Ulster University

LoT-NET

Thermal Performance Enhancement of Latent Heat Storage Heat Exchangers Using Different Fin Configurations

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There are a variety of PCM to choose from, but not all PCM can be used for latent heat storage. Generally, the ideal PCM available for latent heat storage should have the following features:

(1) **Appropriate phase transition temperature** to satisfy the practical application;

(2) **Large melting enthalpy** to provide the high latent heat storage capacity;

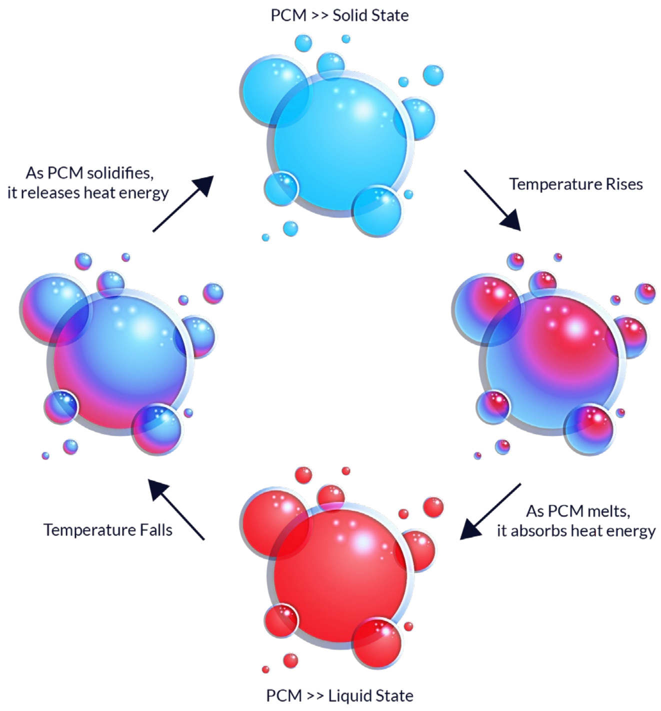
(3) **High thermal conductivity** to achieve faster charging and discharging rate;

(4) **Stable thermal and chemical properties** to ensure the persistent thermal storage capacity;

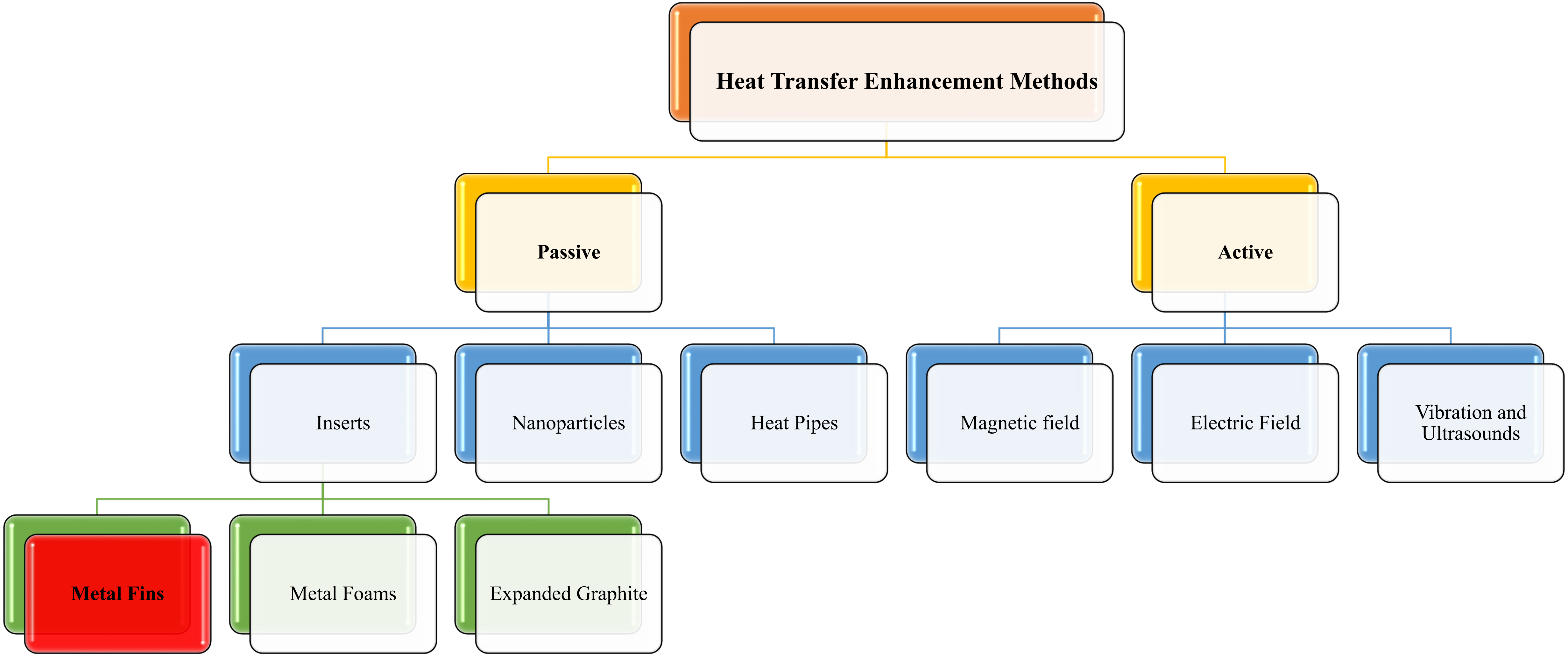
(5) **Non–toxic, non–corrosive, non–flammable** to ensure the safety and harmless to surroundings;

(6) **Small supercooling**;

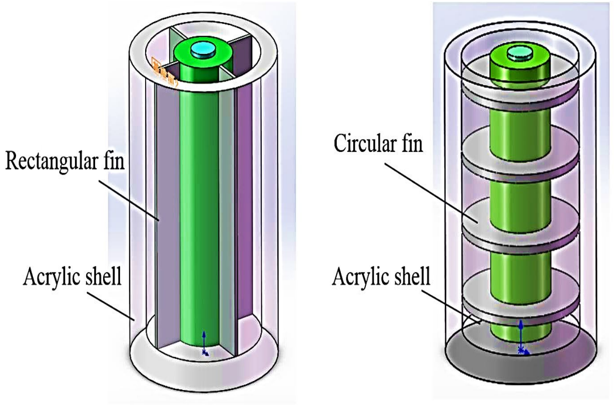
(7) **Low volume change** during phase transition;



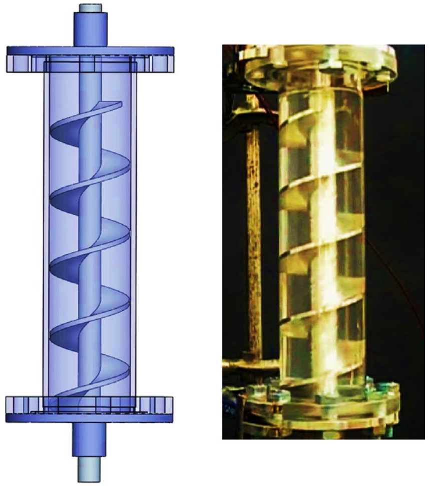
Heat Transfer Enhancement Methods of Phase Change Materials



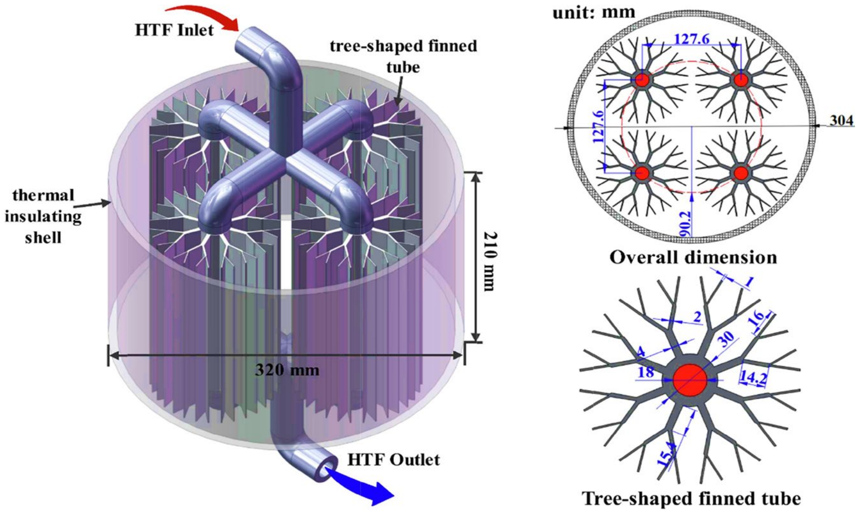
Different Fin Configurations to Improve the Thermal Performance of Latent Heat Storage Systems



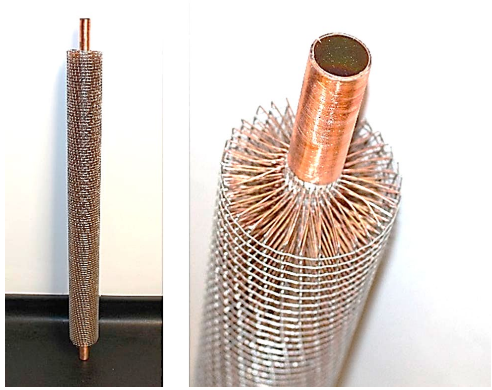
Rectangular and Circular fins



Spiral fins

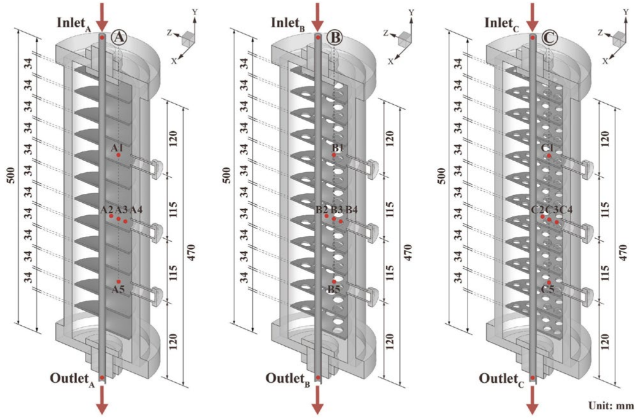


Fractal (Branched) fins



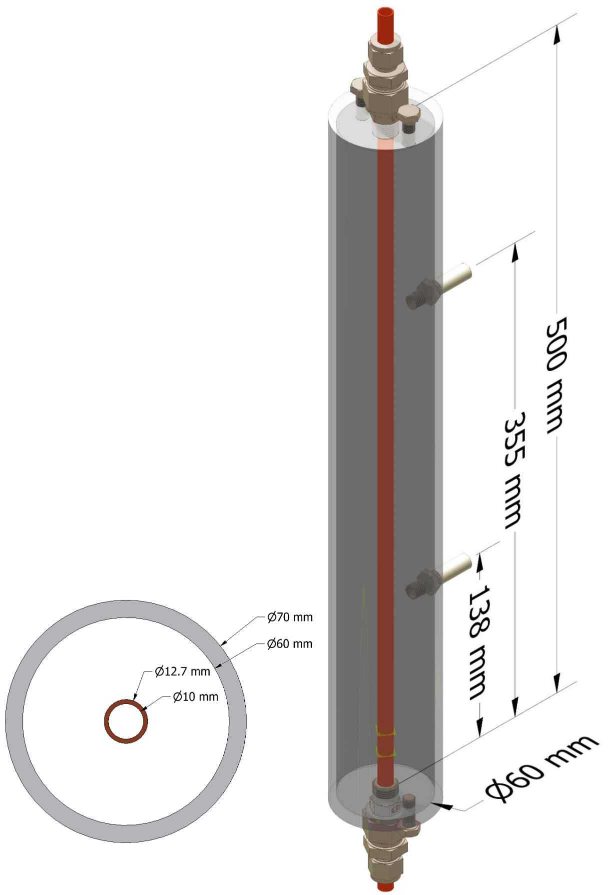
Wire fins

Pin fins

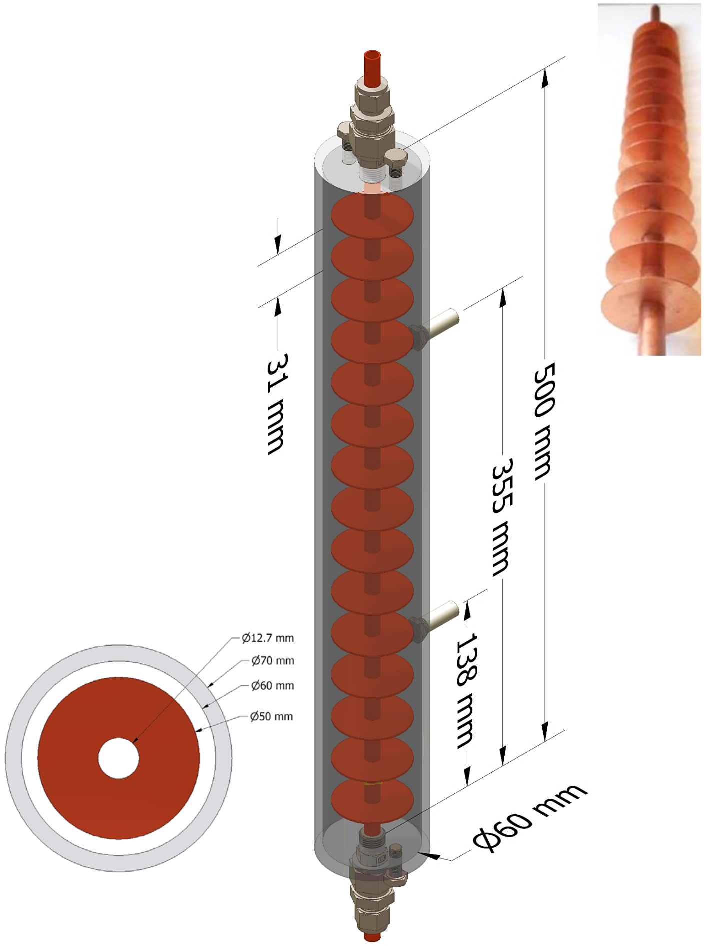


Perforated fins

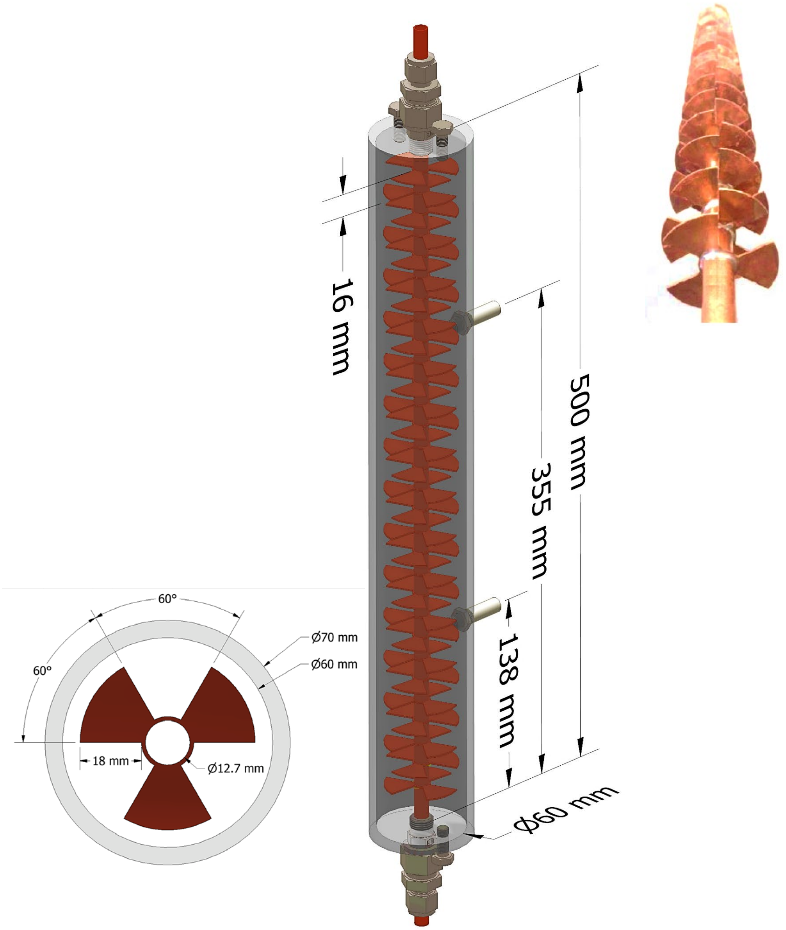
Comparison of Wedge-Finned tube and Annular-Finned Tube Heat Exchangers at Constant Fin Volume Fraction



Bare Tube (Reference)

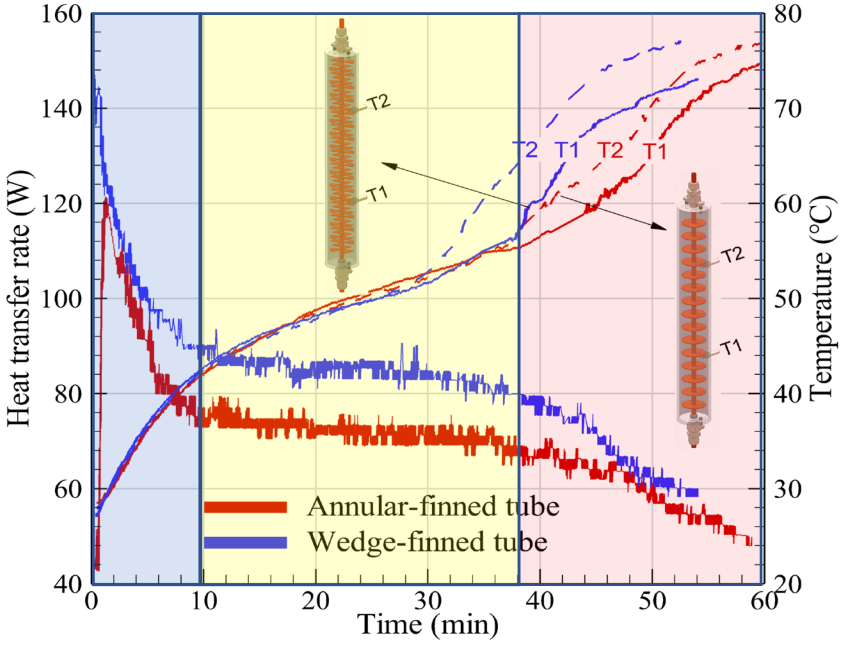


Annular-Finned Tube

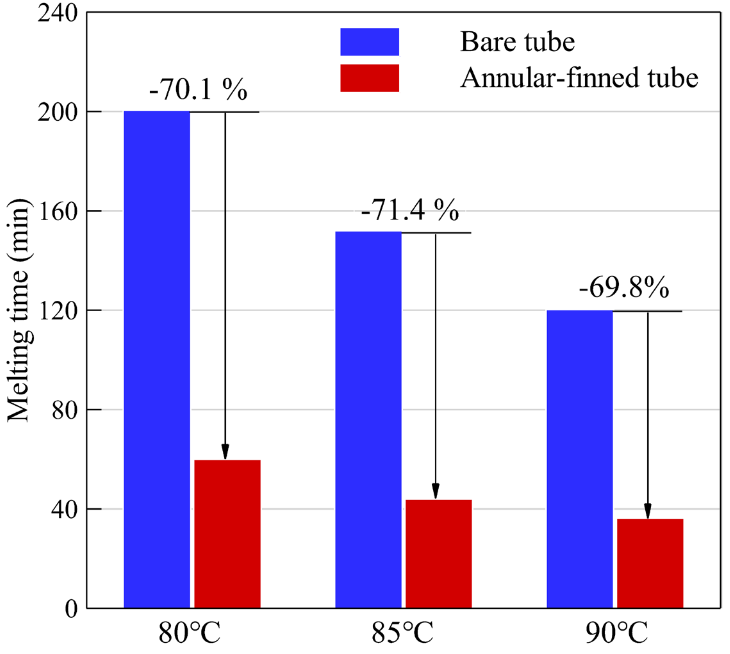


Wedge-Finned Tube

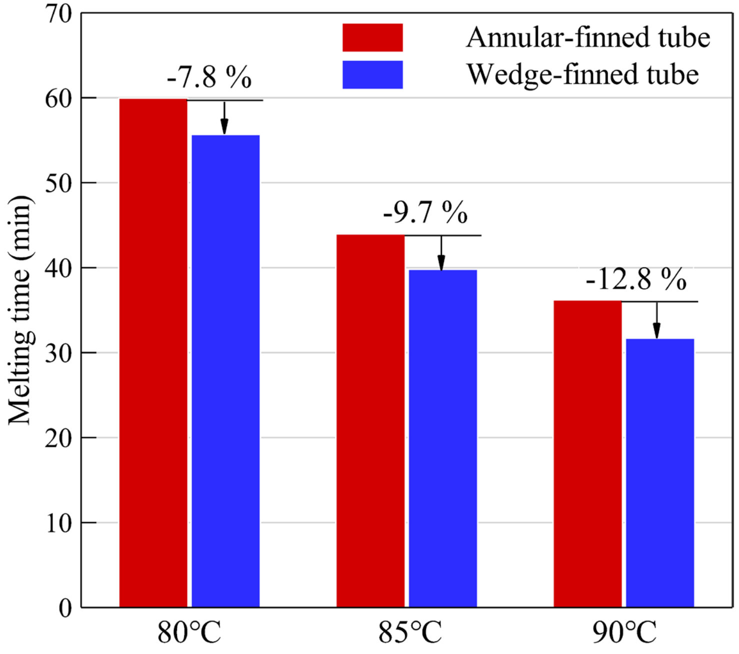
Experimental Results



Comparison of heat transfer rate and temperature between the annular and wedged finned tube

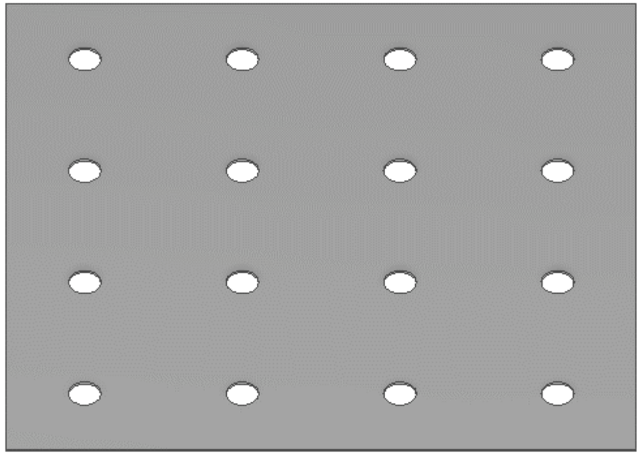


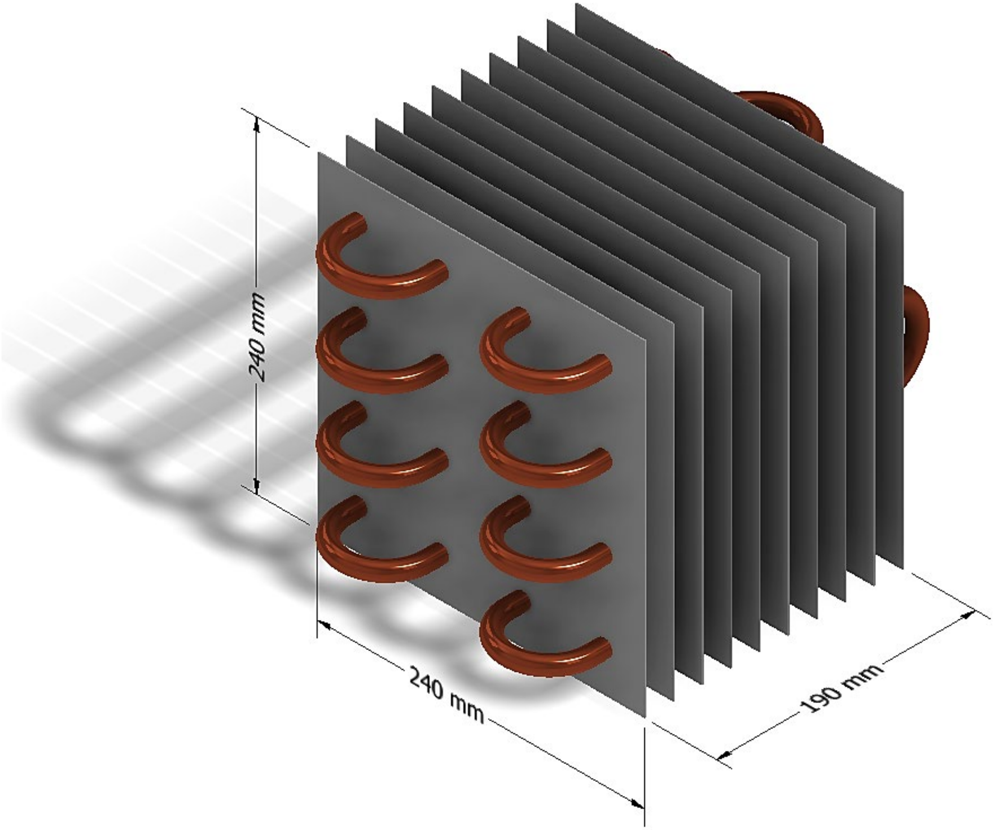
Comparison of total melting time between the bare and annular finned tube



Comparison of total melting time between the annular and wedged finned tube

Different Designs of Plate Fin and Tube Heat Exchangers for Latent Heat Storage Applications





Numerical simulation of the melting process –Governing Equations

- The melting process is modeled using the **enthalpy-porosity approach**. In this technique, the whole computational domain is considered as a Porous Zone, in which the porosity is represented by the value of liquid fraction (γ) varying between 0 and 1.
- The governing equations including continuity, momentum, and energy equations are as below:

Continuity:

$$\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0$$

Momentum:

$$\frac{\partial(\rho u)}{\partial t}+\frac{\partial(\rho uu)}{\partial x}+\frac{\partial(\rho uv)}{\partial y}+\frac{\partial(\rho uw)}{\partial z}=-\frac{\partial P}{\partial x}+\frac{\partial}{\partial x}\left(\mu\frac{\partial u}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial u}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu\frac{\partial u}{\partial z}\right)+S_x \rightarrow S_x=-\frac{(1-\gamma)^2}{\gamma^3+\varepsilon}A_{mush}u$$

$$\frac{\partial(\rho v)}{\partial t}+\frac{\partial(\rho uv)}{\partial x}+\frac{\partial(\rho vv)}{\partial y}+\frac{\partial(\rho vw)}{\partial z}=-\frac{\partial P}{\partial y}+\frac{\partial}{\partial x}\left(\mu\frac{\partial v}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial v}{\partial y}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial v}{\partial z}\right)+S_y \rightarrow S_y=-\frac{(1-\gamma)^2}{\gamma^3+\varepsilon}A_{mush}v$$

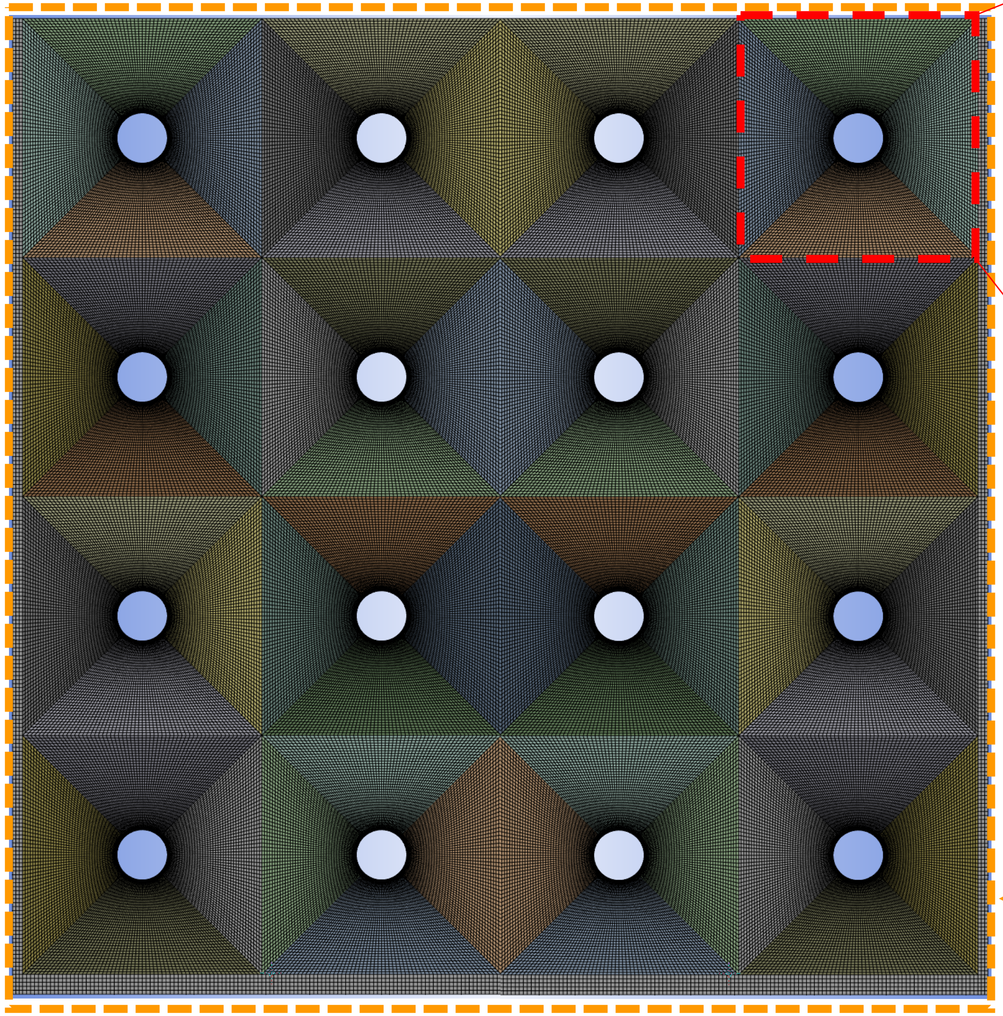
$$\frac{\partial(\rho w)}{\partial t}+\frac{\partial(\rho uw)}{\partial x}+\frac{\partial(\rho vw)}{\partial y}+\frac{\partial(\rho ww)}{\partial z}=-\frac{\partial P}{\partial w}+\frac{\partial}{\partial x}\left(\mu\frac{\partial w}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial w}{\partial y}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial w}{\partial z}\right)+S_w \rightarrow S_z=-\frac{(1-\gamma)^2}{\gamma^3+\varepsilon}A_{mush}w$$

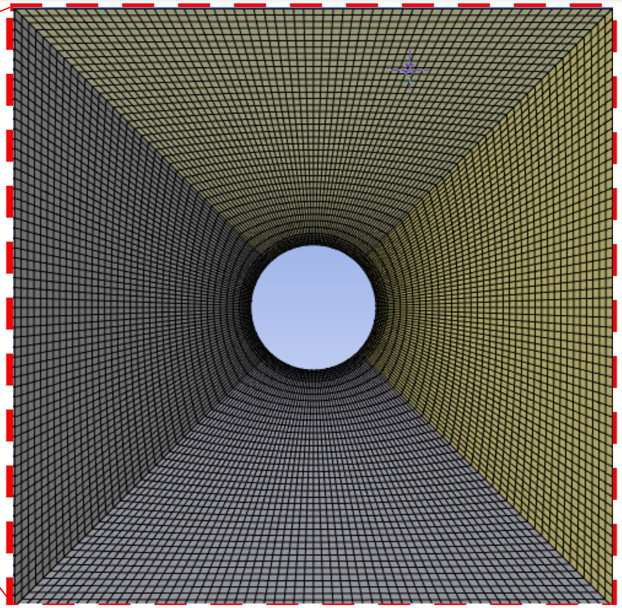
Energy:

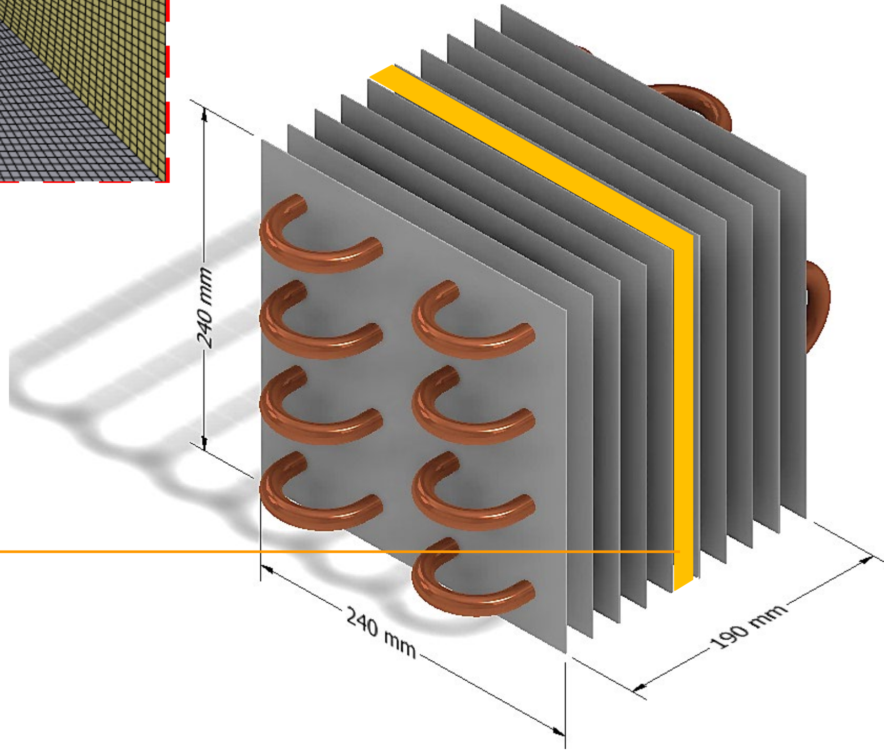
$$\frac{\partial}{\partial t}(\rho H)+\frac{\partial}{\partial x}(\rho uH)+\frac{\partial}{\partial y}(\rho vH)+\frac{\partial}{\partial w}(\rho wH)=\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right) \qquad H=h+\Delta H$$

$$\gamma=\frac{\Delta H}{h_{sl}}=f(x)=\begin{cases}0 & if\quad T<T_{solidus}\\ \dfrac{T-T_{solidus}}{T_{liquidus}-T_{solidus}} & if\quad T_{liquidus}<T<T_{solidus}\\ 1 & if\quad T>T_{solidus}\end{cases}$$

Numerical simulation of the melting process- Physical Domain and Computational Grid

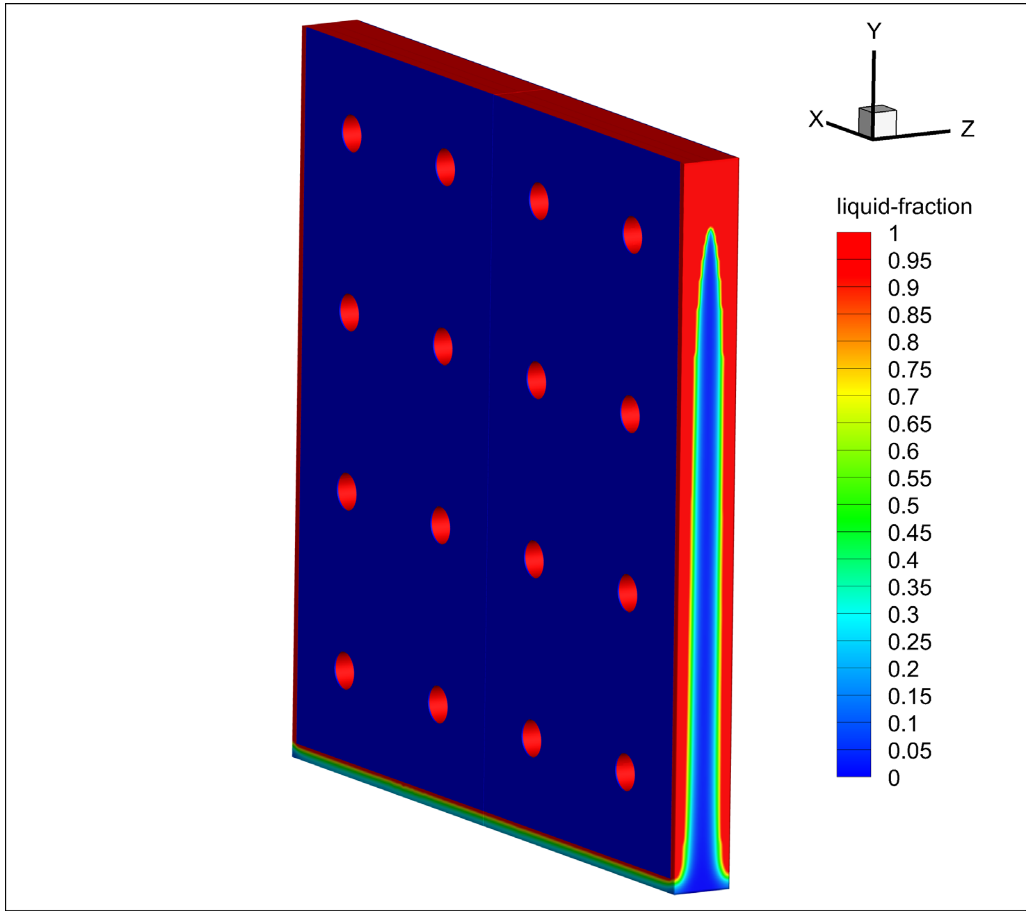




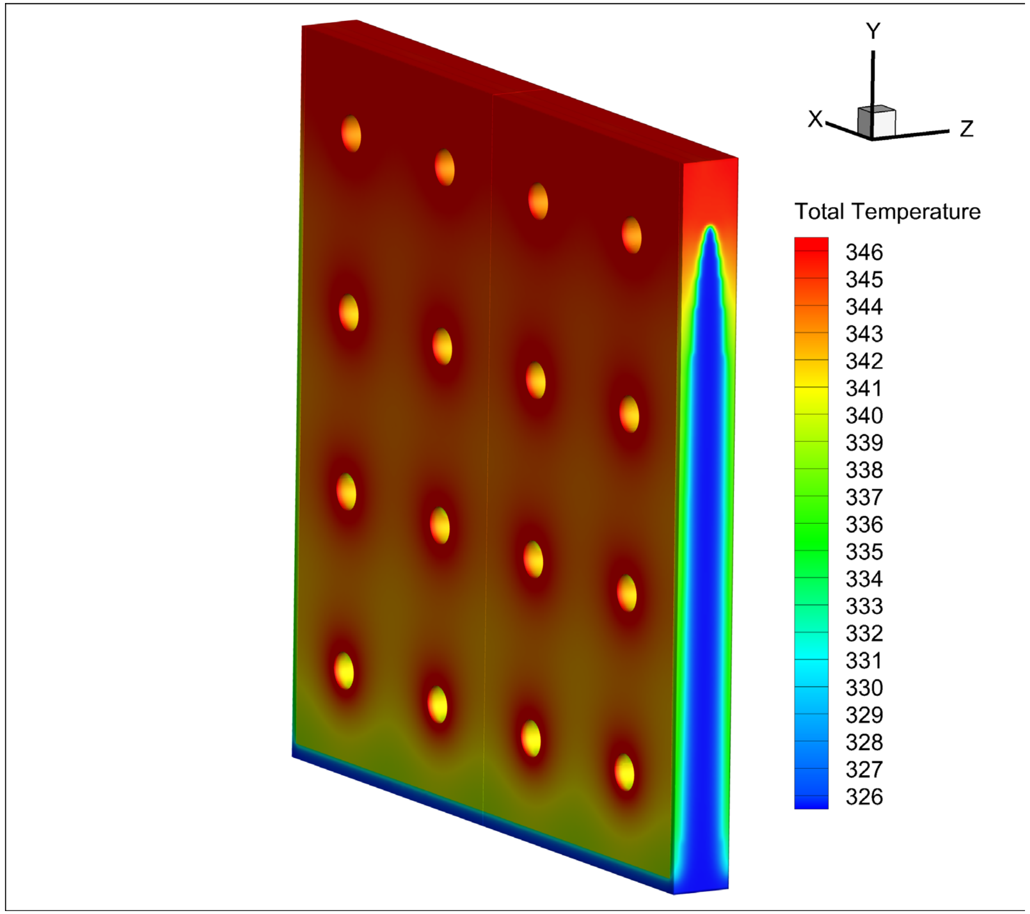


Computational Grid

Numerical Results

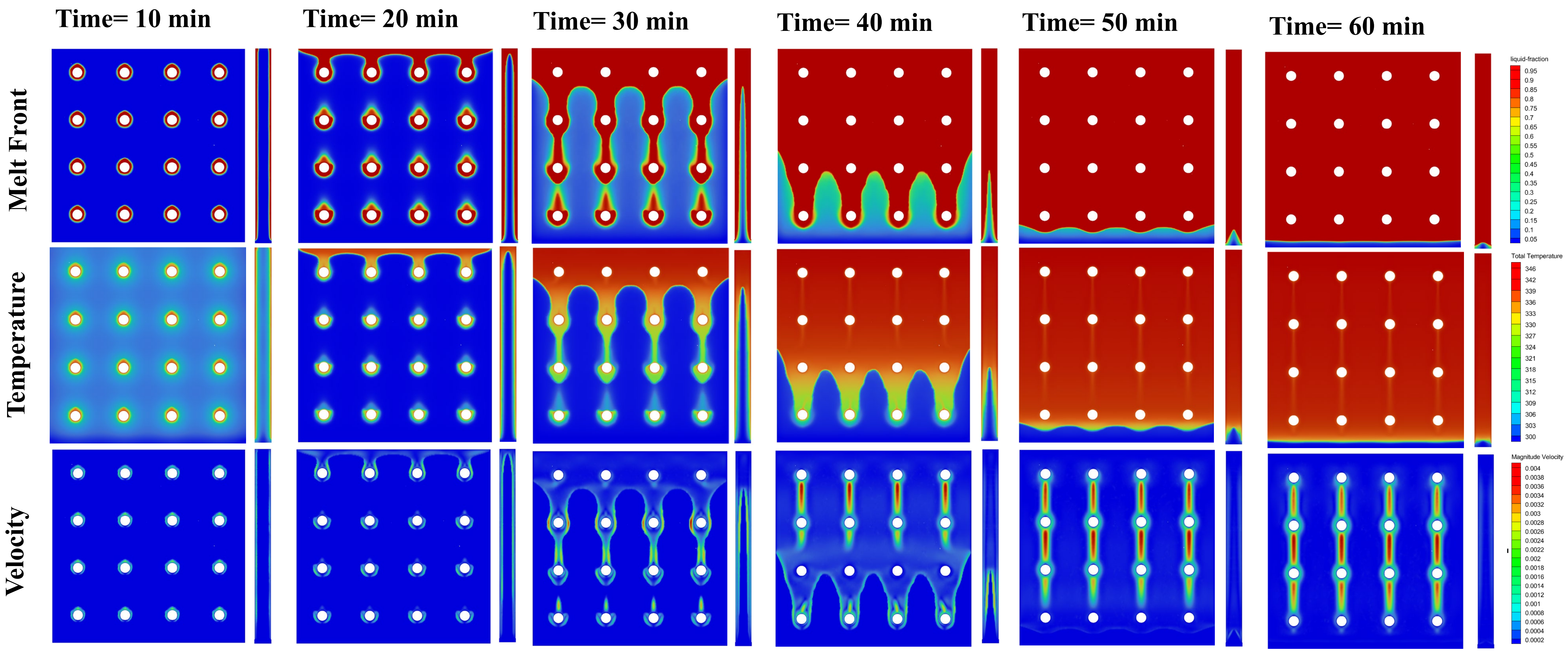


Phase field of PCM during the melting process

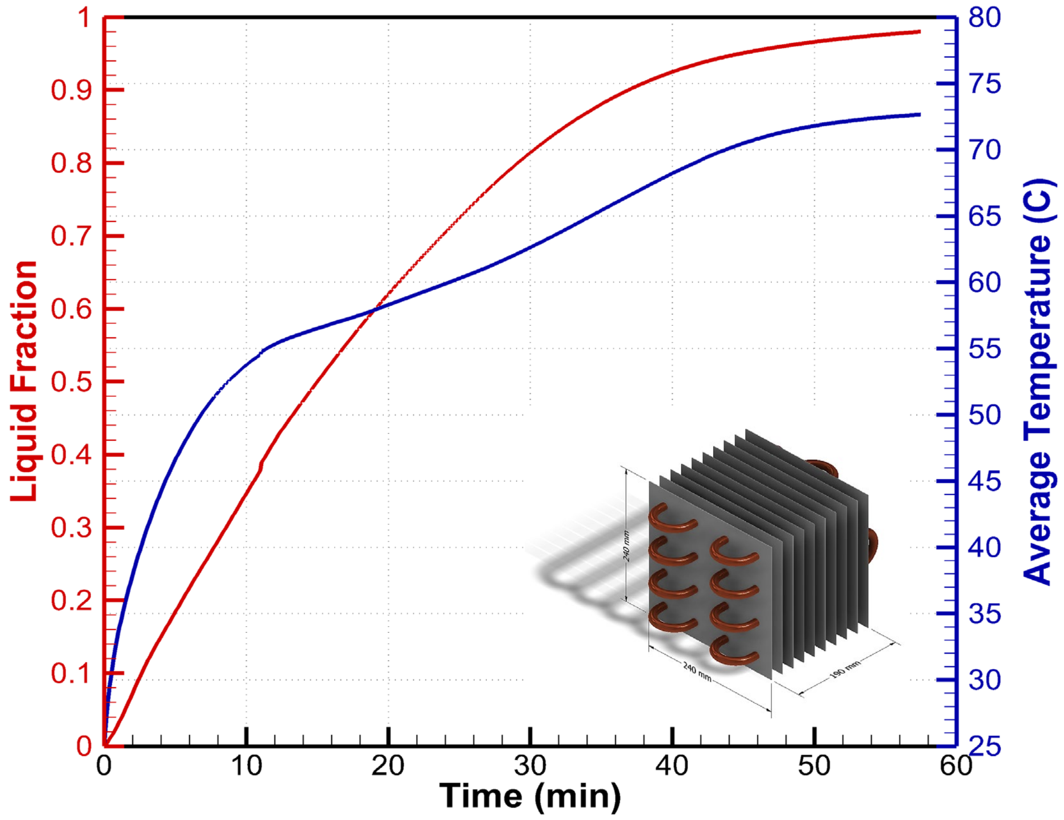


Temperature distribution of PCM during the melting process

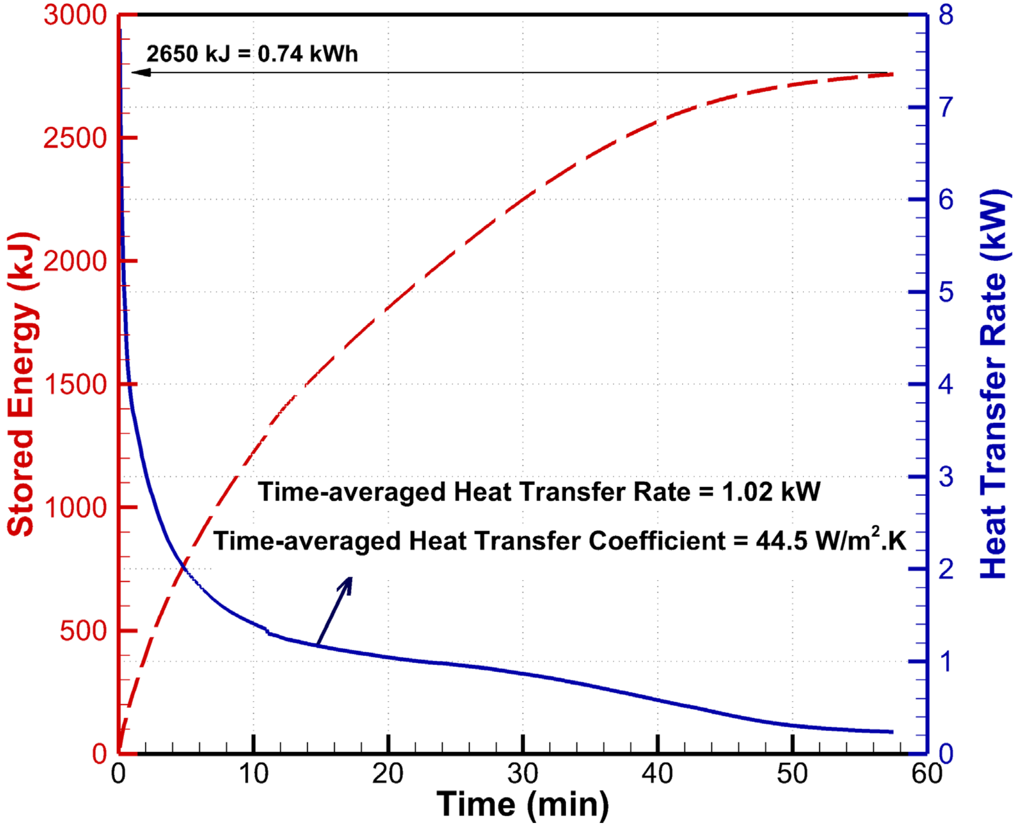
Melt front, temperature field and Velocity contours during melting process



Numerical Results for Plain Plate and Tube Heat Exchanger



Variation of liquid fraction and average temperature with time



Variation of stored energy and heat transfer rate with time

Melt Front Evolution

Temperature Distribution

Thank you for your attention

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