MODELING OF ADSORPTION HEAT EXCHANGERS

Heat Transfer between Fins and Monolayer Pellet Beds

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AGENDA

- Introduction
- Mathematical Model
- Implementation in COMSOL Multiphysics®
- Results
- Conclusion

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Adsorption heat transformation

- Applications
  - Thermally driven cooling
  - Thermally driven heat pumps
  - Loss free heat storage
    - MERITS A RECHARGEABLE HEAT BATTERY
- Sorption materials
  - Silicagels
  - Zeolithes
  - MOFs
  - Hygroscopic salts

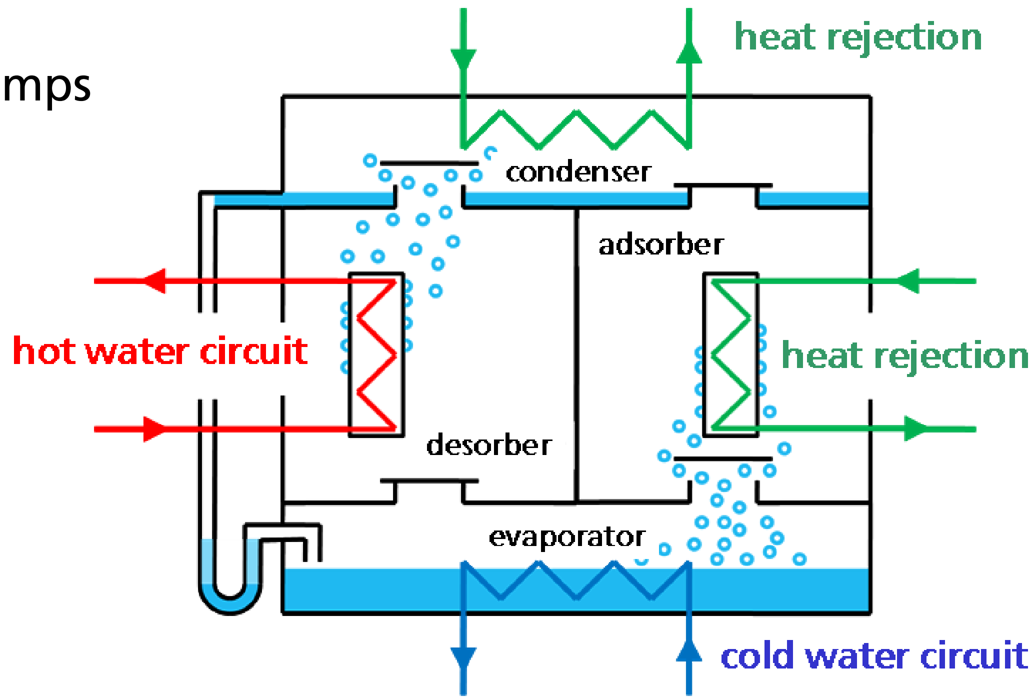

Fig 1: Principle of the adsorption cycle

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Adsorption cycle modelling

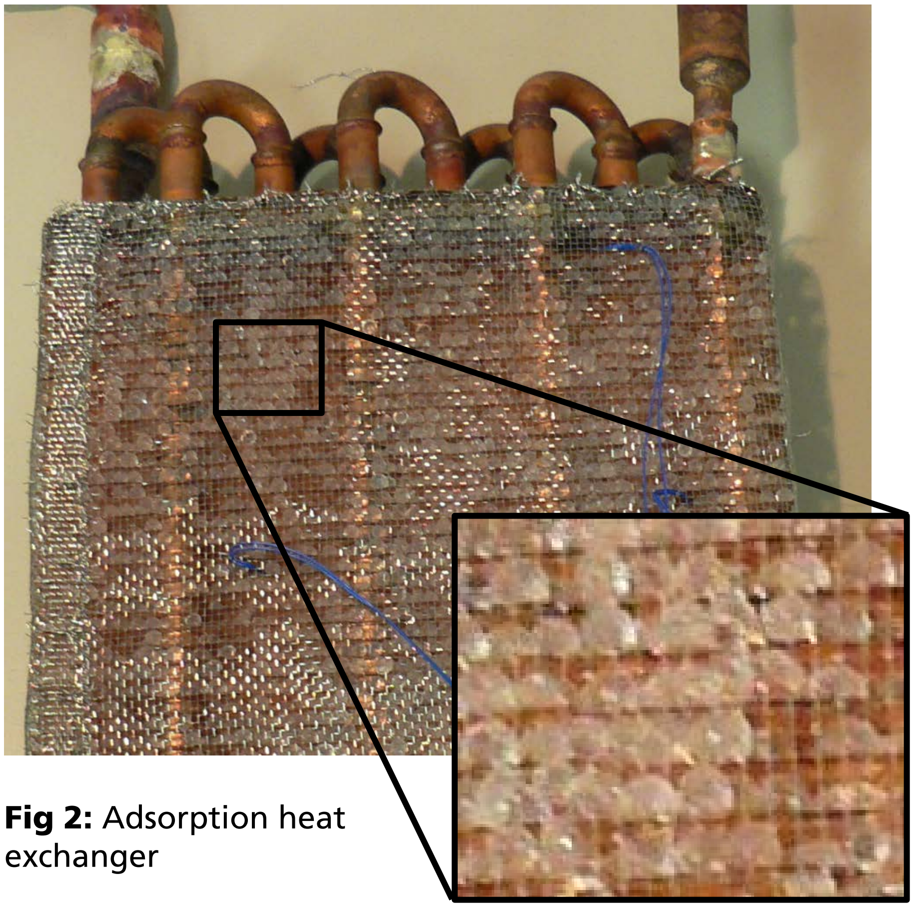
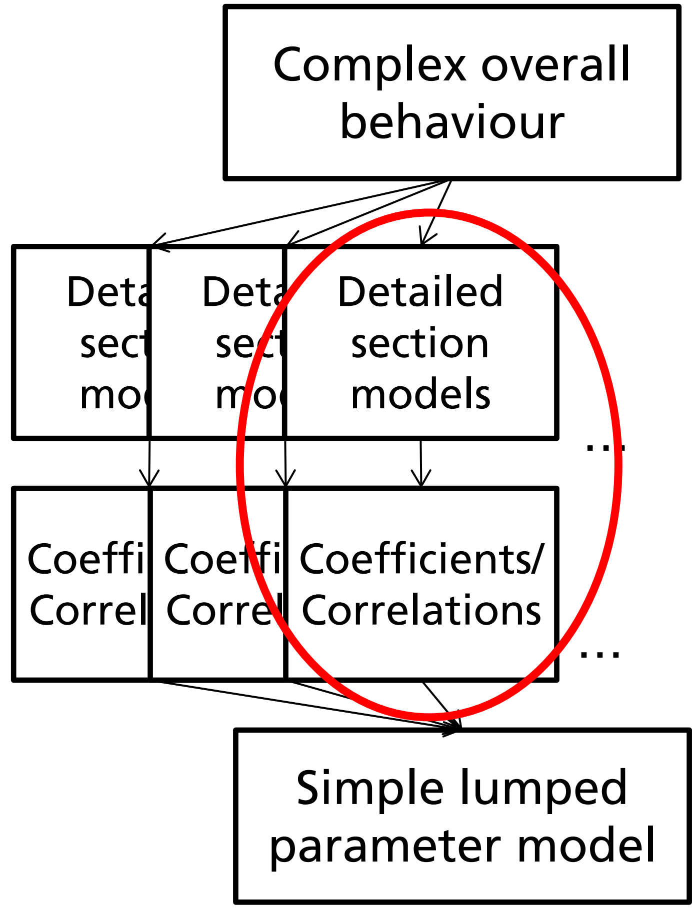


Fig 2: Adsorption heat exchanger



Mathematical Model

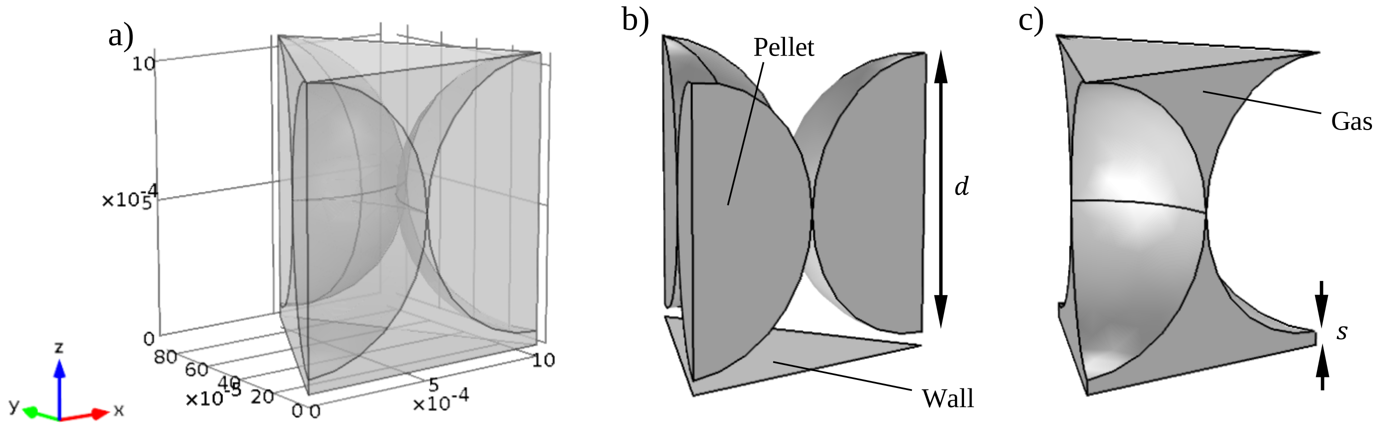


Fig 3: Model geometry

No convective term

Assumptions:

- Heat transfer dominated by conduction.
- Gas domain as a continuum
- Constant material properties
- Gas is adsorbed homogeneously
- The heat conductivity of the fin in x and y is high.

$$0 = \nabla(\lambda \nabla T) + \dot{q}_{\text{ad}}$$

Constant conductivity

Heat source in pellet

$$T_{\text{wall}} = const.$$

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Implementation

- COMSOL Multiphysics 4.4
  - "heat transfer in solids"

- Evaluation
  - $\bar{\dot{q}}_w$: av. wall heat flux
  - $\bar{T}_p$: av. pellet temperature
  - Wall-pellet heat transfer coefficient:

$$\alpha_p = \frac{\bar{\dot{q}}_w}{\bar{T}_p - T_w}$$

Tab 1: Values used for simulation

Parameter		Value
pellet diameter	d	0.2-4 mm
pellet roughness	s	20-100 µm
gas conductivity	λ_g	0.01-0.03 W/(m K)
pellet conductivity	λ_p	0.1-0.5 W/(m K)
wall temperature	T_w	20 °C
heat source from adsorption	$\dot{q}_{ad}$	100 kW/m³

Large parametric sweep (n = 450)

Results

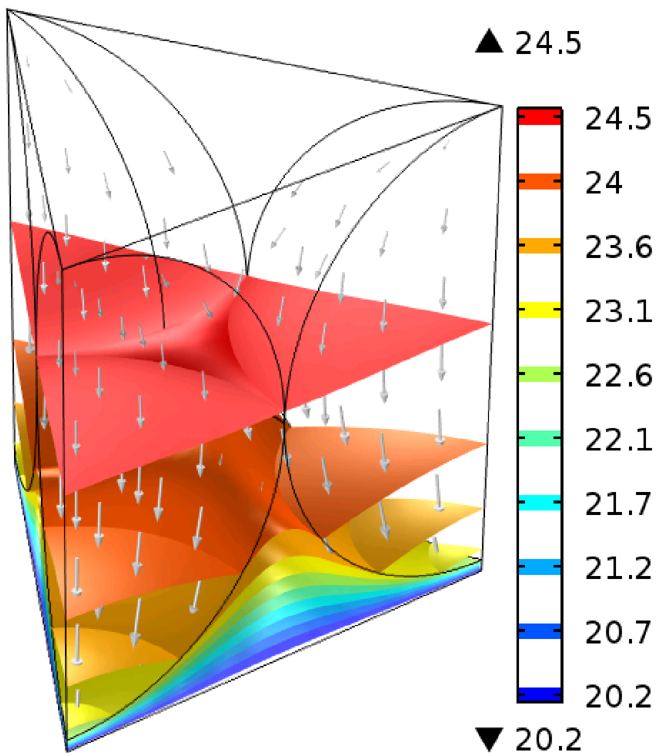

Fig 4: Resulting isotherms (scale in °C) and qualitative representation of heat flux (arrows)

- Data reduction with dimensionless quantities (Buckingham π theorem):

$$\alpha_p = \mathrm{f}(d, s, \lambda_p, \lambda_g) \overset{\pi}{\Leftrightarrow} Nu_p = \mathrm{f}(\epsilon_p, r_\lambda)$$

  - Nusselt number

$$Nu_p = \frac{\alpha_p d}{\lambda_g}$$

  - Spec. pellet roughness:

$$\epsilon_p = \frac{s}{d}$$

  - Ratio of conductivities:

$$r_\lambda = \frac{\lambda_p}{\lambda_g}$$

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Results

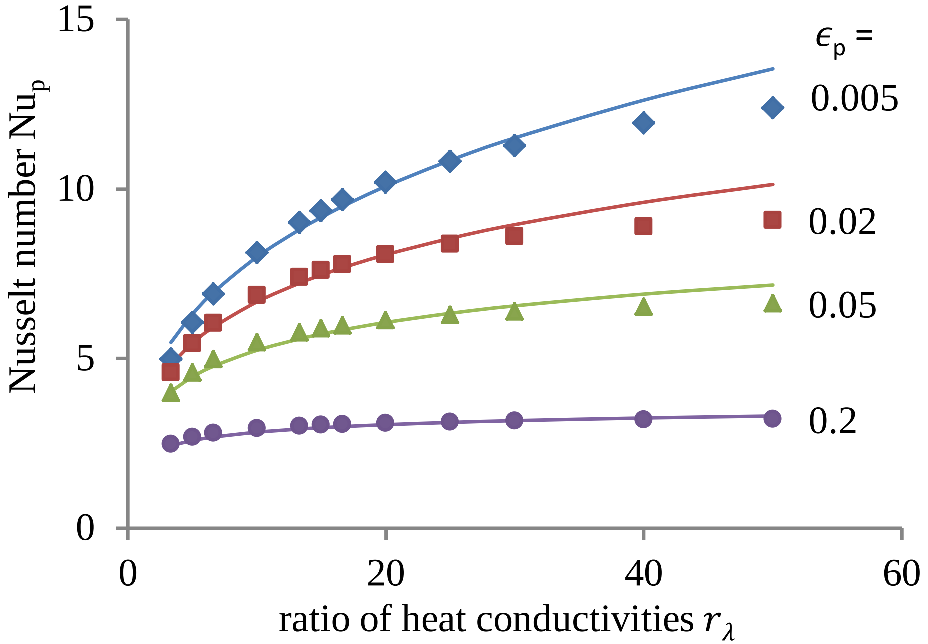

Fig 5: Reduced results of the simulation (points) and the fitted approximation (lines)

$$Nu_p \approx \left(0.896\epsilon_p^{0.817} + 0.268 r_\lambda^{-0.374}\right)^{-1}$$

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Conclusion

Summary

- 3D heat transfer model set up
- Extensive parametric sweep performed
- General Nusselt correlation derived

Outlook

- Extended to non-continuum transport

Acknowledgement

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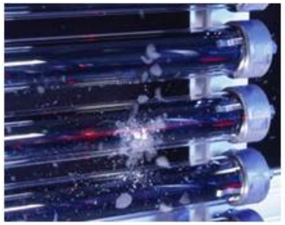
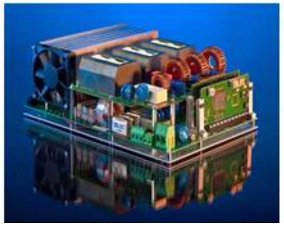
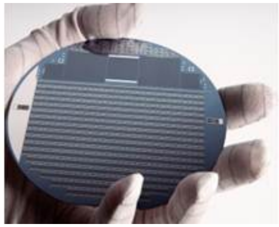
Thank you for your attention!

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