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A Review on Heat Transfer Enhancement of PCM Using Fin Tubes in Latent heat thermal energy storage (LHTES)

Ritik Tiwari[1], Shivendra Singh[2]

[1]*Research Scholar, Department of Mechanical Engineering,*
Corporate Institute of Science and Technology
[2]*Assistant Professor, Department of Mechanical Engineering,*
Corporate Institute of Science and Technology

Abstract: Due to its high heat storage density and practically constant temperature throughout the phase shift process, "latent heat thermal energy storage (LHTES)" is gaining popularity in the thermal energy storage area. However, the LHTES system is inefficient because of the low heat conductivity of "phase change material (PCM)". The aim of this work is to provide a summary of the literature on improving PCM heat transfer by use of fin tubes. Using the fin structure to increase the heat transfer area is one of the most effective ways to boost the LHTES devices' heat transfer performance. In addition, this paper discusses the research done on how the fin location and fin shape affect the heat transfer performance of the heat storage unit.

Keywords: Shell and tube LHTS, PCM melting, fin tubes, heat storage, heat transfer.

I. INTRODUCTION

"The high thermal efficiency and low phase change temperature point of latent heat thermal energy storage (LHTES)" have recently piqued the scientific community's attention; nevertheless, the thermal conductivity of the PCM is typically poor and unsuited for many applications. As a result, several methods have been proposed to improve the PCM's heat transfer efficiency during charging and discharging. [1]

The term TES describes the act of putting energy into storage for later use. Several fields, including cogeneration, Solar Power, HVAC systems, and others, may benefit from this technique. When using the right TES technology, energy may be stored and used on a diurnal or seasonal basis. This indicates that in locations where cooling in the summer and heating in the winter are both necessary, heat may be stored throughout the warmer months and used in the colder months. This strategy would focus on a long period of time, such as many months. Small-scale versions of similar TES technologies may be employed to meet every day heating needs. TES has several benefits, including: [2] [3]

- Application in active and passive systems (allowing usage of waste energy)
- Peak load shifting strategies
- Rational use of thermal energy
- Increase overall efficiency and better reliability
- Reduction in investment and running costs

• Reduction in CO2 emissions and pollution of the environment

A. Latent Thermal Energy Storage (LTES)

Latent heat storage is a kind of TES that involves storing energy via a phase shift (when a solid turns into a liquid or a liquid turns into a vapour without a temperature change). These setups use PCMs as a means of energy storage, with thermal energy being stored during the phase transition from solid to liquid. The phase transition temperature and the specific heat of solidification/fusion/vaporization are important design parameters. It is possible for both sensible and latent heat TES to coexist in the same storage medium.[4]

Many different setups have been proposed for using PCMs as data storage. Most of the time, specific containers like tubes, shells, and shallow panels are used to hold them.

PCMs, also known as Latent Thermal Energy Storage (LTES), provide many benefits over Sensing Energy Storage: [5]

• Higher Thermal Storage capacities

• Relatively constant temperatures during charging and discharging

• Chemical and Thermal Stability

II. LITERATURE REVIEW

A section of the study on improving PCM heat transfer using fin tubes has been covered in certain reviews. These studies, however, have mostly concentrated on various techniques, such as composite PCM, microencapsulated PCM, etc., or various LHTES devices, to enhance heat transfer performance. Fin structures for improving PCM heat transmission have not been the subject of a systematic study. This study provides a concise overview of the latest literature reviewing the impact of various fin shapes on LHTES devices.

(Munteanu & Tudose, 2022) [6] Scientists have been compelled to find ways to harness various forms of waste energy using a wide range of technologies and resources in response to the world's worsening energy problem and the harmful effects of present technology. Phase change materials are an efficient storage medium and the sun is a primary source of heat for energy harvesting systems. The focus of this article is on TES setups developed in the laboratory, namely those that employ phase change materials as the working fluid. Everything that has to be present in PCM-TES materials is here.

(Ahmed et al., 2022) [7] In this research, we provide the findings of a numerical simulation study into the melting of NePCM in a circular thermal storage system. The TES system is made out of a cylindrical tube with three fins and a wavy shell wall. Using the Galerkin FE methodology, we solved the system's governing equations, and the enthalpy-porosity method was applied to account for the melting process's transient behaviour. "The results were displayed for different inner tube positions (right-left–up and down), inner cylinder rotation angle ($0 \leq \alpha \leq 3\pi/2$), and the nano-additives concentration ($0 \leq \phi \leq 0.04$)."

(Ramadan et al., 2022) [8] The use of latent heat thermal energy storage (LHTES) devices is hampered by the PCMs' poor thermal conductivity. If you want to improve the efficiency of your LHTES system despite PCM's poor thermal conductivity, adding fins is a smart move. Using CFD, this research looks at how changing the fin design and the operating circumstances affect the efficiency of a fin-assisted shell-and-tube system. In order to evaluate the thermal behaviour of the suggested system, we look at the heat transfer rate and the liquid percentage. The phase transition is simulated using the enthalpy-porosity method. To do this, we compare the recorded temperatures with our estimates of the temporal temperature changes at each PCM position.

(Tiji et al., 2022) [9] This research makes use of a mathematical model of the energy charging process to examine how changes in design might affect the thermofluidic behaviour of a PCM contained in a triplex tube. To maximise the heating and cooling capabilities of the system, single or multiple internal frustum tubes in vertical triplex tubes are used to support the surface area of the middle tube, where the PCM is located. Research was done on the results of implementing various tube layouts and spacings. Results show that all frustum tube systems outperform the straight tube system in terms of heat storage rates.

(Mozafari et al., 2022) [10] This research suggests an innovative dual-PCM design for a horizontal shell-and-tube energy storage device, which results in an excellent solidification response. The results of several numerical simulations are provided and compared with those of alternative configurations of dual-PCM to show that the suggested PCM configuration is better in its thermal responses. Given the importance of the melting/solidus point to the solidification rate, dual PCMs are selected such that their combined melting point is the same as that of the single-PCM in the reference scenario. To further guarantee that comparable PCM volumes are compared, equal-area sectors are taken into account for all circumstances.

(Buonomo et al., 2022) [11] “Latent heat thermal energy storage system (LHTESS)” is studied numerically, with the system built around a phase change material (PCM)-filled aluminium foam. The PCM is a pure paraffin wax that has a high latent heat of fusion and melts over a wide temperature range. The vertical shell and tube LHTESS geometry is being studied. The assumption is made that the temperature within the corrugated interior of the hollow cylinder is above the PCM melting point. All the other surfaces are considered to be adiabatic. While the metal foam is modelled as a porous medium according to the Darcy-Forchheimer equation, the phase transition of paraffin wax is analysed using the enthalpy-porosity theory. To examine the heat transport in the metal foam, a “local thermal non-equilibrium (LTNE)” model is adopted.

(Al-Mudhafar et al., 2021) [12] The low thermal conductivity of PCMs is the primary factor limiting their use in “thermal energy storage (TES) applications.” The most common approach to improving PCM-TES efficiency is to use metal fins. This study used a computational approach to examine the effects of PCMs on the thermal performance of a “shell and tube heat exchanger (STHX).” An alternative fin shape, in the form of a tee, is proposed as a means of hastening the PCM melting process in the STHX. The thermal efficiency of the tee fin was measured and compared to that of the more conventional longitudinal fin design. Several heat exchangers with different fin configurations were put through their paces and compared in this study. They included a finless heat exchanger, one with six tee fins, one with six longitudinal fins, and a tree-shaped heat exchanger with six tee fins.

(Duan et al., 2021) [13] To deal with the pressing need for thermal storage and the erratic nature of renewable energy use, an unique prototype of a solar energy storage heating radiator (SESHR) loaded with low-temperature phase change material (PCM) has been created. Water and paraffin wax were used as heat transfer fluids and energy storage materials, respectively, in this apparatus that was combined by numerous separate heat storage units (HSUs). It was planned and set up as an experimental testbed for low-temperature SESHR. Different operating circumstances were studied to determine the total storage/ dissipation duration, average storage/ dissipation capacity, rate, and overall thermal efficiency. It was found experimentally that increasing the temperature differential between the heat source and the melting point of the PCM considerably increased both the PCM's heat storage capacity and rate.

(Yang et al., 2021) [14] High efficacy of heat transmission and charging/discharging power are provided by shell-and-tube latent heat thermal energy storage devices, which use phase change materials to store and release heat at a virtually constant temperature. There is a lack of study on the storage unit design process, despite the fact that numerous studies have looked at the material formulation, heat transport through modelling, and experimental tests. Materials are evaluated using "MDM (multi-attribute decision-making) and MODM (multi-objective decision-making) tools," the epsilon-NTU approach is proposed, and the use of a GA is suggested to minimise costs.

III. CONCLUSION

One of the most interesting heat storage methods is LHTES. However, PCM's heat storage and release capability is limited by its poor thermal conductivity. Fin tubes are a great way to improve the LHTES system's heat transmission. The impact of various fin configurations has been the subject of a great deal of research. Examining the effects of fin structure on the efficiency of LHTES heat exchange is the focus of this work.

The melting rate and the time needed to complete one cycle are both affected by the number of HTF tubes and their shapes, as shown by the research in the literature on the phase transition process of PCM in TES systems. Therefore, it will be necessary to conduct a thorough study in subsequent endeavours.

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