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Performance Analysis of Parabolic Trough Collector and Simulation of Absorber tube using ANSYS

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Abstract—The increased trend in fuel price coupled with escalating carbon dioxide emission has encouraged the world to shift towards renewable energy sources. Parabolic trough collector is the most proven technology used for generating power and also for many other purposes. The purpose of this paper is to conduct an experimental analysis of parabolic trough collector and to know how the performance of the Flat plate and evacuated tube solar collectors are used to collect heat for space heating, domestic hot water or cooling with absorption chillers. Parabolic troughs, dishes and towers are used almost exclusively in solar power generating stations or for research purposes. The whole solar panel absorbs the ligh collector is varying accordingly with the change in wind speed, ambient temperature and solar insolation.And for validating the experimental results, finite element method have been conducted for the heat transfer analyses in the absorber tube of the Cylindrical parabolic trough collector using ANSYS.

Index terms: Parabolic trough collector; Thermal performance; ANSYS simulation

1. INTRODUCTION

Solar parabolic trough collectors have been used to generate power by converting water to steam in much the same way that a conventional thermal power plants work with the exception being that instead of utilizing thermal energy released by the burning of fossil fuels, solar power is utilized to obtain thermal energy. The current industrial growth and environmental impacts show that solar energy for solar thermal power plants is the most promising of the unconventional energy sources. The most common commercially available solar power plants use parabolic trough concentrators parabolic trough is a type of solar thermal energy collector. It is constructed as a long parabolic mirror usually coated silver or polished aluminium with an absorber tube running its length at the focal point. Sunlight is reacted by the mirror and concentrated on the absorber tube. Working fluid which passes through the absorber tube is heated due to transfer of heat primarily by means of convection with the absorber tube wall. Some of the common applications where parabolic trough systems are used are

- Boiler feed water preheating
- Air conditioning
- Milk pasteurization
- Industrial process heat
- Power generations[1]

2. SOLAR COLLECTORS AND DIFFERENT TYPES OF APPLICATION

Solar collectors fall into two general categories:

a) Non-concentrating
b) *Concentrating collectors*

- Concentrating collectors use mirrored surfaces to concentrate the sun's energy on an absorber called a receiver.
  Concentrating collectors achieve high temperatures they can do so only when direct sunlight is available.
- The mirrored surface focuses sunlight collected over a large area onto a smaller absorber area to achieve high temperatures. Some designs concentrate solar energy onto a focal point, while others concentrate the sun's rays along a thin line called the focal line.

There are four basic types of concentrating collectors:

- ✓ Parabolic Trough System
- ✓ Parabolic Dish
- ✓ Power Tower
- ✓ Stationary Concentrating Collectors

3. PARABOLIC TROUGH COLLECTOR

Parabolic trough is a very attractive technology for using solar energy. Solar parabolic trough collectors have been used to for three purposes

- To heat water
- To generate steam directly from water for a power generation cycle

Heat thermal Fluids to be used for steam generation in a power generation unit

A parabolic trough is a type of solar thermal energy Collector. It is constructed as a long parabolic mirror with an absorber tube running its length at the focal point. Sunlight is reflected by the mirror and concentrated on the absorber tube. Working fluid which passes through the absorber tube is heated due to transfer of heat primarily by means of convection with the absorber tube wall. The dimensions of the parabolic trough collector and its absorber tube have been taken from the Renewable Energy Sources Laboratory at Amal Jyothi College of Engineering Kanjirappally is taken into consideration. Water is used as the working fluid. The experimentation set up is taken in a closed circuit configuration.[2]-[7]

Fig 1 .Experimental setup of a parabolic trough collector

The solar parabolic trough collector in the Renewable energy sources laboratory in Amal Jyothi College of Engineering Kanjirappally is used for experimentation. The axis of the parabola is placed in a North South orientation. The parabolic mirror is adjusted in such a way that the reflected radiation from the mirror is incident on the absorber tube. Real time beam radiation is continuously noted down from the Solarimeter. A water tank is connected to the inlet of the absorber tube. The outlet of the absorber tube is connected back to the water tank, to make it a closed loop.

The experimental study of parabolic trough collector with its sun tracking system to facilitate rapid diffusion and widespread use of solar energy. To assure good performance and long technical lifetime of a concentrating system, the solar reflectance of the reflectors must be high and long term stable. During the research carried out, focus had been shifted from evaluation of the performance of concentrating solar collector to analysis of the properties of reflector and absorbing materials. The shift of focus was motivated by the need to assess long term system performance and possibilities of optimizing the optical efficiency or reducing costs by using new types of reflector materials and absorbing materials.[8]-[10]

4. PARAMETERS OF A PARABOLIC TROUGH SYSTEM

- **Overall Heat Loss Coefficient**

All the heat that is received by the receiver tube does not result into useful energy some of the heat gets lost to the surrounding. The amount of heat loss depends upon the convective, conductive and radiative heat loss coefficients. Estimation of heat loss coefficient of the system is important for its performance evaluation. A higher value of heat loss coefficient indicates the lower heat resistance and hence the lower efficiency.

- **Heat Removal Factor**

Heat removal factor represents the ratio of the actual useful energy gain to the useful energy gain if the entire receiver were at the fluid inlet temperature. It depends upon the factors like inlet and outlet fluid temperature, the ambient temperature, area of the tube etc. The importance of heat removal factors remains with the efficiency of the system. For a highly efficient system a higher value of heat removal factor is must.

Collector efficiency Factor

Collector efficiency factor is constant for any collector design and fluid flow rate. This represents the ratio of actual useful energy gain to the useful energy gain that would result if the receiver tube surface temperature had been at the fluid temperature.

- **Thermal efficiency**

Efficiency is the most important factor for a system. This factor determines the systems output. For a parabolic trough system the efficiency is defined as the ratio of the useful energy delivered to the energy incident on the aperture of trough.

5. SIMULATION

The procedure of the Finite Element modelling consists of the main parts namely, pre-processing, solution and post-processing. This model creation phase starts with the determination of the pre-processor with the APDL command /PREP7.FORTRAN Programs facility the full parameters include geometries and thermal loads by the sophisticated thermal theory for the pre-processor. After the pre-processing phase we start with the /SOLU and solve command the solution phase and for further evaluation of the temperature result we apply the /POST1 post-pre-processor.

6. STEADY STATE ANALYSIS

A Steady state thermal analysis calculates the effects of steady thermal loads on a system or a component. We always perform a steady state analysis before performing a transient thermal analysis for establishing initial conditions. A steady state analysis is the First step of a transient thermal analysis performed after all transient effects have diminished. We use this steady state thermal analysis to determine temperatures, thermal gradients, heat flow rates and heat fluxes in an object or a system that are caused by thermal loads that do not vary over time. such loads include

1. Convections
2. Radiation
3. Heat flow rate
4. Heat flux
5. Heat generation rates
6. Constant temperature boundaries[12]-[14]

7. SIMULATION RESULTS

i Steady state temperature model of the absorber tube made of stainless steel

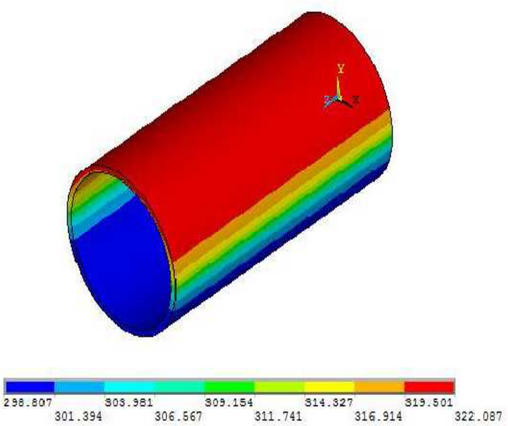


Fig 2: Steady state temperature distribution model (SS)

ii Steady State temperature distribution model of the absorber tube made of copper

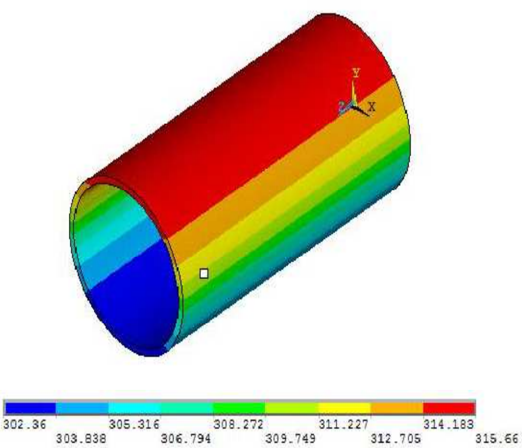


Fig 3: Steady state temperature model(Copper)

iii Variation of thermal conductivity v/s temperature(Stainless Steel)

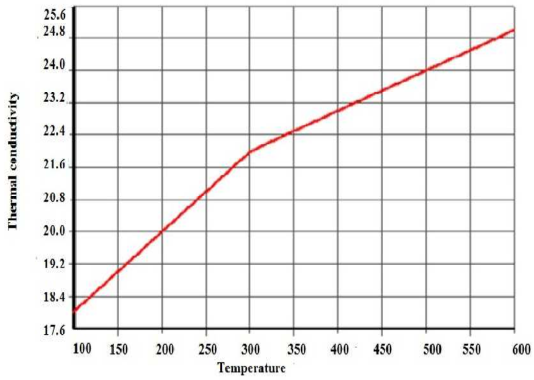


Fig 4: Thermal conductivity variation in stainless steel

For stainless steel thermal conductivity is linearly varying with temperature .For copper, thermal conductivity is very higher at low temperature and from simulation results we can say that the temperature difference is low for copper that is easily heat distributed.

ivVariation of Thermal Conductivity v/s Temperature(Copper)

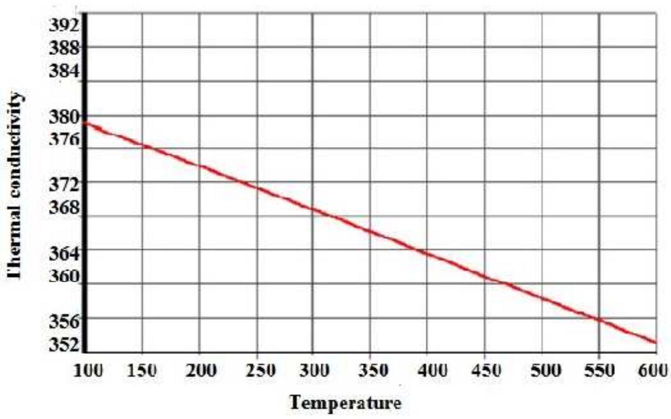


Fig 4: Thermal conductivity variation in Copper

8. EXPERIMENTAL ANALYSIS

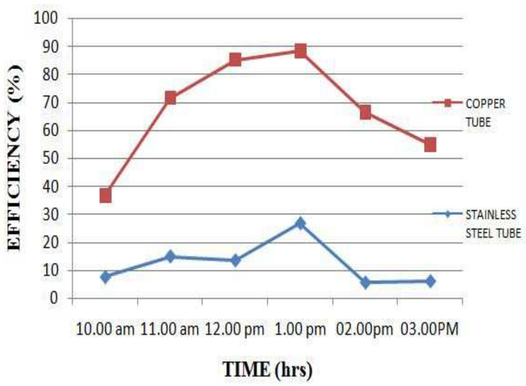
Table 1 : Calculation of efficiency when absorber made of Stainless steel .

m	Ib	ABSORBER INLET	ABSORBER OUTLET	EFFICIENCY
1.4	840	30.4	31.8	7.7
1.4	892	32.3	35.2	15.1
1.4	950	36	38.8	13.7
1.3	630	39	43	26.9
0.6	560	44.4	46	5.7
0.6	580	46.0	47.8	6.2

Table 1 : Calculation of efficiency when absorber made of Copper

m(m/sec)	$I_b(W/m^2)$	$T_i(^0C)$	$T_o(^oC)$	η
0.1	780	28	35	29
0.1	803	25	40	56.46
0.1	900	30	45.0	71.46
0.1	950	30	45	61.35
0.2	800	34	48	60.72
0.2	750	35.0	41.0	48.578

From the table we can say that by replacing stainless steel the efficiency is increased to a high value.



From the figure we can say, As the fluid inlet temperature increases the temperature of the absorber tube also increases .As a result, losses due to re radiation and convection to the surrounding increases, resulting in decrease in efficiency. The difference between the values of efficiencies is a measure of the losses due to re radiation and convection.

9. CONCLUSION

1. Evaluated the performance of the Parabolic Trough Collector under various conditions
2. Developed a Steady State Temperature Distribution Model of the receiver made up of stainless steel and copper
3. Experimental analysis carried out by replacing the absorber tube made of stainless steel by copper and found that the trough collector performance was improved and efficiency also increased.

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