MODELING POST-COMBUSTION CO_2 CAPTURE WITH AMINE SOLVENTS

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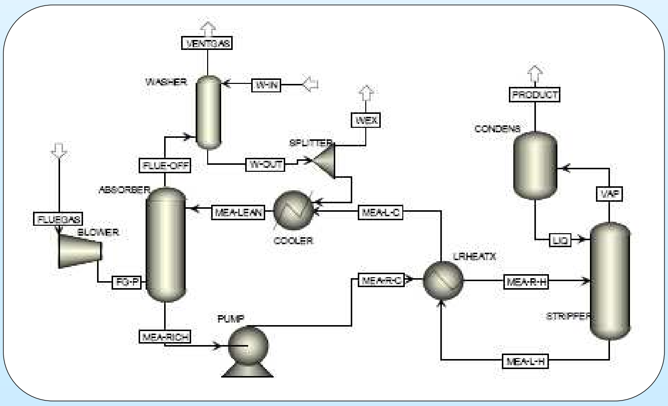
Abstract

Post-combustion carbon capture with amine solvents is currently one of the most promising technologies to prevent large quantities of CO_2 from being emitted into the atmosphere and so to limit the influence of anthropogenic activity on climate change. Two models (equilibrium and kinetics) have been built using the Aspen Plus software in order to optimize the CO_2 capture process in monoethanolamine (MEA). A sensitivity study at constant CO_2 capture rate has shown that the solvent concentration, its flow rate and its regeneration pressure have the largest influence on the process energy requirement. To decrease the energy cost of the process, different modifications of the process flowsheet have been simulated such as the lean vapor compression, an absorber inter-cooling and the split-flow configuration. Tests on a real pilot will be made in the future to validate this model.

Model description

Two approaches have been considered for modeling CO_2 capture with amine solvents. In the equilibrium model, calculations are made using the assumption of a thermo-dynamical equilibrium state on each theoretical plate of the mass transfer columns. This assumption neglects the effects of kinetics and mass transfer limitations inside the columns. In the rate-based model, those limitations are considered. So, the geometry and hydrodynamics of the columns are very important.

The flue gas rate reaches 2500Nm³/h with a 12 vol-% CO_2 content. The capture rate has been set at 90%. The amine solvent is a 30 wt-% aqueous solution of monoethanolamine. Thermodynamic and kinetics properties have been retrieved from the literature (Abu Zhara, 2009). Geometrical data for the rate-based model are data of an existing pilot plant located at Esbjerg in Denmark (Knudsen et al., 2009).



Process optimisation

Sensitivity study of different process parameters has been performed so that three parameters have been identified as having the largest influence on the process efficiency: solvent mass flow, solvent concentration, and regeneration pressure. Results are slightly different between the two models, as shown in the following table:

	Stripper pressure	Solvent concentration	Solvent flow rate
Equilibrium model			
Basecase value	1.2 bar	30 wt-%	15 m³/h
Optimum value	2.2 bar	37 wt-%	12.8 m³/h
Regeneration energy	-11.6%	-8.2%	-1.6%
Rate-based model			
Basecase value	1.2 bar	30 wt-%	15 m³/h
Optimum value	2.2 bar	37 wt-%	12.4 m³/h
Regeneration energy	-16.9%	-5.4%	-2.8%

Process modifications

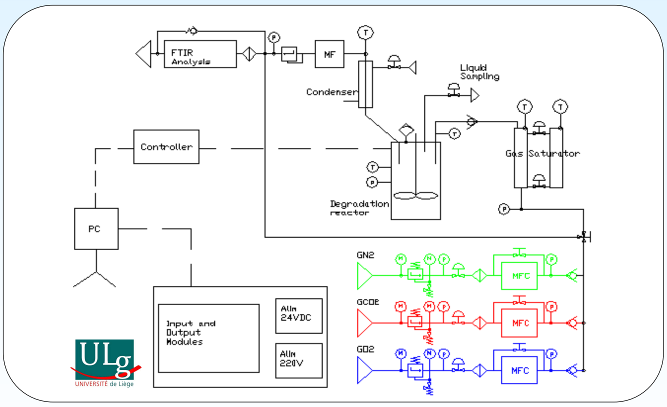
Process modifications would require additional equipment but they can lead to significant reduction of the process energy requirement. Three modifications have been tested: lean vapor compression (LVC), intercooling of an absorber stage and split-flow configuration. Those modifications have been implemented in the rate-based model which is more accurate for describing column internals since it considers kinetics and mass transfer limitations.

The most interesting modification is the LVC, which is a flash evaporation of the regenerated solvent. The vapor is compressed and fed back to the regeneration column, decreasing the process exergy requirement by about 17%. In the case of an intercooling in the absorber as well as for the split-flow configuration, the gain in term of process efficiency reaches approximately 4%.

Perspectives

Simulation work is of first importance for development of post-combustion capture with amine solvents. However, the corrosivity and degradation of the solvent have not been taken into account in this work. Since solvent make-up costs due to solvent degradation represent up to 35% of the capture direct operation costs, i.e. 4,78 million Euro per year in the case of a 600MWe bitumous coal-fired power plant (Abu Zahra, 2009), a test bench for the study of solvent degradation has been built and experimental degradation studies are being carried out at the University of Liège.

Combining experimental results and simulation work, a multi-objective optimisation of the CO_2 capture process will be performed, taking into account possible environmental impacts of the amine solvent degradation and its financial impact on the capture costs. The scheme of the experimental installation for degradation studies is presented on the right.



References

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