Model calculations of a hybrid adsorption compression heat transformer

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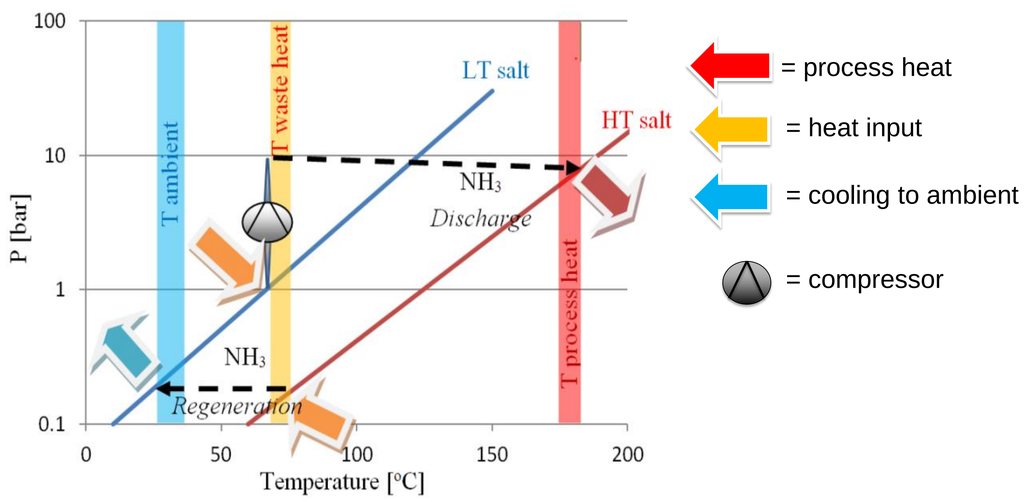
Hybrid cycle

A hybrid heat transformer upgrades low temperature waste heat to process heat using:

- Heat-driven sorption cycle based on reactions of NH_3 with a low-temperature salt ($CaCl_2$) and a high-temperature salt ($MnCl_2$) producing sorption heat
- Mechanically driven compression cycle using a compressor



Goal

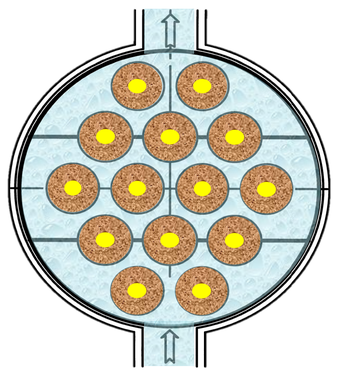
To accurately describe performance of hybrid heat transformer system

Objectives

- Obtain model description
- Calculate multiple cycles, both adsorption and desorption
- Compare with measurements of sorption behaviour
- Design tool for sizing demonstration and full scale heat transformer

Sorbent reactor design

- ‘Shell & Tube’ heat exchanger
- Sorbent inside tube using carrier material (ENG)
- Open gas volume (yellow) in centre of tube
- Heat transfer medium flows outside the tubes



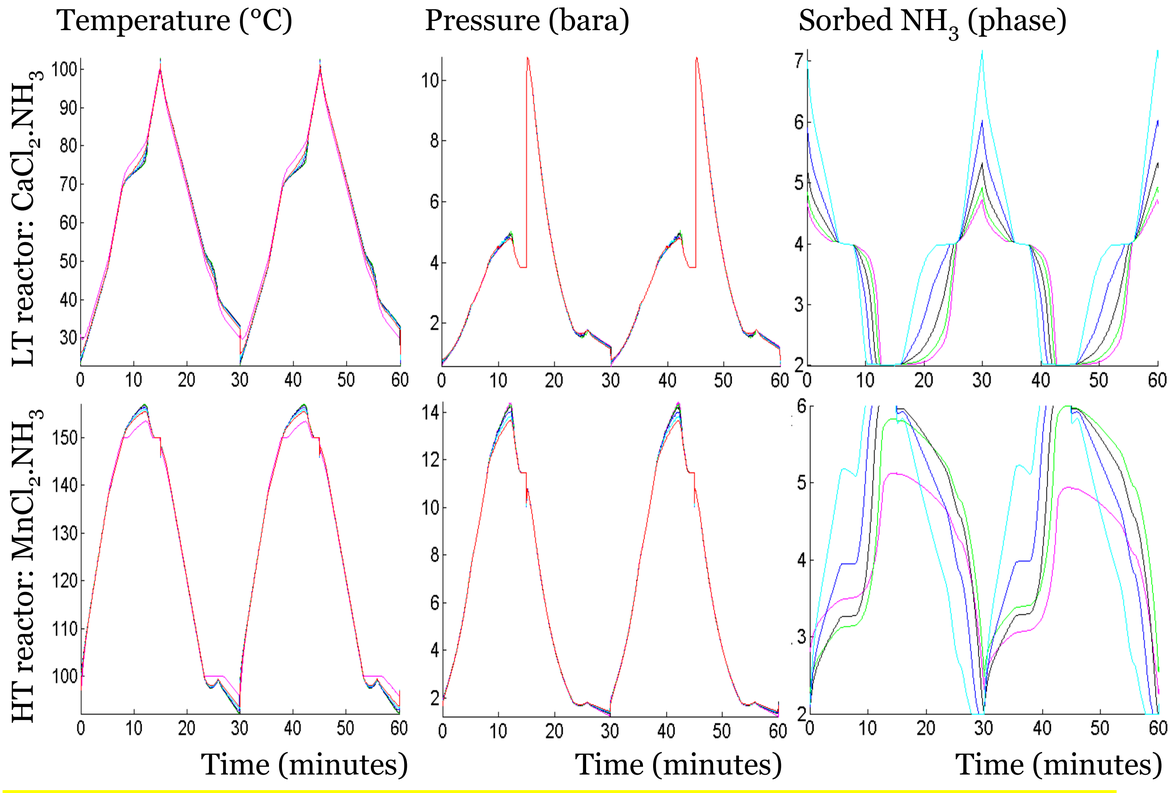
Model assumptions

- Transient & 2D rotation symmetric in Matlab
- Single tube configuration (‘Shell & Tube’ replaced by one long concentric tube with the same ratio of heat transfer medium)
- Evenly distributed & fixed cycle time (no optimisation of cycle times)
- Compressor simplified to constant pressure ratio of 3
- Heat transfer proportional to temperature gradient; Reaction rate proportional to sorption temperature difference at given pressure and actual sorbent temperature

Model results

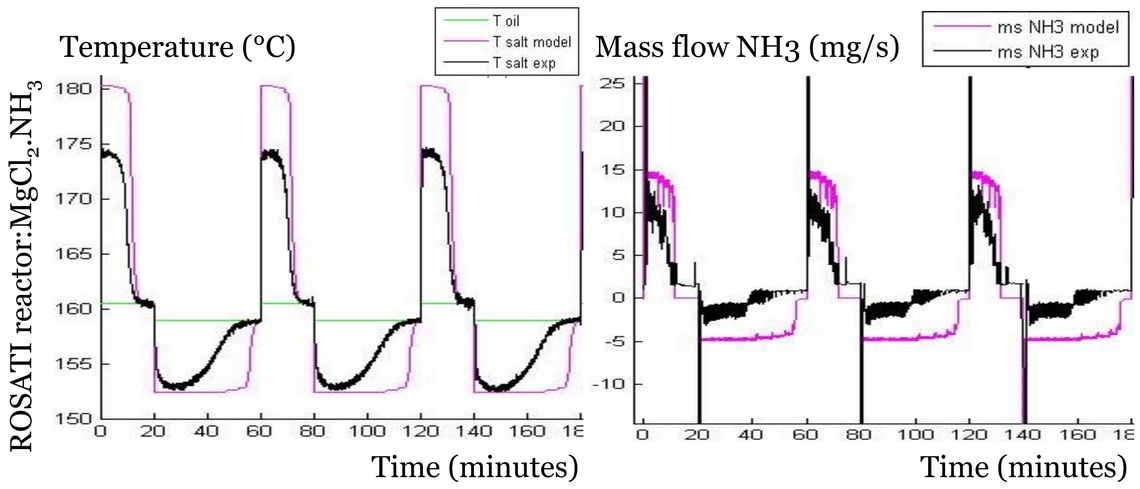
- A 1 MW commercial system results in a power density of 25 kW/m^3 and a COP_{heat} of 0.30
- System consists of 4 reactor pairs with each requiring 4200 meters of tubing consisting ± 400 kg sorbent

Model results 1 MW system



Model compared with measurements

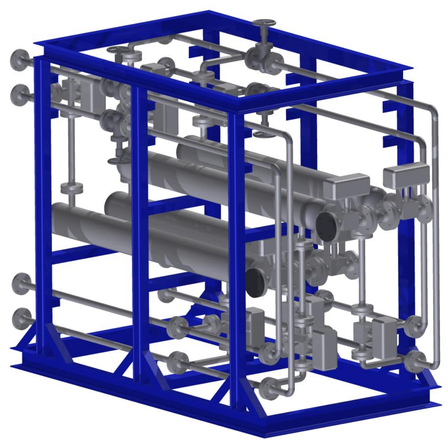
- Experimental setup with hollow 1 inch tube of length = 0.25 m filled with ENG impregnated with $MgCl_2.6NH_3$. The container contains an accurate control of the ammonia pressure. The experiments are isothermal
- The model overestimates the ammonia sorbed by ± 25%



Conclusions

- The calculated power density of 25 kW/m^3 and COP_{heat} of 0.30 for a hybrid adsorption compression heat pump indicates very reasonable performance
- This value can be improved by optimising the reactor dimensions, the cycle time and including heat / mass recovery
- The model shows a good correlation with experimental data
- The overestimation of the ammonia sorbed is not yet clear and requires further investigation in future projects

A design of a 10 kW demonstration unit with 2 pairs of reactors



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