A REVIEW OF THERMAL ENERGY STORAGE MATERIALS USED IN VARIOUS TYPES OF SOLAR COOKERS

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ABSTRACT

With the reckless use of non-renewable sources of energy, the need of the hour is to look for alternatives and solar is one of the best and abundantly available alternative . The utilization of solar energy is one of the possible alternative solutions for the cooking the food, but its reliability is less due to intermittent nature of solar energy. The intensity of solar energy varies throughout the day and also varies with the months. The reliability of solar energy may be improved to some limit by designing the heat storage system for solar based cooking system. This paper is a review on various techniques used to make the different types of solar cookers work effectively during the night time . The references are taken from various research papers already published in this domain but on different types of solar cooking arrangements. This paper tells how efficiently the concept of sensible and latent heat storage units can be used to facilitate the cooking in the later hours of the day .

Keyword - *Thermal energy storage(TES), phase change materials (PCMs),latent heat storage(LHS),specific heat storage(SHS), solar cooking, Heat transfer.*

1. INTRODUCTION

Since the beginning of time people have beneficiated by sun. Ancient civilizations personified by the sun. Only recently suns however have we developed the ability to harness the suns awesome power . Cooking by means of solar energy started in the ‘70s in response to the growing shortage of firewood resulting from chronic deforestation. A solar cooker needed solar energy—just a free fuel from the sky for operation. Having the concept to utilize this free fuel from the sun in the mind, many of the research institutes developed solar cookers for some different designs but with certain limitations. The use of a solar box 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 box cooker, then there is a possibility of cooking food in the evening and the storage will increase the effectiveness and reliability of the solar cookers.

2. CLASSIFICATION OF HEAT STORAGE MATERIALS

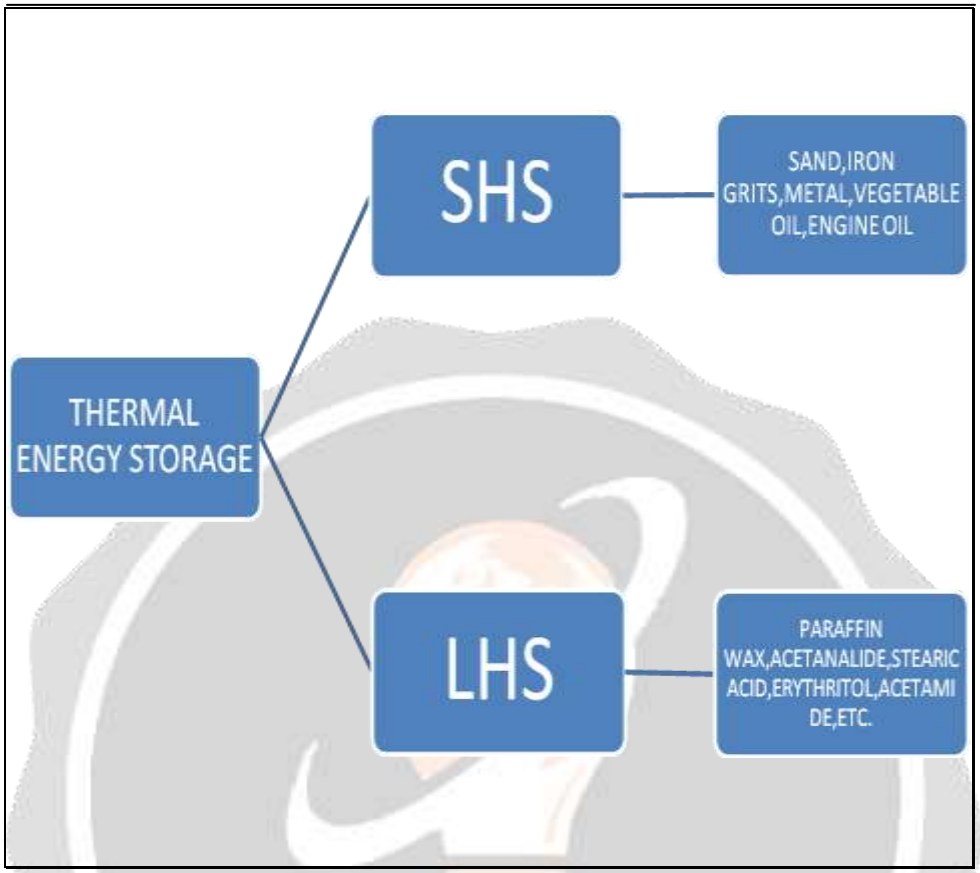

Fig -1: Classification of Solar cooker with Thermal Energy Storage

2.1 Sensible Heat Storage

The most direct way is the storage of sensible heat**.** Sensible heat storage is based on raising the temperature of a liquid or solid to store heat and releasing it with the decrease of temperature when it is required. The volumes needed to store energy in the scale that world needs are extremely large. Materials used in sensible heat storage must have high heat capacity and also high boiling or melting point. Although this method of heat storage is currently less efficient for heat storage, it is least complicated compared with latent or chemical heat and it is inexpensive.

From thermodynamics point of view, the storage of sensible heat is based on the increase of enthalpy of the material in the store, either a liquid or a solid in most cases. The sensible effect is a change in temperature. Heat stored can be obtained by the equation:

$\Delta Q = m. \int c_p(T).dT$ –{where ,upper limit $–T_2$ and lower limit $–T_1$}

and where :

ΔQ is the energy stored [J]

m is the mass of an object [kg]

c_p is the specific heat capacity [$J.kg^{-1}.K^{-1}$]

dT is the temperature difference

2.2 Latent Heat Storage

A common approach to thermal energy storage is to use materials known as phase change materials (PCMs). These materials store heat when they undergo a phase change, for example, from solid to liquid, from liquid to gas or from solid to solid (change of one crystalline form into another without a physical phase change).The phase change "solid-to-liquid" is the most used, but also solid-to-solid change is of interest. These materials can be used as an effective way of storing thermal energy (solar energy, off-peak electricity, industrial waste heat). In comparison to sensible heat storage systems, the latent heat storage has the advantages of high storage density (due to high latent heat of fusion) and the isothermal nature of the storage process. The heat of fusion or the heat of evaporation is much greater than the specific heat capacity. The comparison between latent heat storage and sensible heat storage shows that in latent heat storage storage densities are typically 5 to 10 times higher.In general, latent heat effects associated with the phase change are significant.Latent heat known also as the enthalpy of vaporisation (liquid-to-vapor phase change) or enthalpy of fusion (solid-to-liquid phase change), is the amount of heat added to or removed from a substance to produce a change in phase. This energy breaks down the intermolecular attractive forces, and also must provide the energy necessary to expand the substance . When latent heat is added, no temperature change occurs.

2.2.1 Phase Change Material (PCM)

Phase Change Materials (PCM**)** are latent heat storage materials. It is possible to find materials with a latent heat of fusion and melting temperature inside the desired range. The PCM to be used in the design of thermal storage systems should accomplish desirable thermophysical, kinetics and chemical properties.

There are a large number of PCMs, they can be divided into three groups:

- Organic PCMs
- Inorganic PCMs
- Eutectic PCMs

As an example, thermal energy storage can be used in concentrating solar power stations (CSP), in which the principal advantage is the ability to efficiently store energy, allowing the dispatching of electricity over up to a 24-hour period. In a CSP plant that includes storage, the solar energy is first used to heat the molten salt or synthetic oil to store thermal energy at high temperature in insulated tanks. Later hot molten salt is used for steam production to generate electricity by steam turbo generator as per requirement. The use of both latent heat and sensible heat in concentrating solar power stations are possible with high temperature solar thermal input. Various eutectic mixtures of metals, such as Aluminium and Silicon (AlSi12) offer a high melting point (577°C) suited to efficient steam generation, while high alumina cement-based materials offer good thermal storage capabilities.

3. REVIEW WORK :

Sr.no	Paper Title	Authors	Solar Cooker and Thermal Energy Storage Method	Summary
1	Thermal Performance of solid and liquid energy storage materials in a	1) Ramalingam Senthil 2)Muthupandian Cheralathan	SHS materials like pebbles , irongrits,steelballs,oliveoil,coconut oil, sunflower oil	In this paper, a solar cooker was coupled with sensible heat storage materials (SHS).These were pebbles, sand & iron

	parabolic dish solar cooker			grits,steel balls,olive oil and coconut oil and these SHS materials solved the problem of cooking at off-sunshine periods. The enhanced thermal performance of cooking pot was observed with around 300KJ & 900KJ for selected solid &liquid material respectively.
2	Solar cooking using PCM as a thermal heat storage	1)Abhishek Saxena 2)Shalini Lath 3)Vineet Tirth	Stearic acid	This paper shows that night cook is not possible with simple solar cooker. But solar cooker with PCM is very beneficial for this as well as for energy conservation. Many PCM's are under testing for solar cooking but stearic acid is used commonly due to easy availability &economical suitable.
3	Hybrid Indirect Solar cooker with latent heat storage	1)Benazeer Hassan K.Ibrahim 2)Victor Jose	Evacuated tube collector Hybrid Indirect Solar cooker PCM Electric source	A hybrid solar cooker with an alternate supply & electric heating plate is used in combination with PCM (electric plate is in the bottom of cooking vessel). The highest cooking temperature achieved was around 95 degrees Celsius. Also use of nano-fluids is suggested over conventional heat transfer fluids
4	Experimental investigation of novel indirect solar cooker with indoor PCM thermal storage & cooking	1)H.M.S Hussein 2)H.H. El-Ghetary 3)S.A. Nada	Indirect Solar cooker Magnesium nitrate hexa hydrate(PCM)	An integrated PCM thermal storage &cooking unit is designed. Steel wool is embedded in PCM with 20% volume ratio & hence

	unit			conductivity us improved. Cookers can be used for heating and keeping meals at night and early morning breakfast of next day.
5	Solar cooker study under Oman conditions for late evening cooking using stearic acid &acetanilde as PCM materials	1)Nagaraj Nayak 2)Hatim Abu Jarir 3)Haitham Al Ghassani	Acetanilde (PCM) Stearic Acid(PCM) Cylindrical vessel	In this case study cooker efficiency of30% & collector efficiency of (60-65) % was achieved (max temperature =120 degrees. Celsius) The study indicated that acetanilde would be better than stearic acid from performance point of view.
6	Experimental investigation of indirect solar cooker using evacuated tube collector with dual Thermal Storage Unit	1)Manish Gupta 2)Sunil kumar 3)Puneet Katyal	Indirect solar cooker Sand and iron gris	A SHS system was used as TSU(thermal storage unit) in which sand & iron grits were used as SHS materials. Indoor cooking is done and two batches of food can be prepared. Heating of system is greater in evening than in the morning.
7	Review of Phase Change Materials based on energy storage system with applications	1)R.Thamaraikam 2)B Kanimozhi 3)M .Anish 4)J Jayaprabakar 5)A.Rohan Nicholas 6)P.Saravan	Stearic Acid Paraffin wax Acetamide	From the study done in the paper it is found that they have carried out various methods of heat transfers techniques to improve the TES system. The paper mainly focused on PCM based TES system. It is found that although the acetamide and paraffin wax are found to be more stable than stearic acid ,they are not

				preferred as stearic acid is easily available and also from the performance point of view .
8	Thermal Performance evaluation of solar cooker with latent &sensible heat storage unit for evening cooking	1)Vikrant Yadav 2)Yogender Kumar 3)Himanshu Agrawal 4)Avadhesh Yadav	PCM in combination with SHSM's PCM-stone pebbles PCM-sand PCM –iron grits PCM-iron ball	The paper presented is an investigation of thermal performance of phase change material (PCM) in combination with different sensible heat storage materials (SHSMs). It has been found that PCM-Sand and PCM-Stone pebble cases store 3 to 3.5 times more heat as compared to PCM-Iron grits and PCM-Iron ball cases. The PCM assists in cooking while the outer material assists PCM to maintain its performance.
9	A review of Thermal Energy Storage designs, heat storage materials and cooking performance of solar cookers with heat storage	1)LameckNikhonjera 2)Tunde -Bello-Ochende 3)Geoffrey John	Rectangular & Cylindrical containers Oils Organic phase change materials	Mainly,inclusion of thermal conductive material into storage medium was the principal technique. The main point drawn out from this paper is that there is no significant difference between cooking powers of SHS and LHS units.
10	Solar cooker with heat storage system: A Review	1.)Ashish Agarwal	Cylindrical vessels Engine oil Vegetableoil sand PCM(paraffin wax,acetamide, stearic acid, magnesium nitrate hexahydrate)	Different designs of solar cooking system with heat storage system have been discussed in this paper. It is observed that solar cookers with heat storage provisions are found to work more efficiently and can provide extra hours of cooking and higher temperature too and cookers with cylindrical

				vessels are used dominantly in which provision for TES is given.

4. CONCLUSIONS

This review paper attempted to provide an overview of different arrangements used in solar cooking to store the heat energy and combination of these arrangements with different types of solar cookers.

1.) It can be concluded that night time cooking is possible in solar cookers having various thermal energy storage units.

2.) Among these TES units, use of Phase Change Materials is mostly preferred over Sensible Heat Storage materials(SHSM's)since they involve storage of latent heat .

3.) And finally Stearic acid is preferred by most of the researchers due to its good performance and easy availability over other PCM's.

5. REFERENCES

[1]. Abhishek Saxena, Shalini Lath, Vineet Tirth ,"Solar cooking using PCM as a thermal heat storage",MIT International journal of Mechanical Engineering,Vol. 3,No.2,August 2013
[2]. Benazeer Hassan K.Ibrahim , Victor Jose," Hybrid Indirect Solar cooker with latent heat storage",International Journal of engineering sciences and research technology,JULY 2016
[3]. H.M.S Hussein ,H.H. El-Ghetary and S.A. Nada,"Experimental investigation of novel indirect solar cooker with indoor PCM thermal storage & cooking unit",Energy conservation and management ,Volume 49,issue 8,August 2008
[4]. Nagaraj Nayak, Hatim Abu Jarir , Haitham Al Ghassani," Solar cooker study under Oman conditions for late evening cooking using stearic acid &acetanilde as PCM materials",Journal of solar energy,Volume 2016,13 October 2016
[5]. Manish Gupta,Sunil Kumar," Experimental investigation of indirect solar cooker using evacuated tube collector with dual thermal storage unit",International journal of Thermal Technologies,Vol 5,n0.3(Sept 2015)
[6]. Ramalingam Senthil, Muthupandian Cheralathan," Thermal Performance of solid and liquid energy storage materials in a parabolic dish solar cooker",Material sciences,2016
[7]. R.Thamaraikam ,B Kanimozhi ,M .Anish, J Jayaprabakar ,A.Rohan Nicholas and P.Saravan," Review of phase change materials based on energy storage system with applications",Frontiers in automobile and mechanical engineering,IOP series:Materials sciences and engineering,197(2017)
[8]. Vikrant Yadav,Yogender Kumar,Himanshu Agarwal and Avadesh Yadav," Thermal Performance evaluation of solar cooker with latent &sensible heat storage unit for evening cooking",Australian journal of mechanical engineering,Volume 15,2017
[9]. LameckNikhonjera, Tunde -Bello-Ochende ,Geoffrey John," A review of thermal energy storage designs, heat storage materials and cooking performance of solar cookers with heat storage",Renewable and sustainable energy reviews,Volume 75,August 2017
[10]. Ashish Agarwal," Solar cooker with heat storage system: A Review",International journal of advanced research in applied sciences,engineering and technology,Vol(1),Issue (1),2019