New froth behaviour observations and comparison of experimental sieve tray entrainment data with existing correlations

Ehbenzener C. Uys, Cara E. Schwarz, Andries J. Burger, Johannes H. Knoetze*

Department of Process Engineering, University of Stellenbosch, Private Bag X1, Matieland 7602, South Africa

A B S T R A C T

A thorough understanding of the hydrodynamics in tray columns is required to optimise column and tray design for specific operating capacities and conditions. Liquid transported by the rising gas to the tray above, defined as entrainment, is one way of measuring the tray column capacity limit. Entrainment correlations available in the literature have been developed with predominantly air/water data, because of the limited availability of non-air/water systems. In this work an experimental setup was constructed to measure entrainment, tray pressure drop andweeping for variousgas and liquid systems. The experimental entrainment data for three systems, namely air/water, air/ethylene glycol and air/silicone oil, is compared to existing correlations. The effect of liquid physical properties on entrainment under flow factors ranging from 1.6 kg0.5/(m0.5 s), for a 415 mm tray spacing to 4.0 kg0.5/(m0.5 s) for a 615 mm tray spacing within a liquid flow range of 2.9–112 m3/(h m) was observed. The experimental results showed a somewhat complex dependency of entrainment on liquid physical properties. At gas flow factors of 2.2 kg0.5/(m0.5 s) for the 415 mm tray spacing, entrainment reached a maximum in the froth regime and then decreased with increasing liquid rates. Notably, the liquid viscosity – not included in previously developed correlations – significantly influences the entrainment behaviour. Existing entrainment correlations agree better with the air/water data than with the air/ethylene glycol or air/silicone oil data.

Keywords: Entrainment; Sieve tray column; Physical properties

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1. Introduction

Distillation, absorption and stripping are the most widely used separation processes in the chemical industry. These separation methods rely on the contact between a gas or vapour, and a liquid in order to achieve the required separation. Contact between phases is established on column internals, typically packing or trays. In this paper the focus is on sieve trays, which is the most common and simplest of all tray types.

Significant contributions have been made (e.g. Lockett, 1986; Hofhuis and Zuiderweg, 1979; Kister et al., 1981; Zuiderweg, 1982; Kister and Haas, 1988; Bennett et al., 1995; Van Sinderen et al., 2003) to add to the understanding and knowledge of the entrainment in tray distillation columns. The capacity of a tray column is limited by the occurrence of significant entrainment (L/G) or jet flooding (Kister and Haas, 1990). Entrainment generally has two definitions with relation to tray capacity and efficiency. When tray capacity is of importance, entrainment is expressed as the mass of liquid that reaches the tray above per mass of rising gas (L/G). When tray efficiency is of importance entrainment is measured as a percentage of the liquid entering the tray (L/L) that is transported to the tray above.

The tray pressure drop, tray efficiency, entrainment, weeping and flow regime depend on the tray and column geometry, liquid and vapour loads, and liquid and vapour physical properties. By understanding how these variables influence entrainment, improvements can be made to the column and tray designs. Improved tray designs could potentially lead to higher column throughputs by retrofitting existing columns, or by reducing column height and therefore capital costs for new designs. The measurement and interpretation