To cite this version : Raynal, Ludovic and Fourati, Manel and Roig, Véronique *Comparison of modern packings : assessing proper choice for post-combustion carbon capture absorption columns.* In: 2nd Post Combustion Capture Conference (PCCC2), 17 September 2013 (Bergen, Norway). (Unpublished)

Comparison of modern packings : assessing proper choice for post-combustion carbon capture absorption columns

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Abstract : CO_2 capture from industrial flue gases is expected by IEA [1] to contribute to up to 19% of carbon mitigation by 2050. Absorption of CO2 into chemical solvents used in post-combustion capture processes is widely recognized as a reference path due to its high selectivity and CO_2 recovery rate [2]. However, absorption and solvent regeneration columns required for that purpose are of huge sizes and further induce high investments impacting avoided CO_2 cost. This impact is important enough so that it cannot be neglected when compared with operating unit costs [3]. We are presenting in this paper what is required in terms of packing characteristics, that is pressure drop, mass transfer performances and also liquid dispersion properties. This latter property, even if little discussed in the literature, is of great importance, since it will be used for determining the maximum height for packed beds as well as for column redistribution internals design. All these properties are presented for both random and structured packings and a discussion about packing choice is proposed, especially based mass transfer performances and on original dispersion results obtained for Mellapak and IMTP packings.

Keywords: CO_2 capture, gas-liquid flow, liquid dispersion, packing, absorption

1. Introduction

Considerable work is dedicated to new solvent screening for lowering the energy penalty of post-combustion capture processes. However, if not associated with adequate packing with optimum column design, one may not take advantage of the solvent performances and impact negatively the CO_2 capture cost. If, for a given packing choice, the column height is underestimated, one would have to compensate by an increase of liquid solvent reducing the optimum value in terms of loading which further turns into an increase in reboiler duty. On the contrary, if the column height is overestimated, one would first have to deal with extra investment and also with extra pressure drop. It is thus of high importance to adapt packing choice and column design to the solvent used. In the following, MEA 30wt.% is considered as a reference case, but the discussion and methodology could apply to any new solvent.

2. Packings performances characteristics

The main characteristics required for packing full modelization in process simulations softwares used for column design are, 1. the packing capacity curve that further gives the column diameter, 2. the pressure drop and the liquid

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holdup, 3. the mass transfer characteristics, which are the gas and liquid side mass parameters and the effective area, 4. the liquid dispersion characteristics. Characteristics 1 and 2 ensure proper hydrodynamics in the column; they are usually given by packing vendors. Characteristics 4 can usually be found in the literature (e.g. [4], [5]), even if not always complete enough for taking into account temperature or loading effects on physical properties. In most cases, all those characteristics are determined from well controlled experiments using high drip points density liquid distributors and small bed height which ensures homogeneous plug flow. From experience in the oil and gas industry, one knows that liquid distribution is not perfect and that it evolves along the packed bed; bed height must thus be limited. Since, for industrial designs, the packed bed height of post-combustion absorbers may be as high as 30 m, liquid dispersion properties should be considered as a supplementary characteristic when choosing the most appropriate design.

3. Liquid dispersion

Liquid dispersion has been studied with an original experimental set-up considering spreading from a point-source injection, this enables the determination of dispersion coefficient in packed bed (see [6],[7]). This work has been performed for two modern third generation packings : Mellapak 250.X Sulzer's structured packing and IMTP-40 Koch-Glitsch's random packing (See pictures r.h.s in Figure 1).

3.1. Experimental methodology

In the experiments, liquid was fed from a distributor with a central injection resulting in a jet-like liquid inlet. This injection has allowed observing liquid spreading along the packed bed via gamma ray-tomography in a 400 mm internal diameter column. The latter system was used to acquire liquid hold-up maps at four given axial positions of the packed bed denoted Z_1, Z_2, Z_3 and Z_4. The experimental set-up as well as tomography technique are described in details in [8]. Air/water as well as Air/mono-ethanolamine 30wt.% in water were considered as fluid systems.

3.2. Experimental results

First, on observes for both packings local liquid hold-up disparities (Figure 1). This has already been highlighted in [6] for the structured packing, this is even stronger for the random packing. Second, two fundamental differences between the two tested packings can be pointed out. For structured packing, one observes strongly anisotropic liquid spreading in positions Z_1 and Z_2 due to the geometry of the packing. This disappears farther downstream; the distribution becoming more and more homogeneous at intermediate scale. On the contrary, relatively big-scale maldistributions can be highlighted in the case of IMTP-40 packing. Concretely, this consists in zones where liquid lacking is noticed (see position Z_4 in Figure 1).

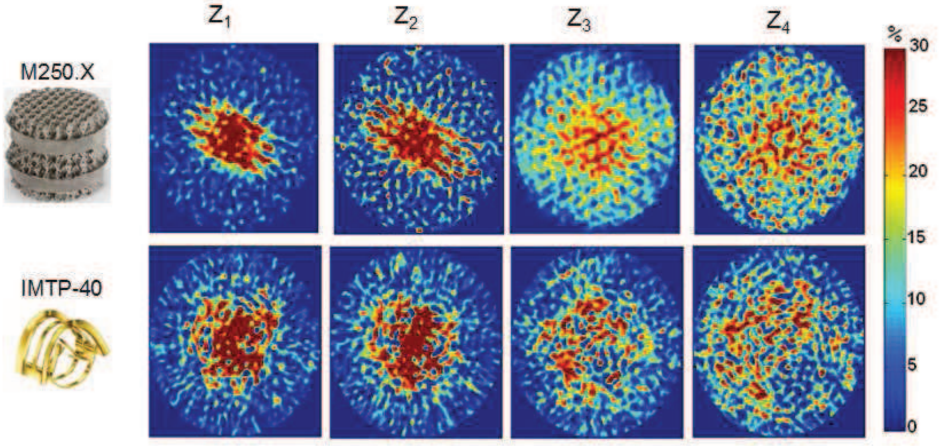

Figure 1: Liquid hold-up maps obtained from Gamma-ray tomography; $Z_{i=1,4}$ correspond to positions from top to bottom of the column.

Liquid maldistribution could be quantified using a "maldistribution indicator", I, defined on position Z_4 as a standard deviation from section-average liquid hold-up. The higher I is, the more the maldsitribution is severe. For the explored range of operational conditions, maldistribution indicator ranges from ~2 to ~6 for IMTP-40, while, for Mellapak 250.X, I ranges from ~2 to ~3 only. This shows the tendency of random packing IMTP-40 to develop relatively large-scale maldistribution.

Last, in order to further used liquid dispersion information in column design, liquid spreading is modelled via a simple transport model based on an advection-diffusion equation. This has been done for both packings, resulting in a dispersion coefficient determination. It is shown that dispersion coefficient is almost constant for structured packing whatever the fluid and the operating conditions. On the contrary, dispersion in random packing is both sensitive to gas and liquid flow rates which makes it more complex to model.

4. Mass transfer performances

From data found in literature on packing mass transfer characteristics ([5], [9]), an original work is performed to compare packings via an in-house simulator that enable the determination of the packed column diameter and height. It is shown that, contrary to what would be first done, that is, prefer high capacity packing, one would rather consider high efficient packings. Indeed, when using the latter, one comes up with larger diameter columns but also with columns of smaller height. This results first in smaller packed volumes which reduces investment, and second in pressure loss reduction which reduces operational costs.

5. Discussion on packing selection for post-combustion carbon capture

From all these, a discussion is proposed about packing selection methodology and propositions are made for further packing developments.

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