

Review of Application of Phase Changing Materials (PCMS) In Solar Water Heater and Proposed Work with Scope & Limitation

Prafull Shahare¹, Dr A N Pawar², A A Karmarkar³

Assistant Professor, Department of Mechanical Engineering Department HVPM COET Amravati, Maharashtra, India¹

HOD, Department of Mechanical Engineering, Government Polytechnic, Nanded, Maharashtra, India²

HOD, Department of Mechanical Engineering, HVPM COET, Amravati, Maharashtra, India³

ABSTRACT: Thermal energy storage has always been one of the most critical components in residential solar water heating applications. Over the last two decades a wide variety of solar energy technologies have been developed through research and development, demonstration and large-scale promotion during the eighties and nineties. Latent Heat Thermal Energy Storage (LHTES) systems using Phase Change Materials (PCMs) as a storage medium offers advantages such as high heat storage capacity, small unit size and isothermal behavior during charging and discharging. In this we have reviewed the use of PCM in Solar water heating applications and proposed work with scope and limitation and methodology to be used.

KEYWORDS: Phase Change Materials (PCMs), TES (Thermal Energy Storage), Latent Heat Thermal Energy Storage (LHTES), Sensible Heat Storage (SHS)

I. INTRODUCTION

Over the last two decades a wide variety of solar energy technologies have been developed through research and development, demonstration and large-scale promotion during the eighties and nineties. As a result, some of these technologies have reached maturity and a user-friendly status and are suitable for decentralized applications. One of the most widespread uses of solar thermal technology is solar water heating. India is blessed with good sunshine. The country receives solar radiation amounting to over 5×10^{15} kWh per annum with the daily average incident energy varying between 4-7 kWh per m² depending on the location. Solar water heating systems (SWHs) have now been used for more than sixty years. In many countries, which include China, Israel, USA, Japan, Australia, South Africa and Cyprus, SWHs are very popular for their use in community, commercial and industrial applications [1]. The magnitude and importance of solar energy are well known. Solar energy is free, environmentally clean, and therefore is recognized as one of the most promising alternative energy recourse options.

The effective use of solar energy is hindered by the intermittent nature of its availability, limiting its use and effectiveness in domestic applications, notably, water heating. Some throughway has been obtained through Sensible Heat Storage (SHS) systems. However, these require large storage capacity in order to cover a minimum of a couple of days with intermittent usage. Storage of solar energy as sensible heat has been a cheap but inefficient means of Thermal Energy Storage (TES). Conversely, Latent Heat Thermal Energy Storage (LHTES) systems using Phase Change Materials (PCMs) as a storage medium offers advantages such as high heat storage capacity, small unit size and isothermal behavior during charging and discharging. However, these systems are not in commercial use as in the case of SHS systems due to poor heat transfer rates during heat storage and recovery processes. Using combined sensible and latent heat storage system eliminates some of the difficulties experienced in the SHS and LHTES systems and possesses most of the advantages of both [2].

For this purpose, latent heat of fusion of Phase Change Material (PCM) is of great interest on account of high storage density and its isothermal nature of the storage process. Solar energy can be stored by thermal, electrical,

chemical, and mechanical methods. Due to the nature of solar energy, two components are required to have a functional solar energy system. These two components are a collector and a storage unit. The collector simply collects the radiation that falls on it and converts a fraction of it to other forms of. The storage unit is required because of the non-constant nature of solar energy; at certain times only a very small amount of radiation or no radiation will be received. The storage of thermal energy as latent heat of fusion has attractive features over the sensible heat due to its high storage density and isothermal nature of storage process at melting temperature. The phase change from solid to liquid or vice-versa is preferred because the operating pressure is lower than liquid to gas or solid to gas phase change. In practice several PCMs are known, such as: paraffin's, fatty-acids, organic and inorganic salt hydrates, organic and inorganic eutectic compounds.

Along with this an alternative source of Solar Energy for Green House is also a matter of concern Various heating systems are used to meet the heating requirements of the greenhouses. The conventional solution for this problem is the burning of some fossil fuel inside the greenhouse during dangerous freezing nights and cold days. Since the fuel prices are high (100–150 \$/ 1barrel), the use of this option is impossible, but it is necessary, considering the possibility of the complete destruction of the plants. Greenhouse farming is a growing industry in many countries. As discussed above STEs with PCM also proves to be an alternative for TES since Solar agricultural greenhouses have been widely used in the past two decades in order to increase plant quality and productivity and to reduce consumption of fossil fuels for heating and cooling. The most effective greenhouses require control of temperature, humidity, solar irradiance and internal gas composition with rational consumption of energy this can be achieved with the use of PCMs for Greenhouse Heating.

II. LITERATURE REVIEW

Atul Sharma, C R Chen et al[2007]:Summarized the investigation of Solar water heating system incorporated with Phase changing materials(PCMs) .Author also put light on practical information on few selected PCMs used in Solar water heating and also provide variety of design to store Solar Thermal Energy(STE). A comparison has been made between different sized latent heat storage vessels and sensible heat storage in a water tank with different degree of satisfaction. The storage vessel consists of a number of closed cylindrical pipes filled with phase change medium. Author also compares the performance of PCM, water and rock based storage system. A review of different Solar Thermal Energy storage with PCM is carried out and it focused on past and current research of energy storage and various design for Solar water heating systems to store STE.

Vikram D, Kaushik D, Prashant V, Nallusamy [2006]: A packed Latent Heat Thermal Energy Storage(LHTES) system containing PCM in cylindrical capsules is designed and fabricated with an effective water storage capacity of about 7 litres, enough to meet the needs of a family of four. The thermal behavior of the LHTES system is investigated experimentally for various operating conditions. The system's discharge characteristics with respect to the HTF are analyzed batchwise discharge. It is concluded that LHTES systems are a commercially viable option for solar heat energy storage with further research in this area.

The temperature distributions of HTF and the PCM in the TES tank for different mass flow rates are recorded during charging and discharging processes. The cumulative heat stored and system efficiency of process is studied in detail during the charging process.

Y.Rabin, E. Korin and B Mikic [1995]: A new type of Integrated Collector Storage(ICS) system for low temperature heat supply has been presented. The ICS system uses a salt hydrate PCM as a solar energy storage medium. The discharging process is performed by a finned coil heat exchanger is performed by a finned coil heat exchanger located in an organic heat transfer fluid layer(oil) floating above PCM. The main advantage of this method is that it uses a water/oil heat exchanger in place of an expensive water/salt hydrate surface heat exchanger .A simplified theoretical model to study thermal performance of such a system in charging process was developed and experimental system was set up to validate it. Comparison between mathematical model and experimental data for temperature profile in salt hydrated PCM

D. Zhou, C.Y. Zhao and Y.tian [2012]: In this paper, previous research works on thermal energy storage with PCMs for building applications have been reviewed. The PCMs to be used in buildings need to meet

International Journal of Innovative Research in Science, Engineering and Technology*An ISO 3297: 2007 Certified Organization**Volume 6, Special Issue 1, January 2017***International Conference on Recent Trends in Engineering and Science (ICRTES 2017)****20th-21st January 2017****Organized by****Research Development Cell, Government College of Engineering, Jalagon (M. S), India**

thermal comfort criteria, meaning the phase change temperature of PCMs should be between 18^oC to 30^oC. In addition, the properties such as chemical stability, fire characteristics and compatibility with constructional materials also need to be considered in the PCMs selections. Latent heat storage with PCMs has been used in the walls, ceilings and floors, showing a significant impact on reducing the temperature fluctuation by storing the solar energy during the sunlight hours for passive solar heating. It is also useful for off-peak thermal storage, ventilation and cooling. Some simulation works are also reviewed which can give guidance for PCM- buildings design. No matter from the experimental works or simulation works, it is clearly that incorporating PCMs into the building structures can significantly reduce the indoor temperature fluctuations. However further investigations still need to be carried out on the incorporation methods for PCMs to be embedded in existing building structures, long-term stability and any other problems which may affect the safety, reliability and practicability of the thermal energy storage used in buildings.

Oluwaseun S. Alajo, Victor C [2013]: Solar energy storage system based on a vegetable-based, non toxic, non-flammable, renewable and biodegradable phase change material (PCM) was developed. The system involves the two storage tank system, one for the PCM and the other for the hot water storage. The system used was designed such that the heated water can be diverted to a heat exchanger by means of a 3-way valve such that a fan can be made to blow air through one of the heat exchangers so that hot air for other purposes such as air heating can also be achieved through the system. Solar energy was applied in the system to power all the electrical components to ensure applicability of the system in parts of the world where electricity is not readily available. An experimental study on the performance of this system was done leading to a number of useful results. Based on the scale of this system, projections show that it can be extended to home building and commercial building applications. One of the results from this study shows that using the best or optimum low flow rate for the HTF for energy storage and energy recovery process gives the best performance by the system. The highest system efficiency of 63.6% was recorded for the summer period. However, results show that more than half of the energy absorbed at the solar collector was stored by the system irrespective of the season. A low heat transfer fluid flow rates of 3 L/min (0.05 kg/s) and 2 L/min (0.033 kg/s) produced the best heat storage and heat recovery processes respectively.

Mr. F.B.A. Amin, Prof. A.M. Patil, Prof. H.M. Dange: In S.H.S (Charging without PCM) heat storage system heat transfer fluid continuously through system and temperature rises gradually till it's temperature reaches 70 ° constant for 45 to 50 minutes. During combined heat storage system i.e.SHS and LHS (charging with PCM) heat transfer fluid is circulated continuously and gradually reaches up to 62 to 63 ° remain constant for period more than conventional system i.e. 60 to 70. Since temperature reaches 9 to 1 less, temperature loosed in sensible form is stored in latent heat form. During initial period of charging heat storage is high and then it is decreasing in temperature due to decreases in temperature differences between HTF and temperature of storage tank. In combined heat storage system uniform rate of charging and discharging for long period result in more heat storage throughout the cycle but in SHS system initially heat storage is more and reduces as temperature differences between inlet HTF and outlet HTF of storage tank reduces. System efficiency of combine heat storage system decreases with time during sensible heating of solid PCM, remain constant during phase change period and then further decreases during sensible heating of liquid PCM. The decreasing efficiency can be accredited to decreasing temperature difference between PCM and HTF during charging. In system efficiency of S.H.S. & S.H.S. +L.H.S., the combine system is remaining constant and more effective than S.H.S system. Since temperature of paraffin wax (63°C) and heat transfer fluid (69°C) is not exceeding melting point of paraffin wax (59°C) so the phase change is from solid to liquid only, the heat transfers only in conduction and convection mode.

K.Kavitha and S.Arumugam [2014]: carried a study on Heat transfer mechanism of PCMs along three dimensional axis and obtain results on thermal properties paraffins as a PCM in axial and radial directions and conclude that The charging process is the melting process, as the charging/melting process proceeds, more solid PCM gets melted due to the natural convection effect. Natural convection increases the thermal conductivity of the PCM with time. Thermal resistance of the PCM decreases with time due to the natural convection and due to the Paraffin's (PCM) effective thermal conductivity increases. So by natural convection the heat transfer occurs in the PCM radially inwards. The heat transfers from the boundary layer of the PCM towards the centre and similarly from

top to bottom layer of the PCM. The results provide conclusive evidence of the role played by natural convection, contact melting and phase change temperature range on the heat transfer.

Zhengguo Zhang *, Xiaoming Fang[2005]: A paraffin/expanded graphite composite phase change thermal energy storage material was prepared by absorbing the paraffin into an expanded graphite that has an excellent absorbability. In such a composite, the paraffin serves as a latent heat storage material and the expanded graphite acts as the supporting material, which prevents leakage of the melted paraffin from its porous structure due to the capillary and surface tension forces. The prepared paraffin/expanded graphite composite phase change material had a large thermal storage capacity and improved thermal conductivity and did not experience liquid leakage during its solid-liquid phase change. The prepared expanded graphite had a wide pore size distribution that mainly consisted of mesopores and macropores and possessed a high sorption capacity for the paraffin. The expanded graphite remained in a worm-like structure in the paraffin/expanded graphite composite PCM. The use of the composite PCM as a storage medium can reduce the weight of the thermal storage unit. The latent heat of the paraffin/expanded graphite composite PCM is equivalent to the calculated value based on the mass ratio of the paraffin in the composite. Liquid leakage did not occur during the solid-liquid phase change of the composite PCM. The heat transfer rate of the composite PCM was obviously higher than that of the pure paraffin owing to the combination with the expanded graphite that had a high thermal conductivity.

Huseyin Benli, Aydin Durmus[2009]: Analysis of Latent heat storage system with phase change material for solar collectors in green house is done with view that The continuous increase in the level of greenhouse gas emissions and the rise in fuel prices are the main driving forces behind the efforts for more effectively utilize various sources of renewable energy. An experimental set up is designed with different type of Collectors and A detailed analytical and experimental study was conducted to evaluate the thermal performance of five types of ten pieced solar air collectors and PCM, under a wide range of operating conditions. This system was considered predominantly useful for heating applications significantly increased. The system proved that it could be used efficiently for heating of the greenhouse night and cold days and shows scope for future development in field of Latent Heat Storage for green house heating.

A. ABHAT[1982]: Heat-of-fusion storage materials for low temperature latent heat storage in the temperature range 0-120°C are reviewed. Organic and inorganic heat storage materials classified as paraffins, fatty acids, inorganic salt hydrates and eutectic compounds are considered. The melting and freezing behaviour of the various substances is investigated using the techniques of Thermal Analysis and Differential Scanning Calorimetry. The importance of thermal cycling tests for establishing the long-term stability of the storage materials is discussed. The knowledge of the melting and freezing characteristics of the heat storage materials, their ability to undergo thermal cycling and their compatibility with construction materials is essential for assessing the short and long-term performance of a latent heat store. Using two different measurement techniques—differential scanning calorimetry and thermal analysis—the melting and freezing behaviour of the heat storage materials is determined. Results from measurements undertaken with representative organic and inorganic substances are discussed. Commercial paraffins are characterized by two phase transitions—a solid-liquid and a solid-solid phase transition—which may be spread over a large temperature range depending on the paraffin concerned, n-Paraffins are preferred in comparison to their *iso-counterparts*, as the desired solid-liquid phase transition is generally restricted to a narrow temperature range. Fatty acids are organic materials with excellent melting and freezing characteristics and may have a good future scope, if their cost can be brought down. Inorganic salt hydrates on the other hand, must be carefully screened for congruent, "semi-congruent", or incongruent melting substances with the aid of phase diagrams. Incongruent melting salt hydrate may be "modified" to overcome decomposition by adding suspension media, or extra water, or other substances that shift the peritectic point. The use of salt hydrates in hermetically sealed containers is recommended. Moreover, the employment of metallic surfaces to promote heterogeneous nucleation in a salt hydrate is seen to reduce the supercooling of most salt hydrates to a considerable extent. Finally, some results from thermal cycling tests and corrosion investigations are presented to illustrate their importance in the appropriate choice of materials from the standpoint of the life of a latent heat store.

International Journal of Innovative Research in Science, Engineering and Technology*An ISO 3297: 2007 Certified Organization**Volume 6, Special Issue 1, January 2017***International Conference on Recent Trends in Engineering and Science (ICRTES 2017)****20th-21st January 2017****Organized by****Research Development Cell, Government College of Engineering, Jalagon (M. S), India**

C.Beckermann and R. Viskanta[1987]: A combined numerical and experimental study is reported of solid/liquid phase change in porous media with natural convection in the melt region. The model is based on volume averaged transport equations, while phase change is assumed to occur over a small temperature range. Experiments are performed in a vertical, square enclosure using gallium and glass beads as the fluid and the porous matrix, respectively. For natural convection, melting and solidification (with initial supercooling), the numerical results show reasonable agreement with the temperature and interface position measurements. Natural convection in the melt as well as heat conduction in the solid is found to considerably influence the interface shape and movement during both the melting and solidification experiments. Experiments were performed in a well insulated test cell of square cross section and discussion is done for Natural Convection, Melting and Solidification.

Yvan Dutil, Daniel R. Rousse, Nizar Ben Salah and Stéphane Lassue: Energy storage components improve the energy efficiency of systems by reducing the mismatch between supply and demand. For this purpose, phase change materials are particularly attractive since they provide a high energy storage density at a constant temperature which corresponds to the phase transition temperature of the material. Nevertheless, the incorporation of phase change materials (PCM) in a particular application calls for an analysis that will enable the researcher to optimize performances of systems. Due to the non-linear nature of the problem, numerical analysis is generally required to obtain appropriate solutions for the thermal behavior of systems. Therefore, a large amount of research has been carried out on PCMs behavior predictions. It shows selected results for several configurations, from numerous authors so as to enable one to start his/her research with an exhaustive overview of the subject. This overview stresses the need to match experimental investigations with recent numerical analyses since in recent years, models mostly rely on other models in their validation stages.

Piia Lamberg, Reijo Lehtiniemi*, Anna-Maria Henell[2003]: Phase change material (PCM) storages are used to balance temporary temperature alternations and to store energy in several practical application areas, from electronics to the automobile industry and also buildings. In current telecommunication electronics both portable and larger scale thermal transients that occur due to temporarily varying power dissipation are customary. The use of PCM heat storage to compensate for temperature peaks that may occur offer significant savings in time-dependent thermal management in the aforementioned products. It obtain physical validation of the numerical results produced using FEMLAB. This validation was obtained through a comparison of experimental data and numerical results. The numerical methods studied were an enthalpy method and an effective heat capacity method. An ensemble of experimental PCM storages, with and without heat transfer enhancement structures, was designed and constructed. The numerical predictions calculated with FEMLAB simulation software were compared to experimental data. Both numerical methods gave good estimations for the temperature distribution of the storages in both the melting and freezing processes.

Thomas Hasenöhr[2009]: Article briefly discusses the physical reason for this property and some important applications of PCMs. Moreover, the major advantages and drawbacks of salt hydrates and paraffins used as PCMs and some solutions to cope with the low thermal diffusivity of paraffins are presented. Author compares different PCMs such as Paraffins with salt hydrates on the basis of different properties and concluded that Phase change materials have two favorable properties. They have a very high heat storage density and they store and release a considerable amount of heat at a constant temperature. This makes PCMs in many applications an interesting alternative to other heat storage mediums and also shows scope for enhancement between temp range of 5-25⁰C.

Mohammad Sajad Naghavi, Mahyar Silaakhori, Mohammad Mehrali, Hendrik Simon Cornelis Metselaar, Irfan Anjum Badruddin[15]: The model introduced here is about the integration of heat pipe solar water heater system (HPSWH) with phase change material (PCM). Two goals were being pursued in this design; first, controlling the overheating of supplied water during the day and second, extending the operation time of the solar water heater system. To achieve these two goals, the energy entering to the heat pipe needs to be adjusted with respect to the amount of absorbed solar radiation energy. A system is set up with the absorber plate sealed inside a glass cover to eliminate convection and conduction heat losses and isolating the absorber plate from adverse ambient conditions. The heat pipe placed at the middle of the absorber plate and two sides of the plate work as fins for heat pipe. In this model

PCM is placed as a layer in the bottom of the absorber panel. Calculation are done for effective radiation ,thermal behavior of PCMs and heat transfer through manifold and obtain result as the PCM will absorb excess solar energy during day time and will release energy when solar radiation is not that effective.

Y. Tian, C.Y. Zhao[2012]: Various types of solar collectors are reviewed and discussed, including both non-concentrating collectors (low temperature applications) and concentrating collectors (high temperature applications). These are studied in terms of optical optimization, heat loss reduction, heat recuperation enhancement and different sun tracking mechanisms. Various types of thermal energy storage systems are also reviewed and discussed, including sensible heat storage, latent heat storage, chemical storage and cascaded storage. They are studied in terms of design criteria, material selection and different heat transfer enhancement technologies. A variety of solar collectors have been discussed, including non-concentrating types and concentrating types. Among non-concentrating collectors, the PVT solar collectors show the best overall performance. Sun-tracking concentrating solar collectors have also been examined, in terms of optical optimization, heat loss reduction, heat recuperation enhancement, different sun-tracking mechanisms. Three different types of concentrating solar collectors have been described and compared: heliostat field collectors, parabolic dish collectors and parabolic trough collectors. The materials used for high-temperature thermal energy storage systems have been compared, and a comparison between different categories of thermal storage systems has been presented.

Yinping Zhang_, Guobing Zhou, Kunping Lin, Qunli Zhang, Hongfa Di [2006]: Investigates previous work on thermal energy storage by incorporating phase change materials (PCMs) in the building envelope. The basic principle, candidate PCMs and their thermo physical properties, incorporation methods, thermal analyses of the use of PCMs in walls, floor, ceiling and window etc. and heat transfer enhancement are discussed. We show that with suitable PCMs and a suitable incorporation method with building material, LHTES can be economically efficient for heating and cooling buildings. It gives idea that When selecting PCMs, their phase change temperature should be close to the average room temperature and appropriate values should be required for latent heat and thermal conductivity. Other properties such as fire characteristics and long-term stability should also be considered for organic and inorganic PCMs, respectively. Thermal analyses showed that PCM walls, floor and ceiling etc. can be effective in shifting heating and cooling load from peak electricity periods to off-peak periods, or storing solar radiation for use during sunless hours. PCM-wallboard is flexible for alteration and refurbishment of a conventional building. However, problems such as long-term thermal behavior, durability of PCM-impregnated wallboards, fire rating and heat transfer enhancement, combination with active systems etc. still need to be focused on in future work.

István Péter Szabó[18]: Precalculation are made on PCM solar tank by considering possibilities of the operating of the collectors at lower temperature. According the current architectural tendencies the boiler rooms are smaller, so the putting of the currently available solar tanks is very difficult. It is necessary to store the energy in a little space. The solution of the problem is the solar tank particularly filled with phase change material. This tank has smaller dimensions and bigger heat capacity than the conventional tanks. PCM tank under two categories are investigated a. PCM tanks with inner core b. PCM tanks with inner balls. The cost of the manufacturing of the tank is lower than the conventional tanks in trade with the same heat capacity and the space demand is much lower too. The other advantage of the PCM tank is the constant temperature during the heat accumulation. This constant temperature could be lower, it depends on the type of the PCM. The lower temperature of the heat accumulation permits the higher efficiency of the collectors at low external temperature. The lower heat capacity of the PCM could result higher temperature in the solar tank, so the higher collector temperature results lower collector efficiency. With proposed PCM-tank we can test different phase change materials to calculate the efficiency.

B.K. Gond, M. K. Gaur, C. S.Malvi [2012]: Designed a solar water heater which can give more effective and reliable as it can provide heat in cloudy or short-term sun-off period. Two small box type solar water heaters are designed and fabricated size of 24”×16”×4”. One has conventional tube-in-sheet flat plate collector and another is modified by using Phase Change Material (PCM) as short term heat storage media. Many practices are tried to fill and seal the PCM to maintain effective thermal contact with water tube. Fabrication techniques and results have been discussed. The prototype is developed and tested for indoor as well as outdoor climatic condition of Gwalior city

India. It is observed that water could be heated to 90°C by mid afternoon in simple water heater where as PCM filled collector keeps water warm even after sun-set. It has been found that 40°C temperature of water is available till 10 pm in winter conditions. It can be concluded that a ½ kg of PCM with some pipe work in the flat plate collector can improve the efficiency as well as dependability of cloudy or short-term Sun off period.

Vasiliki Antoniou[2004]: Hot water storage tank with and without PCM are designed and tested for different temperature range with aim of Reduce storage volume by increasing the energy storage capacity of a solar system, Increase the cost effectiveness of the system, Improve the formation and preservation of the stratification, Simulations in different temperature levels and Experimental investigations of the operation of the storage tank. Calculation were carried out using simulation model and comparison is done between energy storage capacity of Tanks with and without PCMs concluded that The use of PCM gives: i) improved energy storage capacity of the system ii) considerable improvement of system behaviour during draw-off. Everything was done in a cost effective method without getting away from the production line of the manufacturers of storage tanks. The flow of 6 l/min seems to be excessive for small storage volume. The results of modified system were also positive and proved the effectiveness of the PCM to preserve stratification.

S. Harikrishnan S. Kalaiselvam[2013]: In this study, thermal and heat transfer characteristics of nano based PCM during energy storage and release processes were investigated. This work also presented the preparation of nanofluid, which is solid-liquid composite material consisting of TiO₂ nanoparticles (NPs) embedded into melting palmitic acid. Size of the TiO₂ nanoparticles synthesized by sol-gel method was measured by using transmission electron microscope (TEM). Differential scanning calorimetry (DSC) measurements were used to determine the phase change temperatures and latent heats of nanofluids for melting and solidification processes. From the experimental results, it was observed that complete melting times of nanofluids with 0.1, 0.2 and 0.3 wt% of TiO₂ nanoparticles were reduced by 6.43, 14.62 and 21.05% respectively, than the palmitic acid. Similarly, complete solidification times of nanofluids with 0.1, 0.2 and 0.3 wt% of TiO₂ nanoparticles were reduced by 6.18, 12.37 and 20.11% respectively, than the palmitic acid. Based on all results, it was clearly understood that the dispersed nanoparticles into palmitic acid had enhanced the heat-transfer characteristics of palmitic acid in a better way, which in turn would accelerate the energy storage and release rates faster as compared to that of palmitic acid. Thus, the newly prepared nanofluids could be considered as a promising candidate for solar water heating system.

B. R. Vijay Prithiv, R. Prabakaran¹, R. Sukumar Dr. A. Rajendra Prasad[2014]: Work focuses on Solar Thermal Energy (STE) storage system and its heat carrying capacity enhancement with the help of encapsulated PCM. In the past three decades, many researchers have contributed their research work in the field of Thermal Flow Enhancement and improvement of Heat Carrying Capacity of the Solar Water Heaters. The major problem faced by them is, during heat extraction from the encapsulated PCM, the heat flow is restricted due to Surface Solidification. To avoid this problem many researchers used different techniques such as Lessing rings, internal fins, composite matrix etc. In this work, to eliminate the surface solidification problem during heat extraction, thin tube concept is introduced. The experiments are conducted using thin copper tube encapsulated with PCM is designed and fabricated to store the heat energy in PCM storage tank. The experiments are conducted with the help of fabricated Latent Heat Thermal Storage System (LHTS). The earlier results reveal that, the heat carrying capacity of the solar water heating system is increased by 40%. So, the existing size of the tank is capable of holding added quantity of heat make it more suitable for domestic applications. The insulated thermal storage tank contains number of copper tubes with PCM materials which absorbs available heat during peak hour's periods of day time and heat is stored in encapsulated PCM tube in the tank. The same can be retrieved from the tank during off peak hours.

III. PROPOSED WORK

The proposed work is aimed at the following objectives.

1. Study the present / available Solar Water heater.
2. Study the properties of Phase changing Materials and their ability to store Solar Thermal Energy (STE).

3. Design & development of Solar water Heater using Cylindrical/Flat PCM cell storage.
4. To assess experimental Investigation on application of PCMs in Solar Energy Storage.
5. To assess the suggested option from multi-criteria perspectives.

IV. SCOPE AND LIMITATION

The scope of PCMs in Solar water heater is limited with Solid-Liquid and vice versa since liquid-gas or solid-gas will increase the volume of Phase changing materials and will lead to increase in size of storage tank. The use of PCM cell is limited with development of accessories required. Installation of Solar Water heater using PCM is similar to common methodology use.

Solar Thermal storage using PCM for Greenhouse heating has wide range of scope for both inside and outside heating considering factor of Climate till now 18-23 % of energy storage has increased with the use of PCMs further research scope is there for increasing the efficiency and major limitation is of economic properties of PCMs which can be overcome.

Solar Energy Storage using PCMs has a wide range of scope and can be used in storing Solar Energy for Building Application, Green houses and Solar Thermal Power plants also.

V. METHODOLOGY

After taking critical review of literature on Different phase changing materials with different results, the need of solar thermal energy storage using PCMs is the planed concept with operating temperature range of 0 to 180⁰C. Therefore the research work on the topic in planed as follows

1. Critical review of literature on Phase Change Material with different aspect as below:
 - Thermal properties: Suitable phase-transition temperature, High latent heat of transition, High thermal conductivity in both liquid and solid phases, Good heat transfer.
 - Physical properties: Favorable phase equilibrium, High density, Small volume change, Low vapor pressure.
 - Kinetic properties: No supercooling, Sufficient crystallization rate
 - Chemical properties: Long-term chemical stability, Compatibility with materials of construction, No toxicity, No fire hazard.
 - Economic Properties: Abundant, Available, Cost effective.
2. Design of Solar Water heater using PCM cell storage.
3. Performance evaluation of Solar Water Heater using Latent Heat Thermal Energy Storage (LHTES) and Sensible Heat storage(SHS).
4. Study of performance of Solar Water heater using PCM cell storage and optimization of different parameters.
5. Comparison of conventional Solar water heater and Solar water heater with PCM of similar capacity.
6. Numerical analysis of results and validation of it.

VI. PROBABLE IMPLICATIONS

The proposed work will be able to use Solar water heater with PCM as a cost effective and energy efficient device in place of conventional Solar water Heater and will provide new source/storage for renewable source of energy and will reduce the use of conventional fuels in Greenhouse heating and will lead to reduction in emission of greenhouse gases responsible for Greenhouse effect.

PCMs can also be used in maintaining building temperature and in electronic devices also along with heat pipes.

REFERENCES

- [1] Atul Sharma, C. R. Chen, "Solar Water Heating System with Phase Change Materials" (I.RE.CH.E.), Vol. 1, N. 4 July 2009.

- [2] Vikram D, Kaushik V, Prashanth S, Nallusamy N, "An Improvement in the Solar Water Heating Systems using Phase Change Materials"
- [3] Y Rabin, IBar-Niv, E Korin and B Mikic, "Integrated Solar Collector Storage System based on a Salt Hydrated Phase change material", Solar energy vol 55, No.6.pp 435-444.1995, Eilsevier Science Limited.
- [4] D. Zhou, C. Y. Zhao, Y. Tian, "Review on thermal energy storage with phase change materials (PCMs) in building applications", School of Engineering, University of Warwick, CV4 7AL, UK.
- [5] Oluwaseun S. Alajo, Victor C. Ibekwe, Emmanuel C. Nsofor, "Experimental Study on the Performance of a PCM-Based Solar Energy Storage System", American Journal of Engineering Research (AJER) e-ISSN : 2320-0847 p-ISSN : 2320-0936 Volume-02, Issue-11, pp-195-203.
- [6] Mr. F.B.A. Amin, Prof. A.M. Patil, Prof. H.M. Dange, "Comparative Study of Solar Water heater with and without Latent Heat Storage System", Amin et al, International Journal of Advanced Engineering Research and Studies E-ISSN2249-8974.
- [7] K.Kavitha and S.Arumugam, "A Study on Heat Transfer Mechanism of a Phase change Material along three Dimensional Axis of Solar Wax Melting Chamber", International Journal of Advanced Technology & Engineering Research (IJATER) National Conference on "Renewable Energy Innovations for Rural Development [2014]"
- [8] Zhengguo Zhang *, Xiaoming Fang, "Study on paraffin/expanded graphite composite phase change thermal energy storage material", Energy Conversion and Management 47 (2006) 303-310, Elsevier Science Ltd [2005].
- [9] Hu'seyin Benli, Aydin Durmus, "Performance analysis of a latent heat storage system with phase change material for new designed solar collectors in greenhouse heating", Solar Energy 83 (2009) 2109-2119, Science Direct.
- [10] A. ABHAT, "Low Temperature Latent Heat Thermal Energy Storage :Heat Storage Materials", Solar Energy vol 10, No. 4. pp 313-332. 1983
- [11] C. Beckerman and R. Viskanta, "Natural convection solid/liquid phase change in porous media", Int. J. of. Heat and Mass transfer. Vol 31, No. 1, pp. 3546. 1988 Printed in Great Britain.
- [12] Yvan Dutil, Daniel R. Rousse, Nizar Ben Salah and Stéphane Lassue, "A Review on Phase Change Materials: Mathematical Modeling and Simulations", University of Canada.
- [13] Piia Lamberg, Reijo Lehtiniemi, Anna-Maria Henell, "Numerical and experimental investigation of melting and freezing processes in phase change material storage", International Journal of Thermal Sciences 43 (2004) 277-287, Science direct.
- [14] Thomas Hasenöhr, "An Introduction to Phase Change Materials as Heat Storage Mediums", Project Report 2009 MVK 160 Heat and Mass Transport May 09, 2009, Lund, Sweden
- [15] Mohammad Sajad Naghavi, Mahyar Silaakhor, Mohammad Mehrali, Hendrik Simon Cornelis Metselaar, Irfan Anjum Badruddin, "Analytical thermal modeling of a heat pipe solar water heater system integrated with phase change material", Computer Applications in Environmental Sciences and Renewable Energy ISBN: 978-960-474-370-4.
- [16] Y. Tian, C.Y. Zhao, "A Review of Solar Collectors and Thermal Energy Storage in Solar Thermal Applications", University of Warwick China[2012].
- [17] Yingping Zhang, Guobing Zhou, Kunping Lin, Qunli Zhang, Hongfa Di, "Application of latent heat thermal energy storage in buildings: State-of-the-art and outlook", Building and Environment 42 (2007) 2197-2209, Science Direct.
- [18] István Péter Szabó, "Design of an Experimental PCM Solar Tank", Department of Technical and Process Engineering, Faculty of Engineering University of Szeged H-6724, Szeged, Mars tér 7 Hungary
- [19] B.K. Gond, M. K. Gaur, C. S. Malvi, "Manufacturing and performance analysis of solar flat plate collector with phase change material", International Journal of Emerging Technology and Advanced Engineering(IJETAE), ISSN 2250-2459, Volume 2, Issue 3, March 2012.
- [20] Vasiliki Antoniou, "Experimental Evaluation of Phase Change Materials (PCM) for energy storage in solar water heating systems" Archimedes Solar Energy Laboratory (ASEL) Cyprus University of Technology 2004.
- [21] S. Harikrishnan, S. Kalaiselvam, "Experimental Investigation of Solidification and Melting Characteristic of Nano fluid as PCM for Solar Water Heating Systems" International Journal of Emerging Technology and Advanced Engineering (IJETAE) Volume 3, Special Issue: ICERTSD 2013, Feb 2013, pages 628-635, An ISO 9001:2008 certified Int. Journal, ISSN 2250-2459.
- [22] B. R. Vijay Prithiv, R. Prabakaran, R. Sukumar and Dr. A. Rajendra Prasad, "Heat Enhancement of Domestic Solar Water Heater using PCM Filled Thin Tubes" ISR NATIONAL Journal of Advanced Research in Mechanical and Production Engineering and Development . Volume: 1 Issue: 1 08-May-2014.
- [23] MNRE Annual Report: 2006-2007. Ministry of New and Renewable Energy (MNRE), Government of India, CGO Complex, Lodhi Road, New Delhi (2007).
- [24] A. Mani, S. Rangarajan, Solar Radiation over India (Allied Publishers Private Limited, New Delhi, 1982).
- [25] Saitoh, T., Hirose, K., 1986. "High performance phase-change thermal energy storage using spherical capsules". Chemical Engg. Commun, 41: 39-58.
- [26] Farid MM, Khudhair AM, Razack SAK, Al-Hallaj S, "A review on phase change energy storage: materials and applications". Energy and Management 2004; 45: 1597-1615.
- [27] A. Sharma, V. V. Tyagi, C. R. Chen, and D. Buddhi, "Review on thermal energy storage with phase change materials and applications": Renewable and Sustainable Energy Reviews, 13, 2009, 318-345.
- [28] S. Mekhilef, R. Saidur, and A. Safari 2011, "A review on solar energy use in industries, Renewable & Sustainable Energy Reviews", 15 (4), 2011, 1777-1790.
- [29] Vikram, Kaushik, Prashanth, Nallusamy, "An Improvement in the Solar Water Heating Systems using Phase Change Material" proceeding of the International Conference on Renewable Energy for developing countries-2006.
- [30] Mohsen, M.S., A. Al-Ghandoor, and I. Al-Hinti, "Thermal analysis of compact solar water heater under local climatic conditions". International Communications in Heat and Mass Transfer, 2009. 36(9): p. 962-968.
- [31] Malvi, C.S., D.W. Dixon-Hardy, and R. Crook, "Energy balance model of combined photovoltaic solar-thermal system incorporating phase change material" Solar Energy, 2011. 85(7): p. 1440-1446.