Experimental exploration of carbon capture by frosting on a moving bed

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1. Introduction
- Cryogenic carbon capture is typically a post-combustion process that captures carbon dioxide by cooling flue gases below the sublimation temperature of carbon dioxide to form a frost.
- Cryogenic carbon capture has advantages over chemical absorption due being able to operate at near atmospheric pressure and being effective at separation of gas streams with relatively low CO₂ concentrations.
- Literature review states that freezing of carbon dioxide in a packed bed is feasible. A current methods of cryogenic capture lead to an accumulation of frost in the heat exchanger, the process loses efficiency as it continues to run.
- This method of carbon capture can be used effectively in scenarios where chemical absorption cannot be effectively scaled down.

2. Background
- This proposed method of carbon capture is a post combustion process that utilizes a moving bed of particles.
- Moving the bed in a counter-flow will result in the frost front remaining stationary, avoiding the scenario of the capture column being saturated with frost.
- The cold beads are fed into the capture column to allow carbon dioxide to form frost on the bed. Frosted bed leaving the column is warmed to separate the carbon dioxide, re-cooled and recirculated into the capture column.
- Recirculating the bed material instead of freeze-thaw cycling the heat exchangers results in more efficient heat transfer and less thermal related stresses on the equipment.
- Lack of supporting research means that the implementation of a moving bed into carbon capture requires preliminary experiments.

3. Aims and Objectives
- Demonstrate the working principle of heat exchange in a moving bed with a purpose build rig.
- Develop a rig that will desublimate a gas stream containing water vapour to investigate the effect of desublimation on the rig.
- Design and characterise a pilot scale cryogenic rig that will capture CO₂ from a binary gas stream of CO₂ and nitrogen for evaluation of the process.

4. Current challenges in design

Energy considerations

The energy requirement to re-cool a fixed packed bed is given as thus

\[ Q = V(1 - \varepsilon_p)\frac{\sum p_{T_f} C_p dT}{\phi_{in} - \phi_{out}} \]

(Tuinier, Annaland et al. 2010)

The energy requirement to re-cool a section of moving packed bed is not dependent on time.

\[ Q = m \frac{\sum p_{T_f} C_p dT}{\phi_{in} - \phi_{out}} \]

5. Current work
Research currently indicates that a cryogenic carbon capture process utilizing a moving bed is feasible however there is little supporting research to create a reliable design. Current work includes designing of the 1st generation rig. Sizing the equipment, selecting materials for use and obtaining quotes for specialist equipment.

References

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