Assessment of Surface Roughness Effects on Encapsulated Phase Change Materials for Heat Transfer Enhancement

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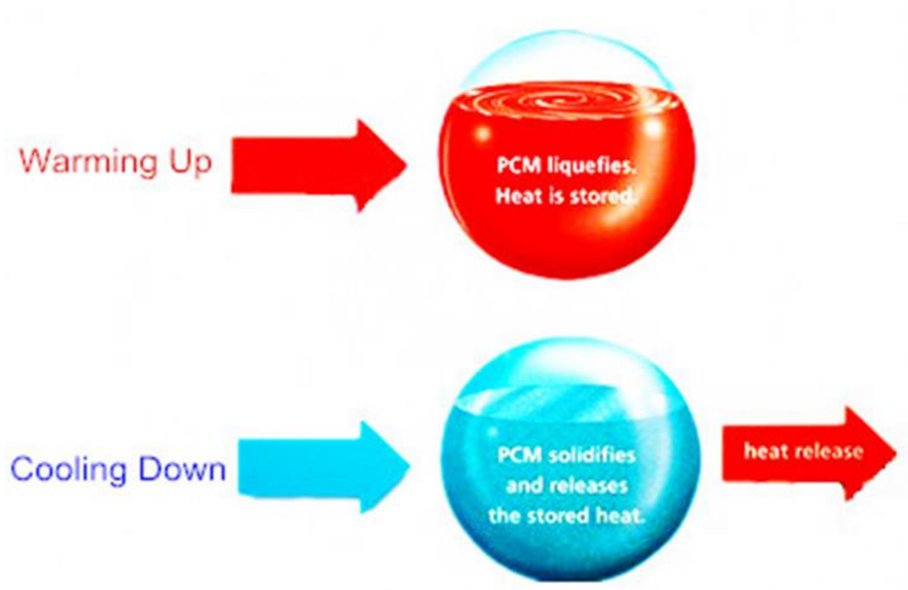
Motivation

- Phase changes in substances are at the core of many engineering applications of interest.
- Phase change materials are an enticing technology that can be used for thermal energy storage and for thermal management systems.
- Heat transfer techniques must be carried out to enhance their thermal response to phase change.
- Encapsulating PCM inside a capsule is a form of enhancing their thermal performance by maximizing their surface area. Yet, the geometrical shape of the capsule plays an important role in the phase change process.

Background

- Phase change materials, have shown promise in recent years due to their ability to store or release energy in the form of heat under near isothermal conditions when they undergo a solid-liquid phase transition.
- Thermal energy is stored in the PCM as latent heat when the material starts melting, while the stored energy is used later by cooling and solidifying the PCM.



- Encapsulating PCM inside capsules increases the specific surface area for faster heat transfer.

Numerical Model

- Numerical simulations were performed using a computational fluid dynamic software called STAR-CCM+.
- The physical model was composed of an axisymmetric 2D model of PCM encapsulated in a cylinder.
- The material that was selected as the PCM is paraffin wax.
- It was assumed that the density and thermal conductivity were constant throughout the melting process and independent on temperature.
- The mesh used for the simulations was a hexahedral mesh with 1500 elements.

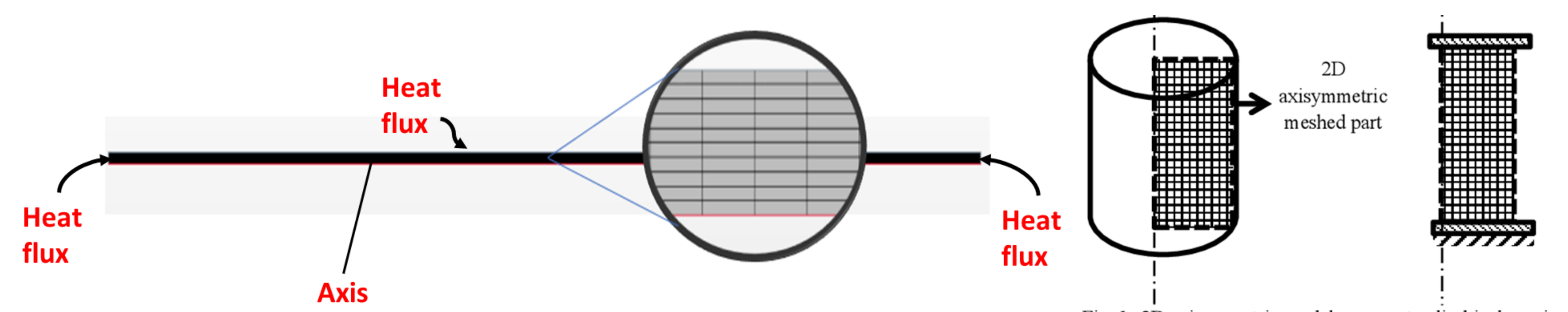


Fig. 1- 2D axisymmetric model represent cylindrical specimen

Preliminary Results and Discussion

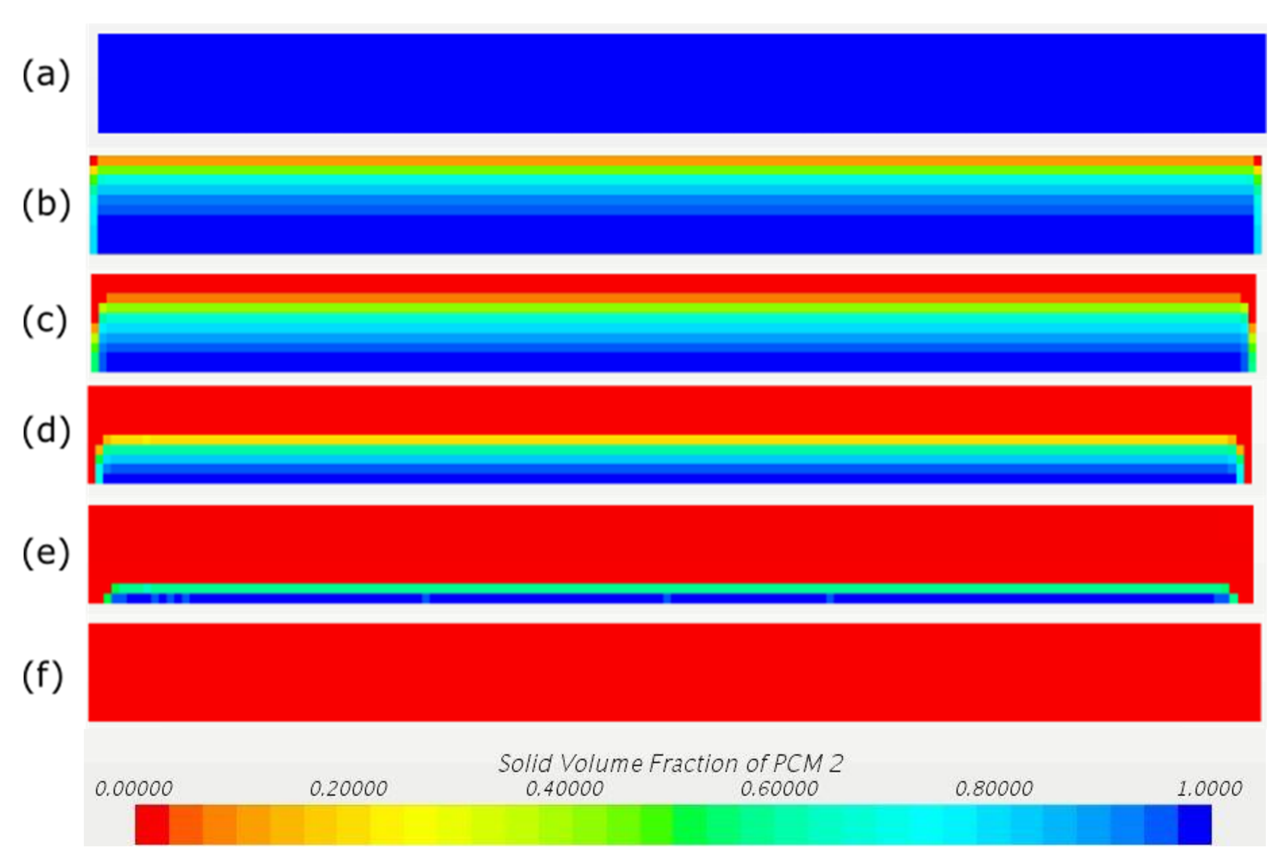


Figure 1. Solid volume fraction at different times (s): (a) 0, (b) 15, (c) 30, (d) 45, (e) 55, (f) 5.

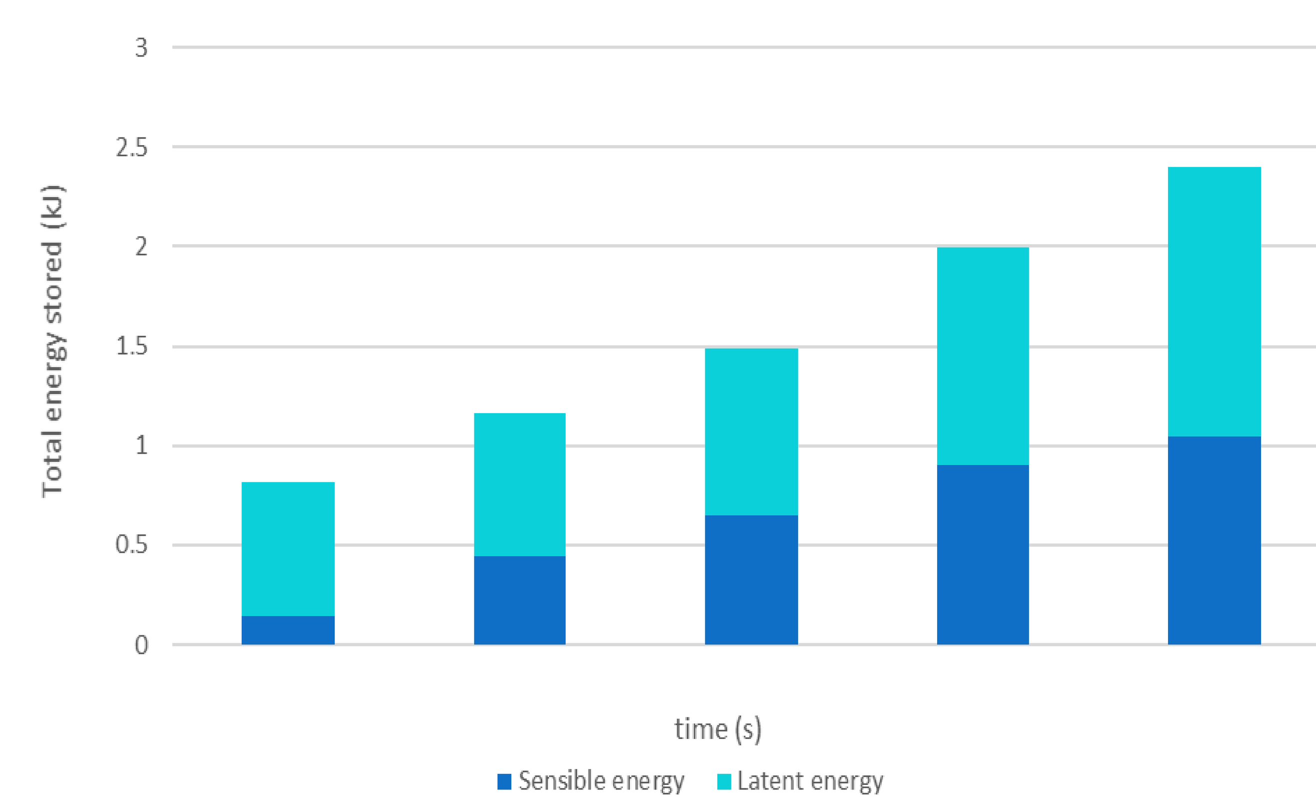


Figure 2. Total energy stored during melting process.

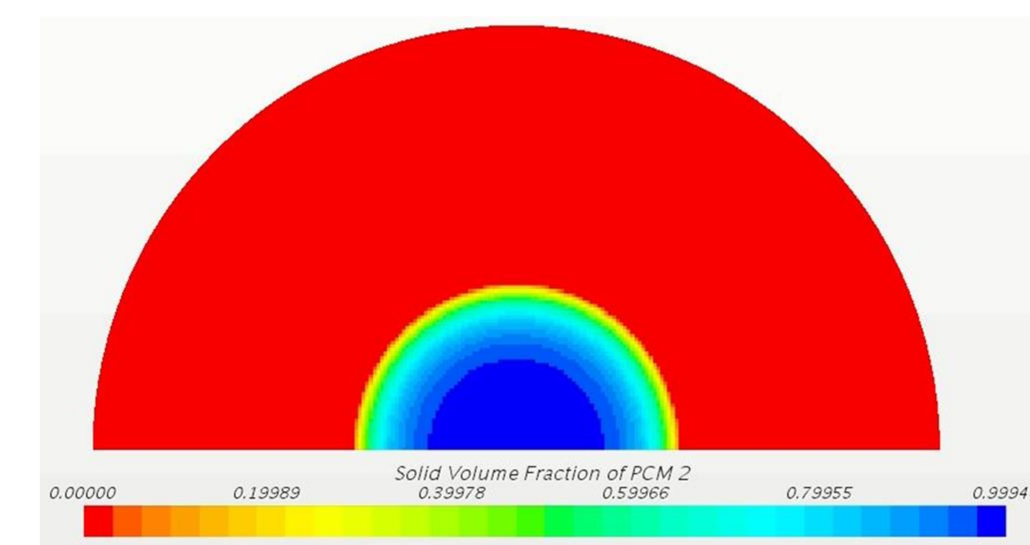
- The solid volume fraction represents the amount of solid PCM throughout the melting process.
- Due to heat conduction, as the temperature increases and reaches the PCM melting temperature, the PCM in the outer surface starts to become liquid and forms the phase interface.
- The total energy stored is approximately 2.4kJ when it completely melts after 58s. It can also be seen that of the total energy stored, 1.4kJ is due to latent heat and 1.0kJ is due to sensible heat.

Future Work

- The following case studies will be carried out:

Case	Geometry	Roughness
1	cylinder	smooth
2	sphere	smooth
3	cube	smooth
4	cylinder	rough (uniform)
5	sphere	rough (uniform)
6	cube	rough (uniform)
7	cylinder	rough (non-uniform)
8	sphere	rough (non-uniform)
9	cube	rough (non-uniform)

- For the spherical shape, an axisymmetric approach with a mesh of 1.1 million elements will be studied.



- All the different shapes will have the same volume and boundary conditions to isolate the shape effect only.
- An energy budget analysis will be performed for each geometry.
- Numerical results will be validated with data performed by other researchers.

Acknowledgements

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