Performance Enhancement Techniques For Domestic Solar Thermal Cooking Applications:- A Review

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Abstract- *The technology used today in solar cooking is very simple but ineffective in terms of cooking time it takes , the most important drawback of solar cooking is that it is not user friendly for various cooking practices and stable operation in peak and off peak hours, the constant temperature is very hard to obtain in most of solar cookers and there is no mechanism present for energy storage. The paper discusses most promising methods to create viable solution for modern day cooking using solar energy. The methods discussed here are suitable to achieve the temperatures as high as 200^{o}C . Nanofluids help to improve system performance by increasing heat transfer rate and Phase change materials are useful in storing thermal energy.*

Keywords- Nanofluids, Solar collectors, Phase change materials, Solar heating, Parabolic collectors, Solar cooking

I. INTRODUCTION

In today's scenario use of fossil fuels has increased resulting in the depletion of natural recourses and huge impact on environment. Only way to reduce this impact is to use non conventional energy recourses .The use solar energy for cooking is not new thing but solar cooker today are not convenient and take huge amount of time. The project is effort to improve the efficiency of solar cooking and making it practical.

The Solar cooking in today's date is very simple in design but when comes to doing actual operation the performance is very poor it has to be improved by new design and introduction of new materials and concepts. The temperatures achieved in the normal solar cooker are about 70^{o}C in average thus to improve performance its temperature has to be increased to about 200^{o}c to achieve this temperature collector design improvements are essential. A nanofluid is a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are generally made up of oxide of metal or nonmetals exhibiting greater heat transfer coefficient. Common base fluids include water, ethylene glycol and oil, these are used to improve heat transfer.

Phase change materials (PCM) are substances which absorb thermal energy release thermal energy during melting freezing cycle .PCM has ability to relese heat at constant temperatures theoretically.. it has tendency to absorb large amount of heat during melting process. The fluctuation of ambient temperatures cause change in phase of PCMs that makes them suitable for various processes and applications involving temperature control. Water is most commonly used PCM.to maintain temperatures below 0°C. But water's freezing point is fixed at 0°C (32°F), making it unsuitable for most of applications energy storage. To overcome this a broad range of temperatures, from -40°C to more than 150°C are now attainable by PCM which are developed by efforts of researchers. Today PCMs are capable of storing more energy than water upto 14 times higher. The nature of PCM and their reliability makes them best option for heat storage.

II. LITERATURE REVIEW

P.-Y. Wang et al[1]. has given his experimental results for performance improvement of parabolic collector with incorporation of evacuated U tube. With the suggested design improvements temperature of fluid that is heated air has reached to temperature of 200^{o}C. as in flat plate collectors higher temperatures than that of 70^{o}C are not easily achieved the parabolic collectors are good alternatives in this case. There are also evacuated tubes which are better in performance than that of normal flat plate collectors it is stated here that in china these type of evacuated tube collectors are widely used and are performing excellent in terms of thermal performance as compared to flat plate collectors they are less in cost and have low energy loss due to vacuum envelope around the absorber surface. This performance is limited to heating of air about 100^{o}C. this is not sufficient in the case where higher temperatures are required there are various applications which require more temperature than that specially industrial processes Only Compound parabolic collector (CPC) system are feasible in higher temperature ranges than that of 100^{o}C. the key of improvement lies in the tube the U tube heat exchanger in the Evacuated tube when used along with CPC gives higher temperature. if further there is transfer fluid between the heat exchanger and the evacuated tube there will be further improvement in this paper the experimental setup consists of compound parabolic collectors each includes evacuated tube fitted with U tube heat exchanger with suitable surrounding conducting fluid to enhance heat transfer to achieve temperatures of range 150-200^{o}C.

The apparatus here consists of pressurized air tank which is provided to ensure the air flow stability through the apparatus , the air circuit is linking 10 collector panels each being made of four components parabolic collector CPC, all glass evacuated tube , U shaped tube made up of copper concealed between the to glass tubes separated by vacuum with absorber coating over outer side of the inner glass tube. In this experiment the simplified CPC is used instead of standard One.

The processing difficulty in this simplified CPC is reduced along with the cost and it has flat curved bottom instead of curved one. Also the CPC is more efficient in absorbing solar radiation without following the track of sun which is not possible with the normal collector. But the concentrating efficiency of the simplified CPC is reduced by about 15% is also stated here in the paper on basis of calculated result.

Heat conduction is carried out here by means of paste like mixture of oil and graphite powder in this experiment the U shaped heat exchanger is the core of technology the thermal conducting medium used here is having good thermal conductivity and possesses considerable expansion capacity State of the conducting fluid is close to solid the U shape helps to improve the heat transfer. The efficiency is considerably improved with the help of conduction medium. From the experiment and simulation results this method of collector performance improvement is viable.

Umish Srivastva et al [2] have discussed recent developments in the heat transfer fluids specifically for solar thermal application . to maximize the heat absorption in the solar thermal system there is need of concentrating collectors , such absorbed heat when it comes to transporting the heat to required destination transfer fluids come very handy . the heat transfer fluids take heat from the collector and carry it to the point where it is required . Mostly low boiling point and high heat capacity transfer fluids are used for human comfort applications lke space heating and cooling , the refrigerants can also be used such as ammonia and sulphur dioxide but there is problem of toxicity when working with the domestic applications so mostly are used in industries. For domestic purpose the use of water glycol mixture very much common as of its non toxic nature.

The other alternative here is water based nanofluids which are direct absorption type the black fluid mentioned here is having black fluid like indiaink or inorganic chromophores . problem associated with chromophores is temperature induced degradation and lower thermal conductivity. Water based nanofluids have shown enhancement in thermal conductivity density and viscosity of nanofluids with lower concentration however the water and aluminum based nanofluids show performance improvement in flat plate collectors but there is problem of long term stability. Also the suitability of mixture is for below 200^{o}C.

Water glycol mixtures of ratio 50:50 , 60:40 form solutions in which temperature of the transfer fluid can go below 0^{o}c due to the fact they are also referred as antifreezes . ethylene glycol is very popular in automotive antifreeze where as propylene is non toxic used for food grade anti freeze. The glycols are used for temperatures up to 100^{o}C and generally in closed loop solar thermal systems.

The transfer fluids for temperature range higher than 120^{o}C up to 280^{o}C.hydrocarbon oils such as petroleum oils can be used these oils have high viscosity thus difficult to pump and ahave low specific heat but relatively cheap and have low freezing point when there is need of transfer fluid in range of 120 ^{o}C to 280 ^{o}C for industrial application based on solar thermal application the hydrocarbon oils are natural choice they are characterized on basis of their composition such as aromatic mineral oils , napthatenic mineral oils or paraffinic oils in order of their increasing operating temperature. naphatamatic oils and aromatics are stable below 210^{o}C beyond the range they degrade at faster rate. Paraffinic oils on other hand are more stable for low as well as high temperatures and are thus used in higher temperature applications nearly 280^{o}C although they do not have heat transfer properties desired.

Table 1.1 – Thermal conductivity of various base fluids and nanofluids[2]

	Materials	Thermal conductivity (W/mk)
Metallic Materials	Copper	401
	Silver	429
Non-metallic Materials	Silicon	148
	Alumina (AL2O3)	40
Carbon	Carbon Nano Tubes (CNT)	2000
Base fluids	Water	.613
	Ethylene glycol (EG)	.253
	Engine oil (EO)	.145
Nanofluids (Nanoparticle concentration %)	Water/Al2O3 (1.50)	.629
	EG/ Al2O3 (3.00)	.278
	EG-Water/Al2O3 (3.00)	.382
	Water/TiO2 (0.75)	.682
	Water/ CuO (1.00)	.619

Table 1.2 - Properties of Aromatics, Napthanes and Paraffins[2]

Properties	Aromatics	Naphthenes	Paraffins
Chemical structure	Benzene ring type	Cycloalkane type	Alkane type
Reactivity	Very high	High	Low
Solvency	Very high	High	Low
Oxidation stability	Low	High	Very high
Pour point	Very low	Low	High
Boiling point	Low	High	Very high
Viscosity index	Low	High	Very high
Heat transfer rate	Very high	High	Low
Wax content	Low	High	Very high
Heat transfer operating temperatures	105 – 160°C	150 – 210°C	180 – 280°C

Nanofluids are colloidal mixture of base fluid containing nanosized particles such as oxide ceramics, nitride ceramics, carbide ceramics , metals, semiconductors, carbon nanotubes and alloy nanoparticles. Research study on Al_2O_3 with 5% concentrations shows significant improvement in heat transfer properties of heat transfer fluid. For temperature ranges above the 500^{o}C air and molten salts of sodium and potassium show excellent properties and salts have shown to improve the efficiency by about 40% range. Molten salts are more user friendly than oils but having very high freezing point of about 250^{o}C due to corrosive nature of salts they also require expensive materials and operational systems. Beyond 550^{o}C some known metals such as liquid sodium are used in nulear industry. Sodium both liquid and metallic has excellent properties for the Heat transfer but it is highly reactive with water thus its use with solar applications is difficult. This problem is solved with NaK sodium potassium alloy which has reportedly overcome this problem , it has lower melting point -12^{o}C which make it suitable for all practical applications . disadvantage here is lower boiling point than sodium , lower heat specific heat and inferior heat transfer properties. The high temperature heat transfer fluid depends on number of factors such as concentrated solar power technology being employed the operating temperature and pressure in system all factors govern the cost for electricity generation by solar thermal power.

Very new concept of fluidized solid particles is new Novel concept of heat transfer fluids in form of dense solid suspension of solid silicon of diameter ~64 micron in which the 30-40% are particle and rest is air . these are circulated in dense suspension circulated upward in specially designed absorbing tubes for temperatures of range 750^{o}C heat transfer coefficients 500W/m^{2}K has been reported to be achieved at particle velocity of 2.5 cm/s, but it is still a challenge to make this concept workable on commercial basis .

Alok Kumar [3]has stated Solar energy is primary source of all type of solar thermal equipments in which concentrating type collector heated the fluid up to 100 to 400^{o}C. It is employed for a variety of applications such as power generation, industrial steam generation and hot water production. Parabolic trough collector is preferred for steam generation because high temperatures it can achieve . the paper discusses main disadvantages associated with solar energy such as low energy density right now most efficient way to utilize it is to use collectors with large area which lead to higher costs . for purpose of calculation of performance of any solar system it is essential to calculate hourly radiation, on horizontal surface with respect to location . the experiments were carried out by covering the aperture of parabolic through and results were compared for single cover and double cover. The experimental results indicated that maximum efficiency was obtained by single cover over receiver also it is found that with increase in cover thickness efficiency is reduced.

Table 1.3 - Comparison of various properties of commonly used heat transfefluids[2]

	Unit	Sodium salt	Sodium Potassium salt	Potassium salt	Salt Hitec XL	Salt Hitec	Salt grade Hitec Solar salt	Solar grade HTF (oil)
Melting point	°C	97.82	-12.6	63.2	120	142	240	15
Boiling point or maximum operating temperature	°C	881.4	785	756.5	500	538	567 (bp 593)	400
Density	Kg/m^3	820	749	715	1640	1762	1794	1056
Specific heat capacity	KJ/KG.K	1.256	0.937	0.782	1.9	1.56	1.214	2.5
Viscosity	Pa.s	0.00015	0.00018	0.00017	0.0063	0.003	0.0022	0.0002
Thermal conductivity	W/m.K	119.3	26.2	30.7	Na	0.363	0.536	0.093
Prandtl number		0.0016	0.0063	0.0043		12.89	4.98	5.38

Maxime Mussardet al [4], have presented comparative study of two types of solar cooker , widespread SK14 cooker and prototype of solar concentrator parabolic through with thermal energy storage SK14 is direct solar cooker where solar pot is placed directly on the focal point of parabolic dish concentrator. In absorber unit there is self circulating fluid loop of thermal oil. In this case thermal oil absorbs heat at parabolic through and transfers it to thermal storage. It is theoretically possible to cook during night or on cloudy day. Both boiling and frying were tested o the system the major issue of heat transfer from storage is solved by modifying shape of storage vassal . the system uses storage unit a steel cylinder with 202 mm insulated with 8cm of pyrogel, full with oil and closed with 1cm thick lid made up of aluminum lid has 8 tubes connecting $NaNO_3$- KNO_3 binary mixture with melting temperature of 210°C to 220°C . the performance testing was carried out for both models and it was found out that for reaching boiling point of water with system took 38 minutes while commercial system took 27 minutes.

The further tests were carried out to compare the performance of storage system with electric coil heater . this test was carried out to check quality of heated surface it was found out that storage took time to reach the temperature of 80°C but it was found out that it took 20 minutes which is too much for food preparation system was able to discharge heat for 3hours after sunset . it was concluded that current storage model is slower as compared with commercial SK14, but there is scope of improvement in quality the system was found out to be competitive to conventional system as it has good frying time , there is scope of improvement in heat storage system for further optimization to reach performance of direct solar cooker. The prototype gave 25% more heating time than conventional SK14 Experiments with smoother surfaces show scope of 55% improvement in time required for achieving temperatures .

Samuel Sami[5] has developed mathematical model to predict behavior of solar thermal system using nanofluids, the model is based upon energy conversion equations and heat transfer using different nanofluids.

The model is based on schematic diagram. system consists of thermal panel collector, thermal storage tank , paraffin wax piping and pump. the heat transfer equations are calculated for each of component. The developed model solves the problem with help of program in six steps the logical flow diagram shows how the problem is solved . the comparison is carried out between various nanoparticles CuO, Fe_3O_4 and CiO_2 at different inlet conditions .the heat transfer fluid here is water the model requires the properties to be entered in the model with the respective inlet and outlet conditions. The results are obtained with the model indicate that efficiencies are directly associated with the nanoparticle concentrations as well as the thermophysical properties of nanofluids. It is found out that higher the flow of nanofluids higher the heat transfer up to designated mass flow rate. From simulation results it has been found out that there is increase in efficiency with increase in nanoparticle concentration.

It was observed here that for higher solar radiation the efficiency of panel was reduced this is due to fact that solar panel is designed for optimum radiation level , beyond optimum level as losses tend to increase the value of efficiency is thus reduced.

Barot Vishalkumar , K.D. Panchal[6],has carried out experiments on nanofluids aluminum oxide and copper oxide . the paper is effort to enhance efficiency of water heating by use of nanofluids. The effort is made to achieve desired thermal properties with lowest concentrations possible. The nanofluids are classified as metallic and non metallic , paper focuses on metallic nanofluids. The nanofluids help to increase parameters such as higher thermal conductivity of nanoparticles increase heat transfer rate. Successful use of nanofluid helps to reduce size of heat exchanger considerably. Along with all these advantages nanofluids have some of drawbacks such as corrosion and erosion of components , pumping problem , pressure drop high cost etc. so proper selection of nanofluid is essential for application desired.

The experimental setup has parabolic collector with reflectivity of 95% . the fluid is stored at the tank made below the fluid is circulated through evacuated glass tube.

Table shows comparison of results found out for water based copper oxide nanofluid with 0.01% concentration by volume at 20l/hr mass flow rate . it has observed her that copper oxide nanofluid shows higher efficiency during the day during certain period of time but initially water shows higher instantaneous efficiency due to high specific heat of water overall there is efficiency improvement with use of nanofluids.

Liwan Fan , J.M. Khodadadi[7] have reviewed the enhancement methods for thermal energy storage . the study discusses various methods of thermal conductivity enhancement .the review covers wide Varity of PCM in various of operating conditions and heat exchange and storage arrangements . the study include insulated boxes , cylindrical, and annular tubes and spheres . and containers that transferred heat into moving fluid. The studies focusing on regimes formed during melting of PCM are also discussed. The early work in PCM was directly linked to fast development in aerospace and electronics earlier work focused on introducing metallic fillers in PCM to enhance its thermal conductivity filler materials such as metallic wool, foam and honeycomb, tetradecane , hexadecane , Octadecane , other materials that were used along with compressed aluminum wool And other options that provided more effective heat transfer.

The experimental studies in aircraft thermal control presented by Hoover et al.[8] with pure PCM and PCM composites such as with metals and other materials the experiments focused on PCM system characteristics , determination of PCM thermal diffusivities , the effects of long term cycleing ,PCM container compatibility he found out that the three PCM are acceptable in the prototype of aluminum thermal control device Lithium Nitrate Trihydrate $LiNo_3$-$3H_2O$ with zinc hydroxyl catalyst, aluminum powder and aluminum honeycomb , alumina Al_2O_3 the PCM to filler ratio here was 8/1 among fillers tested aluminum honeycomb exhibited greatest increase in thermal diffusivity of about 80% the procedure was repeated for 10 freezing melting cycles . in all tests no changes in freezing melting points were noticed.

PCM based thermal capacitor with honeycomb filler designed and investigated by Abhat[9] the container and filler materials employed were n-octane(C18H38) and aluminum experimental setup was described in detail. A side view of structural configuration of capacitor with net dimensions 288mmX188mmX40mm the setup was filled with honeycombs of uniform size nominal storage capacity of this device was up to 100 watt-hours.the epoxy of high thermal conductivity is used here to bond honeycomb with the container to avoid thermal contact resistance which is undesirable. The honeycomb was filled with help of pinch tubes , PCM filled was liquid which was gas free and to measure temperatures at different locations ten thermocouples were mounted. A foil resistance heart was used constant heat flux was ensured by same size of heating surface and container . remaining walls of container were insulated to avoid heat losses. Then by both experimental and numerical approach the interface location and molten fraction were studied. The three different heat inputs were used and graphs are drawn on basis of it.

The finite difference based lumped capacity thermal model was developed to predict the heat conduction and two dimensional phase change within the container. With both experimental a numerical approach the study was done of molten fraction , wall temperature and interface location. The results show that melting not only starts at heated bottom but also at insulated surface at top. this is due to aluminum honeycomb path which serves as the heat conduction medium between two surfaces as heat flux is increased melting happens at faster rate both at bottom and top surfaces . the difference in numerical and actual data is due fact that the convection effect of the honeycomb structure was neglected in this model. This also benefits as it gives device low temperature uniformity. .

Thomas Bauer et al[10], have given overview of thermal energy storage system based on molten salts . the state of art molten salt system are discussed . the paper also summarizes pervious work related to molten salt storage systems. Most importantly the thermophysical property value of solar salt at various temperatures is given. The tests were carried out to check stability of nitrate and nitrite mixtures . currently the concentrated solar systems have only two tank thermal storage system for large applications only. This system has two tanks only , filled with molten salt and both at temperature levels different than each other. There are two types of thermal storage system direct and indirect , in indirect system the storage loop is de coupled from the HTF loop of solar receiver via heat exchanger. There is comparison done between these two technologies.

Table 2.1: Commercial two-tank systems [10]

	Direct Thermal storage	Indirect Thermal storage
System name	Gemasolar	Andasol 1
Thermal capacity	~ 1000 MWh[#]	1010 MWh
Inventory	8500 tones	28500 tones
Cold tank temp.	290 °C	292 °C
Hot tank temp.	~565 °C	386 °C
*Estimated from ΔT = 275 K, 8500 tones, 1.55 kJ kg^{-1} K^{-1}		

Most of concepts today try to minimize cost by use of single tank storage , but single tank requires stratification with defined hot and cold temperature zones and free convection is undesired. the previous work was concerned about thermophysical properties of $NaNO_3$ in this paper values of density , thermal diffusivity, heat capacity and thermal conductivity of solar salt are compared. The reliable thermophysical properties of molten salt are important in design of thermal storage systems.

Table 2 2: matrix of (minimum) melting temperature of subsystems of the quinary reciprocal system ca,k,li,na//no_2,no_3 [10]

Single salts and binary systems with common cation			
Ca	398 °C[#]	561 °C[#]	393 °C
K	440 °C	334 °C	316-323°C
Li	220 °C	254 °C	196 °C
Na	275 °C	306 °C	226-233°C
Binary systems with common anion and ternary reciprocal			
Ca,K	185 °C	145-174 °C	130 °C
Ca,Li	205-235 °C	235 °C	178 °C
Ca,Na	200-223 °C	226-230 °C	154 °C
K,Li	98 °C	126 °C	94 °C
K,Na	225 °C	222 °C	142 °C
Li,Na	151 °C	196 °C	126 °C
Ternary additive common anion and quaternary reciprocal			
Ca,K,Li	N/A	117 °C	N/A
Ca,K,Na	N/A	130 °C	N/A
Ca,Li,Na	N/A	170 °C	N/A
K,Li,Na	N/A	119 °C	75 °C
Quaternary additive common anion and quinary reciprocal			
Ca,K,Li,Na	N/A	109 °C	N/A
[#] Decomposition at the melting temperature			

The nitrates show Mass losses with gas evolution of alkali metal nitrate salts may occur due to three mechanisms, nitrate formation in the melt and oxygen release formation of alkaline metals and oxygen release also due to nitrate salt vaporization. The focus is now on the development of new innovative salt mixtures to ensure low melting temperature with higher thermal stability. The main advantage of using molten salts in parabolic through is reduction n cost of heat transfer fluid. The molten salts are not only cheaper than thermal oil but also they act as thermal storage medium.

Husenyin Benli, Aydin Durmus [11] the study in this paper focuses mainly on thermal performance of phase change materials in this study the PCM used is $CaCl_26H_2O$ having melting temperature of 29°C. In this experiment the experimental apparatus uses ten piece solar collector which delivers hot air this air is passed through PCM to charge the unit the study is based on analyzing the transient behavior of the thermal storage during charging and discharging. The proposed setup in this experiment provided up to 18-23% of total daily energy requirements for greenhouse up to four hours.

The setup includes ten solar collectors, located near the greenhouse to collect more sunlight the collectors were positioned towards south. At an angle of 28.6° collector entrance are connected to radial fans having 3900 RPM and 2.5KW, to minimize the losses from bottom the collector was insulated with glass wool. The phase change material used here is about 300 Kg of KNo_3 about 6Kg was added in $CaCl_26H_2O$. the solar air collectors are not widely used in greenhouse heating as little information is available on subject. The system worked efficiently during the day period and managed to create temperature difference of about 6-9°C. The system performed well during day and phase change material managed to release the heat for about period of four hours. but on cloudy day this system is not very effective.

Amos Veremachi et al[12] in this experiment the solar salt mixture has been directly heated by using direct solar heating, the solar salt used here is mixture of $NaNO_3$ with KNO_3 in ratio 60:40 . the melting temperature of phase change material used here is 220°C which I suitable formost of cooking applications . The setup has two reflectors most of cooking applications . The setup has two reflectors primary and secondary the secondary reflector reflects all the radiation back to the latent heat storage situated below the primary reflector through a hole. To ensure proper melting of the phase change material the fin arrangement is used. the fins help to improve conduction and uniform heating of the phase change material throughout the volume. The system is suitable to heat up the thermal storage during peak hours and this heated storage is then can be used for cooking in of peak hours. The system uses primary reflector made up of aluminum the reflectivity of the surface is 98% . the cylindrical aluminum container is used to hold the PCM

The system has two reflectors thus for tracking system there is need of tracking for both reflectors. The commercial controller having two axis racking. The double reflector tracks sun while the storage is stationary. With active solar tracking the the temprature in this case was about 277^{o}C which was higher than melting temperature of mixture. The readings indicated melting of salt the system took almost four hours to heat up to 250^{o}C from room temperature.

M.M. Kenisarin et al[13]. Phase change materials perspective for storage thermal and a solar energy in the range of temperature from 120 to 1000^{o}C. The considerable quantity of mixes and compositions on the basis of fluorides,chlorides, hydroxides, nitrates, carbonates, vanadates, molybdates and other salts, and also metal alloys is given. Thermophysical properties of potential heat storage salt compositions and metal alloys are presented. Compatibility of heat storage materials (HSM) and constructional materials have found its reflection in the present work

M. Kenisarin, K. Mahkamov [14]has stated economically viable realiable and functional solar thermal energy storages with viable running and maintainence costs . The paper discusses the problems associated with existing P.C.M. , their properties methods of heat transfer enhancement and optimum design for storage for solar heating , cooking or drying system

Nallusamy et al [15]. studied the performance of paced bed thermal energy storage with the paraffin wax as phase change materials, the phase change material was encapsulated inside spherical shells. He carried out batch wise experiments, to study performance parameters such as instantaneous heat stored, cumulative heat stored, charging rate and system efficiency. he concluded that the mass flow rate has significant effect on the heat extraction rate from the solar collector. He also concluded from the experimental results that the packed bed LHS system reduces the size of the storage tank appreciably compared to conventional storage system. The experiental step included solar collector(Flat plate), thermal storage tank containing encapsulated PCM capsules in spherical shape.

The water is used as transfer fluid as well as sensible heat storage 49% of tank volume is filled with water and rest with PCM. The PCM used is paraffin wax which has melting temperature of 61^{o}C .. the system had main governing parameters which are heat transfer fluid flow rate, the increase in floe rate decreases charging period of the PCM the experiment shows improvement of up to 24% when the flow rate is increased.

Belen Zalba et al,[16] have reviewed various PCM available in wide range along with the information about the properties and methods need to be implemented during the usage of PCM . the main focus of paper is on study of heat transfer analysis of phase change materials and their analysis. There is discussion of various properties of PCM which are important when considering its use for thermal energy storage. There are a large number of PCMs (organic, inorganic and eutectic), which can be identified as PCMs. Paraffin, Non-paraffin, Fatty Acids ,Salt Hydrates, Eutectics ,Cross-linked Polyethylene, Poly-alcohols but only few are commercialized as there are various factors which play role while considering commercial systems, such as chemical stability , non corrosiveness these factors are important while considering commercial use of any PCM.

Masayuki Kamimoto et al[17] the paper investigates use of nitrate salts as phase change materials , among heat storage options latent heat storage is most suitable for applications which require temperature stability as due to high energy storage density it can offer reliable buffer during off peak hours. another characteristic is constant temperature during charging and discharging which makes latent heat storage better option for both small and large application. But it is not easy to apply it as it has various factors involved. Most important being temperature of phase change. The use of sodium hydroxide , potassium hydroxide and mixed salts is evaluated in this paper. The experimental results show that $NaNO_3$ and other nitrates shown temperature history similar for charging and discharging thus it is suitable to be used in thermal storage.

Dan Zhou, Philip Eames[18] the mixture composition studied is $LiNO_3$ –NaCl(87-13%) this experimentation was done to evaluate its suitability as phase change material th major problem in industry is waste heat , the waste heat can be stored using PCM but due to varying temperature range it is not suitable to ue any PCM as it requires certain melting temperature. but constant temperature of exhaust gases can not be maintained in industry , to solve this this composite mixture is an effort the mixture. The salt was prepared by heating solution of both $LiNO_3$ and NaCl in water at 150^{o}C. The mixture showed varying melting temperature range. By experiments conducted it was found out that the latent heat capacity around 220^{o}C was 300kj/kg which is higher than most of PCM offering such wide melting temperature range that is between 120^{o}C to 300^{o}C . the thermal decomposition occurs between 400-450^{o}C which , if considered melting temperature range then it is well above it thus it makes the material suitable for medium temperature thermal storage. The $LiNO_3$ and NaCl are cheaper in price thus they are tempting to be used as PCM is suitable applications.

CHALLENGES TO OVERCOME

1. Temperature range

The temperature range required to operate smoothly will be biggest challenge here in this case we need to achieve 200^{o}C temperature . this is not easily achievable there is need of modification in this aspect the P.-Y. Wang et al[6]. has given his experimental results for performance improvement of parabolic collector with incorporation of evacuated u tube. With the suggested design improvements temperature of fluid that is heated air has reached to temperature of 200^{o}C.

With suggested improvements it appears to be achievable the design improvements in collector are very simple with nano fluid in evacuated tube it is very promising design .

2. Time for natural circulation

Natural circulation is achieved due to density difference the hot fluid is at the top as it gets lighter .the challenge here is the time required for starting natural circulation.

3. Thermal energy storage

The thermal energy storage is widely researched area but still thera are problems yet to be overcome . the effort has been made by Dan Zhou, Philip Eames[18] to widen temperature range of PCM. The use of honeycomb structure to ensure homogenous melting Abhat[9] are bigger steps. Amos Veremachi et al[12] have used fins to ensure proper heat distribution within PCM. Further there is need of research in this area specifically for domestic applications such as solar cooking and air conditioning.

III. CONCLUSION

In today's scenario use of fossil fuels has increased resulting in the depletion of natural recourses and huge impact on environment. Only way to reduce this impact is to use non conventional energy recourses .

The use solar energy for cooking is not new thing but solar cooker today are not convenient and take huge amount of time. There need of is effort to improve the efficiency of solar cooking and making it practical. The technologies discussed can together be used to formulate the complete solution for solar cooking.

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