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Experiment on a Finned Tube Heat Exchanger for Thermal Energy Storage

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***Abstract:** This experiment was conducted on thermal energy storage with shell and fins tube heat exchanger, to check the effect of fins on the heat transfer rate. Potassium nitrite (KNO3) is used as thermal storage material which has a specific heat capacities of 1.21 KJ/Kg K and water (H2O) is used as a heat transmission fluid (HTF), which has a specific heat capacities of 4.187 KJ/Kg°K.*

The shell tube contains energy storage material like potassium nitrate (KNO3) and the tube side is water as heat transfer fluid. In this experiment, only sensible heat is stored in this salt.

There are three basic steps involved in this project, one is charging mode and the second one is storage mode and the last one is discharging mode. Three different tubes are used, one is a plane tube, and the next is five fins attached tube and finally ten fins attached tube.

In charging mode inlet water temperature is kept constant at 60°C, and the flow rate was maintained at 80 litres per hour throughout the experiment. Readings were taken till storage material reaches to 60°C with respect to time. In discharging mode inlet water temperature was kept at room temperature and readings were taken till material temperature reaches to room temperature with respect to time.

This procedure carried out for three different arrangements. Finally, heat transfer rate was calculated for zero fins tube, five fins tube, and ten fins tube, and corresponding graphs were plotted against storage material temperature vs. time, heat energy rate vs. time. From above graphs and calculation, we can conclude that increasing the number of fins on the tube, heat transfer rate will increases up to a particular stage, and finally, ten fins tube gives optimum performance compare to other two pipes.

Keywords: Thermal energy storage, finned tube, non-phase change material, heat transfer fluid, charging, discharging.

I. INTRODUCTION

Energy storage system is the latest and progressive trending technology for the storage of both sensitive heat energy and latent heat energy. There are primarily two kinds of material used for heat energy storage; one is phase change material and another non-phase change material. Thermal storage technology is still not practical because it is difficult to find proper thermal storage material and they possess some thermodynamic, mechanical, chemical, technical properties and should be economic characteristics. Good thermal conductivity, large latent heat, low super-cooling and good stability are the most important key points in the selection of storage material. The thermal storage system of the solar thermal power plant is necessary for the power plant stability and reducing rate of mismatch between energy demand and supply. And also to increases the heat transfer rate as well as thermal efficiency.

There are many ways of heat exchanger like helically coiled heat exchanger, plate type, compact surface type, and many more. The quality of energy is measured by the entering temperatures of the materials, exiting temperature, and stored within storage media is an important consideration in TES. For example, one kilowatt-hour of energy can be stored by heating one metric ton of water at 0.85◦C, or by heating 10 kg of water at 85◦C and the time factor is also important. The most important criteria to evaluate TES process such as sizing, feasibility environment.

In this project, we used shell and fins tube heat exchanger device, which has better effective value compare to the bare tube arrangement. In this experiment, I took effect of the number of fins on the heat transfer rate, and heat recovery efficiency. First the experiment was conducted on the five fins stainless tube then ten fins stainless tube both fins tube is compared to the bared stainless tube and on technical data, there be more efficient as goes on an increasing number of fins. All tubes are the same dimension, and mild steel is used for fin material of the same size, and these fins are welded on tube. Shell is made up of stainless steel on both sides of the shell flange plates are welded for closing and opening of the shell pipe. This experiment will be conducted on non-phase change material like salt material, in salt material we can save the sensible heat energy, and it does not change phase while the heating process. Performance data of all different fins tubes are compared to each other for which is suitable for thermal energy storage. In this experiment, KNO3 salt is taken as non-phase change material. Which has good thermal as well as chemical properties and physically and chemically equilibrium also low-cost material and it is easily available in the market.

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II. DESIGN AND CONCEPT

Table 1 material for components.

SL No	component	Material used
1	Corrugated tube	stainless steel
2	shell	stainless steel
3	Baffle plates	mild steel
4	Flange plate	Mild steel

There are many types of the heat exchanger are available but for better efficiency of heat transfer, I had tested on the fins tube heat exchanger. In industries application, the double pipe heat exchanger is used widely, and they always try to increase their effectiveness as well as heat transfer rate. So the fins attached tube with shell arrangement heat exchanger will gives way to increase the heat transfer rate. The exchange of heat is a major part of the thermic energy storage process. This experiment consists of heat addition to material and extracting heat energy from stored material by using shell and fins tube heat exchanger arrangement. The precautions are taken for manufacture of all components and final heat device was designed and fabricated according to proper dimensions.

Fig 1. Five finned tube.

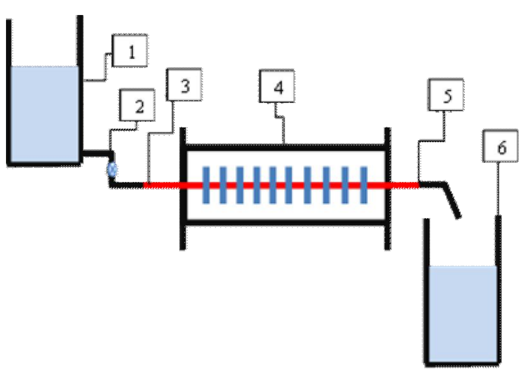
Fig 2. Shell tube.

Fig 1 and 2 shows the sample of shell and tube set up, which are made up of steel material and fins are welded on tube with gas welding and similar type shell tube designed and fabricated table no. 1 and 2 show detail of data of shell and tube arrangement.

Table 2 design data of components.

SL No	Parameter	Dimenssion
1.	Type of heat exchanger	horizontal
2.	Shell diameter	0.1m
3.	Shell length	0.5m
4.	Tube diameter	0.05m
5.	Tube length	0.45m
6.	Tube thickness	.001m
7.	Number of baffle	5
8.	Baffle spacing	0.08m
9.	No. of passes	single

III.EXPERIMENT PROCEDURE.



1. HTF Storage tank.
2. Ball valve.
3. Inlet temperature.
4. NPCM temperature.
5. Outlet temperature.
6. HTF collecting tank.

Fig 3 Experimental setup

A. Component Required

To complete the experimental set up major following component are required and explained below.

1) *Shell And Tube Set Up:* This is main device which consist of shell of 5cm diameter pipe and thermal storage material is placed inside the shell. And 2.5cm corrugated stainless steel pipe on which finned are welded as shown in figure and heat transfer fluid or hot fluid is flowing inside this pipe.
2) *Thermometer:* Digital thermometer is used to measure the temperature of inlet and outlet HTF T1 T2 and also measure the thermal storage material temperature as T3.
3) *HTF Storage Tank:* A steel tank of 10 litre capacity is taken as HTF storage tank, in that water is placed and is heated externally by electric heater.
4) *HTF Collecting Tank:* After out coming cold water collected in another tank which is also made up of steel of 10 lit capacity.
5) *Valve:* In this experiment ball valve is used of 1cm diameter, it consist ball inside the valve and is used for control flow rate of working fluid.
6) *Flow Measurement:* In this experiment I am taken gravity type flow. According to that adjustment of flow rate is controlled by ball valve.
7) *Pipe:* Hose pipe is used to connect water tank and prototype. Which is made up of plastic with high withstand temperature about range of 100 to 120°C.

B. Standard Procedure

There are mainly 2 step involved and they are given below.

1) *Charging:* First arrange all components as shown in figure 3. Next collect water in heat transfer fluid storage tank and heat it up to 60°C, and maintain it constant throughout charging process. Set flow rate at 80ltr/hr. constant level by using ball valve which is attached to hose pipe. Attach digital thermometer as required position to measure the temperature as shown in fig. Allow to flow water by opening valve then at every 45 second note down temperature of NPCM material and outlet temperature of water. Repeat the procedure up to NPCM temperature will attend 60°C. And corresponding outlet temperature should be note down.
2) *Discharging:* After achieving NPCM temperature at 60°C stop the experiment then fill HTF as cold water in storage tank. Then measure initial temperature of water at tabulates it. Then again with same flow rate the cold water will allow to flow in heat exchanger setup. And measure NPCM temperature and HTF outlet temperature then note down it. Repeat the experiment up to NPCM temperature will attend room temperature. Then by using data calculate the heat transfer rate of both charging and discharging.

IV. RESULT AND DISCUSSION

A. Charging

Charging is a process of continuous addition of heat to non-phage change material (NPCM). The first experiment set up will arrange with a plane tube as shown in the figure and temperature of water is kept constant to 60°C throughout charging mode. And continue experiment according to the procedure.

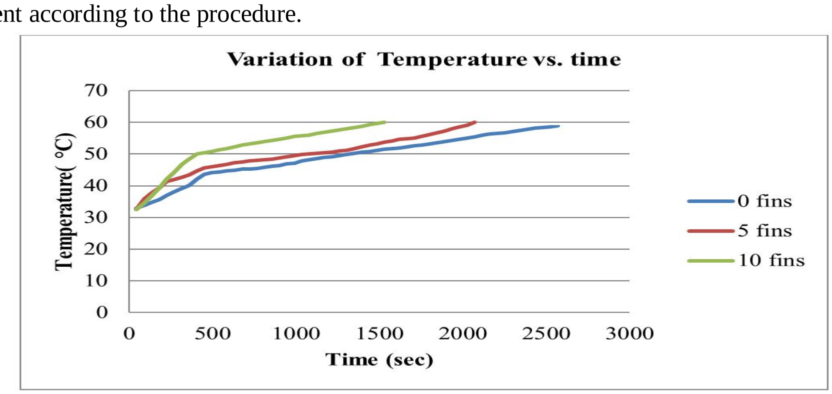


Fig 4 variation of temperature vs time.

From above the graph the blue line which shows the plane tube with the variation of temperature with respective to time, as goes on increasing the time the NPCM temperature also increases and finally it will approaches 60°C temperature at 2500 sec or 45 minutes. Similarly for five fins tubes took 34.5 minutes to attend 60°C temperature. The brown line shows five fins tube reading in the above graph. And finally, for 10 fins tubes, it took only 25.5 minutes to approach the 60°C temperature of the

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NPCM material. This process is called the charging process. From the above data and graph, it will show that the rate of temperature increase is depending upon fins. As increasing the number of fins on the same tube it will take less time to attend 60°C temperature of the material because the heat absorption rate is faster as increasing the number of fins. The temperature of storage bed is depend upon entire volume of material as well as fins material and is function of time only. There is conduction mechanism takes place between a hot pipe and KNO3 salt (NPCM) material. The maximum temperature of the material is available at depth of the bed because at the down position there is less heat transfer mechanism.

B. Discharging.

Figure 5 shows the temperature variations in the storage unit during discharging with an HTF flow rate of 80 LPH. Significant temperature drop at beginning of the discharging process due to sensible energy loss. When zero finned pipe there is decreases.

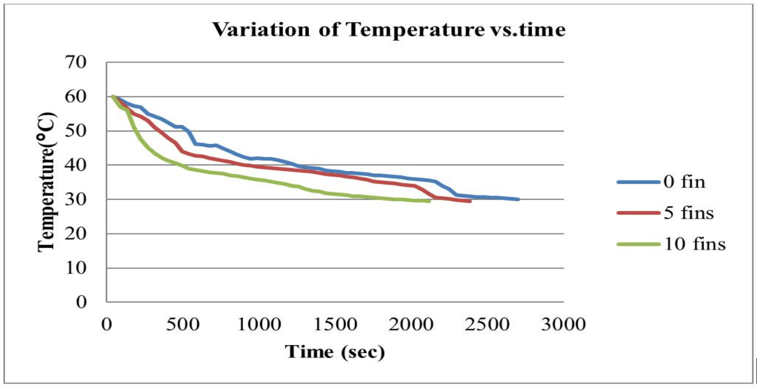

Fig 5 variation of temperature vs. time.

In temperature takes place slowly because there is less heat transfer rate and finally it will take time 50 minute to reduce temperature from 60°C to room temperature. And simultaneously HTF fluid temperature also decreases parallel to NPCM temperature. And for plane tube the blue line indicated in above graph. Similarly for five finned tube it will take 40 minute to reduce to room temperature, compare to plane tube there is slight faster reduces takes place because of the heat transfer rate is slightly more due to fins, the brown line shows variation of five finned tube. And finally the green line shown ten finned tube in that reduction of temperature takes place little bit faster than five finned tube because heat transfer rate is more as increasing number of fins. And it will take 34 minute to come to room temperature. From above three lines at beginning there is sudden decrease takes place due to low heat capacity and as goes on time the reduction rate come slowly and normally parallel to HTF temperature.

C. Effect of Heat Transfer Rate

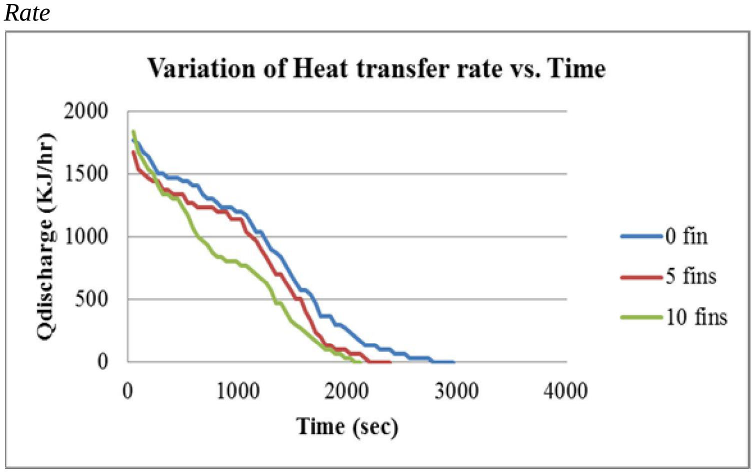

Fig 6 variation of heat transfer rate vs. time

We have to calculated heat transfer rate of both charging mode and variation with time which is shown in above figure 6. As we seen in graph there is continuously reduction in heat transfer rate of all three lines because the temperature difference continuously reduced at each reading. And ten finned tube which get faster rate compare to the five and zero finned tube.

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V. CONCLUSIONS

From this experiment, we concluded that this is an advanced experimental setup for thermal energy storage. In this experiment fins mounted on the tube is highlighted. According to result, in charging mode the zero fins tubes consume 45 minutes time to achieve the 60°C temperature of the material. While five fins tubes took 34.5 minutes and ten fins tubes took 25.5 minutes to attend 60°C temperature. While in discharging mode, the zero fins tubes took 50 minutes to reduce room temperature of the material and another side five fins tubes will take 40 minutes, while ten fins tubes took 35 minutes to attain room temperature of the material. From the above data shows that increment in the fins on the tube, the heat rate also increases in both charging and discharging mode. Also, the recovery efficiency of the plane, five fins tubes, and ten fins tubes will vary in between 53% to 90%, from all performance data, the ten fins tube gives optimum result compare to other two pipes.

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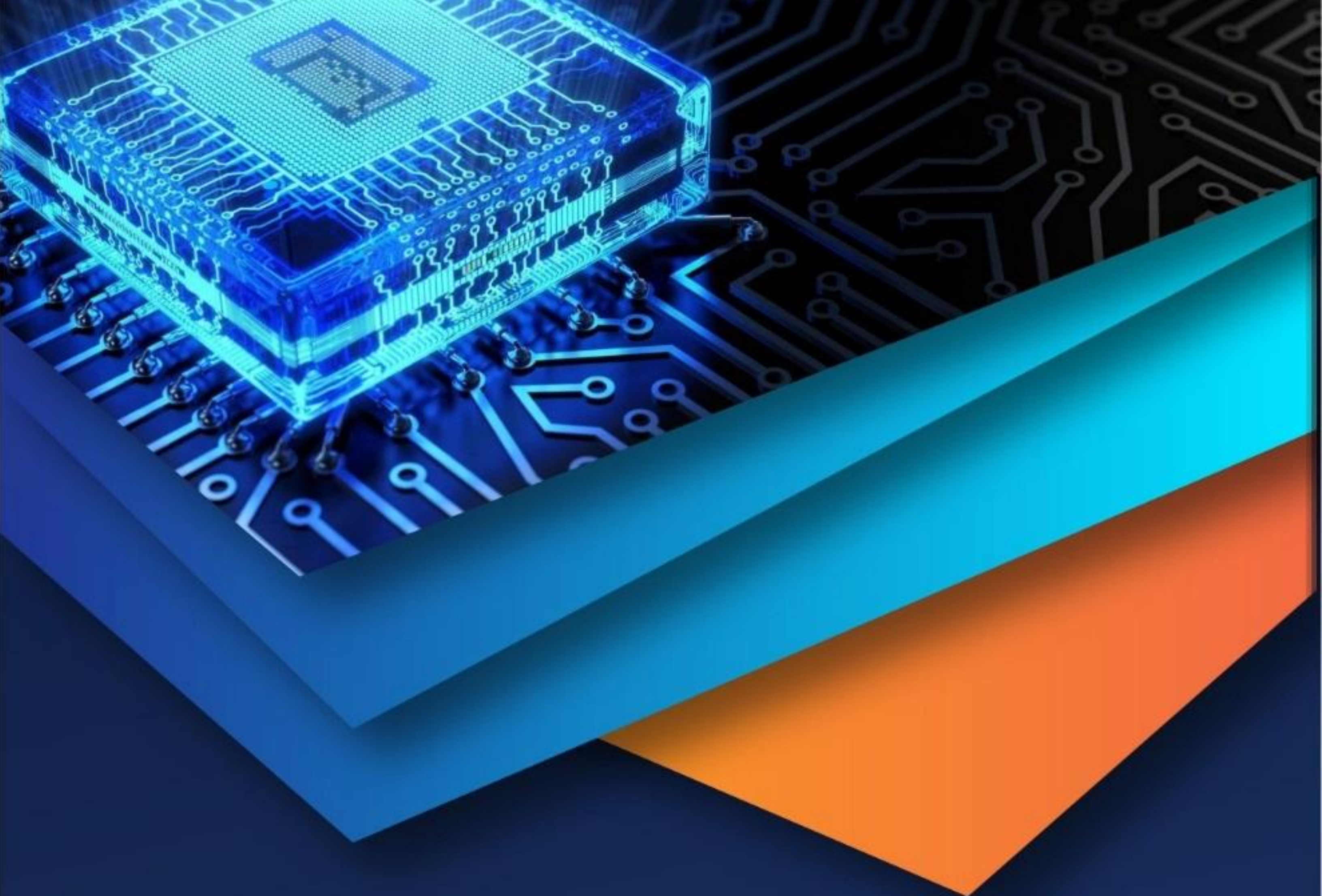

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