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# Assessment of mass transfer correlations for $CO_2$ absorption using different column packings

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***Highlights***

- Developments of dynamic mathematical model for industrial size $CO_2$ capture process.
- Mass transfer assessment of $CO_2$ absorption using different random and structured packings.

## 1. Introduction

In order to limit the climate change, it is now widely recognized that large-scale reductions in carbon dioxide emissions are required. Among the technologies proposed for carbon capture, post-combustion $CO_2$ capture with chemical solvents is currently considered the most viable option. The advantages of $CO_2$ capture with alkanolamine are: the ability to treat flue gas flows from power stations and its suitability for retrofitting existing power plants and other energy-intensive processes (e.g. metallurgy, cement, chemicals etc.). $CO_2$ capture from power plant flue gases using the amine-based process consists in two main packed columns, an absorber and striper. In the absorber, the $CO_2$ is captured from the flue gas by lean amine solvent, being counter-currently contacted. The rich solvent is then thermally regenerated in the striper; this heat duty being the main energy ancillary consumption of the power plant equipped with post-combustion $CO_2$ capture.

Dynamic flexible operation of $CO_2$ capture plant as well as integration of capture unit within the main energy conversion process are fundamental important issues to successfully implement the design at industrial scale. Developed of detailed modeling and optimization of a post-combustion capture process remain a complex task. Determinant parts of the gas-liquid absorption model are the effective interfacial area, the mass transfer coefficient, pressure drop and liquid hold-up models. In this work, a complex dynamic model was utilized for assessing the effect of correlations for mass transfer coefficients and effective interfacial area on the performance of $CO_2$ absorption process for different random and structured packings.

## 2. Methods

The mathematical model of carbon dioxide gas-liquid absorption includes differential partial equations, e.g. mass and heat transfer models to study the coupled effect of temperature and concentration on the absorption rate, reaction kinetics, vapor-liquid equilibrium, hydrodynamic aspects, etc. Determinant parts of the absorption model are the effective interfacial area, the mass transfer coefficient, pressure drop and liquid hold-up models [1]. Using discretization numerical method, the partial differential equations of model were transformed in ordinary ones and the mathematical model has been implemented in Matlab/Simulink.

## 3. Results and discussion

A number of design correlations for prediction of hydrodynamics and mass transfer efficiency have been published in the literature for absorbers packed with random or structured packings. Selecting the best correlations for the $CO_2$ capture process is the scope of this work. The mass transfer correlations developed by Billet & Schultes, 1999; Rocha et al., 1996; Brunazzi et al., 1995; Xu et al., 2002; Hanley and Chen, 2002 was implemented in Matlab [2]. The experimental results published in literature [3] (packing type: Sulzer DX; absorber diameter 0.02 m, packed height 2 m) are used to find the best fit mass transfer correlation method and to validate the developed model. The simulation results show that the model proposed by Billet and Schultes and Rocha et al. predicts well in case of MEA (see Figure 1). The results show that there is not significant difference between the results provided by these pressure drop models. Other important study is the influence of specific surface area on $CO_2$ mass transfer, 3 different column packing: Rasching rings

(specific area 90 $m^2/m^3$), Mellapack 250Y (250 $m^2/m^3$) and Sultzer DX (492 $m^2/m^3$) was considered. The increase in transfer coefficient values ($k_g$ and $k_l$) was observed with the increase of the specific surface area of the column packing, the lowest values being observed for the random packing.

Using the best fitting model for mass transfer and effective interfacial area (Billet and Schultes correlations), the developed model was scale-up to 7 m and 17 m column and validated against experimental data [4]. The two considered control approaches have been investigated in the presence of typical disturbances, such as the step change of the inlet flue gas flow rate, having an increase of 10% with respect to its nominal operating point. The manipulated variable was the liquid flow. The results revealed that the PI and MPC controllers were capable to maintain the concentration of the $CO_2$ gaseous mixture close to the desired set point.

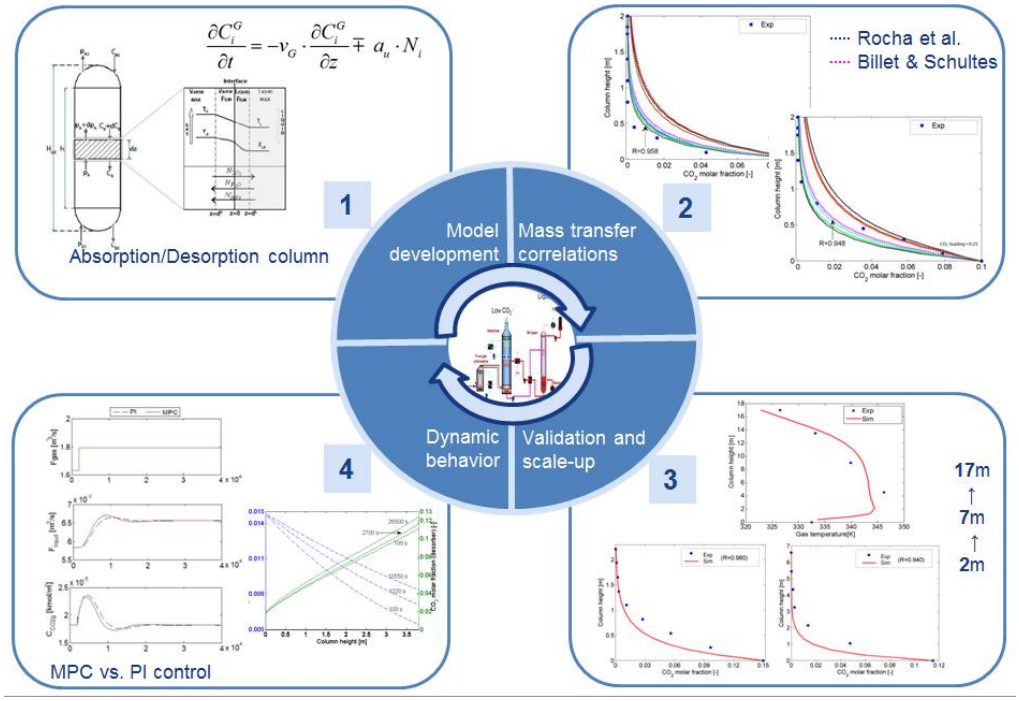


**Figure 1.** Problem approaches for $CO_2$ capture process.

## 4. Conclusions

The complex mathematical model for $CO_2$ - MEA system has been tested and validated again experimental data. The simulation results show that the effective mass transfer area, the mass transfer coefficients are the main aspects that influence the mass transfer rate in packed column. The best fitted model depends on the column operating condition for the carbon dioxide absorption process in MEA, (the best fit model is Billet and Billet & Schultes in case of $CO_2$ loading 0.25, and Rocha et al. in case of $CO_2$ loading 0). Following the simulation of the process, the increase in transfer coefficient values was observed with the increase of the specific surface of the column packing, the lowest values being observed for the random packings. The developed dynamic model of $CO_2$ capture by gas-liquid absorption was then integrated in various high $CO_2$ emissions and energy-intensive industrial applications (e.g. heat & power, cement, metallurgy etc.).

## References

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***Keywords***
"$CO_2$ absorption using alkanolamine", "Mass transfer correlations", "Rate-based modeling", "Integration of $CO_2$ capture in energy-intensive industrial applications".