International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 07 | July 2019 www.irjet.net p-ISSN: 2395-0072

OPTIMIZATION OF FLAT PLATE SOLAR COLLECTOR WITH NOVEL HEAT COLLECTING COMPONENTS

Joga Venkata Sandeep[1*], S Anil Kumar[2], G Pramod Kumar[3]

[1,2,3]Assistant Professor, M.V.G.R. College of Engineering, Vizianagaram, Andhra Pradesh-535005

ABSTRACT - *Many works have been undergone for increasing the efficiency of the solar water heaters like new materials, geometrics, heat pipe collectors, heat transfer fluids and hybrid PV-solar thermal collectors. This paper focuses on applying an optimization technique to a solar thermal application, more specifically for the optimization of a flat plate solar collector using aluminium heat collecting component. The component consists of flat plate absorber and heat pipes made of aluminium integrated with it. The basic aim of the simulation is to investigate the effect of mass flow rate of water on the collection efficiency.*

Key words: Flat plate solar collector, heat collection, collector, solar energy, optimization

1. INRODUCTION

The non renewable resources are depleting at a faster rate. So it's time to think of using renewable resources like solar energy, wave energy etc. in an optimal way. Energy saving is a key factor for the development of a country. Many types of technologies are been undergone in the last few years. Harvesting solar energy through solar collectors is widely used all over the world because of cheap cost and less maintenance. The using of solar water heaters are applicable to domestic, industrial and commercial buildings where hot water is required.
This report provides an outline and brief description, including fundamentals of solar water heater using heat pipe flat plate heat collecting component.

Even if the solar collectors have reached good development the scientific world has shown frequent attention to the optimization of the existing technologies. These new innovations have some cost constraints also. In the last years, the improvement of new technologies has been applied to thermal efficiency of the solar collector, the absorbance of the absorber plate to optimize the geometry of solar thermal collectors in relation to costs and maintenance. Many works have been undergone for increasing the efficiency of the solar water heaters like new materials, geometrics, heat pipe collectors, heat transfer fluids and hybrid PV-solar thermal collectors.

As we know the photo-voltaic, photo-thermal and photochemical conversion formed the basis for the solar energy utilization. Among these, the best method of photo-thermal utilization is to directly convert the solar radiation into thermal heat.

Conventional solar heat collectors display some short comings, in which the forced or natural circulation system is adopted for transferring the heat captured by the solar heat collector. The water may freeze in cold days; a pump is required to maintain the forced circulations, the heat loss due to the natural convection and radiation from the collector surface is considerably large and the working life of the collector may be shortened due to the pipe corrosion.

The main device of photo-thermal utilization is solar collector, which includes flat plate solar collector and evacuated tube solar collector. Thermal solar collector is an important component of solar water heating system. Its thermal efficiency mainly determines the efficiency of the whole system. Copper or aluminium is the most frequently used material for heat absorbing surface in the solar collectors. Flat plate solar collector has many advantages over evacuated tube solar collector simple structure, uniform collection of solar radiation and can be easily integrated with the buildings. But the conventional flat plate solar collector has some drawbacks like the structure of water pipe will be frozen to crack while the ambient temperature goes below zero and the working fluid will tends to reflux at night. To overcome the above disadvantages in flat plate solar collector by introducing heat pipe into the heat collecting component. Heat pipe is a heat transfer element, which uses the phase change of the working fluids to transfer heat quickly over long distances.

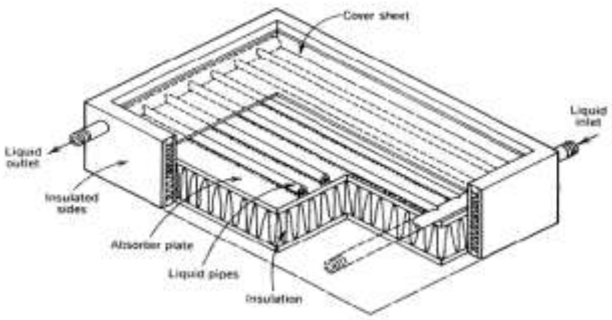


Fig. 1 A typical liquid Flat Plate Collector

Here the system is an aluminium heat pipe flat plate solar collector. Heat pipe uses a working fluid to transfer heat from the collector to the tank by the process of boiling in the evaporator, vapour flow, condensation in the condenser and condensate return. The Evaporator is placed on absorber plate and the condenser inside the tank. Working fluid is ethanol inside the heat pipe.

The heat pipe solar collector consists of aluminum heat pipe of size half inch. Length of heat pipe=1850 mm. The Wick consists of two layers of stainless steel screen. Each heat pipe was thoroughly cleaned with acetone and then with de-mineralized water. After the tube has been evacuated, working fluid ethanol was charged to tube. Each heat pipe was mechanically bonded to Al absorber plate which was coated with matt black to increase its ability to absorb heat. The heat exchanger consisted of collars with an outside diameter of 20mm and 300mm length which was fitted around the condenser section of the heat pipe. An analysis of the operation parameters of the system, study of evaporation condensation operation cycle, quantitative investigation of the energy fluxes from collector to the heat pipe and from the heat pipe to the tank, correlation of energy fluxes with the basic operation parameters of heat pipe were done. Temperature in different parts of the evaporator, condenser and tank is measured by using thermocouples. The absolute pressure inside the heat pipe is measured using electronic manometer. Solar irradiance, ambient temperature was also measured.

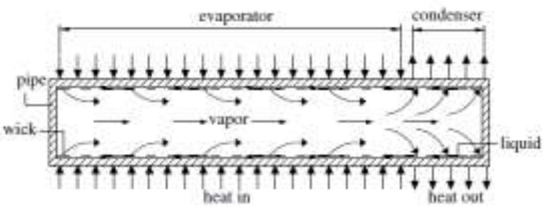


Fig 2. Heat Pipe Schematic

The heat pipe is a passive heat transfer device. It utilizes the phase change of a working fluid for achieving heat transport. Heat pipe can transfer heat over considerably long distances with relatively small temperature drop. The heat pipe consists of a metal container and a capillary wick inside the container. The wick may be layers of metallic mesh, simple longitudinal grooves in the wall, or fabricated from porous material. There is an evaporator section and a condenser section in the heat pipe. A working fluid circulates inside the heat pipe. The circulation is set up due to capillary action in the wick and so no external pumping is required. Heat pipe is a structure of very high thermal conductance. The het pipe is evacuated first and then charged with a pre-calculated amount of working fluid. At this condition, the working fluid exists partially as liquid and partially as vapour, at equilibrium. The system will be set as the saturation pressure corresponding to the cold state temperature. Heating the evaporator section forces more liquid to vaporize bringing the system to another equilibrium state. Heat is utilized in producing this phase change. Cooling the condenser side transforms the vapour to liquid phase, taking away the heat. The vapour pressure at the evaporator is less than the saturation pressure at the evaporator temperature. The vapour pressure at the condenser is greater than the saturation pressure at the condenser temperature. This creates evaporation and condensation at the ends. Under operation, a higher vapour pressure at the evaporator section and a lower vapour pressure at the condenser section get established. This creates the vapour flow. Due to the depletion of liquid by evaporation the liquid vapour interface recedes into the wick surface. Capillary pressure is developed and condensate moves to the evaporator through the wick. Circulation of the working fluid is setup. Heat pipes can be used to provide a uniform temperature, generating isothermal surfaces.

Many advantages are there with the employment of heat pipe solar collectors. In general, the position of condenser is not restricted to any specific orientation. Heat pipes behave as a thermal diode. Heat is transferred only from the evaporator to the condenser but never in the reverse direction. This advantage can cut off the heat loss when the absorber temperature is lower than that of the liquid in the heat exchanger. Another advantage is the redundancy, which is the failure of one heat pipe does not have a major effect on the operation of the collector. Freezing of the heat pipe can be eliminated through working fluid selection and only the heat exchanger section to be insulated. The design and manufacture of heat pipe must be careful because evaporation/condensation mechanisms strongly depend on geometry and dimensions of components. Because the heat pipe operates almost isothermally, it is used to collect solar energy from a large area and transfer it to a small area where the liquid is heated. Ammonia can be used to avoid freezing.

2. METHODOLGY

ANSYS is one of the software which created a platform which allows researchers and designers to use its commercial CFD codes in conjunction with response surface based optimization tools within their workbench environment. Parameters for the geometry are input in the design modeller module of workbench. This section discusses the modelling, mesh generation, material and boundary conditions and the settings used for ANSYS Fluent.

2.1 CFD method

To maximize the energy output, it is efficient when the heat pipe operates under huge temperature difference and low temperature in tank. We are considering condenser portion as a heat generating body of constant heat flux corresponding to the solar radiation. So our area of concern is the tank inner surface, both ends and a number of condensers are attached to the inner surface with constant heat flux and an inlet and outlet. Through the inlet, water is entering at a mass flow rate and leaving. So our main aim is to optimize the mass flow rate corresponding to the condenser heat flux. Obtain the temperature distribution corresponding to the heat flux from the condenser.

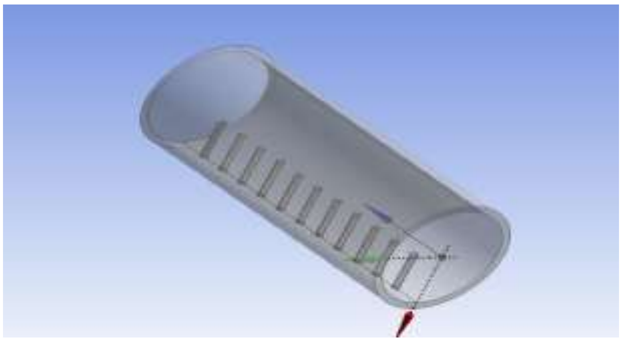


Fig.3 geometry of tank and condenser

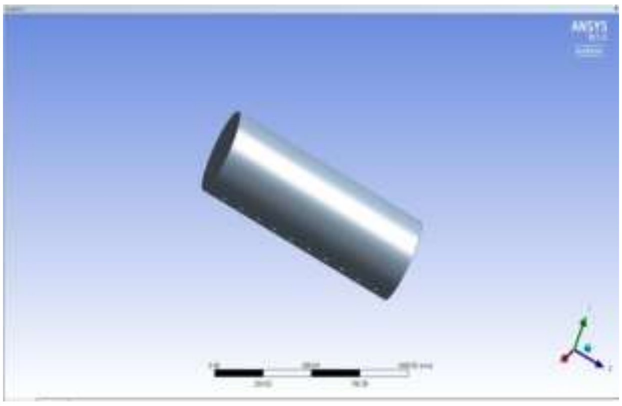


Fig.4 geometry after closing the ends

2.2 Mesh generation

Sample geometry is made with tank and condenser. The modelling and analysis of heat pipe solar water heater using fluent 15 to divide the governing equation by finite volume method. The geometry is modelled where symmetry is not used. The meshing packages (ANSYS WB 15) were used to generate the mesh. The selected geometry consists of a triangular mesh with different face sizing elements in each zone. In this optimization process the face size elements were set to soft for getting more freedom for automatic mesh generation. For ensuring smoother mesh with cells concentrated around the condenser (due to the high gradients expected in those areas), the relevance centre and smoothing settings was selected as fine, the curvature normal angle and growth rate were set at 7 and 1.05 respectively. fig.8 shows the mesh generated for the computational domain. Because poor mesh quality may produce problems in convergence and influence accuracy of results; the skewness and aspect ratio of the mesh was checked inside the computational domain. Grid system used was nearly 5 lakh because the outlet temperature varies less than 2%

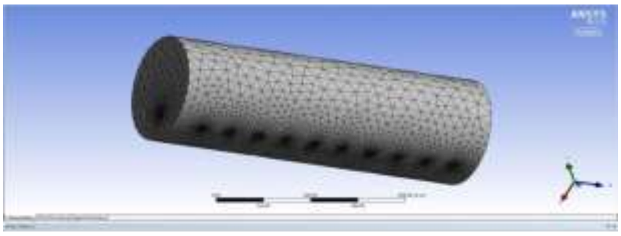


Fig.5 geometry after mesh generation.

Material properties and boundary conditions:

Flow analysis was developed in CFD considering domain as water giving 835 W/m^2 heat flow on the wall. A 0.15 m/s inlet flow velocity was given at 293 K temperature and 0.00 Pa outlet relative pressures. Assumption made is water is a continuous medium and incompressible. Flow is steady and laminar. Thermo physical properties are independent of temperature. Each iteration required 3hours. Heat transfer rate is increased due to the low temperature in the tank.

3. OPTIMIZATION OF MASS FLOW RATE

The availability of user friendly software have led to use CFD in a cost effective manner whose total expense is not much when compared with that of experiment. There are several advantages of CFD over experimental based approaches to fluid systems design.

4.1 Results and discussions

The results obtained from CFD analysis of solar flat plate collector were presented in this section. The simulation is carried out for different mass flow rates. Thus the result obtained by simulation is compared with experimental results.

Thermal profile

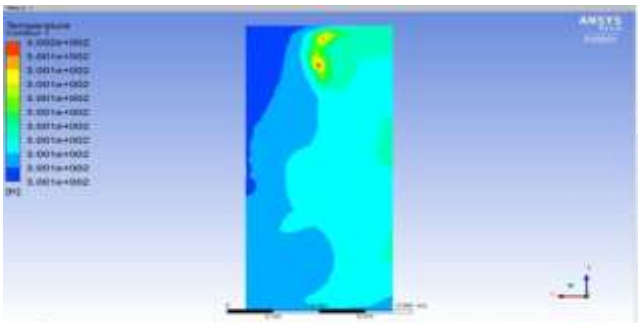


Fig.6 temperature profile at centre of the tank

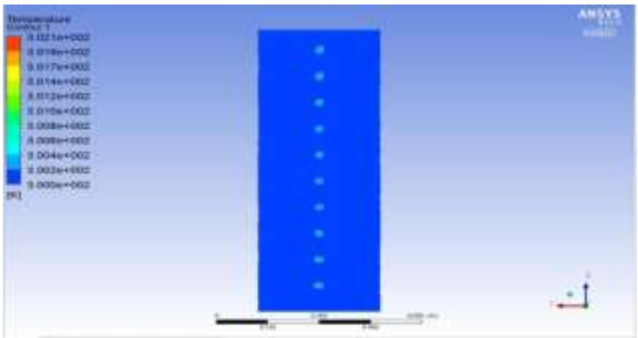


Fig.7 Temperature profile at plane below the centre of tank.

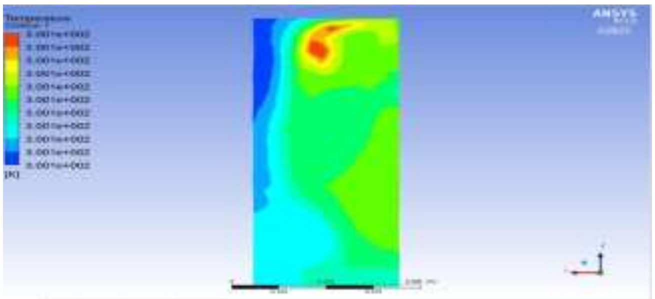


Fig.9 Temperature profile at plane above the centre of tank.

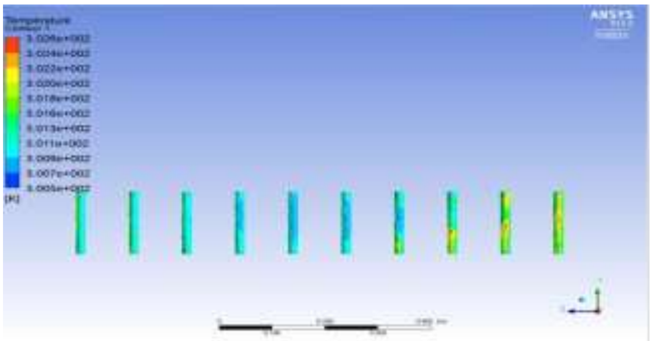


Fig.11 Temperature profile of condenser tubes.

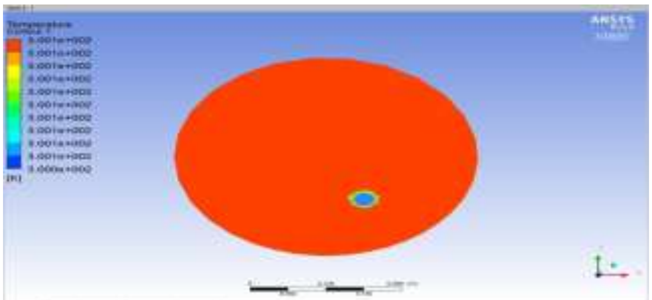


Fig.8 Temperature profile at inlet of tank

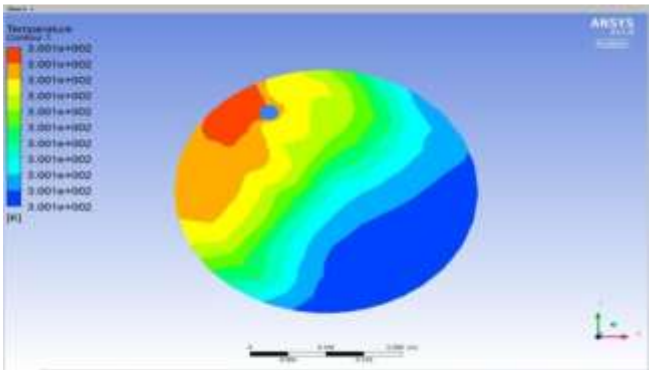


Fig.10 Temperature profile at outlet of tank

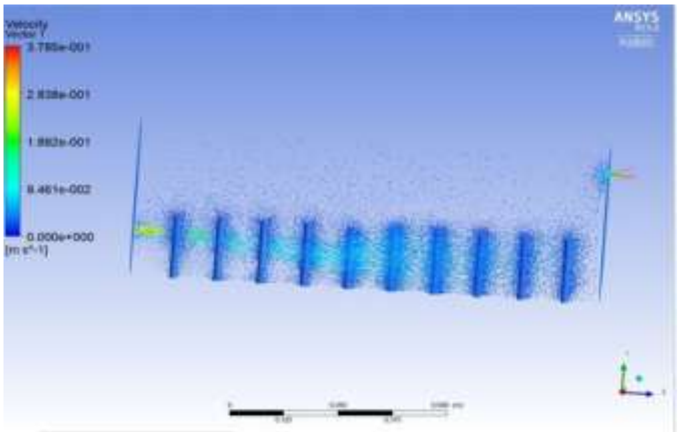
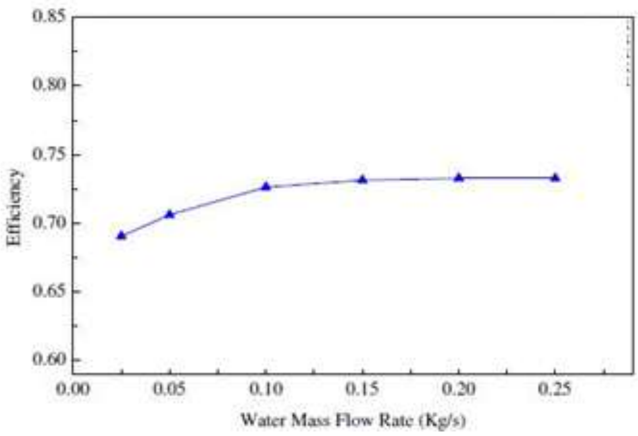


Fig.12 Velocity profile

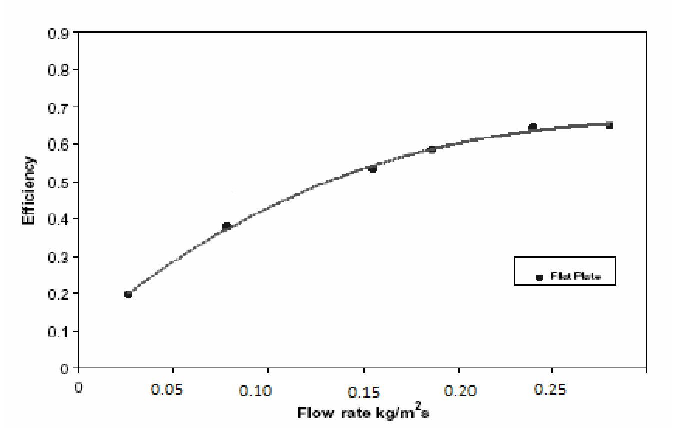
4. COMPARISON WITH EXISTING RESULTS

After simulation the efficiency Vs mass flow rate graph is obtained as follows.



Graph.1 Variation of Efiiciency with Water mass flow rate in Simulated results

It is been compared with the experimental graph mentioned below



Graph.2 Variation of Efiiciency with water mass flow rate in Experimental results

5. CONCLUSION

A 3-D numerical simulation was carried out to investigate the efficiency of flat plate solar collector. The basic aim of this simulation is to investigate the effect of mass flow rate of inlet water on the collection efficiency. The maximum efficiency was observed at an optimized flow rate of 0.15 kg/s.

REFERENCE

1. J.A. Duffie, W.A. Beckman, Solar Engineering of Thermal Process, Wiley Inter science, New York, 1991.

2. P.D. Dunn, D.A. Reay, Heat Pipe, third ed., Pergamon Press, New York, 1982.

3. S.W.CHI, Heat pipe theory and practice: A source book.

4. S. P. Sukhatme, "Solar Energy-Principle of Thermal Collection and Storage", Tata McGraw Hill Pub, Co., Delhi, 1984.

5. G.D.Rai. 2005 "Solar Energy Utilization", Khanna Publishers.