Experimental Analysis of Shell and Tube Heat Exchanger with Dry Cooling Method by Using Phase Change Material

P. L. Navaneethakrishnan\textsuperscript{1}, G. Naga Shanmuga Pradeep\textsuperscript{2}, M. Pugalenth\textsuperscript{3}, P. Ramkumar\textsuperscript{4}, C. Sathish\textsuperscript{5}

\textsuperscript{1}Assistant Professor, Dept. of Mechanical Engineering, Adithya Institute of Technology, Coimbatore, India
\textsuperscript{2,3,4}Student, Dept. of Mechanical Engineering, Adithya Institute of Technology, Coimbatore, India

Abstract: The aim of the present work is to improve the thermal performance of the Shell and Tube Heat Exchanger using enhanced heat transfer technique. This is experimentally accomplished by incorporating a PCM (Phase changing materials) in the Heat Exchanger. The purpose of using PCM is which has a capability of changing its phase from solid to liquid and liquid to solid and during phase changes a thermal (heat) energy transfer occurs. In this paper, using a phase change material in a shell and tube heat exchangers is experimentally analyzed and investigated. Experiments were performed for different mass flow rates and inlet temperature of heat transfer fluid for consecutive seven days. The effect of mass flow rate on the performance of the system was studied. The results show that, using of phase changing, materials in shell and tube heat exchangers with different configurations lead to enhance the effectiveness and cooling performance of the heat exchanger. All these observations along with their discussions have been discussed in detail inside the paper.

Keywords: Phase changing materials, Shell and tube type heat exchangers, Effectiveness.

1. Introduction

A heat exchanger is a device that is used to transfer thermal energy between two or more fluids, at different temperatures and in thermal contact. The shell and tube type heat exchanger is the most versatile type of heat transfer apparatus. It is the most common type of heat exchanger in oil refineries and other large chemical processes, and is suited for higher-pressure applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called a tube bundle. Phase change material (commonly known as PCM), which has become an attractive means to store thermal energy, has a wide range of applications in today’s world. As the name suggests, these materials change their phase with a change in temperature. In this paper we are concerned about the performance analysis of shell and tube type heat exchanger with phase changing materials under different loading conditions. To do the same we have first designed a shell and tube type heat exchanger along with PCM to get the dimensions of the parts involved and thereafter fabrication and testing of the actual working model has been done to see the effects of various parameters on the performance of the heat exchanger.

2. Literature survey

Experimental Evaluation of a Paraffin as Phase Change Material for Thermal Energy Storage in Laboratory Equipment and in a Shell-and-Tube Heat Exchanger

The thermal behavior of commercial paraffin with a melting temperature of 58°C is analyzed as a phase change material (PCM) candidate for industrial waste heat recovery and domestic hot water applications. In the laboratory characterization, its thermal and cyclic stability, its health hazard as well as its phase change thermal range, enthalpy and specific heat are analyzed using a differential scanning calorimeter, thermos gravimetric analysis, thermo cycling and infrared spectroscopy. Results from the pilot plant analysis allowed understanding the different methods of heat transfer in real charging and discharging processes as well as the influence of the geometry of the tank on the energy transferred and required time for charging and discharging processes.

Analysis of thermal energy storage system using paraffin wax as phase change material

The increasing gap between the global demand and supply of energy is becoming a major threat as well as a challenge for the engineering community to fulfill the needs of the energy hungry society. A significant amount of heat is wasted in electricity general, manufacturing, chemical and industrial process. Recovery and reuse of this energy through storage can be useful in conservation of energy and meeting the peak demands of power. Paraffin wax (Melting Point 54\degree C) was used as storage media due to its low cost and large-scale availability in Indian market. Experiments were performed for different mass flow rates and inlet temperature of heat transfer fluid for recovery and use of waste heat. The utilization of the abundant source solar, thermal energy and hot waste streams available in industries has attracted the scientific community to provide attractive solutions for the problems on energy conservation and storage/ retrieval.
3. Main components and its description

The setup consists of a shell and tube type heat exchanger, Phase changing materials in aluminum boxes, temperature sensors linked to the circuits containing LCD to display the readings.

A. Heat exchanger

In this project, we have used shell and tube heat exchangers by passing hot water of different temperature ranges in the shell side and cold water in the tube side. Here the shell is made up of mild steel and the copper tubes are used for inner tubes.

B. Phase changing materials

PCMs possess the ability to change their physical state within certain temperature ranges. In a heating process the PCM absorbs a small amount of sensible heat and its temperature rises constantly. However, when the melting temperature is reached in such a heating process, the phase change from the solid state to the liquid state occurs. During this melting process, the PCM absorbs and stores a large amount of latent heat. We selected paraffin wax, paraffin C20 enclosed within aluminum box which has a melting point of 64°C & 68°C, Heat of fusion – 173.6 KJ/Kg, Thermal conductivity-0.167 W/mK for this experimental analysis.

C. Temperature sensor

In our project, we have used Thermocouple to measure the temperatures of the inlet and exit hot water & cold water from the heat exchanger as well as the storage tank of PCM. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is created. The voltage can then be interpreted using thermocouple reference tables to calculate the temperature.

D. Control unit

The control unit circuit consists of Microcontroller, oscillating circuit, amplifier circuit and LCD. When the thermocouple senses the temperature it sends the signals to the microcontroller and it is processed and displays the reading in the Liquid Crystal Display.

4. Experimental description

The cold water is feeded into the boiler which is installed nearer to the heat exchanger. The water is heated in the boiler and is passed to the tube side of the heat exchanger and at the same time the cold water is passed to the shell side of the heat exchanger, the heat transfer occurs. After heat transfer, the cold water is drained out and the hot water coming out from the heat exchanger is guided to the storage tank containing PCM. The heat from the hot water is absorbed by the PCM and it gets melted and the hot water coming out from the storage tank is collected and the temperature is measured for experimentation.
Then we have tested two variations by passing the hot water in sheel side and cold water in tube to test the performance of the heat exchanger with the storage tank containing PCM.

### 7. Testing and Analysis

![Fig. 5. Day 1 by using Paraffin Wax PCM](image1)

![Fig. 6. Day 2 by using C20 PCM](image2)

<table>
<thead>
<tr>
<th>Day</th>
<th>Mass flow rate (Cold) in m$^3$/s</th>
<th>Mass flow rate (Hot) in m$^3$/s</th>
<th>Overall heat transfer (W)</th>
<th>Correction factor</th>
<th>Heat capacity ratio</th>
<th>Effectiveness of heat exchanger (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>0.04487</td>
<td>0.03202</td>
<td>2.38</td>
<td>1</td>
<td>0.678</td>
<td>2.62</td>
</tr>
<tr>
<td>Day 2</td>
<td>0.05526</td>
<td>0.04636</td>
<td>2.16</td>
<td>1</td>
<td>0.702</td>
<td>1.88</td>
</tr>
</tbody>
</table>

8. Conclusion

This project reports on the fabrication, analysis and testing of the Shell and Tube Heat Exchanger with Storage tank containing PCM. The main motive of the present work is to increase the effectiveness of the Shell and Tube Heat Exchanger by using the phase changing material (paraffin wax & paraffin C20). On the basis of the above study, it is clear that the effectiveness got increased day corresponding to varying the flow rate of hot water and cold water in the Heat Exchanger. The performance of heat transfer rate of paraffin wax is found good which reduced the hot water temperature coming out from the Heat Exchanger to around 25$^\circ$C.

### References