International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

Review on PCM based solar air preheater with thermal storage

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Abstract - Solar energy is probably cleanest and most beneficial energy kind of renewable energy available. Solar energy is the intermediate source of energy and hence there is mismatch between energy demand and generation. This gap can be reduced by energy thermal storage system. It can be stored as latent heat or sensible heat or combination of latent heat and sensible heat by phase change material. Latent heat concept is most beneficial way for thermal storage compared to sensible concept in small temperature difference. This study is accomplished to familiar various kinds of thermal energy storages which are commonly used in solar air heater and it also carried out to analyze solar air heater. Comparative study has been carried out for various kinds of solar air heater with taking care of solar collector.In PCM based solar air preheater;Phase change material absorbs and releases thermal energy in order to maintain constant temperature as per requirement.

Keywords *– Air preheater, Phase Change Material, Solar Energy, Thermal Storage and Latent Heat*

I. INTRODUCTION

Solar energy is easily available in large amount. But it is available only during sunshine hours, and therefore it's require powerful thermal storage so that the extra amount of heat collected during sunshine hours can be stored for later usage (during night). Energy storage plays significant roles in saving available energy and improving its usage since many energy sources are intermittent in nature. Short term storage of less time (in days) is essential in almost applications and long term storage of quite more time (few months) may be required in some applications.

Thermal energy storage is one of the most impressive way to store solar energy for heating air by energy received from the sun. The thermal energy storage can be used in places where solar energy varies or in area where there is high temperature difference during day and night .The latent heat approach of thermal storage and their materials, which are Paraffins, Hydrated salts, Fatty acids and eutectics of organic and non-organic compound.

II. SOLAR AIR PREHEATER

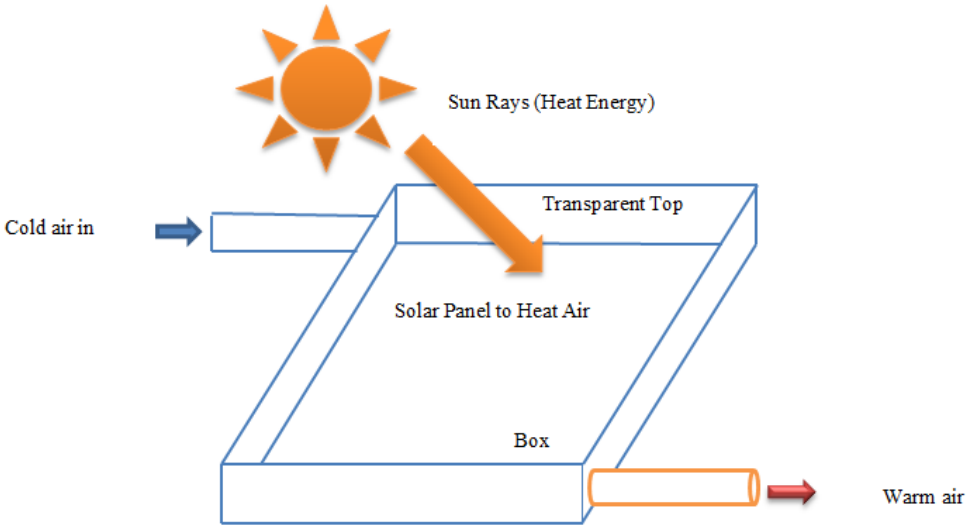

Fig1. Solar air preheater

Solar air preheater as shown in fig 1, which absorbs the irradiance from the sun and converted into thermal energy at absorbing surface this thermal energy absorbs by which is fluid flowing through the collector .Solar air preheater is broadly used for space heating, timber seasoning and agriculture drying. It is observed from literature, all elements of solar heating system such as absorber tray, the ducts, glazing, insulation extended surface as well as tilt angle, have significant effect on thermal performance of system.Efficiency of solar air preheater mainly influenced by factors like collector length, collector depth, types of absorber plate ,glass cover, wind speed , inlet temperature etc. Among all, the collector glass cover and absorber plate shape factor are most significant parameters in the design of any kind of solar heating preheater. Absorber plate is another parameter that plays very important role in performance of solar air heater.

Air Preheater can be classified as shown in fig 2.

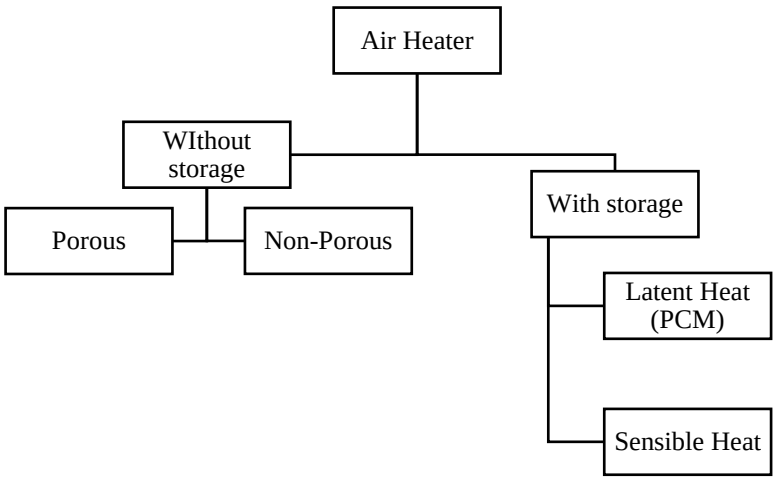

Fig 2. Classification of air preheater

III. ROLE OF PCM IN AIR PREHEATER

Phase change material(PCM) can be workas thermal storage in air preheater. Phase change material absorbs and release heat energy in order to reduce the temperature variation in room. Solid PCM is absorbed heat when ambient temperature is higher than PCM melting temperature and this stored energy release during solidification. The PCM works as thermal switch, it absorbs heat during sunshine hours and releases heat during night or off sunshine hours. Hence, variation in room temperature is reduced and provide comfort condition in specified space or room.

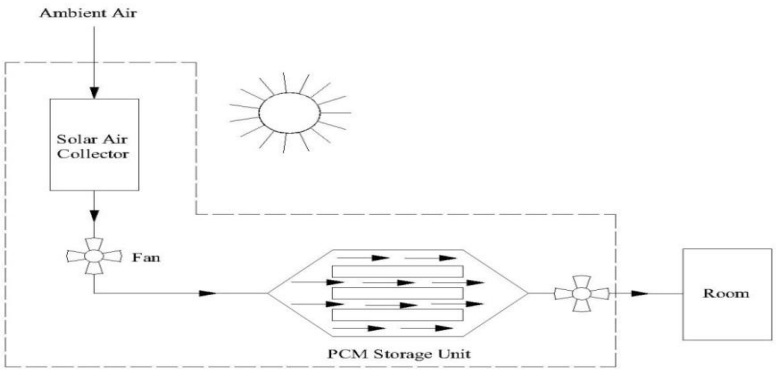

Figure 3 Operation during sunshine hours

During day:

As shown in above Fig. 3, solar collector collects the heat and air will heat due to heat transfer during sun-shine hours. Then, when hot air is passed through the PCM unit, PCM will absorb heat of air and air will condense and it will go to the room and temperature of room will goes down. Thus, function will fulfill.

During Night:

During off-sun shine hours, cold air passing through the PCM unit, phase change material will release the heat so air will getting hot. So, temperature of room will increase. Thus, temperature will be controlled. The induced draft fan is used for circulation.

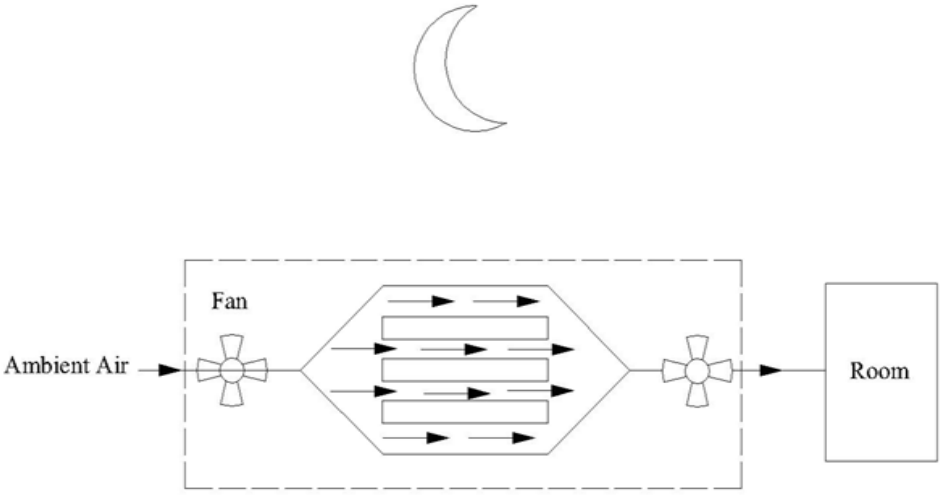

Fig.4 Operation during off sun shine hours

IV. PHASE CHANGE MATERIAL

Phase change material is nothing but material with high latent heat of fusion which solidify and melting at certain temperature, which is able to store and release large amount of thermal energy. Heat is released or absorbed when the material changes from solid to liquid and vice versa.Material to be used for phase change thermal energy storage should have large heat and high thermal conductivity.

Selection criteria:

Phase change material should have following criteria.

i. Melting temperature in required range for better results.
ii. High latent heat of fusion per unit volume
iii. High specific heat, high thermal conductivity and high density
iv. Small volume change on phase transformation
v. Chemically stable
vi. Complete reversible freeze or melt cycle
vii. Less costly
viii. Easily available, Safe, fire resistant
ix. Complete reversible

Applications:

- In solar heating system as thermal storage.
- Cooling for milk product, food etc.
- Blood transportation, hot-cold treatment.
- Waste heat recapture
- Protection for electronic devices.

Behavior of phase change material with respect to temperature and heat:

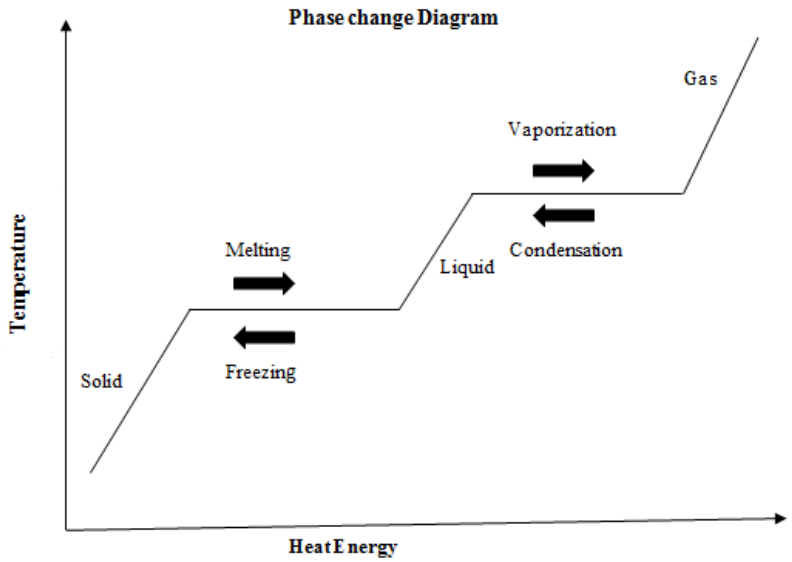

Fig.5 Phase change material behavior

Phase change material used for thermal storage classification is shown in Fig. 6

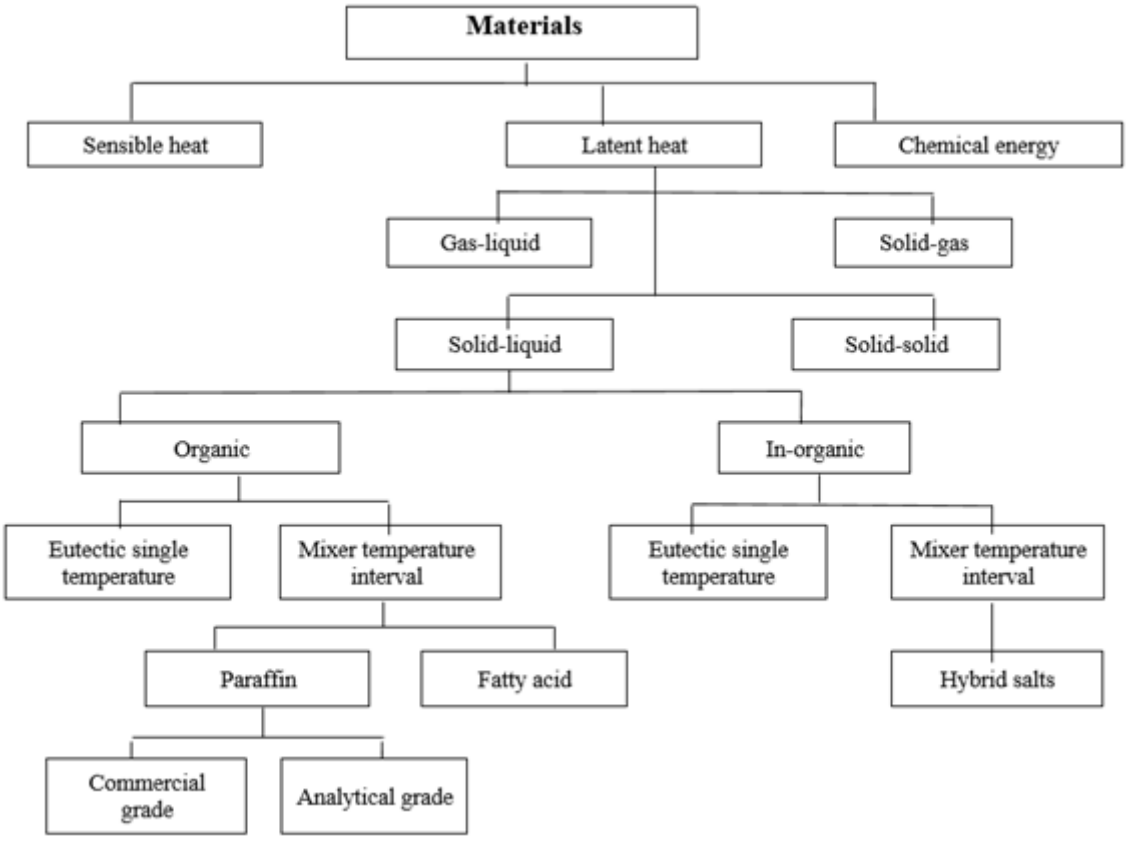

Figure 6 Types of material used for PCM

V. LITERATURE REVIEW

Thirugnanam*et al.*[1]carried out experimental work for performing different mass flow rates of fluid at same inlet temperature.In order to recovery of heat during discharging process (off-sunshine hours), temperature of heat transfer fluid is maintained at ambient temperature. The effect of mass flow rate on the performance of the system was studied. Fromresult, they concluded that feasibility of using paraffin wax as storage media in heat recovery system. When the flow rate of fluid is increases, efficiency ofdouble pipe type heat exchanger with two stages feed water tank will also increasing.

Adeel Waqas *et al.*[2] presented the parametric analysis of phase change material (PCM) based solar air heating system to achieve comfort temperature during winter season.A major reason of this kind of system is to reduce risk of air pollution. When the melting point of PCM is equal to require temperature then performance of system is maximized. Performance of system is minimized if melting point of PCM deviates away from the required temperature.The most sensitive parameters affecting on the performance of PCM storage unit are the melting or freezing point of storage material and mass of PCM and air flow rate.

Sanda Budea *et al.*[3] concluded that solar air collector is used for heating and it also reduces the usage of fossil fuels. They concluded that use of baffles and double air passage with solar collector increased efficiency above 50% for solar irradiation of 900–1000 W/m^2.Ventilation can be produced by forced ventilation, using fans and air cleaning apparatus, by natural ventilation, where possible, or by mixed methods using solar air collectors.

Alkilani *et al.*[4]carried out theoretical analysis for thermal and physical properties of paraffin wax with 5% aluminum powder as phase change material (PCM). They observed that temperature of air achieved due to discharging energy from PCM. But, temperature of air will less achieve if PCM takes long time to freeze and mass flow rate of air is low.

P. S. Chopade [5] carried out comparison between old and new design of solar air preheater. Orientation of both designs are different. In new design, orientation is put as direction ofradiation. Results says that maximum efficiency is gained around 23% higher when orientation as per radiation direction .But one problem is occurred in new design, which is manual rotation of frame is required as per radiation during whole day.

P.N.Sapkal*et al.*[6]carried outcomputational fluid dynamics analysis for in-line tube arrangement for estimating effect of different parameters like gas flow rate, gas temperature, tube pitch, etc. The model can also be used while selecting a new type of surface geometry for optimizing the design of air-preheater. Outside diameter can be easily changed by arrange number of tubes and increase in flue gas flow rate and temperature results in enhanced heat transfer coefficient.

Genevieve *et al.*[7]concluded that transparent perforated solar collectors (TPSC) are more preferred, when backed with a black cladding, which offers the highest efficiency around 9.5%.Black-cladding-backed TPSC offers the greatest energy preheating potential. There is a potential for energy storage for TPSC backed with the brick cladding.

Cristiana *et al.*[8]concluded that heat transfer between the fluid and the metal is enlarged depending especially on the flow's characteristics. The solar collector was analyzed and the results indicated that the system can attain a high thermal performance, but only for a certain range of airflow rates.

A.P. Omojaro *et al.*[9]analyzed performance of single and double pass solar air heater with fins attached and using a steel wire mesh as absorber plate. The efficiency increases with increasing air mass flow rate. If flow rate of air remain same, double pass collector is more effective compared to single pass collector. Efficiency of double pass collector is greater than single pass collector by 7 to 19.4%.The temperature difference between the outlet flow and the ambient, which reduces as the air mass flow rate increase. Comparison of both type of collector is also done.

Haoxin Xu *et al.*[10]presented a systematic selection procedure of PCMs for latent heat thermal energy storage in a typical solar air conditioning system. PCM selection for solar system is based on material availability and required temperature to be controlled.

Belen Zalba*et al.*[11] studied about materials, heat transfer and applications of phase change material. Materials used by researcher as potential PCMs are described with their thermo-physical properties.All commercial PCMs have also been listed. Problems in long term stability of the materials are discussed. Heat transfer is considered mainly from a theoretical point of view, considering different simulation techniques. PCMs can be used as ice storage, in building applications for space heating and cooling, protection and movement of temperature sensitive materials and so many.

A.P. Omojaro et al.[12] observed that higher efficiency of collector can be achieved with lower porosity. This also increases the pressure drop, which becomes important at high volume flow rate of air.Experimental investigation is done for both single and double pass (counter-flow) solar air heater with porous media and results show that efficiency of double pass is higher than single pass collector by 7 – 19.4% depending upon mass flow rate of fluid. Thermal analysis is also done for both by varying mass flow rates. Results show that maximum efficiency can be obtained in between 59.62% to 63.74%.

Paisarn Naphon[13]carried out performance comparison of both old and new design of solar air preheater. In this, new design has rotational arrangement, due to that maximum solar energy utilized. So, outlet temperature is increasing around 14.5% and efficiency increased around 23%. Results show that, it is necessary that rotation of frame should be according to orientation of sun rays.

A.A.Mohamad et al. [14]carried out energy balance analysis for four types of air heater which are conventionalwith one glass cover, conventional with double glass cover and counter air heater and without porous matrix. The flow velocity is decreases if spacing between glass cover and absorber increasing. Hence heat transfer coefficient decreases. Using counter flow arrangement, heat losses are reduced up to 50%.Conventional solar air heaters have less efficiency due to more heat loss from the absorber to air stream.

Summary: PCM based solar air preheater is one of best way for space heating and cooling. Double type solar air preheater is more preferable compared to single type solar air preheater. Porous media concept is used to increase the efficiency of solar air preheater. In solar air preheater, if orientation of solar collector is as per radiation then maximum efficiency of solar collector can be gained. In PCM based solar system, PCM must be selected according to required temperature and its thermal and physical properties. If melting/freezing temperature of PCM is nearly equal to require temperature, then performance will maximized. If melting/ freezing point of PCM deviate away then performance will minimized. Mass flow rate of fluid is another main criterion which is directly affected on the performance of solar system. If mass flow rate of fluid is increasing then heat transfer will increase, too.

VI. CONCLUSION

It is found from literature review that every thermal energy storages (TES) have effect on the thermal performance of solar air preheater. Double pass SAH is more efficient compared to single pass SAH. Maximum efficiency can be gained when orientation of solar collector as per radiation. When the flow rate of fluid is increases, efficiency of system is also increasing. Phase Change Material (PCM) based solar air heating system is most promising concept to fulfill comfort conditions in a living space during whole day with minimizing risk of air pollution. The most sensitive parameters like melting point of storage material, mass of PCM and air flow rate which are affecting the performance of storage unit. If melting /freezing temperature of phase change material is near to the required temperature, best results can be gained. So for selection of PCM, most important criteria is melting or freezing temperature of PCM.

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