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DOI
10.1016/j.sctalk.2025.100439

Publication date
2025

Document Version
Final published version

Published in
Science Talks

Science Talks 14 (2025) 100439

Contents lists available at ScienceDirect

Science Talks

journal homepage: www.elsevier.es/sctalk

Commercially focused strategies to enhance PCM thermal conductivity in latent thermal energy storage systems

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ARTICLE INFO

Keywords:
Phase change material
Cost analysis
Thermal conductivity enhancement
Metal foam
Latent energy storage

ABSTRACT

It is widely recognized among specialists that PCMs (Phase Change Materials) typically have low thermal conductivity, which significantly restricts their commercial use. This study presents alternative, low-cost, yet effective approaches to enhance the average thermal conductivity of a PCM system (a commercially available paraffin wax with a phase change temperature around 40 °C) intended for thermal energy storage. The system contains 600 g of PCM within an annular space around an inner tube, through which heat is either added to or removed from the PCM. Experiments were conducted to assess the effects of water flow rate and temperature, used as the heat transfer fluid, on the system's performance. The flow rate was varied from 2 to 8 L/min, and the temperature was set between 45 and 55 °C. We tested three types of aluminum-based thermal enhancers: a commercial metal foam, a wire mesh, and irregular aluminum flakes (chips) produced as waste from machining processes. The PCM-only sample required the longest time for both charging and discharging, while the PCM with metal foam had the shortest times. The intermediate solutions, using chips and wire mesh, showed moderate phase change times. To evaluate the economic feasibility, we introduced a performance metric based on cost per phase change rate, showing that these two affordable thermal conductivity enhancers could play a vital role in promoting the broader application of latent thermal energy storage technology across various fields.

Video to this article can be found online at https://doi.org/10.1016/j.sctalk.2025.100439.

Tables and Figures

Table 1
Cost analysis of a 15kWh case study.

	PCM cost	Metal insert cost	Total cost	Total energy stored	Cost per stored energy	Average time estimated for 1 cycle (47 °C and 4 L/min)	Cost * cycle time/energy stored
	€	€	€	kWh	€ /kWh	min	€ /kW
PCM only	1500	–	**1950**	15.05	**130**	190	**410**
PCM + foam	1425	10,000	**11,875**	14.30	**831**	20	**277**
PCM + chip	1425	25	**1900**	14.30	**133**	75	**166**
PCM + wire mesh	1425	200	**2075**	14.30	**145**	140	**338**

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http://dx.doi.org/10.1016/j.sctalk.2025.100439
Received 23 December 2024; Received in revised form 5 February 2025; Accepted 20 February 2025
Available online xxxx
2772-5693/

Fig. 1. Description of the Department of Management and Engineering.

Fig. 2. Research group picture.

Fig. 3. Picture of the test sample full of metal chips.

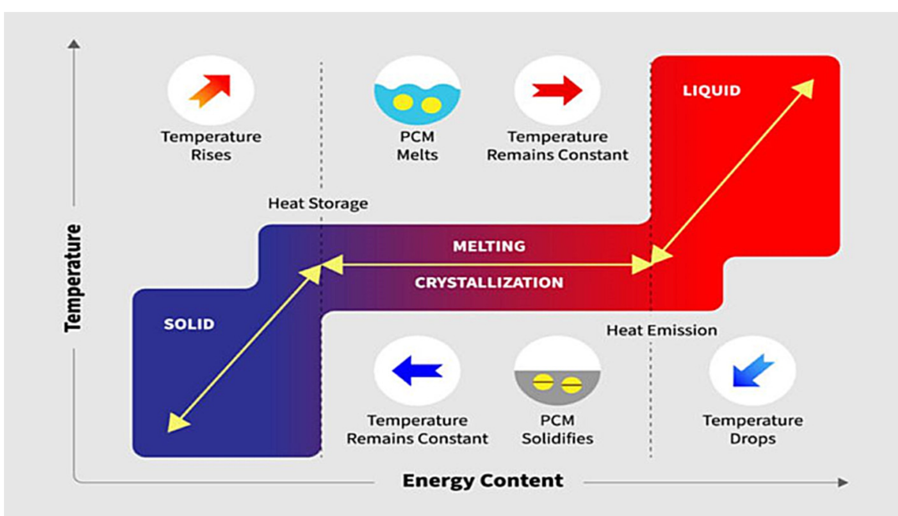

Fig. 4. Explanation of how a PCM works.

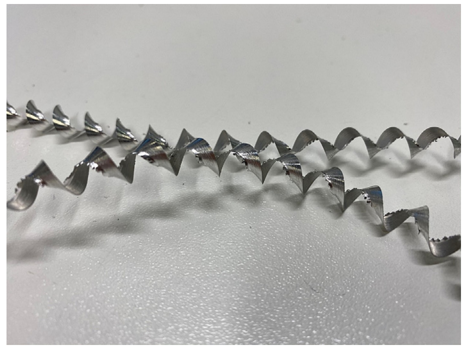

Fig. 5. Metal chips.

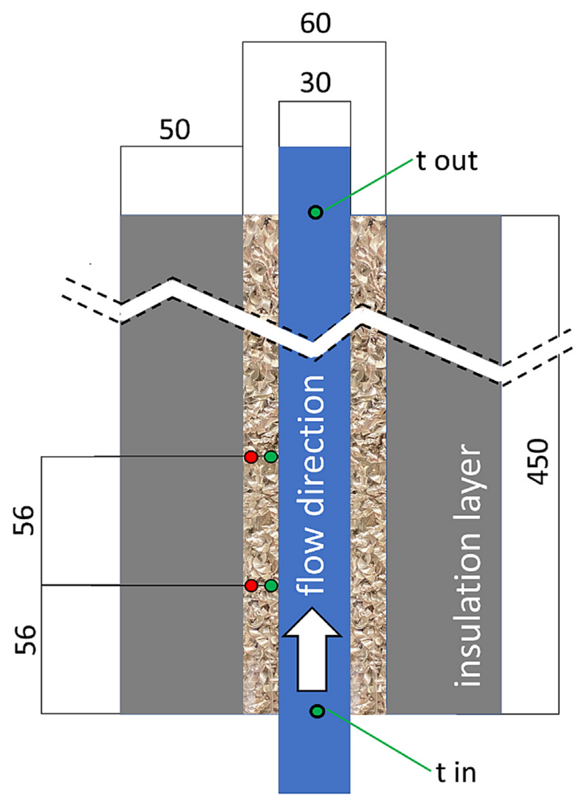

Fig. 6. Scheme of the test section.

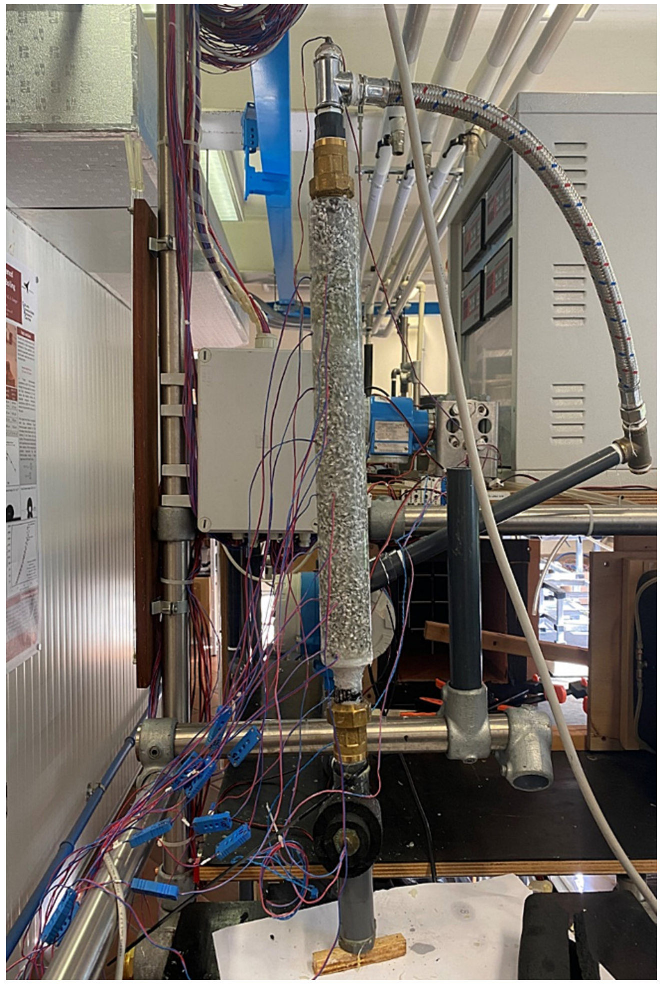

Fig. 7. Picture of the test section.

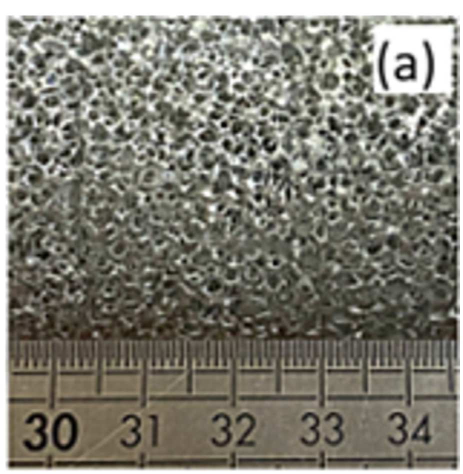

Fig. 8. Picture of the metal foam.

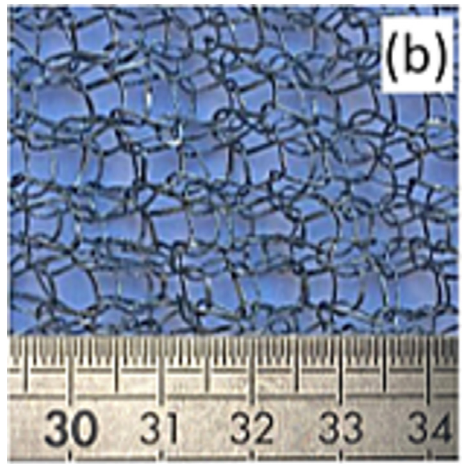

Fig. 9. Picture of the wire mesh.

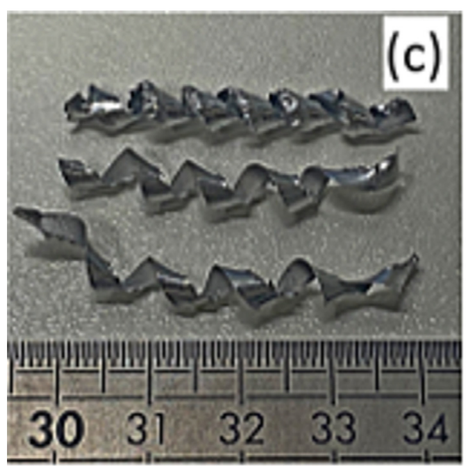

Fig. 10. Picture of the metal chip.

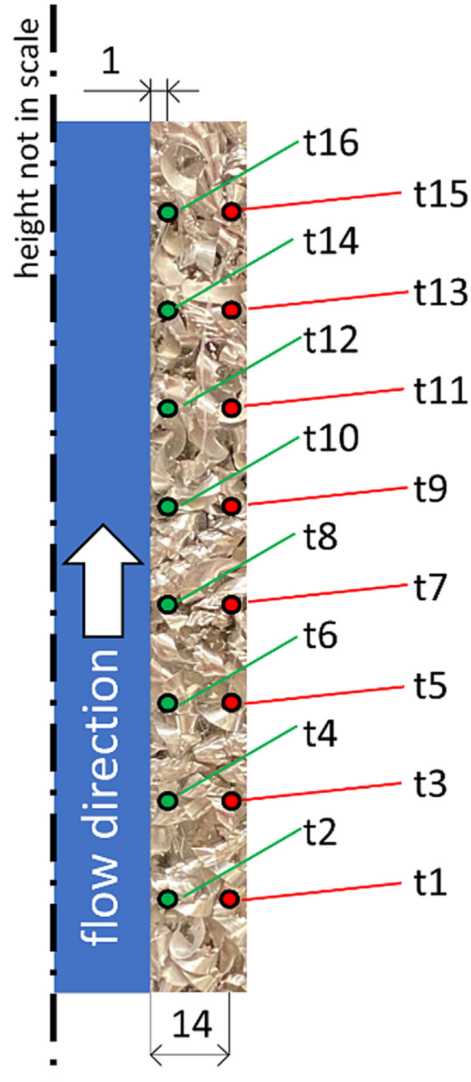

Fig. 11. Thermocouple position.

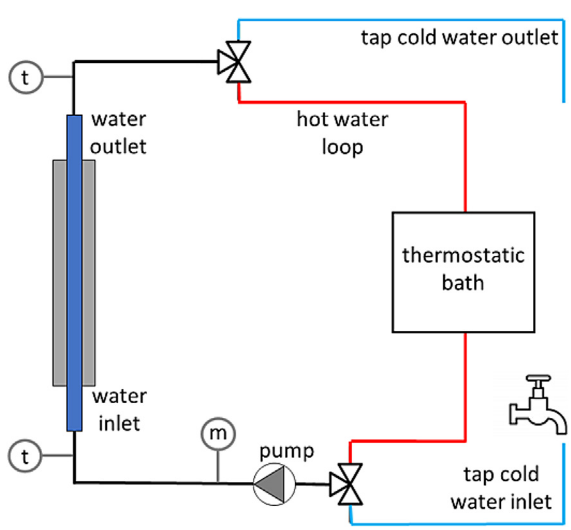

Fig. 12. Experimental set up scheme.

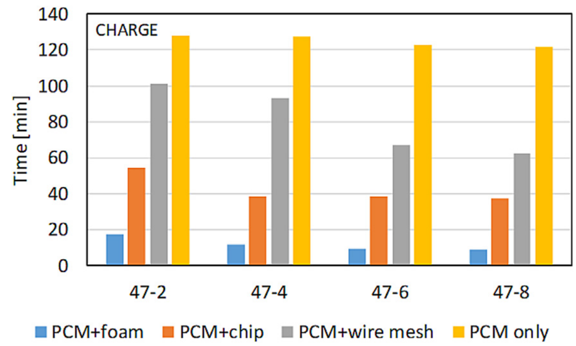

Fig. 13. Charging time of the four samples at different water flow rates.

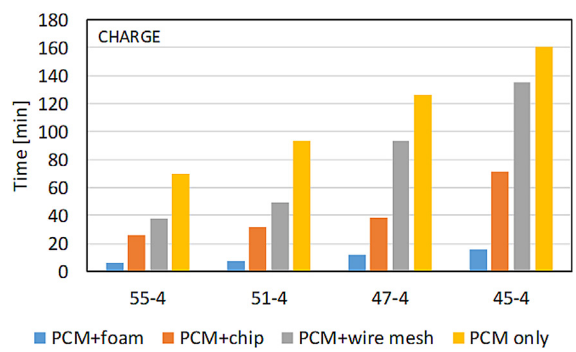

Fig. 14. Charging time of the four samples at different water temperature.

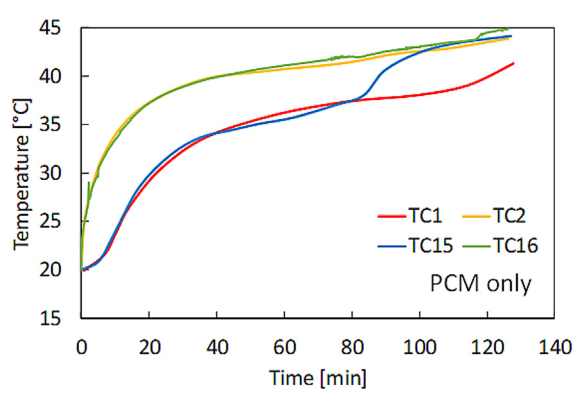

Fig. 15. Temperature field in the PCM only sample.

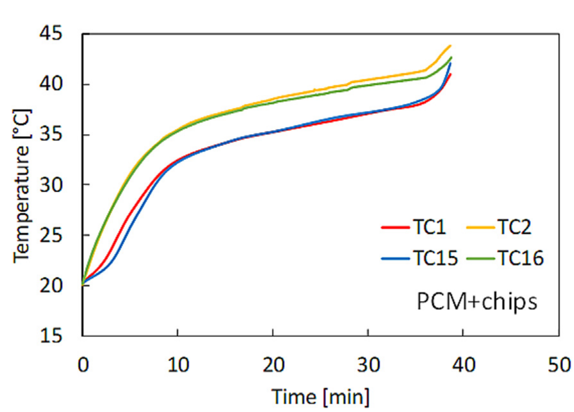

Fig. 16. Temperature field in the PCM + chip sample.

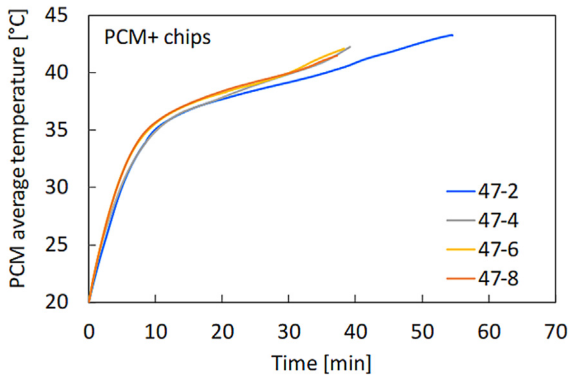

Fig. 17. Average temperature in the PCM + chip sample at different flow rates.

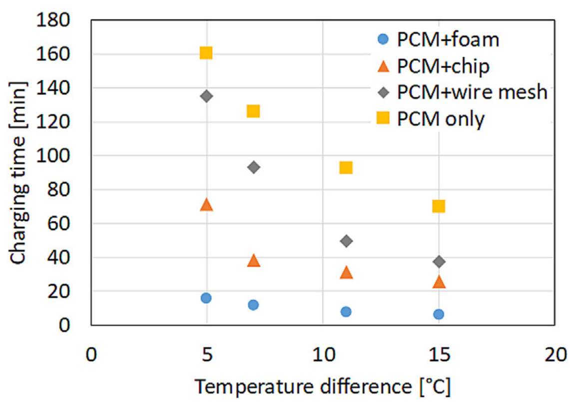

Fig. 18. Charging times in the four samples at different temperature differences.

Acknowlegments

The financial support of the Italian Ministry of University through the PRIN 2017 FlexHeat 2017KAAECT project and of the European Commission through the LIFE22-CCM-IT-LIFE ITS4ZEB project (GA n° 101113714) is appreciated.

Founding sources

This work was supported by the European Commission through the LIFE22-CCM-IT-LIFE ITS4ZEB project (GA n° 101113714).

CRediT authorship contribution statement

Righetti Giulia: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Hooman Kamel:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Zilio Claudio:** Writing – review & editing, Supervision, Funding acquisition, Data curation, Conceptualization. **Guarda Dario:** Writing – original draft, Formal analysis, Data curation. **Mancin Simone:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Data availability

Data will be made available on request.

Further reading

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