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Performance characteristics of an intermediate area high performance structured packing

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ABSTRACT

Results are presented of total reflux distillation experiments carried out with Montz-Pak B1-350MN in a 1.22 m internal diameter column at Fractionation Research Inc. using two tests systems at two operating pressures, i.e. cyclohexane/*n*-heptane, at 0.31 and 1.62 bar, and paraxylene/orthoxylene at 0.1 and 1 bar, respectively. In all cases an impressive packing efficiency was achieved, ranging from five stages- at low to four stages per unit bed height at high vapour loads. Comparison with data obtained earlier with B1-250MN under similar conditions indicates a relatively higher maximum useful capacity of B1-350MN, while the relative efficiency and pressure drop are close to the ratio of installed specific geometric areas. The Delft model captures observed packing geometry related effects quite well qualitatively. Quantitatively, the efficiency and pressure drop predictions are on the safe side.

1. Introduction

Prototypes of Montz high performance corrugated sheet structured packings (B1-MN series) with specific geometric area of 250, 350 and 500 m^2/m^3 have undergone total reflux distillation tests in a 0.59 m internal diameter column at Bayer Technology Services (BTS) in Leverkusen, Germany. The test system was chlorobenzene/ethylbenzene at 0.1 bar (Olujić et al., 2012). All packings performed accordingly, and thereupon decision was made to start with manufacturing and delivery of these highly efficient packings. Since then, these packings have found numerous applications and have proven to be a cost-effective choice in both new designs and retrofits.

Regarding their favourable performance characteristics, an industrial scale confirmation came recently, from a series of total reflux distillation tests performed in 2011 with B1-250MN at Fractionation Research Inc. (FRI), using 1.22 m internal diameter (I.D.) column in conjunction with standard tests systems cyclohexane/*n*-heptane (C6/C7) at 0.31 and 1.62 bar, and paraxylene/orthoxylene (px/ox) at 0.1 bar (Olujić et al., 2013). Even more, the obtained efficiencies appeared to be highest one measured so far with a 250 m^2/m^3 packing in a FRI test. Such a result has impressed and motivated FRI membership to choose B1-350MN for a category 1 test in 2012. This paper provides a summarized overview of the results obtained during the performance evaluation tests conducted with this intermediate area structured packing.

Interesting to mention here is that efficiency curves for B1-250MN measured at BTS and FRI overlapped each other, i.e. this packing with two close boiling systems exhibited same efficiency and same maximum useful capacity (Olujić et al., 2013). However the difference in measured pressure drop was rather large, well above that that could be attributed to the difference in column diameters employed in these tests. So, a

Abbreviations: BTS, Bayer Technology Services; CB/EB, chlorobenzene/ethylbenzene; C6/C7, cyclohexane/*n*-heptane; DM, Delft Model; FRI, Fractionation Research Inc.; HETP, height equivalent to a theoretical plate; ID, internal column diameter; Montz, Julius Montz GmbH; px/ox, paraxylene/orthoxylene.

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Nomenclature

a_e	effective (interfacial) area (m^2/m^3)
a_p	specific geometric area (m^2/m^3)
c_G	packing capacity factor (m/s)
dp/dz	pressure drop per unit bed height (mbar/m)
F_G	*F-factor*, the vapour load (m/s(kg/m^3)$^{0.5}$ or Pa$^{0.5}$)
HETP	height equivalent to a theoretical plate (m)
u_G	superficial vapour velocity (m/s)
u_{Ls}	specific liquid load (m^3/m^2 h)
ρ_G	vapour density (kg/m^3)
ρ_L	liquid density (kg/m^3)

question was raised whether B1-350MN will behave similarly in this respect.

As it will be shown later, the Delft model, which accounts for corrugation geometry features (short smooth bend at the bottom of corrugations and a corrugation inclination angle below 45°) of B1-MN series packings, appeared to be capable of reproducing observed trends and approaching measured efficiencies and pressure drop from the safe side.

2. Experimental

Total reflux distillation tests with Montz-Pak B1-350MN have been conducted in 2012 using facilities available at Fractionation Research Inc. (FRI) in Stillwater, OK, USA. Detailed description of experimental set-up and procedure can be found in a paper describing similar tests carried out in 2011 with Montz-Pak B1-250MN (Olujić et al., 2013). A difference was that in addition to tests performed with cyclohexane/*n*-heptane (C6/C7) system at 0.31 and 1.62 bar, and paraxylene/orthoxylene (px/ox) at 0.1 bar also a test has been performed with the latter at 1 bar.

The specific geometric area of the B1-350MN packing is around 350 m^2/m^3. Approximately 10% of surface area is void, i.e. occupied by a regular pattern of holes. Fig. 1 shows a photograph of a side segment of B1-350MN packing on a layer assembled of four segments of this packing, illustrating the build-up of a packed bed with subsequent layers rotated to each other by 90°. To avoid achieving too high purities of

Fig. 1 – Layout of a layer of B1-350MN with a segment indicating corrugated sheet design. (Courtesy of Dr. S. Chambers of FRI).

Fig. 2 – High turndown narrow trough Type-R Montz liquid distributor.
(Courtesy of Dr. S. Chambers of FRI)

overheads the total bed height was limited to 2.6 m, while in the case of B1-250MN it was 3 m.

Fig. 2 shows a photograph of the high turndown, narrow trough Type-R Montz liquid distributor (143 pour or drip points per m^2 cross sectional area) with integrated predistributor, used in this as well as in a previous test with Montz-Pak B1-250MN (Olujić et al., 2013). A difference with respect to earlier tests was that condensers of high- and low-pressure installations were coupled in parallel (a necessary arrangement during a preceding summer time test). This resulted in excessive subcooling of reflux in case of tests with px/ox at 1 bar, which however has not influenced temperature profile of the packed bed, i.e. the results of the tests.

Final results of a total reflux distillation test are measured packing efficiency, i.e. the number of equilibrium stages or theoretical plates per unit bed height or depth, which is in the present study expressed as the height equivalent to a theoretical plate, HETP (m), and the pressure drop per unit height, dp/dz (mbar/m), both shown here as a function of the vapour load (*F-factor*).

One should note that FRI in their reports and publications usually expresses HETP and dp/dz as a function of the vapour capacity factor, c_G (m/s), which is related to *F-factor* via following relation: $c_G = F_G/(\rho_L - \rho_G)^{0.5}$, where $F_G = u_G \rho_G^{0.5}$ (m/s(kg/m^3)$^{0.5}$ = Pa$^{0.5}$) is *F-factor* or the vapour load, u_G (m/s) is superficial vapour velocity, and ρ_L (kg/m^3) and ρ_G (kg/m^3) are liquid and vapour densities. One should keep in mind that in a total reflux distillation test the liquid load increases proportionally to the vapour load. Unlike all other properties and parameters, which are based on an average of top and bottom of the bed values, the *F-factor* corresponds to the bottom of the bed conditions. All data were taken twice at a time interval, and the *F-factor*, HETP and dp/dz values shown in this paper are arithmetic averages of two, mainly nearly identical values (except at vapour loads close to the flooding point).

3. Results and discussion

3.1. *Experimental evidence*

Measured efficiencies and pressure drops for px/ox system, at 0.1 and 1 bar, and C6/C7 system, at 0.31 and 1.62 bar, are