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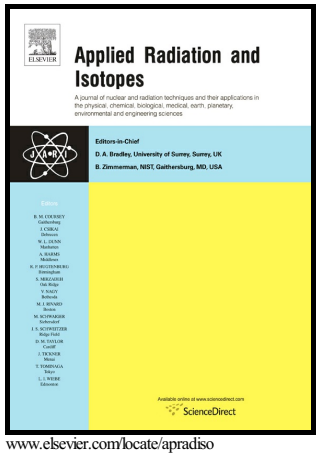

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Radiotracer investigation on the measurement of residence time distribution in an ethyl acetate reactor system with a large recycle ratio

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Abstract:

A radiotracer investigation was carried out on the measurement of residence time distribution (RTD) of process fluid in an industrial-scale ethyl acetate reactor system, which consists of two independent reactors with recirculation and connected in series with each other. Bromine-82 as ammonium bromide was used as the radiotracer for the RTD experiments at different operating conditions. The individual reactors and the overall reactor system were modelled using physically representative phenomenological models comprising of continuously stirred tank reactors (CSTRs). The results showed that the recirculation rate considerably affected the flow mixing behaviour and mean residence time of the process fluid in the reactor system. The results also showed that there was bypassing of the fluid in the first reactor that ranged from 12 to 22% and 40% dead volume at different operating conditions, whereas the second reactor behaved closely as an ideal CSTR. The results of the investigation can be used to optimise the process parameters and design new improved reactor systems for the production of ethyl acetate.

Key words: Ethyl acetate reactor, Radiotracer, Bromine-82, Residence time distribution, Mean residence time, Bypassing, Stagnant volume, Continuously stirred tank reactor

1. Introduction

In chemical engineering, an equipment is designed to behave as either an ideal plug flow reactor (PFR) or an ideal continuously stirred tank reactor (CSTR) depending upon the process requirement. However, in actual operating systems, the flow patterns deviate from the designed ideal flow patterns because of the occurrence of one or more abnormalities such as bypassing, dead zones and channelling. (Fogler, 2004) These abnormalities cause deviation in the flow patterns and eventually lead to deterioration in product quality and decrease in process efficiency, thereby causing significant economic loss for the industry and even posing a threat to the manufacturing plants and the environment. (Pant and Yelgoankar, 2002; Othman and Kamarudin, 2014) Measurement and analysis of residence time distribution (RTD) of process material is an important approach to identify abnormalities, if any, and to investigate the hydrodynamics of process equipment in the chemical process industry. The approach is very reliable and provides valuable information about the performance of process equipment such as reactors and columns. (Levenspiel, 1998). This is also used for the evaluation and optimisation of the design of laboratory- and pilot-scale systems at the design stage.

Conventional tracer techniques using dyes, chemicals and salts are often used to measure the RTD of process fluid in laboratory-scale systems; however, they cannot be applied to pilot-scale and large-scale industrial systems because of their many disadvantages (van Gelder and Westerterp, 1990; Jafari and Soltan Mohammadzadeh, 2005; Le Moullec et al., 2008). The disadvantages of the conventional tracer techniques are overcome by

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