iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: X Month of publication: October 2020

DOI: https://doi.org/10.22214/ijraset.2020.31921

Optimization of Flow Configuration of Solar Flat Plate Collector

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Abstract: The solar flat plate collector consists of five major parts transparent cover, absorber plate, absorber flow channels, thermal insulation layer, frame, back sheet. The absorber plate adapt imported full plate magnetic sputtering coating plate or black chrome plate, which has a stable performance and durable service. Heat absorber plate and riser have been joined by imported laser welding technology in a strong manner without any damage on the heat absorbing film. The absorber looks artistic with high heating efficiency. The solar water heater are consisting of several components such as pipe, flexible pipe, metallic container. The temperature of outlet water has been analysed several times and found to be around the range of 52°C at the time 13.00 for water flow rate of 12 lit/min. Experimental analysis has been conducted considering various spacing factor for single, double and triple glazing of FPC. Finally in the air gap of 10mm has found to be optimal combination for a FPC with black paint absorber. Further, hole the conventional flow configuration (circular type) have been found have efficiency of 50% - 60%. An attempt has been made to final possibilities of improving efficiency by changing the flow configuration of FPC.
Keywords: flat plate collector, heat loss coefficient, exergy, exergy loss

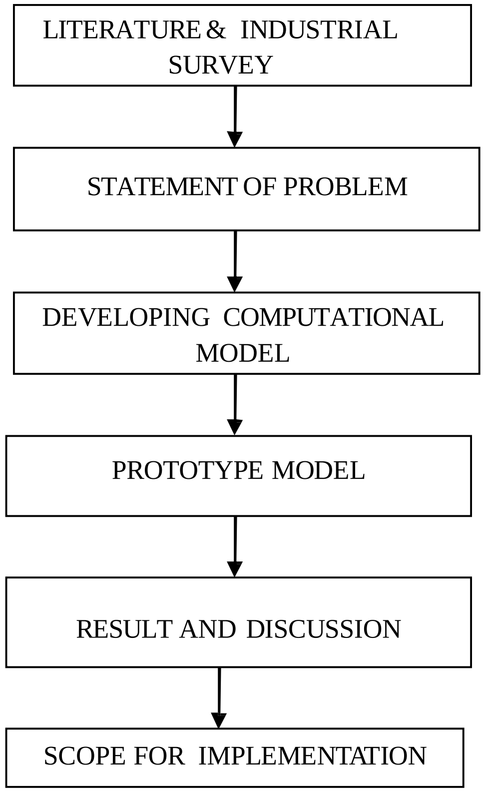
I. INTRODUCTION

In a solar domestic hot water system, the flat plate solar collector is the main part of the system. Hence, the optimal performance of the solar collector is highly important. On the other hand, the energy equation alone does not encounter the internal losses; it cannot be a sufficient criterion for the flat plate solar collector efficiency. But, the second law analysis is
more informative in regard to the optimum operating zone, quantifying the inefficiencies, their relative magnitudes and locations . Therefore, the consideration of this article will be on the detailed energy and exergy analysis of flat plate solar collectors for evaluating the thermal, optical and energetic performance and finding the optimum values of the mass flow rate, the absorber plate area and the maximum exergy efficiency under given operating conditions. Much research has been carried out in this category. Models of thermodynamic analysis for solar collectors using concepts such as exergy output, exergy efficiency and entropy generation are elaborated. However, it is assumed that the overall loss coefficient is constant or is computed from the empirical equation that has specific restrictions. discussed the optimal operation of flat plate solar collector by means of exergy analysis using numerical simulation technique and finally gave some useful results for a typical water heating system under given operating conditions. However, they assumed the exergy flow rate in the global solar radiation to be equal to the solar flux; the overall thermal loss coefficient, the heat removal factor, the efficiency factor, agent fluid properties and other heat transfer coefficients of the solar collector are constant. Also, they considered the fluid inlet temperature to be equal to the ambient temperature and constant. They neglected the destroyed exergy caused by the ducts' pressure drop. These subjects are not considered in the previous literature

A. A general model for the collector optical and thermal performance is not fulfilled or it is assumed that the overall loss coefficient and other heat transfer coefficients are constant or at minimal effect.
B. The complete optimization with respect to the design and operating conditions is not carried out. Design conditions include the dimensions of the solar collector and operating conditions include the mass flow rate of the solar collector.
C. A common error using the Patella efficiency equation obtaining the solar radiation exergy is noted.

The previous subjects have been corrected for several types of solar collectors. In this paper, a procedure to design and optimization of flat plate solar collectors based on exergy analysis is developed. The exergy analysis of the solar collector is parametrically dependent on its optical and energy analysis. Hence, firstly the optical and energy analysis of the flat plate solar collector will be carried out. Then, the solar collector exergy efficiency will be computed and optimized.

II. METHODOLOGY



III. LITERATURE SURVEY

The literature survey about the solar collectors has been performed in this chapter. The survey gives idea about current development and future scope in solar energy utilization.

Abdulkadir Kocer et al.[1] had concluded this paper, "The F-chart" is a method that provides an easy way to determine the thermal performance of the solar heating and hot water systems. In this study, the solar systems are analyzed with the F-chart method in order to meet the hot water requirements of hotels. Annual fraction and heating loads for different solar collector areas and number of people is estimated. Flat plate and evacuated tube type collectors are compared and analyzed. The coverage rate of energy requirements for water heating in household consumption over Turkey by selective, copper and galvanized absorber plate solar water heaters were ranged between 64-100%, 44-89% and 41-88%, respectively. In addition, the payback periods (PBPs) were calculated by considering savings equivalent in electricity and liquid petroleum gas (LPG). The PBPs ranged between 2.98 and 12.28 years for electricity and between 2.02 and 5.04 years for LPG. In general, the number of collectors was decreased by using ETCs.

Andrew Sorter et al.[2] had concluded this paper details the research, design and installation of the solar thermal water-heating project. The flat plate collector is a shallow, usually 4 ft by 8 ft [1.22 m by 2.44 m] insulated box with a glass cover. Running through the box are a series of copper pipes connected by dark absorber plates that maximize solar absorption. Temperature sensors have been installed in key locations throughout the system, and a pyranometer has been installed in the plane of the flat plate collectors. These instruments are 15 connected to data logging equipment, and these data will be used to create a profile of the general operation and performance of the system we were able to cultivate both the theoretical and practical skills needed to complete renewable energy project design and installation.

Anupras Shukla et al.[3] had concluded this paper, the solar water heater are consisting of several components such as circular pipe, flexible pipe, and metallic container for water and circulating pump. We are analysed the outlet temperatures of hot water using of various flow rate (in litres/ Minutes). In this experimental study, we are analysed the maximum temperature of hot water using of various flow rate of water, which are controlled with the help of regulator. We are finding out the maximum temperature 52 °C at the Time 13:00 using of water flow rat are 12 litres/ Minutes.

Assilzadeh et al.[4] had concluded This paper presents a solar cooling system that has been designed for Malaysia and similar tropical regions using evacuated tube solar collectors and LiBr absorption unit. Solar radiation is clean form of energy, which is required for almost all natural processes on earth. In order to achieve continuous operation and increase the reliability of the system , a 0.8metre cube hot water storage tank is essential. The optimum system for Malaysia`s climate for a 3.5 kW (1 refrigerator ton) system consists of 35 metre cube evacuated tubes solar collector sloped at 20 degree.
Balachandar et al.[5] had concluded Flat plate collector is a low temperature solar thermal collector which is used for domestic water heating, air heating/drying and applications requiring fluid temperature of 40oC to 100oC. This paper is used to enhance the heat transfer characteristics of solar flat plate collector with the help of an inner grooved copper tube instead of existing copper tube. The performance of solar flat plate collector will be further 16 enhanced by implementing readily available different specification of the inner grooved tube along with Computation Fluid Dynamics (CFD).
Bandana Swain et al.[6] had concluded This work presents the experimental investigation of a solar water heater in technical collaboration with Wilson Energy Systems, where variable water flow rate in the range 0.001 to 0.02 kgs-1 is used. Most areas of the nation receive solar radiation more than 5 kWh per day for most of the year. A series of experiments were conducted and observations were carried out both for “without greenhouse effect” and “with greenhouse effect” to investigate the characteristics of instantaneous efficiency, second law efficiency and average temperature rise for different water flow rate. The problem parameters were investigated with different orientations such as south-west and due-south.
Daniela Milostean et al.[7] had concluded The paper provides an overview, using information from the literature, on the technical solutions developed by the researchers, in order to increase the thermal efficiency of the flat-plate solar collectors. When solar radiation passes through the glazing and reaches the absorber plate which has a selective surface, about 80% of this energy is absorbed, and then transformed into heat which is transferred to the working fluid that passes through the absorber flow tubes. the most intensively studied method by which can be increased the thermal efficiency of flat-plate solar collectors is by replacing the conventional working fluid with nanofluids. The nanoparticles generally used are: Al2O3, Silver, Copper, SiO2, CuO, TiO2, MWCNTs and Graphene nanoplatelets.
Dattatray D. Chincholkar et al.[8] had concluded The efficiency improvement for flat-plate solar collector can reduce its size and obtain higher temperature fluid at outlet for wider application. It can increase the temperature of the fluid up to 1000oC above ambient temperature. A large number of 17 geometrical parameters influence the performance of a flat plate collector as selective surfaces, numbers of covers, spacing between covers and absorber plate etc. In this study, shape of tube is considered. Following are some of the findings of the research work in connection with thermal enhancement of flat plate solar collector. From the literature surveys it is observed that performance of solar flat plate collector can be enhanced by using passive techniques i.e. increasing surface area of the absorber tube with different tube geometry.
Dhrupad Sarma et al.[9] had concluded The goal of this project is to find out the optimum. Spacing (Air Gap) of Glazing covers; of Single, Double and Triple Glazed Black painted Flat Plate Collector (FPC). For that purpose, three ‘one factor at a time’ experiments were designed for Single, double and triple Glazed FPC, taking Spacing of Glazing cover as variable factor having three levels (5 mm, 10 mm and 15 mm). Optimum Spacing of Glazing cover is 10 mm for Single, Double and Triple Glazed FPC.
Farahat et al.[10] had concluded In this paper, an exergetic optimization of flat plate solar collectors is developed to determine the optimal performance and. Design parameters of these solar to thermal energy conversion systems. A detailed energy and exergy analysis is carried out for evaluating the thermal and optical performance. Exergy flows and losses as well as exergetic efficiency for a typical flat plate solar collector under given operating conditions. Thus, more accurate results and beneficial applications of the exergy method in the design of solar collectors have been obtained
Fathima et al.[11] had concluded this paper, Water heating accounts for a substantial portion of energy use at many residential, commercial, institutional, and Federal facilities. Nationwide, approximately 18% of energy use in residential buildings and 4% in commercial buildings is for water heating. Solar water heating systems, which use the sun’s energy rather than electricity or gas to heat water, can efficiently serve up to 80% of hot water needs with no fuel cost or pollution and with minimal operation and maintenance expense. Solar water heating currently represents less than 1% of the potential water heating market (about 1% of residential buildings have solar water heating, fulfilling about two-thirds of each building’s water heating requirements).
Ibrahim Halil Yilmaz et al.[12] had concluded this paper, “The F-chart” is a method that provides an easy way to determine the thermal performance of the solar heating and hot water systems. In this study, the solar systems are analyzed with the F-chart method in order to meet the hot water requirements of hotels. Annual fraction and heating loads for different solar collector areas and number of people is estimated. Flat plate and evacuated tube type collectors are compared and analyzed.

The coverage rate of energy requirements for water heating in household consumption over Turkey by selective, copper and galvanized absorber plate solar water heaters were ranged between 64-100%, 44-89% and 41-88%, respectively. In addition, the payback periods (PBPs) were calculated by considering savings equivalent in electricity and liquid petroleum gas (LPG). The PBPs ranged between 2.98 and 12.28 years for electricity and between 2.02 and 5.04 years for LPG. In general, the number of collectors was decreased by using ETCs.

Jayant. V. Madan et al.[13] had concluded this experimental study, the active solar water heating direct circulation systems the thermo siphon solar flat plate collector has been tested at Government medical college, (21.15ºN, 19 79.09ºE), Nagpur, Maharashtra, India. The maximum temperature was obtained was around 70ºc and the minimum ambient temperature was 18ºc. Maximum outlet temperature = 73ºC,Maximum recorded efficiency = 65%.Since hot water is circulated by thermo siphon principle (through evaporation and condensation), ideal final temperature of hot water should be 100ºC in the absence of any heat loss. So as to get maximum efficiency of the system.

Nalini Dasari et al.[14] had concluded commonly used solar collector is the flat-plate. These collectors heat liquid or air at temperatures less than 90°C. A way to describe the thermal performance of a Flat Plate Solar collector has been shown. The most important measure is the collector efficiency. A more precise and detailed analysis should include the fact, that the overall heat loss coefficient (UL) and other factors as the heat removal factor (FR) are not constant values.

Prakash Kumar Sen et al.[15] had concluded this paper, a commonly used solar collector is the flat-plate. Flat Plate Collector (FPC) is widely used for domestic hot-water, space heating/drying and for applications requiring fluid temperature less than 100oC. On the basis of the measured efficiencies, the efficiencies for the collectors as functions of flow rate are obtained. The calculated efficiencies are in good agreement with the measured efficiencies. Solar energy that reaches the earth is around 4x1015 MW and it is 200 times as large as the global utilization. A detailed mathematical derivation for the flat-plate solar collector cross sections (cover, air gap, absorber, working fluid, and insulation) was presented. A way to describe the thermal performance of a Flat Plate Solar collector has been shown. The most important measure is the collector efficiency. A more precise and detailed analysis should include the fact, that the overall heat loss coefficient.

IV. OBJECTIVES

A. To increase the efficiency.
B. To improve the quality of the life.
C. To improve performance by optimizing the flow configuration.
D. To increase the productivity, promote live hood.
E. To apply solar energy technology as the enabling technology.
F. To promote the use of sustainable economic and least cost.

V. PROBLEM IDENTIFICATION

Solar energy technologies offer a number of strategic benefits to India. States as sunlight is a free resource; once solar technologies are installed, they have very low operating costs and require minimal non-solar inputs. This provides increased resilience with respect to conventional fuel supply disruptions and price volatility. In addition, growing the domestic solar energy industry could establish our country as a global leader in solar technology innovation and support a growing number of solar-related jobs. According to the EIA, DHW accounted for 6.7% of commercial building energy use, and solar energy supplied approximately 2% of the 6.7% (0.05 Quads/year) in 2001 .

VI. COMPUTATIONAL MODELLING AND ANALYSIS

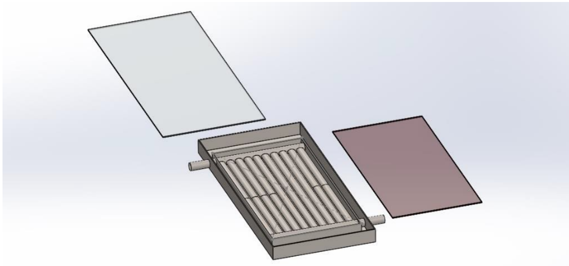


Fig. 1. Exploded view of flat plate collector This Design is solid modelling of solar flat plate collector which is shown in fig 1

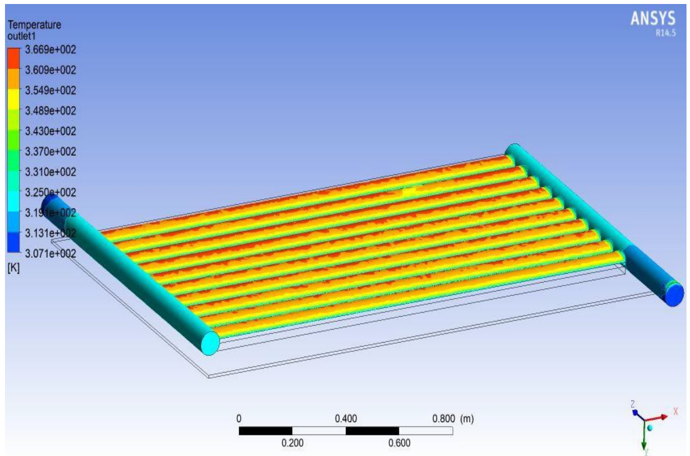


Fig.2. Temperature Distribution inside the flat plate collector of the elliptical tube

That the temperature distribution during the flow of hot air through the flat plate collector . The range of temperature found inside the flat plate collector is from 34℃ to 75℃ .The gradual decreases in the temperature have been indicated with gradient colours. The temperature values mentioned here are in terms of Celsius. The analysis in this figure has been done with ANSYS FLUENT software. That the temperature distribution during the flow of hot air through the flat plate collector of the elliptical tube at the time of the 11am to 5 pm

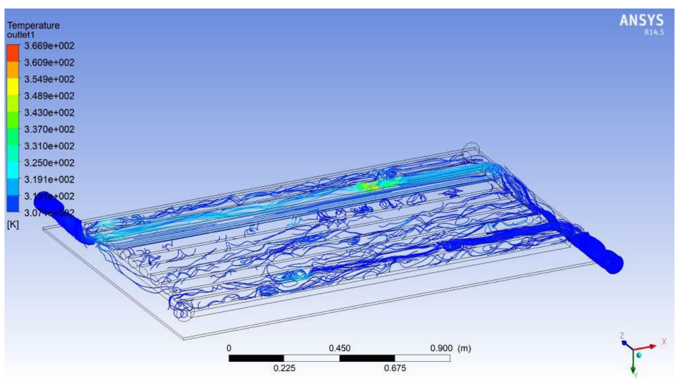
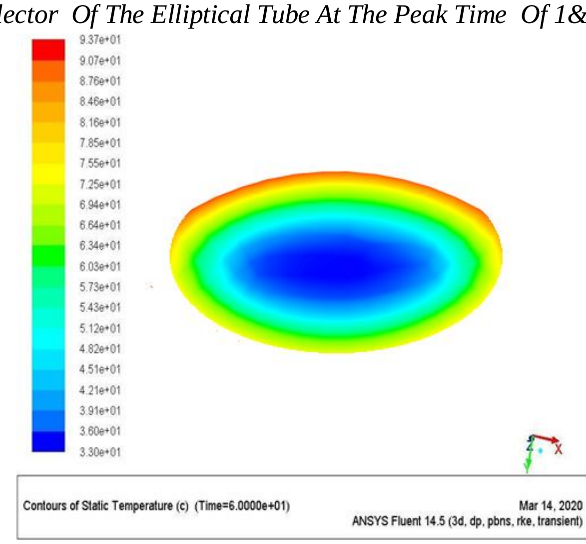
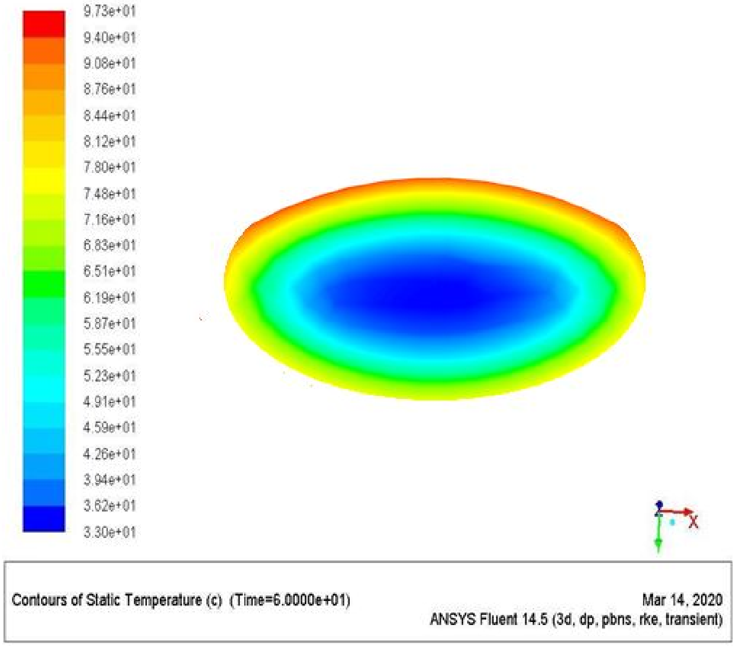


Fig. 3. Fluid flow in the flat plate collector of the elliptical tube

A. Solar Radiation Fall On The Collector Of The Elliptical Tube At The Peak Time Of 1&2 Pm



International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue X Oct 2020- Available at www.ijraset.com



VII. GRAPH AND SPECIFICATIONS

The specifications of solar flat plate collector are given below:

1) Length of FPC –200cm
2) Height of FPC – 100cm
3) Thickness of FPC – 10.16cm
4) Materials to be used
a) Glass
b) Copper
c) Wood
d) Steel

A. Graph For Circular Tube In Solar Collector

The graphical plot in Fig. Explains that there has been a gradual increase in temperature until mid-noon during day time. Eventually, the temperatures from the outlet of the Collector have been found to be varying in accordance with those readings. The temperatures of Collector at inlet and outlet after change the elliptical tube have been shown in Table.

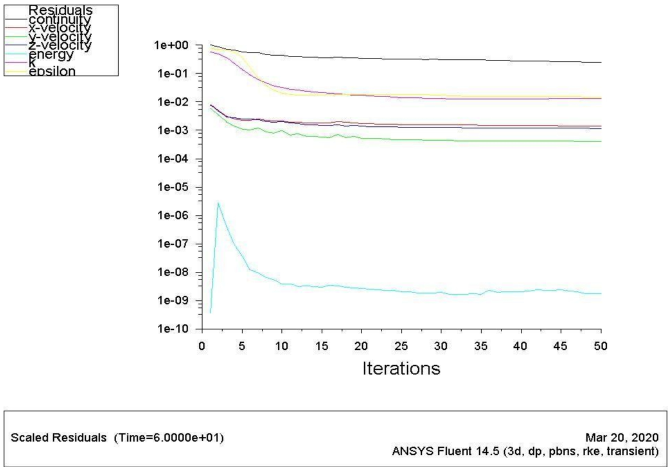


Table.1 Inlet and outlet temperature of circular tube in Solar Collector

S.NO	Time	Inlet Temperature (°C)	Outlet Temperature (°C)
1	11.00 AM	33	56
2	11.40 AM	34	57
3	12.20 PM	38	57
4	1.00 PM	35	60
5	1.40 PM	36	54
6	2.20 PM	40	58
7	3.00 PM	39	56
8	3.40 PM	39	57
9	4.20 PM	37	55
10	5.00 PM	35	54

B. Graph For Elliptical Tube In Solar Collector

The graph plotted explains that there has been a gradual increase in temperature until mid-noon during day time. Eventually, the temperatures from the outlet of the Collector have been found to be varying in accordance with those readings. The outlet temperatures of the solar collector before and after changing elliptical tube have been compared in the graph shown.

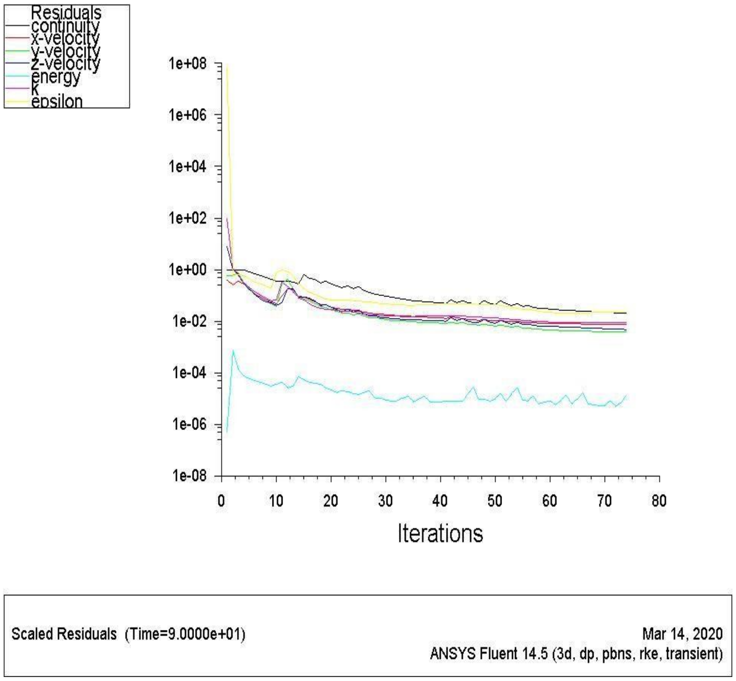


Table.2 Inlet and outlet temperature of elliptical tube in Solar Collector

S.NO	Time	Inlet Temperature (℃)	Outlet Temperature (℃)
1	11.00 AM	33	62
2	11.40 AM	34	65
3	12.20 PM	38	68
4	1.00 PM	35	69
5	1.40 PM	36	70
6	2.20 PM	40	71
7	3.00 PM	39	70
8	3.40 PM	39	70
9	4.20 PM	37	69
10	5.00 PM	35	67

VIII. RESULTS & DISCUSSIONS

A. The results obtained and experimental parameters as referred in design setup and design calculation were plotted and assessed.

B. The efficiency of circular tube and elliptical tube in the flat plate collector, maximum radiation absorption Collector and a comparative study between circular tube and elliptical tube have been considered as separate stages.

IX. CONCLUSION

In this project work, the review had been done about the features of the solar collectors and their various configurations. Further, the utilization of solar energy along with the elliptical collector for the heat transfer and the possibilities to enhance the performance of the heat exchangers and elliptical collector had been analysed. The Collector tilting angle determination for maximum radiations absorption and a comparative study between circular and rectangular collector Solar assisted processes have been considered as parts of the experimental analyses. The following are some important conclusions inferred from the experimental work.

A. The temperature of the hot air from Collector could be raised by 30℃ by using elliptical collector.

B. The maximum temperature (71℃) has been observed at the outlet of Solar Collector for its tilting angle of 60◦ .

C. The quality of the Solar elliptical collector tube products has been visibly found to be better than that of circular collector tube.

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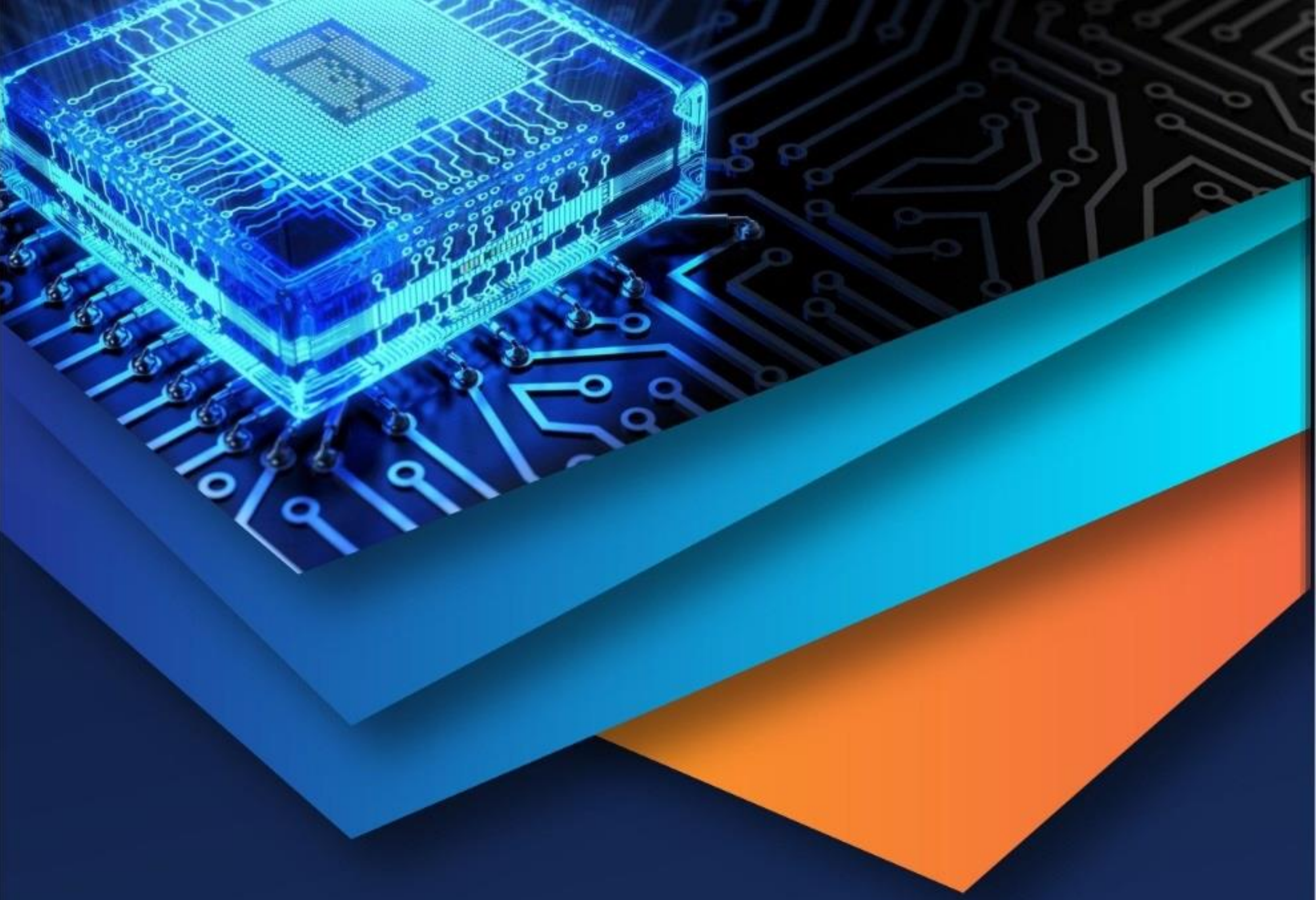

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