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Distillation studies in rotating packed bed with split packing

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ABSTRACT

Rotating packed bed (RPB) with split packing has been developed recently to overcome the limitation of negligible tangential slip velocity between vapor and packing obtained with single rotating packing element of conventional RPB design. This work evaluates the performance of this contactor for separation of binary mixture methanol–ethanol by distillation. Experiments were carried out at total reflux condition. The height equivalent of a theoretical plate (HETP) of 2.9 cm was obtained at F-factor = 0.6 (m/s) (kg/m^3)$^{0.5}$ and rotor speed of 1100 rpm. Comparison with distillation studies reported for this system in the literature indicated that the mass transfer performance of this rotor design was superior to that of conventional RPB. Analysis of the experimental data also suggested that the rotor speed influenced the overall volumetric mass transfer coefficient to a greater degree in this design.

Keywords: Rotating packed bed; Wire mesh; Split packing; Distillation; Methanol/ethanol

1. Introduction

Distillation operation constitutes one of the most important separation processes in chemical process industries. The conventional distillation column is a vertical vessel wherein liquid flow down under gravitational force countercurrent to the flow of vapor. The flow and the mass transfer rates in the distillation column are thus dictated by gravity. A rotating packed bed (RPB) provides a means for generating centrifugal force hundreds of times the earth's gravity. This contactor consists of a doughnut shaped rotating packed bed. Liquid introduced at the inner periphery of the bed is thrown outward under centrifugal acceleration. The gas introduced at the outer periphery flows inward countercurrent to the liquid due to an imposed pressure gradient. Reduced tendency to flood, and higher volumetric mass transfer coefficients under centrifugal acceleration decreases equipment size and improves separation efficiency compared to conventional packed column.

Investigators have studied the performance of rotating packed beds for distillation process with various binary mixtures. Kelleher and Fair (1996) carried out separation of cyclohexane/n-heptane with metal sponge packing of specific surface area 2500 m^2/m^3. The maximum number of transfer units that could be achieved in a bed depth of 21 cm was 6. Lin et al. (2002) obtained 1–3 theoretical plates for methanol–ethanol system with wire mesh packing. They also noted that packing with less axial length gave better mass transfer performance. Nascimento et al. (2009) determined that for n-hexane/n-heptane system the conventional distillation contactor volume could be reduced by nearly 5 times by application of centrifugal acceleration. In contrast to these studies at total reflux condition, Xiuping et al. (2008) evaluated the mass transfer performance of a 2-bed RPB system representing the rectifying and stripping section. The number of transfer units was approximately 2.0–5.0 for alcohol/water system.

The above mentioned distillation studies were carried out in RPB with a single packing element. Sandilya et al. (2001) noted that volumetric vapor side mass transfer coefficient in these RPBs were not significantly higher compared to that in conventional packed bed due to negligible angular slip velocity between liquid flowing over a packing and vapor. Further their estimations showed severe liquid maldistribution in the rotor. Chandra et al. (2005) proposed a radically different design to promote the tangential slip velocity and increase vapor side mass transfer coefficient. The single packing element was split into annular rings with space between consecutive rings devoid of any packing. With metal foam packing (specific surface are = 2500 m^2/m^3), vapor side mass transfer coefficient as high as 307 1/s was obtained by Reddy et al. (2006) compared to a value of ~8 1/s (Kelleher & Fair, 2006; Sandilya et al., 2001)

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