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Liquid distribution and holdup in the random packed column

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ABSTRACT

In the present work, a third-generation gamma transmission tomography system was used to evaluate the liquid distributions of a Raschig rings random packed column, at two different water flows: 2 and 6 l/min. For each water flow, the measurements were carried out at nine column heights. The liquid-gas holdup was determined by the reconstructed images. The distribution of the Raschig rings, as well as the position and the average accumulated amount of the water concentration among the Raschig rings were capable to be determined, even at low temporal resolution of the system of 8.8 h. The regions of accumulated water concentration were similar for the water flow velocities at 2 and 6 l/min. The average accumulated water concentration for 6 l/min was higher compared to 2 l/min. The spatial resolution of the tomography system determined by the modulation transfer function (MTF) analysis was of 1.45 mm.

1. Introduction

Random packed distillation columns are used extensively in chemical and petrochemical industries to perform highly efficient process separation. With the recent advances in computational fluid dynamics, it is now possible to model the effects of heterogeneities in the bed on flow profiles and, hence, on the mass transfer efficiency [1–3]. Liquid flow distribution has been a major concern when scaling up random packed columns. The liquid distribution in random packed columns is not often uniform, even if the liquid is uniformly introduced into the column [4]. The knowledge on porosity variation (gas holdup) of random packed columns is useful for understanding the fluid dynamics [5,6]. The porosity variation in the random packed columns has long been recognized as a potential source of maldistribution and it has been studied extensively. Little information is available on modern high efficiency packings like stainless steel Raschig rings. Chu & Ng [7] and Mc Greavy et al. [8] showed that the porosity distribution has a significant effect on the liquid flow distribution within a packed column near the wall region. Non-uniform distribution of porosity results in liquid flow maldistribution and a reduced separation efficiency.

From the mid-80, the description of the first works using non-destructive methods, such as computed tomography and X-ray range, may be found in the literature. Niu et al. [9] used the X-ray computed tomography to analyze the radial porosity distribution in a bed of randomly packed uniform spheres and observed oscillations in the porosity distribution in the radial direction. Chaouki & Dudukovic [5] and Chen et al. [10,11], measured the porosity distribution in random packed beds with gamma ray computed tomography. Toye et al. [12] used the X-ray computed tomography to measure the porosity distribution and liquid holdup in complex packed beds widely used in distillation and absorption. All these results showed that, for the packings with complex geometrical shapes, the porosity distribution in packed beds was non-uniform and the radial variation did not show oscillatory patterns, such as those found for spheres.

Yin et al. [4] studied the liquid (water) holdup distribution in a large scale packed column filled with metal Pall rings, using non-invasive gamma ray tomography technique. It was found that the liquid holdup distribution was not uniform and that the liquid distributing design had a significant effect on the holdup distribution. Vasquez et al. [3] studied the porosity distribution in a column randomly packed with three different sizes of stainless steel Raschig rings with the gamma ray scanner at L/D = 2 plane, where L and D is the length and the diameter of the column. They demonstrated that the spatial porosity distribution in random packed columns is not uniform and, for the circumferentially averaged radial porosity distribution, the porosity in the column wall region tends to be higher than that in the bulk region, due to the effect of the column wall.

Schubert et al. [13] studied the solid patterns and the liquid distribution in a 300 mm diameter column packed with a metal Pall Rings. Both measurements were carried out using a tomography system comprising 320 lutetium-yttrium-orthosilicate (LSYO) detectors, each one of 2 mm × 8 mm active area and a collimated isotopic ^{137}Cs, with a 44° fan beam. The Pall Rings were arranged in three sections: (a) random packing, (b) horizontal layer and (c) in upright orientation. The

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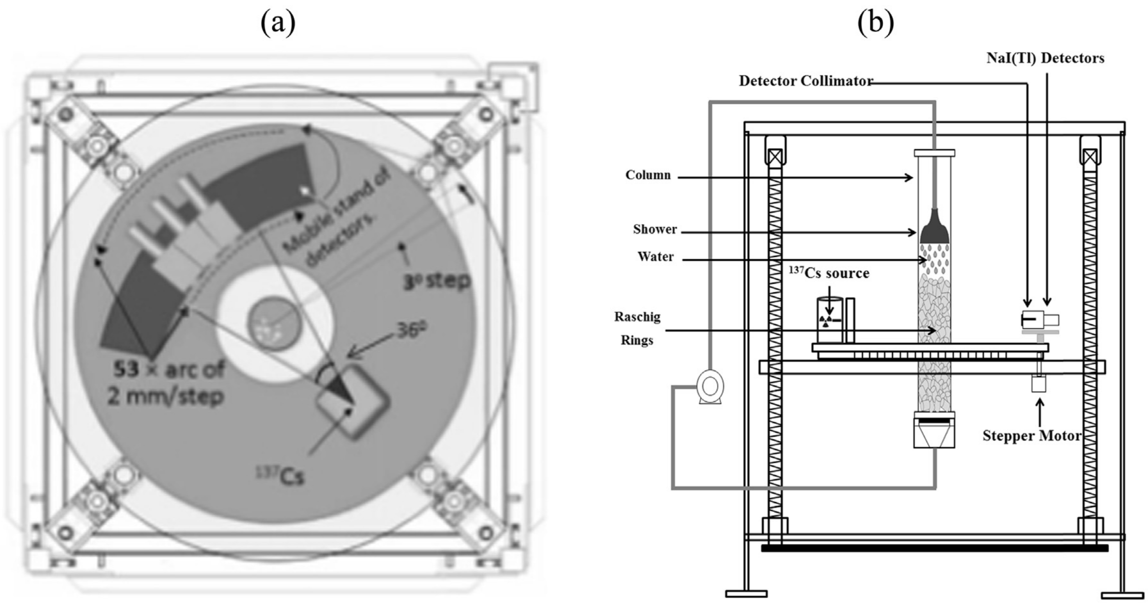

Fig. 1. Diagram of the third generation CT scanner used. (a) Top view and (b) side view.

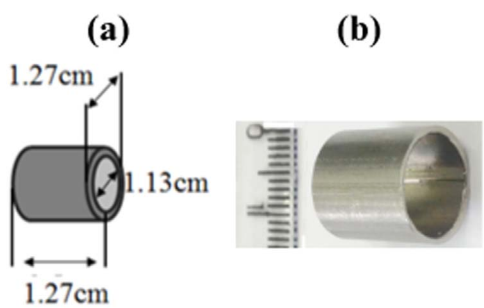

Fig. 2. Scheme (a) and picture (b) of the metal Raschig rings.

tomography measurements were performed only in a single layer. The differences in solid patterns, as well as the liquid distribution were clearly visualized with the tomography used. Loane et al. [14] showed experimentally that the gas superficial velocity does not influence the liquid hold up in an open-structure random packed column with counter current flow, contrary to what is observed for more conventional packings. The liquid hold up is determined only by liquid superficial velocity and a simple correlation is proposed.

In the present work, a third-generation gamma transmission tomography system was used to evaluate the gas and liquid distributions at two different water flows: 2 and 6 l/min in the random packed column filled with Raschig rings. For each water-flow, the measurements were

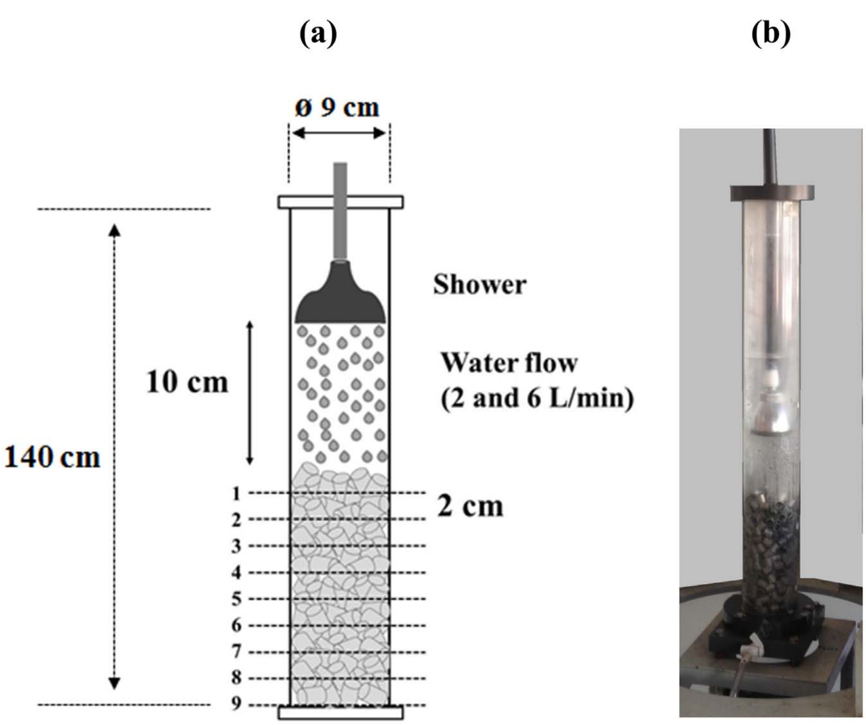

Fig. 3. Scheme (a) and picture (b) of the experimental random packed column.