A STUDY ON THE THERMAL ENERGY STORAGE SYSTEM USING MULTIPLE PCMS

Omer S. Elsanusi, Emmanuel C. Nsofor

Abstract

Application of Phase Change Materials (PCMs) for energy storage has been found to exhibit high potential due to the high energy storage capacity. This study investigated the performance of multiple PCMs in a number of energy storage systems. The effects of conduction and natural convection on the thermal energy storage systems were measured using the conservation equations were conducted on the defined geometries. It was found that natural convection has significant positive effects on the heat transfer in these systems. It was also found that application of multiple PCMs generally enhances performance. However, different effects were observed on the heat transfer mechanisms. The parallel configuration enhances heat suppression compared to the series configuration does the opposite. It was also found that the vertical orientation enhances convection more than the horizontal orientation for the multiple PCMs configurations. Energy storage with the series configuration in vertical orientation was found to be the superior with 47% and 60% reduction in complete melting time respectively, compared to the single configuration in vertical orientation and to the single and series configurations (horizontal and vertical) in the conduction only case.

Introduction

1. Sensible Heat Storage
2. Thermophysical Storage
3. Latent Heat Storage Using Phase Change Materials (PCMs)

Thermal Energy Storage (TES)

- Reasonable Choice when considering Solar Energy
- Classified into three methods [1]:
  1. Sensible Heat Storage
  2. Thermophysical Storage
  3. Latent Heat Storage Using Phase Change Materials (PCMs)

Thermal Conductivity enhancement with additives

<table>
<thead>
<tr>
<th>No.</th>
<th>Additive</th>
<th>Sources</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sodium Carbonate, Magnesium Carbonate, and Calcium Carbonate</td>
<td></td>
<td>Effective in melting point and latent heat of water and other electrolyte melts.</td>
</tr>
<tr>
<td>2</td>
<td>Paraffin and Microencapsulated PCM</td>
<td></td>
<td>Suitable for high heat storage capacity.</td>
</tr>
<tr>
<td>3</td>
<td>Nanoparticles (Graphite and Carbon Nanotubes)</td>
<td></td>
<td>Improves thermal conductivity and heat transfer rate.</td>
</tr>
<tr>
<td>4</td>
<td>LiBr or other halide salts</td>
<td></td>
<td>Increases latent heat of fusion.</td>
</tr>
</tbody>
</table>

Use of Multiple PCMs

- Increased Energy Demand
- Fossil Fuels Depletion
- Environmental and Ecological Concerns

Renewable Energy

- Solar, Wind, Hydro, ...
- Present high potential to address energy challenges

Obstacle

- Fluctuation nature
- Efficient means of energy storage are needed

Phase Change Materials (PCMs)

Advantage

- Have high energy storing densities

Disadvantage

- Have low thermal conductivities lead to low heat transfer rates and hence slow energy storage and recovery processes

Mathematical Model

- Heat transfer and fluid dynamics of this setup are governed by:
  - The mass conservation equation
  - The momentum conservation equations
  - The energy equation
- Assumptions:
  - No slip boundary condition
  - Negligible resistance and no heat loss to the surroundings
  - All the thermophysical properties are constant except for the working fluid temperature dependency and the PCMs phase change temperature dependency
- Computational Method:
  - Navier-Stokes equations for the momentum equation taking into account the density variation
- Results

- Conduction heat transfer only (Case 1)
  - Single PCM configuration
  - Complete melting time: 10 hours
  - PCMs in series configuration
  - Complete melting time: 13 hours
  - PCMs in parallel configuration
  - Complete melting time: 1 hour
  - Reduction in melting time is 40%

- Conduction and natural convection in vertical orientation (Case 2)
  - Single PCM configuration
  - Complete melting time: 4 hours
  - PCMs in series configuration
  - Complete melting time: 7 hours
  - Reduction in melting time is 57%

- Conduction and natural convection in horizontal orientation (Case 3)
  - Asymmetric assumption not valid
  - Single PCM configuration
  - Complete melting time: 8 hours
  - PCMs in series configuration
  - Complete melting time: 10 hours
  - Reduction in melting time is 25%

Conclusion

- Natural convection has a significant positive effect on the heat transfer characteristic of the systems.
- The application of multiple PCMs generally enhances performance.
- Different configurations and orientations have different effects on the heat transfer mechanisms.
- Energy storage with the series configuration in vertical orientation was found to be superior with 47% and 60% reduction in complete melting time respectively, compared to the single configuration in horizontal and vertical orientation respectively.

References