Design and Analysis of Fixed Point and Linear Focus Concentration on Horizontal Cylindrical External Receiver using Parabolic Dish

Jeniwer Bimro N[1], Praveen Kumar V[3]
[1,3]M.Tech (Energy System), Post-Graduate Scholar,
University of Petroleum & Energy Studies,
Dehradun, India

Madhu Sharma[2]
[2]College of Engineering Studies, Assistant Professor,
University of Petroleum & Energy Studies,
Dehradun, India

***Abstract*— A Parabolic dish type of concentrator which is one of the widely used effective energy conversion technologies in concentrated solar power for various thermal application. Parabolic dish is meant for point focus concentration but in this paper the approach is to use it for linear focus. A cylindrical External Receiver design is modelled for such concentrator, then it is focused by solar radiation under condition of both point focus and linear focus on horizontally placed receiver body by adjusting the focal length between concentrator and receiver. And the steady state thermal analysis is done by simulation source so that the heat transfer properties like heat flux and temperature distribution of such receiver material can be studied for further improvement in the existing design of the system.**

Keywords—Concentrated Solar Power, Parabolic Dish, External Receiver, Point Focus, Linear Focus

I. INTRODUCTION

India is located in the equatorial sun belt of the earth which is empowered with abundant solar energy with the capability of generating about 5,000 trillion kilowatts of clean energy with around 250- 300 days of clear sun days annually with 4-7 KWh per m² per day. So it this energy is used effectively, then it can reduce the energy deficit condition and also the low carbon emission.

There are two type of technologies used in utilization of solar energy to produce electricity – PV and CSP, where CSP leading on PV for utility-scale power generation, because of its maturity and relative cost. CSP, a commercially available technology utilize direct sunlight and mirrors to boil water instead of a fossil fuel as a heat source for producing steam and drive conventional steam turbines. The are various of advantages there on CSP over PV like CSP units can be constructed with an integral thermal energy storage system, thereby providing the capability of generating electricity into the evening hours and also solar thermal plants can be equipped with auxiliary burners in order to produce electricity when sunlight is unavailable. Other considerations are that of thermodynamic efficiency and cost of energy per unit area. The converting solar heat into electricity correspond to an efficiency of about 42% against 15% of PV systems but also, to produce the same energy.

The Concentrated solar power systems namely parabolic trough, linear Fresnel reflector, power tower and parabolic dish are capable of producing thermal power. Among the CSP technologies, parabolic dish collector is recognized as the most efficient system for energy conversion. It consists of mirrors arranged in the shape of parabola and concentrates the incident beam irradiation onto a small region called focal point where the receiver needs to be located. The concentrated solar irradiation is absorbed by the receiver and transferred to the working fluid that flows through the receiver.

The receiver of the parabolic dish concentrator has to be well designed such that it can achieve high temperatures with minimal heat losses. Basically there are two types of receiver design widely used: external receiver and cavity receiver. External receiver are basically a cylindrical shape with length to diameter ratio is 1 and the heat flux will be directly incident of the receiver system which contains working fluid.

The external receiver will be preferred over cavity receiver for some application due to following reasons:

- Receiver has a wide acceptance angle but cavity receiver has maximum half acceptance angle of 60 degree
- Cavity receiver is supported on the external surface while external receiver is supported internally which make it structure easy and light
- Easy to repair the external receiver
- Easy to design minimal constraint support and structure for external receiver panel
- Easy to operate external receiver

II. DESIGN OF EXTERNAL RECEIVER

The receiver is the part of the system that converts solar radiation to heat energy in a working fluid. The receiver consists of an absorber, heat exchanger and possibly heat storage. The absorber is the impinging surface for reflected solar radiation to strike. Radiation is absorbed into the absorber material as heat. The heat exchanger transfers the energy to a working fluid that carries the energy out of the receiver.

So a simple cylindrical external receiver is designed in which multiple annular tube of same diameter is done to increase the surface area which act as the heat exchanger for effective heat transfer. And design is also included with flanges to couple the multi annular pipe into one pipe for easy usage. Fig. 1 below shows the Conceptual Design of

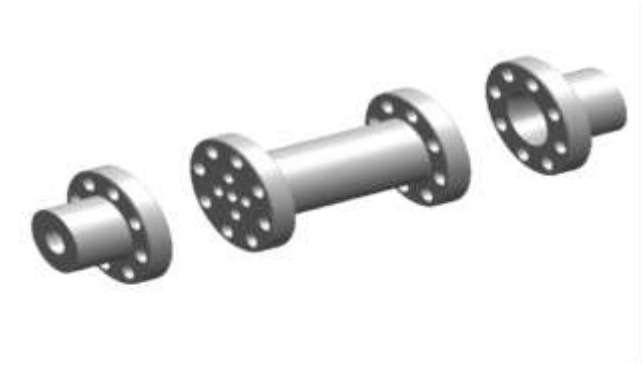

Fig. 1 Conceptual Design

the receiver which is designed using the modelling software SOLIDWORKS.

III. Thermal Analysis on the Receiver

The requirement of thermal analysis in the receiver design is to check whether the design can withstand thermal stress that act on the receiver when temperature applied on the surface. The thermal output from the parabolic dish can be applied in two way i.e. point focus and line focus. So the model is tested using ANSYS in both the condition to know the thermal stress that taken place in both total heat flux and temperature distribution. Total thermal flux is the rate of heat energy transfer through a given surface.

Assumption done for Receiver model to do thermal analysis:

- No Fluid flow in the Receiver
- No heat loss by convection and radiation
- Length of the receiver = 1 m
- Inner radius of the receiver = 0.25 m
- Outer radius of the receiver = 0.50 m
- Material Used for receiver = Steel
- Temperature act on the receiver = 200 ^{0}C

A. Point Focus on the Receiver

In this simulation, the thermal output from the parabolic dish is incident toward all over a single point at the midpoint of the receiver by adjusting the focal length between the dish and receiver and the following result are obtained. Fig. 2 shows the Point focus on the Receiver, Fig. 3 shows the Total Heat Flux act on the receiver by uniform Focus and Fig. 4 shows the Temperature Distribution on the receiver by Uniform Focus.

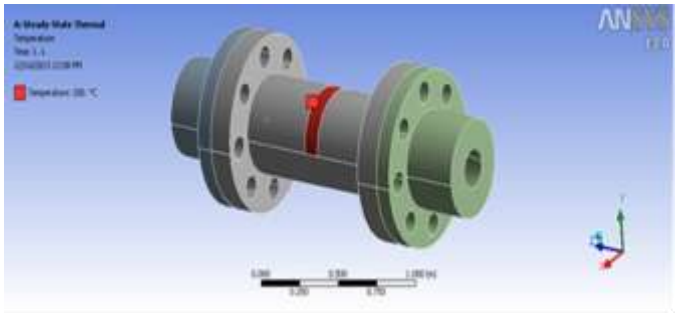

Fig. 2 Point Focus

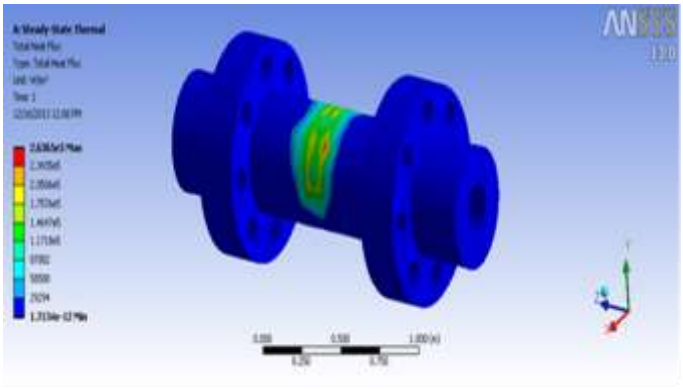

Fig. 3 Total Heat Flux by point Focus

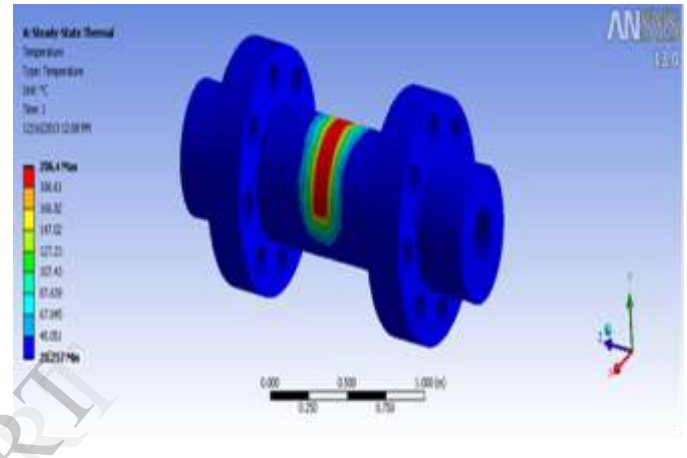

Fig. 4 Thermal Distribution by Point Focus

B. Linear Focus on the Receiver

In this simulation, the thermal output from the parabolic dish is incident toward all over the upper surface of the receiver by adjusting the focal length between the dish and receiver and the following result are obtained. Fig. 5 shows the Linear focus on the Receiver, Fig. 6 shows the Total Heat Flux act on the receiver by Linear Focus and Fig. 7 shows the Temperature Distribution on the receiver by Linear Focus.

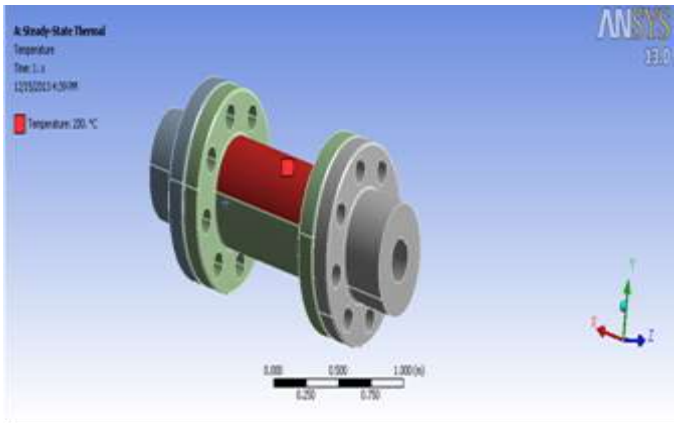

Fig. 5 Linear Focus

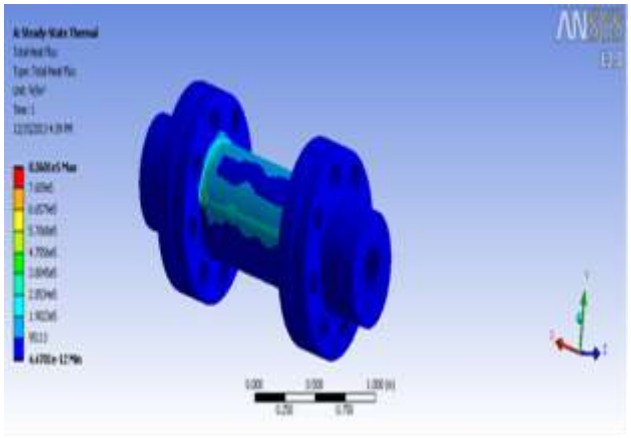

Fig. 6 Total Heat Flux by linear focus

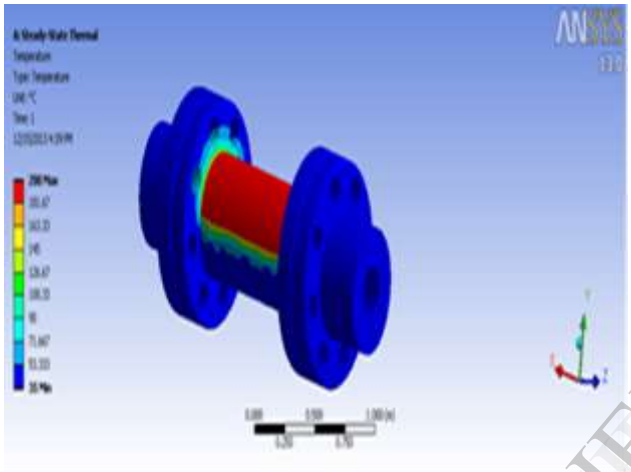

Fig. 7 Thermal Distribution by linear Focus

IV. RESULT

By the Thermal analysis on the Surface of the receiver various result has been observed:

- From Fig. 3 and Fig. 4 we found that Point Focus of about 200 ^{0}C on the center of the receiver result in heat flux about 2.0506* 10^5 W/m² on the focusing Receiver body and there is no thermal stress in the flange joints. And also there will be no loss in heat by conduction of heat to the flange joints.
- From Fig. 6 and Fig. 7 Linear Focus of about 200 ^{0}C on the upper surface of the receiver result in formation of about 3.8045*10^5 W/m² thermal stress and Temperature of about 90 ^{0}C to 126 ^{0}C act on the flange joints which result in degradation of the receiver material by thermal stress act on the joints and heat loss.

V. CONCLUSION

A Cylindrical External Receiver is designed for parabolic dish concentrator. Heat flux and thermal Distribution phenomenon which act on the receiver body by concentrating the solar radiation by both point focus and linear focus through analysis software ANSYS. And it is observed that using of Point Focus concentration will be more advantages than linear focus concentration because of the degradation of the receiver body by thermal stress which act on the flange joints which leads in heat loss and reduction of receiver life cycle.

REFERENCES

1. Lu Jianfeng, Ding Jing, Yang Jianping, Heat transfer performance of an external receiver pipe under unilateral concentrated solar radiation, Solar Energy, Volume 84, Issue 11, November 2010, Pages 1879-1887
2. Nicholas Boerema, Graham Morrison, Robert Taylor, Gary Rosengarten, High temperature solar thermal central-receiver billboard design, Solar Energy, Volume 97, November 2013, Pages 356-368
3. K.S. Reddy, G. Veershetty, Viability analysis of solar parabolic dish stand-alone power plant for Indian conditions, Applied Energy, Volume 102, February 2013, Pages 908-922
4. Shuang-Ying Wu, Lan Xiao, Yiding Cao, You-Rong Li, Convection heat loss from cavity receiver in parabolic dish solar thermal power system: A review, Solar Energy, Volume 84, Issue 8, August 2010, Pages 1342-1355
5. Shuang-Ying Wu, Lan Xiao, Yiding Cao, You-Rong Li, A parabolic dish/AMTEC solar thermal power system and its performance evaluation, Applied Energy, Volume 87, Issue 2, February 2010, Pages 452-462
6. Safa Skouri, Salwa Bouadila, Mohieddine Ben Salah, Sassi Ben Nasrallah, Comparative study of different means of concentrated solar flux measurement of solar parabolic dish, Energy Conversion and Management, Volume 76, December 2013, Pages 1043-1052
7. Leonard D. Jaffe, Test results on parabolic dish concentrators for solar thermal power systems, Solar Energy, Volume 42, Issue 2, 1989, Pages 173-187
8. Oliver Garbrecht, Faruk Al-Sibai, Reinhold Kneer, Kai Wieghardt, CFD-simulation of a new receiver design for a molten salt solar power tower, Solar Energy, Volume 90, April 2013, Pages 94-106
9. Tom Melchior, Christopher Perkins, Alan W. Weimer, Aldo Steinfeld, A cavity-receiver containing a tubular absorber for high temperature thermochemical processing using concentrated solar energy, International Journal of Thermal Sciences, Volume 47, Issue 11, November 2008, Pages 1496-1503
10. Richard B. Bannerot, John R. Howell, and Gary C. Vliet. Solar-Thermal Energy Systems, Analysis and Design. McGraw-Hill,Inc.,1982