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LITERATURE REVIEW ON SOLAR COOKER USING PCM

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Abstract: Solar cooking technology has to undergo a sea change if at all it's to be accepted as the main source of cooking energy. This is why a better model that incorporates both the traditional heat trapping cum concentrator mechanism and the latest techniques like that which uses a solar battery (phase change materials with high heat retention capability) can be used as the basic idea for the purpose. In this paper parabolic dish collector is selected because it gives better solar energy with minimum loss. Acetanilide is selected as PCM material according to temperature required for cooking and its high latent heat of fusion which is about 222 kJ/kg. This paper reviews relevant issues related with solar cooking using latent heat storage that include cooking pot and concentrating parabolic collector. Cooking utensil is developed by welding two Aluminum cylindrical pots of different diameters concentric to each other. Phase change material (Acetanilide) is filled in hollow space between two pots and pot was kept in parabolic collector.

Keywords: Solar Cooker, PCM

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INTRODUCTION

1.1 BACKGROUND

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].

The continuous increase in the level of greenhouse gas emissions and the climb in fuel prices are the main driving forces behind efforts to more effectively utilize various sources of renewable energy. In many parts of the world, direct solar radiation is considered to be one of the most prospective sources of energy. The scientists all over the world are in search of new and renewable energy sources. One of the options is to develop energy storage devices, which are as important as developing new sources of energy. The storage of energy in suitable forms, which can conventionally be converted into the required form, is a present day challenge to the technologists [2].

1.2 Phase change Material (PCM)

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 a change in state, or 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 when the 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, 4].

1.3 Limitations of Solar Thermal Energy (STE)

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:

1. Availability is limited to sun hours.

2. In cloudy days and during night time efficiency of STE reduces.

3. Need of storage.

4. Large area entails high capital cost.

5. Owing to change in the position of sun, tracking is required.

1.4 Use of PCM

The application of PCM is to restrict the maximum temperature of electronic components seems very promising, especially as they act as passive elements and therefore do not require any additional source of energy. Other applications of PCM are engines and hydraulic machines. These systems are started from low temperatures; the energy consumption and abrasion are high. Therefore, several companies have already investigated and developed latent heat stores for motor vehicles [5].

Another application of PCMs has been its inclusion in solar cookers to extend their usage time. The use of PCM storage for increasing thermal comfort in vehicles has been implemented by companies like BMW. PCM storage has been included in a paint-drying system to recover exhaust heat [5]. A vast range of PCM and technology is available for the development and use of solar water heaters. Many designs of suitable heat exchanger mechanism with PCM for solar water heaters are developed by researchers. Researchers have shown that theoretically and experimentally PCM is a viable option for Solar thermal storage. However there is no commercial design is available in the market.

1.5 Solar cooking

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;

1. Cooking occurs only in sunshine hours.
2. No ease of cooking as the user has to wait longer for simple cooking processes like boiling.
3. 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.

Depending upon the heat transfer mechanisms to the cooking pot, solar cookers can be classified in two types: direct solar cookers (i.e. hot box cookers and concentrator cookers) and indirect solar cookers (i.e. flat-plate collector cookers and evacuated tube collector cookers). The direct solar cookers use solar radiation directly in the cooking process, while the indirect cookers use solar radiation to heat a thermal fluid that transports this heat to the place of the cooking processes. Hot box solar cookers have been widely accepted in India and other countries where there is a shortage of energy and pressure on biomass resources. Various models with different designs of hot box solar cookers have been sold commercially. Concentrator solar cookers in which the cooking pot is placed at the focus of a concentrating mirror have not been widely adapted due to the need of continual adjustment of its orientation. Hot box solar cookers and concentrator solar cookers are simple in terms of fabrication, handling and operation and are cheap and effective [6].

1.6 Existing system of solar cooker

A. Box Cookers

Box cookers are the most common type made for personal use. They consist of an enclosed inner box covered with clear glass or plastic, a reflector, and insulation. There is a wide variety of patterns and plans that can be adapted to work with available materials. While they do not heat quickly, they provide slow, even cooking. Box cookers are very easy and safe to use, and fairly easy to construct.

B. Panel Cookers

Panel cookers are flat reflective panels which focus the sunlight on a cooking vessel without the inner box common in box cookers. Panel cookers are the easiest and least costly to make, requiring just four reflective panels and a cooking vessel, but they are unstable in high winds and do not retain as much heat when the sun is hidden behind clouds.

C. Parabolic Cookers

Parabolic cookers reach higher temperatures and cook more quickly than solar box cookers, but are harder to make and use. Parabolic cookers require more precision to focus the sunlight on the cooking vessel When the parabolic oven is used, the temperature must be watched so the vessel does not overheat, burning the food. The risk of burns and eye injury is greater with homemade parabolic designs [8].

1.7 Need of solar cooking

In India various sources are used for cooking .following fig shows us sources for cooking.

As our demand for LPG and electrical energy are escalating day by day, the amount of fossil fuel will become scarce on one day. By implementing solar cooker for cooking we will find useful solution for this problem. The overall system will work only during the daytime then it will not be compact and there will be many predicaments cooker in each and every house will replace LPG and electric stove. Installation of this system in India reduces more than millions of tons CO_2 emissions. The rise in the rate of global warming temperature can be greatly reduced. Thus this system could bring extravagant changes to this hectic world [9]

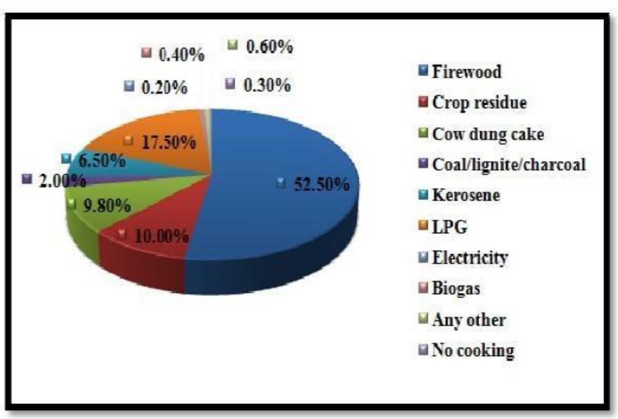

Fig 1.1 Sources of cooking in India

1.8 Aim & objectives of present study

Aim of the project was to study the effects of PCM on the performance of solar cooker systems. In order to achieve this aim, following objectives were set for the project:

1. To review literature published on the PCM for selection of proper material for solar cooker.
2. To develop experimental facility in the lab for testing the solar cooker with PCM.
3. Selection of proper insulation.
4. Performance tests on systems with and without PCM.
5. Analysis of results and conclusions based on results.

Literature Review

Introduction

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 have 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°C and 110oC [4, 6, 10].

2.1.1. Phase change process

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 a 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.

During complete melting process, temperature of PCM as well as its surrounding area remains nearly constant. When temperature increases, the PCM microcapsules absorbed heat and storing this energy in the liquefied phase change materials. When the temperature falls, the PCM microcapsules release this stored heat energy and PCM solidify [2].

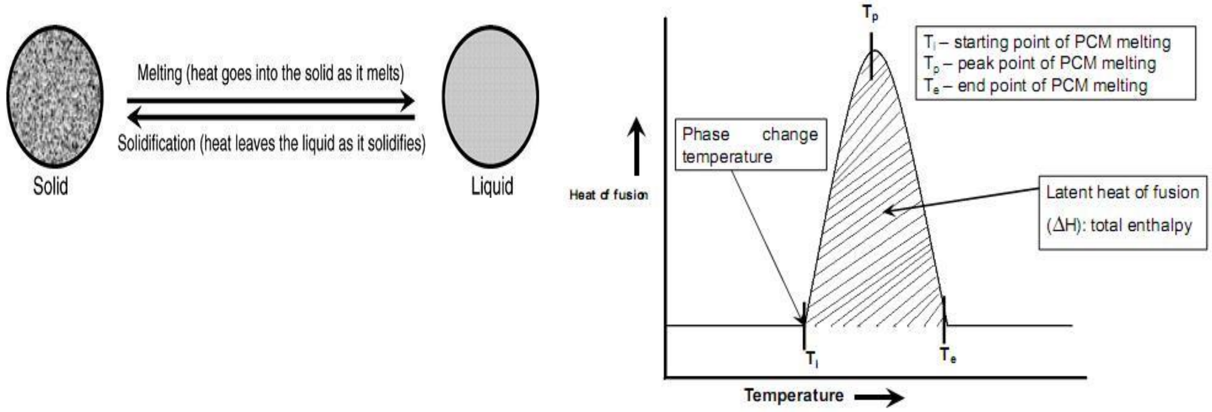

Fig.2.1. Schematic representation of phase change process [2]

2.1.2. Working principle of PCM

When a material converts from one state to another, this process is called phase change. There are four kinds of phase change processes, such as (a) solid to liquid (b) liquid to gas (c) solid to gas and (d) solid to solid. Heat is absorbed or release during the phase change process. This absorbed or released heat content is called latent heat.

Modes of heat transfer are strongly depend on the phase of the substances involve in the heat transfer processes. For substances that are solid, conduction is the predominate mode of heat transfer. For liquids, convection heat transfer predominates, and for vapours convection and radiation are the primary modes of heat transfer.

A phase change also occurs when water is heated to a temperature of 100oC at which point it becomes steam. In order to compare the amount of heat absorbed by a PCM during the actual phase change with the amount of heat absorbed in an ordinary heating process; water can be used for comparisons. When ice melts into water it absorbs approximately a latent heat of 335 kJ/kg. When water is further heated, a sensible heat of only 4 kJ/kg is absorbed while the temperature rises by one degree Celsius [2].

2.1.3 Properties of PCM

Thermal properties

- Suitable phase-transition temperature.
- High latent heat of transition
- Good heat transfer.

Physical properties

- Favourable phase equilibrium
- High density
- Small volume change
- Low vapour pressure.

Kinetic properties

- No super cooling
- Sufficient crystallization rate

Chemical Properties

PCM can suffer from degradation by loss of water of hydration, chemical decomposition or incompatibility with materials of construction. PCMs should be non-toxic, non flammable and non-explosive for safety [2].

Work on solar cooker with PCM materials

Energy storage not only reduces the mismatch between supply and demand but also improves the performance and reliability of energy systems and plays an important role in conserving the energy. Solar energy applications require an efficient thermal storage. Hence, the successful application of solar energy depends, to a large extent, on the method of energy storage used [1].

Overall review of recent work in solar cooker using PCM is as follow.

Table 2.1 Review of recent work on solar cooker using PCM.

No	Year	Author	PCM Material	M.P (^oC)	Latent heat of fusion (kj/kg)	Type of collector	PCM temp achieved (^oC)
1	1997	Buddhi and Sahoo	Stearic acid	55	161	Box Collector	80
2	2000	S.D Sharma	Acetamide	82	263	Box Collector	105
3	2003	Buddhi and Sharma	Acetanilide	118.9	222	Box Collector	130
4	2005	S.D Sharma	Erythritol	118	339.8	Evacuated tube	140

5	2008	H.M.S Hussein	Magnesium nitrate hexahydrate	89	134	Flat plate collector	142
6	2012	A.Arunasalam	$MgCl_2.6H_2O$	116.7	168.6	Parabolic Collector	152
7	2013	A. lecuona	Paraffin	100	140	Parabolic Collector	164
8	2013	A.Chaudhary	Acetanilide	118.9	222	Parabolic Collector	186.3

2.3 Overall summary of literature review

Solar Cooker latent heat storage has been receiving considerable attention only over the last decades, yielding promising results. Previous research on LHTES and Solar Cooker shows us performance characteristics of these systems, theoretically and experimentally. The majority of the literature research on the solar cooker using latent heat storage has been performed for box type solar collector arrangements. More recently, it is also used with parabolic designs. Experimental research work has been done with one or two materials and main difficulty faced is low heat transfer. However, it can be made more comprehensive with use of different types of heat transfer enhancement methods. Such work will help to get better result with existing models.

The research work done so far on PCM for Solar Cooker application is not yet extensive. Hence, no commercial design or system has been observed yet in national as well as international market based on use of PCM. An inbuilt thermal storage can be an alternative to the present day solar Cooker due to less complicated design and cost effective.

From literature survey it is observed that latent heat storage may be promising option for solar energy storage. Effective use of PCM can reduce the size of a tank and improve the efficiency of the system. Literature review reveals that main problem is difficulty in achieving cooking temperature. It is difficult to select proper PCM material as it depends on various parameters i.e. melting point of PCM, latent heat of fusion, heat transfer coefficient of PCM.

From above survey we found that heat transfer enhancement gives us very good results in TES system but it is yet not used in Solar Cooker, so we can encorporate this in to conventional models to get better results. Also for sterilization of food temp required is nearly 70oc hence to achieve this temp we need PCM with melting temp in the range of 105 to 110oc,and from above review we concluded that acetanilide is best suitable material with M.P 118oc. From review we also say that parabolic collector is best collector compare to other because it gives us more solar energy with minimum losses.

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