Dual-Piston Pressure Swing Adsorption Apparatus

Daniel Friedrich, Wenli Dang, Maria-Chiara Ferrari, Stefano Brandani
Institute for Materials and Processes, School of Engineering
The University of Edinburgh
d.friedrich@ed.ac.uk

DP-PSA apparatus and aim of experiments

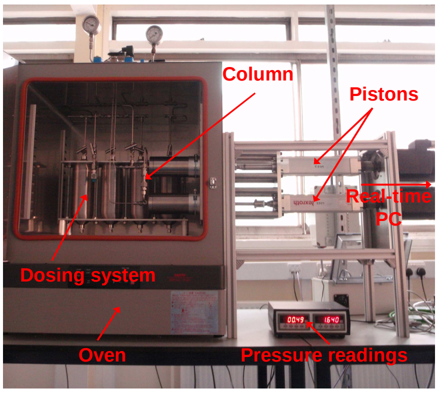

Figure 1: Picture of DP-PSA apparatus

Aim: Testing of novel materials for the separation of CO_2 from flue gas

Process: The adsorbent material preferentially adsorbs CO_2 under high pressure and releases it under low pressure

Benefits of DP-PSA:

- Direct test for the separation performance, Fig. 2
- Only small amount of adsorbent required
- Rapid testing of adsorbent materials
- Model system for large-scale, industrial process
- Many experiments with different conditions can be performed automatically in a short timeframe

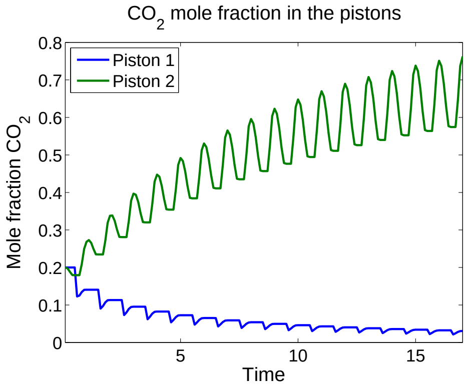

Figure 2: Separation of CO_2 from uniform starting concentration

Schematic of the DP-PSA apparatus and device operation

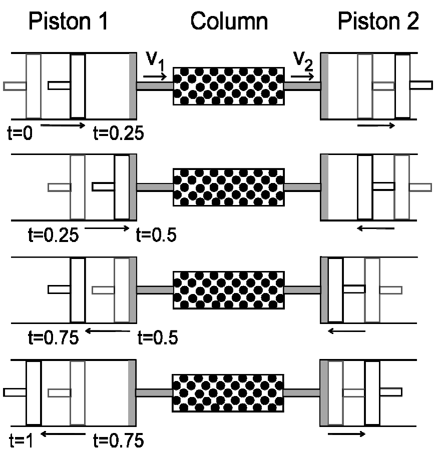

Figure 3: One cycle of the DP-PSA system

Device operation:

- Continuous, cyclic operation of the pistons: cyclic pressure and flow velocity profile, Fig. 4
- Strongly adsorbing component (CO_2) collects in piston 2, weakly adsorbing component collects in piston 1, Fig. 2 and Fig. 6

Variable operation conditions:

- Different piston configurations: stroke lengths, phase angle and cycle shapes
- Fast cycle times down to 1 Hz: potential for increased productivity
- Different starting pressure: 0.1 bar to 20 bar
- Thermal control: 20° C to 200° C

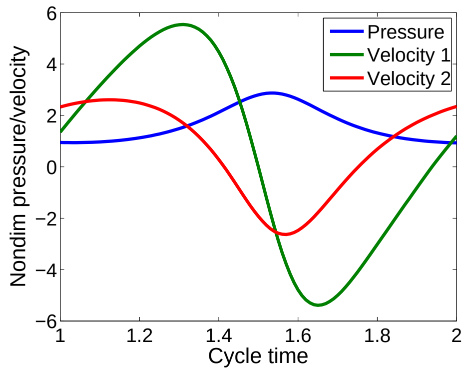

Figure 4: Pressure and flow velocity profile for one cycle of the DP-PSA system

Modelling and numerical simulation of the DP-PSA system

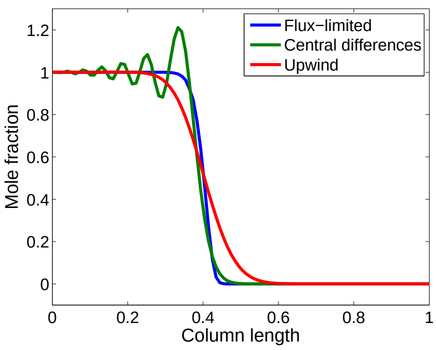

Figure 5: Comparison of different spatial discretisation schemes

Aim: Analyse the large amount of experimental data and estimated equilibrium and kinetic parameters

Challenges:

1) Closed system: requires a conservative method
2) Dynamic, nonlinear system with many parameters and variables: long computation times
3) Large Peclet number, i.e. ratio of convection to diffusion: sharp moving fronts, Fig. 5

Numerical implementation:

- Spatial discretisation: flux-limited finite volume method; conservative and shock tracking, Fig. 5
- Time discretisation with sophisticated ODE solver SUNDIALS

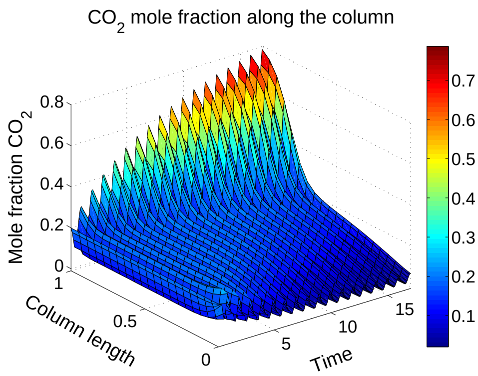

Figure 6: Dynamic simulation of the mixture separation in the DP-PSA system

Acknowledgements

We acknowledge the financial support from UOP, a Honeywell company, and the EPSRC for the Innovative Gas Separations for Carbon Capture, EP/G062129/1, grant.

Conclusion

- DP-PSA apparatus is uniquely suited to test novel materials for the efficient separation of CO_2 from flue gas
- Rapid testing of many process configurations
- Numerical simulations are used to analyse the experimental data