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THERMAL PERFORMANCE ANALYSIS ON SOLAR INTEGRATED COLLECTOR STORAGE

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Abstract-The current trend very well signifies that the world is losing all its fossil fuels at a rapid pace. The main solution to get rid of this problem is to effectively make use of the Renewable Energy Sources available around us. Solar energy is one such renewable source of energy available and is encouraged to be used in every country for its sustainability. However, the energy source and the demand do not match each other, especially in solar heating applications. So at present, energy storage is the main focus in any solar heating and cooling system. Solar radiation is a time dependent energy source with an intermittent character. The main aim of this work is to analyze the charging and discharging performance of solar thermal energy storage system with phase change materials (PCMs) and to investigate the appropriate method of enhancement of heat transfer from fin to PCM and PCM to heat transfer fluid (HTF). The utilization of PCM in the heat storage is investigated experimentally for convective heat transfer between the PCM and air. The selected PCM, Magnesium Chloride hexahydrate worked well in the practical range of temperature of around 110°C for a variety of domestic and industrial applications.

Key Words: *PCM, thermal energy storage, sensible and latent heat, solar collector*

1. INTRODUCTION

The recent statistics show that the energy requirement in India will double by the year 2031 with the current trend. It is necessary that the current generation find out alternate solutions to overcome the energy crisis for the future generation. One such alternative solution for the current energy crisis is to replace Fossil fuels by Solar Energy. This can be done by trapping the radiation from the sun and converting it to the required forms. The solar radiation available at the Earth's surface has a variable intensity level from zero to around 1 kW/m^2. India has a daily solar potential of 4 to 7 kWh/m^2 with about 1500 –2000 sunshine hours annually. This available solar potential of 600TW (5 x 10^{12} kWh/year) is much more than the current energy consumption. A solar system, either PV or thermal power generation, with around 10% conversion efficiency can easily fulfill the India's energy needs. Many methods have been adopted in order to trap this energy and use it in daily needs. The field of solar energy has shown tremendous growth in the past decade. But it is widely noted that there lies a discrepancy between the energy supply and demand. It is necessary to rectify this discrepancy and suggest a system that can overcome this problem. Through this paper we present our work on latent heat thermal energy storage system for solar concentrated collector using phase change material. The major drawback of the intermittent solar availability would be compensated by this efficient thermal energy storage system. This work will not only concentrate on the collection of solar energy, but will also show the possibilities of storing solar energy and using that energy during the non-availability of sun radiation. The most interesting physical parameters of a thermal storage device are its storage capacity and temperature range. These two parameters determine the size and suitability of the storage to an application, respectively. The existing sensible heat energy storage has the advantage of being relatively cheap, but the energy density is low and the space requirement is very high. Also it has a gliding discharging temperature. To overcome these drawbacks latent heat thermal energy storage system using phase change material is introduced. The change of phase can be a melting or a vaporization process. Melting processes have energy densities in the order of 100 kWh/m^3 compared to 25 kWh/m^3 for sensible heat storage.

Latent heat thermal energy storage is particularly attractive technique because it provides a high-energy storage density and shows isothermal behavior during charging and discharging. When compared to conventional sensible heat energy storage systems, latent heat energy storage system involves a smaller weight and volume of material for a given amount of stored energy. In addition, latent heat storage has the capacity to store heat of fusion at a near constant temperature that corresponds to the phase transition temperature of the phase change material (PCM).

Many solar heat collection systems are based on transportation of heat from the focal point to the storage by a circulating heat transfer fluid. With a double-reflector arrangement, the storage is heated directly, and no heat transport fluid is needed in this system. Copper fin was used to increase the heat transfer rate from the heated top plate into the heat storage medium. Developing efficient and cost effective solar dryer with thermal energy storage system for continuous drying of agricultural food products at steady rate and moderate temperature (40–75°C) has become potentially a viable substitute for fossil fuel in much of the developing world. Solar dryer with storage unit is very beneficial for humans and the energy conservation. Francis.A et al., investigated the behavior of a phase change storage material (Magnesium Chloride Hexahydrate) in thermal energy storage system for solar cooking application. The results obtained by them showed the successful application of Magnesium Chloride Hexahydrate in thermal energy storage applications. The properties of Magnesium Chloride Hexahydrate are given in the Table 1.

Sl. No.	Description
1	Molecular Formula = MgCl2.6H2O
2	Melting point, Tm = 116.7 □C
3	Boiling point, Tb = 1331 □C
4	Heat of fusion(LH), Enthalpy = 168.6 kJ/kg
5	Specific heat of PCM, liquid, Cp (l) = 0.89 kJ/kg-K
6	Specific heat of PCM, solid, Cp(s) = 1.05 kJ/kg-K
7	Thermal conductivity of PCM, liquid, ,(@ 300 □C), kl = 0.708 W/m-K
8	Thermal conductivity of PCM, solid,(@ 20 □C), ks = 0.825 W/m-K
9	Density of PCM, liquid,(@ 300 □C), □l = 1360 kg/m3
10	Density of PCM, solid,(@ 20 □C), □s = 1570 kg/m3

In this work, the feasibility of double reflector based solar operated air dryer with latent heat based thermal energy storage (LHTES) employing Magnesium Chloride Hexahydrate as selective PCM is tested experimentally for charging and discharging process successfully.

2. METHODOLOGY

The hypothesis of this project is to study the performance of solar thermal energy storage for operating an air dryer for domestic and industrial heating and to find the best method for effective solar energy collection and an efficient solar thermal energy storage system. The heat transfer fluid is circulated to retrieve the heat energy stored in the LHTES. This work involved fabrication and testing of double reflector and LHTES system for the utilization of solar energy during off-sunshine hours. The device is shown in Fig.1.

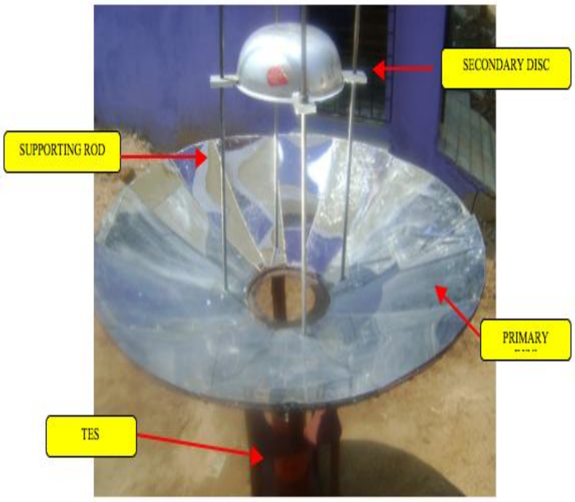


Fig.1. Experimental set-up of Solar ICS system

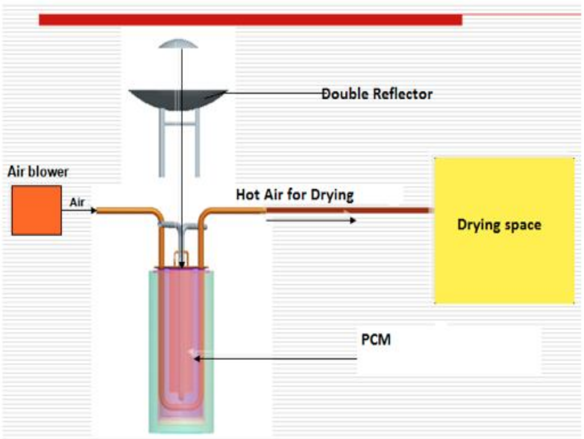


Fig.2. Schematic layout of the Solar ICS system

The primary dish collector of diameter 1.2 m and depth of 0.185 m is used to reflect the incident solar rays to the secondary dish of diameter 0.3 m with depth of 0.076 m. The secondary dish concentrates the reflected rays as point focus on the copper plate of the LHTES and the heat transfer takes place through the fin to the PCM stored. The LHTES system consists of copper plate of diameter 0.11m and thickness 0.002 m, fin having dimensions of 0.25 x 0.05 x 0.003 m (length width and thickness), stainless steel container of diameter 0.10 m, height 0.3 m and 0.003 m, heat transfer tube made up of copper having diameter 0.125 m of and the thermal insulation made up of glass wool with wooden casing as outer layer. The thermal energy can be stored by using different kinds of thermal masses like water, oils and PCM materials.

This topic describes the proposed methods for testing, producing and measuring temperature and flow rate of HTF through the Solar TES. This topic also explains the basis of the proposed testing methods. The main objective of effective storage is tested repeatedly with the test parameters in a natural environment. The fabricated double reflector solar collector is tested with its thermal energy storage for air space heating application with the help of pyranometer (Kipp&Zonnen) and thermocouples (0-500□C) which are fitted in the copper plate, fin and PCM side in order to measure the temperatures at various points. The schematic diagram of the experimental set-up of solar thermal energy storage with an application of an air dryer is shown in the Fig.2.

3. RESULTS AND DISCUSSIONS

The useful heat gained by the HTF depends on the various factors like variation in the solar intensity, ambient temperature, solar travel path and tracking, fluid inlet temperature, type of fluid, thermal gradient in the PCM, velocity of wind, insulation of thermal energy storage etc. The obtained results for the two different flow rates 1 m^3/min and 2 m^3/min were compared.

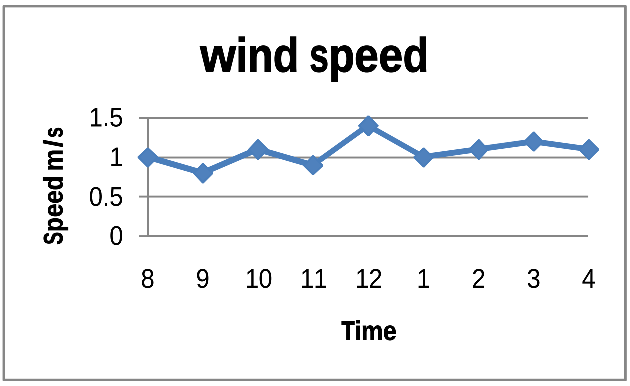
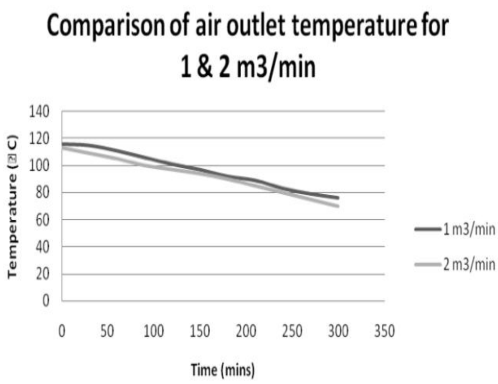
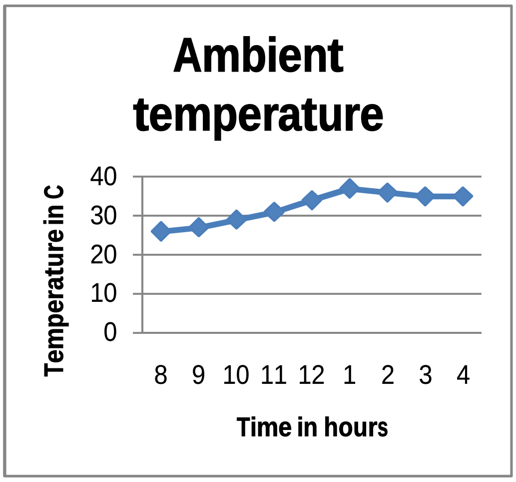
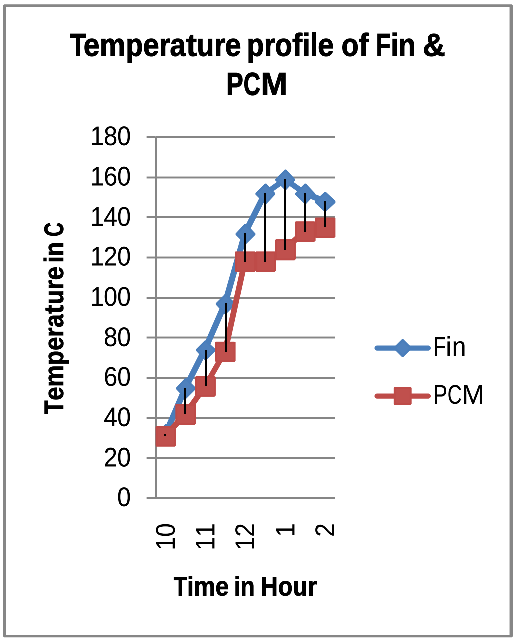


Fig.3. Wind speed

The higher mass flow rate showed slightly increased useful heat gain. The heat transfer from the plate to PCM through the fin is accounted and the reverse effect from PCM to plate through the fin is ignored in this analysis due to top plate insulation, however it should be considered in the future studies. The experimental results show that the effective hot air supply around 80 °C for more than 4 hours with temperature gradient of air 30 °C. The very high temperature space heating is also feasible in near future by choosing a suitable PCM operating temperature in the range of 150 – 300 °C with selective concentration techniques. The various results obtained are represented in the following graphs (Fig3-5) namely, Wind speed, Ambient temperature, PCM Temperature, Fin temperature profile and air outlet temperature.







4. CONCLUSION

The temperature histories of fin and PCM during charging process for two different flow rates are discussed. The thermal mass material undergoes sensible heating as well as phase change process inside the TES container. It is concluded from the repeated experimentation that the reusability and chemical stability of PCM are good enough to supply the hot air for the space heating application. The combined sensible and latent storage concept provides the flexibility of space heating operation during the non-solar periods. The combined sensible and latent heat based TES finds application in the medium to high temperature air dryer and space heating applications. The large scale fabrication of solar thermal energy storage set up will be more successful for the community space heating with increased collector area, improved solar rays concentration, effective high latent heat and high melting temperature PCMs, performance enhancement techniques like multiple PCM or Impregnation of metal powders to improve the thermal conductivity, use of Fresnel lens which leads to reduced maintenance of reflector dishes etc.

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