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Thermal Energy Storage Using Phase Change Material

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Abstract: An experimental study is conducted to investigate the melting and solidification processes of paraffin wax as a phase change material (PCM) in a spiral pipe with twisted tape inserts latent heat storage unit. The present work on phase change process includes study of temperature variations along the axial distances in PCM, determination of heat transfer coefficient as well as the heat flow rate. A series of experiments was conducted to investigate the effect of increasing the inlet temperature and the mass flow rate of the heat transfer fluid (HTF) both on the charging and discharging processes of the PCM.
Keywords: Heat transfer coefficient, Phase change material, Peak load, Paraffin wax.

I. INTRODUCTION

Scientists all over the world are in search of new and renewable energy sources to reduce the CO2 emissions from the combustion of fossil fuels, particularly in areas where low temperature applications are involved. Energy storage plays important roles in conserving available energy and improving its utilization, since many energy sources are intermittent in nature. Short term storage of only a few hours is essential in most applications; however, long term storage of a few days may be required in some applications. Solar energy is available only during the day, and hence, its application requires efficient thermal energy storage so that the excess heat collected during sunshine hours may be stored for later use during the night. Similar problems arise in heat recovery systems where the waste heat availability and utilization periods are different, requiring some thermal energy storage. Also, electrical energy consumption varies significantly during the day and night, especially in extremely cold and hot climate countries where the major part of the variation is due to domestic space heating and air conditioning. Such variation leads to an off peak period, usually after midnight until early morning. Accordingly, power stations have to be designed for capacities sufficient to meet the peak load. Otherwise, very efficient power distribution would be required. Better power generation management can be achieved if some of the peak load could be shifted to the off peak load period, which can be achieved by thermal storage of heat or coolness. Hence, the successful application of load shifting and solar energy depends to a large extent on the method of energy storage used.

II. BLOCKDIAGRAM

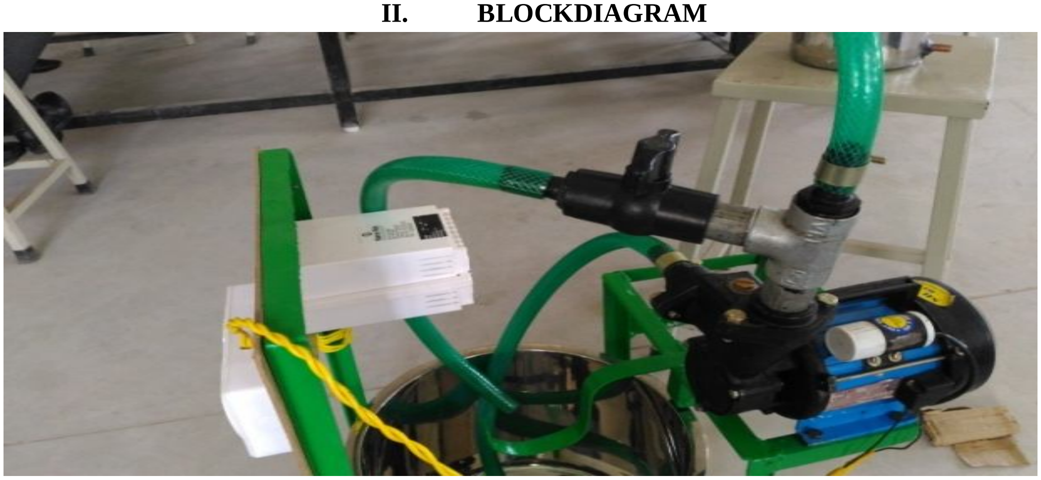

Fig.1

Fig.2

III. WORKING PRINCIPLE

During sunshine period, valve 1 is kept open and valve 2 is kept closed. The cold water from the storage tank goes through the flat plate solar collector, absorbing heat energy from the solar radiations. It then passes through the PCM heat exchanger, where it loses its heat to the phase change material. It then goes back to the storage tank. In this way, the PCM gains heat energy which will then be used to heat water during non-sunshine period. During non-sunshine period, valve 1 is kept closed and valve 2 is kept open. The cold water from the storage tank goes through the PCM heat exchanger, absorbing heat energy from the heat stored in the phase change material. It then goes back to the storage tank. By this way cold water is heated with the help of heat stored in the PCM.

IV. DESIGN CALCULATION

A. Water Storage Tank

Dimension of the water storage tank

Length = 0.3 m

Width = 0.3 m

Depth = 0.3 m

Volume of water tank = 0.03 m^3 **=** 30 liters

B. Flow Analysis

Diameter of pipe **(D)** = 0.501621251 inch =12.5mm

For a flow rate of = 7.5 lit/min

Kinematic viscosity **(V)** = 5.2275E-07 m^2/s

calculated velocity of water through the pipe line **(U)** =0.98 m/s

Reynolds number (ud/v) = 23885.9038 >2300

Type of Flow = Turbulent

C. Heat Transfer Analysis

Heat input = 2000 watts

Cp = 4.186 kJ/kg K

V. DESIGNING PCM BASED HEAT EXCHANGER

A. The calculation for the PCM based heat exchanger is done in the following steps

1) Amount of hot water required during non-sunshine period is estimated. Accordingly, amount of energy needs to be stored is estimated.
2) A suitable type of heat exchanger is selected.
3) A suitable phase change material is selected.
4) Dimensional parameters of heat exchanger are then calculated.

B. Components Of Test Rig

Following are components of the test rig constructed for the testing of PCM heat exchanger

1) Energy storage unit The energy storage unit is the main component of the test rig. The outline of the energy storage unit is shown in Figure 3.3. The heat transfer fluid flows from the inner copper pipe. The outer pipe is of PVC, which also acts as insulating material. It prevents the melted wax to solidify after charging. The paraffin wax is incorporated in the outer pipe of the energy storage unit.
2) Storage tank The purpose of the storage tank is to act as a reservoir of water which will be circulated in the circuit. Ideally the storage tank should be insulated to prevent any exchange of heat through it.
3) Motor Motor is a prime mover . motor are used to convert the electrical energy in to mechanical energy .the water are used pump by the purpose of the pump is to create a circulation in the circuit. The pump used in the circuit is a non-submersible water pump with a head of 6 feet. The mass flow rate of the pump was calculated as 15 lpm.
4) Heating coil The purpose of the heating coil is to heat the water in the storage tank. As mentioned earlier it is done to eliminate the flat plate collector in the Figure 3.1. The heating coil used in the setup is of 1500 W rating.
5) Flow control valve The purpose of flow control valve is to regulate the mass flow rate of the heat transfer fluid through the circuit. The valve used in the circuit is a simple gate valve type valve
6) Thermocouple wire The thermocouple wire used for temperature measurement is of J-Type. The two dissimilar metal wires used in this thermocouple are of iron and constantan. The thermocouple wires are incorporated at predetermined points. Before inserting the thermocouple at the points, ends of the two metal wires are joint using a gas welding flame to form a bead. The thermocouple wire is calibrated at two standard temperatures, melting point and boiling point of water. The following were calibration readings obtained for different thermocouples

Calibration readings of thermocouples

Thermocouple	Reading at $100^{O}C$	Reading at $0^{O}C$
Thermocouple 1	$89^{O}C$	$5^{O}C$
Thermocouple 2	$90^{0}C$	$5^{O}C$
Thermocouple 3	$90^{o}C$	$5^{O}C$
Thermocouple 4	$90^{0}C$	$5^{O}C$
Thermocouple 5	$90^{0}C$	$5^{O}C$

Table.1

7) The readings of thermocouple are adjusted according to the calibration curve, which is plotted for each thermocouple using the above data.
8) Temperature indicator The temperature indicator consists of 8 channels. Each channel receives input from different thermocouples which are incorporated in the energy storage unit.

VI. APPLICATION OF PARAFFIN

A. Air Conditioning
This is the Zero Energy Office, designed to capture energy during night time for release during daytime hours

B. Free-Cooling Of Buildings
Free-cooling is understood as a means to store outdoors coolness during the night, to supply indoors cooling during the day

C. Shipping
Phase Change Material is now utilized in road, air and sea freight as a cooling medium that provides electricity free cooling solutions.

D. Solar Heating
Paraffin wax is used as solar water the energy stored in the PCM can also be used in night tine.

E. Road Transport
A huge percentage of our food is transported by road with refrigerated vehicles to common place. PCM technology offers both mechanical-refrigeration-free and back-up cooling options.

F. Cold Store Back-Up
A power failure is potentially extremely costly in food storage. In countries with less reliable power supplies, PCM technology has been employed in warehouses to effectively soak the heat out of the storage area to ensure that the products remain unspoiled.

G. Telecom Shelters
It is imperative to keep electronics under 45 °C in order to keep systems functioning. PCM systems freeze over night, even in desert climates, soak heat from the electric circuits, melt and release cool during the daytime

H. Electronic Back-Up Cooling

Many I.T. centers have their power supply backed up by generators or UPS for the computers. Unfortunately, as soon as the power goes off, the temperature rises. The PCM acts like a thermal sponge, soaking the heat from area and offers an electric free back-up cooling solution etc.,Even though paraffin is used as thermal energy storage medium in many applications the thermal conductivity of paraffin is very low. Due to low thermal conductivity heat transfer, thermal diffusion are also very low. So it requires more surface area of contact and loading and unloading operation takes more time**.**

VII. CONCLUSION
In this project the thermal behavior of phase change material was improved by including CuO nano particle with paraffin phase change material. An experimental setup was designed and fabricated to carry out the behavior of PCM. The improvement in the thermal property (thermal conductivity) is necessary to reduce the loading and unloading time of the PCM and also to have uniform melting of PCM, this is possible only if the thermal conductivity is more. Therefore it is mandatory to increase thermal conductivity of PCM. Initially the thermal conductivity of paraffin was 0.17W/mk supplied by purchaser and this also verified by us using transient hot wire method. After mixing the Cuo nanomaterial with the paraffin PCM, the thermal conductivity has increased to 0.3 W/mk (as per transient hot wire method) and 0.28W/mk (as per Maxwell Garnett equation). Thus there is an improvement in the thermal conductivity of PCM. The loading and unloading times of paraffin PCM were 5.4 hrs and 3.5 hrs for thermal energy storage

of 313kJ. The results were phenomenal after adding CuO nanoparticles, the loading and unloading time were 5 hrs and 3.2 hrs respectively for thermal energy storage 313kJ.further the thermal properties of the PCM can also be studied for various volume concentration and the optimum proportion can be determined.

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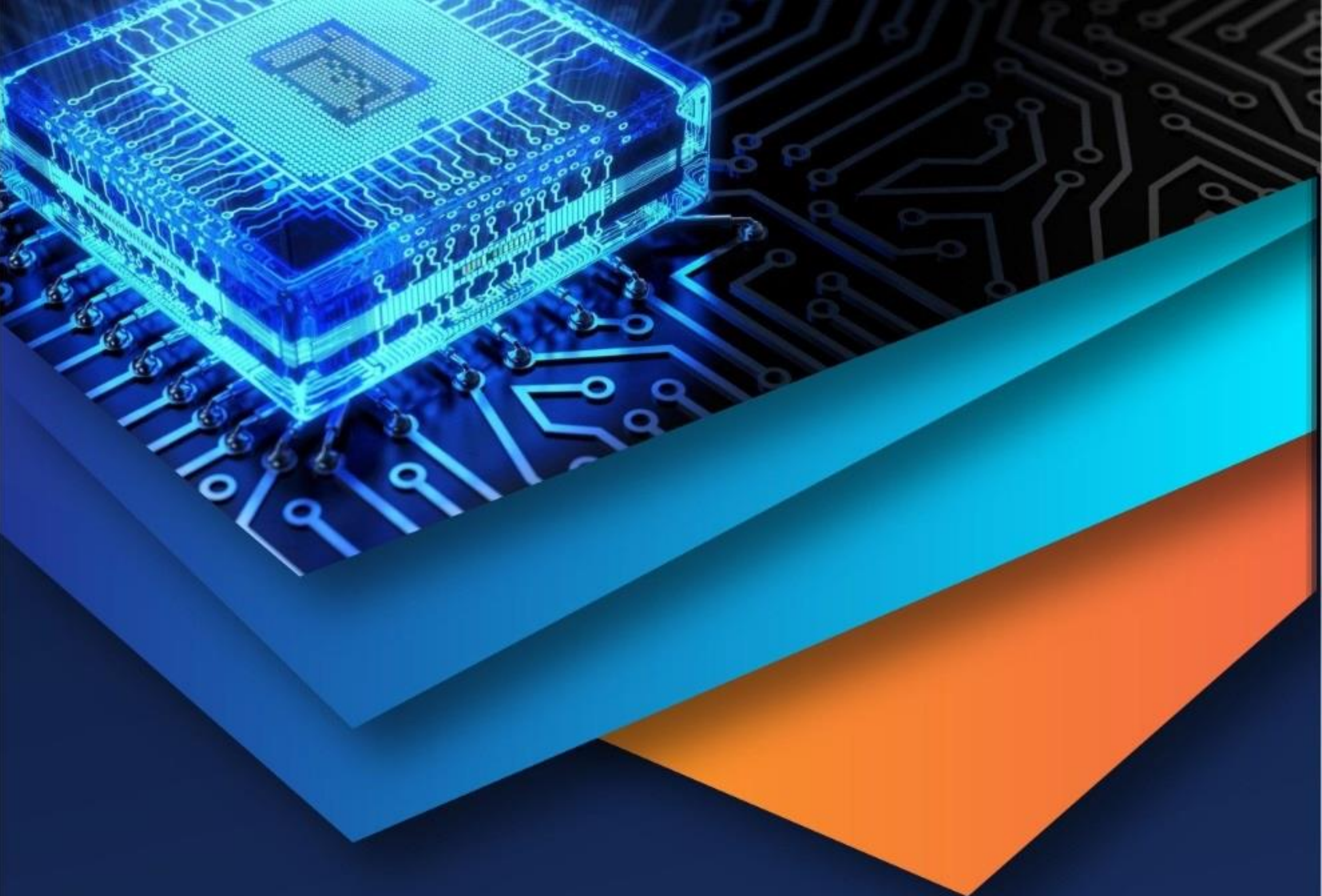

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