IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 13, Issue 5 Ver. II (Sep. – Oct. 2018), PP 34-38
www.iosrjournals.org

Thermal Energy Storage System Using Longitudinal Fins Arrangement (120˚ apart)

[1]*QamarAkhter, [2]Hissan Hafeez,[3]†Bilal Ahmad, [4]Muhammad Ammar Khan
[1,2,3]Department ofElectrical Engineering University of the PoonchRawalakot, Azad Kashmir, Pakistan
[4]School of Electronic Science and Engineering, University of Electronic Science and Technology, 611731, P.R, China
Corresponding Author: QamarAkhter

***Abstract**: Solar power is a clean and sustainable energy as it is pollution free and environment friendly. This energy can be stored as thermal energy using latent heat storage system. The storage material used in our work is paraffin wax that stores the heat as latent heat. Phase change materials (PCMs) are preferred because latent heat storage is more efficient than sensible heat storage. This paper presents a key idea to minimize the energy shortcomings in Pakistan using renewable energy and thermal storage system. In order to increase the thermal conductivity several types of fin arrangement are being studied and it is found that cross fins arrangement gives the maximum output in terms of thermal conductivity. Keeping in view a new longitudinal (120˚ apart) fin arrangement is made and tested. Experimental results verify that our fin arrangement exhibits much better results than the cross fin arrangements.*

***Key words-** Thermal energy storage, paraffin wax, fins arrangement, Latent heat energy, Thermal conductivity*

Date of Submission: 17-11-2018 Date of acceptance: 04-12-2018

I. Introduction

The development of alternative energies is becoming more important issue because of continuous increase in the greenhouse gas emissions levels and the fossil fuels increasing prices. The main characteristics of the new alternative energy must be clean, inexpensive, and sustainable. Solar energy can be considered as the most appropriate energy that possesses these requirements. 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 1980s and 1990s. As a result some of these technologies have reached to the maturity and a user-friendly status that are suitable for decentralized applications. One of the most widespread use of the solar thermal technology is solar water heating (Purohit & Michaelowa, 2008). Solar energy has a great prospect for buildings heating and cooling, heating water for domestic and industrial purposes, cooking, warming greenhouses for agricultural crops, etc. However, solar energy is sporadic, fluctuant, and is available only during the day. Hence its applications require active thermal energy storage so that the overabundant heat collected during sunshine hours may be stored for later use during the night. Solar energy needs a heat storage system to be used as a buffer to pacify the alteration of solar incidence. Therefore some form of thermal energy storage is necessary for the most effective utilization of this energy source (Senthilkumar, R, & N, 2014). Paraffin wax is the most commonly used commercial organic heat Storage PCM. The normal paraffin of type CnH2n+2 is a family of saturated hydrocarbons with very similar properties. Increasing the number of C-atoms increases the melting point too. Paraffin between C5 and C15 are liquids, and the rest are waxy solids. Paraffin waxes are cheap and have moderate thermal energy storage density but low thermal conductivity and require larger surface area. These materials can store energy by the melting at a constant temperature. Paraffin wax is the most commonly used commercial organic heat storage PCM.By using high thermal conductive fins in thermal storage is one of the simplest and effective approach for improving the melting rate of PCM in the thermal storage. However increasing the number of metallic fins will only improve the effective thermal conductivity of the system and will not lead to a sharp improvement of the overall heat transfer coefficient. This is because natural convection heat transfer effect is diminished within the smaller fin gap volume (Tomlinson, 1990).

Rest of the paper is organized as: section II illustrates previous research contributions, section III demonstrates research methodologies, sectionIVpresents our proposed method and section V presents experimental results. Finally in section VI the research work is concluded.

II. Literature Review

This section describes various existing works on the thermal storage systems and the fins arrangement. There are different systems of heat storage with different types of materials. Several types of fins arrangement were studied such as straight fin arrangement, cross fin arrangement, T and Y shaped arrangement. All these arrangements were studied earlier and it was found that cross fin configuration gives the maximum output. The storage material may be quartz, silica, mineral oil and paraffin wax. One of the most widespread uses of solar thermal technology is solar water heating (Purohit & Michaelowa, 2008). Various materials have been investigated for the energy storage systems based on the solid-liquid phase change.

In order to be suitable for heat storage, these materials should satisfy a number of conditions related to their properties:

1) Thermal properties:Phase change temperature fitted to application, high change of enthalpy near the temperature of use and sufficient thermal conductivity in both liquid and solid phases.
2) Physical properties:Low density variation, high density, small or no under cooling.
3) Chemical properties, stability and absence of phase separation, compatibility with container materials and non-toxicity, non-flammability, friendliness to environment.
4) Economic properties: Low price and abundance.

We studied the properties of different storage materials and found that Phase Changing Materials (PCMs) are the best.

III. Related Methodologies

Thermal energy storage (TES) is achieved with greatly differing technologies that collectively accommodate a wide range of needs. It allows excess thermal energy to be collected for later use, hours, days or many months later, at individual building, multiuser building, district, town or even regional scale depending on the specific technology (Tomlinson, J, & Landis, 1990).The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process. PCMs have been widely used in latent heat thermal storage systems for heat pumps, solar engineering, and spacecraft thermal control applications (Sharma, Tyagi, & CR, 2009).In the literature (Antoni, Marc, Ingrid, Ana, Belen, & Luisa, 2010) various properties of concrete and ceramic are described as shown in table 1.

Table1: Properties of concrete and ceramics.

Material	Ceramic	Concrete
Density (kg/cubic meter)	3500	2750
Specific Heat (J/Kg.K)	866	916
Thermal Conductivity(W/mK)	1.35	1
Coefficient of thermal expansion(1/K)	11.8	9.3

In all phase changing materials paraffin wax was found practically well due to its large heat capacity over a limited temperature range. Paraffin wax store energy when they change phase from solid to liquid (melting) and release heat by changing from liquid to

Various types of heat storage systems are shown in figure1 (N, 2009).

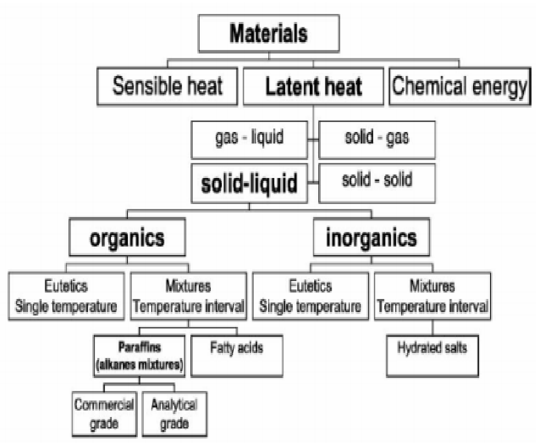

Figure 1: schematic diagram of various heat storage systems

With the development of technology and by studying of various shapes of fins cross fin arrangement was developed. Cross-fin shape has shown more natural convective response at the top surface of fins with the increase in horizontal and vertical area. However recent studies have shown that cross-fin configuration does not show good results at the lower regions of process. So it is necessary that an advance and more efficient system with the proper fins geometry to increase the efficiency of solar thermal storage system must be developed.

Finally we have trying to develop an efficient fin arrangement in our storage system. We have tried our best to keep these fins in proper geometry for getting maximum efficiency more than other types of configurations of fins discussed above.

We used a paraffin wax having temperature range from 45˚C- 60˚C. So this type of wax can easily be melted at low temperature and output can be obtained in less time. In other studies other PCM materials have used like mineral oil, fatty acids and salts etc. But the melting temperature of these materials is higher than wax. Electrical conductivity of these materials is also lower than this. In short wax is best in all respects then other materials. In order to make the system efficient we developed fins on the copper pipe. There are many fins arrangements but we used three fins at an angle of 120˚C apart from each other. The reason to choose this arrangement of fins was that all other fins arrangements i.e Straight-shaped, T-shaped, Y-shaped and Cross shaped were studied earlier.
Some important properties of wax are given in table 2 (R.K, 2012).

Table 2: Thermo physical properties of paraffin wax ∞

Parameters	Values
Density [kg/m3]	880 (solid)/760 (liquid)
Specific heat [kJ/kg K]	2.9 (solid)/2.2 (liquid)
Thermal conductivity [W/m K]	0.2
Melting temperature	47
Latent heat [kJ/kg]	140
Thermal expansion [K-1]	0.001

IV. Proposed Strategy& Discussions

We developed a new arrangement of fins for better heat transfer than cross fins arrangement. We placed three fins at an angle of 120˚C. We have used latent heat storage system. For better heat transfer we have used paraffin wax as it has high storage capacity. From design point of view we used an electric geyser instead of solar collectors due to shortage of time and to maintain constant supply of heat. Two tanks can be used to store hot and cold fluid separately but this will not be economical. Therefore we used a single storage tank to get high efficiency to the cost ratio. An electric rod is placed in a tank of steel filled with water. Ac voltage is supplied to the rod which increases the temperature of water gradually. The input to the geyser is a constant power supply, with the increase in time the temperature of water rises and begins to flow in the storage tank filled with the wax. The copper pipe with fins placed around the wax transfers heat to wax uniformly .when the temperature rises to 45˚C-60˚C then wax starts melting and store the thermal energy.

Due to low melting temperature of paraffin wax we used a single storage tank. The tank was made of steel and covered with insulation to eliminate heat loss. To make the flow of water in reverse direction we used a dc water circulating pump. The output result can be shown in different ways, threedifferent thermo couples can be used and a single data acquisition system (DAS) with the output on monitor screen can be used. For simplicity we used a LCD displaying the different temperatures at a time by using PIC microcontroller. Paraffin wax used in our experimental tests is shown in figure 2.

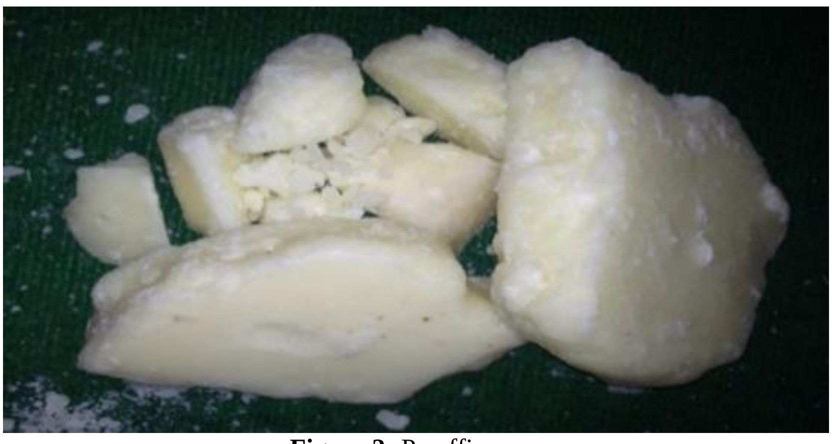

Figure 2: Paraffin wax

Schematic representation of our experimental set up is shown in figure 3.

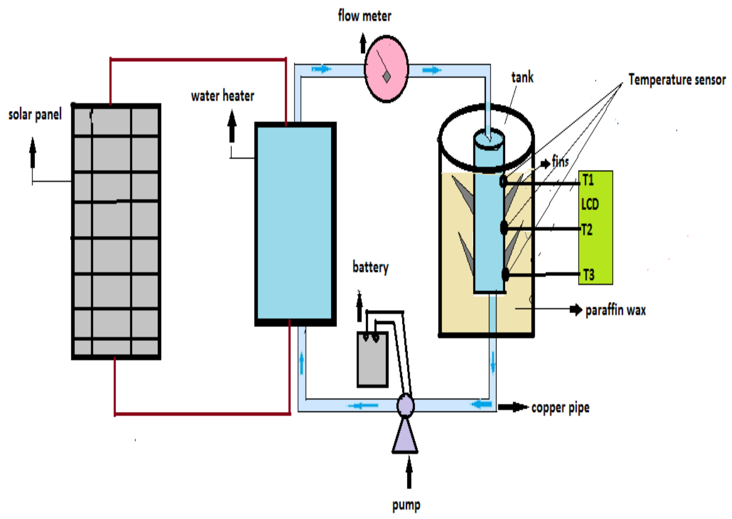

Figure 3: Schematic representation of proposed work

The paraffin wax is placed inside the storage tank made up of acrylic material in which a copper pipe with fins is placed. The hot water flows inside the copper the copper tube and heat is transferred to the wax by natural conduction and convection processes (Cui, Qi, & Saffa, 2011).The tank is made up of acrylic material instead of plastic or glass as this material provide high insulation strength and saves the heat to flow out of tank. Due to this the heat transfer rate increases and wax melt in less time and stores energy for a long time.A PIC microcontroller 16f877 is connected with the LCD pin 1-4 are used as analogue to digital converter circuit that are connected with thermistors. The pin 13 and 14 are connected to the clock generator with the clock frequency of 4MHz. pin 1 is ground and 2 is connected with 5 volt supply. The pin 21 and 22 of controller are connected with pi 4 and 6 of LCD. From ADC circuit the data flows in binary numbers that is received on LCD from pin 11-14.

Resistors of different ratings are used for different purposes. Mainly the resistance used is 220Ω a few variable resistors are also used having rating 10 ohms. Capacitors of different ratings including 10 microfarad and 27 micro farad are used. Thermistors are also used whose one end is connected with 5 volt and other is grounded. These thermistors are connected to pin 1-4 of PIC controller. As the resistance normally increases with the increase in temperature but the resistance of thermistors decreases with increase in temperature.

V. Experimental Results

We performed the experiment and found that temperature at the bottom of the storage tank is high, a moderate temperature is observed at the middle and low temperature at the top of the tank.
The melting temperature of wax was found to be 48˚C.Similarly other parameters actually calculated during the experiment are given below.

Temperature	Readings
T_1	48˚C
T_2	35˚C
T_3	29˚C
$\Delta T=T_1-T_2$	13˚C
$\Delta T=T_2-T_3$	6˚C
$\Delta T=T_1-T_3$	19˚C

The temperature difference can be converted directly into electrical energy bySee beck effect by connecting thermoelectric generator.
According to which
$V=\alpha\Delta T$
Where α is See beck co-efficient.By using the above relation we can calculate three different voltages as v_1, v_2 and v_3 from bottom to top respectively.

VI. Conclusion

We have proposed a new arrangement of fins for better heat transfer a The experimental results showthat our supposition of fins arrangement using copper as a raw material for fins is excellent as the heat transfer rate of this arrangement is found to be maximum. This is a new research regarding fins configuration with optimum results. So it is concluded that for better heat transfer, efficiency, high conductivity and stability all other types of fins arrangement can be replaced to some extent by the fins arrangement used in our research.

Secondly due to the use of acrylic material for storage tank the heat energy remained inside the tank and the loss of heat energy is minimum which increases the overall efficiency of latent heat storage system using low melting paraffin wax.

As a future research direction several other phase change materials can be investigated to get better results. Similarly for fins arrangement aluminum and other metals can be used for the construction of fins in order to increase thermal conductivity and overall efficiency of the system.

Acknowledgements

This research paper is made possible through the help and support of my research fellows. They kindly read mypaper and offered invaluable detailed advices on theme of the project. It’s because of them that the project was asuccess.

Reference

[1]. P. Purohit and A. Michaelowa, "CDM potential of solar water heating systems in India," Solar Energy, vol. 82, no. 9, pp. 799--811, 2008.
[2]. Senthilkumar, S. R and S. N, "Experimental Investigation of Solar Water Heater Using Phase Change Material," International Journal of Research in Advent Technology, vol. 2, no. 7, pp. 1-87, 2014.
[3]. J. Tomlinson, "Thermal Energy Storage," Mechanical Engineering, vol. 112, no. 9, p. 68, 1990.
[4]. P. Purohit and A. Michaelowa, "CDM Potentail of Solar Water Heating in India," Solar Energy, vol. 82, no. 9, pp. 799-811, 2008.
[5]. J. Tomlinson, K. J and D. Landis, "Thermal energy storage," Mechanical Engineering, vol. 112, no. 9, p. 68, 1990.
[6]. A. Sharma, V. C. Tyagi and B. D. CR, "Review on thermal energy storage with phase change materials and applications," Renewable and Sustainable energy reviews, vol. 13, no. 2, pp. 318--345, 2009.
[7]. G. Antoni, M. Marc, M. Ingrid, L. Ana, Z. Belen and F. Luisa, "State of the art on high temperature thermal energy storage for power generation. Part 1—Concepts, materials and modellization," Renewable and Sustainable Energy Reviews, vol. 14, no. 1, pp. 31-55, 2010.
[8]. R. N, "Thermal Mass, Night Cooling and Hollow Core Ventilation System as Energy Saving Strategies in Buildings," 2009.
[9]. S. R.K, Explaining creativity The Science of Human Innovation, OXFORD UNIVERSITY PRESS, 2012.
[10]. Y. Cui, R. Qi and Saffa, "Review on Phase Change Materials for Building Applications," in {Applied Mechanics and Materials, vol. 71, 2011, pp. 1958--1962.

IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) is UGC approved Journal with Sl. No. 4198, Journal no. 45125.

QamarAkhter " Thermal Energy Storage System Using Longitudinal Fins Arrangement (120˚ apart)." IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) 13.5 (2018): 34-38