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Thermal Analysis of Solar Parabolic Dish with Thermoelectric Material

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***Abstract*— India stands third largest consumer of electricity all over the world. In India on an average of 935 kWh of electricity and 107 watts of power is being consumed by per person. India is also responsible for almost 10% increase in global energy demand since 2000. Due to deficient presence of fossil fuels. We are in urgent need to find alternative way to produce electricity in order to meet the demand. One such is solution is Solar. In this study, the analysis of parabolic solar dish is done using ANSYS fluent. The convergence of all flow equations is solved for heat transfer simulation flow inside solar thermo-electric module. The result shows that the solar dish works effectively with the presence of fin.**

***Keywords*— Super duplex stainless steel, Turning, Surface Roughness, Temperature, Optimization.**

I. Introduction

Due tothe deficient amount of fossil fuels and increase in population. We need to adapt some other method in order to meet the demand in electricity also it should be the one which is renewable. There are many renewable energy sources to produce electricity but oneof the effective sources for producing electricity is Solar Energy. India stands in 5th position all over the world in production of solar energy. But India is still capable for producing electricity due to the resources and climatic conditions. In order to increase the efficiency of the present solar technique this journal is proposed. In this study temperature distribution, velocity distribution, turbulent intensity along the flow and overthe thermos-electric module analysis is done with and without fin in ANSYS Fluent software.

II. Literature Survey

M. Eswaramoorthy, et al[1] developed the power generation from the combined system of solar parabolic dish collector and commercial thermoelectric modules. The results of absorber plate temperature, power output and overall conversion efficiency are derived from the experimental investigation are reported for the different solar beam radiations. The performances of the systems are greatly affected by the heat sink temperature. Correlations for determining the plate temperature, electrical power output and overall conversion efficiency have been developed in terms of solar beam radiation. The experimental investigation shows that the generation of electricity from the low cost solar parabolic dish collector and commercial thermoelectric modules is a feasible option and also it is highly suitable for isolated energy demand where the conventional grid is not feasible or available.

Sambeet Mishra et al.[2] proves that the solar thermal power plants are a technically feasible option to supply a significant fraction of the world energy demand. Though current cost of electricity produced by solar thermal power plants is still high, there is a large potential for cost reduction in a medium to long term. A lot of money is currently invested to develop improvements and innovations that will achieve a significant cost reduction, thus making reduction of public subsidies possible. The MENA(Middle East and North Africa) region can play a significant role in the solar thermal power market, not only producing electricity for internal consumption and but also exporting it.

Jorge Alexander Alarcón[3]presents the development of a solar parabolic dish collector prototype for rural areas with high solar resource availability in Colombia, which have no access to electricity service or budget resources to purchase a stove (electric or gas). The solar collector prototype proposes a solution to solve these kinds of issues and use sunlight to work it. Through a polished stainless steel parabolic dish, solar radiation is concentrated into a specific area called focus, where thermal energy is generated and is used for cooking or fulfilling a necessity without high investment and helping the environment. To finish, it describes the decisive stages of the prototype implementation, which provides the solar resource analyzed in Colombia, the theoretical analysis, the structural design, the study, and manufacturing materials.

Wei-Hsin Chen et al. [4] studied and provides the performance of a thermal-concentrated solar TEG using a numerical method where the temperature dependent properties of the commercial thermoelectric material were taken into account. Different geometry types of TEG were tested and compared with each other. The predictions suggest that the output power of the solar TEG increases with increasing substrate area, stemming from the increased thermal concentration ratio.

M. Hasan Nia et al. [5] provides the experimental investigation of an electricity and preheated water cogeneration system by thermoelectric module. In the

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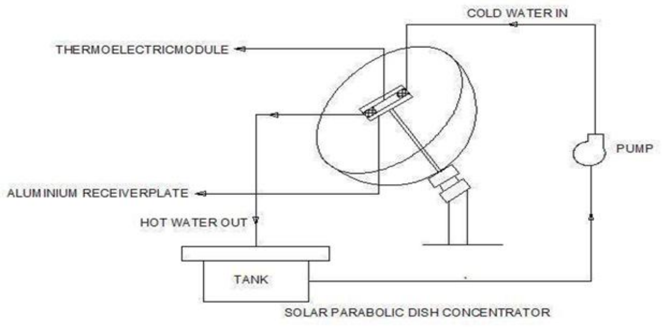
presented design, Fresnel lens and thermoelectric module (TE module) were utilized in order to concentrate solar beam and generate electrical power, respectively. The energy of concentrated sunlight on the heat absorber of TE module is transferred to cold water reservoir.Heat transfer in TE module leads to temperature difference in its 46 both sides and finally electrical power is generated. The main components of this system consist of a monoaxial adjustable structure, a thermoelectric generator (TEG) and a Fresnel lens with an area of 0.09 m^2. Results revealed that matched load output power is 1.08W with 51.33% efficiency under radiation intensity of 705.9 W/m^2. In order to apply TE module capacity optimally for electrical generation, it is recommended to employ an array of Fresnel lenses which transfer heat to TE module by an intermediate fluid. Ibrahim ladanmohammed et al. [6] designed and developed the parabolic dish solar water heater for domestic hot water application (up to 100^oC) is described. The heater is to provide 40 litres of hot water a day for a family of four, assuming that each member of the family requires 10 litres of hot water per day. For effective performance the design requires that the solar water heater track the sun continuously, and an automatic electronic control circuit was designed and developed for this purpose. Experimental test runs carried out showed that the overall performance of the solar water heater was satisfactory. Thermal efficiencies of 52% - 56% were obtained, and this range of efficiencies is higher than the designed value of 50%. The use of a linear actuator (Superjack) to the sun eliminates the need for constant monitoring by a human operator and, thus reduces the cost labour.

III. MODEL DESCRIPTION

A solar dish in parabolic shape is done which absorbs heat from sunlight. It is a collector that collects solar radiation whose energy in the form of electromagnetic radiation from infra-red to ultraviolet radiation. There is no necessity to create or make a new dish because by using the satellite dishes that are being left over or outdated. Thus there will be a reduction of cost of production. Figure 1 shows the setup of the solar parabolic dish with thermoelectric module. Here in this dish, reflecting surface is made by polished aluminium surface. A small lever is provided in the bottom in order to adjust the dish according to the sun's position. The reflector surface consists of aluminium is in the form of triangular form which is placed and fixed on the rib. The antenna is made of aluminium plate which is flat that receives the concentrated solar radiation on the dish. This receiver absorbs heat and transmits it to hot side of thermo-electric module. This entire assembly unit is fixed on two rigid cross stands.

A.CA



Model setup of the solar parabolic concentrator coupled to TE module

A. Parameters

Severalparameters are to be considered while designing the dish. Those parameters help the dish to work effectively. The acceptance angle is the angle through which a source of light can be moved and still converge at receiver. The aperture area is the area where the collector that intercepts solar radiation. To track sun continuously small acceptance angle is enough but for seasonal adjustment a concentrator with large acceptance angle is used. The absorber area is the total area of the absorber surface that receives the concentrated solar radiation. It is the place where energy that can be useful is extracted. The concentration ratio is the ratio of the aperture area to the absorber area. The optical efficiency is the ratio of the energy absorbed by the absorber to the energy incident on the concentrator.

B. Thermo-electric Generator

Thermo-electric effect is where the temperature difference between two ends of thermo-electric couples is converted to electric voltage or vice-versa. The thermo-electric generator unit consists of receiver plate made up of aluminium, thermo-electric couple made of bismuth telluride and the heat sink made of stainless steel materials. Four thermo-electric couples that are capable to produce power of about 58.8 watts are embedded between the receiver plate and the heat sink. Thermal grease is placed between all thermo-electric modules and heat sinks in order to minimise the thermal contact resistance. In order to avoid side heat losses the unit is placed inside a board of 9 mm thickness. The receiver unit has dimensions of 202 mm and thickness of 1 mm. Thermo-electric modules produces electric power of 14.7watts when the temperature of 230ºC and 30ºC and heat supplied is at 350 watts.

IV. COMPUTATIONAL METHODOLOGY

A. Model preparation

The analysis is done for the two different arrangement of heat absorber setup. The first model is prepared with pipe for coolant flow along with an absorber unit without fin and the second model is prepared with pipes for coolant flow with three fins. The absorber unit is modelled with 200x200x30 mm size. The pipe for coolant flow is modelled with diameter of 15mm. The length of pipe is about 600mm on both inlet and outlet sides.

B. Meshing

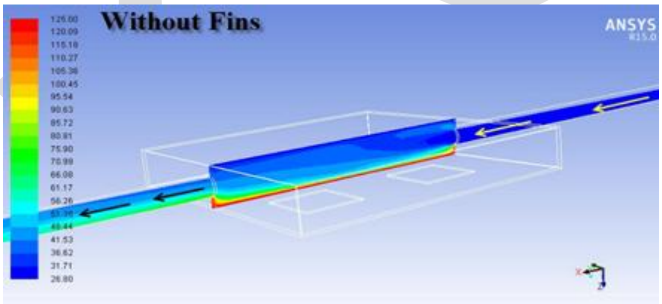
The model is discretised into small finite elements using HYPERMESH software. The surfaces are meshed with triangular elements and the volume mesh is done with tetra elements. The minimum mesh size is maintained around 0.5mm and the maximum element size is about 2mm around the pipe region. Mesh refinements have been carried out at required regions especially around the pipe inlet into the heat transfer module. The heat transfer unit is maintained with an overall element size of 1mm.

C. Boundary Conditions

After the flow domain is meshed, the boundary conditions are applied over the boundaries to define the heat transfer and flow physics. A 'Mass Flow Inlet' boundary condition is imposed at the inlet side of the water flow with a value of 0.01 kg/s. The outlet of the pipe is given with 'Pressure Outlet' boundary condition with a gauge pressure of 0 Pa. The reference pressure is taken as 1 atm. The bottom of the heat transfer receiving unit is given with an accumulative heat flux to get the required temperature. Rest of the wall surfaces are insulated with heat flux zero. Standard 'k-epsilon' turbulence model is used for solving the turbulence during computations.

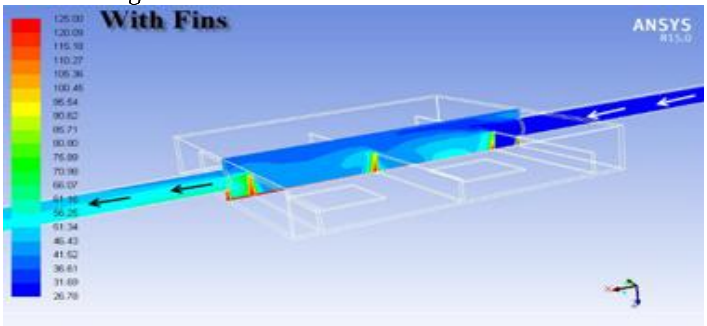
V. Results and Discussion

All flow equations (Continuity, Momentum, Energy and Turbulence) solved for the simulation of heat transfer flow inside a solar thermo electric module using ANSYS Fluent solver. All the equations got converged and the convergence criteria are kept as 10^{-3}. The converged solutions are post processed with ANSYS-Fluent Solver and various contours and plots are obtained for comparing the performance of heat transfer unit with and without fins. The temperature distribution across and along the flow direction is obtained and compared. Computational Fluid Dynamics effectively predicts the flow features and heat transfer characteristics of thermo-electric module.



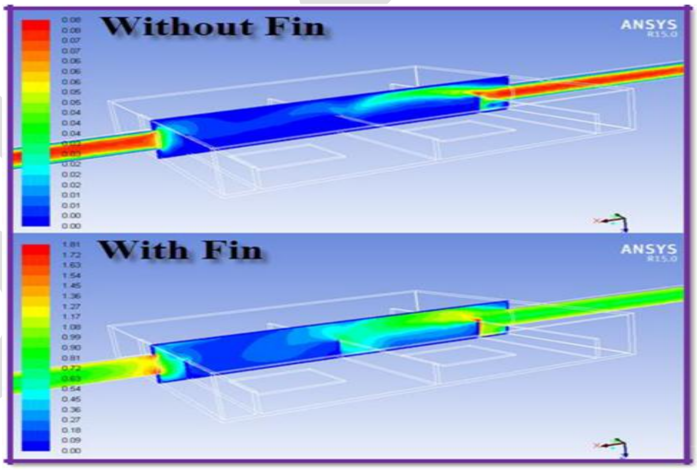
Temperature Distribution along the fluid flow direction

This figure shows the temperature distribution along the flow of heat transfer fluid (water). It is observed from the figure that the temperature distribution is not much predominant till the top absorber layer of the thermo-electric module. Also the average temperature through the outlet pipe is around 60° C and the height of this average temperature is not much significant.



Temperature Distribution across the fin

This figure shows the temperature distribution along the flow for the thermo-electric heat transfer module with fins. It can be noted that the distribution after the first fin is very much significant and the average temperature at the outlet of the pipe is more than 65° C.



Velocity Distribution along the flow

This figure shows the velocity distribution along the flow for the thermo-electric heat transfer module with and without fins. The flow inside the heat transfer chamber is not much disturbed as the chamber passage allows the flow with less turbulence. This leads to lesser heat transfer in the case of chamber without fin. But the flow distributions are much disturbed due to the presence of fins which in-turn reflects in turbulence creation.

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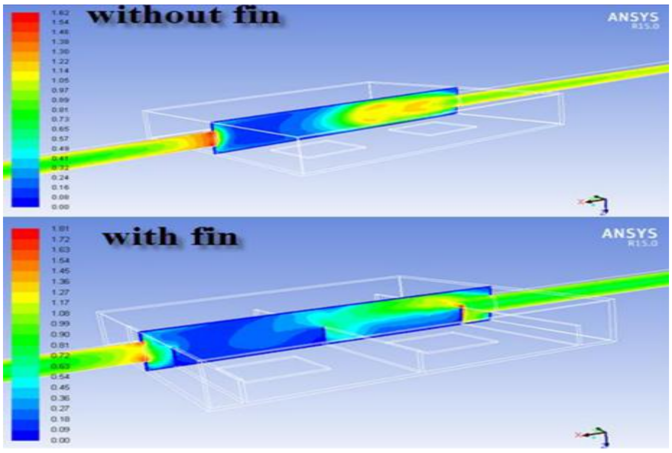
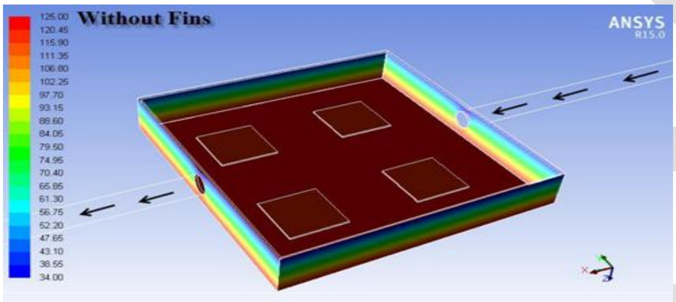


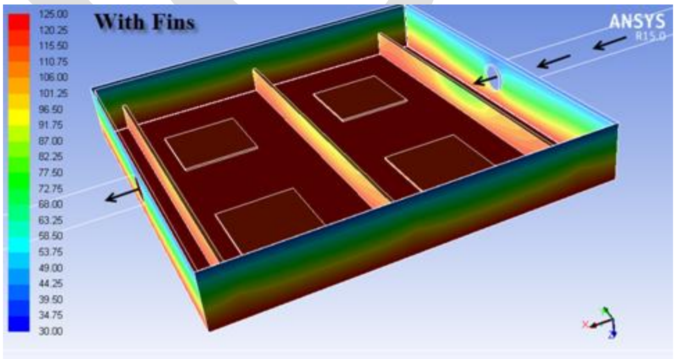
Turbulent Intensity along the Flow

This figure shows the variation of turbulence intensity along the flow path. It is clearly evident that the turbulence induced in the chamber without fin is very less as well as uniformly distributed. But the heat transfer unit with fins produces more turbulence and hence the uniformity of the flow is significantly disturbed. This allows more heat to flow from bottom receiving end to the top absorbing end.



Temperature Distributions over the Thermo Electric Module

This figureshows the temperature distribution over the outer surfaces of heat transfer chamber with and without fins. It is observedthat the chamber without fins distributes the temperature profile evenly from top to bottom. This leads to lesser temperature difference between the receiving and absorbing ends. The minimum temperature obtained at this case is around 34°C.



Temperature Distributions over the Thermo Electric Module with fin

This figure shows the temperature distribution over the outer surfaces of the heat transfer chamber with fins. Here it is clearly visible that the temperature distribution is more at the middle and also at the location of fins.

Without Fin

Area-Weighted Average Static Temperature	(k)
absorbing-end	313.14999
receiving-end	398.14999
Net	352.26724

Temperature Difference = 85 C

With Fin

Area-Weighted Average Static Temperature	(k)
absorbing-end	303.14999
receiving-end	398.14999
Net	346.86929

Temperature Difference = 95 C

Temperature Results obtained from ANSYS Fluent

This figure shows the CFD predictions that the temperature difference in the heat transfer unit without fins is 85°C whereas it is 95°C in chamber with fins.

VI. Conclusion

The computational analysis of Solar Thermo Electric Module has been carried out with a proper physics definition as per the experimental set up.The CFD results significantly predict the flow and heat transfer behaviour of a thermo electric module.The heat transfer analysis is carried out with and without fins. The absorbing end temperature is less in the case of chamber with fins which leads to reasonable temperature difference.The CFD predictions show that the temperature difference in the heat transfer unit without fins is 85°C whereas it is 95°C in chamber with fins.The experimental result was 4V (without fin case). The CFD results shows the output can be increased by having fin arrangement in the heat transfer unit.

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