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Effect of Fin Number and Distribution on Heat Transfer and Energy Storage in PCM-Based Thermal Systems

Jacob O'Neill, Ryan Clemmer, Shohel Mahmud, Syeda Humaira Tasnim
School of Engineering, University of Guelph, Guelph, Ontario N1G 2W1, Canada
First.joneil04@uoguelph.ca; Second.rclemmer@uoguelph.ca; Third.smahmud@uoguelph.ca; Fourth.stasnim@uoguelph.ca

Extended Abstract

Latent heat thermal energy storage systems (LHTESS) are often integrated with solar thermal collectors to enhance their efficiency in residential air and water heating, where phase change materials (PCMs) store heat during melting and release it during solidification. However, the low thermal conductivity of most PCMs slows charging and discharging, making performance improvements essential. Fins are widely used to address this limitation by increasing heat transfer surface area and reducing the distance between heat transfer surfaces and PCM. This study numerically investigates the effect of fin geometry on thermal performance including melting time, average temperature, heat transfer, and energy stored, comparing straight and curved fins in single-PCM storage units under identical conditions. Three PCMs were tested: n-octadecane, Rubitherm RT-42, and coconut oil, chosen for their moderate melting points suitable for residential applications. Fins were incorporated to a numerical model in various geometries altering the number of primary fins, the number of secondary fins, and the half length of each secondary fin, all while maintaining the total fin length. Maintaining the total fin length ensures that the mass of PCM remains constant throughout all trials which allows for a more in-depth analysis of melting behaviours. Results show that both fin geometry and PCM type strongly influence melting and solidification behavior. Across all PCMs, curved fins consistently outperformed straight fins by reducing the maximum distance between heat source and PCM, leading to faster and more uniform melting and enhancing natural convection within the liquid phase. Straight fins provided directional conduction but left underutilized PCM zones, particularly in the outer regions; increasing fin number reduced this effect but yielded diminishing returns when fins were unevenly distributed. Among the PCMs, Rubitherm RT-42 required longer charging times due to its higher melting temperature, though it still showed substantial improvement with curved fins; coconut oil, with its lower latent heat, melted fastest but also benefited from curved geometries. Overall, curved fins improved heat transfer efficiency across all PCMs by minimizing thermal resistance paths, while the differences among PCMs highlighted the importance of matching fin design with material properties. This study demonstrates that optimizing fin geometry, particularly through the use of curved fins, combined with careful PCM selection such as n-octadecane, RT-42, or coconut oil, can significantly accelerate charging and discharging, improve temperature uniformity, and enhance the practicality of solar thermal storage for residential heating applications. By showing how fin design and PCM properties interact to govern melting dynamics, this work underscores the importance of integrated design optimization for efficient latent heat thermal storage systems in residential solar heating applications.