A Novel Energy Saving Wood Product with Phase Change Materials

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Abstract

Phase change materials (PCM) are utilized for thermal energy storage. Structure and properties of PCM have been studied extensively in the past because they are highly correlated to materials’ energy saving ability and application. However, with the quickly growing requirement of PCM application in buildings, to reduce our reliance on air conditioning and heating through solar energy storage, the problem of PCM leakage must be solved first. This study is focusing on verification of the feasibility of manufacturing a novel energy saving wood product with PCM, using wood as a low cost porous structure material for PCM instead of the porous materials that are widely studied. Scanning electron microscope (SEM) imaging was carried on to investigate the possibility of paraffin to get into lumen of wood chips. The ability of wood flour to absorb paraffin is calculated. PCM and wood flours were compounded utilizing a parallel co-rotating twin screw extruder. Melting and crystallization behavior of the blends were investigated by differential scanning calorimeter (DSC). Based on the hypothesis that wood encapsulation and polymer sealing can help to restrict leakage of PCM, a novel energy saving wood product with PCM by using wood lumen as containers of PCM is possible to be made.

Keywords: Phase change materials, wood product, energy saving, composites, paraffin
INTRODUCTION

Thermal energy can be stored in several ways, sensible heat, thermochemical, and latent heat. Phase change materials possess high energy storage density and isothermal operating characteristics making them very efficient materials for utilizing latent heat in application [1-3]. Many researchers are focusing on organic PCM, inorganic PCM, and eutectics[4] for passive solar energy storage, all very promising areas for energy saving in buildings. Phase change materials can be implemented in the walls of buildings. When absorbing energy instead of the interior of buildings, the phase of PCM can be changed from solid to liquid. When the ambient temperature drops, PCM begins to solidify, releasing stored thermal energy to the building and stabilizing the interior temperature. The temperature of PCM will be maintained closer to the desired temperature during each phase transition period for a long period of time until the phase change is complete. In this way, PCM can be used to increase human comfort by decreasing swings in internal air temperature[5]. Energy conservation is achieved through this reversible and repeatable phase change.

The primary phase change of interest in the proposed work is the solid-liquid change in PCM. Other types of phase change store and release latent heat energy during transition, but they are impractical for most energy storage applications. In solid-liquid PCM, exudation occurs after the PCM absorbs enough energy to complete the phase change to liquid, undermining its application value. Controlling this leakage is the current major obstacle to the use of PCM in the thermal envelopes of buildings. Encapsulation is widely applied to contain PCM to prevent leakage. But this method comes with some issues, such as low flame retardancy and thermal conductivity with the core-shell structure, low chemical and thermal stability, and high cost[6, 7]. To use porous structure materials, such as expanded perlite (EP), diatom earth (DE), expanded graphite[8-10], concrete[11], porous metallic foams[12] and so on, instead of conventional encapsulation method is a promising way to capture PCM and protect it from leakage when melting.

For a mature cell in wood in which there is no protoplast, the open portion of the cell is known as the lumen. Most wood cells in wood have two domains which are the cell wall and the cell lumen[13]. The cell lumens are connected by pits by which cell walls are modified to allow communication between the cells in the living plant[13]. The objective of this study is to verify the feasibility of manufacturing a novel energy saving wood product with phase change materials, using wood as a low cost porous structure material for PCM instead of other porous materials which have already been widely studied.

MATERIALS AND METHODS

Materials. The materials used are paraffin (Technical Octadecane) from Roper Thermals, Ponderosa pine flour from American wood fibers, and maple chips.

SEM. The maple chips are soaked in melt paraffin for 10 min followed by SEM imaging.
Extrusion. Paraffin and WF (40, 60, 80 mesh) mixtures in 60/40, 70/30, and 80/20 (wt%) ratios were prepared, respectively, and blended in a co-rotating twin screw extruder (Leistritz ZSE-18HP) at 50°C.

DSC. The melting temperature and crystallization temperature of paraffin in composites were determined using a differential scanning calorimeter (DSC) in the range from 0 to 75°C. The scanning rate was 10°C/min.

RESULTS AND DISCUSSION

Wood is a natural structural material with a honeycomb-like microstructure. Fig.1 shows a SEM image of paraffin infiltration into maple lumen. The lumen size may influence paraffin infiltration. If sealing a layer of plastic on the external surface of wood, we can achieve a good encapsulation of PCM in wood composites.

The result above shows that it is possible to encapsulate PCM into wood. In addition, how much PCM could be encapsulated? To estimate how much PCM could be penetrated into wood, the density values in table 1 are used.

<table>
<thead>
<tr>
<th>Species</th>
<th>Density (g/cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ponderosa Pine</td>
<td>0.35</td>
</tr>
<tr>
<td>Paraffin</td>
<td>0.65</td>
</tr>
<tr>
<td>Wood cell wall</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Table 1 Density

Wood porosity (Φ) is calculated as follows.

\[
\phi = 1 - \frac{1/\rho_{\text{cellwall}}}{1/\rho_f} = 0.77
\]
Assuming that paraffin fills wood lumen completely, we calculate the maximum paraffin weight fraction in the mixture as follows.

\[ W_p = \frac{\rho_p \phi}{\rho_p \phi + \rho_{cellwall}(1-\phi)} = 0.59 \]

In the equations above, \( \rho \) is density, \( f \) represents fiber, and \( p \) represents paraffin.

DSC results in figure 2 show that after blending with wood flour, paraffin maintains its phase change and its energy saving ability is not removed. Besides, based on our study on miscibility of polyethylene (PE)/Paraffin blends, after blending with PE, paraffin functions well, too. Further, with the help of plastic, good encapsulation of PCM is expected to be achieved. Thus, it is possible to make a novel energy saving wood product with phase change material (paraffin) and polyethylene.

![Figure 2. Influence of wood flour content on melting and crystallization of paraffin](image)

**CONCLUSIONS**

It is possible to make a novel wood product with PCM by using wood lumen as containers of PCM for efficient energy saving. The encapsulation of paraffin with wood flour and plastic combined together needs to be studied. Composites formulation and wood lumen size need to be considered as well.

**References**

Acknowledgments

I’m grateful to my professor Dr. Michael Wolcott’s advice, encouragement and patience. Useful discussions with Dr. Bo Liu are greatly appreciated.