Experimental Analysis of Heat Transfer During the Melting of A Phase-Change Material in Triplex Tube Heat Exchanger

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ABSTRACT

Triplex tube heat exchanger was fabricated and tested for analyze the heat transfer of the internal and external fins by phase change material melting behavior experimentally .The TTHX is designed by Solidworks 2010. The (TTHX) two models are fabricated by brass welding. The fin length is varied to determine the time taken for achieving the maximum temperature in the PCM and heat transfer and fin efficiency. The three experiments were conducted by varying the water charging temperature in two models of TTHX. The readings are analyzed and results are presented.

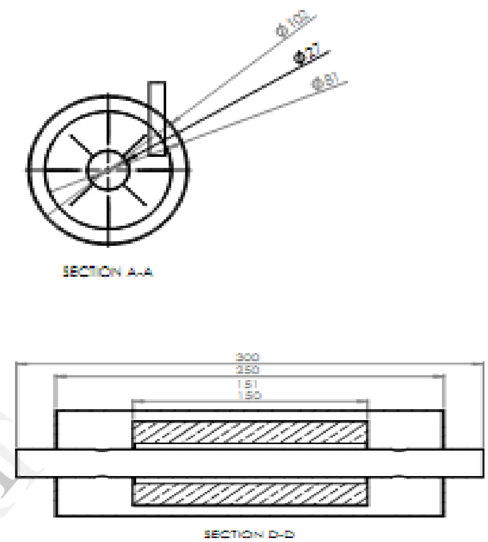
INTRODUCTION:

It is becoming increasingly difficult to ignore the mismatch between the energy supply and energy demand for solar thermal energy applications, since solar energy is considered as a periodic energy source, which leads to low efficiency of those applications. Latent heat thermal energy storage is an important component and plays a key role in the energy efficiency improvement of the solar-energy applications. Recently, thermal energy storage systems, especially latent heat thermal energy storage, have gained a greater attention from the viewpoint of global environmental problems and the energy-efficiency improvement. It promises an elevated performance and reliability with the advantages of high storage.The main disadvantages of PCMs that limit the using of these materials as thermal energy storage is the lowthermal conductivity,which causes a long time for the melting and solidification process.Several researchers have studied the heat transfer enhancement inPCMs, including finned tubes insertion of a metal matrix to the PCM, using multitudes , using bubble agitation in PCMs [, using a PCM dispersed with high conductivity particles,and employing multiple families of PCMs.so we need to recover the heat and enhance the heat transfer by some of the techniques like enhancement and PCM storage.

Abduljalil A.,et.al study theHeat transfer enhancement for a triplex tube heat exchanger by using internal and external fins to accelerate the melting rate of RT82 as a PCM were investigated numerically; different design and operation parameters include the fin length, TTHX materials, number of fins, fin thickness, Stefan number and PCM unit geometry were analyzed. Based on the simulation results, these parameters have a significant influence on the time for complete melting; the effect of fin thickness is small compared to the fin length and number of fins, which have a strong effect on the melting rate time.**Velraj,**et.alinvestigated numerically and experimentally the effect of internal longitudinal fins on the solidification process of paraffin (RT60) inside a vertical cylinder. They considered the heat transfer through the fin tip and the circumferential wall of the cylinder. The effects of different tube radii and different numbers of fins have been studied theoreticallywith respect to the surface heat flux on the solidification process of the paraffin.**IsakKotcioglu,** et.alInvestigate, in addition to above given studies an experimental investigation is described by Taguchi methods, which include the enhancement of forced convection heat transfer in a rectangular channel using inclined thin plates as wing-type vortex generators.**M.J. Hosseini,**et.alThe focus of this study is to evaluate natural convection effects during melting of paraffin wax in double pipe heat exchange systems. The main feature of this study is the detailed measurement of the temperature field within the PCM. Theeffects of the inlet temperature of HTF on the enhancement heat transfer were studied.**N.H.S. Tay,**et.alexperimentally validated CFD model of a PCM thermal energy storage system with plain tubes containing the heat transfer fluid wasmodified to accommodate the heat transfer enhancement techniques of pins and fins attached to the tube.This difference of the heat transfer surface area has provided the finned tube design to be able to transfer heat more effective and faster.**M. Hatami,**et.alinvestigated the effect of Darcy and Rayleigh Number on temperature distribution and heat transfer through longitudinal and rectangular porous fin and we showed that LSM is the most accurate method among the applied procedures.**S.A.VijayPadmaraju**,et.al A LHS system containing PCM in cylindrical capsules is designed and fabricated with an effective water storage capacity of about 48 liters, enough to meet the needs of a family of four. The thermal behavior of the LHS system is investigated experimentally for various operating conditions. The effects of flow rates on charging times and energy storage of the TES systems are studied ,From the literature survey of we conclude many author says to increase the heat transfer by various modification in fins and PCM to achieve our required.

METHODOLGY:

In this study the TTHX is designed by solid works, Then it is fabricated by proper suitable material, mostly many author says copper is good for the thermal energy storage system and recovery system because it has a high thermal conductivity, two models of TTHX is fabricated only the fin length is varied other parameters are same in those models. Then the suitable PCM are selected in this study the paraffin (C22-C45) was chosen by availability criteria.The experiment was conducted by non flow of HTF(hot temperature fluid).Results validated by both experimentally and theoretical calculation.



Experimental setup:

ASSUMPTION & CONDITION:

- The water is charging at temperature of 80^0C, 85^0C, 90 ^{0}C.
- Steady-state;
- 1-D conduction in x direction;
- Constant properties.
- Negligible radiation;

Uniform heat transfer coefficient;

The water is heated up to a corresponding temperature by electric heater or LPG.Then the heated water is charged in the TTHX by the tube 1.At the charging time the opening is closed by the PVC end cup. After the charging the another end is also closed by the end cup. At that time the stop watch is switched on.Then the TTHX is placed on the stand for without any disturbance.The digital thermometer is placed on the tube 2 to measure the temperature rise. After 5mins the temperature rise in the thermometer is noted. The temperature rise in the thermometer is noted for an hour.After the completion of the experiment the TTHX is to be cooled. First discharge the hot water inside the TTHX by opening the end cup.Then it is cooled by atmosphere air.After the complete cooling of the TTHX then the water is charged again with the corresponding temperature. Repeat this procedure.Same procedure were followed for model(2).

THEORITICAL VALIDATION:

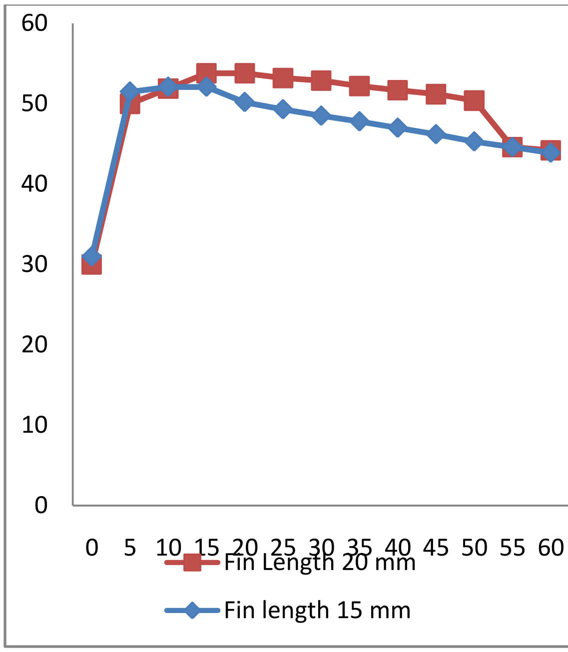
The designed TTHX is validated theoretically by some predetermined equation for fins.Theequation are derived from some databook.

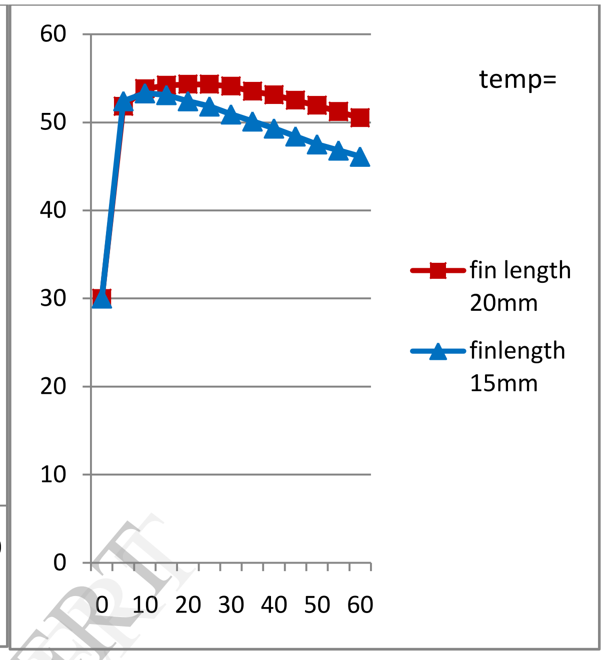
$Q_f = (\sqrt{h*P*k*A_c})$ *tan h (mL)*(T_b-T_f) $\longrightarrow$ equation (1)

Fin efficiency = tan h (mL) / mL $\longrightarrow$ equation (2)

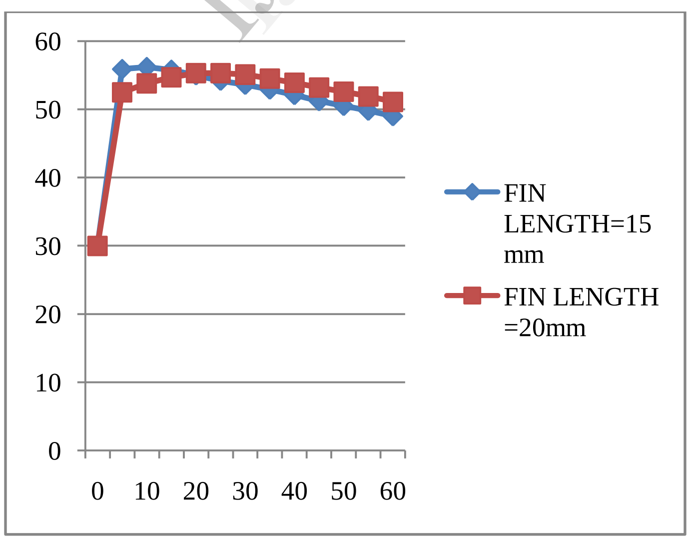
Using the design parameter values and results are obtained.

Hot water charging temperature= 80°CHot water charging temperature= 85°C





Hot water charging temperature= 90°C



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RESULT & DISCUSSION:

At first the water is charging at the temperature of 80^{o}C.the readings observed, and graph is plotted between time and temperature. From the graph and readings the maximum temperature attained in the model1 is 52.1^{o}C at 10mins after charging. Similarly the model (2) attains the maximum temperature of 53.8^{o}C at 15mins from the charging. Compared to those models the maximum temperature attained in model (2) only. The heat is dissipated gradually decrease 1^{o}C interval of 5mins.The lowest temperature in the model (1) and model (2) were 43.9 ^{o}C& 44.2 ^{o}C. The model (1) dissipate the heat in a quick manner. The dwell time of steady state is achieved in the model (2). The dwell time it may be 5 to 7 mins. but in the model(1) less than 3mins.

The water is charged at 85^{o}C. The readings were obtained. The graph is plotted between time and temperature. The model (1) attained the maximum temperature of 53.3 ^{o}C at 10mins from the charging. Model(2) is attained the temperature of 54.3 ^{o}C at 15mins from the charging. The heat is dissipated gradually decrease of 1^{o}C at 5mins interval in model(2). The model (1) dissipates the heat in a quick manner. The dwell time of steady state is achieved in the model (2). The dwell time it may be 5 to 7 mins. but in the model(1) less than 3mins.

The model (1) attained the maximum temperature of 56.2^{o}C at 10mins after the charging. The model (2) is attained the maximum temperature 55.3^{o}C at 20mins after the charging. The lowest temperature in the model (1) & model 2 were 49 ^{o}C& 51.1^{o}C.The model (1) attained the maximum temperature of 56.2^{o}C at 10mins after the charging. The model (2) is attained the maximum temperature 55.3^{o}C at 20mins after the charging. The lowest temperature in the model (1) & model 2 were 49 ^{o}C& 51.1^{o}C.

The graph shows that short fin that means model (1) attain the maximum temperature in a short time duration and also dissipate the heat to the surrounding in a quick manner compared to model (2).but in the long fins have a high heat transfer area compared to model (1).so it attain the steady state at 20 mins from the charging and also it dissipate or decrease of the temperature slowly compared to model (1).

The theoretical calculation shows that the heat transfers by the fin of the model (1) and model (2) were 36.53 W & 41.99 W. the fin efficiency of the model (1) and model (2) were 77.27 % & 66.66 %.The values shows that fin length increase the heat transfer. The fin length increased it decrease the fin efficiency.so the effective fin length is only to achieve the maximum heat transfer as well as increase in fin efficiency.

CONCLUSION

In the present work from the experimental and theoretical result shows that if the fin length increased the heat transfer is also increased if the fin length is decreased the time taken to achieve the maximum temperature was also decreased. In the long fin takes more times to dissipate the heat, the short fin dissipate the heat shortly. If the fin length is over the effective length it decreases the heat transfer. The results also show that if the fin length increases the efficiency is also decreased. Fin efficiency depends upon the width and thickness of the fins.

The long fins are most suitable for solar thermal application because the sun radiate in moderately. The short fins are suitable for instantaneous heating from heat energy sources.

REFERENCE:

A.A. Al-Abidi, S. Bin Mat, K. Sopian, M.Y. Sulaiman, C.H. Lim, A. Th, Review of thermal energy storage for air conditioning systems, Renewable and Sustainable Energy Reviews 16 (2012) .

V. Pandiyarajan, M. ChinnaPandian, E. Malan, R. Velraj, R.V. Seeniraj, Experimental investigation on heat recovery from diesel engine exhaust using finned shell and tube heat exchanger and thermal storage system, Applied Energy 88 (2011).

A.A. Al-Abidi, S.B. Mat, K. Sopian, M.Y. Sulaiman, A.T. Mohammed, CFD applications for latent heat thermal energy storage: a review, Renewable and Sustainable Energy Reviews 20 (2013).

A. Erek, Z.Iken, M.A. Acar, Experimental and numerical investigation ofthermal energy storage with a finned tube, International Journal of Energy Research 29 (2005) .

R. Velraj, R.V. Seeniraj, B. Hafner, C. Faber, K. Schwarzer, Experimental analysis and numerical modelling of inward solidification on a finned vertical tube for a latent heat storage unit, Solar Energy 60 (1997).

P.V. Padmanabhan, M.V.K. Murthy, Outward phase change in a cylindrical annulus with axial fins on the inner tube, International Journal of Heat and Mass Transfer 29 (1986) .

K. Sasaguchi, R. Viskanta, Phase change heat transfer during melting and resolidification of melt aroung cylindrical heat source(s)/sink(s), J. Energy Resources Technol. 111 (1989) 43–49.

I. Kotcioglu, S. Caliskan, T. Ayhan, S. Baskaya, An experimental investigation ofheat transfer enhancement in a rectangular duct with plate fins, Heat Transfer Res. 40 (2009) .

H.A. Adine, H.E. Qarnia, Numerical analysis of the thermal behavior of a shell and tube heat storage unit using phase change materials, Applied Mathematical Modelling 33 (2009).