Experimental studies on CO$_2$ desorption from amine solutions

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Motivation

• Desorption energy consumption
  • Responsible for most of the energy demand for CO₂ capture
  • High energy penalty (~13% points) for the power plant
  • Determines cost of capture process

• Stripper operation not so well-known as for absorber
  • Studies usually concentrate on absorber performance
  • Lack of experimental data
  • Needed better understanding of desorption-related phenomena
Desorber

- Energy required for regeneration:
  - Heat of reaction
  - Sensible heat
  - Heat of water vaporization

\[ Q_{\text{regeneration}} = Q_{\text{des}} + Q_{\text{sens}} + Q_{\text{strip}} \]

\[ Q_{\text{des}} = -n_{\text{CO}_2}\Delta H_{\text{strip}} \]

\[ Q_{\text{sens}} = L_{\text{in}}c_p(T_{\text{bottom}} - T_{\text{top}}) \]

\[ Q_{\text{strip}} = m_v\Delta H_{\text{vap}} \]
Experimental approach

- Understanding of desorber performance
- Parameter study on reboiler energy duty – regeneration rate
  - Effect of solvent flow rate
  - Effect of solvent inlet temperature and reboiler heating temperature
  - Effect of amine concentration
  - Effect of amine type
Experimental setup

- $L_{\text{in}} = 10 - 40 \text{ g/min}$
- $T_{\text{in}} = 80 - 90^\circ\text{C}$
- $T_{\text{reb-heating}} = 120 - 130^\circ\text{C}$
- $P = \text{atm}$
- Amine solvent:
  - MEA: 20 - 30 wt.\%
  - DEA: 34.4 wt.\%
- Rich loading:
  - $0.5 \text{ mol}_{\text{CO}_2}/\text{mol}_{\text{Amine}}$
- $T_{\text{condenser}} = 25^\circ\text{C}$
Effect of solvent flow rate

Experimental conditions: MEA 20wt%; $T_{reb} = 120^\circ C$; $T_{in} = 80^\circ C$

- Low solvent flow rate: stripping steam rate production dominant energy sink $\rightarrow$ solvent highly regenerated
- Optimum: higher lean loading reduces regeneration energy, higher amount of CO$_2$ released $\rightarrow$ lower specific reboiler duty
- High solvent flow rate: sensible heat becomes more important
Desorber temperature profile

- Lower solvent flow rate: higher temperatures $\rightarrow$ little steam condensation in the column
- Higher solvent flow rate: higher amount of vapour needed to heat up the solution $+\,$ desorption occurs in the column to a larger extent $\rightarrow$ higher condensation rate in the column $\rightarrow$ lower temperatures
Effect of reboiler and solvent inlet temperature

Experimental conditions: MEA 20wt%; L = 23 g/min

- Higher reboiler temperature: T-profile becomes straighter \( \rightarrow \) reboiler efficiency increases
- Higher inlet temperature: T-profiles do not differ much, some desorption occurs prior to the stripper
Higher reboiler temperature increases vapour rate $\rightarrow$ higher desorption rate with a lower lean loading

Higher inlet temperature: stripping prior to desorber lowers average loading in the column $\rightarrow$ higher vapour rate needed for regeneration offsets reduced sensible heat
Effect of amine concentration

Experimental conditions: MEA; $T_{\text{reb}} = 120^\circ\text{C}; T_{\text{in}} = 80^\circ\text{C}$

- 30wt.% MEA achieves a higher lean loading: lower cyclic capacity $\rightarrow$ less energy required for regeneration
- Higher concentration: higher CO$_2$ uptake per unit of solvent rate $\rightarrow$ higher amount of CO$_2$ to be released
Effect of amine type

Experimental conditions: MEA 20wt%; DEA 34.4 wt.%; $T_{reb} = 120^\circ$C; $T_{in} = 80^\circ$C

- DEA: greater regeneration rate for a given circulation rate due to lower reaction energy
- MEA requires higher vapour rates for stripping to establish driving force
- With DEA desorber could be operated with a lower energy input
Summary

• An optimal solvent flow rate can be found which achieves minimum specific reboiler energy duty and optimal solvent lean loading
• Each amine type and concentration has a different optimum solvent flow rate
• Optimal solvent flow rate range depends on amine type and concentration

• Experimental desorption data are essential for an effective design and operation of CO₂ capture units
• Aim: develop a strategy to estimate reboiler heat duties for solvent regeneration
Thank you for your attention!

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