A REVIEW ON PERFORMANCE INVESTIGATION OF PHASE CHANGE MATERIAL IN HEAT EXCHANGER FOR LATENT COOL STORAGE

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ABSTRACT

Many researchers investigated on theperformance of PCM(Phase Change Material) heat exchanger for latent cool storage. Now it's a need of time to develop an experimental investigation which indicates the results in a simplest manner so that we can predict the results within the acceptable range of numerous results. A number of experiments were carried out to investigate the effects of the inlet coolant temperature and coolant flow rate on melting and solidification of PCM, heat transfer rate. The inlet coolant temperature is set below the temperature with 100% nucleation probability then it is found that cool energy can be fully stored in the form of latent heat. The aim of this paper is to discuss the performance of heat exchanger with phase change material as a latent cool storage by individual charging and discharging processes for various performance parameters and the results are presented and discussed.

KEYWORDS: Heat transfer rate, Latent cool storage, Phase Change Material, Solidification

I. INTRODUCTION

Air conditioning imposes a huge electricity load during certain times of day. A phase change material (PCM) based approach is to place a PCM storage device in the loop of the air conditioning. By this means we can save the peak of electricity load. Latent cool storage energy technique is getting more attention due to high energy storage densities and smaller temperature differences as compared to sensible storage techniques. These systems include PCM contained in small capsules. Fundamental investigations in thermal storage with PCM are made since more than 20 years. The basic concept of the thermal storage air-conditioning

system utilizes the characteristics of PCM inside capsules in the storage tank, whichreleases or absorbs a great amount of latent heat during phase change process. This system makes use of peak electricity for cool energy that is stored in PCM in the form of latent heat, and releases cool energy by melting PCM for air-conditioning during daytime to achieve the goal of shifting peak power consumption. Water is widely used as the PCM for thermal storage because of such advantages as high latent heat of melting, stability, low cost and easy acquisition, no environmental pollution concern and compatibility with the material of air-conditioning equipment.

II. EXPERIMENTAL INVESTIGATION

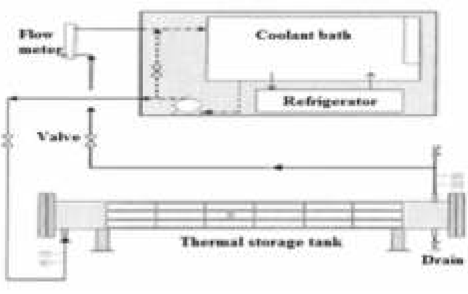

Fig. 1: Schematic of Latent Cool Energy Storage System

A schematic diagram of the experimental apparatus shown in Fig.1 contains a horizontal thermal storage tank, a large isothermal bath and piping system. Adding nucleation agentsinto capsules not only increases the freezing probability of water but also the capsule weight. This prevents the capsules from moving because of the reduced density of the water inside capsules during charging. A small amount of air is put into each capsule to prevent capsules from cracking due to thermal expansion in the phase change process. The aqueous solution of 25 wt% ethylene glycol is used as HTF (Heat Transfer Fluid). To prevent bypass, the coolant passes a distributor located in the inletof the tank to uniformly flow through the capsules. A series of charging experiments are performed under conditions of different coolant flow rates and inlet temperatures. There are three different coolant flow rates and inlet coolant temperatures: 5, 10, 20 l/min and prior to starting each charging test, the experimental unit is cooled down to 10°C.After reaching initial condition, the experiment starts and thecoolant begins to circulate through the tank at the prescribed flow rate and temperature.

III. LITERATURE REVIEW

Many investigations were carried out in order to analyze Investigation of a Phase Change Material in Heat Exchanger for Latent Cool Storage.

Turnpennyet. al, [1] studied A latent heat storage unit incorporating heat pipes embedded in phase change material (PCM) is developed and tested for a novel application in low energy cooling of buildings. In most cases, the model over-predicted heat transfer rate by about 100%, but predicted heat pipe surface temperature within 280C. The measurements show that a large temperature difference between air and PCM was needed to melt and freeze the material in practical timescales.

Yingxinet. al.[2]made an encapsulated ice tank and the tank is packed with ice balls, the fluid medium (usually glycol solution) flows slowly through the tank and exchanges heat with the ice balls, which charges or discharges the tank. The model uses a simple one-dimensional fluid flow and a lumped capacity model for the ice ball. Comparison between the model and experimental results showed that the model applies to a wide variety of encapsulated ice tanks and different ice ball diameters.

Chen Sih-Liet. al.[3] experimentally investigates the thermal performance and the pressure drop of an encapsulated thermal storage tank during the charging process. A polyvinyl chloride (PVC) hollow cylinder is used as the thermal storage tank. The cylindrical capsules inside the thermal storage tank utilize water added with nucleation agents as the phase change material (PCM), and the coolant is the aqueous solution of ethylene glycol and concluded that Cool energy can be fully stored in the form of latent heat, if the inlet coolant temperature is lower than the temperature of 100% probability of crystallization. The lower the inlet coolant temperature, the shorter the time it takes to finish cold storage.

Eames et. al. [4] describes and evaluates the results of an experimental study aimed at the characterization of the freezing and melting processes for water contained in spherical elements of the type often found in the beds of thermal (ice) storage systems used building air conditioning systems. The results of the investigation contribute towards a better understanding of the phase change process of water–ice contained within spherical storage elements. Furthermore, the results of this investigation will be particularly useful for those wishing to model the performance of thermal (ice) storage units used in building cooling systems.

Cheralathanet. al. [5]investigates the transient behaviour of a phase change material based cool thermal energy storage (CTES)system comprised of a cylindrical storage tank filled with encapsulate PCMs in spherical container

integrated with an ethylene glycol chiller plant. Results that for lower porosity, the time required for freezing the PCM is longer than for higher porosity at constant heat transfer fluid (HTF) flow rate. This is due to increaseporosity that would result in increased HTF passage and lower mass of PCM capsules in the entire storage tank.

Wang et. al.[6]recognizedPCM as energy storage tanks. These tanks have been introduced into the refrigeration system to enable its capacitance to take account of fluctuations in the daily account load .The result shows that for energy savings, PCM also improves the system C.O.P. 4% to 7% by minimizing the superheat.

Felix et al., [7] analyzed the behavior of a packed bed latent heat thermal energy storage system. The packed bed is composed of spherical capsules lled with paraf n wax as PCM usable with a solar water heating system. The model developed in this study uses the fundamental equations similar to those of Schumann, except that the phase change phenomena of PCM inside the capsules are analyzed by using enthalpy method. Key parameters of the analysis are the heat transfer uid inlet temperature, mass ow rate, phase change temperature range and the radius of the capsule. In the present work a cylindrical storage tank of 1 m diameter and 1.5 m length (length to diameter ratio 1.5) completely lled with PCM capsules has been considered for the storage of energy collected by a solar collector system for a period of 6 h per day.This study investigatesthe effects of heat transfer fluid inlet temperature, mass flow rate,phase change temperature range and the radius of the capsule onthe dynamic response of a packed bed latent heat thermal energystorage system using spherical capsules for both charging anddischarging modes.

Stritih et al., [8] made simulation model defining the transient behavior of the phase change unit was used. The heat transfer problem of the model, which was treated as two-dimensional, was solved numerically by an enthalpy-based finite differences method. The computer program was written in Fortran program language and can calculate temperature fields in certain time in paraffin area, as well as air temperatures. Energy conservation was calculated from meteorological data for a reference year in a specific country. The difference between inlet and outlet temperature were calculated, from which energy conservation for a cooling season were obtained. Calculated energy savings are from 14 to 87% depending on selected parameters.

Reddigari et al., [9] carried out experiments on the TES unit to study its performance by integrating it with constant heat source. The variables studied include PCM, mass flow rate, and inlet temperature of HTF. PCM temperature gradually increases with time and remains constant during the phase change and continues to increase after the phase change before it attains charging temperature. The charging times can be reduced with increased mass flow rates of HTF (from 2 l/min. to 6 lit/min.). By increasing the HTF inlet temperature the charging times are reduced (66 to 70 °C). Stearic acid attains maximum temperature (equal to HTF inlet temperature) faster compared to paraffin (12% less). This is due to higher density of stearic acid compared to paraffin. From economic point of view, the stearic acid is recommended as PCM for TES system.

Seong et al., [10] investigated the energy saving potentials in buildings when various PCMs with different phase change temperatures are applied to a lightweight building envelope by analyzing the thermal load characteristics. As results, the annual heating load increased at every phase change temperature, but the peak heating load decreased by 3.19% with heptadecane (phase change temperature 21 °C), and the lowest indoor temperature increased by 0.86 °C with heptadecane (phase change temperature 21 °C). The annual cooling load decreased by 1.05% with dodecanol (phase change temperature 24 °C), the peak cooling load decreased by 1.30% with octadecane (phase change temperature 29 °C), and the highest indoor temperature dropped by 0.50 °C with octadecane (phase change temperature 29 °C).

Teggar et al., [11] studied numerically of a PCM heat exchanger for latent cool storage. This model has been validated by comparison with available experimental results of the literature. The model is then used for numerical study on ice banks of the parallel plate type. The temperature and enthalpy history, the heat flow rate and the evolution of the solidified mass fraction are presented and discussed. In the extreme conditions, complete loading of the cool storage tank is achieved within 3 h 37 min. 81% of loaded energy is done in 57% of the total solidification time.

IV.CONCLUSION

1. The measurements show that a large temperature difference between air and PCM was need to meltand freeze the material in practical timescales.

2. The result shows that PCM also improves the system C.O.P. and Energy conservation was calculated from meteorological data.

3. Results shows that for lower porosity, the time required for freezing the PCM is longer than for higher porosity at constant HTF flow rate. This is due to increase porosity that would result in increased HTF passage and lower mass of PCM capsules in the entire storage tank.

4. The charging times can be reduced with increased mass flow rates of HTF (from 2 lit./min.to 6 lit/min.). By increasing the HTF inlet temperature the charging times are reduced (66° C to 70° C).

5. The results of the investigation contribute towards a better understanding of the phase change process of water–ice contained within spherical storage elements. Furthermore, the results of this investigation will be particularly useful for those wishing to model the performance of thermal (ice) storage units used in building cooling systems.

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