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Capacitance-resistance-modeling of sorption thermal energy storage systems

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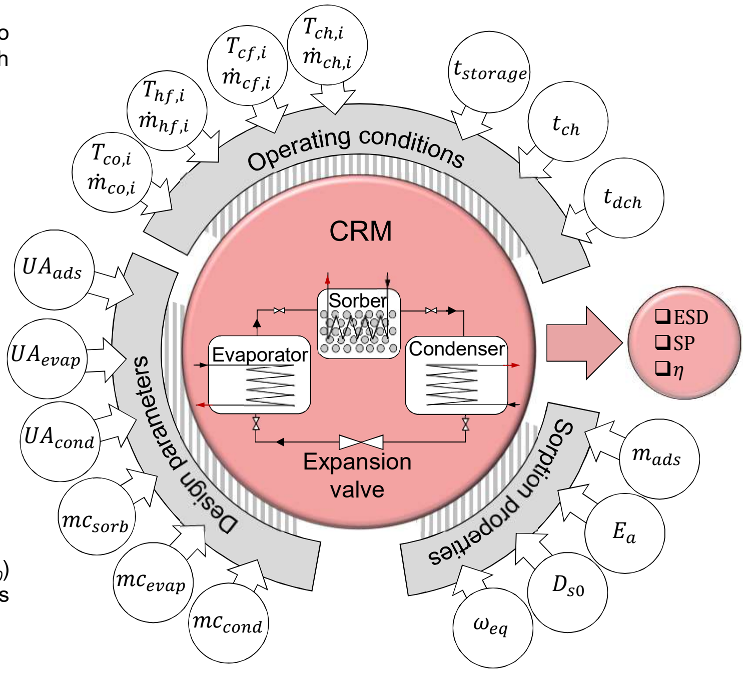
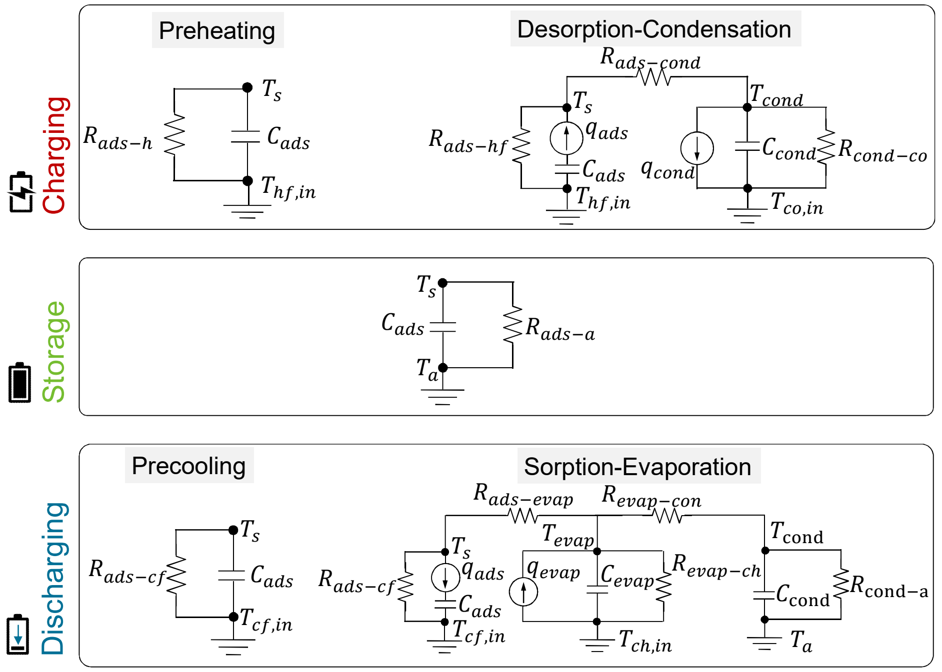
Capacitance Resistance Model (CRM)

- ☐ A lumped-parameter capacitance resistance model (CRM) is developed to design, optimize, and control thermal energy storage (S-TES) systems, which offers a reasonable trade-off between accuracy and computational time.
- ☐ Thermal network of the CRM:
  - Heat transfer resistance ≡ Resistance
  - Thermal mass ≡ Capacitance
  - Sorption, evaporation, and condensation energy ≡ Current sources
  - Inlet temperatures of HTF, coolant, and chilled water ≡ Voltage sources
- ☐ Assumptions:
  - Thermodynamic equilibrium between sorbent and sorbate.
  - Uniform temperature and sorbate distribution inside sorbent.
  - Uniform sorbent size
  - Negligible heat loss
- ☐ Equations
  - Heat balance of the sorber, evaporator and condenser
  - Mass balance of sorbate
  - Sorption equilibrium equation
- ☐ The kinetic properties of the sorber bed, including the mass diffusivity (D_{s0}) and characteristic energy (E_a), which are obtained from our in-situ mass measurement of the full-scale sorber bed, are fed to the proposed CRM.



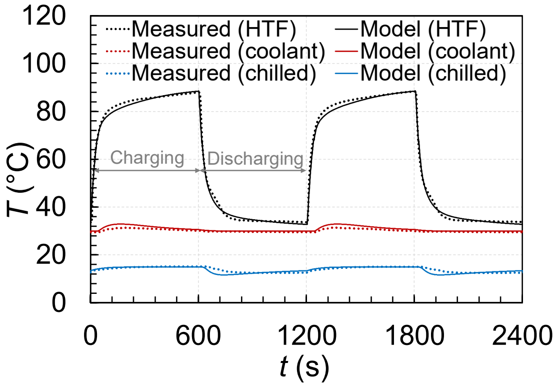


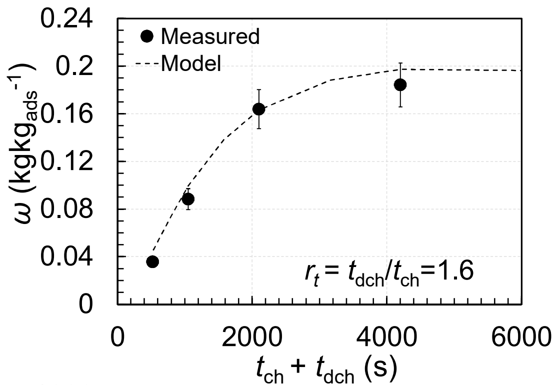
Resistances, capacitances, and heat sources

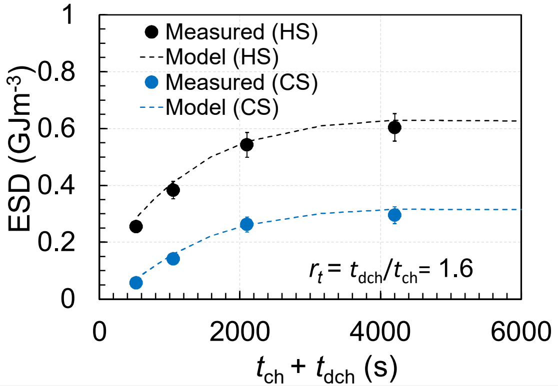
R_{ads-hf}	Resistance between the sorber bed and heating fluid
$R_{cond-co}$	Resistance between the condenser and coolant fluid
$R_{ads-cond}$	Resistance between the condenser and sorber bed
C_{ads}	Thermal capacitance of the sorber bed
C_{cond}	Thermal capacitance of the condenser
q_{ads}	Heat source in the sorber bed
q_{cond}	Heat source in the condenser
R_{ads-cf}	Resistance between the sorber bed and heating fluid
$R_{evap-ch}$	Resistance between the condenser and coolant fluid
$R_{evap-cond}$	Resistance between the condenser and evaporator
$R_{ads-evap}$	Resistance between the condenser and sorber bed
C_{ads}	Thermal capacitance of the sorber bed
C_{evap}	Thermal capacitance of the condenser
q_{ads}	Heat source in the sorber bed
q_{evap}	Heat source in the condenser
$R_{ads-amb}$	Resistance of the sorber bed
C_{ads}	Thermal capacitance of the sorber bed

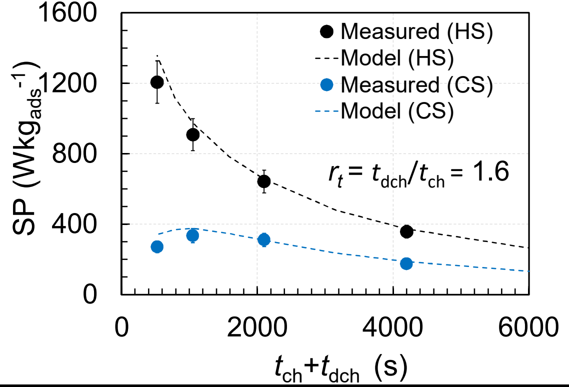
Ref.: M. Rouhani, "Sorption thermal energy storage for sustainable heating and cooling," PhD Thesis, Simon Fraser University, 2019.

Results



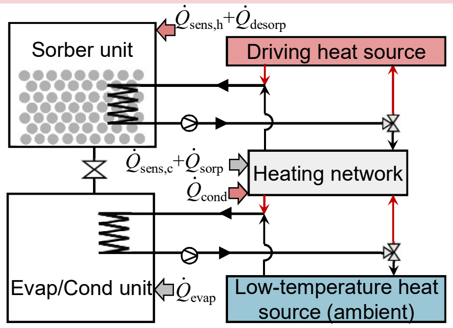


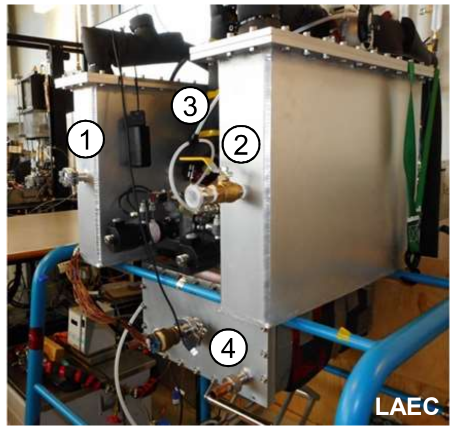


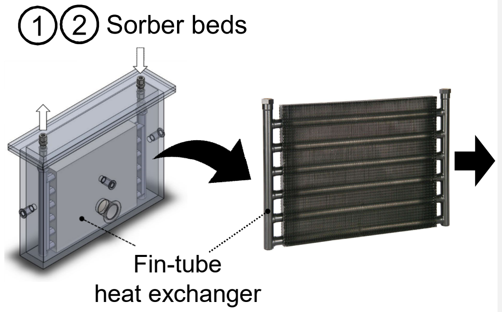


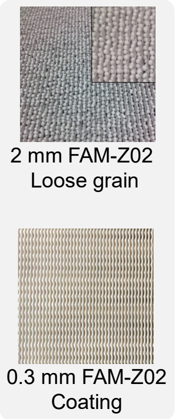
- A CRM is developed that significantly simplifies the assessment of the **impact of materials**, **components**, and **processes on overall performance metrics** and enables **real-time control** of the thermal storage system based on demand, supply, and state-of-charge of sorption thermal energy storage systems.
- The present model is successfully validated with the experimental data, which was collected from a custom-built S-TES in our lab, under various operating conditions.
- For heat storage (HS) coated FAM-Z02 S-TES, the material-based energy storage density (ESD) of 0.934 MJkg$_{ads}^{-1}$ (0.607 GJm^{-3}) and averaged specific power (SP) of 504 Wkg$_{ads}^{-1}$ are measured.
- For cold energy (CS) coated FAM-Z02 S-TES, the material-based ESD of 0.493 MJkg$_{ads}^{-1}$ (0.320 GJm^{-3}) and averaged SP of 267 Wkg$_{ads}^{-1}$ are obtained.
- Considering the optimum discharge-to-charge time of 1.6, a maximum SP of 1,207 and 335 Wkg$_{ads}^{-1}$ are measured for heat storage, HS, and cold storage, CS, coated S-TES, respectively.

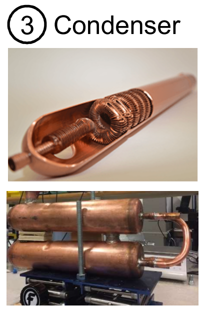
Experimental Study

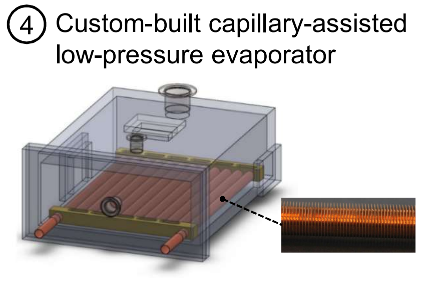












Nomenclature

UA_{ads}	(W K^{-1})	Overall heat transfer coefficient of sorber bed	mc_{ads}	(J K^{-1})	Thermal capacitance of the sorber bed	$\dot{m}_{co,i}$	(kg s^{-1})	Flow rate of inlet coolant to the condenser	t_{ch}	(s)	Time of charging
UA_{evap}	(W K^{-1})	Overall heat transfer coefficient of evaporator	mc_{evap}	(J K^{-1})	Thermal capacitance of the evaporator	$\dot{m}_{hf,i}$	(kg s^{-1})	Flow rate of inlet hot fluid to the sorber bed	t_{dch}	(s)	Time of discharging
UA_{cond}	(W K^{-1})	Overall heat transfer coefficient of condenser	mc_{cond}	(J K^{-1})	Thermal capacitance of the condenser	$\dot{m}_{cf,i}$	(kg s^{-1})	Flow rate of inlet cold fluid to the sorber bed	$t_{storage}$	(s)	Time of storage
E_a	(kJmol^{-1})	Activation energy	ω_{eq}	(kgkg$_{ads}^{-1}$)	Equilibrium water uptake	$\dot{m}_{ch,i}$	(kg s^{-1})	Flow rate of inlet chilled water from the evaporator	ESD	(GJm^{-3}, MJkg^{-1})	Energy storage density
D_{S0}	(m^2 s^{-1})	Surface diffusion coefficient in LDF model	m_{ads}	(kg)	Mass of the sorbent material	HTF		Heat transfer fluid	SP	(W kg$_{dry,ads}^{-1}$)	Specific power