International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
doi : https://doi.org/10.32628/IJSRST

Development and Fabrication of Box Type Solar cooker with PCM to Enhance Its Efficiency

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ARTICLEINFO

Article History:
Accepted: 05 May 2023
Published: 20 May 2023

Publication Issue
Volume 10, Issue 3
May-June-2023

Page Number
205-210

ABSTRACT

Till date rural areas are abandoned with wooden and agricultural wastes which ultimately use for energy source for cooking purpose. Though it is very harmful many of people opt for it as its availability and low cost. The alternative source for availability and cost is readily available solar energy. Its effective utilization and implementation are expected in all of the parts of world. But due to efficiency and limitations during night- and cloudy-time solar energy cannot be the one to reply upon. But in this work use of PCM along with box type solar cooker is developed to utilize it any time even if solar energy is not available. The heat storing medium present in the developed cooker makes it useful in off sunshine period also. Increase in fuel prices with immense speed also rises the need of the such developed mediums. Also the recognition of the solar energy for cooking is worldwide. So only thing is that better model that integrates both traditional and renewable energy source of heat will prove to be helpful. Hence an attempt towards its integration model is carried out to utilize solar energy for cooking purpose with the help of box type solar cooker. Two way supply of energy can be obtained directly through solar energy in day time and from phase change material during off sunshine time. This work focuses on related issues of solar cooking using latent heat storage that include cooking pot and box type collector.

Keywords— Box type solar cooker, PCM, Latent heat, Phase change material

I. INTRODUCTION

Energy is the backbone of human activities. The importance of energy in economic development is very critical as there is a strong relationship between energy and economic activity. Historically fossil fuel in its solid phase, i.e. wood and coal, has been the prime source of energy. The increment in global energy demands due to population growth and 20th century industrial revolution leads fossil fuel through a transitional phase. It is being widely realized that for sustainable development presently used energy mediums such as fossil fuel and nuclear power have to be quickly replaced by renewable energy sources.

The latter are sustainable and have the potential to meet present and future projected global energy demands without indicting any environmental impacts. Renewable energy sources such as solar, wind, hydropower and biogas are potential candidates to meet global energy requirements in a sustainable way [1].

Thermal energy storage (TES) is the temporary storage of high or low temperature energy for later use. It bridges the time gap between energy requirements and energy use. Among the various heat storage techniques of interest, latent heat storage is particularly attractive due to its ability to provide a high storage density at nearly isothermal conditions. Phase-change thermal energy storage systems offer other advantages, such as a small temperature difference between storage and retrieval cycles, small unit sizes and low weight per unit storage capacity. One of prospective techniques of storing thermal energy is the application of phase change materials (PCMs). Unfortunately, prior to the large-scale practical application of this technology, it is necessary to resolve numerous problems at the research and development stage [2]. Phase change materials (PCM) are Latent heat storage materials. The thermal energy transfer occurs when a material changes from solid to liquid, or liquid to solid. This is Called phase Change. Initially, these solid–liquid PCMs perform like conventional storage materials; their temperature rises as they absorb heat. Unlike conventional (sensible) storage materials, PCM absorbs and release heat at a nearly constant temperature. They store 5–14 times more heat per unit volume than sensible storage materials such as water, masonry, or rock. A large number of PCMs are known to melt with a heat of fusion in any required range [3].

Phase change materials possess the ability to change their state with a certain temperature range. These materials absorb energy during the heating process as phase change takes place, otherwise this energy can be transferred to the environment in the phase change range during a reverse cooling process. The insulation effect reached by the PCM depends on temperature and time; it takes place only during the phase change (in the temperature range of the phase change) and terminates whenthe phase change in all of the PCMs would complete. Since, this type of thermal insulation is temporary; therefore, it can be referred to as dynamic thermal insulation. Numerous engineering applications have made the topic melting of phase change material as one of the most active fields in heat transfer research today [2].

The solar thermal energy is clean, cheap and abundantly available renewable energy which has been in use since ancient times. The sun is a sustainable source providing solar energy in the form of radiations, visible light and infrared radiations. This solar energy is captured naturally by different surfaces and converted into thermal energy by using solar collectors. The STE are more efficient nowadays. However, there are certain limitations of STE which are given below:

i) Availability is limited to sun hours. ii) In cloudy days and during night time efficiency of STE reduces. iii) Need of storage. iv) Large area entails high capital cost. v) Owing to change in the position of sun, tracking is required. vi) It will take more time to heat fresh water entering in tank.

Solar cooking with all its benefits, starting from environment-friendliness to its cost effectiveness, is yet to be accepted as a viable option for cooking. The main reason for this can be traced out as;

i) Cooking occurs only in sunshine hours. ii) No ease of cooking as the user has to wait longer for simple cooking processes like boiling. iii) Limited number of dishes that can be cooked.

While in the day time cooking will not be an issue, for the night there has to be some form of back-up energy stored throughout the day. This is achieved by selecting a material that has high heat retention capability. However recent studies show that sensible heating is not the option, even if the material has a high Specific heat. This is why we opted for Latent Heat storage using phase change materials.

Latent heat storage is a relatively new area of research which can be used for storing heat by changing the phase of the material without rise in its temperature. To improve the ease of cooking one must separate the traditional model of a solar cooker that has its absorber, cooking surface and heat storage system all jammed to the same place. We can implement the design by having an outdoor arrangement for heat absorption and storage. Solar cookers are heat exchangers designed to use solar energy in cooking processes [6].

II. LITERATURE REVIEW

Shukla A [1] has been studied that The importance of energy in economic development is very critical as there is a strong relationship between energy and economic activity. Historically fossil fuel in its solid phase, i.e. wood and coal, has been the prime source of energy. Renewable energy sources such as solar, wind, hydropower and biogas are potential candidates to meet global energy requirements in a sustainable way. S. Mondal [2] has been studied and investigated the advantage of latent heat that can be stored or released from a material over a narrow temperature range. PCM possesses the ability to change their state with a certain temperature range. These materials absorb energy during the heating process as phase change takes place and release energy to the environment in the phase change range during a reverse cooling process. Insulation effect reached by the PCM depends on temperature and time. Atul Sharma[3] has been studied the use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process. PCMs have been widely used in latent heat thermal- storage systems for heat pumps, solar engineering, and spacecraft thermal control applications. The uses of PCMs for heating and cooling applications for buildings have been investigated within the past decade. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications. He also summarizes the investigation and analysis of the available thermal energy storage systems incorporating PCMs for use in different applications. Ederm Cuce [4] has reviewed the available literature on solar cookers is presented. The review is performed in a thematic way in order to allow an easier comparison, discussion and evaluation of the findings obtained by researchers, especially on parameters affecting the performance of solar cookers. The review covers a historic overview of solar cooking technology, detailed description of various types of solar cookers, geometry parameters affecting performance of solar cookers such as booster mirrors, glazing, and absorber plate, cooking pots, heat storage materials and insulation. Moreover, thermodynamic assessment of solar cooking systems and qualitative evaluation of thermal output offered by solar cookers are analysed in detail.

III.SYSTEM MODELING

One of the most important aspects in the selection of the material is conformable melting point and high latent heat of fusion. The choice of the substances used largely depends upon the temperature level of the application. Residential and commercial cooking often has requirements at around 150°C. The right melting point enables that the phase changing comes off during every usage cycle. Thereby the latent heat could be fully utilized. According to the required temperature of the domestic solar cooker the melting point should be between 105^0C and 110^0C [4, 5, 6].

Latent heat storage is one of the most efficient ways of storing thermal energy. Unlike the sensible heat storage method, the latent heat storage method provides much higher storage density, with a smaller temperature difference between storing and releasing heat. Every material absorbs heat during heating process while its temperature is rising constantly. The heat stored in the material is released into the environment through a reverse cooling process. During the cooling process, the material temperature decreases continuously. Comparing the heat absorption during the melting process of a phase change material (PCM) with those in normal materials, much higher amount of heat is absorbed if a PCM melts. A paraffin-PCM, for an example, absorbs approximately 200 kJ/ kg of heat if it undergoes a melting process. High amount of heat absorbed by the paraffin in the melting process is released into the surrounding area in a cooling process starts at the PCM'scrystallization temperature. After comparing the heat storage capacities of textiles and PCM, it is obvious that by applying paraffin-PCM to textiles their heat storage capacities can substantially enhanced [2].

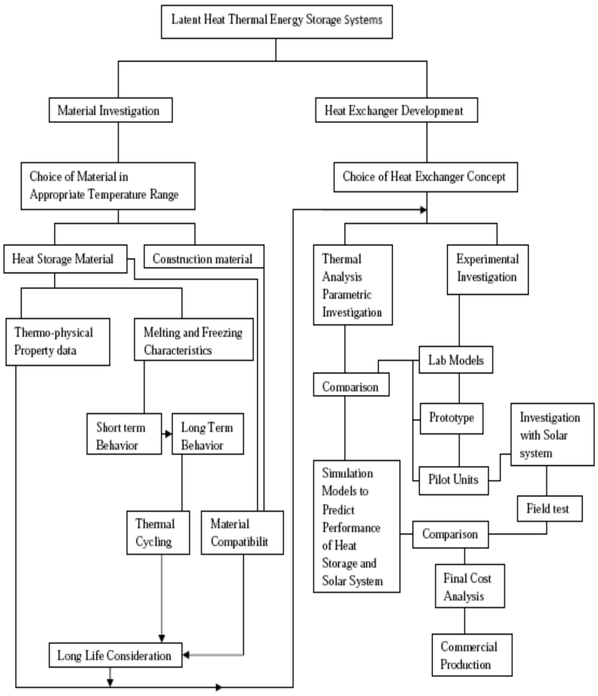


Fig. 3.1. Latent heat thermal energy storage system

During complete melting process, temperature of PCM as well as its surrounding area remains nearly constant. The same is true for the crystallisation process; during the entire crystallisation process the temperature of the PCM does not change significantly either. Phase change process of PCM from solid to liquid and vice versa is schematically shown in Figure 3.2 the large heat transfer during the melting process as well as the crystallization process without significant temperature

IV.EXPERIMENTAL SETUP AND RESULTS

The primary objective of the project is to develop solar cooker system with PCM. Box type based solar cooker system can be utilized for cooker development by using several modifications. PCM is the prime material used to modify the conventional system. It is added in the vessel which after heating turns in to liquid and vice versa.

Acetanilide material is implemented as phase change material. It is selected because of its high latent heat of fusion which is about 222 kJ/kg. It has the ability to change its phase with application of heat.

Following parameters are important for PCM selection

[1] Melting point

[2] Latent heat of fusion

[3] Heat transfer coefficient

[4] Good PCM properties

The experiment is conducted to investigate the thermal performance of solar cooker with Phase change thermal storage unit. The test section of solar cooker is based on box type collector.

Basic components of set up is

[1] Box type collector

[2] Solar Cooker

[3] Insulator box

[4] Acetanilide PCM

Photograph: Actual Experimental Set up Vessel

Properties of Phase Change Material

[1] Required melting point of PCM - 105⁰C to 125⁰C

[2] Name - Acetanilide

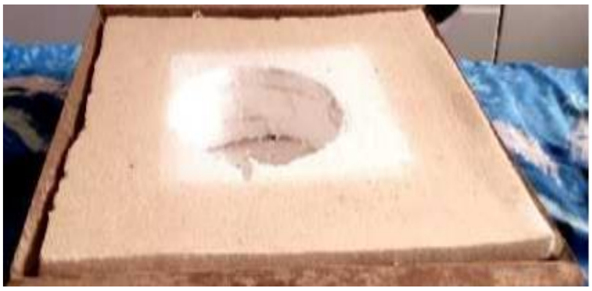
[3] Melting point - 118⁰C

[4] Appearance- White powder

[5] Latent heat L - 222 kJ/kg

[6] Specific heat capacity Cp – 2 kJ/kgC

[7] Density =1219 kg/m



Photograph: Insulator Box

Photograph: Glazing

Photograph: Temperature Indicator

System comprises of various functioning mode like charging mode, discharging mode, standby mode for its effective operation. With this set up actual cooking operation is performed to check whether all these instruments comply to our requirement or not.

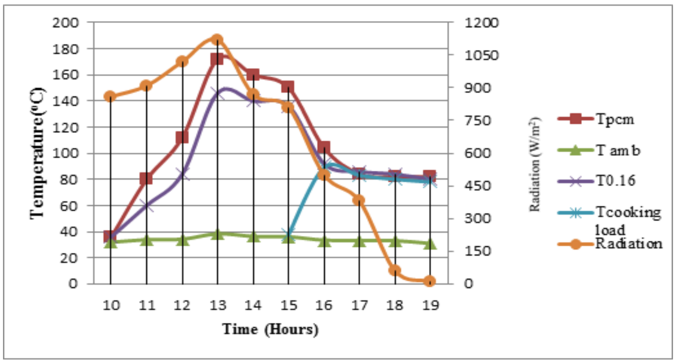


Fig. 1 : Experimental Variation of Temp with Cooking Load and Glazing (Loading at 3 pm)

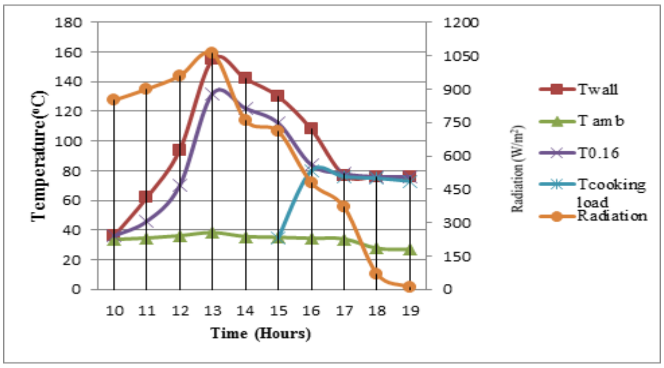


Fig. 2 : Experimental Variation of Temp with Cooking Load and with Glazing (Loading at 3 pm)

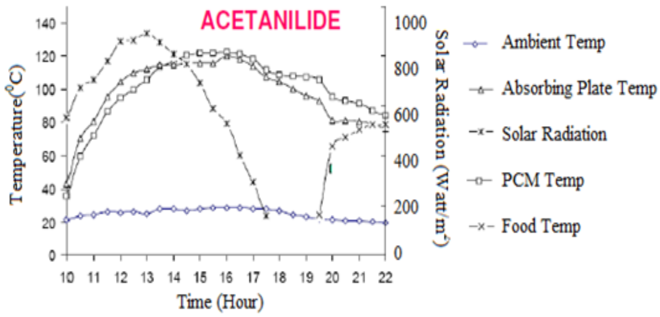


Fig. 3 : Box type Solar Cooker with PCM Storage Unit for Night Cooking in Indian Climate

V. CONCLUSIONS

The results show the feasibility of solar cooker based on box type solar cooker with thermal storage unit for late evening cooking in Indian climatic conditions. This system is initially expensive but shows good potential for community applications. It provides PCM temperatures up to 175⁰C and allows cooking in the shade and also in a conventional kitchen during non-sunshine hours or in the evening. The higher melting heat and conductivity of a PCM like Acetanilide is an advantage for fast cooking indoors. Heat storage and retention is much better when water is removed from the inner pot or a high boiling temperature cooking medium. The use of parabolic solar collector gives better results than box type of solar collector

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