

Liquid volume fraction and residence time distribution in an open-structure random packed column with counter current flow

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LIQUID VOLUME FRACTION AND RESIDENCE TIME DISTRIBUTION IN AN OPEN-STRUCTURE RANDOM PACKED COLUMN WITH COUNTER CURRENT FLOW

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Abstract:

Structured foam packing has been proven to enhance mass and heat transfer and decrease pressure drop due to the intrinsic open pore nature of a foam[1]. The high accessible surface area that this type of packing offers makes it easy for fluids to access the catalyst. Furthermore, the heat generated by, or needed for the reaction is efficiently redistributed into the main stream avoiding thus the formation of hot spots. Previous studies focus on a continuous large piece of foam of the same size order as the reactor dimensions. These large blocks of foam are difficult and labor intensive to incorporate in a column which gives space to a new type of foam packing, the open-structure random packing, OSRP. OSRP are essentially small pieces of foam with a specific shape and size and they are especially attractive as they can be easily dumped into a column, acting as a packed bed. The performance of the OSRP is largely determined by liquid volume fraction and residence time distribution, RTD. RTD experiments were conducted to determine the ideality of the liquid flowing alongside these particles. A pulse of saturated NaCl solution was used as tracer in the range of liquid superficial velocities of 0-2.7 cm/s and gas superficial velocities of 0-27 cm/s for trickle flow regime and its response was evaluated. The RTD results were interpreted with an interaction model that suggests the presence of dynamic and stagnant fluid with exchange within the column[2]. The dynamic fluid is a liquid volume fraction of the main stream that flows alongside the OSRP with the same superficial velocity while the stagnant fluid is a liquid volume fraction that flows inside the OSRP with a lower through flow. By means of the mean residence time, also acquired via the RTD measurements, and knowing the liquid flow rate, the total liquid volume fraction was quantified. The relative permeability model[1,3,4] is used to model and describe this liquid volume fraction. The results are then compared to previous work done in a continuous foam block[1]. One of the difficulties when working with OSRP is the irreproducibility of the packing. Once the column is emptied and re-stacked, the packing gains a new configuration which largely influences the results. The flooding point, liquid dispersion coefficient and liquid volume fractions were determined for 10 comparable restacked columns. A variation of 10% in packing height was observed which resulted in variations in liquid volume fraction and flooding points. The flooding point occurred on average at lower gas superficial velocities than observed for a continuous foam packing[1]. This is likely due to the higher hydrodynamic force on droplets at the bottom of the OSRP elements which do not form in a continuous foam block with liquid film flow. The liquid volume fraction is higher for the OSRP than in a continuous foam block due to the same effect: the OSRP fills up with liquid that is be easily drained.

Reference 1: C.P. Stemmet, j. Van der schaaf, b.F.M. Kuster, j.C. Schouten, solid foam packings for multiphase reactors: modelling of liquid holdup and mass transfer, chem. Eng. Research and design 84 (2006) 1134-

Reference 2 : F. Seguret, Y. Racault, M. Sardin, Hydrodynamic behavior of full scale trickling filters, Wat. Res. Vol. 34 No.5 (2000) 1551-1558

Reference 3 : A.E. Sáez, R.G. Carbonell , Hydrodynamic Parameters for Gas-liquid concurrent flow in Packed beds,AIChE journal Vol. 31 No.1 (1985) 52-62

Reference 4 : D.C. Dankworth, S. Sunsaesan, A macroscopic model for Countercurrent gas-liquid flow in packed columns, AIChE journal Vol. 35 No.8 (1989) 1282-1292

Highlight 1: OSRP are pieces of foam with a specific shape and size a column, acting as a packed bed.

Highlight 2: Structured foam packing has been proven to enhance mass and heat transfer

Highlight 3: The liquid volume fraction is higher for the OSRP than in a continuous foam block