A Review Paper on Nano mixed Phase Change Material for Indoor and Outdoor Solar Cooker Application

V.V. Bamane[1], C.V. Papade[2]

[1]*P.G. Student Department of Mechanical Engineering, N. K. Orchid. College of Eng. & Tech. Solapur, Solapur University, Maharashtra (India)*
[2]*Assistant Professor Department of Mechanical Engineering, N. K. Orchid. College of Eng. & Tech. Solapur, Solapur University, Maharashtra (India)*

Abstract: *In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is solar energy. Again there is need to store solar energy because solar energy is not available for whole day and the intensity of solar radiation is not constant throughout the day time. Hence the best option to store solar energy in thermal form is the use of phase change materials (PCM) due to their large heat storing capacity than sensible heat storing material. Again there are some drawbacks of these energy storing materials such as low specific heat, low thermal conductivity, high melting point. So to overcome these drawbacks of energy storing materials such as PCM has to be done. Addition of nano particles into base PCM plays an important role in its thermal performance.*

Keywords: *Solar Energy, Solar Cooker, Latent Heat Storage, Pcm, Nanoparticle*

1. Introduction

Energy is a thermodynamic quantity that is often understood as the capacity of a physical system to do work. Besides its physical meaning, energy is vital for our relations with the environment. Solar energy offers a wide variety of applications in order to harness this available energy resource. Among the thermal applications of solar energy, solar cooking is considered as one of the simplest, the most viable and attractive options in terms of the utilization of solar energy.

The storage of thermal energy is achieved by internal energy of a material as sensible heat, latent heat, and thermo-chemical heat or combination of these. Sensible heat storage system uses the specific heat capacity of the substance and the temperature of a material. Temperature of the substance increases during charging and decreases during discharging. Latent heat storage (LHS) is based on absorption or release of heat when a storage material undergoes a phase change. There are some drawbacks of the phase change material used for the storage of the solar energy such as the low thermal conductivity, high melting point, low specific heat and others. Nano particles play an important role in this situation because of their unique properties at the nano level. So by combination of the PCM and nano particles the properties of PCM can be revamped by mixing the nano particles in exact proportion. Hence the effective, efficient and user friendly energy storage can be done.

2. Literature Review

The literature related to phase change material and nanoparticles will be considered for the review for the indoor and outdoor solar cooker application.

G. Kumaresan et al. [1]: He conducted the performance evaluation of a newly developed double walled cooking unit (tava type) suitable for an indirect type solar cooking application integrated with thermal energy storage system is presented .Therminol 55 and D-Mannitol are used as the heat transfer fluid (HTF) and storage medium respectively. During the cooking experiment the maximum temperature reached by the olive oil in the cooking unit was 152^0C within a duration of 15 min which is comparatively lesser than the time taken by a conventional LPG stove in simmering mode.

Nayak A.O. et al. [2]: In this paper he has considered various PCM like paraffin wax, sodium acetate tri-hydrate and phenolphthalein which are used to absorb heat from the coolant water from the engine. Due to conduction and convection of heat transfer heat is stored inside the PCM in the form of latent heat. Convection and heat flux effect due to temperature change has been simulated and studied in detail using GAMBIT and FLUENT. Coolant water loses maximum heat to sodium acetate tri-hydrate which is obtained as drop in temperature from 343 K to 324 K (in the coolant water).

Hajare V. S. et al. [3]: In this paper work paraffin wax is taken as PCM for experimentation work. In paraffin wax Al_2O_3 nano particles were added in 0.5%, 1% and 2% to enhance its thermal performance. For the experimentation solar water heating system is considered as latent heat thermal storage from

experimental investigation carried out it is found that there is enhancement in heat transfer rate of PCM due to the incorporation of nano particles. Heat transfer rate in the PCM is totally depends upon the amount of melt fraction.

Karunamurthy K. et al. [4]: In this paper, K. karunamurthy has explained the effect of the CuO nano particles on paraffin PCM. He preferred PCM because of its higher storage density, with less volume. Poor thermal conductivity, more time period and more surface area for charging and discharging of thermal energy are the main drawbacks of the selected PCM. The thermal conductivity of PCM is determined both analytically and experimentally. From the experimental investigation carried out, it was observed that, the thermal conductivity of PCM is increased by around to 77% experimentally for 0.15% of CuO nano particles.

Sharama R.K. et al [5]: In this paper thermal energy storage as sensible or latent heat is an efficient way to conserve the waste heat and excess energy available such as solar radiation. Storage of latent heat using organic phase change materials (PCMs) offers greater energy storage density over a marginal melting and freezing temperature difference in comparison to inorganic materials. They focuses on three aspects: the materials, encapsulation and applications of organic PCMs, and provides an insight on the recent developments in applications of these materials.

Ahmet S. et al [6]: In this paper a series of poly (styrene-co-allyalcohol)-graft-stearic acid copolymers were synthesized as novel polymeric solid–solid phase change materials (SSPCMs). Thermal energy storage properties of the synthesized SSPCMs were measured using differential scanning calorimetry (DSC) analysis.

Prabhu B.et al [7]: In this paper Models for oil pebble-bed thermal energy storage (TES) system and the thermal energy utilization (TEU) system of an indirect solar cooker are used to perform discharging simulations. The model is validated with experimental results and reasonable agreement is obtained between simulation and experiment. On the other hand, the controlled load power discharging method has a slower initial rate of heat utilization but the maximum cooking temperature is maintained for most of the discharging process and this is desirable for the cooking process.

M.M. Valmiki et al. [8]: In this paper a novel design and the prototyped solar cooking stove which uses a large fresnel lens for the concentration of sunlight. The technology demonstrates high safety and efficiency of solar cooking and heating using fresnel lenses which are low cost and available from off-the-shelf. The heat is used to maintain a stovetop surface at temperatures around as high as 300 ^{0}C, which is practical for cooking applications in a very safe, user-friendly, and convenient manner. The indoor stovetop could reach a temperature of 150 ^{0}C for cooking application.

M. Mussard et al. [9]: He found a comparative experimental study of two solar cookers. The first is the widespread SK14 cooker; the second is a prototype of a solar concentrator (parabolic trough) using a storage unit. The SK14 is a direct solar cooker where the cooking pot is placed on the focal point of a parabolic dish; in the trough system heat is transported from an absorber to a storage unit by means of a self-circulation loop filled with thermal oil. Cooking takes place directly on the top of the storage. Both boiling and frying are tested to estimate the cooking efficiency of the heat storage system.

S.B. Joshi et al. [10]: He found a small scale box type solar cooker (SSB) weighing 4.8 kg is modified into a novel photovoltaic and thermal hybrid solar cooker named as small scale box type hybrid solar cooker (SSBH) weighing 6.5 kg. Five solar panels each of 15W are attached with this cooker. Cooking time is reduced due to the photovoltaic power generated by solar panels along with the solar thermal power. The design features of this hybrid solar cooker include proper sizing of solar photovoltaic panels, battery and dc heaters.

M. Bansal et al. [11]: He found an effort has been made to review the developments occurred in cooking sector rural areas in Indian context. The work carried out on different cooking fuels and cook stoves has been presented in order to use renewable energy sources and to identify the barriers of their dissemination. In order to make the cooking exercise clean, cooking fuel plays an important role.

3 Classification of PCM

A large number of phase change materials (organic, inorganic and eutectic) are available in any required temperature range. There are a large number of organic and inorganic chemical materials, which can be identified as PCM from the point of view melting temperature and latent heat of fusion. However, except for the melting point in the operating range, majority of phase change materials does not satisfy the criteria required for an adequate storage media as discussed earlier. As no single material can have all the required properties for an ideal thermal-storage media, one has to use the available materials and try to make up for the poor physical property by an adequate system design. The PCM to be used in the thermal-storage systems should passes desirable thermo physical, kinetics and chemical properties which are as follows.

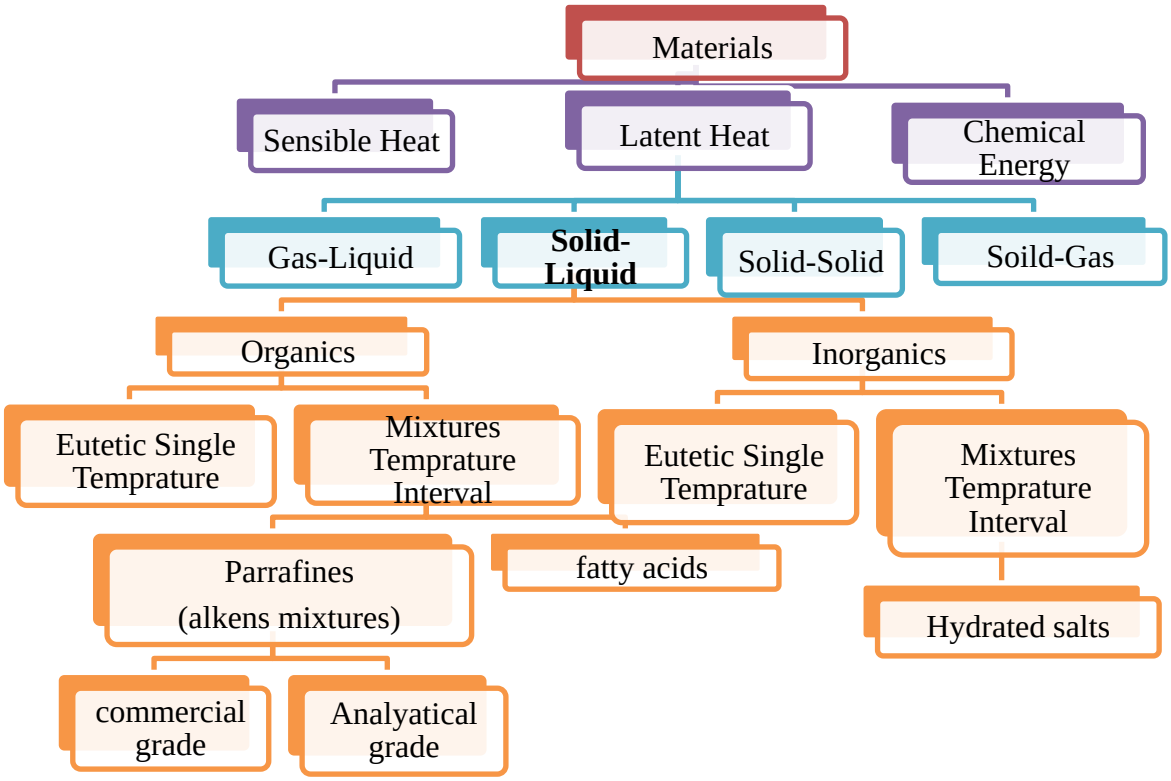

Fig.1 Classification of Pcm

4 Phase Change Material Mixed Nano Particle

The properties of PCM such as low thermal conductivity, high melting point and specific heat so as to increase the performance of PCM in the heat storing application. This PCM can be done with the help of the dispersing the nano particles in appropriate amount into it. Selection of nano particle for the dispersion in the PCM is the main task in this work. So while selecting the nano particle we have to consider the following points

- It should have high thermal conductivity
- Resist strong acid and alkali attack at high temperature
- Good thermal conductivity
- High strength and stiffness
- High melting point
- Cost effective
- Availability

5 Concept of Indoor and Outdoor Solar Cooker with Nanomixed PCM

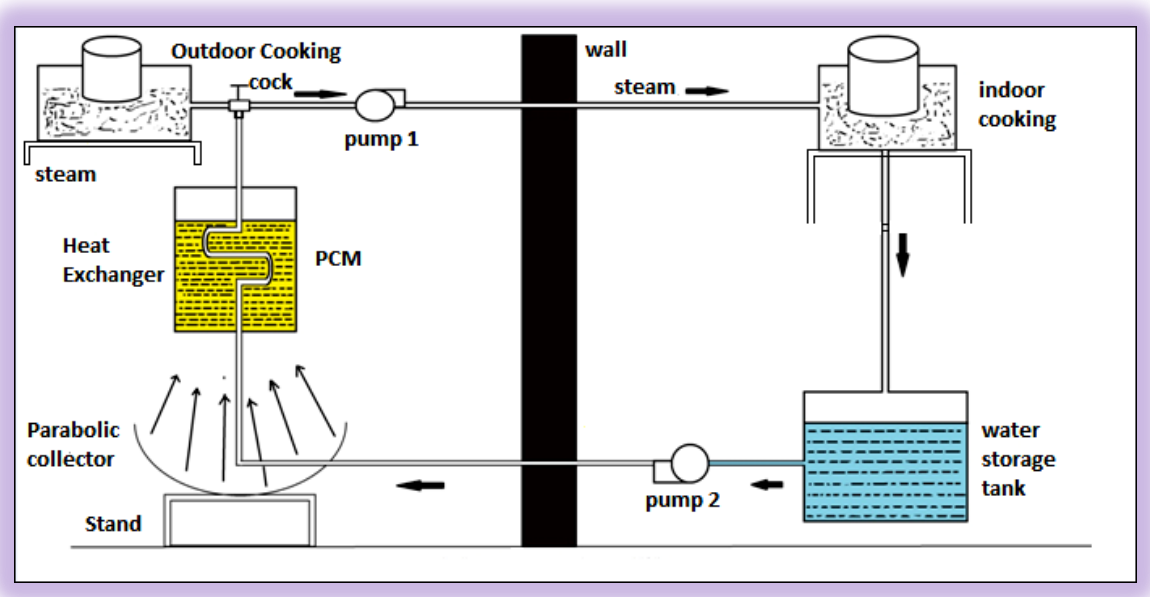

Fig.2 Line Diagram of Indoor and Outdoor Cooker

The concept of device in this work serves as a proof of concept of both outdoor and indoor use of a novel solar cooking stove. A properly implemented system is projected to maximize efficiency, safety, and the convenience of using solar energy for cooking and heating. As schematically illustrates in Fig. 2, the system is comprised by several components including: a parabolic collector, heat exchanger and along with pump provide. This system may also have an added benefit of energy storage to supply heat when sunlight is off. As we seen that there is water storage tank along with water. This water lifts through along with pump and its passes through along with heat exchanger. There is parabolic collector due to that sun rays concentrated through oil chamber. Due to concentrated rays acting on oil chamber there is increase in temperature. This increase temperature will help to increased temperature of water. Due to excess temperature of water then water becomes steam. This steam passes through pipe along with a cock. There is a cock provide due to that steam can pass through both side. This steam can be used as indoor as well as outdoor steam.

5 Conclusion

PCM mixed nanoparticle is important to enhance thermal performance of energy storing material for solar cooker application. In this review paper of phase change material final conclusion can be drawn in such a way that, there is

definite need of change of phase change material for energy storing application. For the phase change material nano particles are playing an important role. Dispersion of the nano particles into the phase change material the poor properties of PCM such as melting point, specific heat and thermal conductivity can be changed. By properties of PCM with the help of nano particles energy storing capacity can be increased to 20-30%. Also charging time can be decreased due to increase in thermal conductivity. This review paper is concentrated on the offered thermal energy storage technology for solar cooking. With the storage unit, foods are often braised at late evening, whereas late evening cooking wasn't attainable with a standard solar cooking. So that, solar cooking with storage unit is incredibly helpful for the humans and likewise as for the energy conservation.

6. References

[1]G.Kumaresan,V.S.Vigneswarans,S.Esakkimuthu,R.Velraj,2016, "Performance assessment of a solar domestic cooking unit integrated with thermal energy storage system", Journal of Energy Storage 6, 70-79.

[2] Nayak A.O., Gowtham M., Vinod R., and Ramkumar G.,"Analysis of PCM Material in Thermal Energy Storage System", International Journal of Environmental Science and Development, Vol. 2, No. 6, 2011.

[3] Hajare V. S, Narode A. R., Gawali B. S., Bamane S. R., "Experimental Investigation of Enhancement In Heat Transfer using Nano - Mixed PCM", International Journal of Engineering Research & Technology (IJERT), Vol. 3 Issue 11, 2014.

[4] Karunamurthy K., Murugumohan K., Suresh S.,"Use Of Cuo Nano-Material for The Improvement of Thermal Conductivity and Performance of Low Temperature Energy Storage System of Solar Pond", Digest Journal of Nanomaterials and Biostructures, Vol. 7, No. 4, 2012.\

[5] Sharma A., Tyagi V.V., Chen C.R., Buddhi D., "Review on Thermal
Energy Storage with Phase Change Materials and Applications",Renewable and Sustainable Energy Reviews, 13, pp. 318-345, 2007.

[6] Ahmet Sarı , Cemil A. "Synthesis and thermal properties of poly(styrene-co-ally alcohol)-graft-stearic acid copolymers as novel

solid–solid PCMs for thermal energy storage", Solar Energy 86 (2012) 2282–2292.

[7] Prabhu Bose, Amirtham v. "A review on thermal conductivity enhancement of paraffin waxas latent heat energy storage material", Renewable and Sustainable Energy Reviews 65 (2016) 81–100.

[8] M.M.Valmiki, Peiwen Li, Javier Heyer, Matthew Morgon, Abdulla Albinali, Kamal Alhamidi, 2010, "A novel application of a Fresnel lens for a solar stove and solar heating", Renewable Energy 36, 1614-1620.

[9] Maxime Mussard, Alexandure Gueneo, Ole Jorgen Nydal, 2013, "Experimental study of solar cooking using heat storage in comparison with direct heating", Solar Energy 98, 375-383.

[10] S.B.Joshi, A.R.Jani, 2015, "Design, development and testing of a small scale hybrid solar cooker", Solar Energy 122, 148-155.

[11] Mohit Bansal, R.P.Saini, D.K.Kathod, 2013, "Devolpment of cooking sector in rural areas in India – A review", Renewable and Sustainable Energy Reviews 17, 44-53