Optimizing pressure drop for the advanced flash stripper

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Abstract

Carbon capture using amine scrubbing requires 20-30% of energy produced to remove 90% of CO₂ emissions, a major obstacle in large-scale implementation. The majority of the energy required is based on two sources: steam required for reboiler heating and compressor work to increase purified CO₂ pressure to 150 bar for storage. Alternative stripper configurations offer promising opportunities to reduce energy costs by recovering lost heat both in the stripper outlet streams and the stripper column itself (Van Wagener 2011). The advanced flash stripper configuration (AFS) shown in Figure 1 reduces reboiler heat duty by 16% compared to simple stripper configurations using 5 m piperazine (Lin 2016). A key part of optimizing AFS energy performance is controlling pressure drop within the heat exchangers and steam heater. The AFS relies upon flashing in the hot exchanger. Flashing is reduced by increased pressure drop. Increased pressure drop across heat exchangers increases the required discharge pressure of the rich solvent pump, increasing the equivalent work required for separation. However, a greater heat transfer coefficient can be achieved with a greater exchanger pressure drop due to increased fluid velocity.

Simulating pressure drop within AFS configurations allowed for accurate measurement of rich solvent vaporization within the warm cross exchanger. Previous AFS simulations account for pressure drop through the cross exchangers, but have not measured the change in pressure within the exchangers to account for the changing bubble point temperature. By modelling the vapor fraction within heat exchangers, temperature pinches can be identified that reduce the overall heat transfer.

Figure 1: Process flow diagram of advanced flash stripper (Lin 2016)
Methods

Experimental process data will be collected from two pilot plant campaigns using the advanced flash stripper configuration with 5 m PZ. The first campaign was completed using synthetic flue gas at the Separations Research Program (SRP) at the University of Texas at Austin in April 2017. The second campaign using coal plant flue gas will be completed at the NCCC plant in Wilsonville, Alabama in Spring 2018. The pressure drop was measured across each cross exchanger and correlated with solvent flow rate, reboiler heat duty, and exchanger heat loss.

Tests completed at both pilot plants will be further modelled using Aspen Plus with the Independence model for piperazine (Frailie 2014). The models were first simulated using previously established correlations for pressure drop across exchangers (Lin 2016), then will be updated with new experimental data from the pilot plants. Using the updated data, the exchanger pressure drops will be optimized to maximize heat transfer while reducing reboiler heat duty and rich solvent pump work.

Preliminary Results

The SRP pilot plant campaign has completed. Figure 2 shows a strong correlation found between pressure drop and heat transfer coefficients for both cross exchangers. While the cold cross exchanger data closely fits a quadratic curve, the warm exchanger data does not neatly regress to a single curve. While in the cold exchanger the rich solvent exits at the bubble point temperature (Lin 2014), the rich solvent in the warm exchanger partially vaporizes, changing the heat transfer coefficient. The vapor fraction of the hot rich stream varies between cases, causing significant variations in heat transfer.

Further analysis of this data will model the AFS to determine the exact locations and temperature approaches within the heat exchangers. Additional correlations will be derived to account for flashing and temperature pinches and their effect on overall heat duty requirements. Once these are complete, the pressure drop will be optimized to minimize total energy costs.

Figure 2: Increased cross exchanger pressure drop increases heat transfer coefficient

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