Thermal Absorption and Insulation Using Phase Change Material

Abstract

A major problem with many homes is their inability to regulate internal temperatures, resulting in the use of costly energy based heating and cooling systems. By combining phase change material (PCM) and copper mesh to use as insulating thermal absorption material, it can eliminate the need for conventional cooling and heating systems allowing saving in energy, cost, and the environment. A proof-of-concept tile was fabricated using PCM and copper mesh that can absorb thermal energy from the sun, and regulate the internal temperatures of a test chamber, keeping it at 25°C for duration of 6 hours. A CAD model of the tile is shown in figure 1.

Project Objectives

• Test the feasibility of using PCM for insulation and thermal absorption purposes.
• Maintain room temperature at 25°C while the external temperature ranges from 15°C to 40°C.
• Design a copper mesh layout to evenly distribute thermal energy and lower surface temperature to prevent thermal pollution.
• Keep the tile under 2 lbs and a size of 4"x4"x2".
• Develop a 3-D analytical COMSOL model that can be used to predict and correlate experimental data as well as be used to assist in design.
• Compare insulation performance to conventional corning insulation material.

Design

The first step of the design phase was choosing non-hazardous polyethylene glycol, with a melting temperature of 22°C as the PCM. This allowed the tile to undergo phase changes in an environment such as Santa Barbara’s. The next step was designing the casing for the tile. The housing is made of clear acrylic which has good insulation properties allowing the heating to only occur at the top of the tile. The top cover is an aluminum plate which allows the heat to be better absorbed into the PCM. The next step in the design process was to incorporate the mesh to provide an even heat distribution throughout the PCM so that it can absorb more energy and bring the top surface temperature down while maintaining the bottom surface temperature below 25°C. The final layout of the mesh we used was a 4x4 virtual cross layer using a mesh screen size of 50.7% open area. To address the over flow problem that occurred as the PCM melted and caused volume expansion, we made a flexible plate at the bottom of the tile that would bend and expand as the PCM inside the tile expanded.

Results

The results of our senior design project was a proof-of-concept 4”x4”x2” tile made with Polyethylene Glycol and copper mesh. It is able to absorb thermal energy from the sun and insulate a test chamber at 25°C under external temperatures of 15°C to 40°C for 2 to 6 hours. In addition a correlating analytical 3-D COMSOL model was developed that can be used to correlate experimental data and help in further project development.

Further Development

With further development, the tile could be used to insulate thermal energy during the day and at night used the energy it has captured to release back into the home. By designing a system to release the energy into the home when temperatures drop below 25°C at night, it could completely eliminate the need for electric based heating systems. One possible solution is based on the PCM shutter design introduced in a research paper by Buddhi. A diagram is shown in figure 5.

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