Master of Science in Engineering

Additive manufacturing of PCM material for optimized heat exchange

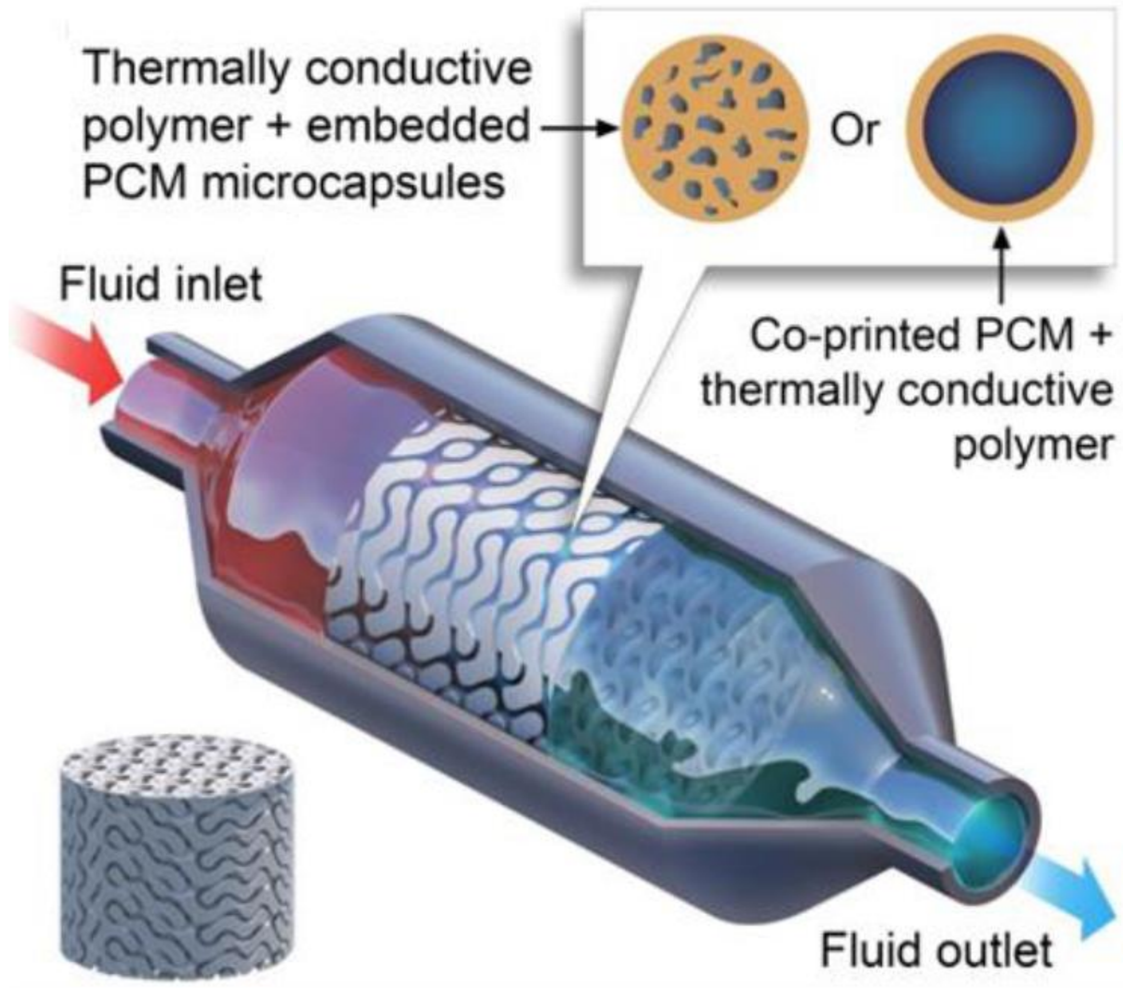

Figure 1: Illustration of concept where the developed latent heat storage device is placed in a tube as regenerator. Picture adapted from Wale Odukomaiya, National Renewable Laboratory.

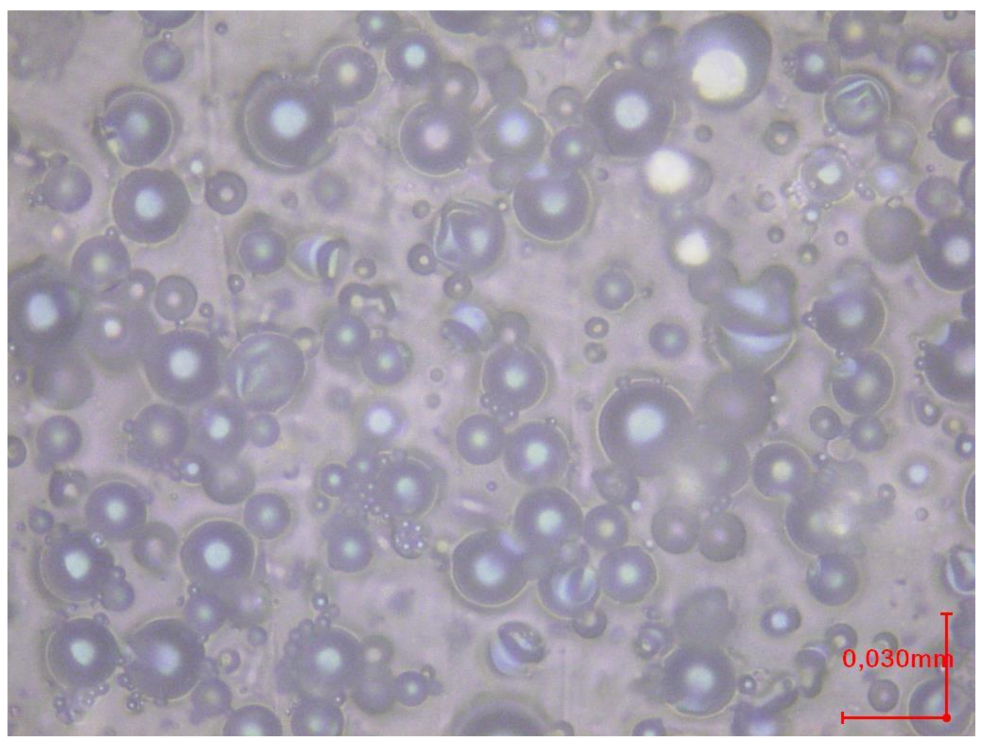

Figure 2: Close up picture with 50 times zoom of a 50wt% composite. Here the microcapsules are good visible.

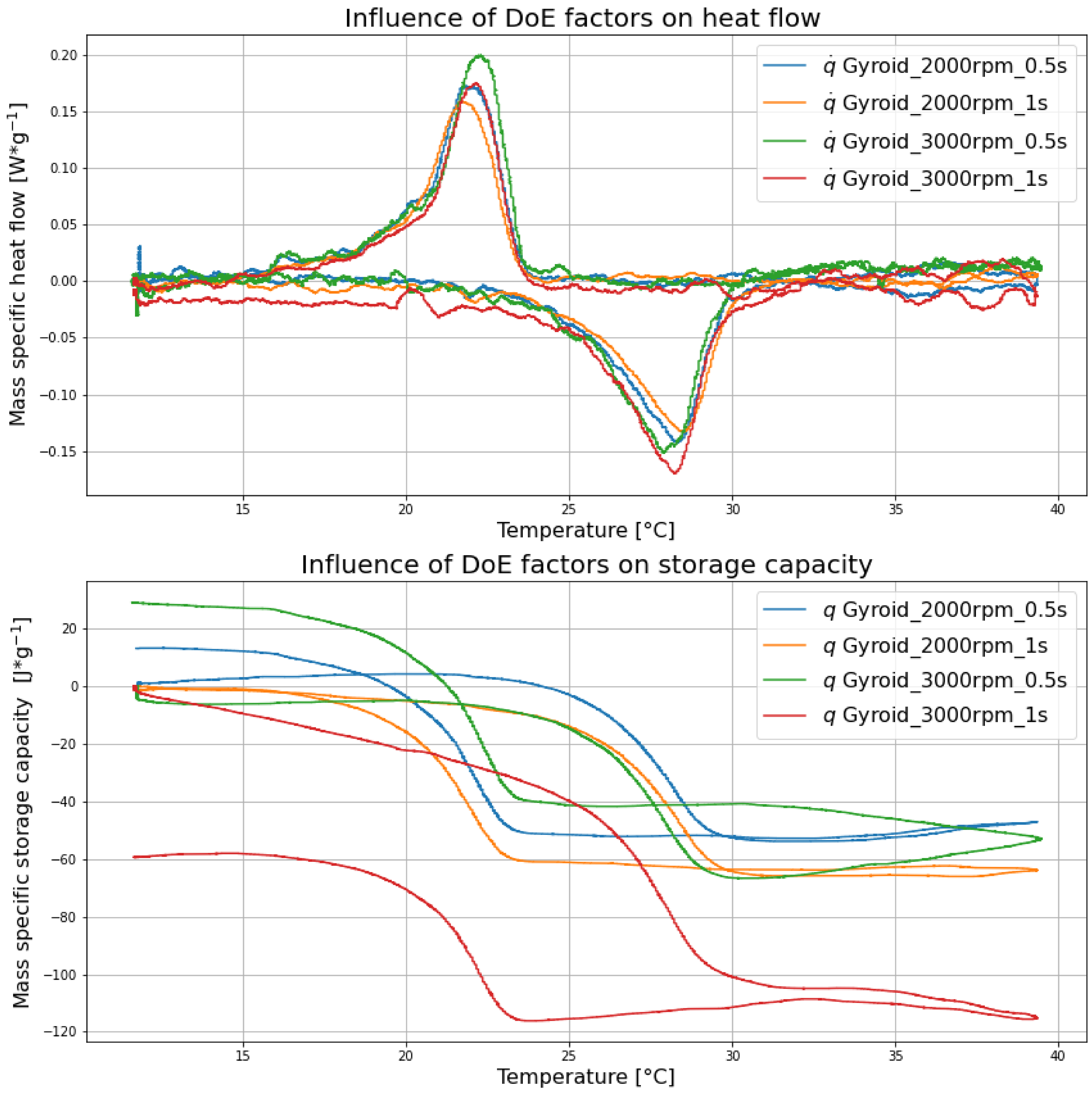

Figure 3: Result of a Desing of Experiment with a Gyroid lattice with 2mm wall thickness and 8mm cell size to identify best operation settings. As influencing factors were pump speed in rate per minute (rpm) and sampling rate in seconds defined.

Problem definition

The global demand for energy has been steadily rising, driven by population growth, industrialization, and technological advancements. This increased energy consumption has led to concerns about the sustainability of our current energy systems and their environmental impacts, particularly the reliance on fossil fuels and the associated greenhouse gas emissions. One of the key challenges in transitioning to a more sustainable energy future is the need to efficiently store and manage energy from intermittent renewable sources, such as solar and wind, to ensure a reliable and stable energy supply. This necessitates the development and implementation of advanced energy storage technologies. The Competence Center for Thermal Energy Storage, short CCTES, specializes in thermal storage solutions. CCTES proposes the manufacturing of a thermal energy storage system using additive manufacturing techniques.

Concept

The employment of microencapsulated phase change material (PCM) is suggested as a viable solution. This material is intended to be blended within a light-curing resin and subsequently printed utilizing a light-curing printing technology, such as Digital Light Processing (DLP).

Results

With an entry-level DLP printer valued at approximately 250 CHF, composites containing up to 50 wt% PCM were successfully manufactured. The mixture, consisting of 40 wt% PCM, was utilized for 3D printing heat storage devices designed with the assistance of nTopology. The chosen geometries were triply periodic minimal surfaces, renowned for their advantageous large surface areas in the context of heat exchangers. The developed heat storage devices showcase a calculated benchmark storage capacity of 30-40 kWh/m³. Employing a test setup, the calculated benchmarks were achieved within the range of 80-95%.

Optimal operational settings were identified using the Desing of Experiment (DoE) method. A low volume flow resulted in minimum deviation at the end of the process as can be seen in Figure 3. The cycle capability was demonstrated through 10 charging and discharging cycles. No tendencies were detected within these numbers of cycles.

Future implementations of the methods and concepts suggested in this work are recommended and seem highly probable, especially assuming that material costs can be reduced, heat storage capacities optimized and printing efficiencies improved.

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