Performance of Composite Adsorbent Heat Exchanger with Metal Foam Coated with Hydrophilic Polymer

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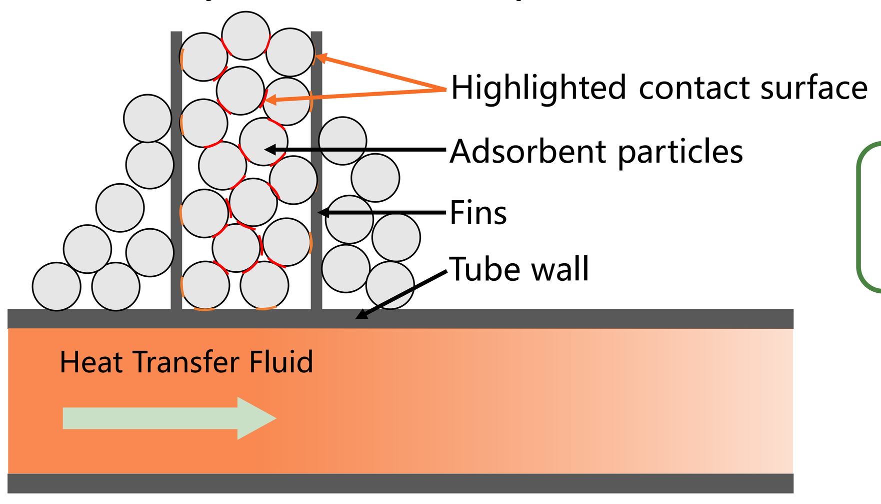
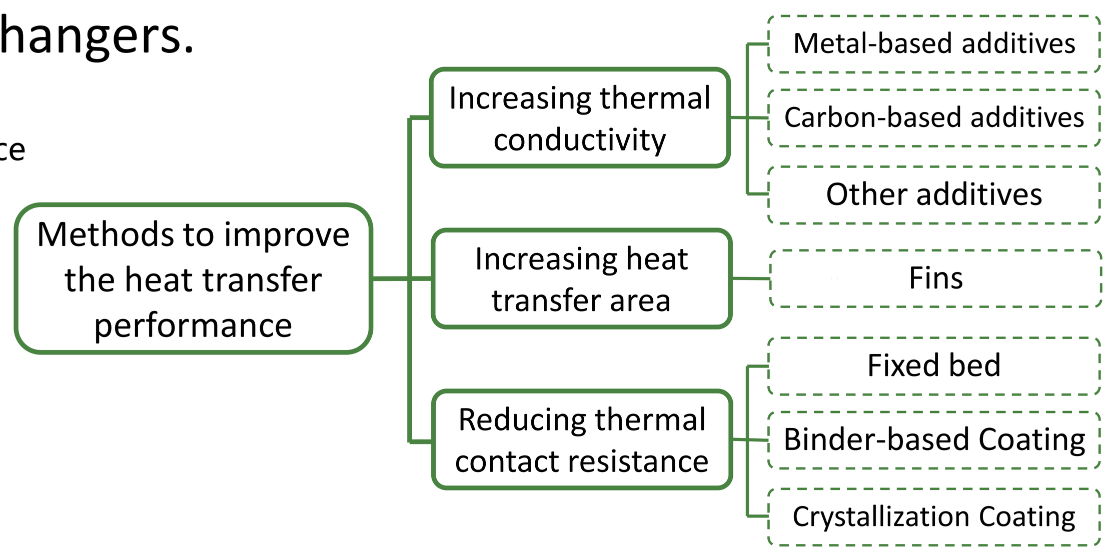
1 Adsorption heat exchanger

Adsorption technology is regarded as an environment-friendly approach for low-grade thermal utilization, such as heat pumps, thermal energy storage and dehumidification etc.
The performance of this technology is highly affected by the heat and mass transfer efficiency in the adsorption heat exchangers.

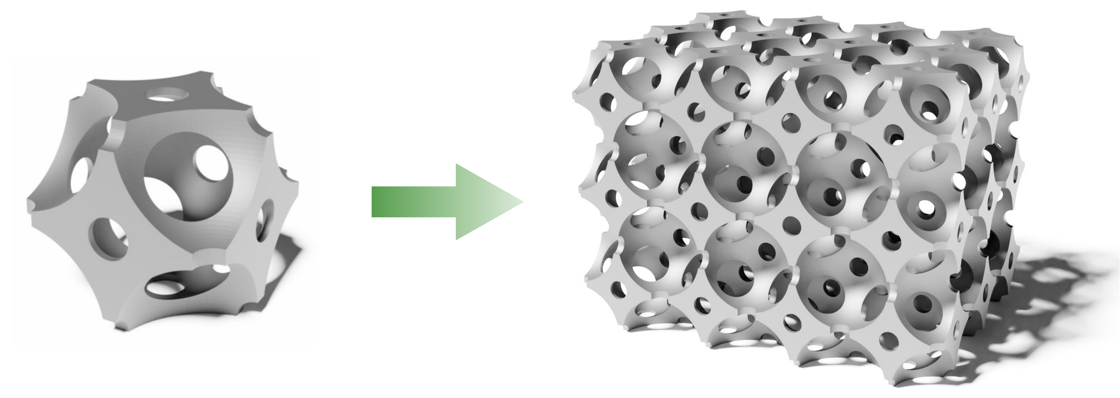




2 Metal Foam

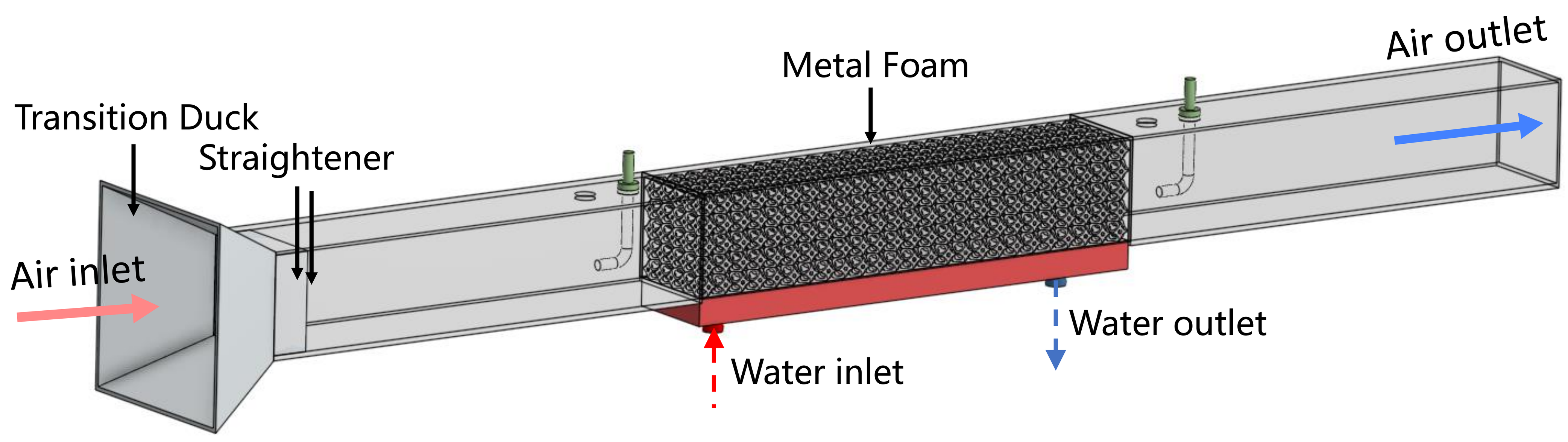
Metal foam is a porous metal material. It has emerged as a potential material for advanced heat exchangers in air-cooling systems due to these advantages:

- High surface area to volume ratio, 1000-3000 [m²/m³]
- High conductivity of the solid struts, 200-400 [W/(m K)]
- Enhanced flow mixing induced by the tortuous flow paths



3 Methodology

◆ Adsorption dehumidification system with metal foam heat exchanger:



◆ Based on the calculation domain, following governing equations are established

- The mass balance in air layer

$$\frac{\partial X_a}{\partial t} = -u_a \frac{\partial X_a}{\partial x} + \frac{h_m}{\delta_a}(X_i - X_a)$$

- The energy balance in air layer

$$\frac{\partial T_a}{\partial t} = -u_a \frac{\partial T_a}{\partial x} + \frac{h_a}{\rho_a c_{p,a} \delta_a}(T_i - T_a)$$

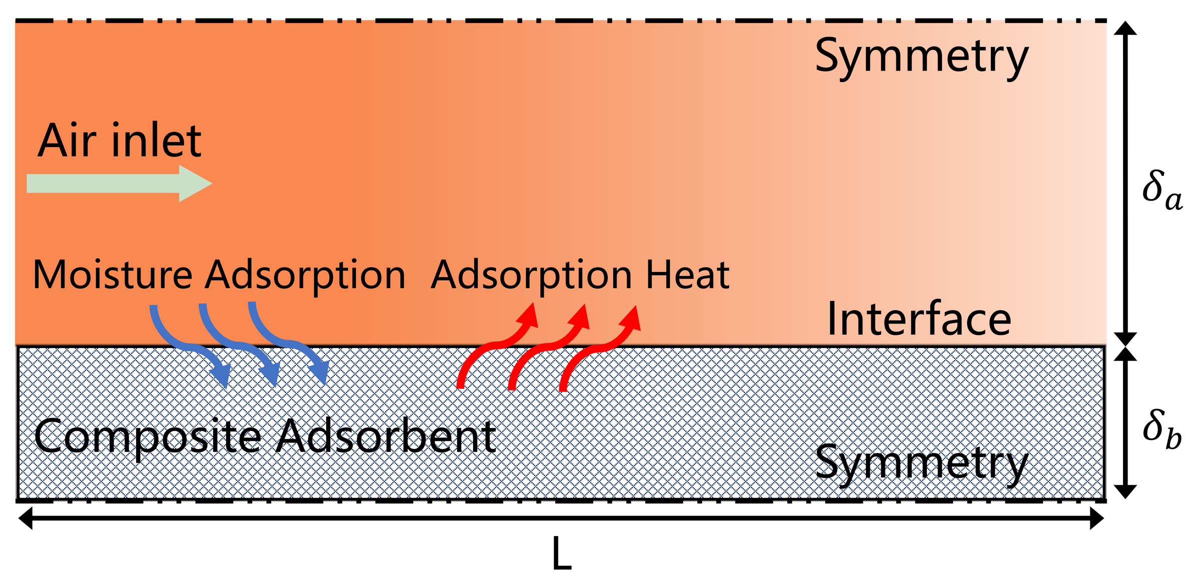
- The mass balance in adsorption heat exchanger

$$\frac{\partial \rho_w}{\partial t} = \frac{D_b}{\zeta \varepsilon}\frac{\partial^2 \rho_w}{\partial x^2} + \frac{3D_b}{\zeta \varepsilon \delta_b^2}(\rho_i - \rho_w) - \frac{\rho_s(1-\varepsilon)}{\varepsilon}\frac{\partial W}{\partial t}$$

- The energy balance in adsorption heat exchanger

$$\frac{\partial T_b}{\partial t} = \alpha_b \frac{\partial^2 T_b}{\partial x^2} + \frac{3\alpha_b}{\delta_b^2}(T_i - T_b) + \frac{q_{ads}\rho_s \zeta(1-\varepsilon)}{\rho_b c_{p,b}}\frac{\partial W}{\partial t}$$

◆ Computational domain:



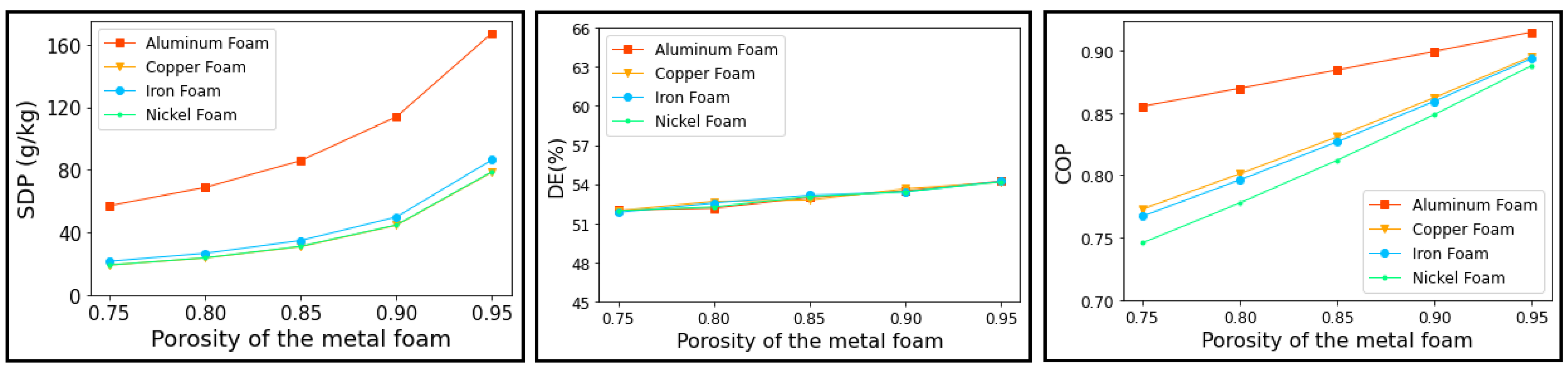
◆ Parameters of different metal foam

Material	ρ_{mf} (kg m⁻³)	$c_{p,mf}$ (J kg⁻¹ K⁻¹)	k_{mf} (W m⁻¹ K⁻¹)
Aluminum	2680	900	237
Copper	8954	385	401
Iron	7870	444	80
Nickel	8908	427	94

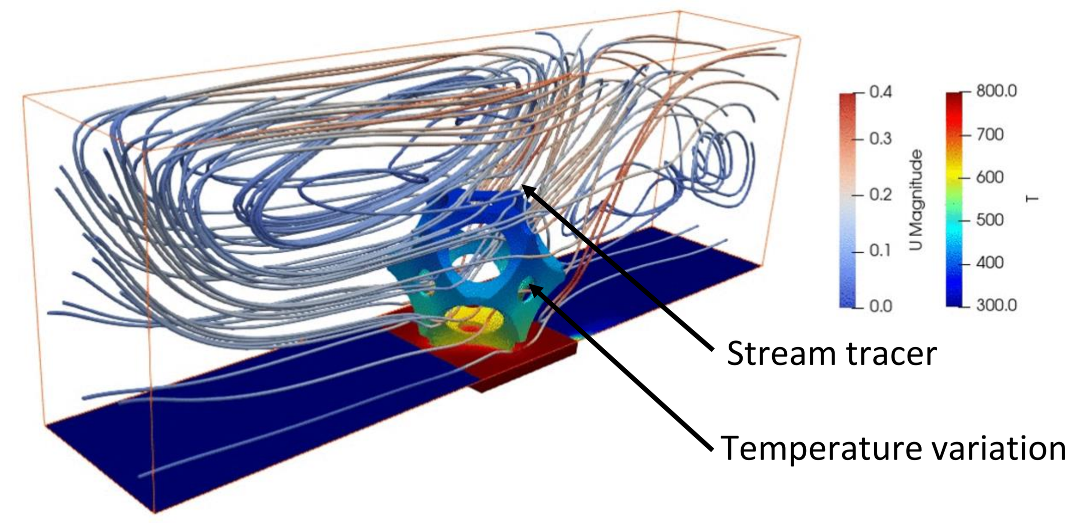
4 Results

◆ The performance of composite adsorbent bed possessing metal foam and hydrophilic polymer coating were investigated through numerical simulations.

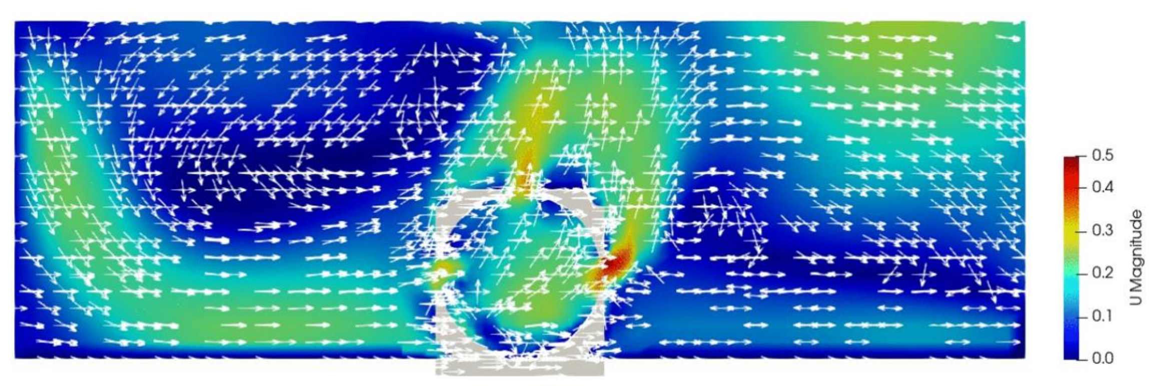
- Compared with other metal foams, the composite adsorption heat exchanger using aluminum foam has higher SDP and COP.
- High-porosity metal foam is recommended, because the SDP, DE and COP of the adsorbent bed all increase with the increase of the porosity of the metal foam.



(a) Specific Dehumidification Power (SDP) (b) Dehumidification Effectiveness (DE) (c) Coefficient of Performance (COP)



Stream Tracer & Temperature variation



Cross-section view – Velocity