A REVIEW ON EXPERIMENTAL ANALYSIS OF FORCED CIRCULATION SOLAR AIR HEATING SYSTEM WITH PHASE CHANGE MATERIALS (PARAFFIN WAX) ENERGY STORAGE

Sanjeet Kumar[1], Dr. M.K Chopra[2]
[1]Research Scholar, [2]Vice principal Dean Academic & HOD, RKDF Engineering College, Bhopal

ABSTRACT: Latent heat thermal energy storage is one of the most efficient ways to store the thermal energy for heating air by energy received from the sun. This project is investigation and analysis of thermal energy storage incorporating with phase change materials (PCM) and integrated solar collector plate for use in solar air heater. The integrated collector storage (ICS) concept is applicable as direction in increasing the economic feasibility and more attractive for space heating, cooling in domestic, agricultural and industrial applications in buildings, solar applications, off-peak energy storage, and heat exchanger improvements. It focuses mostly on applications involving a reduction of electric power consumption. A system of this combines collection and storage of thermal energy in a single unit. Compared with the other conventional domestic air heating system, the integrated collector heating system has the more advantage of simplicity, both in erection and in operation. The thermal performance of this solar air heater with phase change material and integrated collector plate are more than conventional type because large surface area for heat transfer is obtained. When the sun ray falls on the solar collector plate, the panel or surface area is responsible for the amount of heat storage. This heat energy is transferred with the help of aluminium fins to the stored paraffin wax which is used as a latent heat storage system. In this project reflector plate with stand and paraffin wax is used. The latent heat storage capacity of paraffin wax is more. So that the amount of heat energy is increased with the help of this reflector. Due to this more amount of heat energy the difference of inlet air temperature and outlet air temperature is more, so that high temperature of hot air is obtained and efficiency of collector plate is increased. This improved collector efficiency by reducing heat loss to the environment, and help achieve an overall efficiency, which accosts of pumping loss for moving air through the collector.

Keywords: Solar air heater, Thermal storage, Paraffin wax, Experimental analysis

I. INTRODUCTION

Now days since last three decades the main environmental problem is the imminent energy shortage and the high cost of energy. Central to the problem is the need to store excess energy that would otherwise be wasted and also to bridge the gap between energy generation and consumption. Latent heat thermal energy storage is particularly attractive technique because it provides a high energy storage density. When compared to conventional sensible heat energy storage systems, latent heat energy storage system requires a smaller weight and volume of material for a given amount of energy. In addition latent heat storage has the capacity to store heat of fusion at a constant or near constant temperature which respond to the phase transition temperature of the phase change material (PCM).After 1970 a large number of studies have been conducted to assess the overall thermal behavior of latent heat thermal storage system .Studies of phase change system have investigated design fundamentals of system and process optimization, transient behavior, and field performance. The research and development has been broad based and productive, concentrating on both the resolution of specific phase change material and the study of the characteristics of new materials. As reported by many researchers the major disadvantage has been the low thermal conductivity possessed by PCM that leads to low charging and discharging rates especially for organic based materials).The development of a latent heat thermal energy storage system therefore involves the understanding of heat transfers/exchanges in the PCMs when they undergo solid-to-liquid phase transition in the required operating temperature range, the design of the container for holding the PCM and problem raised due to formulation of the phase change. The experiment was conducted on phase change materials (PARAFFIN WAX-IOCL) and smooth aluminium.

II. LITERATURE REVIEW

AISSA W.et al [3] conducted an experiment on force convection flat plate solar air heater with granite stone storage material bad. He performed experiments at different mass flow rate, for five summer days. He concluded that (I) The rise of outlet air temperature from the air heater above the ambient air temperature was in the range of 10-25ºC.(II)Air mass flow rate and solar radiation are predominant factors which affect the performance of SAH. Increasing the air mass flow rate causes a consequent decrease of air, plate, and storage material temperatures.

Alkalani [4] designed, fabricated and perform indoor testing of solar air heater integrated with PCM Experimental results indicated that the charging time was reduce by approximately 70% when used the paraffin wax aluminum composite . The thermal storage efficiency reached the maximum magnitude 71.9 and 77.18% at mass flow rates 0.05 and 0.07 kg per sec for pure paraffin wax and the compound respectively. The result indicated that the heater filled with PCMs with 51 and 430C melting temperatures gives the best performance; otherwise the system daily average efficiency varies between 27 and 63% depending on the PCM melting temperature solar intensity and system air flow resistance.

A. Modemed [5]found that a packed bed of porous media improve heat transfer as well as pre-warming the air by first running it between glazing plates. This also improved collector efficiency by reducing heat loss to the environment, and help achieve an overall efficiency, whichaccosts of pumping loss for moving air through the collector, of 75%.Esan[15]compered several obstacles mounted on flat plate to a planeflat and found that shout triangular shaped varies improved heat transfer efficiency the most by breaking up the boundary layer and reducing dead zones in the collectors. Sahu and Bhagoria[16] short (1.5mm) ribs perpendicular to the absorber plate to break up air flow as it went over the absorber plate and ribs.

B.Kumar[9] used a tank of paraffin wax which absorb solar radiation, and heat was removed by water flowing through three finned heat exchangers. In some cases, water flowed through pipes between an absorber surfaces with integrated phase change material. The oil served as an interface between the PCM and water, spreading the heat over the surface. A black absorber plate was above the oil to collect the solar energy.

B.S.Romdhane[10] used small extensions from a metal plate to improve mixing of air on the plate. These extensions had the advantage of not increasing pressure drop light packed bade solar air heaters. HO et al.[18]increased the collector efficiency of a plate metal absorber plate to 68% by running the air above and below absorbing plate as shown in plate. The flow turns 180 degree to move back above the plate this configurance increase pressure drop inflow, but the paper does report.

DR. F. Bruno [16] unlike conventional sensible thermal storage method PCM provide much higher energy storage density and the heat is stored and released at an almost constant temperature; PCM can be used for both active and passive space heating and cooling systems. In passive systems PCM can be encapsulated in building material such as concrete , gypsum wallboard, in the ceiling or floor to increase their thermal storage capacity, they can either capture solar energy directly or thermal energy through natural convection. Increasing the thermal storage capacity of a building can increase human comfort by decreasing the magnitude of internal air temperature swings so that the indoor air temperature is closer to that desired over a longer period of time.

D. Jain[17] used an air heater for crop draying that contained a sensible heat storage medium placed below the absorber plate. The collector contained two glazing and air passed between the glazings and then over the absorber plate. It then passed under the bottom side of the absorber storage combination, and into the crop dryer. He achieved a minimum temperature raise of 5ºC during the night with 900w/m2 of incident radiation. The efficiency of dryer never exceeded 35%.

Edward K.Summer [18] investigated on a high efficient solar air heater with novel built in heat storage for use in a humidification and dehumidification desalination cycle. He used paraffin wax with melting temperature of 51ºC, as a phase change material below the aluminium absorber plate. The volume of PCM's bad was 1×0.30×0.10m3.The result showed, it was sufficient to produce a consistent (day or night) output temperature close to the PCM's melting temperature.

H.E.S.Fath [22]. He used a series of closed packed tubes containing wax, hot salt, or sand (for comparison with sensible heat storage). The tubes were arranged close to each other in parallel to make a flat-plate-style configuration with air flow in above and below then simultaneously.

The collector could maintain a minimum of 5ºC of temperature difference and ran at design condition 8 hours longer than a collector without storage. The collector used a wax PCM that melted at 51oC.

HuseyinBenli[24] has used ten pieced solar air collectors heating system for space heating of a greenhouse. He used CaCl26H2O as PCM for thermal energy storage with a melting temperature of 29ºC.Hot air delivered by ten pieced solar air collector is passed through the PCM to charge the storage unit. The stored heat is utilized to heat ambient air before being admitted to a greenhouse. His study was based on experimental results of the PCM employed to analyze the transient thermal behavior of the storage unit during the charge and discharge periods. The proposed size of collectors integrated PCM provided about 18–23% of total daily thermal energy requirements of the greenhouse for 3–4 hour, in comparison with the conventional heating device.

[Storage type solar air heater by HuseyinBenli]

W.Saman [38] used PCM for a roof integrated solar heating system .His unit consists of several layer of phase change material slabs with a melting temperature of 29ºC. Warm air delivered by a roof integrated collector passed through the spaces between the PCM layers to charge the storage unit. The stored heat is utilized to heat ambient air before admitting ta a living space. Form this study he conclude that (I) A higher inlet air temperature increases the heat transfer rate and shortens the melting time . Conversely, during freezing, a lower inlet air temperature increase the heat transfer rate and shortens the freezing time.(II) A higher air flow rate increases the heat transfer rate and shortens the melting time but increases the outlet air temperature and reverse in the case of freezing.

III. DIFFERENT TYPES SOLAR AIR HEATER WITH ENERGY STORAGE

Storage of solar energy is an important issue as solar radiation is a time dependent energy source, i.e. has an intermittent character. Thus, the energy source and the heating demands of the systems do not match. Solar thermal energy can be stored as sensible heat (water and rock), latent heat (water/ice and salt hydrates), heat of reaction, or combination of these. Parameters including storage period required, economic viability or operating conditions are effective on selection of these methods. Latent storage system via phase change material (PCM) was preferred in this study. The reason for this selection is the fact that the use of PCMs for thermal energy storage (TES) in solar heating systems has received considerable attention in the literature. PCMs can store large amounts of heat changing the phase from solid to liquid. In a latent heat TES system, determining of the PCM plays important role in addition to heat transfer mechanisms in the PCM [32].The most important PCMs include Glauber's salt, calcium chloride hexahydrate, sodium thiosulfate pent hydrate, sodium carbonate decahy- drate, fatty acid, and paraffin waxes. These applications are listed in Zalba et al. [33]. Both fatty acids and paraffins are cheap, readily available, and melt at different temperatures. However, PCMs are good TES from the point of view security of energy supply. There are many applications of PCM for different area in the literature for solar collectors, greenhouses, building heating.

3.1 Types of ENERGY STORAGE METHODS

3.1.1 Mechanical energy storage

Mechanical energy storage systems include gravitational energy storage or pumped hydropower storage, compressed air energy storage and flywheels. These technologies can be used for large-scale utility energy storage while flywheels are more suitable for intermediate storage. Storage is carried out when inexpensive off-peak power is available, e.g., at night or weekends. The storage is discharged when power is needed because of insufficient supply from the base-load plant.

3.1.2 Electrical energy storage

Energy storage through batteries is an option for storing the electrical energy. A battery is charged, by connecting it to a source of direct electric current and when it is discharged, the stored chemical energy is converted into electrical energy. Potential applications of batteries are utilization of off-peak power, load leveling, and storage of electrical energy generated by wind turbine or photovoltaic plants. The most common type of storage batteries is the lead acid and Ni–Cd

3.1.3 Thermal energy storage

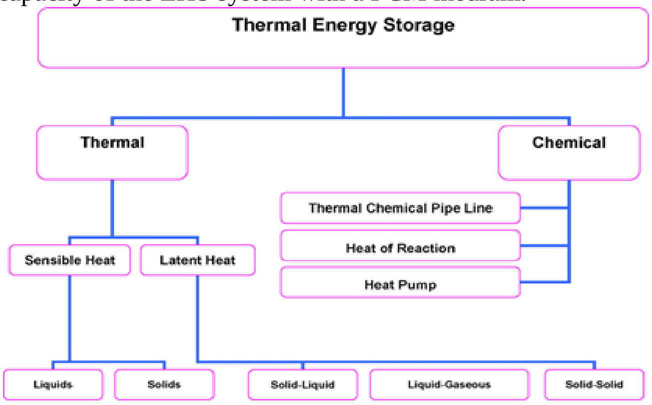
Thermal energy storage can be stored as a change in internal energy of a material as sensible heat, latent heat and thermo chemical or combination of these.

1) Sensible heat storage

In sensible heat storage (SHS), thermal energy is stored by raising the temperature of a solid or liquid. SHS system utilizes the heat capacity and the change in temperature of the material during the process of charging and discharging. The amount of heat stored depends on the specific heat of the medium, the temperature change and the amount of storage material.Water appears to be the best SHS liquid available because it is inexpensive and has a high specific heat. However above 100ºC, oils, molten salts and liquid metals, etc. are used. For air heating applications rock bed type storage materials are used.

2) Latent heat storage

Latent heat storage (LHS) is based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice versa. The storage capacity of the LHS system with a PCM medium.



Different types of thermal storage of solar energy

IV. HISTORY OF PARAFFINS

Paraffin wax was first created in 1830 by the German chemist Karl von Reichenbach when he tried to develop the means to efficiently separate and refine the waxy substances naturally occurring in petroleum. Paraffin represented a major advance in the candle making industry because it burned more cleanly and reliably, and was cheaper to manufacture than any other candle fuel. Paraffin wax initially suffered from having a low melting point; however, this shortcoming was later remedied by the addition of harder stearic acid. The production of paraffin wax enjoyed a boom in the early 20th century as a result of the growth of the meatpacking and oil industries, which created paraffin and stearic acid as byproducts.

4.1 MANUFACTURING OF PARAFFINS

The feedstock for paraffin is slack wax, which is a mixture of oil and wax, a byproduct from the refining of lubricating oil.

The first step in making paraffin wax is to remove the oil (de-oiling or de-waxing) from the slack wax. The oil is separated through crystallization. Most commonly, the slack wax is heated, mixed with one or more solvents such as a ketone and then cooled. As it cools wax crystallizes out of the solution, leaving only oil in the solution. This mixture is filtered into two streams: solid (wax plus some solvent) and liquid (oil and solvent). After the solvent is recovered by distillation, the resulting products are called "product wax" (or "press wax") and "foots oil". The lower the percentage of oil in the wax the more refined it is considered (semi-refined versus fully refined).The product wax may be further processed to remove colors and odors. The wax may finally be blended together to give certain desired properties such as melt point and penetration. Paraffin wax is sold in either liquid or solid form.

V. AIR HEATER COLLECTOR

5.1 Collector Box

Collector box is constructed from plywood of 1.5 inch thickness. The external dimension of the collector box is 2.04m×0.42m×0.19m. Bottom wall of the box has been insulated with insulating materials (wooden powder), having thickness of 5.2cm. The side wall of the collector has been insulated with insulating material of thickness 3.4cm. The internal wall of the collector box is made of plywood having thickness 6mm.Internal dimension of the box is 2m×0.30m×0.132m. Cross-section area of the heater channel is 0.3m×0.03m. Triangular flow straighteners have been used at the inlet and outlet of the heater channel. Cross-sectional areas of the flow straightener are0.3m×0.03m and 0.03m×0.03m for larger and smaller section respectively, while length of the straightener is 0.6m.

[Collector Box]

5.2 Absorber Plate

The absorber plate is made of aluminum sheet having dimension 2m×0.3m×0.002m. The upper surface of absorber plate is painted with matt black layer to increase the absorptivity of the solar radiation and whereby reduces the temperature gradient between the inside and outside surfaces. 490 aluminum fins(dia. 4mm×100mm) are welded in 49 rows and 10 columns on the bottom of absorber plate. These fins are dipped into the PCM's bed for better conduction of heat from absorber plate to PCM's and vice-versa.

[Aluminium absorber plate]

[Aluminium fins welded on bottom surface of absorber plate]

VI. CONCLUSION

From this study it is concluded that the recent researches focused on the phase change materials (PCMs) as a storage materials, because of the higher thermal energy storage density of these materials in contrast of sensible heat storage materials. For a better thermal performance of solar air heater a phase change material with high latent heat and with large surface area for heat transfer is required. The researchers' designs going to the integration between solar energy collection and thermal storage to reduce the heat loss, volume and system cost. Paraffin wax is a good PCM for energy storage in latent heat storage system. It has a suitable transition temperature range of 58-60°C and a relatively high latent heat of 210 kJ/kg. In addition, it does not exhibit any sub cooling. A simple tube in-tube heat exchanger system can be used for energy storage with reasonable charging and discharging times and heat release rates. In a near future, PCMs will be more and more incorporated in global energy management solutions as the stress for innovative low environmental-impact technologies, the overall negative effect of energy consumption on the environment, and the cost of energy will all necessarily increase.

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