Modeling And Simulation of Phase Change process in Ice Thermal Energy Storage

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Introduction

Ice Thermal Energy Storage is a form of Latent Heat Thermal Energy Storage in which water is used as the Phase Change Material which undergoes phase transformation during charging and discharging periods of operation.

Present study is focused on the phase change simulation using CFD analysis for the 2D model developed in the COMSOL Multiphysics ® software. Figure 1 depicts the 2D model used for simulation and the table alongside lists the dimensions of the variables used in the schematic.

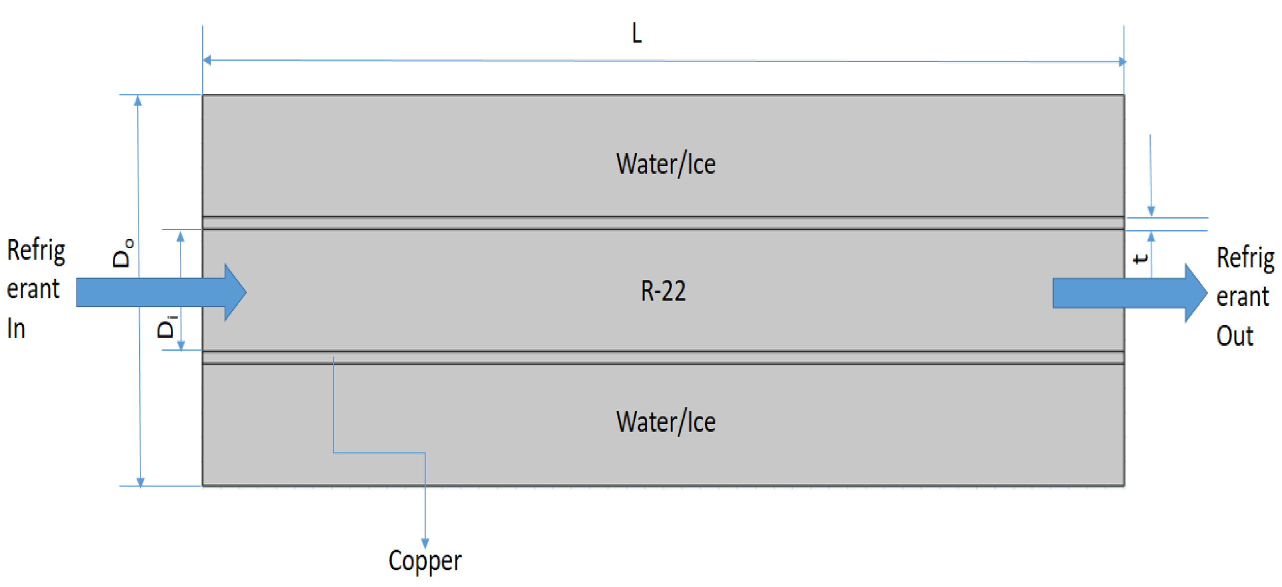


Figure 1. Schematic representation of the 2D model used for simulation

Parameter	Value
Di	10
Do	32
t	1
L	100

Table 1: Dimensions of the 2D model

Computational Methods

Incompressible laminar flow is assumed for both the discharging and charging periods. Actual conditions have been simulated for a small cut section of the helical coil heat exchanger to be used for experiment purpose. As the heat exchange is taking place while the fluid is flowing inside the conductor, the conjugated heat transfer physics using "Apparent Heat Capacity" method is used to simulate the heat transfer phenomenon for our case. The governing equations for fluid flow and heat transfer with phase change are as mentioned below :

$$\rho \frac{\partial u}{\partial t} - \nabla . \eta\left(\nabla u + (\nabla u)^T\right) + \rho(u.\nabla)u + \nabla p = 0$$

$$\nabla . u = 0$$

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p u.\nabla T + \nabla . T + \nabla . q = Q + q_0 + Q_p + Q_{vd}$$

$$q = -k\nabla T$$

$$\rho = \theta \rho_{phase1} + (1-\theta)\rho_{phase2}$$

$$C_p = \frac{1}{\rho}\left(\theta \rho_{phase1} C_{p_{phase\,1}} + (1-\theta)\rho_{phase2} C_{p,phase2}\right) + L\frac{\partial \alpha_m}{\partial T}$$

Mat.Properties	Ice	Water
Density (kg/m³)	918	997
Specific Heat Capacity (J/kgK)	2052	4179
Thermal conductivity (W/mK)	2.31	0.613

Table 2 : Material properties used for simulation

Similar equations can be written for K and α. Following table shows the input conditions used for discharging and charging periods.

Parameter	Value
Discharging Inlet Temperature	-10 ˚C
Discharging Outlet Temperature	-4 ˚C
Storage fluid temperature (Discharging)	0 ˚C
Charging Inlet Temperature	6 ˚C
Charging Outlet Temperature	-2 ˚C
Storage Fluid Temperature (Charging)	-6 ˚C
Heat Transfer Fluid (R-22) mass flow rate	0.00159 kg/s

Table 3: Input parameters for discharging and charging periods of Ice Thermal Storage

Results

The simulation was run for 4100s physical time for both discharging and charging cases, computational time to solve for both the periods was 20 min 20 s for charging period and 10 min 49 s for the discharging phase respectively.

Table 3 shows the phase transformation in discharging and charging periods respectively with time.

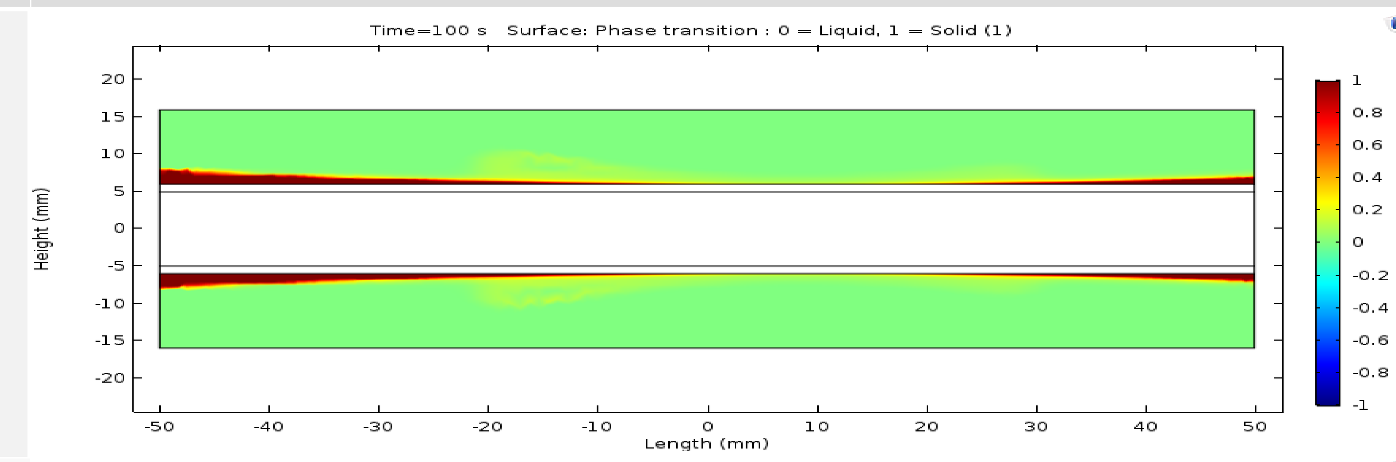
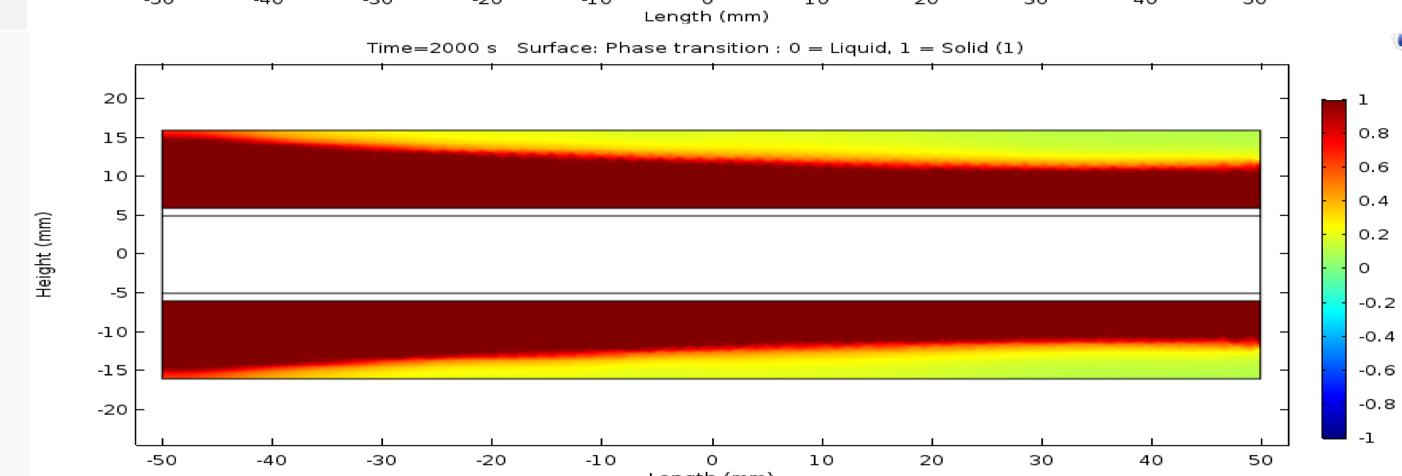
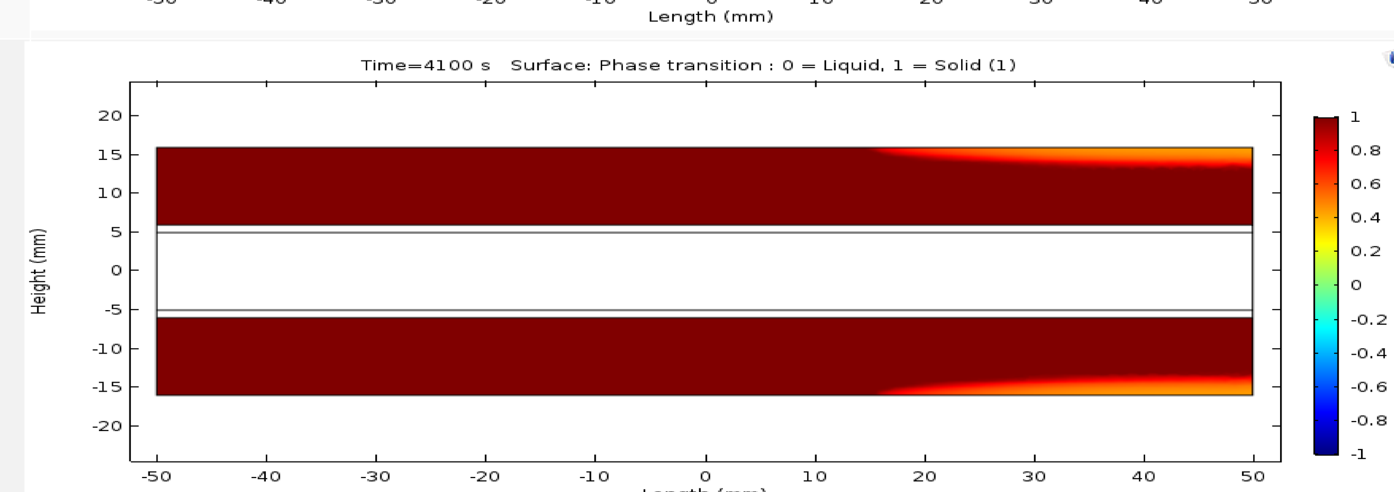
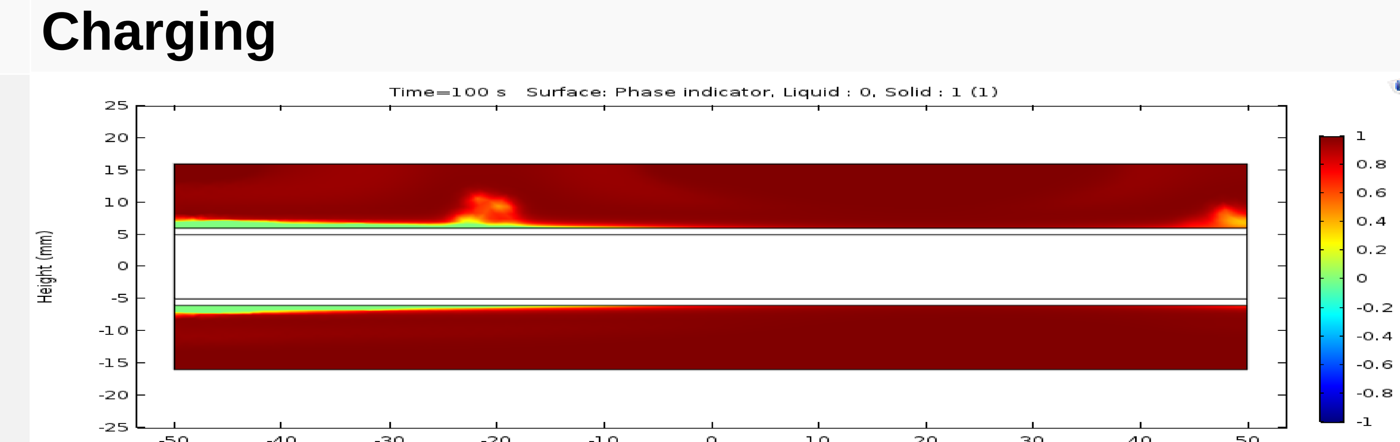
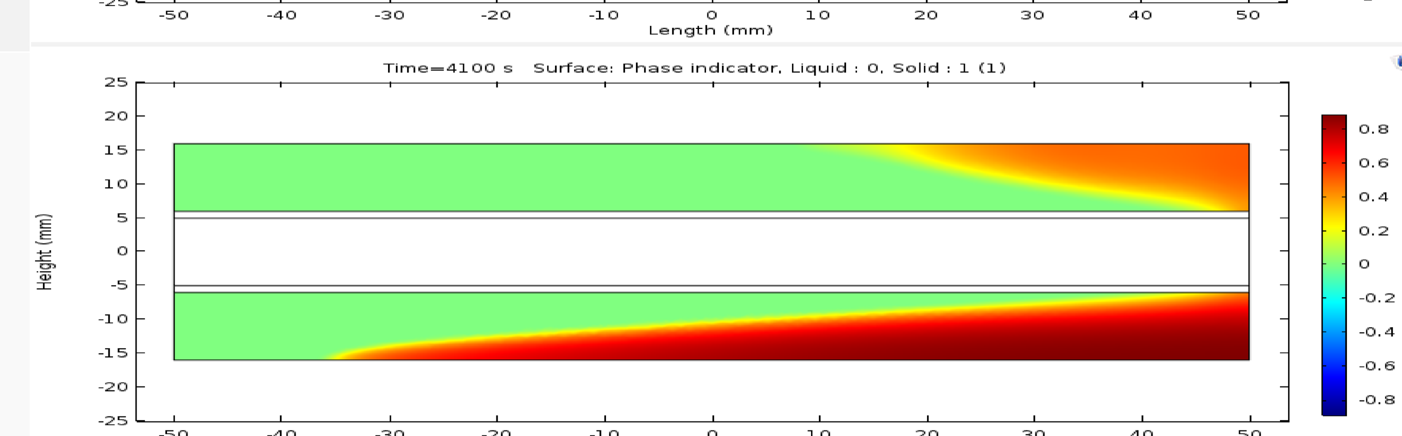
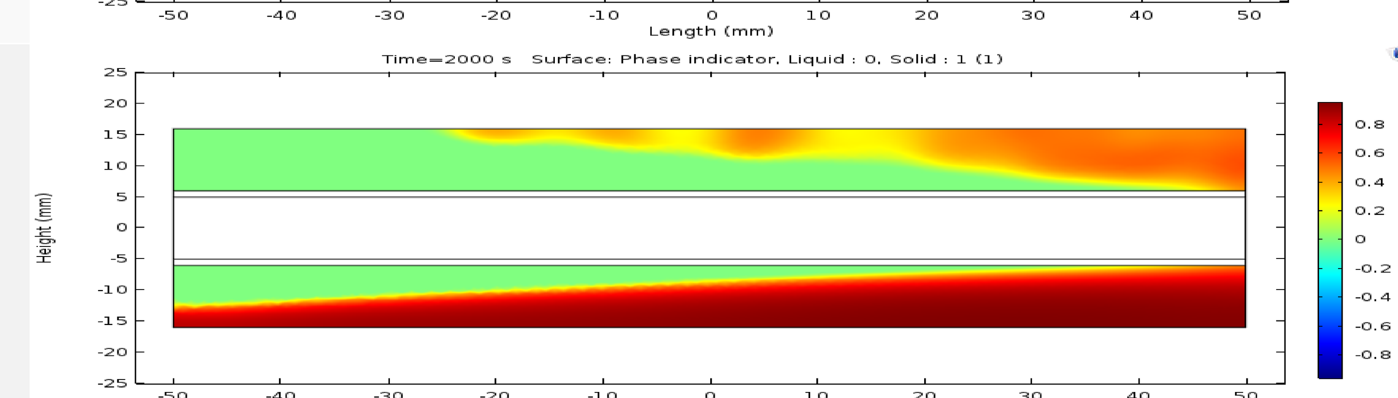
Time	Discharging
100 s	
2000s	
4100s	
Time	**Charging**
100s	
2000s	
4100s	

Table 3: Simulation results for discharging and charging periods at different times.

Conclusions: From the results obtained, it can be concluded that the phase change of water takes place after the heat exchange with refrigerant. Further study can be done on 3D models to obtain accurate predictions.

References:

1. Armand Fopah Lele, Thomas Ronnebeck, Christian Rohde, Thomas Schmidt, Frederic Kuznik, Wolfgang K.L.Ruck, Modeling of heat exchangers based on thermochemical material for solar heat storage systems, Energy Procedia 61 (2014) 2809-2813.
2. Mandhapati Raju, Sudarshan Kumar, Modeling of a helical coil heat exchanger for Sodium Alanate based On-board Hydrogen Storage system, Excerpt from proceedings of the COMSOL Conference 2010 Boston.
3. Andrea Mammoli, Matthew Robinson, Numerical analysis of heat transfer process in a low-cost, high-performance ice storage device for residential applications, Applied Thermal Engineering 128 (2018), 453-463.