# STUDY OF IMPROVEMENT OF THE EFFICIENCY OF PARABOLIC TROUGH COLLECTOR

**A Project and Thesis submitted in partial fulfillment of the requirements for the Award of Degree of**
**Bachelor of Science in Electrical and Electronic Engineering**

**by**
**MD. Assrafujzaman Fuad**
**(ID #:153-33-3080 )**
**Mostake Ahmed**
**(ID #: 153-33-3086)**

**Supervised by**
**SAIKAT BASAK**
**Senior Lecturer**
**Department of EEE**

**DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING**
**FACULTY OF ENGINEERING**
**DAFFODIL INTERNATIONAL UNIVERSITY**

**December 2019**

# CERTIFICATION

This is to certify that this project and thesis entitled “STUDY OF IMPROVEMENT OF THE EFFICIENCY OF PARABOLIC TROUGH COLLECTOR” is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering.

**Signature of the Supervisor**

**Saikat Basak**
Senior Lecturer
Department of EEE

**Signature of the candidates**

Assrabuzzaman

**Name: MD. Assrafujzaman Fuad**
ID #: 153-33-3080

Mostake

**Name: Mostake Ahmed**
ID #: 153-33-3086

**Dedicated to**

# Our Parents

# CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| CA | central axis |
| CSC | concentrating solar collector |
| PTC | parabolic trough collector |
| CSP | Concentrating solar power |
| HTF | Heat transfer function |
| TES | Thermal Energy Storage |
| PCM | Phase change material |
| CPTC | cylindrical parabolic trough concentrator |
| LCZ | lower convective zone |
| SCA | Solar Collector Assembly |
| MC | Monte Carlo |

# LIST OF SYMBOLS

| | |
|---|---|
| Io | Extraterrestrial radiation intensity |
| $\gamma$ | Latitude of location |
| $\delta$ | Declination angle |
| t | Hour angle of the sun |
| Z | Zenith angel |
| $I_z$ | Direct normal radiation or, intensity of solar radiation after passing through the atmosphere |
| $I_{SC}$ | Extraterrestrial solar radiation constant |
| $I_h$ | Horizontal radiation |
| d | Aperture diameter |
| h | Height from the vertex to the aperture |
| F | Focal point distance from the vertex |
| psm | Specula reflectance of concentrating foil. |
| Tg | Transmittance of any glass envelope covering the receiver. |
| $A_r$ | Absorbance of the of the receiver. |
| S | Receiver shading factor |
| Aa | Aperture area of the collector. |
| Ia | Direct radiation falling on collector aperture. |
| $A_p$ | Total Area of the receiver heat losing surface. |
| $T_r$ | Temperature difference between absorber and surrounding. |
| $T_{pm}$ | Mean absorber surface temperature. |
| $T_a$ | Ambient temperature. |
| L | length of the receiver. |
| r | radius of the receiver pipe. |
| $\Psi_{rim}$ | Rim angle |
| $D_r$ | Reciver diameter |

| | |
|---|---|
| $D_{ro}$ | Outer diameter |
| Dri | Inner diameter |
| UL | Overall heat loss coefficient of the collector |
| $A_{tub}$ | The surface area of the absorber pipe before modification |
| Wd | Wide of modification receiver |
| $A_{sur}$ | The rounded surface area out of rim angle |
| Amod | The total surface area of the modified receiver |
| $\eta$ | Collector efficiency |
| $Q_{loss}$ | Heat loss in receiver |
| $Q_w$ | Reflected optical energy |
| $A_a$ | Aperture area of the collector |
| $I_a$ | Direct radiation on the collector |
| Yx | Tubular receiver efficiency |
| Ymod | Modified receiver efficiency |

# ACKNOWLEDGEMENT

First of all, we give thanks to Allah or God. Then we would like to take this opportunity to express our appreciation and gratitude to our thesis supervisor **Saikat Basak, Senior Lecturer** of **Department of EEE** for being dedicated in supporting, motivating and guiding us through this project. This project can’t be done without his useful advice and helps. Also thank you very much for giving us opportunity to choose this project.

We also want to convey our thankfulness to **Professor Dr. Md. Shahid Ullah, Head** of the **Department of EEE** for his help, support and constant encouragement.

Apart from that, we would like to thank our entire friends for sharing knowledge; information and helping us in making this project a success. Also thanks for lending us some tools and equipment.

To our beloved family, we want to give them our deepest love and gratitude for being very supportive and also for their inspiration and encouragement during our studies in this University.

# ABSTRACT

In the present era the environment conscious country and people are interested to use renewable energy rather than using fossil fuel. Sun is the best source of renewable energy. We can collect solar energy almost everywhere and is free to harness. To produce electricity from solar radiation concentrating solar collector is the most efficient and environment helpful. Parabolic trough collector performance were analyzed using MATLAB. Modified the receiver pipe using geometry and the loss was analyzed and compared with the previous receiver. The results were analyzed by simulating the equations and calculating the efficiencies of different model of absorber pipe and showing them in graph. The goal of research is to increase the efficiency of the concentrating collector by simulating equations with MATLAB and compare the theoretical results with the results of the researchers was compatible.

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

The sun is radiating energy continuously. Being the part of solar system the earth and as well as we getting the energy from the sun. But the question is how efficiently are we using the solar energy. Solar radiations conserved by means of Concentrated Solar Collectors (CSC) are widely used for electricity production. Hence, Concentrated Solar Power (CSP) plants are developed and globally there are many projects under construction.

## 1.2 Energy from the sun

The distance of sun from the earth is $1.5\times10^8$km on average. The effective temperature on the surface on the sun is about 5762k (5489°C). On the other hand the temperature at the center is estimated between $8\times10^6$K to $40\times10^6$K. The fusion reaction produces huge amount of nuclear energy in the sun.[1]

The 40% mass of the sun the 90% of energy is produced at the zone of 0 to 0.23 of the radius of the sun. from 0.7 of the radius the temperature drops to about 130,000K. From 0.7 to 1.0 radius of the sun is considered as convective zone. The upper layer of the convective zone is called the photosphere. It is essentially opaque as the gases it composed of are strongly ionized and able to absorb and emit a continuous spectrum of radiation. The photosphere is the source of most solar radiation.[2]

### 1.2.1 Receiving energy of earth

The sun's energy which is nuclear energy released in fusion reaction reaches the earth as electromagnetic in the wavelength band of about 0.3µm with its peak spectral intensity near 0.5µm. The intensity of solar radiation on a surface normal to the sun’s rays beyond the earth's atmosphere at the mean earth-sun distance is defined as the solar constant. The accepted value is 4353w/m$^2$. But the earth orbit is slightly oval shaped. Therefore the distance between the sun and earth varies in a whole year. The extraterrestrial radiation intensity Io is inversely proportional to the square of earth-sun distance. Therefore the value of Io is maximum of 1398w/m$^2$ on January 3 at the lowest earth-sun distance and minimum of 1310 w/m$^2$ on July 6 at highest earth-sun distance.

The incoming electromagnetic solar radiation suffers following exhaustions before reaching the surface of earth:

1. Absorption by the ozone in the upper atmosphere.
2. Scattering by dry air.
3. Absorption, scattering and diffuse reflection by suspended solid particles.
4. Absorption and scattering by thin cloud layers.
5. Absorption and scattering by water vapour.

### 1.2.2 Radiation on a certain location surface

Before calculating the direct radiation as a function of time on the surface in a certain location, we have to know the followings:

$\gamma$ -latitude of location

$\delta$ -declination angle

t -hour angle of the sun

Z -zenith angel

IZ -direct Normal Radiation or, intensity of solar radiation after passing through the atmosphere

ISC-extraterrestrial solar radiation constant

Ih -horizontal radiation

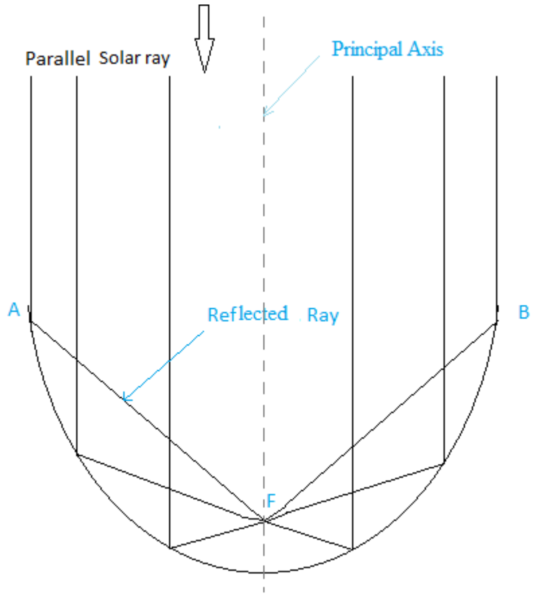
Using specific equations we finally get the value of radiation on a horizontal surface.[5]

$I_h=Iz\cos z$ ------------------(1)

For Nigeria with geographical location of latitude between $4^{o}$ N and $13^{o}$ N and longitude between $3^{o}$ E and $15^{o}$ N the value of Ih is 912W/m2.[5]

## 1.3 Concentrating Collector

Concentrating solar collector (CSC) consists of a reflector and a receiver. Lenses or reflector can be used to focus sunlight into a sharp beam in a CSP system. There are different types of reflector. Parabolic reflector is mostly used. The solar radiation rays fall on the collector parallelly and the parabolic reflector work as a concave mirror concentrates the rays to a focal point. Function of concave mirror is shown in Fig. (1.1). In this figure a cross section of concave mirror is drawn to illustrate the function of concave mirror.



Where,

F=Focal point

AB= Aperture diameter or weight of mirror

Fig. (1.1): Function of concave mirror

The central axis CA (Optical axis) is parallel to the solar radiation rays shown in Fig. (1.1). By the rules of optics we know, if light rays falling parallelly with the CA on a concave mirror those being reflected the light rays are concentrated at the focal point of the concave mirror. At the focal point the concentrated rays produce a massive amount of heat. The receiver is act as an absorber of the produced heat and transfer the heat to a heat transfer fluid (HTF) like water or molten salt which flows through the inside of the receiver.

Concentrating collector are of four types

1.Parabolic trough collector
2.Power tower receiver
3.Parabolic dish collector
4.Fresnel lens collector

This research is about the parabolic trough collector (PTC). There is a focal line instead of focal point in the PTC. A model of PTC is shown in Fig. (1.2).

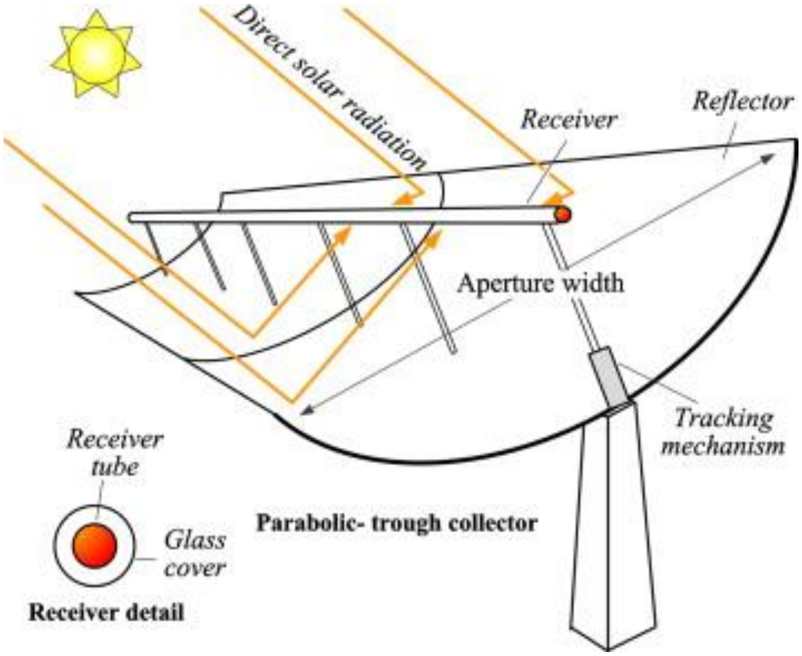


Fig. (1.2): Parabolic trough collector structure diagram

### 1.3.1 Parabolic Trough Collector

The reflector of PTC is parabolic trough shaped. when the solar radiation falls on the parabolic reflector, the reflector reflects the radiation along a line. Every point in this line act as a focus point. An absorber pipe is placed along this line. The concentrated solar rays hit on the pipe and the absorber pipe transfer the generated heat to the HTF. As a result the temperature of the HTF is increased when passing through the pipe. That high temperature HTF is used to generate steam. We can use the steam in different purpose.

### 1.3.2 Placing Direction and Tracking Mechanism

We know that the sun rises from east to west. To get the output energy from the concentrator properly the solar radiation should be fall on the concentrator in such a direction that concentrated on the focal line. If the CSC is placed in north-south direction like the figure below.

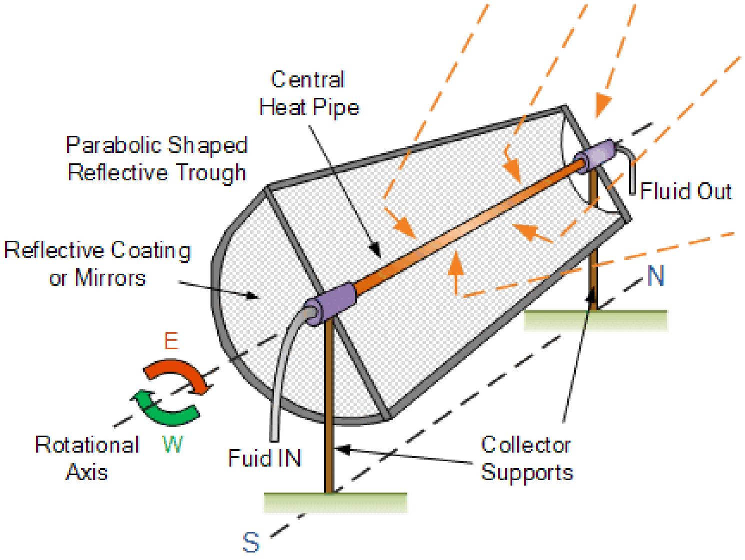


Fig. (1.3): PTC placed in north-south direction

In this Fig. (1.3) a PTC (the length of the collector) is placed along the north-south direction. The CA (illustrated in Fig. (1.1)) of PTC is maintained to be along with the parallel solar ray. The sun moves from east to west. So that an automation system is applied to rotate the rotational axis and maintain the direction of CA parallel to the solar ray. By this mechanism the solar ray is concentrated at the receiver in whole daylight.

## 1.4 Problem statement

Nowadays solar radiation is mostly used as source of energy. But the processes how we collect solar energy is very low efficient. Scientists and engineers are trying to develop the efficiency of collecting solar energy. From three decade ago photovoltaic cell is used to produce electricity from solar radiation. In recent years use of concentrating solar collector is increasing rather than PV cells. The efficiency of converting radiation into heat has reached 79%. The efficiency is less because of some losses at collector and receiver. Firstly optical loss from the reflector is caused by material imperfection. secondly heat loss in the receiver because of the temperature difference between the receiver and circumference.

## 1.5 Objective

The objective is mainly to increase the efficiency of concentrating collector. To increase the efficiency we have to reduce losses somehow. In a concentrating collector there are mainly two types of loss. They are optical loss and heat loss. In this research the objective is to identify the causes of heat loss at the receiver and to improve the system to reduce the heat loss. Then analyze the performance data with MATLAB. Also illustrating the improvement of efficiency in graph.

## 1.6 Research Methodology

The cross section of the parabolic trough collector is drawn in Fig. (1.4).

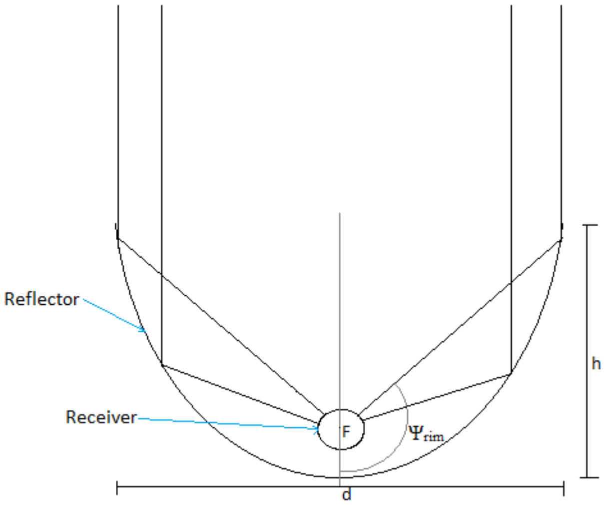


Fig. (1.4): Concentrating collector

The receiver is fully rounded pipe. The center of the round shape receiver is located at the focal point of the parabolic reflector. As a result all of the reflected radiation concentrated at the surface of the receiver.

## 1.6.1 Reflector

In this diagram d is indicating the aperture diameter**.** Aperture diameter is the distance between two end of the parabolic reflector or the opening of the reflector through which the solar radiation can fall on the concentrating collector. The distance or height from the vertex to the aperture is indicated by h. And F is the focal point. The distance of F from the vertex of the reflector is calculated by the following equation.[3]

$$\mathrm{F} = \frac{\mathrm{d}^2}{16\mathrm{h}} \qquad \text{---------(2)}$$

$\Psi_{\text{rim}}$ stands for the rim angle. Rim angle is the angle between the reflected ray coming from the highest reflector end and the vertical line along through the focal point and top vertex point. The ratio of the focal length to aperture diameter f/d is used to calculate the rim angle.

$$tan\Psi\mathrm{rim} = \frac{f/d}{2(f/d)^2 - 1/8} \qquad \text{--------------(3)}$$

$$or, \quad f/d = \frac{1}{4\tan\,(\Psi\mathrm{rim}/2)} \qquad \text{--------------(4)}$$

### 1.6.1.a Aperture area of the reflector

For a parabolic tough collector to calculate the aperture area we have to look at the upper view of the PTC. A figure Fig. (1.5) is given below. From the upper view the collector is look like a rectangular shape. If the collector is placed in such a direction that the length is along the north to south direction the length L of the collector is equal to the length of the receiver.

The width of the aperture is equal to aperture diameter, d. then the area of the aperture will be

$$\mathrm{Aa} = \mathrm{d.L} \qquad \text{-----------------(5)}$$

The total amount of reflected radiation will be calculated with this aperture area, Aa.

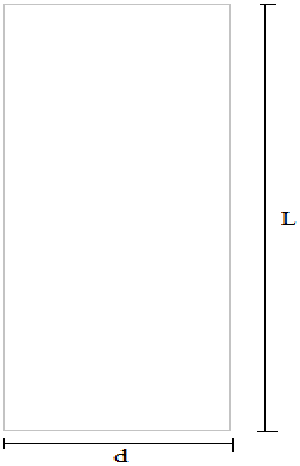


Fig. (1.5): upper view of aperture area of the collector

### 1.6.2 Receiver

In a PTC the center of the receiver pipe is located along the focal line of the parabolic reflector. In the Fig. (1.6) the length, L and the diameter, Dr of the receiver pipeline is given below.

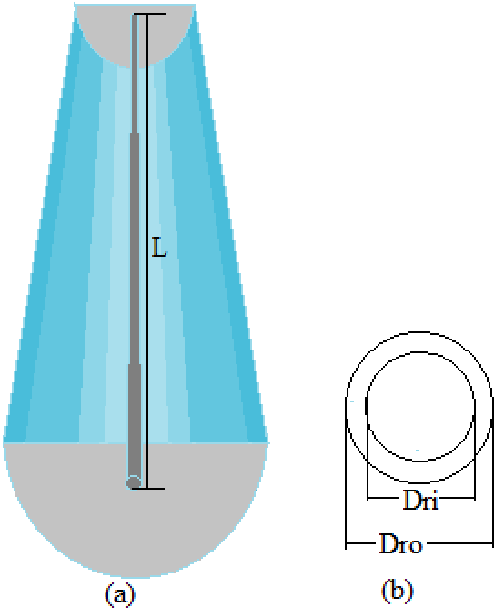


Fig. (1.6): schematic diagram of PTC and receiver diameter

In this diagram length of the pipe is L in part(a) and the outer diameter is $D_{ro}$ and inner diameter is Dri is shown in part(b). we will consider the outer diameter of the pipe in calculation because the magnitude of inner or outer diameter have no effect on our efficiency increasement method.

The of the length, L and the outer diameter, $D_{ro}$ are assumed 34mm and 2m respectively.[4] The value of absorbance of the receiver, ar depends on the materials of absorber pipe.

### 1.6.3 Absorbed Energy of the receiver

The CSC solar tracking system keeps the collector in the direction of facing the sun. When the solar radiation falls on the parabolic reflector, the reflector reflects the rays towards the receiver. The output optical energy and the heat transfer to the receiver from the reflector is calculated from the following equation.[3]

Output optical energy, Qw= psm.Tg.ar.S.Aa.Ia ----------(6)

psm - specula reflectance of concentrating foil.

Tg - transmittance of any glass envelope covering the receiver.

ar - absorbance of the of the receiver.

S - receiver shading factor (fraction of collector aperture not shadow by the receiver).

Aa – aperture area of the collector.

Ia – direct radiation falling on collector aperture.

In a whole daylight we can’t get the maximum solar radiation constantly. Considering the value of Ia from [550 600 650 700 750 800] $W/m^2$. S, ar, Psm and Tg are constants dependent on the materials used and the structure accuracy of the collector.

### 1.6.4 loss in the receiver

the concentrated solar radiation heats up the receiver and HTF. The temperature of the receiver and the HTF increases simultaneously. But the surrounding temperature of the receiver very low than the receiver temperature. Some heat is radiated from the receiver and absorbed by air due to the temperature difference. Thus the heat loss occurs though the receiver is covered with glass. The heat loss equation is

$$Q_{loss}= UL.\ A_p.T_r \quad \text{-----------(7)}$$

$$\text{Or, } Q_{loss}=UL.\ A_p(T_{pm}-T_a) \quad \text{--------(8)}$$

Here, UL - Overall heat loss coefficient of the collector.[9]

$A_p$ - Total Area of the receiver heat losing surface.

$T_r$ - Temperature difference between absorber and surrounding.

$T_{pm}$ - Mean absorber surface temperature.

$T_a$ – Ambient temperature.

The coefficient UL is used to measure all losses. Typical values of UL range from 2 to 10W/$m^2$K [8]. In this thesis considering the value of UL = 9.8 W/$m^2$K and the value of $T_r$ =6.50 (considering the starting moment temperature difference).

### 1.6.4.a Loss for full rounded receiver

The full rounded receiver surface area is calculated as a geometrical cylindrical shape.

Let, the surface area of the absorber pipe = $A_{tub}$

$$A_{tub} = L.2\pi.r \quad \text{---------(9)}$$

$$\text{Where, } r=D_{ro}/2 \quad \text{----------(10)}$$

L = length of the receiver.

r = radius of the receiver.

Then the loss equation will be

$$Q_{loss}= UL.\ A_{tub}.T_r \quad \text{------(11)}$$

### 1.6.4.b Modification of the Receiver

From observing the Fig. (1.4) we can notice that a portion of upper area of the receiver surface is out of the rim angel. Therefore any concentrated ray is not falling on that surface. But this area is radiating the heat. If this area is reduced the heat loss will be reduced. If we convert this portion of area from round shape to flat surface then the area will be reduced. simultaneously the heat loss will be reduced and inversely the efficiency will be increased. This modification is shown in Fig. (1.7)

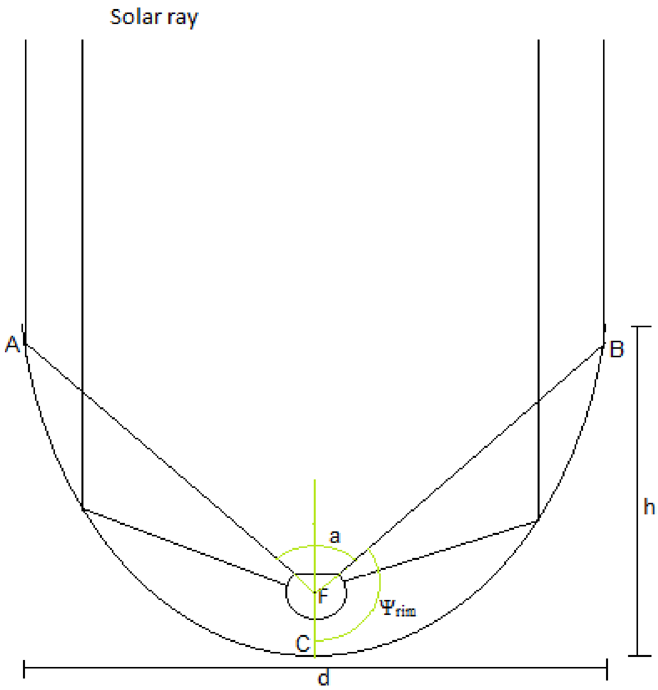


Fig. (1.7): Cross section of CSC with modified receiver

In this figure the rim angle is angle BFC=angle AFC= $\Psi_{rim}$. The angle out of rim angle from both side is named as 'a'. If we consider a circle with angel of 2π radian. Then we can write

$$\text{angle a} + 2\,\Psi_{rim} = \text{full circle}$$

$$\text{Or, angle a} + 2\,\Psi_{rim} = 2\,\pi$$

$$\text{Or, angle a} = 2\pi - 2\,\Psi_{rim} \quad \text{------(12)}$$

In this diagram the upper portion is flat and this portion is out of rim angle. But the area in the absorbing portion is remaining same which is in the range of rim angle. And the amount of direct radiation falling on the upper portion in case of flat surface is same as the round surface.

In Fig. (1.8) both the full rounded and modified receiver are placed together to compare the area of both.

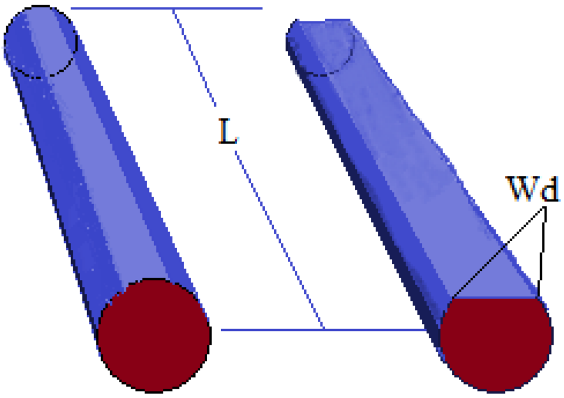


Fig. (1.8): modification of receiver

### 1.6.4.c Area of the modified Receiver

Now one portion of the receiver is remaining round shape under the rim angle and the other portion out of rim angel is flat. The length of the flat surface is same as L. the width is calculated by the following diagram.

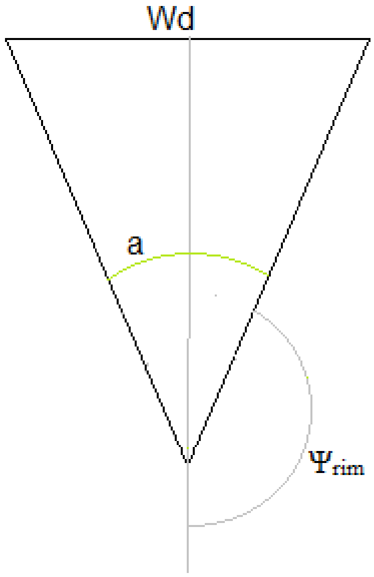


Fig. (1.9): triangle out of rim angle

This figure is the simple part of Fig. (1.8). In this figure considering a full circle angle a is out of double of rim angle. From equation (12) the value of angle a is in radian.

There are two right triangles situated together we can calculate the width by using trigonometric rules. The width, $W_d$ is double of the land of each right triangle. And the land is calculated by using the trigonometric sine ratio of polygon of each right triangle. The polygon of each triangle is same as the radius of the receiver.

$$W_d = 2. (\sin(a/2).r) \quad ----------(13)$$

Here, r stands as the polygon of each right triangle. The value of ris obtained from equation (10)

Then using the value of $W_d$ from equation (13) the area of the flat surface (or rectangle) is

$$A_{rec} = W_d.L \quad ---------(14)$$

Before finding the total surface area of the modified receiver we have to find the rounded surface area which is out of rim angel. This area is calculated using the angle a in radian from equation (12) and length, L of the collector and radius, r of the absorber pipe.

Let, the surface area out of rim angle is $A_{sur}$, Then

$$A_{sur} = L.a.r \quad -------------(15)$$

This area $A_{sur}$ is shown in the Fig. (1.10) below.

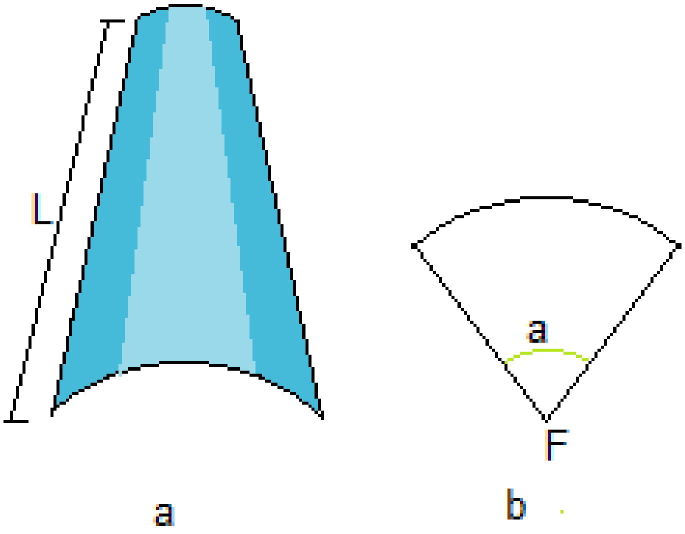


Fig. (1.10): removal surface area

In Fig. (1.10) part (a) shows the upper view of the surface area out of rim angle and part (b) is cross sectional view.

After removing the upper portion from the full rounded receiver, we will get the remaining surface under the rim angle. This is illustrated in cross sectional view in the figure below.

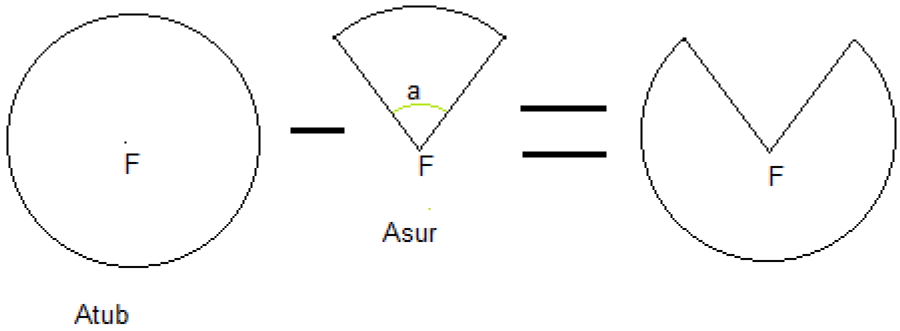


Fig. (1.11): cross sectional view of pre-modification

The total surface area of the modified receiver pipe is obtained by summation of the flat rectangular surface area from equation (14) with the remaining surface area of the receiver under the rim angel zone.

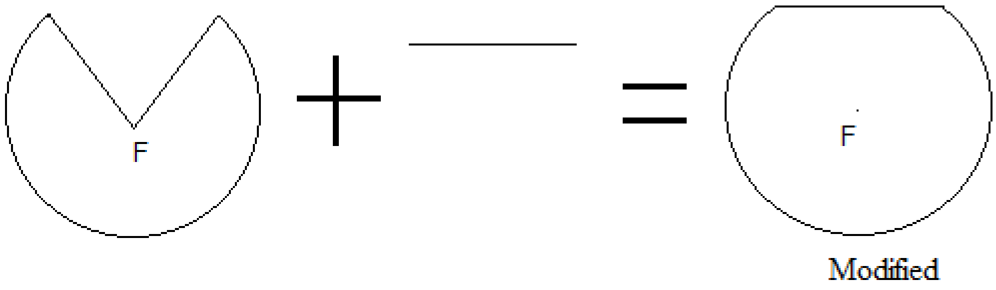


Fig. (1.12): cross sectional view of modification

Finally, the total surface area of the modified receiver, $A_{mod}$ is

$$A_{mod}= (A_{tub} – A_{sur}) + A_{rec} \quad \text{--------}(16)$$

Substituting from equations (9), (14) and (15) the equation (16) will be

$$A_{mod}= (L.2\pi.r) – (L.a.r) + (W_d.L)$$

$$\text{Or, } A_{mod}=L(r.(2\pi – a)+ W_d) \quad \text{---------}(17)$$

## 1.6.5 Collector Efficiency Improvement

As we know Efficiency is the ratio of output energy to input energy of a system. In concentrating collector, the input energy is the amount of direct radiation falling on the total area of the concentrator and the output energy is the heat energy which is transferred to the HTF by the receiver. The equation of Efficiency, η of the concentrating collector

$$\eta = \frac{output}{input} \qquad \text{-------(18)}$$

The output energy at the receiver is obtained by subtracting heat loss in the receiver, $Q_{loss}$ from the reflected optical energy, $Q_w$. The values of $Q_w$ and $Q_{loss}$ is calculated in equations (6) and (11) respectively.

$$\text{output energy} = Q_w - Q_{loss} \qquad \text{------------(19)}$$

The input energy is the total amount of direct radiation falling on the collector.

Before calculating the output energy we have to discriminate the heat loss equations of the receiver before and after modification. According to equation (7).

Heat loss of the receiver before modification from equation(11),

$$Q_{lossx} = UL.\, A_{tub}.\, T_r$$

Heat loss of the receiver after modification is

$$Q_{loss} = UL.\, A_{mod}.\, T_r \qquad \text{--------(20)}$$

The input energy is the total amount of direct radiation falling on the collector.

$$\text{Input energy} = A_a.\, I_a \quad \text{----------(21)}$$

Where, $A_a$ = aperture area of the collector and $I_a$ = direct radiation on the collector. Substituting these values on equation (18)

$$\eta = \frac{Qw - Qloss}{Aa.Ia} \qquad \text{----------(22)}$$

$$\eta\% = \eta.\ 100 \quad \text{-----------(23)}$$

now comparing both full rounded and modified receiver heat loss area and equations of heat loss and with applying the values of all variable in MATLAB simulation we can realize that the modified receiver is more efficient than the full rounded receiver.

## 1.7 Thesis Outline

Chapter 1 introduces with the whole thesis and contains the theory of this study.

Chapter 2 shortly reviews the literature of previous works related to this thesis.

Chapter 3 shows the Simulation of equations and analysis data in graphical view.

Chapter 4 illustrates the Results in tabular analysis of data and contains with the discussion about the work.

Chapter 5 Concluding the study with showing the limitation and the future scopes of this work.

## 1.8 Summary

In this chapter firstly discuss about sun power and receiving earth energy. Then We briefly discuss about the design structure of CSC and PTC. We illustrate the equation of heat loss of receiver and efficiency. We illustrate the process how to reduce the heat loss area of the receiver with geometrical rules and diagram.

# CHAPTER 2

# LITERATURE REVIEWS

## 2.1 Introduction

There are many papers & journal are related to concentrating solar system. We discuss about previous papers & journal, what they wanted. Like Design of Solar dish concentration by using MATLAB program and Calculation of geometrical concentration parameters and heat transfer, Report for Concentrating Solar Power Thermal Storage Workshop, Parabolic trough collector system for low temperature steam generation: design and performance characteristics, An optimized model and test of the China's first high temperature parabolic trough solar receiver. Sol. Energy , The effects of Sun attraction and solar radiation pressure on Medium Earth orbit Satellites, Rotational Dynamics of a Solar System Body Under Solar Radiation Torques, A Simulated Design and Analysis of a Solar Thermal Parabolic Trough Concentrator, Optical and thermal analysis of parabolic trough solar collectors for technically less developed countries, Examination of Parametric Study of Thermal Performance of Cylindrical Parabolic Trough Solar Collector in Ogbomoso Environs, "Thermal modeling Of Solar Pond in MATLAB, MATLAB based Model of 40MW Concentrating Solar Power Plant, Mathematical Optimization of Solar Thermal Collectors Efficiency Function Using MATLAB, Numerical simulation of parabolic trough solar collector: Improvement using counter flow concentric circular heat exchangers, power from the Sun, Performance of Concentrated Solar Collectors , Design, Construction and Testing of a Parabolic Solar Steam Generator.

## 2.2 Design of Solar dish concentration by using MATLAB

By using MATLAB in this paper shows convert of all parameter & equations for design solar concentration and also find heat transfer in receiver & tank by using the temperature of inlet & outlet. By considering the optical factors and thermal analysis, the result clearly showed that there must be an equilibrium achieved between the increasing thermal losses due to the increasing aperture area, with the increasing optical losses due to the decreasing aperture area. In plotted diagram it clear to us. It also shows the efficiency of concentrate solar disk collector have to increase by due to decreasing heat loss.

## 2.3 Concentrate Solar Power Thermal Storage Workshop

We have find some idea from this report about CSP technology like CSP plants offer an attractive means for near-term, utility-scale, dispatchable, renewable electricity generation. For CSP technology this report show a thermal storage option. This report show what Challenges is create about system & materials for Thermal Energy Storage. Also highlights about the improvement of system & materials for thermal storage. In this report Thermochemical storage may provide the ultimate solution to the TES challenge if a suitable system can be identified and developed for high-temperature CSP applications. For phase Change Storage encapsulation of phase-change media at scales from nano to macro must be developed to improve heat transfer and construction of a cascade of PCMs that cover the operating range of the power cycle. For high temperature materials characterization PCM is needed that show in this report.

## 2.4 An optimized model and test high temperature parabolic trough solar receiver.

Both theoretical analysis and experimental measurement are used to identify the heat loss of this 2m high temperature Sanle-3 solar receiver in this paper. Comparison between two model this paper shows how many heat losses in vacuum test & non vacuum test. Here, optimizing 1-D

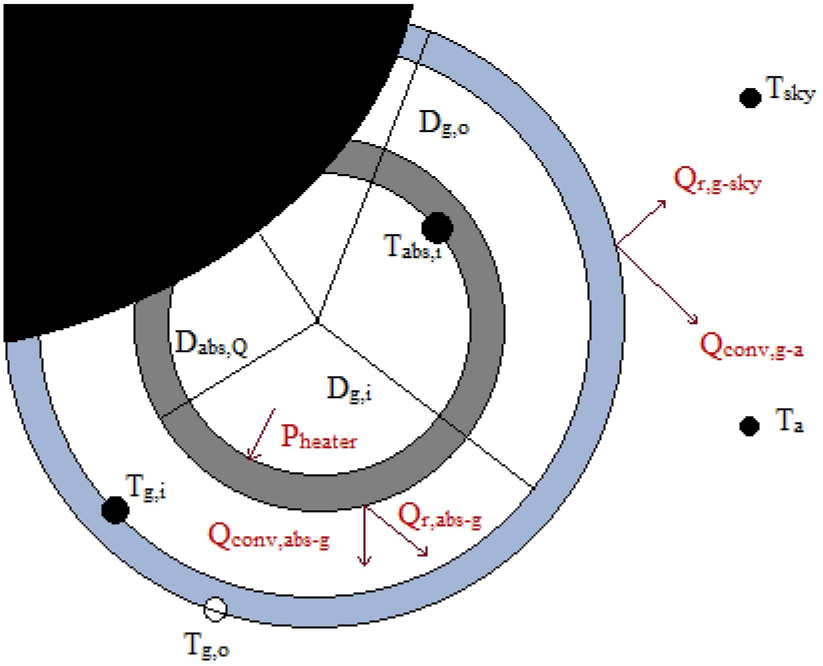


Fig. (2.1): Simplified 1-D solar receiver heat transfer model.

model in MATLAB, we find in here the major factors of solar receiver’s heat loss are visualize and analyze. In the conditions of coating’s emittance and vacuum have a significant role on receiver’s heat loss while the influences of environmental conditions are quite indirect and negligible. Here shows a comparison between 1-D model and test that have different factors. Mostly they do not agree well because the different heat loss mechanisms in receiver’s ends are ignored, which is verified by contrast test with ends covered. For China’s first parabolic trough solar system, the heat loss comparison with several existing solar receivers denotes this 2 m Sanle receiver has a good thermal property & it is better choice for solar system. It is a better side for solar system that 3-D structure model is carried out by CFD software. 3-d model identify experimental data of heater powers and IR photo. This paper provides some future step to develop newly produced 4m Sanle-3receiver like large scale solar system(1Mw). In near future consider a design that achieve a higher benefit. And also a higher operational temperature being multiply utilized in DSG and molten salts systems

## 2.5 The effects of Sun attraction and solar radiation pressure on Medium Earth orbit Satellites

In developing an equation of orbital motion of two body problems with perturbations due to the effects of the solar radiation pressure and attractions of the sun by using MATLAB. For this solar radiation pressure perturbation has been calculated for orbital cycles in here. In this paper we find the effect of sunny radiation pressure on position vector when the position vector began to turn normally moving, but after many turn the position vector began to decrease. Two fig. (2.2) & (2.3)

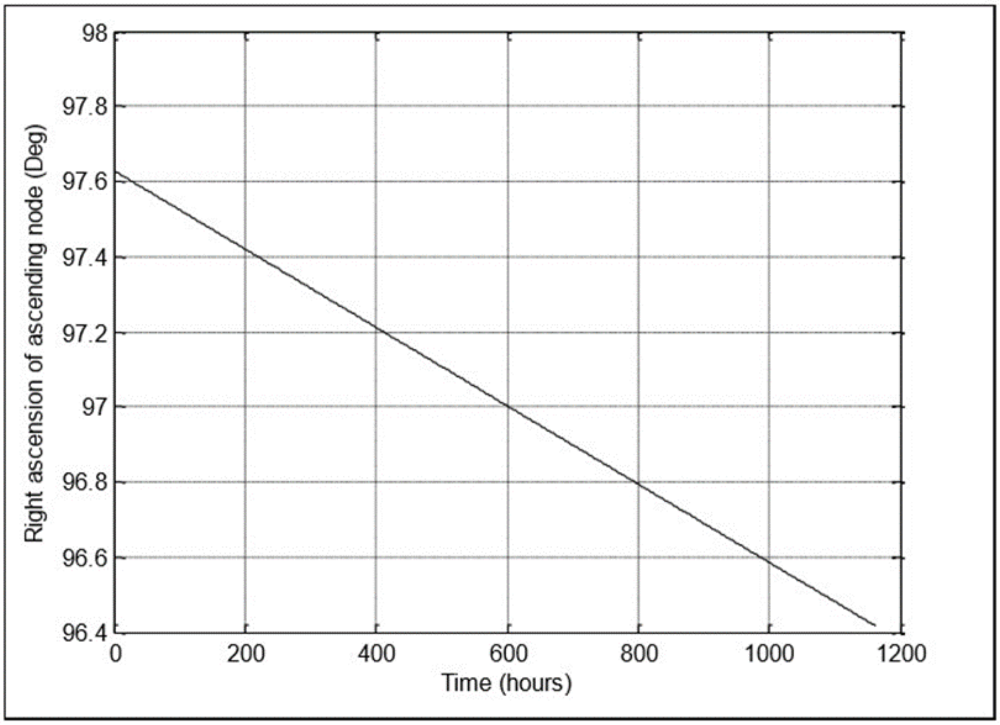


Fig. (2.2): The effect of sun attraction on right ascension of ascending node.

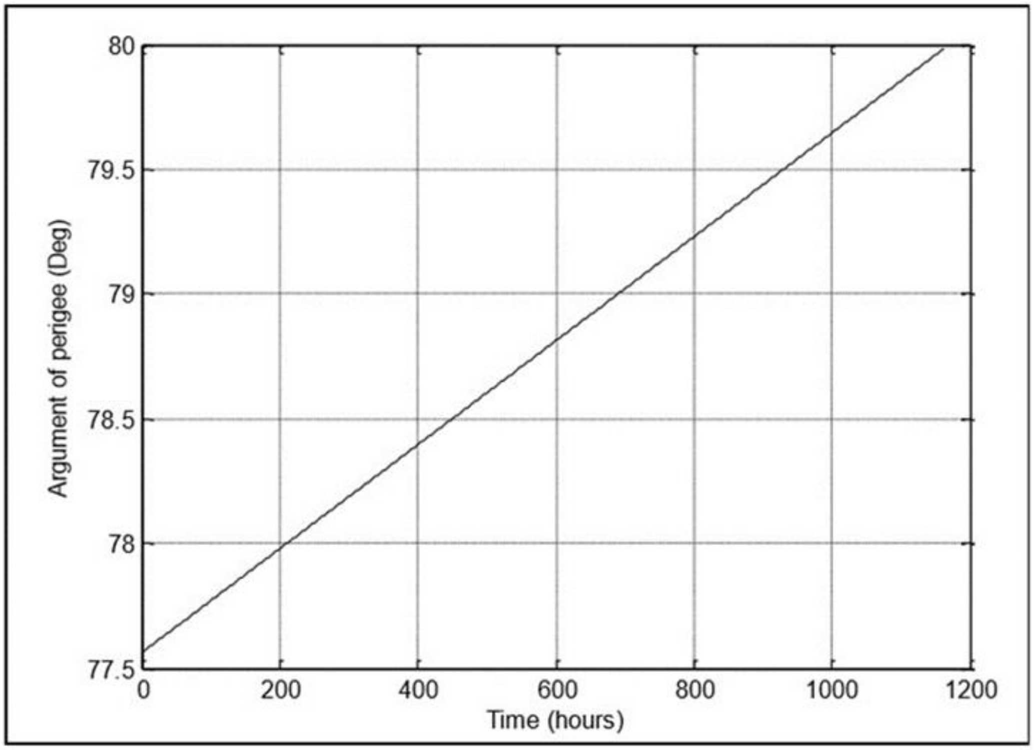


Fig. (2.3): The effect of sun attraction on argument of perigee.

In this paper shows the sun attraction. In figure (2.3) shows relationship between position vector with time without solar radiation pressure effect. By controlling the area-to-mass ratio of the satellite depending on the equation, it is possible to is decrease this perturbation effect. we can get basic idea of perturbation which are effect position and velocity of satellite then at lifetime of satellite , gravitational and non-gravitational, gravitational perturbations include the spherical harmonics , Earth tide ,ocean tide effect and effect of sun and moon attraction, non-gravitational perturbations include atmospheric drag force , solar radiation pressure , magnetic forces from it.

## 2.6 Rotational Dynamics of a Solar System Body Under Solar Radiation Torques.

In here, it analysis uniformly dynamic rotation asteroid subject to YORP effect. We find in this paper as solving the equations of rotational motion to derived the secular evolution of rotation rate and solar inclination of the asteroid. By calculating the effect of finite thermal conductivity we can find thermal lag by reading this paper. It helps us to understand functional relationship between the asteroid rotation rate and the thermal reemission lag. Here also discuss the Dynamics with nonzero thermal conductivity. Using nonzero thermal conductivity, it can prove the nature of the obliquity dynamics can change if a reversal in spin direction occurs. By reading this paper shows dynamical evolution of asteroid rotation states due to YORP can be performed easily. An explicit model define as enables the averaging analysis to be performed entirely analytically. An explicit model of the YORP torques acting on an asteroid in terms of spherical harmonic coefficients.

## 2.7 A Simulated Design and Analysis of a Solar Thermal Parabolic Trough Concentrator

The processes that are necessary to evaluate the performance of a CPTC and to use the data to design a model by simulation using real meteorological data of locations in Malaysia which highlights by this paper. This model efficiency versus the concentration ratio for three different working fluids related to the efficiency of collector. Due to increasing aperture area, the increasing optical losses due to decreasing aperture area there must be an equilibrium achieved by considering the optical factors and thermal analysis. By reading this paper we find that a concentration ratio of 10 and the receiver’s diameter of 0.03 m are the optimum parameters for the highest efficiency of the model.

## 2.8 Design, Construction and Testing of a Parabolic Solar Steam Generator.

From the title of this paper we can understand that it highlights design analysis, Construction and Testing of a Parabolic Solar Steam Generator. we find from this paper the physical and chemical behavior of the sun before its application to heating and also explain the sun ray & solar radiation of surface by calculating design equation & Zenith angle. Calculating heat loss for find out the overall efficiency. For the construction of a parabolic dish solar steam generator arose as an alternative to solve the thermal energy needs of the populace in order to need for conclusion. In here it proves that the thermal energy of the populace also reduce the total dependency on fossil fuels and other non-renewable and exhaustible energy source. By the way deforestation and other environmental populations are reduced to a minimum. The density of population in rural area, natural disaster, climate change are also reduce to a minimum. By calculating all things this paper may prove that parabolic dish solar steam generator is very efficient heating equipment.

## 2.9 Optical and thermal analysis of parabolic trough solar collectors

In this report firstly discuss optical and then thermal analysis of parabolic ridge solar collector. The results of the optical analysis obtained by using the comprehensive optical model and universal error parameters are presented by this report. Some random error are present in the result of optical analysis. Some angle which is called optimum rim angle based on random errors have to be found in report. Here they developed a model that is used comprehensive design method. In this presents models for the thermal analysis of PTC's.

A one-dimensional heat transfer model for the thermal analysis of the receiver subsystem is shows in this report. Here this report prove that a one-dimensional heat transfer model can be used to calculate heat-loss parameter of receiver surface area which is characterize the thermal behavior of the receiver. In this report comprehensive models for optical and thermal analysis of PTC's to be used in comprehensive design studies for establish. It also proved that PTC optical models is not the trough is highly recommended. comprehensive. To investigate the effect of non-random (systematic) errors on the performance of the trough is highly recommended. For studying to investigate the wind induced parallel-flow heat loss from receiver is also recommended.

## 2.10 Thermal Performance of Cylindrical Parabolic Trough Solar Collector in Ogbomoso Environs.

The effect of design and operating conditions on the system performance draw from the parametric studies conductivity. In here it is proved optimal values of the key design parameters has been established for length is 1.30 m and mass flow rate is 0.036 kg/s with collector instantaneous efficiency of 46.47. This report shows the effect of mass flow rate coupled with twisted tape factor on inlet fluid temperature, effect of mass flow rate coupled with twisted tape factor on collector efficiency factor, effect of mass flow rate coupled with twisted tape factor on collector heat removal factor In the absorber tube as insertion reduces the losses in the system thermal performance and it increases the heat transfer leading to increase in the system thermal performance. Here this paper shows the significant increase in heat transfer coefficient is observed with high value of Nusselt number.

## 2.11 Thermal modeling Of Solar Pond in MATLAB

In experimental result in this paper which has gain with respect to the size of the solar-pond. By the way of this result it has proved in here that the salinity of the LCZ increases, the temperature of the LCZ and efficiency of the pond increase. But it also shows an effect that is higher salt concentration in LCZ. In result of this paper find 50 g/Kg is the optimal salinity for the LCZ for calculating pond. The solar-pond can be used as a pre-heater. By portability, low space requirement and its environmental friendliness make it more advantageous when know about many pre-heating applications of solar-pond.

## 2.12 MATLAB based Model of 40MW Concentrating Solar Power Plant

Under theoretical process this paper has been determined a MATLAB based model of the primary loop of a CSP. The model is based on a real CSP located in South of Italy, but another installation site has been considered. The relation between thermal power of a single SCA with the flow capacity of the molten salts, thermal performance of a single SCA to the length of receiver, thermal efficiency to the length of SCA shows in this paper. By showing the secondary loop and the electrical energy production cycle, they have not been considered standard common fossil fuel power station. The typology of only primary loop is considering as interest because of the typical problems of solar plants are overcome by means of a couple of tanks, the hot one and the cold one. In this paper it shows that hot tank represents the storage of the thermal energy to be used also when the radiation is not present or is not sufficient.

## 2.13 Numerical simulation of parabolic trough solar collector: Improvement using counter flow concentric circular heat exchanger.

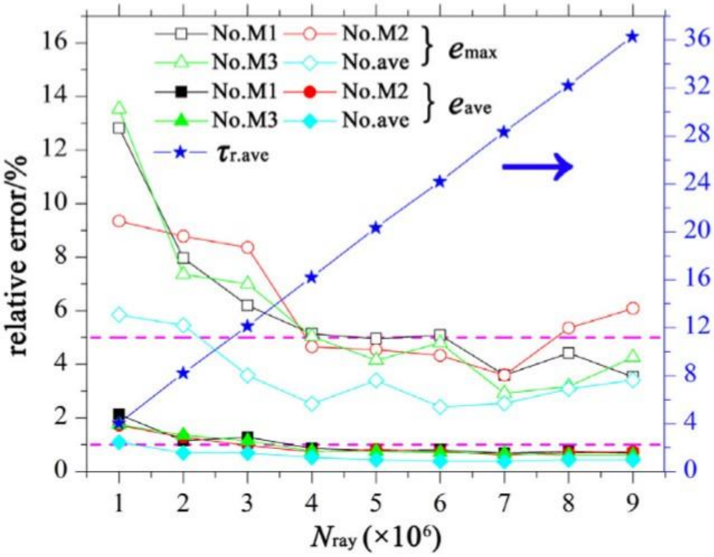
In this journal considering a rigorous mathematical model of its the geometrical, optical, thermal and fluid dynamic aspects of a single-pass and double-pass solar PTC has been carried out. In details of simulation model accuracy that is demonstrated in this paper by comparison for increment of temperature, thermal efficiency and thermal losses with steady state experimental data. For evaluate twenty data points in thermal efficiency both system a maximum error of 6.02% with a mean deviation of±2.19%. For the increment of temperature, the maximum error is5.99% or 1.07 _C with a mean deviation of ±2.25% or ±0.41 _C. The numerical model is based on the applications of governing equations and used general empirical correlations; for this reason, it is possible to make use of it with greater confidence to other fluids, mixtures and operating conditions .Which allows to use the model develop as an important tool to design and optimize these kinds of systems. By solving equation numerically and its result show in this journal that improve heat transfer rate is obtained if the solar PTC is operated with external recycle or with a double-pass without recycle. The evaluation of economical sense including the operating cost in the double-pass heat exchanger is necessary before take a decision to construct a solar PTC with counter flow concentric circular heat exchangers with or without recycle or to decide if vacuum or air technology between receiver and cover is used.

## 2.14 Performance of Concentrated Solar Collectors

By analyzing two main requirements: output temperature and inlet velocity, the system can be designed in this paper. In the studies of this paper we know that performance criteria is passed for 400 and 500 kW/m2 cases indicating the minimum heat flux required. According to pipe length it is found that temperature increased linearly. In near future it is highly expected to be carried out considering the similar parameters observed in the simulation. According this, the input parameters that will be measured mainly will be the heat flux on the pipe surface and inlet velocity. The experimental work which is expected to be completed in order to clarify and validate simulation results.

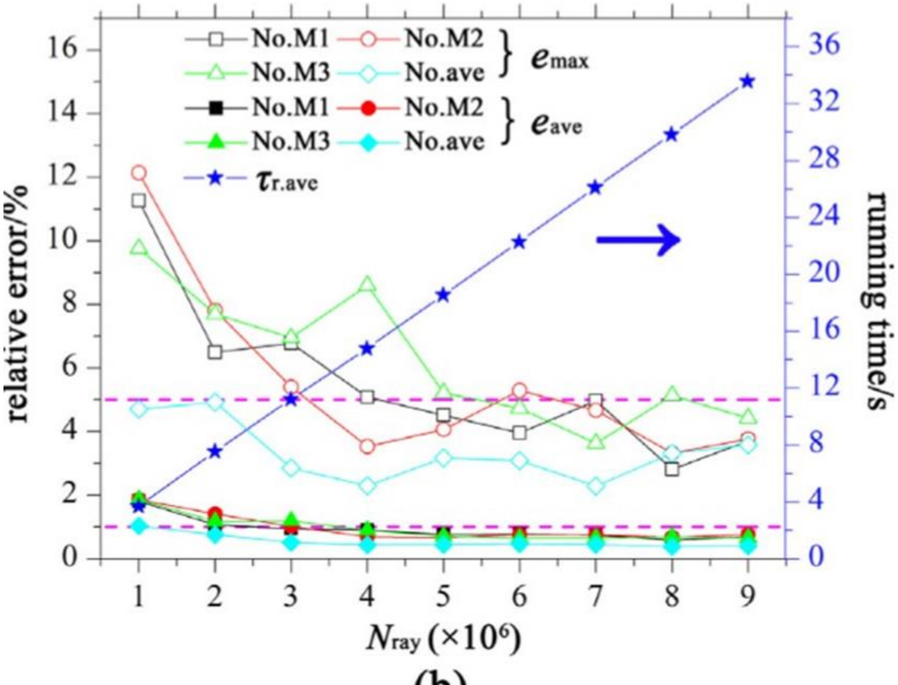
## 2.15 A Monte Carlo method and finite volume method coupled optical simulation method for parabolic trough solar collectors

According to this paper here it uses a Monte Carlo method, finite volume method and coupling optical simulation method for parabolic trough solar collectors. This paper highlights four optical models for parabolic trough solar collectors, Characteristics of Monte Carlo Method and Finite Volume Method, a novel method is present for combining advantages of different models. Here some of simulated results for different rays number in multiple runs with model (a) MM and (b) MC.



(a)

Fig. (2.4): Simulated results of different rays number in multiple runs with model (2.4)



(b)

Fig. (2.5): Simulated results of different rays number in multiple runs with model (2.5)

## 2.16 Summary

In this chapter there are discussion about designing of concentrating solar dish using MATLAB, designing of receiver, high temperature testing through parabolic though solar receiver. Analysis and simulation of the performance of concentrating solar collector. Thermal modeling of solar pond in MATLAB.

# CHAPTER 3

# ANALYSIS AND SIMULATION

## 3.1 Introduction

From theorical part, we find a relation between aperature diameter,radiation,optical loss efficiency & heat loss .Then we are determind a table by analysing & simulating data. Here, We present the data table by grapical structure between aperture diameter,direct radiation, optical loss and efficiency.

## 3.2 Analysis & Simulation

Before simalation we need to specify the assumption the values of the variables

d=1.5;2;2.5 m
h=0.2;0.25;0.3 m
L=2 m
Dro =0.034 m
UL=9.8 W/m$^2$ K
Tr=6.5000
aar=0.95
psm=0.8
Tg=1
s=1
Ia=550 W/m$^2$

These values depend on the materials and the magnitudes are collected from previous works on CSC.[3][4]

Note: These values are same for both of the unmodified and modified receiver of PTC. So, the range of these values have no effect on our modification process.

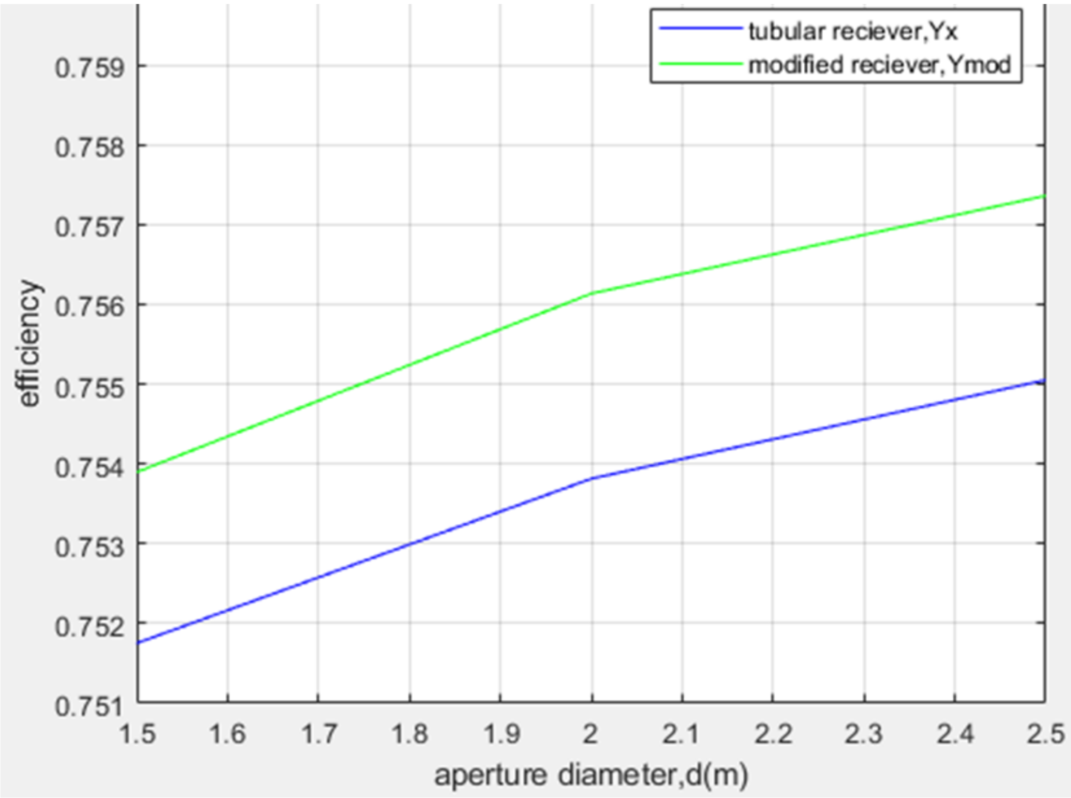


Fig. (3.1): graphical illustration of full rounded and modified receiver efficiency Vs aperture Diameter

In Fig. (3.1) there Yx represents the efficiency of full rounded pipe in blue color that discuss in previous chapter and Ymod represents the modified receiver pipe efficiency identified by green color. In graph we can see that when aperture diameter of the collector at 1.5m before modifying where efficiency was near 0.752. When increasing the aperture diameter we saw that efficiency increases. After modifying the receiver pipe we see that at same diameter the efficiency is higher than the full rounded receiver. Also see that when we are increasing diameter efficiency increases.

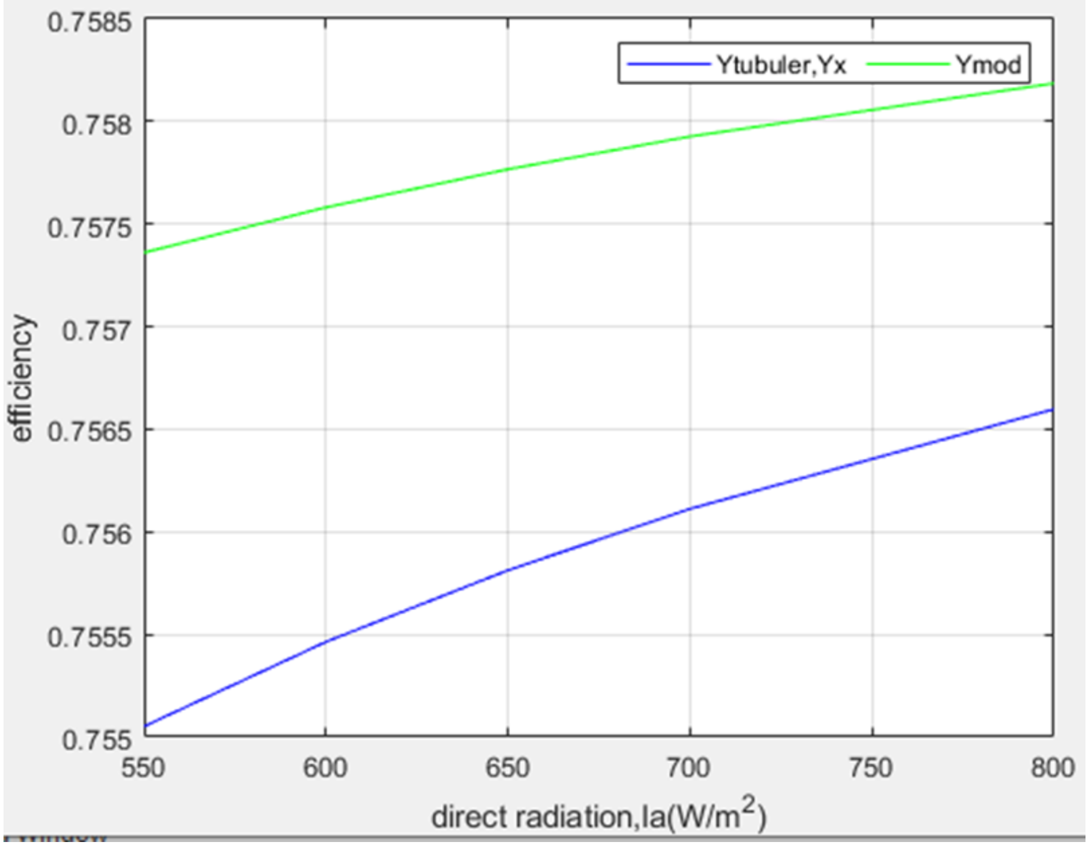


Fig. (3.2): show the relation between direct radiation and efficiency

In Fig. (3.2), where x -axis is direct radiation, $I_a$ and y-axis is efficiency. Before modifying it is seen that, when direct radiation is 550 W/m^2 the same time the efficiency was about 0.755. After modifying the receiver we see in same radiation the efficiency is near 0.7575. we also see that, when increasing radiation the efficiency has increased. Seeing in graph by increasing radiation 600 W/m^2 then it increases the efficiency.

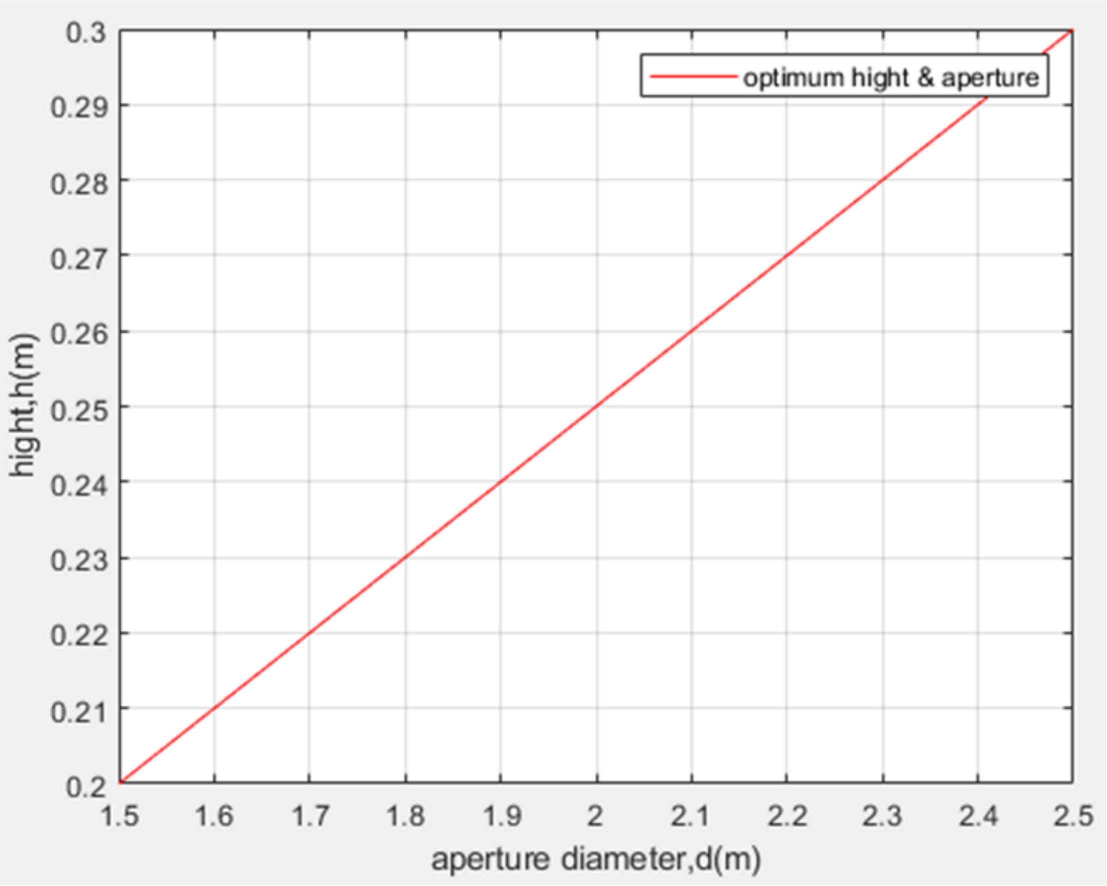


Fig. (3.3): illustrate aperture diameter with height

In Fig. (3.3) we find from graphical analysis the aperture diameter and height in linear line. By analyzing data, we have seen that increasing aperture data same time increase height. But previous paper it had shown that height and aperture data are same level.

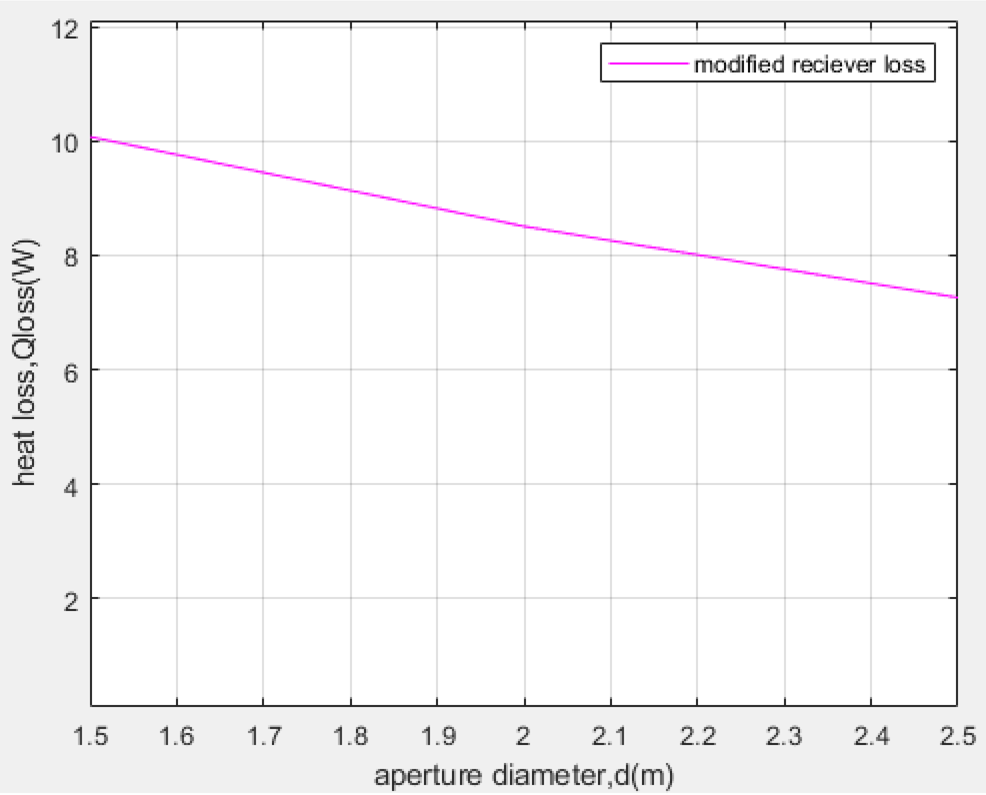


Fig. (3.4): relation between aperture diameter and heat loss

In this Fig. (3.4) relation between the modified receiver pipe heat loss, $Q_{loss}$ and the aperture diameter, d. In this figure we see that, when aperture diameter at 1.5 m at this time heat loss is 10W. Next step when we increase aperture the heat loss has decreased. So from Fig. (3.4) we can come to a decision that the heat loss of the modified receiver decreases due to increase of aperture diameter. On the other hand the heat loss in the receiver before modification remains constant with the change of aperture diameter.

## 3.3 Summary

In this chapter, we basically show in graphical relation between efficiency, the aperture diameter, height, optical loss, radiation by analyzed & simulated data. In here we also compare between previous simulation result and us. We have discussed simulating and analyzing data.

# CHAPTER 4

# RESULTS AND DISCUSSIONS

## 4.1 Introduction

Every work has a result. Result represents the outcome of the thesis which may contain improvement or success of the research. In this research we have analyzed the performance of parabolic trough collector PTC before modification of the receiver. Then we have modified the receiver and analyzed the efficiency after modification. And the improvement of the efficiency of the receiver is the result of this thesis. And we have illustrated the mathematical relation between aperture diameter, d and height, h.

In this chapter we firstly show the improvement of efficiency. Before modifying receiver according to aperture diameter in Fig. (3.1) efficiency was near 75.2% and after modification it's efficiency is near 75.4%. We have increased 0.20% efficiency according to aperture diameter. We have also increased 0.25% efficiency according to direct radiation Fig. (3.2).

## 4.2 Tabular analysis

We have used the equations above to calculate different values. At first we assume different values of d and h using these values we have calculated the rim angle, area of the receiver surface, width of the receiver to modify and the surface area of the modified receiver shown in table (4.1)

Table (4.1): Shows the geometrical concentration for many solar concentration.

| d(m) | h(m) | f(m) | ψ rim | Surface area of receiver Pipe Atub | Wd | Modified Area Amod |
|---|---|---|---|---|---|---|
| 1.5 | 0.20 | 0.46<br>88 | 1.3495 | 0.2136 | 0.033 | 0.1581 |
| 2 | 0.25 | 0.833 | 1.0808 | 0.2136 | 0.030 | 0.1335 |
| 2.5 | 0.30 | 1.302 | 0.890 | 0.2136 | 0.0265 | 0.1139 |

In table (4.2) we have shown the constant values $T_r$, psm, $T_g$, S taken in our next calculation. In this tabular analysis heat loss, $Q_{lossx}$ of the receiver and efficiency, $Y_x$ of the whole PTC is calculated with the values of the area of the receiver, $A_{tub}$ before modification. And the modified heat loss, $Q_{loss}$ and efficiency, $Y_{mod}$ is calculated with modified receiver area, $A_{mod}$. Both the values of $A_{tub}$ and $A_{mod}$ is gained from table (4.1)

Table 4.2: Show the energy lose, useful energy and efficiency of solar concentration

| Tr | Q loss | Psm | Tg | Qw | Q out | Q lossx | Yx | Y mod |
|---|---|---|---|---|---|---|---|---|
| 6.5 | 10.07 | 0.80 | 1 | 1.254 | 1.2439 | 13.608 | 0.7518 | 0.7539 |
| 6.5 | 8.50 | 0.80 | 1 | 1.672 | 1.66636 | 13.608 | 0.7538 | 0.7561 |
| 6.5 | 7.256 | 0.80 | 1 | 2.09 | 2.0827 | 13.608 | 0.7551 | 0.7574 |

Table 4.3: Shows the changes of unmodified, $Y_x$ and modified efficiency, $Y_{mod}$ of PTC with direct radiation

| Direct radiation(W/m^2) | Unmodified efficiency | Modified efficiency |
|---|---|---|
| 550 | 0.7551 | 0.7574 |
| 600 | 0.7555 | 0.7576 |
| 650 | 0.7558 | 0.7578 |
| 700 | 0.7561 | 0.7579 |
| 750 | 0.7564 | 0.7581 |
| 800 | 0.7566 | 0.7582 |

## 4.3 Summary

We have calculated the result of efficiency and determine the receiver efficiency in this section. Some of date for calculation of collector efficiency have discussed in table (4.1) and (4.2).
We discuss the improvement of efficiency what we have found.

# CHAPTER 5

# CONCLUSIONS

## 5.1 Conclusions

All over the world use of renewable energy is increasing day by day. Specially harness of solar power is most popular. In this thesis we have analyzed the performance of parabolic trough collector considering the full rounded receiver with MATLAB. Then observed how to reduce the heat loss surface area. We have modified the receiver by reducing the portion of surface area out of rim angle and improved the efficiency of PTC. And illustrated how the heat loss of the modified receiver changes with aperture diameter, height and rim angle in this thesis.

## 5.2 Limitations of the Work

In this thesis values of some constant we have taken which depends on the materials may be a little bit different. But it will not effect on the theory of modification of the receiver. The values of the constant may change in another environmental condition.

## 5.3 Future Scopes of the Work

In near future our main source of energy will be solar energy. We may see some opportunity for working on concentrating solar collector like reducing of heat loss, increase of solar radiation etc. In Bangladesh CSC can be used to replace photovoltaic cell which is expensive and harmful for environment. Experimental study on the efficiency of PTC in Bangladesh is expected.

# REFERENCES

[1] Duffie J.A. and Beckman.W., Solar energy Thermal Processes. John Wiley, New York, 1974

[2]. Garg. H.P. Advances in Solar Energy Technology, Vol. 3 chapter 1, D. Reidel Publishing Co., Holland, 1987.

[3]. Design of Solar dish concentration by using MATLAB program and Calculation of geometrical concentration parameters and heat transfer ISSN: 1813 – 1662. Tikrit Journal of pure science (2015).

[4] Performance of Concentrated Solar Collectors Studying the absorber pipe outlet temperature variations falnaimat@uaeu.ac.ae (5th International Conference on Renewable Energy) (2018)

[5] Folaranmi ," Design, Construction and Testing of a Parabolic Solar Steam Generator". Journal of Practices and Technologies ISSN 1583-1078. Vol-14, p 115-133 (2009).

# APPENDIX

## Program Code

```
clear all
d=[1.5;2;2.5] %  (d(m)) input aperture
h=[0.2;0.25;0.3]% (h(m)) input depth
j=d.^2
k=16.*h
F=j/k
W=(F)./(d)
l=2*W.^2
G=(l)-1/8
H=(W)./G
Ri = atan(H) %rim angel
a=2.*pi-2.*ri % angel out of focus
L=2 %length of receiver (m)
Dro=0.034 %diameter of reciver tube(m)
r =  Dro./2
Asur=L.*a.*r %surface area of tube out of focal area
Atub=L.*2.*pi.*r %surface area of reciever fully tube
Wd=2.*(sin(a./2).*r) %wide of rectangle out of focus
Arec=L.*Wd
Amod=(Atub-Asur)+Arec
Ar=Amod
UL=9.8 %considering radiation coefficient
Tr=6.5000
Qloss=Ar.*UL.*Tr % Q Loss for modified receiver
ar=0.95 %absorbance of receiver
psm=0.8 %reflectence of reflector
```

```
Tg=1 %transmittance of glass covering reciever
s=1 %fraction collector aperture
Ia=550 %radiation falling on reflector W/m^2
Aa=d.*L %area of aparture
Qw=psm.*Tg.*aar.*s.*Aa.*Ia %(Q opt w) output
Qout=Qw-Qloss  %(Q out)out put for modified
Qlossx=Atub.*UL.*Tr %loss of full tubular receiver
Yx=(Qw-Qlossx)./(Aa.*Ia) %efficiency for full tubular receiver
Ymod=(Qout)./(Aa.*Ia) %efficiency
x=d
y1=Yx
y2=Ymod
plot(x,y1,'--b',x,y2,'-g')
xlabel('aperture diameter')
ylabel('efficiency')
legend('Ycylinder','Ymod')
```