Characterisation of an automated Dual Piston Pressure Swing Adsorption (DP-PSA) system

Wenli Dang, Daniel Friedrich, Stefano Brandani

SCCS, School of Engineering, University of Edinburgh

W.Dang@ed.ac.uk, D.Friedrich@ed.ac.uk, S.Brandani@ed.ac.uk

http://www.eng.ed.ac.uk/carboncapture/

Overview of DP-PSA apparatus

Figure 1. DP-PSA system

Aim

To design an efficient CO_2 separation process for carbon capture and storage.

Challenge

To design experiments that allow testing materials and process configurations under fast cycle conditions.

Benefits of DP-PSA

- Rapid testing of adsorbent materials.
- Automatic control increases the reliability and throughput.
- Many different experiments are possible:
  - Cycle times from seconds to minutes
  - Different pressure ratios and profiles
  - Different oven temperatures

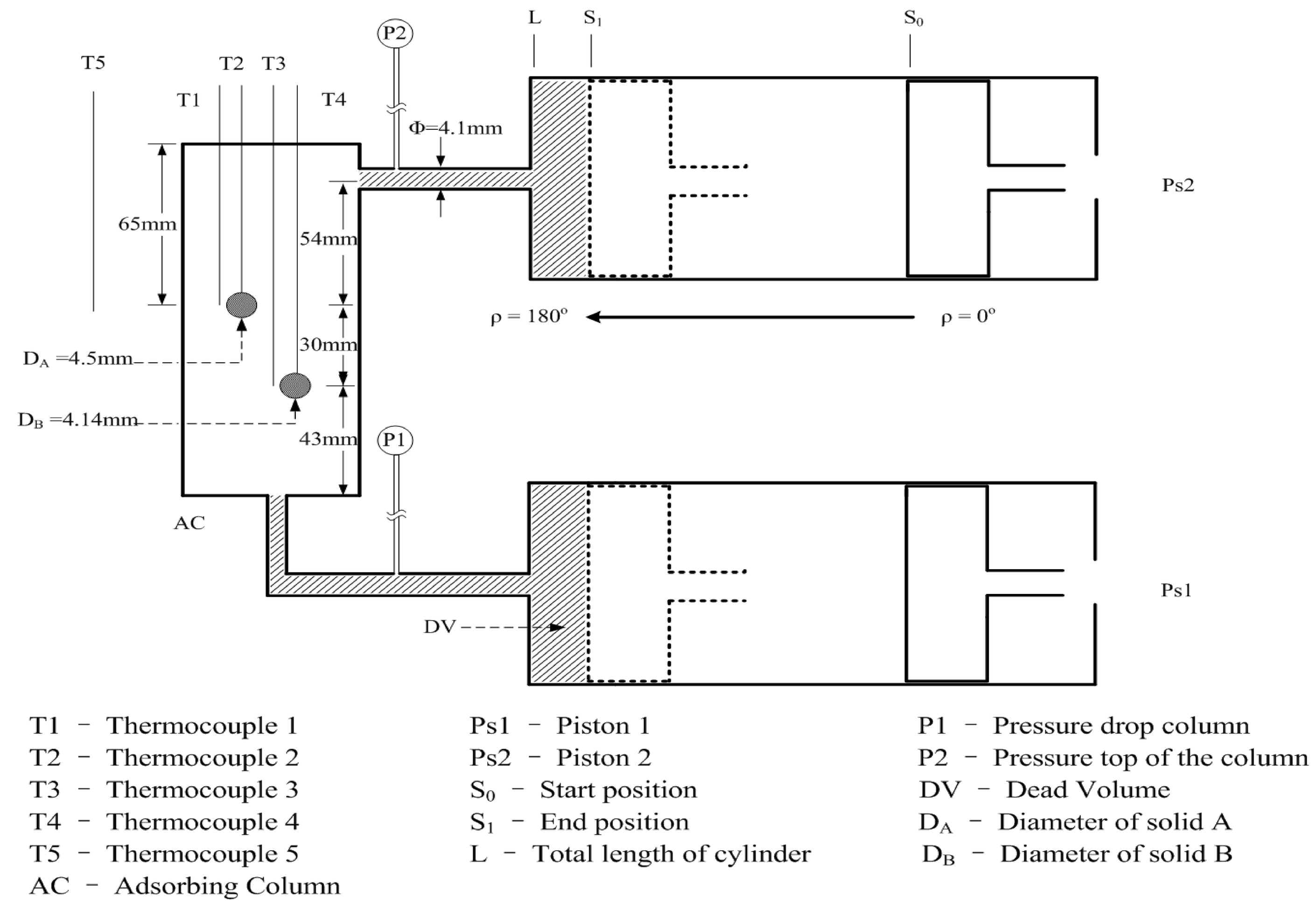

Figure 2. Schematic showing the DP-PSA system

Pressure and temperature profiles for non-adsorbing gases

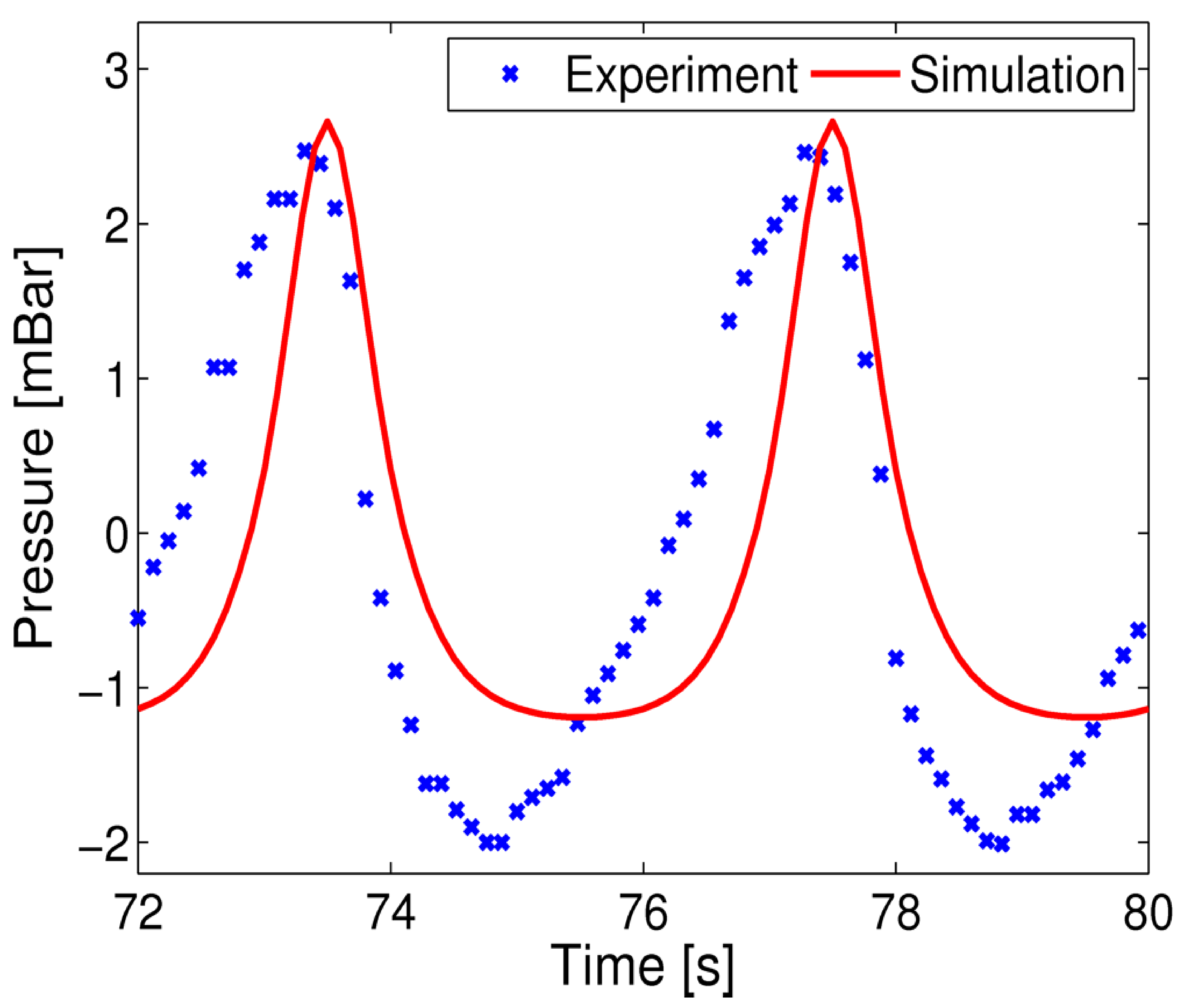

Figure 3. Pressure drop across the column for the Helium run with t_c=4s

- Experimental and simulated pressure profiles agree which confirms DP-PSA system parameters (dead volume, sizes,…).
- Qualitative shape of the pressure drop profile and the magnitude are well described by the Ergun equation.
- Runs with an offset between the two pistons generate a temperature gradient along the column: see Figure 4.
- Simulated temperature clearly confirms the temperature gradient along the column seen in the experimental data.
- The two pistons perform the compression and expansion phases of the cycle with different pressures and thus require different amounts of work, therefore, the temperature profiles are asymmetric.

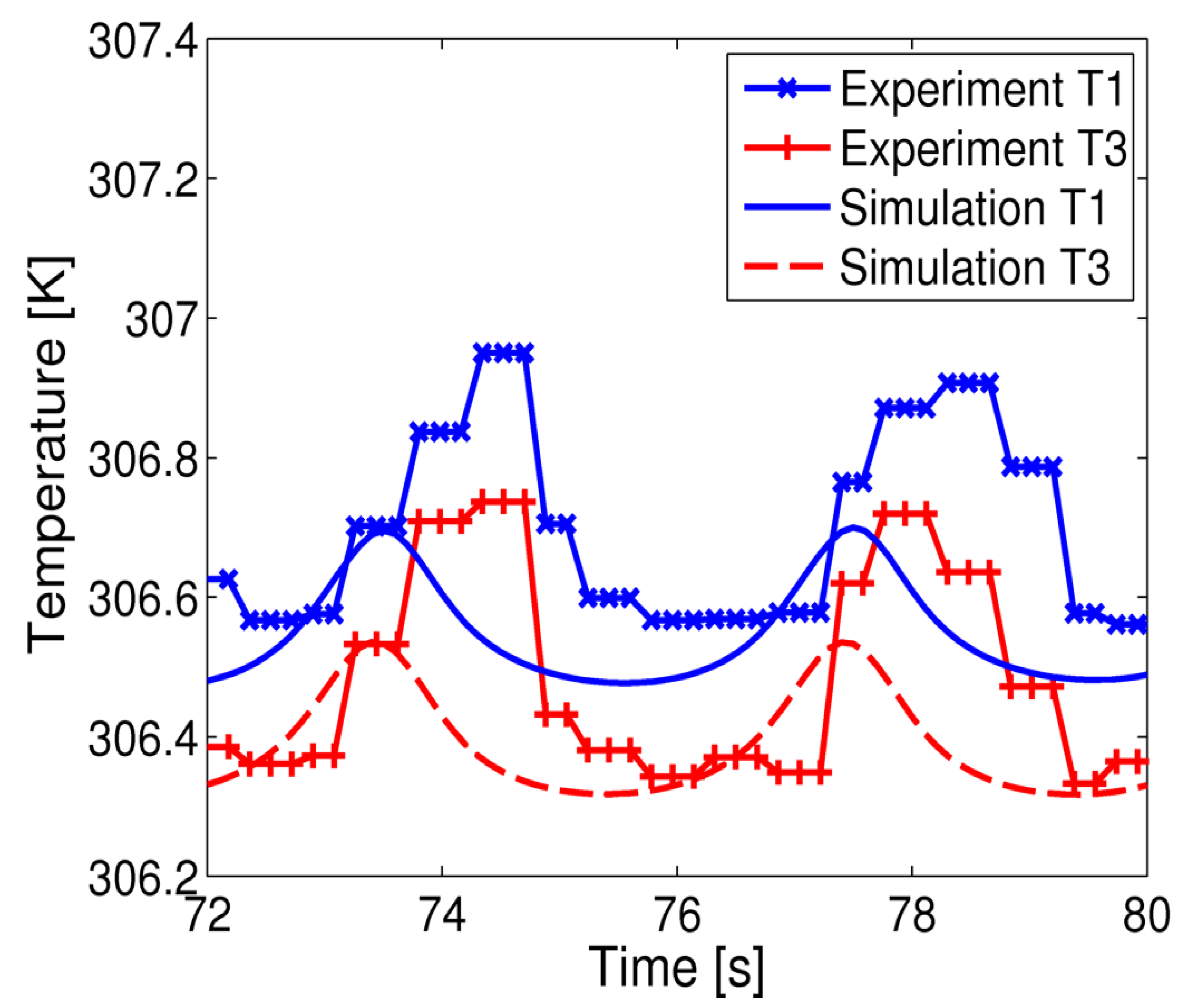

Figure 4. Experimental and simulated temperature profiles for the two thermocouples in the gas phase. See Fig. 2 for the location of the thermocouples T1 and T3.

Pressure and temperature profiles for adsorbing gases

Slow cycles

- Isothermal and non-isothermal simulations agree with experimental data.
- For cycle times greater than 10s, isothermal model which is computationally less expensive and requires fewer physical parameters is sufficient.

Fast cycles

- Isothermal model deviates from experimental data.
- Non-isothermal model agrees with experimental data.
- Heat generated by the adsorption lowers the isotherm so that less CO_2 is adsorbed, thus, the pressure is larger.

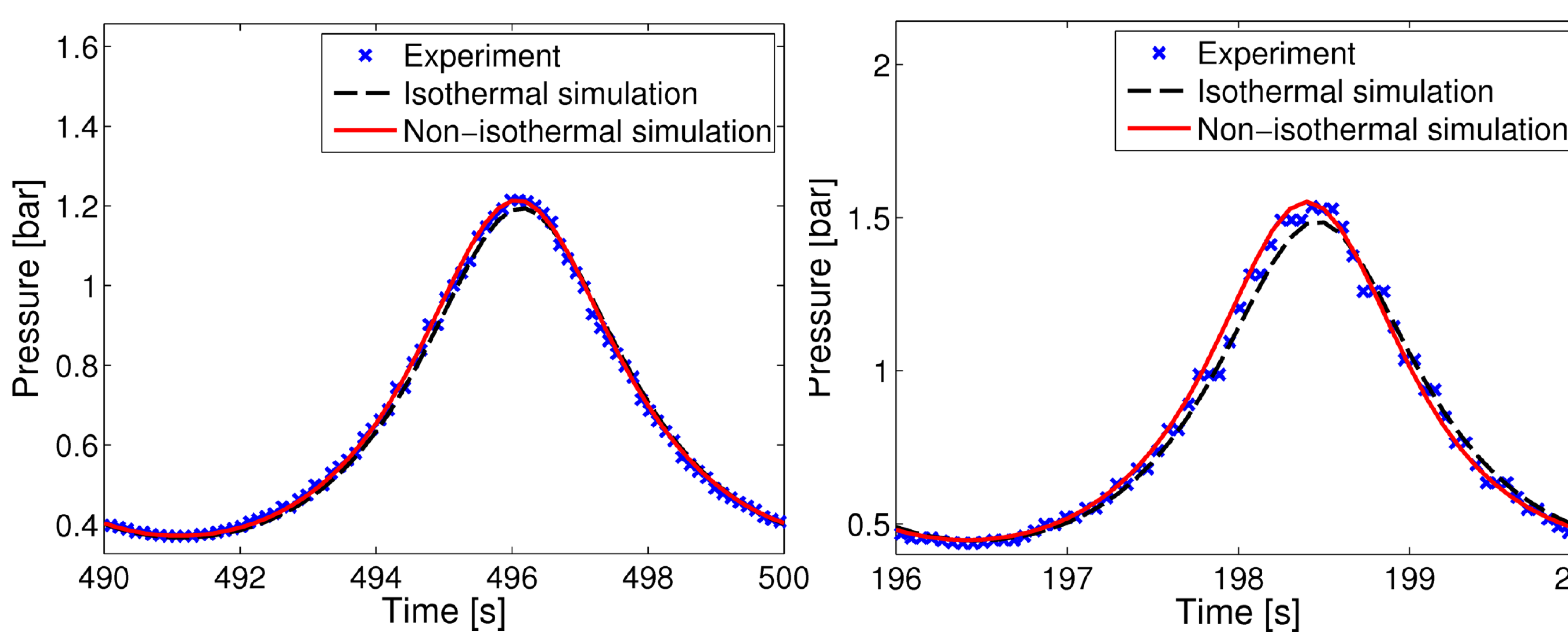

Figure 5. Pressure profile for the mixture run of CO_2:N_2=1:1 with (a) t_c=10s and (b) t_c=4s

Acknowledgements

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Conclusion

- DP-PSA system in combination with the mathematical model is ideal for the testing of materials and process configurations for fast PSA cycles.
- Inert and adsorbing gas experiments are used to characterise the system and validate the model.
- The isothermal model is sufficient for slow cycles, but the temperature profiles must be considered in fast cycle experiments.