DESIGN AND EXPERIMENTAL STUDY ON SOLAR DISH COLLECTOR FOR STIRLING ENGINE

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Abstract:

Solar energy is the most promising energy in today's world as it is most abundant and ecofriendly. It is an important source of renewable energy resource. To utilize such energy, we require a concentrating solar collector. It optically reflects and focuses the suns incident solar energy onto a small receiving area using mirrors or lenses is called a Solar Dish Collector. The Parabolic Dish Solar Collector technology is very useful as it is used for approximately all solar energy applications such as steam and power generation, water heating, air heating etc. In this paper, design of a parabolic solar dish collector is accomplished and performs experimental study of concentrating solar collector used in Stirling engine.

Keywords: Solar energy, solar dish collector, stirling engine.

1. INTRODUCTION

The world energy requirements are now completely depend on non-renewable energy resources such as oil, coal and natural gas. As these were going to depleted in near future, we need to search for an alternative energy resources such as renewable energy sources. Renewable resources are an important aspect of sustainability, the most frequently used renewable resources are biomass, water, geothermal, wind and solar. Unlike fossil fuels, we can regenerate or replenish these resources. The selection of type of energy source depends on economic, environmental and safety considerations. Solar energy is considered to be more suitable on the basis of environmental and safety considerations. The solar energy is the most abundant, permanent and free of cost. The energy from the sun cannot be used directly such as for air heating, hot water generation, electricity and in drying applications. Solar collector is one of the main components in a solar thermal system. It absorbs the solar radiation as heat and transfers it to the heat transport fluid. The collected solar energy will be transferred either for hot water generation or space heating or to a thermal storage tank etc.

Based on the way of solar collection, the solar collectors are classified into non concentrated or stationary solar collector and concentrated type. A non-concentrated solar collector has the same area for intercepting and absorbing solar radiation. They are permanently fixed in position and do not track the sun, three set of collectors fall in this category: the flat plate collectors (FPC), compound parabolic collectors (CPC), and the evacuated tube collectors (ETC) single axis tracking and two axis tracking. While concentrated type will have a concave shaped reflective surface for intercepting radiation and it will be focused to a small area and thus increases radiation flux. Another advantage of concentrated collectors is that higher temperature can be achieved than that of non-

concentrated collectors.

The three main types of concentrated collectors are parabolic dish, parabolic trough and tower receiver. Among them, parabolic dish collector is one of the developing technologies. Since it has small absorber area, it has less radiation losses. Stirling engines are a type of reciprocating external heatengine that uses one or more pistons to achieve useful work through some input of heat from an external source.Stirling engines use the same gas over and over, unlike internal combustion engines which constantly intake and exhaust the gas. Also, they do not use explosions like normal gasoline engines, therefore they are very quiet.

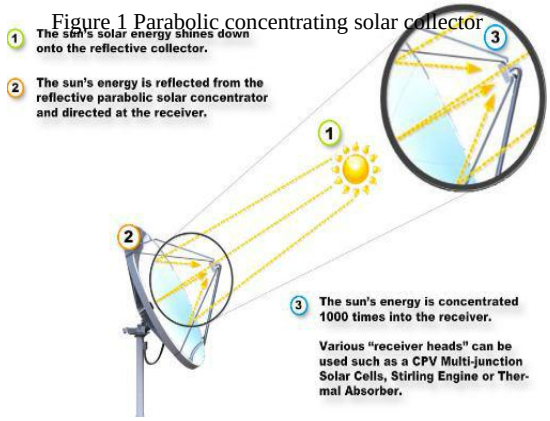


Figure 1 Parabolic concentrating solar collector

Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium, it is the major component of any solar energy systems. Using parabolic dishes is a well-tested approach to concentrate solar radiation, and was an early experimental tool at many locations worldwide. The optical efficiency of parabolic dishes is considerably higher than that of parabolic trough, Linear Fresnel reflector or Power tower systems because the mirror is always pointed directly at the sun. In this study, the reflector for the parabolic concentrator is made is made of a mirror; the interior of the parabolic concentrator is covered with the reflective mirrors, which reflect the solar rays on the face of a receiver placed at the focal position of the parabolic concentrator.

2. A REVIEW OF INVESTIGATIONS

Lifang Li et al. [1] developed a new concept for designing and fabricating large parabolic dish. The dish mirror was formed from several optimal-shaped thin flat metal petals with highly reflective surfaces. Attached to the rear surface of the mirror petals were several thin layers whose shapes optimized to reflective petals form into a parabola when their ends were pulled toward each other by cables or rods.

B. Ricardo, V .Nicolas, E. C. Alma , S. Daniel and P. Guillermo [2] (2012) developed a mathematical model of a system consisting of parabolic dish collector with cavity receiver and stirling engine at its focal point.

Atul [3] (2012) had performed an experimental study of parabolic dish solar water heater with coated and non-coated receiver. The system consists of parabolic dish of 1.4m diameter with aluminium mirrors and cone shaped helical coil made of copper and is coated with nickel chrome is placed at its focal point. The experimental results showed that with the increase in mass flow rate, the total heat loss increased and thus the efficiency of the system also reduced. In this paper a parabolic dish collector system was designed for hot water generation and simulation of dish collector was also done.

El Ouederni et al [4] presented an experimental study of a parabolic solar concentrator, the solar flux and temperature distribution on the receiver was carried out, the results describe correctly the awaited physical phenomena.

Saleh Ali et al. [5] have presented an interesting study that aims to develop a 3-D static solar concentrator that can be used as a low cost technology for production of portable hot water in rural India. They used the ray tracing software for evaluation of the optical performance of a static 3-D elliptical hyperboloid concentrator

Pavlović et al. [6] presented a mathematical and physical model of the new offset type parabolic concentrator with a spiral coil absorber

for calculating its optical performance. The designed parabolic concentrator is a low cost solar concentrator for medium temperature applications.

G. Shiva, G. Barat, H. T. Teymour and B. Ahmad [7] calculated the thermal efficiency of a point focus parabolic dish steam generating system under varying climatic conditions. A parabolic dish collector with cylindrical receiver was used for steam or hot water generation. A performance analysis was done over an entire year and it was found that as the absorber temperature was increased from 150 to 2000C, the convective heat loss coefficient was increased by about 25 to 41%

M. R. A. Ghani, A. Rosnani, G. K. Chin, R.H. Siti and Z. Jano [8] (2014) had done an analysis to determine about influence of material reflectivity and aperture size on the heat transfer rate from concentrator to receiver in parabolic dish systems. Among the different reflective materials, silver has highest reflectivity (96%) followed by aluminium (92%), iron sheet (87%) and stainless steel (67%).

Eswaramoorthy et al. [9] conducted an experiment on small scale solar parabolic dish thermoelectric generator. They fabricated solar parabolic dish collector using an unused satellite dish antenna fitted with polished aluminum sheet as concentratorsurface. The concentrated solar radiation and water cooled heat sink was the driving potential to generate electricity; they studied various operating parameters like receiver plate temperature, power output and conversion efficiency with respect to solar radiation. From the experiment it was found that the receiver plate temperature was significantly affecting the power output.

Yadav et al. [10] investigated a solar powered air heating system using parabolic trough collector using different reflectors. In this experiment, the reflected solar radiations were focused on absorber tube which was placed at focal length of the parabolic trough. In this setup, air was used as working fluid which collects the heat from absorber tube. He used three different reflectors for analysis and they observed that performance of Aluminum sheet is excellent as compare to steel sheet and Aluminum foil as reflector.

3.DESIGN OF PARABOLIC SOLAR COLLECTOR

In a parabola, all the incoming solar rays from a light source are reflected back to the focal point of the parabola. The solar concentrator was developed using a semi-spherical surface covered with many small sections of mirrors to form a segmented, spherical concentrator. The frame of the parabola was made from a mini dish satellite receiver plate. The solar concentrator takes advantage of all incoming solar radiation and concentrates it at the focus.

Figure 2 shows the parabolic dish concentrator parameters. The equation for the parabola in cylindrical coordinates is given by:

----------(1)

The diameter of the opening parabolic surface is d, and the focal distance of the parabola is f. the surface of this parabola is given by :

------- (2)

The cross-section of the opening is:

----------(3)

To calculate the focal distance, the following equation is used

----------(4)

Where

h is the height of the dish d is the diameter of the dish f is the focal point

F is the load

r is the radius

Figure 2 parameters of parabolic dish collector

The geometric concentration of this model is

$$C_g = \frac{S_0}{S_a} \quad \text{----------(5)}$$

Characteristics of the solar concentrator

Diameter of opening of the parabola	2.2m
Surface collecting of the parabola	3.8m2
Depth of the parabola	0.4m
Focal distance, f	0.75m

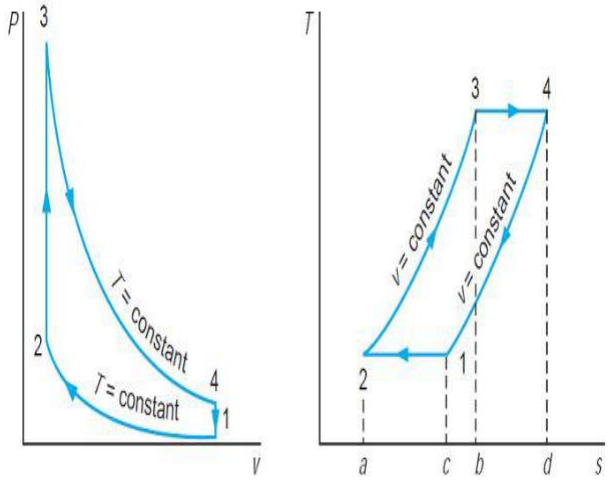
Table 1 characteristics of solar concentrator

4. USE OF SOLAR DISH COLLECTOR IN STIRLING ENGINE

Stirling engines are a type of reciprocating external heat engine that uses one or more pistons to achieve useful work through some input of heat from an external source. Stirling engines use the same gas over and over, unlike internal combustion engines which constantly intake and exhaust the gas. Also, they do not use explosions like normal gasoline engines, therefore they are very quiet. Solar energy is one of the famous renewable energy sources that can be used as an input energy source for Stirling engine. Solar Stirling systems convert the thermal energy in solar radiation to mechanical energy and then to electrical energy. Solar Stirling systems have demonstrated the highest efficiency of any solar power generation system by converting nearly 30% of direct-normal incident solar radiation into electricity after accounting for power losses. Solar Stirling system produces electricity by using parabolic collector and Stirling engine. Dish/Stirling concentrating solar power (CSP) converts solar heat into electricity by focusing solar radiation onto a receiver containing a heat-engine known as a Stirling engine.

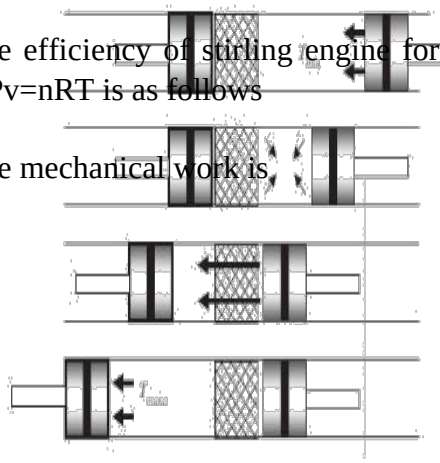
4.1 Thermodynamics of stirling engine

The cycle consist of four processes namely isothermal compression and expansion and isentropic heat addition and rejection processes in the sequence. The below Figure 3 shows the PV and TS diagrams and Figure 4 shows the operating cycles of the stirling engine schematically.



4.2 Efficiency of Stirling engine

The efficiency of stirling engine for an ideal gas Pv=nRT is as follows



The mechanical work is

On the isothermal curves the change in the internal energy is zero.

The efficiency is then

--------(6)

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So final efficiency in terms of temperature and volume is

-------(7)

It is smaller than the efficiency of the Carnot cycle. But it should be equal to it if all processes are done reversibly. The efficiency of stirling engine lies between 15% to 25% if it is run with motors. Stirling engines have the advantage to use any heat source (i.e., renewable energy sources, especially solar), to be quieter and to be more reliable and with less maintenance costs depending of their design.

4.3 Solar stirling engine

Solar collectors include a special type of solar engine built into the solar receiver. This so called heat engine, is driven by the solar thermal energy converting it into rotational mechanical output by the cyclic compression of the engine's working gas, which is usually helium or hydrogen. The mechanical power that is produced is then used to drive an electrical generator or alternator producing a significant amount of AC electrical power. These types of solar heat engines are commonly called a Stirling Engine.

Stirling engines belong to the group of closed-loop hot-gas machines that work on the basic principal that a gas will change its volume when subjected to a heat change producing an isothermal compression of the cold and isothermal expansion of the hot gas at a constant volume. This temperature change, and thus the continuous operation of the engine, is produced by moving the gas between two different chambers producing a constantly high and a constantly low temperature.

The efficiency and operation of the Stirling heat engine is determined by the operating temperature of the gas which is kept between 650oC and 750oC. To constantly keep the reflected solar radiation at the correct focal point and temperature during the whole of the day, a two-axis sun tracking system is used with the dish which continuously rotates the solar concentrator.

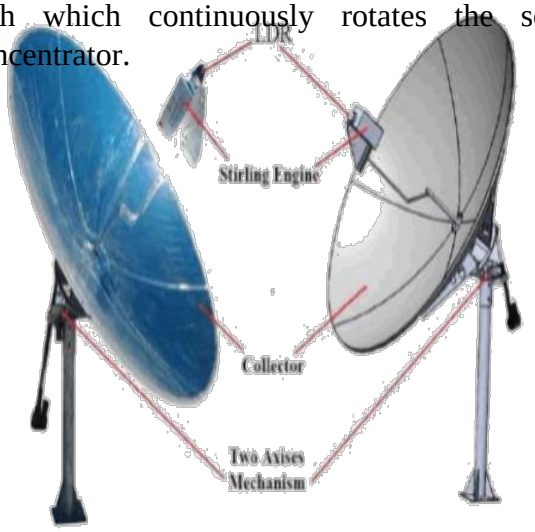

Figure 5 Solar stirling components

5. SUMMARY

The solar stirling engine dish convert sunlight in most climates, however they have proven to be most effective in hot and dry climates, where the system converts one third of the solar energy into electricity. It is an efficient solar stirling engine technology that combines a both low environmental impact and low Levelized Cost of Energy, making it very competitive with all alternative electrical energy technologies. Ripasso energy AB is the company from Sweden, designed a Solar stirling dish module that set a new efficiency world record of 32% when compared to normally operated stirling engine. Considering that recent reports and negotiations point towards the need to reduce carbon emissions, solar stirling engine.

Today we are moving toward the use of natural resource for the energy generation. Stirling engine is one of the effective and efficient device to convert solar energy into mechanical work. It is the best device as compare to other solar device in power generation.

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6. RESULT

Today worldwide concerns about the best way of utilization of the natural energy and developing technique to reduce pollution. Stirling engine is one of the best example of heat engine which convert heat energy into mechanical work. Stirling engine is also operated by heat from sunrays. The solar Stirling have better efficiency than that of other solar device like photovoltaic cell, solar panel etc.

REFERENCES

1. Lifang Li, Steven Dubowsky "A new design approach for solar concentrating parabolic dish based on optimized

flexible petals", Mechanism and Machine Theory 46(2011) pp 1536-1548

2. B. Ricardo, V .Nicolas, E. C. Alma, S.Daniel and P. Guillermo, "Mathematical model for the study and design of a solar dish collector with cavity receiver for its application in Stirling engines," Journal of Mechanical Science and Technology, vol.26, pp.3311-3321, May 2012.

3. A. S. Atul, "Experimental Investigation of variation of mass flow rate on the performance of parabolic dish collector with nickel chrome coated receiver," International Journal of Sustainable Energy Development, vol.1, pp.29-35, December 2012.

4. A.R. El-Ouederni, et al., Experimental Study of a parabolic solar concentrator. Revue des Energies Renouvelables 2009. 12(3): p. 395-404.

5. Saleh Ali, I. M., et al., An Optical Analysis of a Static 3-D Solar Concentrator, Solar Energy, 88 (2013), Feb., pp. 57-70

6. Pavlović, S., et al., Optical Model and

Numerical Simulation of the New Offset Type Parabolic Concen-trator with Two Types of Solar Receivers, Facta Universitatis, Series: Mechanical Engineering, 13 (2015), 2, pp. 169-180

7. G. Shiva, G. Barat, H. T. Teymour and B. Ahmad, "Thermal performance of a point-focus solar steam generating

system" Annual International Conference on Mechanical Engineering,

May 2013.

8. M. R. A. Ghani, A. Rosnani , G.K. Chin, R.H. Siti and Z. Jano, "The Influence of concentrator size, reflective material and solar irradiance on the parabolic dish heat transfer," Indian Journal of Science and Technology, vol.7, pp.1454-1460, September 2014.

9. M.Eswaramoorthy1, .Shanmugam2, A R. Veerappan "Experimental Study on Solar Parabolic Dish Thermoelectric

Generator", International Journal of Energy Engineering (IJEE)Jun. 2013, Vol. 3 Iss. 3, PP. 62-66.

10. Avadhesh Yadav, Manoj Kumar, Balram "Experimental Study and Analysis of Parabolic trough Collector with Various Reflectors" International

Journal of Mathematical, Computational, Physical and Quantum Engineering Vol:7 No:12, 2013 pp1161-1165