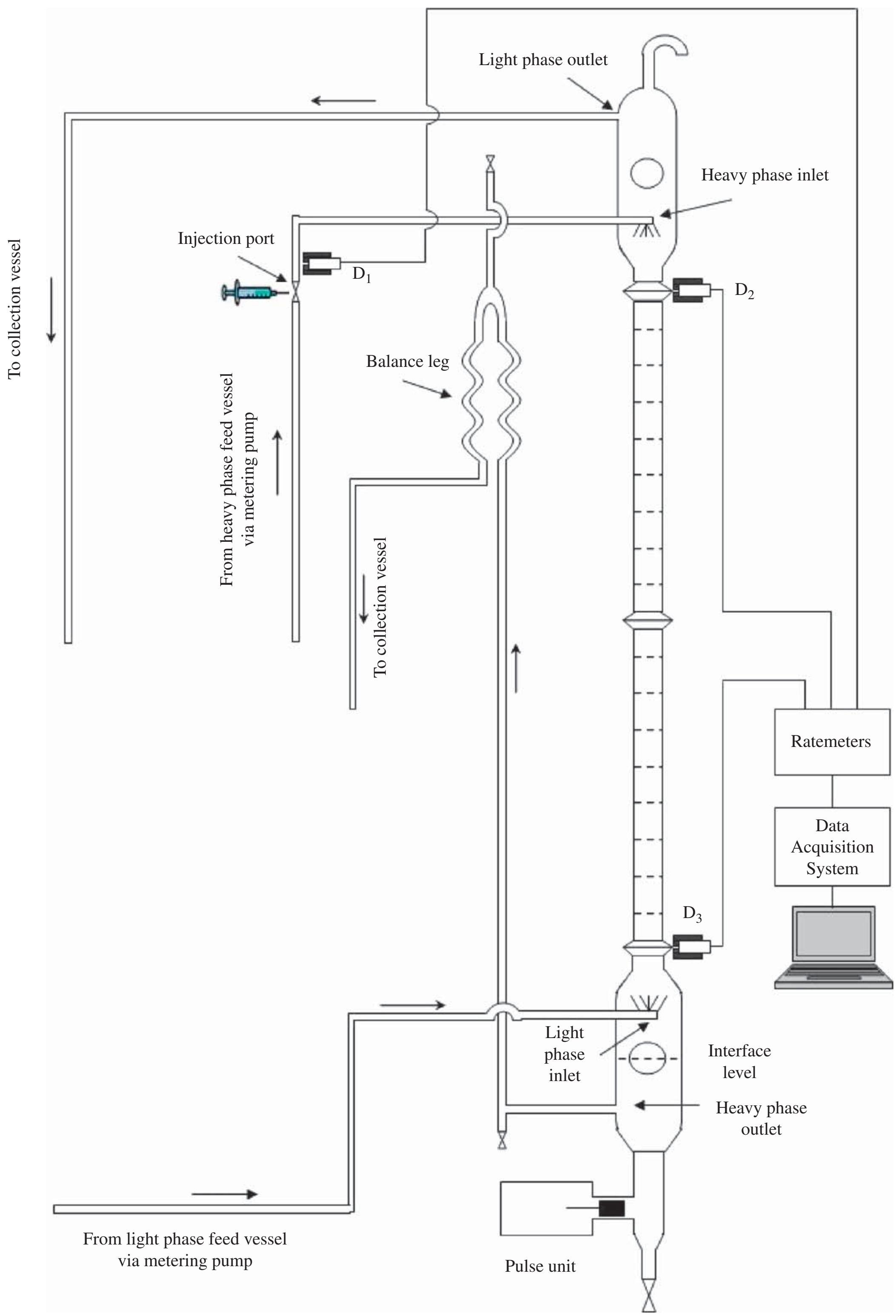

Fig. 1. Schematic diagram of pulsed sieve plate extraction column.