ANALYSIS OF SOLAR WATER HEATING SYSTEM

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Abstract - *The main objective of this paper is to present of existing solar flat plate collector with internal fins and without fins using CFD-star CCM+ software to perform thermal analysis in the month of May at 10am to 3.30pm for every half hour keeping the mass flow rate constant to optimize the performance. The effect of flow on temperature distribution of flat plate water collectors by finned riser pipes is simulated and compared with solar collector without fins at flow rates of 0.4,0.5&0.6Kg/min. The simulation results show that the flat plate water solar collectors with fins were higher enhancement of heat transfer than plain tube. The efficiency in case of fins is 10-15% higher than the case of plain riser tube solar collector at the mass flow rate of 0.4 Kg/min.*

Key Words: *solar flat plate collector, water collectors, finned riser pipes, plain riser tube.*

I.INTRODUCTION

The solar energy is the most capable of the alternative energy sources. Due to increasing Demand for energy and rising cost of fossil type fuels (i.e., gas or oil) solar energy is considered an attractive source of renewable energy that can be used for water hearing in both homes and industry. Heating water consumes nearly 20% of total energy consumption for an average family. Solar water heating systems are the cheapest and most easily affordable clean energy available to homeowners that may provide most of hot water required by a family.

Solar heater is a device which is used for heating the water, for producing the steam for domestic and industrial purposes by utilizing the solar energy. Solar energy is the energy which is coming from sun in the form of solar radiations in infinite amount, when these solar radiations falls on absorbing surface, then they gets converted into the heat, this heat is used for heating the water. This type of thermal collector suffers from heat losses due to radiation and convection. Such losses increase rapidly as the temperature of the working fluid increases.

Energy consumption increases very rapidly as the world developing. Conventional sources are not able to fulfill the today energy needs. Fossil fuels are the main conventional sources for energy production till now. The two main limitations of fossil fuels: Limited in quantity and environment pollution makes the world think for alternative energy sources. Renewable energy sources eliminate the weaknesses of conventional sources. But because of less knowledge about these sources and high initial cost of the conversion systems limits the use of these resources. From the renewable energy resources, solar energy has a huge potential for the fulfillment of today energy needs. The total solar radiation energy falling on earth atmosphere is 10^{17} watts. Amount of solar radiations reaches earth is 10^{16} watts, this is 1000 times more than the world energy need. So if 5% of this energy is utilized, this is 50 times of world energy demand.

2. LITERATURE REVIEW

Rama Subba Reddy Gorla: Developed the 2D finite element model for the flat plate solar collector. The different Characteristics of the system are studied and compare with the experimental data for the validation of the model. The following parameters are evaluated for the validation of model.

- ✓ Fluid temperature increases along the length of the tube.
- ✓ Fluid temperature varies linearly at high flow rates along the length of tube.
- ✓ Fluid outlet temperature decreases with increase in mass flow rate.
- ✓ Efficiency decreases with increase in fluid inlet temperature.
- ✓ Efficiency higher with single cover for low inlet temperature range after some Temperature efficiency of two glass cover higher than single.
- ✓ Efficiency increases with increase in tube spacing to tube diameter ratio and after some point it decreases with further increase in tube spacing to tube diameter ratio.

Ho-Ming Yeh et al.: Study the effect of aspect ratio (l/n·w) on collector performance. l is the length of the tube carrying fluid, n is the number of tubes and w is the spacing between the tubes. In this collector area is fixed and aspect ratio is varied by the variation in n and l. From the study it is concluded that efficiency increases with decrease in aspect ratio. It is also observed that efficiency decreases with increase in solar intensity when the inlet temperature is low and efficiency increases with increase in intensity when the inlet temperature is high.

H. Kazeminejad: Studied the variation in results between the 1D model and 2D models for the FPLSC evaluation by applying different boundary conditions. FVM is used for solving of these equations. The following results are obtained after comparing the two models. Result obtained from the one dimensional Analysis is different from two dimensional Analysis at low mass flow rates.

- ✓ Fluid outlet temperature decreases with increase in mass flow rate and also increases with increase with distance between tubes.
- ✓ Fluid outlet temperature increases with increase in inlet temperature.
- ✓ Fluid temperature increases along the tube.
- ✓ Efficiency increases with increase in mass flow rate. Efficiency increases with increase in thermal conductivity of plate.
- ✓ Optimum performance at tilt angle 28.98 degree.
- ✓ In this case efficiency decrease with increasing number of glass covers.
- ✓ Efficiency decrease with increase in spacing between the tubes. Efficiency decrease with increase in temperature difference between inlet and outlet fluid temperature.

K. Sopian et al: A flat plate solar collector is fabricated from the thermoplastic natural rubber. Absorber plate and tube are made of thermoplastic natural rubber. The performance parameters of the collector are FR and FRUL are .72 and 9.67. Thermo siphon solar water heater developed by this collector produce water outlet temperature to 65^0C for the radiation level 500 W/m2. There are two approaches used for the performance evaluation. In first case everyday fresh water is filled to take the readings. There is a temperature rise of 15^0C for the energy input 4.5 kWh/m^2. In 2^{nd} method no water is withdrawn from the storage. There is an increase in water temperature of 60^0C.

N.K. Vejen et al.: Theoretical and experimental analysis of HT solar collector with different insulation materials, absorber, anti-reflecting coating and number of risers is carried out. There is a 23-37% output improvement using improved HT collector. Rock wool (low thermal conductivity) insulation gives better thermal performance than glass wool at temperature between 40^0C-80^0C. Efficiency improves with number of risers but only at low temperatures. Efficiency improve with improve in absorber properties for all temperatures. Effect increases with increase in temperature of the fluid. Efficiency improved with decrease in glass thickness.

Md.Imran: A Thesis "Comparative experimental studies on variable header with finned tube (triangular fins) and plain tube solar water heating system" guided by Mr.C.Sivarajan, Associate Professor, Department of Mechanical Engineering, Annamalai University.

3. EXPERIMENTAL WORK

Flat plate solar water heating system is installed at the solar laboratory at Annamalai University, Chidambaram as shown in figure-1. The specification of the same collector and absorber tube are considered for the present analysis as shown in table-1. Absorber plate material used in made of aluminium, riser tube material is gray cast iron and fins are made by copper

Fig-1: combined flat plate liquid solar collector

4. SPECIFICATION OF SOLAR FPLSC SYSTEM

Table-1: specifications

Sl. no	Components of Collectors	FPLSC&FPLSCIFT
1	Absorber tube	GI
2	Fins material and size	copper & triangular in shape - 6mm base and 9m height
3	Insulation materials	Glass wool
4	casing	MS
5	Selective coating	Black board painting
6	Flow cross section	Circular& circular-triangular shaped fin projected inside the tube 16 no's
7	Internal diameter of tube	0.0127m
8	Length of tube	1.02m
9	Area	1.25mx0.075m
10	dimension	1.25mx0.75mx0.06m
11	Absorber plate material	Aluminium
12	Absorber plate	0.001m
13	Tube center to center distance	0.1m
14	Insulating material	Glass wool

15	Thickness of Insulation material at bottom	0.01m
16	Number of flow paths	6
17	Location of collector tray	Annamalai Nagar, Chidambaram.

5. MODELLING

Expected set up modeling done on CFD –star CCM+ software as shown below

Fig-2: model of solar collector

In this experimental set up consist of insulated collector box, glass glazing, raiser tube header tube, digital temperature indicator and rota meter. Outlet temperature of water from each raiser tube is measured by temperature sensor.

6. MESHING

A time consuming process while designing the proposed geometry was the creation and later meshing of the volume of the water within the pipe. The difficulty occurred because of the complex shape of this particular volume of water. This was due to the large number of pipes created at the external surface of the water because of parallel connection as shown is shown in fig-3. That shape is then projected at the volume water. The computer package had difficulties in dealing with this profile. The meshing element-scheme used for meshing the whole domain was Tetrahedral/Hybrid. This scheme allowed the mesh to be composed primarily of tetrahedral mesh elements including wedge (prism) elements where appropriate.

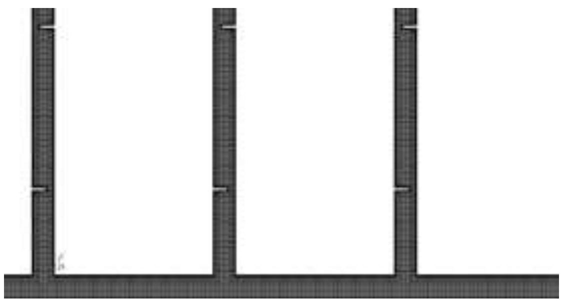


Fig-3: Meshed Pipe with Fin

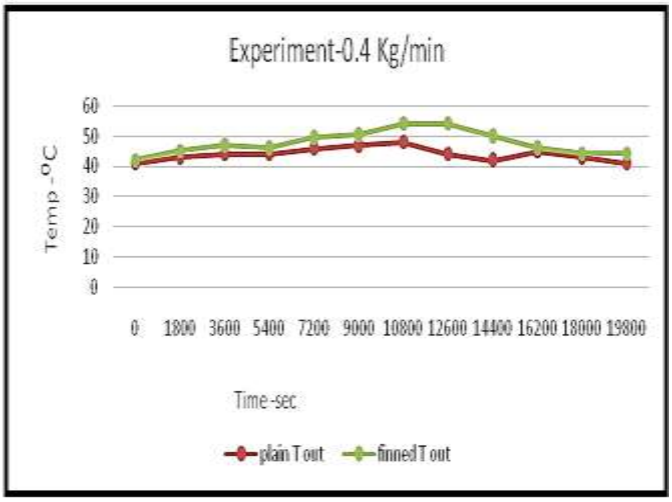
The total number of mesh cells created in the entire geometry was about 13.32 lacks with density of the grid being grater in some areas as shown in fig -3.

Volume Mesh properties:
Cells-1332292
Interior faces-3894244
Vertices-1418166

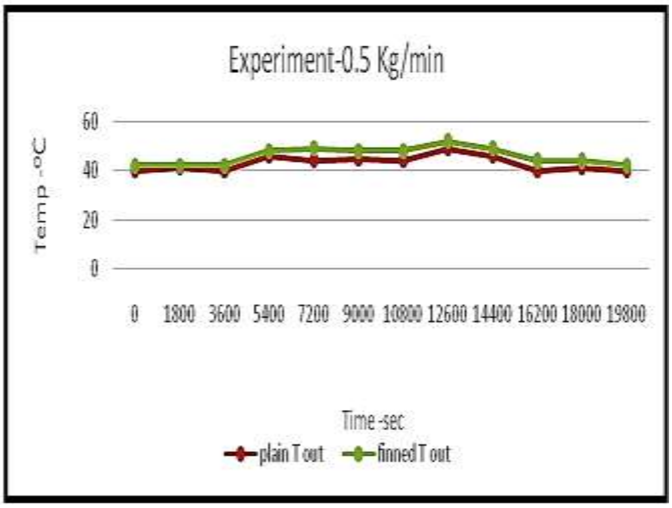
7. RESULT AND DISCUSSION

Temperature gain with respect to time obtained from the FPLSC and FPLIFSC are plotted by experimental values in figure 4, 5&6, that the same graph plotted with CFD results in figure 7, 8&9 by various flow rate it can absorbed that the effect of fins on temperature distribution with influence of solar intensity, the finned material and more surface area helps the increase in temperature than the plain tube. The mass flow rate of 0.4Kg/min provides more outlet temperature than other because of the effect of flow rate on heat distribution through the raiser tube. It can be absorbed that the increase in temperature is to be considerably more with high solar intensity probably we got more output temperatures difference in between the plain and finned if its analyses under the mass flow rate of 0.4Kg/min for the experimental values, but in case of CFD result we got maximum temperature different at noon rather than the mass flow rate of 0.6Kg/min.

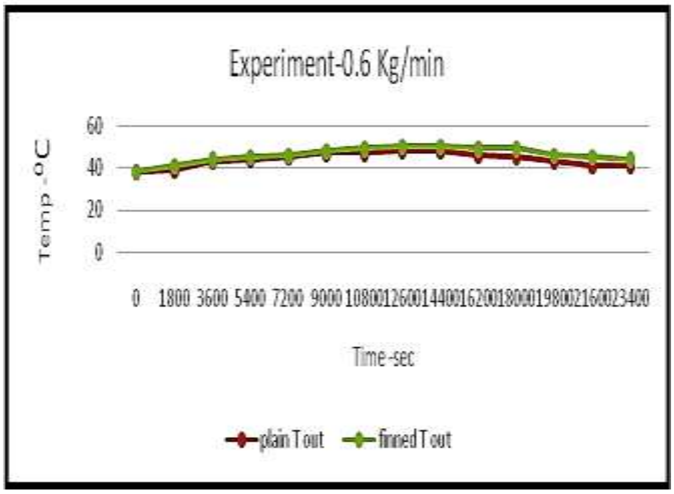
7.1: TEMPERATURE VS TIME



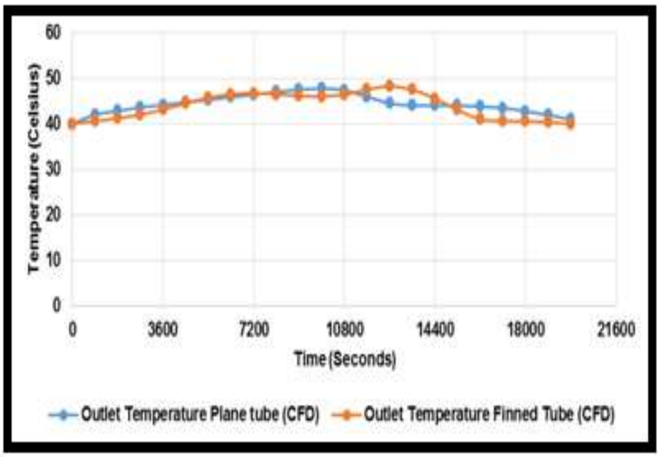
Graph-1: temp vs time at 0.4kg/min (exp)



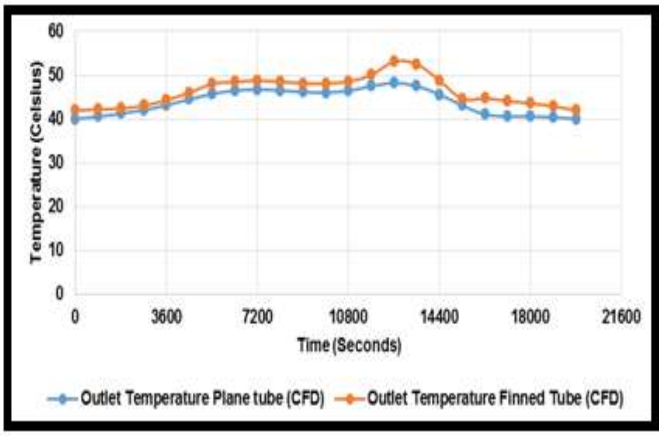
Graph-2: temp vs time at 0.5kg/min (exp)



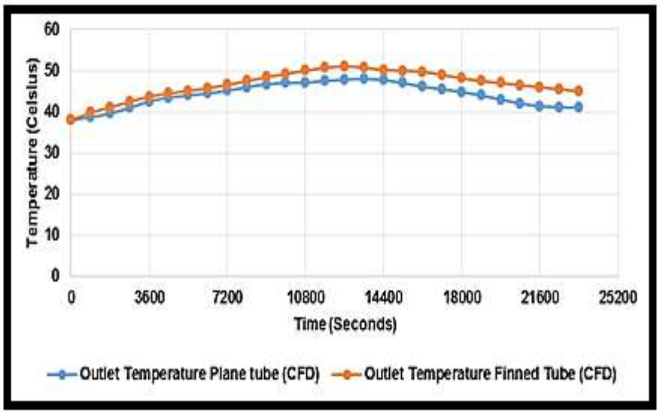
Graph-3: temp vs time at 0.6kg/min (exp)



Graph-4: temp vs time at 0.4kg/min(CFD)



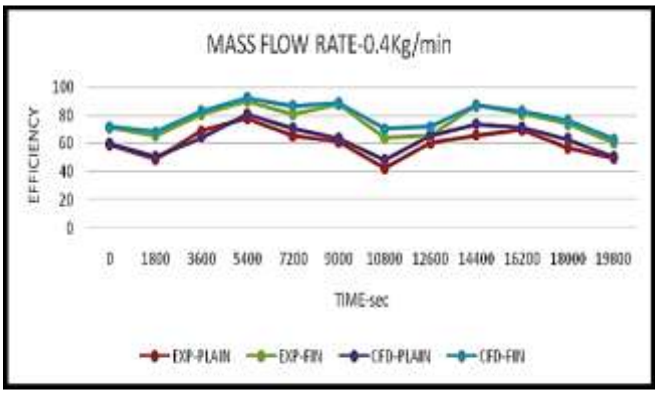
Graph-5: temp vs time at 0.5kg/min (CFD)



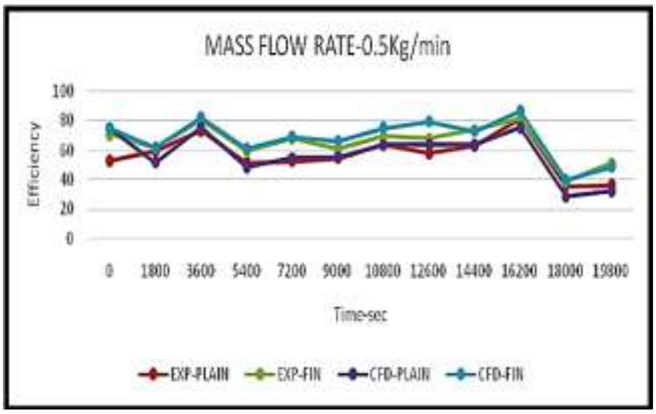
Graph-6:temp vs time at 0.6kg/min (CFD)

7.2: EFFICIENCY VS TIME

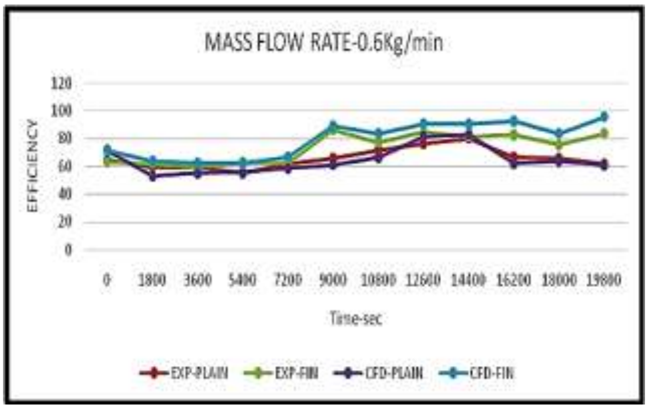
The experimental and CFD data obtained both the system and efficiency calculated than plotted graph in between the time versus efficiency. It is shown in figure 10, 11&12. That the increasing output temperature functions of solar intensity, wind velocity and heat transfer area. That the graphs are has more efficiency variation due to changing thermal properties of atmosphere that is clearly shown in figure 10, 11&12,eventually got more efficiency for internally finned raiser tube and optimum mass flow rate is 0.4Kg/min.



Graph-7: efficiency vs time at 0.4Kg/min



Graph-8: efficiency vs time at 0.5Kg/min



Graph-9: efficiency vs time at 0.6Kg/min

VI. CONCLUSIONS

The result obtained from the CFD for tube with fin is validated with the CFD and experimental value for plain tube as shown in below

- ✓ There is an increase in temperature of about 6-9˚C for experiment and 7-11 ˚C for CFD analysis.
- ✓ There is an increasing efficiency of about 9-12% for experiment and 10-15% for CFD analysis
- ✓ This proves that there is a good agreement between the CFD analysis and the experimental values.

From this experiment we are conclude that the finned raiser tube has more heat transfer rate compare to the plain tube due to extended cross section area.

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