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Review on Thermal Energy Storage Using Phase Change Materials

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ABSTRACT

There is a need to produce energy from inexhaustible sources as exhaustible sources are being getting decreased day by day. Solar energy can be used to fulfil this need of energy. The efficiency of solar system can be improved with the help of thermal energy storage with necessary characteristics. Phase change materials can be used for thermal energy storage as it provides more benefits than others. Phase change materials have low thermal conductivity but this can be resolve by using it in proper design for effective functioning. This article summarizes the development in design of thermal energy storage system using phase change materials.

Keywords: Heat transfer fluid, Paraffin, Phase change material, Thermal energy storage.

I.INTRODUCTION

It is important to find an available energy source which can be explored to its maximum use. Solar energy is an available source which can be used for storing energy. Large amount of solar energy is being getting waste which can be used. Energy can be stored by heating, melting or vaporisation of material and it is made available as heat. Thermal energy storage system can be used to store the energy with high efficiency. Phase change material used in thermal energy storage system gives great benefits.

II.THERMAL ENERGY STORAGE USING PHASE CHANGE MATERIALS

Farnarelli et al [1] Latent heat thermal energy storage (LHTES) System for concentrated solarpower plant (CSP) is analysed numerically using CFD simulation. A shell and tube heat exchanger consist of number of tube in tubes, where heat transfer fluid is flowing top to bottom in inner tube and outer tube is filled with paraffin RT20 as a phase change material. They analysed heat transfer effect with considering pure convective model to pure conductive model. It is found that with convective model time required to stored heat is reduced and it is about 30% less time compared with pure conduction heat transfer model. They also study the effect of mushy parameter on melting process and they suggested that melting process is little influenced by mushy parameter.

Elisa Guela et al [2] studied entropy generation analysis for the design improvement of finned tube thermal energy storage unit. In this paper they compared performance of finned tube and unfinned tube LHTES system.

Finned tube is further modified according to the entropy generation analysis. The result shows that the region between fins gap and upper part of system where entropy generation is locally higher. Entropy generation is uniform when increasing number of fins and reducing thickness of fin. As results of this solidification time is reduced by 16% as compared to original finned tube unit.

Abhy dinkar et al [3] study shows experimental analysis of rectangular thermal energy storage unit, in which copper helical coil carrying hot fluid and phase change material is filled around it. They also studied the thermophysical behaviour of natural beewax as phase change material obtained from honey bees. They found that increasing fluid flow rate through helical coil, time required for charging the system is reduced. They also suggested that for low temperature energy storage application beewax as a phase change material is thermal performance wise better than convectional phase change materials.

Tay et al [4] conducted an investigation in to characterizing and optimizing the useful latent energy that can be stored within a tube-in-tank phase change thermal energy storage system, with particular reference to off peak thermal storage applications for cooling buildings. The useful energy that can be stored within the PCM was determined using a validated effectiveness-NTU model. This storage effectiveness was optimized delivering a storage effectiveness of 68% and 75%. It was found that tube-in-tank systems can store more than 18 times more useful energy than sensible storage systems per unit volume.

Korti and Tlemsani [5] experimentally investigated thermal behaviour of three different paraffin as PCMs and water is flowing through helical coil as heat transfer fluid. The effect inlet temperature of HTF on PCM, solid fraction and thermal effectiveness are analysed. The effects of inlet temperature of HTF, flow rate of HTF and the type of PCM used on the time for charging and discharging heat were discussed. The result shows that effect of water flow rate in case of charging process is less as compared to discharging process. But inlet temperature of water has a great effect on charging process. It is observed that adding engine oil to the paraffin can improve the speed of charging and discharging heat process.

Meng and Zhang [6] experimentally and numerically investigated performance of tube in tank latent thermal energy storage unit using composite PCM. The composite PCM is developed by adding copper foam into paraffin. They experimentally investigated the thermal performances of the LTES unit during the heat charging process and discharging process, and a number of experiments are performed under different temperatures and flow rate of the heat transfer fluid (HTF). Results shows good heat transfer performance of the LTES unit using composite PCM and large temperature difference between the heat transfer fluid and PCM can enhance the heat transfer and required less the time durations of the heat charging process and discharging process.

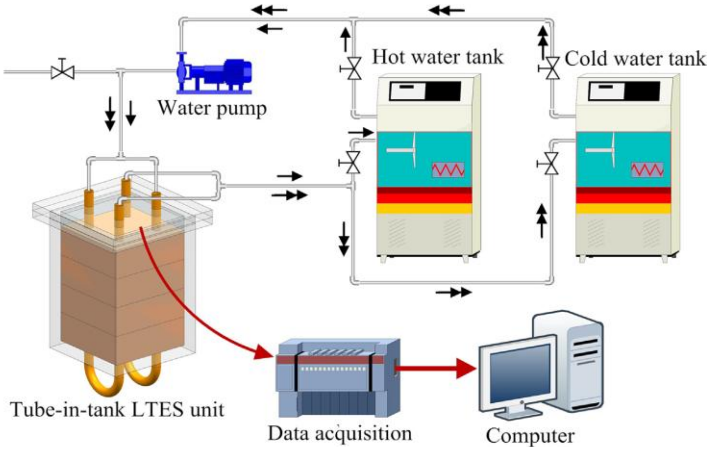

Fig 1.1 Schematic diagram of experimental setup

El-Sawi et al [7] studied the long-term performance of a centralized latent heat thermal energy storage system that is integrated with a building mechanical ventilation system. Paraffin RT20 was used as a PCM and fins were used to enhance its performance. Artificial neural network (ANN) was used to relate the relationship between the input and outputs to reduce the computational time. They check the effect of flow rate of HTF and unit fin size and length on the output temperature of HTF. The use of centralized LHTES system has high potential to reduce the cooling load with a wider range of phase change temperature. Also, it reduces the cooling load from 21% to 36% when the unit length is increased from 500 to 650 mm at a flow velocity of 1.5 m/s.

Promoppatum et al [8] experimentally and numerically investigate performance of the cross flow heat exchanger with phase change material. They described the design of a cross flow type shell and tube heat exchanger with staggered tube array containing phase change material to absorb the heat form the warm air come out from building HVAC, and heat is released to cold air. This arrangement is shown in fig 1.2. CFD simulation was used to study the effect of geometrical and operational parameters on the thermal performance of heat exchanger. They concluded that for the large number of tube rows require less cycle time resulted in the higher thermal efficiency. And if reducing PCM tube diameter by keeping the same pitch to diameter ratio pressure drop remains same.

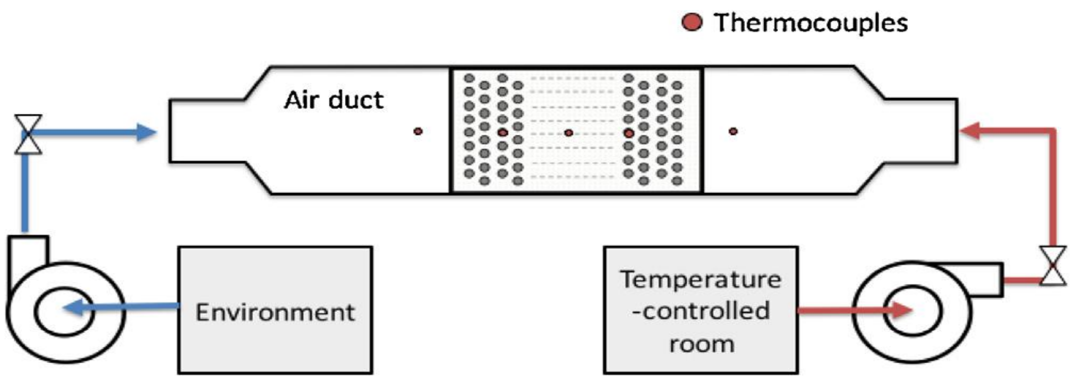

Fig 1.2 Schematic illustration of experimental system.

Atal et al [9] Thermal performance of shell and tube type thermal energy storage unit is instigated in this paper. The shell side contains paraffin as phase change material saturated in aluminium foam. They investigate the effect of the porosity of aluminium foam on the thermal performance of the system by comparing two foams with different porosity (95 and 77 percent). Both experimental and CFD analysis of shell and tube thermal energy device was performed in this study. Results shows that the use of conducting matrix with phase change material significantly reduced the time needed for an operating cycle, and metal foam with less porosity further reduce the cycle time due to higher thermal conductivity.

Sciacovelli et al [10] performed CFD and experimental analysis of thermal storage unit filled with PCM. They used single tube in tube type LHTS device. Water is circulated inside the inner tube & act as heat transfer fluid. Paraffin is used as latent heat energy storage material. During charging process notice that largest variation of melt thickness occurs in small length of the cylinder. Conduction is important for lower part where melted PCM has not yet reached the outer shell. Larger Rayleigh number and Stefan number led to shorter melting time indicating better performance of unit. During discharging process natural convection takes place in the entire shell. Small effects due to natural convection can be observed in the top portion of the cylinder.

Babak kamkari et al [11] carried out simulation on phase change material in rectangular enclosures with & without horizontal partial fins. Different wall temperatures such as 55˚C ,60˚C and 70˚C used for finned & unfinned enclosures found higher melting rate of PCM at the base of fin relative to the tip of the fin because temperature decrease along the fin length due to heat conduction. The temperature distribution in 1 fin enclosure shows that temperature rise of PCM at middle of enclosure where fin is added. As fins increases from 1 to 3 temperatures in melt region become more uniform due to formation of vortex motions above fins. Also observed that both time averaged Nusselt number & heat transfer rates increase by raising the temperature due to natural convection flows in the enclosure.

Selvan Bellan et al [12] studied effect of capsule size and the mass flow rate of heat transfer fluid (HTF) on temperature distribution, melting and solidification processes of the system. Spherical capsules are packed in tank and capsules contain thermal energy storage material. The capsules are filled with sodium nitrate and shell of capsule made up of nickel. It is seen that as the size of capsule decrease the heat transfer rate increase due to surface to volume ratio. The time required for solidification process is less than that of melting process due to the convection effects during melting process.

Matthieu Martinelli et al [13] in this paper copper foam is used in a shell and tube heat exchanger as phase change thermal energy storage unit and studied experimentally. Charging and discharging processes are carried out in both vertical and horizontal directions. The result shows that charging and discharging processes are faster in vertical direction than horizontal direction and charging and discharging processes are faster when HTF is flowing from top than bottom. The time required for melting and solidification process are about 1.6 times faster with a top side injection of HTF than with bottom injection. They also compared exchanger with copper foam and with copper fins and it is clear that copper foam is more efficient than copper fins.

Sharma et al. [14] have done a thorough review on the thermal energy storage system with PCM. They discussed different ways to store the thermal energy. Also discussed desirable properties include thermaophysical, kinetics and chemical properties that requited to selecting phase change material for thermal energy storage. Listed the various phase change materials with its melting point and latent heat of fusion. They have also study in detail measurement techniques of PCM properties. They have given detailed applications of thermal energy storage unit using phase change materials. Also given that numerical techniques to calculate heat transfer parameter of thermal energy storage unit and also given what are problems to analyse numerically performance of thermal energy storage unit.

Al-Kayiem and Lin [15] experimentally measured performance of a flat plate solar collector integrated with built in thermal energy storage. Paraffin wax as a PCM and a nanocomposite of paraffin wax with 1.0 wt% of 20-nm nano-Cu particles were tested as the energy storage medium for TES. They investigated three cases in this paper, namely without PCM, with PCM, and with the Cu-PCM nanocomposite, at 10˚, 20˚, and 30˚ inclination angles of each case. The best performances analyzed were at 10˚, with efficiencies of 47.6%, 51.1% and 52.0% for the cases without PCM, with PCM and with Cu-PCM nanocomposite, respectively.

Merlin et al [16] experimentally investigates performance of thermal energy storage unit using a phase change material along with various configurations of conductive structures: finned exchangers, graphite powder and Expanded Natural Graphite (ENG) matrix. The numerical simulations are also compared to the experimental results and used to investigate the impact of the thermal contact resistance on the heat transfer process of the LHTS system.

Siming Zhang et al [17] investigated the performance of latent thermal energy storage unit using phase change material. In this, spiral tube in latent thermal energy storage tank is investigated experimentally, with composite of paraffin as the phase change material. It is found that inlet temperature of hot fluid has greater influence rather than mass flow rates on heat transfer performance.

Marcel [18] developed theoretical model for predicting the transient behaviour of shell-tube thermal energy storages unit with the PCM on the shell side and inner tube contain HTF. In this paper two types of tubes are namely bare tube and finned tube. Numerical simulation is used to study effects of shell radius, volume flow rates and inlet temperature of HTF and also studied the effect of fins on thermal behaviour of phase change material. The result shows that for moderate volume flow rate and at small inlet temperature annular fins are most effective.

III.CONCLUSION

PCMs are widely used in cold storage and heat storage applications. Usage of PCM along with TES system in such applications leads to improved performance, efficiency, and as well as the energy storage capacity of the total system. But thermal conductivity is very low, which is a major disadvantage of the PCMs. Hence the Thermal Energy Storage system or the PCM tank must be used such that improved overall performance of the system is obtained. Performance improvement can be through proper consideration of the material with high thermal conductivity, design with higher heat transfer areas and several parameters like input temperature, dimensions. Effective design of TES, promotes the melting/charging and freezing/discharging processes of the PCM faster. It is important that the TES design is in such a way that the melting process and solidification process are improved.

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