COMPARSION OF HEAT TRANSFER ANALYSIS OF DOUBLE PIPE HEAT EXCHANGER WITH & WITH OUT PCM

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Abstract - *The double pipe heat exchanger type has low heat transfer rate compared with other types of heat exchangers. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications. These materials are used in applications where it is necessary to store energy due to the temporary phase shift between the offer and demand of thermal energy. Experimental study of Double pipe heat exchanger with PCM & without PCM was analyzed. The Cynamide used as a phase change material and its melting temperature is 45°C. The result was showed in best heat transfer coefficient and effectiveness obtained in with PCM set up. And compare to without PCM maximum 20% of effectiveness is occurred in with PCM.*

Key words: Double pipe heat exchanger, With PCM & without PCM, Melting temperature, Effectiveness.

1. INTRODUCTION

Techniques for heat transfer augmentation are relevant to several engineering applications. In recent years, the high cost of energy and material has resulted in an increased effort aimed to produce more efficient heat exchange equipment [1]. Furthermore, there is a need for miniaturization of heat exchangers in specific applications, such as space and vehicle applications, through the augmentation of heat transfer rate [2]. There are three types of heat transfer augmentation techniques, passive, active and combined type [3]. Passive techniques generally use surface or geometrical modifications to the flow channel by incorporating inserts, additional devices or surface treatment which promotes higher heat transfer coefficients by disturbing the existing flow behavior and they do not require any external power input. Active techniques are more complex than passive techniques because they require some external power input to cause the desired flow modification and improvement in the rate of heat transfer such rotating bodies, electric field, and acoustic or surface vibration [4]. In most of the previous heat transfer studies, constant wall temperature is used as a boundary condition, since thermal boundary conditions affect the Nusselt number for fully developed flow in straight tubes. Further, changing the inlet temperature or inlet flow rate changes the Nusselt number, and accordingly has an effect on the heat transfer coefficient Latent heat thermal energy storage is particularly attractive technique because it provides a high energy storage density. When compared to a conventional sensible heat energy storage system, latent heat energy storage system requires a smaller weight and volume of material for a given amount of energy. In addition latent heat storage has the capacity to store heat of fusion at a constant or near constant temperature which correspond to the phase transition temperature of the phase change material (PCM). The study of phase change materials was pioneered by Telkes and Raymond [5]. Therefore, the scope of the present study is compared the effectiveness and overall heat transfer coefficient in double pipe heat exchanger with PCM and without PCM.

2. SELECTION OF PHASE CHANGE MATERIALS.

There are several factors that need to be considered when selecting a phase change material. An ideal PCM will have high heat of fusion, high thermal conductivity and density, long term reliability during repeated cycle and dependable freezing behavior. The PCM melts and absorbs part of the heat gain through the melting process and solidifies then releases the stored heat. The net effect is increased the heat transfer coefficient. PCM should be selected based on the melting temperature, cost and availability [ ]. The selected PCM is Cynamide and its melting temperature and thermo physical properties are shown Table 1.

Table – 1: Properties of PCM & Heat exchanger.

Material	Melting Temperature (°C)	Density kg/m^3	Specific Heat KJ/Kg.K	Heat of fusion KJ/Kg	Thermal conductivity W/mK
Cynamide	44	1280	78.3	259	
Copper	1085°C		0.386 J/gmK		385 W/mK
Aluminium	660.3°C		0.900 J/gmK		205W/mK
G.I	1510°C				

3. METHODOLOGY

Fabricate the two double pipe heat exchanger, one is PCM pipe included and another one is PCM pipe is not included. The dimension of double pipe heat exchanger showed in Table 2.

Table – 2: Dimensions of Heat exchanger.

	With PCM	Without PCM
Length	1m	1m
Outer pipe diameter	0.035m	0.035m
Inner pipe diameter	0.025m	0.025m
PCM pipe	0.001m	0.001m

3.1 EXPERIMENTAL SET UP

Fig – 1: Double pipe arrangements.

Fig – 2: Arrangements of Double pipe heat exchanger with PCM & without PCM.

An Experimental set up Constructed for the present study in shown in fig 1. Fig 2 shows the experimental setup of two double pipe heat exchanger, one is PCM attached another one is PCM not attached. These set up is used for evaluating the heat transfer characteristics during charging and discharging of PCM. The double pipe heat exchanger which works as a heat storage consists of two pipes. The outer pipe is made up aluminum is 1m long and 0.025m diameter of inner pipe , 0.035 diameter of outer pipe. The PCM attached pipe is made up of copper and its having a 1m length and 0.001m diameter.

3.2 PROCEDURE FOR EXPERIMENTAL ANALYSIS

The heat exchanger system is placed horizontally and liquid PCM is filled inside the pipe. A few test runs are required in order to check the leakage of PCM. We used water as a HTF, the hot water stored in tank and which is maintained at the desired temperature with an electric heater and temperature controller. The pressure gauges are used to control the flow rate where inlet and outlet of both liquids. Same arrangements carried also without PCM double pipe heat exchanger. Inlet of hot and cold water flow is supplied with respect to time. Initially 33°C hot water and 20°C cold water entered to the heat exchanger, the temperatures are recorded to use of temperature sensor. Every 15 minute interval we are recorded the temperatures both inlet and outlet of fluids in with PCM and without PCM.

When the inlet hot water temperature reaches the 44°C the PCM starts to melt and stored the heat itself. At that time heat transfer is increased. At that same time the temperature are measured in with PCM heat exchanger. The maximum heat transfer is occurred in heat exchanger with PCM arrangement.

3.3 PROCEDURE FOR CALCULATION

Heat exchanger analysis is the determination of the heat transfer rate and the outlet temperatures of the hot and cold fluids for prescribed fluid mass flow rate and the inlet temperatures when the type and size of the heat exchanger are specified [ ]. From Text book of Heat & Mass Transfer by cengel the following equations to be find.

$$\varepsilon = \frac{\dot{Q}}{Q_{max}} = \frac{\text{actual heat transfer rate}}{\text{maximum possible heat transfer rate}} \quad (1)$$

The actual heat transfer rate in a heat exchanger can be determined from an energy balance on the hot or cold fluids and can be expressed as

$$\dot{Q} = C_c\,(T_{c,\,out} - T_{c,\,in}) = C_{h.}\,(T_{c,\,in} - T_{c,\,out}) \quad (2)$$

Where Cc= ṁc cphand Ch = ṁc cph are the heat capacity rates of the cold and hot fluids, respectively. To determine the maximum possible heat transfer rate in a heat exchanger, we first recognize that the maximum temperature difference in a heat exchanger is the difference between the inlet temperatures of the hot and cold fluids. That is,

$$\Delta T_{Max} = T_{h,\,in} - T_{c,\,in} \quad (3)$$

The heat transfer in a heat exchanger will reach its maximum value when (1) the cold fluid is heated to the inlet temperature of the hot fluid or (2) the hot fluid is cooled to the inlet temperature of the cold fluid. These two limiting conditions will not be reached simultaneously unless the heat capacity rates of the hot and cold fluids are identical (i.e., Cc=Ch). When Cc ≠ Ch, which is usually the case , the fluid with the smaller heat capacity rate will experience a larger temperature change , and thus it will be the first to experience the maximum temperature, at which point the heat transfer will come to a halt. Therefore the maximum possible heat transfer rate in a heat exchanger is

$$\dot{Q}_{Max} = C_{min}\,(T_{h,\,in} - T_{c,\,in}) \quad (4)$$

Where Cmin is the smaller of Ch and Cc. The determination of Q˙max requires the availability of the inlet temperature of the hot and cold fluids and their mass flow rates, which are usually specified. Then, once the effectiveness of the heatexchanger is known, the actual heat transfer rate Q˙ can be determined from

$$\dot{Q} = \varepsilon\,\dot{Q}_{max} = \varepsilon\,C_{min}\,(T_{h,\,in} - T_{c,\,in}) \quad (5)$$

Where,

If $C_c = \frac{\dot{Q}}{\dot{Q}_{max}} = \frac{Cc\,(Tc,out - Tc,in)}{Cc\,(Th,in - Tc,in)} = \frac{Tc,out - Tc,in}{Th,in - Tc,in}$ (6) If $C_h = \frac{\dot{Q}}{\dot{Q}_{max}} = \frac{Ch.(Th,in - Th,out)}{Ch.(Th,in - Tc,in)} = \frac{Th,in - Th,out}{Th,in - Tc,in}$ (7)

Therefore, the effectiveness of a heat exchanger enables us to determine the heat transfer rate without knowing the outlet temperatures of the fluids. The effectiveness of a heat exchanger depends on the geometry of the heat exchanger as well as the flow arrangement. Therefore, different types of heat exchangers have different effectiveness relations. Effectiveness relations of the heat exchangers typically involve the dimensionless group UAs/Cmin. This quantity is called the number of transfer units NTU and is expressed as

$$NTU = U = (N \times C\_min)/A \quad (8)$$

Where U is the overall heat transfer coefficient and As is the heat transfer surface area of the heat exchanger. Note that NTU is proportional to As. Therefore for specified values of U and Cmin, the value of NTU is the measure of heat transfer surface area As. Thus the larger the NTU, the larger the heat exchanger. In heat exchanger analysis, it is also convenient to define another dimensionless quantity called the capacity ratio, c as

$$C = \frac{C_{min}}{C_{max}} \quad (9)$$

4. RESULTS AND DISCUSSION

Using the apparatus and procedures described above, several experiments were conducted to study the transient thermal behavior of heat exchanger with PCM and without PCM. The temperatures of both apparatus are recorded every 15 minute time interval. The recorded readings are shown in below table 3 & 4.

Table – 3: Recorded readings for With PCM

Time (min)	Hot water inlet temperature (°C)	Cold water inlet temperature (°C)	Hot water outlet temperature (°C)	Cold water outlet temperature (°C)
15	33	20	28	27
30	35	25	32	32
45	40	28	37	33
60	44	30	38	36
75	50	35	46	39
90	65	28	55	45
105	70	30	59	50
120	75	33	62	51
135	80	35	69	55

Table – 4: Recorded readings for Without PCM

Time (min)	Hot water inlet temperature (°C)	Cold water inlet temperature (°C)	Hot water outlet temperature (°C)	Cold water outlet temperature (°C)
15	33	20	26	27
30	35	25	34	30
45	40	28	39	31
60	44	30	40	32
75	50	35	47	34
90	65	28	60	36
105	70	30	66	37
120	75	33	70	41
135	80	35	74	45

We are used cynamide as a PCM, and its melting temperature is 44°C. initially hot water enter the heat exchanger as 33°C, we increased the temperature slightly with respect to time. When the temperature reaches 44°C at that time PCM is start to melt and store the heat. So the outlet temperature of hot water is decreases and outlet temperature of cold water is increased. From the table 3 & 4, when 50°C obtained the heat exchanger with PCM at that time the outlet temperature of hot water is 46°C and outlet temperature of cold water is 39°C. And same condition without PCM showed the outlet temperature of hot water is 47°C, cold water is 34°C. The maximum changes occurred when the inlet temperature reaches 80°C and 135 minute, the differences of cold water outlet temperature of with PCM to without PCM is 10°C.

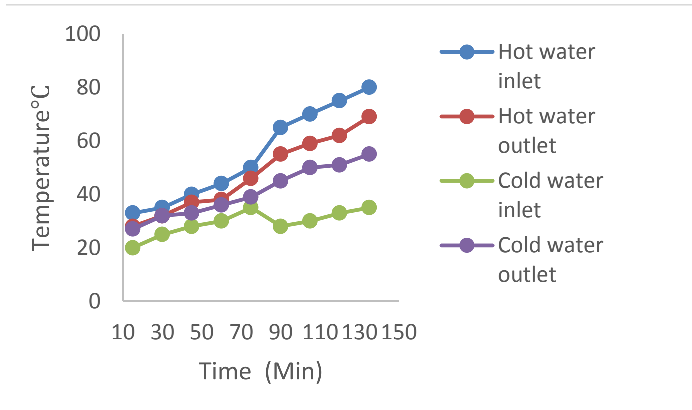

Chart – 1: Variation of temperatures in With PCM with respect to time.

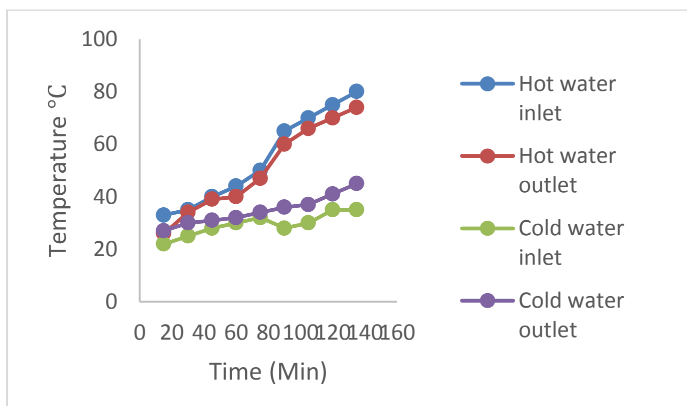

Chart – 2: Variation of temperatures in Without PCM with respect to time.

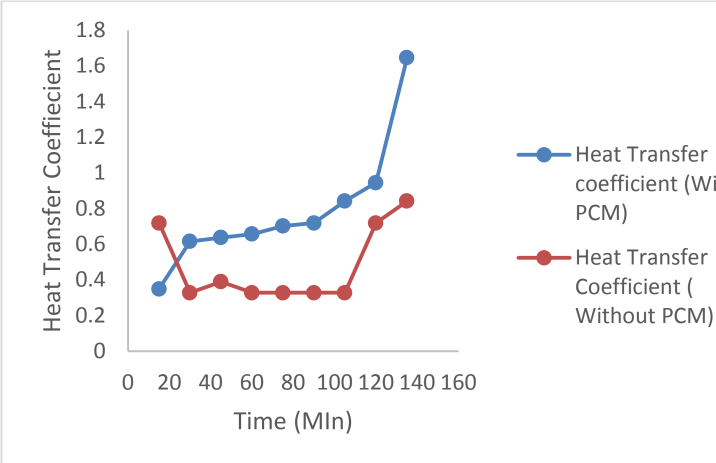

Chart – 3: Variation of heat transfer coefficient in with PCM & without PCM with respect to time.

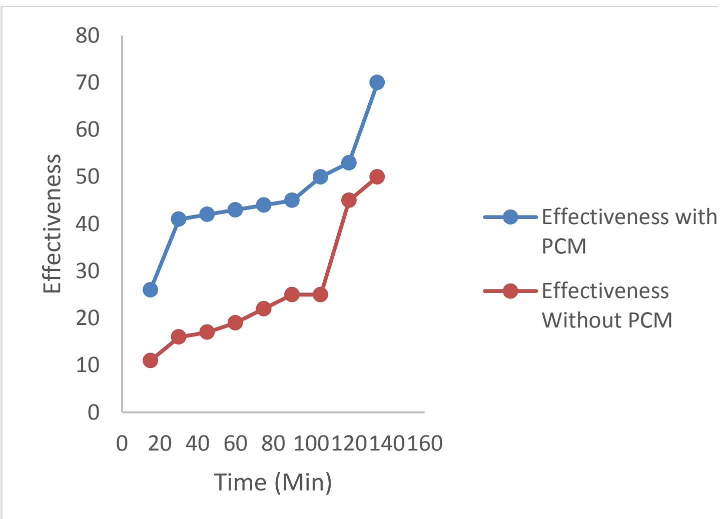

Chart – 4: Variation of Effectiveness with PCM & without PCM with respect to time.

Chart 1 & 3 represents the temperatures differences of with PCM and without PCM with respect to time. The maximum difference is occurred when the PCM is fully melted that is 80°C. The differences can be measured using the temperature sensor. Chart 3 shows the variation of heat transfer coefficient in with PCM and without PCM. The graph indicates the maximum heat transfer coefficient is 0.804 W/m²K. Chart 4 shows variation of effectiveness in with PCM & without PCM. It indicates the maximum 20% effectiveness is found the comparison.

5. CONCLUSION

The experimental model is constructed the double pipe heat exchange with PCM and without PCM. The heat transfer coefficient and effectiveness of the both heat exchangers are compared. Several experiments were conducted to study the transient thermal behavior of heat exchanger with PCM and without PCM. The results showed significant improvement in PCM in thermal performance. The PCM completely melted after 1 hours for the case of double pipe heat exchanger. When compare the two heat exchangers during the time interval maximum 20 % effectiveness and maximum 0.804 W/m²K heat transfer coefficient was obtained.

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