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Solar Cooker using PCM Material

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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. 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 project 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 in parabolic collector solar cooker that include. In order to study internal behavior of PCM, one dimensional heat balance model is developed and compare with experimental results.In order to improve its performance glazing is used and it shows that efficiency of cooker is improved by 7% to 9% over non glazing. From results it clearly shows the possibility of all day around cooking with low initial cost.*

1. INTRODUCTION

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. Phase change materials possess the ability to change their state with a certain temperature range. Solar cooking with all its benefits, starting from environment-friendliness to its cost effectiveness, is yet to be accepted as an 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.

Aim & objectives of present study

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. Analysis of results and conclusions based on results.

2. LITERATURE REVIEW

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 (°C)
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	MgCl2.6H2O	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

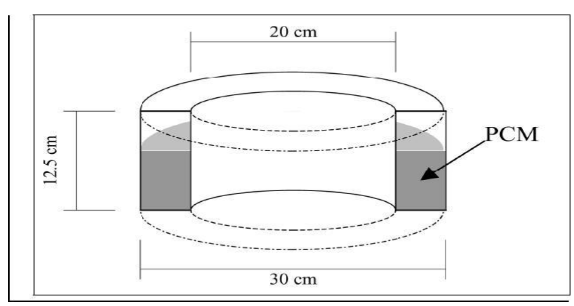

Fig. 2.1: Latent heat storage unit for evening cooking in a solar cooker[12]

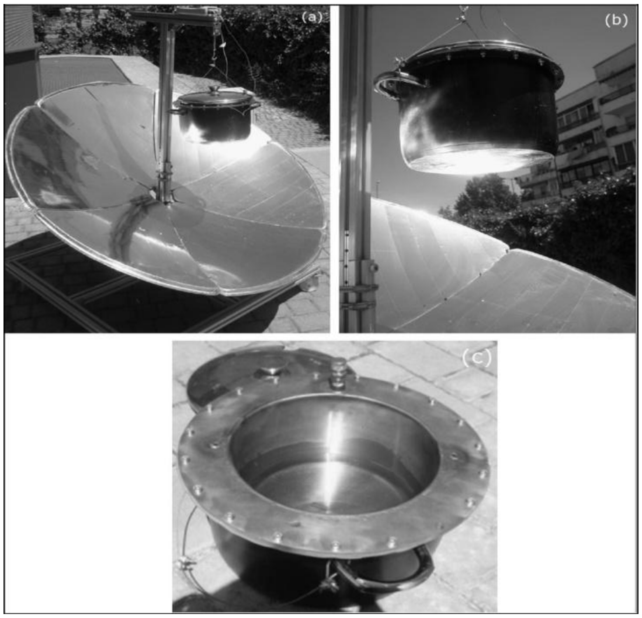

Fig. 2.2: (a) Cooker A in operation. (b) Focused sun on utensil. (c) Inner pot view with water[16]

3. EXPERIMENTAL SET-UP

3.1 Experimental Set-up

This system consists of parabolic dish collector, solar cooker, and insulator box. Acetanilide is used as a phase change material and it is filled in between the hollow space of inner and outer wall of solar cooker. The experimental setup consists of following components:

A. Parabolic solar dish collector

The parabolic dish collector refers to a point focusing device which includes the concentrator and the absorber. In this system, segments of the reflecting material are joined to form the concentrator. A flat surface works as the absorber which absorbs the solar energy concentrated on a point.

B. Solar cooker

C. Phase change material : Acetanilide

Required melting point of PCM - 105oC to 125oC, Melting point - 118oC, Appearance- White powder Latent heat L - 222 kJ/kg , Specific heat capacity Cp – 2 kJ/kg oC

D. Insulator box

E Glazing

3.2 One dimensional energy balance model for solar cooker

This performance model uses an energy balance between the cooking medium and the atmosphere, and includes all equations and correlations necessary to predict the terms in the energy balance, which depend on the collector type, PCM properties, and ambient conditions.

3.3 Selection of measuring Instruments

Instruments were selected with good accuracy and precision. These instruments were calibrated following the standard procedures. Following instruments will used in experimentation.

- Pyranometer
- Temperature sensor
- Temperature indicator

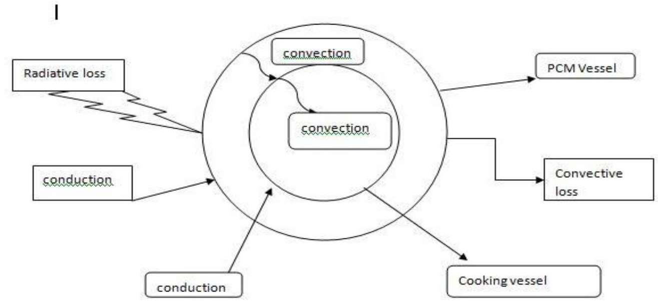

Fig. 3.1: One dimensional energy balance model showing energy distribution

3.4 Summary

Experimental setup was developed keeping provision for further likely modifications in future. Acetanilide as a PCM selected considering various properties of PCM materials and our requirement. Required measuring instrument are selected. Quantity of PCM is calculated considering project requirement. 12 port temperature indicator is selected and calibrated for experimentation. The system was fitted with required measuring instruments with proper accuracy. PCM is checked by heating it up to its melting point and comparing with standard value. PCM is poured in cooking vessel in molten form before experimentation. One dimensional theoretical model is developed in order to compare experimental results.

4. EXPERIMENTAL RESULTS AND DISCUSSION

Following section gives the details of the results and discussions for each test. In the experimental setup, cooking experiments were conducted using a solar cooker based on parabolic dish collector with thermal storage unit. The readings were taken for without cooking load and with cooking load on May 14 to June 2, 2014. Four cases are considered and the various results are obtained:

- Solar cooker with cooking load and with glazing (loading at 10.30 am).
- Solar cooker with cooking load and without glazing (loading at 10.30 am).
- Solar cooker without cooking load and glazing (loading at

3.30 pm).

- Solar cooker without cooking load and without glazing (loading at 3.30 pm).

Experiments were conducted on four different cases mentioned above and compared with heat balance model.

4.1 Experimental results

4.1.1. Solar cooker with cooking load and glazing (loading at 10.30 am)

Fig. 4.1 shows variation of temperature and solar radiation intensity with time in case of solar cooker with cooking load and glazing (loading at 10.30 am)

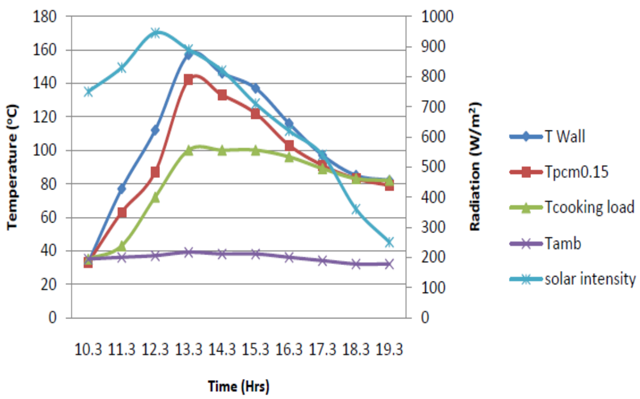

Fig. 4.1: Experimental variation of temperature with time in cooker with glazing (loading at 10.30 am)

Above results are also compare with theoretical model as shown in fig 4.2

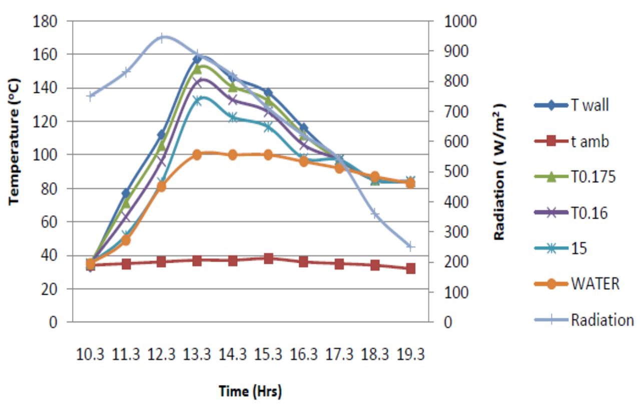

Fig. 4.2: Theoretical variation of temperature with time in cooker with glazing (loading at 10.30 am)

4.1.2. Solar cooker with PCM and without glazing (loading at 10.30 am)

Fig. 4.2 shows experimental variation of temperature and solar radiation intensity with time in case of ordinary solar cooker with pcm;

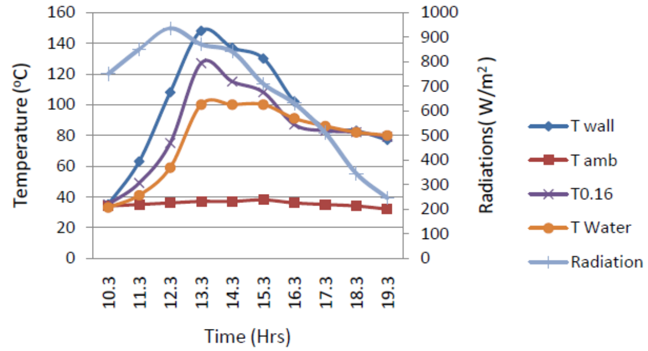

Fig. 4.3: Experimental variation of temp with time in case of solar cooker without glazing (loading at 10.30 am)

In this case maximum temp achieved by PCM is lower compare to cooker with glazing. This cooker is 7 to 9 % less efficient compare to cooker with glazing and this is due to loss of heat by air flowing around the cooker. These results are compared with theoretical model as shown in fig 4.4.

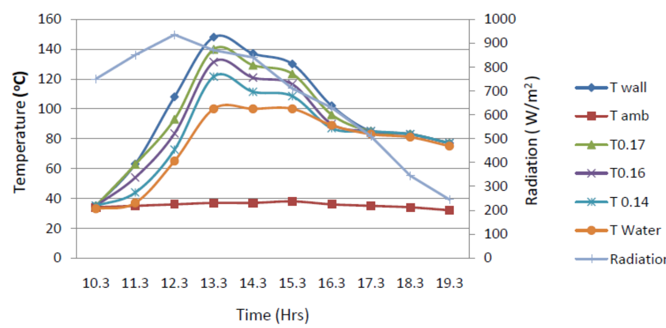

Fig. 4.4: Theoretical variation of temperature with time in cooker without glazing (loading at 10.30 am)

4.1.3. Solar cooker without cooking load and glazing (loading at 3.30 pm)

Experimental variation of temperature with time in this case shown in fig 4.5

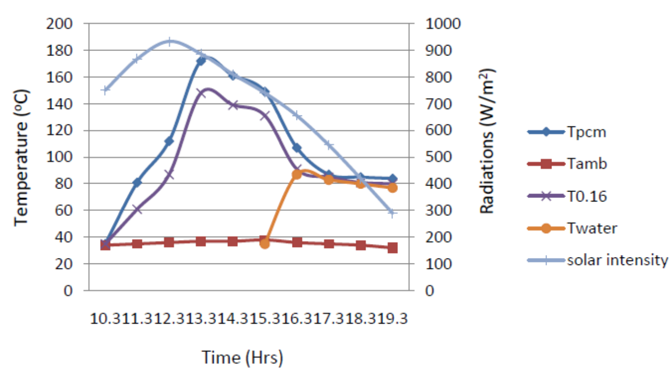

Fig. 4.5: Experimental variation of temperature with time in cooker with glazing (loading at 3.30 pm).

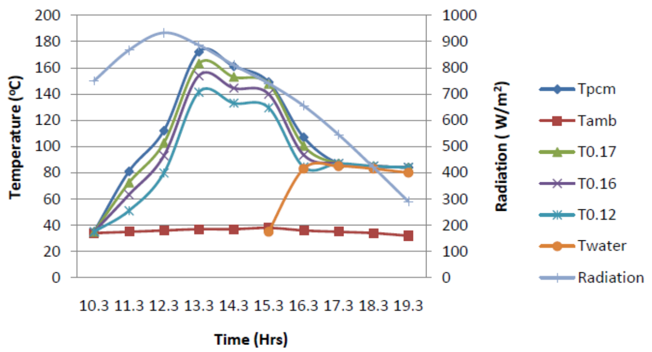

Fig.4.6: Theoretical variation of temperature with time in cooker with glazing (loading at 3.30 pm).

4.1.4. Solar cooker without cooking load and without glazing (loading at 3.30 pm)

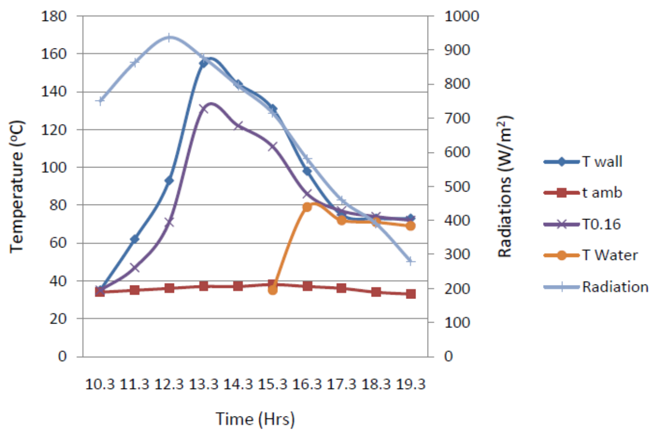

Fig. 4.7: Experimental temperature variation with cooking load and with glazing (loading at 3.30 pm)

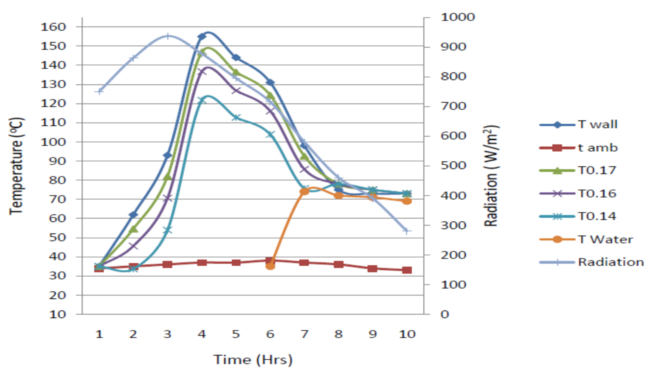

Fig. 4.8: Theoretical temperature variation with cooking load and with glazing (loading at 3.30 pm)

4.2 System efficiency comparison

System efficiency is defined as the ratio of the amount of energy stored by the thermal energy storage pot to the heat energy available from solar radiation. The system efficiencies were calculated and compare it with four different cases under study. Fig 4.7 shows efficiency comparison between four cases.

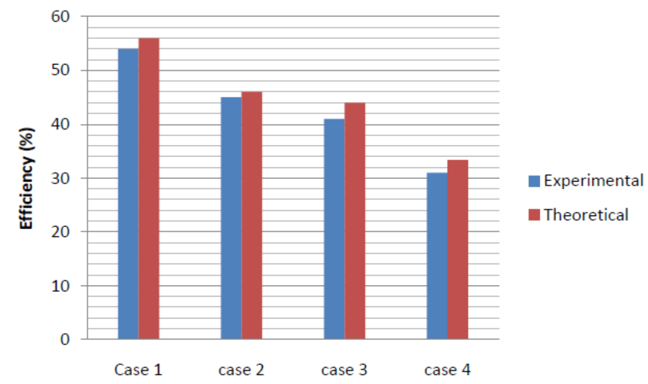

Fig. 4.9: Efficiency comparison between four cases under study

From above result we find out that case 1 i.e. system with cooking load and glazing has maximum efficiency compare to other cases also with glazing there is improvement of 6 to 8 % in efficiency. Efficiency of case 1 is more than all other cases due to glazing and presence of water all the time causing better heat transfer and more heat storage. Efficiency of case 3 is more than case 2 is due to glazing but less than case 1 due to absence of water from cooking vessel causing lower heat storage.

4.3 Energy stored by various systems

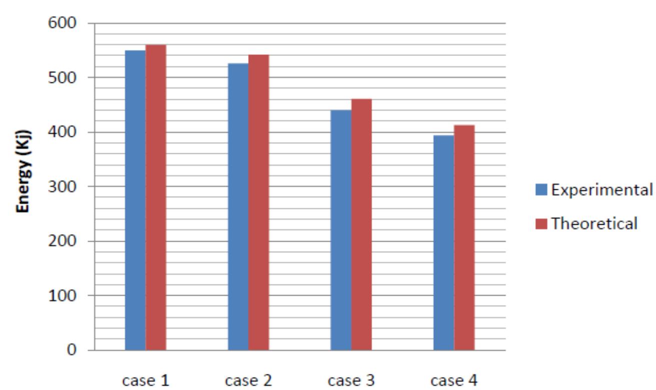

Fig. 4.10: Energy collected by solar cooker in four cases.

4.4 Summary

In this project we find out feasibility of solar cooker with PCM storage and compare experimental result with theoretical model. From result t is shown that system with full day cooking load and with glazing is more efficient than other systems because it store more energy compare to other cases and PCM temp achieved is also more compare to other cases. Efficiency improvement due to glazing is about 6 to 8% and efficiency of theoretical model is greater than actual one in all cases. End temperature achieved in four cases is 89 oC, 81 oC, 78 oC & 72 oC respectively.

Water loss in solar cooker with full day loading with glazing is higher compare to non-glazing cooker while there is no boiling loss of water in cooker with evening loading. The above results show the feasibility of solar cooker based on parabolic dish collector with thermal storage unit for late evening cooking in Indian climatic conditions.

5. CONCLUSION

In this project, use of phase change material (PCMs) for evening / night cooking is discussed. The use of a solar cooker is limited because cooking of food is not possible due to frequent clouds in the day or in the evening. If storage of solar energy can be provided in a solar cooker, then there is a possibility of cooking food during clouds or in the evening and the storage will increase the utility and reliability of the solar cookers. Hence, PCM is the best option to store the solar energy during sun shine hours and is utilized for cooking in late evening/night time. In a country like India these types of cookers are widely acceptable because of electricity and cost of cooking gases.

In this project 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.

To avoid heat loss to surrounding air we also find out the possible use of glazing and decide to use during our study to avoid loss of solar energy due to air flow and to improve its performance. From result it is proved that efficiency of cooker improved by 6 to 8% by possible use of glazing also in case of cooker with evening loading end temperature achieved is 780C which is more than sterilization temp of most of the food.

6. FUTURE SCOPE

1. PCM used in experimentation is commercial grade Acetanilide. It is possible to conduct these experiments with other categories of PCM.
2. Optimization of the system parameters in modified system can improve the performance of the system.
3. We can use other type of collector for solar energy collection.

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