Alternative Solar Sterling Power Generation

PVSR Vinay Kumar Kotnani and Dr.V.Suryanarayana
Dept. of Mechanical Engineering
Ramachandra College of Engineering
Eluru, Andhra Pradesh, India
vs@rcee.ac.in

Abstract— **The purpose of this research was to design, create, and construct a Dish Stirling engine capable of producing between 9 and 12 volts of energy. Before deciding on a beta-type architecture centred on a single-cylinder air compressor, many concepts were examined. Due to limited sun exposure during the testing period, concentrated solar energy was evaluated as a possible heat source, although a kerosene burner had to be used if necessary. The systems for the heater, cooler, regenerator, flywheel, and piping were planned, fabricated, and assessed. When monitoring temperatures throughout the assembly, little instrumentation was used. Several tests were conducted on the engine prototype to increase its operating efficiency, and major issue areas were identified and efficiently handled. Future efforts will include testing a prototype of a Dish Stirling engine capable of producing between 9 and 12 volts of energy.**

Keywords- Dish-Stirling Technology, Solar Thermal Power Systems, Trough Systems

I. INTRODUCTION

A. *Dish-Stirling Technology*

With the reorganisation of utility markets, the creation of green power markets, and the rising global demand for distributed generation, the opportunities for small power systems ranging from a few kilowatts (kW) to several megawatts (MW) are expanding rapidly. In fact, Dish Stirling systems are now being used in pre-commercial settings. Solar thermal power systems, also known as concentrating solar power systems, use the heat produced by focusing and absorbing the sun's energy to drive a heat engine/generator and create electricity. Power-generating solar thermal systems include power tower, trough, and dish engine systems. Using linear parabolic concentrators, trough systems concentrate sunlight along the focal lines of the collectors. In a power tower system, a field of heliostats, which are two-axis tracking mirrors, reflect solar energy onto a receiver situated atop a central tower. Dish-engine systems, the third kind of solar thermal system, consist of a parabolic dish concentrator, a thermal receiver, and a power-generating heat engine/generator positioned at the focal point of the dish. Trough systems generate around 75 suns of concentration and operate at temperatures of approximately 400°C with an annual efficiency of approximately 10%. Dish-Stirling systems follow the sun and concentrate solar energy in a receiver cavity, where it is absorbed and delivered to a heat engine. Figure 1 depicts a Dish Stirling System with the major system components, the dish, the power conversion unit (PCU), etc. from the reference [1], U.S. Department of Energy, June 2003, we describe some of the background of Dish-Stirling Systems and present design and performance details for the four pre-commercial, prototype systems, currently being developed in the United States and Germany. We also provide some information on the development of innovative components for dish systems. A concave mirror, also known as a converging mirror, has an inwardly bulging reflecting surface (away from the incident light). Concave mirrors reflect light toward a single point of focus. They serve to concentrate light. In contrast to convex mirrors, concave mirrors produce multiple forms of images based on the object's distance from the mirror. These mirrors are referred to as "convergent mirrors" because they tend to gather light that strikes them, redirecting parallel incoming rays towards a focal point. Concave mirrors are used in lighting applications to collect light from a tiny source and guide it outward in a beam, as in torches, headlights, and spotlights, or to collect light from a vast area and focus it into a small point, as in concentrated solar power. Basic information related to Analysis of the Ray Tracing as well as Mirror Equation, Focal Length is taken from the websitehttps://en.wikipedia.org/wiki/Curved mirror which is the basis for selecting the Curved Mirror in relation to required focal point temperature.

B. ***Mirror equation, magnification, focal length, Ray Tracing***

The Gaussian mirror $1/d_o + 1/d_i = 1/f$ equation, The relationship between object distance and image distance and focal length is also known as the mirror and lens equation. Sign convention dictates that the focal length is positive for concave mirrors and negative for convex mirrors, and that and are positive when the object and image are in front of the mirror, respectively. (When the thing or picture is genuine, they are positive.) When the term is moved to the right side of the equation to solve for convex mirrors, the result is always a negative integer, indicating that the image distance is negative—the image is virtual and placed "behind" the mirror. This comports with the stated behaviour. Whether the picture produced by concave mirrors is virtual or real depends on the ratio of the object distance to the focal length. If the term is greater than the word, the term is positive and the picture is genuine. Aside from that, the phrase is negative and the picture is imaginary. Again, this verifies the indicated behaviour. The magnification of a mirror is calculated by dividing the height of the image by the height of the item being reflected by *bym* = h_i / h_o = d_o / d_i. By convention, the picture appears vertical if the resultant magnification is positive. Negative magnification results in an inverted picture (upside down). Regarding Ray Tracing, the mathematical treatment is performed using the paraxial approximation, which means that a spherical mirror is a parabolic reflector under the first approximation. This image displays the ray matrix for the concave reflecting surface of a spherical mirror. The element of the matrix where the sun protects the optical device's focus point. If you want to construct a parabolic cooker, you will need to locate the cooker's focal point in order to position the water container where the sun's rays are greatest. In the Focus of Parabola presentation from Humboldt State University, you may raise or decrease the parabola's curvature to see how the focus point varies as the dish's depth varies.

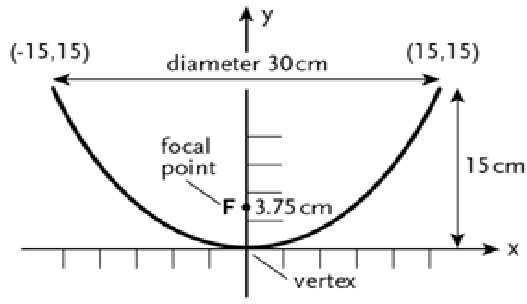

Fig: 1: Focus of Parabola

Determine the following equation related to focal point using the below equation taken from www.ies.co.jp/math/java/conics/focus/focus.html or www.ies.co

i.e. $f = x^2 /4a$.

To find the focal point of a parabola, follow these 4 steps:

Step 1: Measure the longest diameter (width) of the parabola at its rim. Step 2: Divide the diameter by two to determine the radius (x) and square the result (x^2). Step 3: Measure the depth of the parabola (a) at its vertex and multiply it by 4 (4a).

Step 4: Divide the answer from Step 2 by the answer to Step 3 (x^2 /4a). The answer is the distance from the vertex of the parabola to its focal point and finding the focal P.

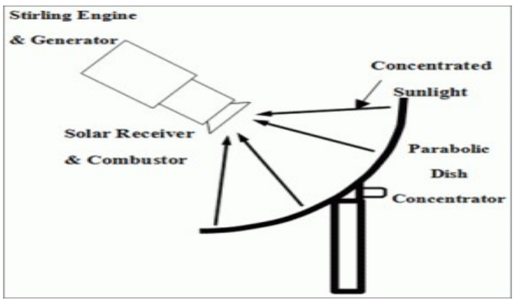

Fig 2: Placing Stirling engine at focal point of concave lens

C. Modeling Based on Focal Length:

Determining the focal length of a parabolic dish (axi-symmetric, circular) using the below formula as follows:

f = (D * D) / (16 * c)

Where,

f =Focal length,

c=Depth,

D=Diameter

Measure the depth using a tight fishing line across the dish and a rule to measure depth c.

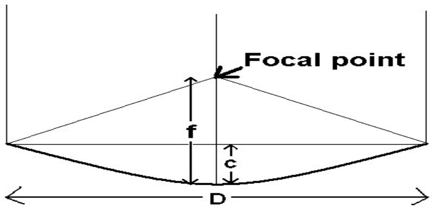

Fig. 3: Parabolic dish showing measurements needed to determine focal length

If the f/D ratio is low, between 0.25 and 0.35, the feed will be near to the dish and must disperse its power across a broad arc in order to effectively light the dish. Therefore, the feed must have a tiny diameter. If the f/D ratio is 0.25, the feed is aligned with the aperture of the dish, which may make it challenging to provide a suitable feed. If the f/D ratio is considerable, such as 0.5 to 0.75, then the feed will be further from the dish and its power must be projected into a narrower angle. The feed must have a wider diameter.

II. Problem Identification

Initial placement of the boiler should be at the spot where the highest temperature is produced. The working gas is compressed in the colder region of the engine and expanded in the hotter portion, resulting in a net conversion of heat into work. We implement focal point with sterling engine air chamber which its surface is covered by efficient heat absorbing chemical film ,it will be replaced in that place of the boiler ,which may not need any steam pressure to produce the power.The dish or Sterling system creates energy by reflecting sunlight onto a tiny focal receiver using parabolically structured mirrors, consequently heating a gas chamber connected to a piston and driving shaft.

Fig. 4: Concave lens with boiler

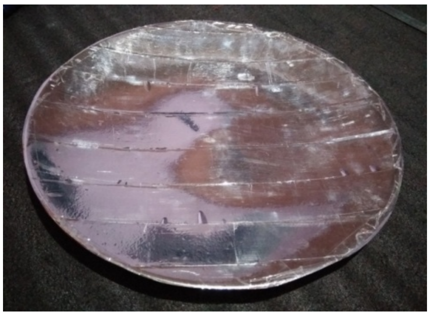

Fig. 5: Cocave mirror

A. Methodology Used:

Fabrication of Dish Stirling Engine:

The fabrication of our project is to get electrical energy and mechanical energy as output with the help of sun for that we designed a equipment which produces both energy at low input. In the equipment we made a refrigeration truck in optimum size the construction of the truck is by placing a concave mirror on the top of truck on focusing .the sun rays should fall on the mirror. As it a concave mirror it reflects the sun rays into one focal point .that focal is sent to our required direction by placing mirrors. Place a Stirling engine where the focal point is formed .arrange the Stirling engine in order to gas chamber of Stirling engine should be focused by Stirling engine. As the heat produced on the gas chamber of Stirling engine it starts moment in the piston. When the piston moves, mechanical energy is produced thus converting to electrical energy. From the exhaust of steam engine some flue gases will occur that flew gases we utilize it for our use. The components required are 0.5mm thickness aluminum sheet as outer cover of the truck, aluminum foil as concave mirror, reflecting mirrors, pressure gauges, coke tins as cylinders, syringes as pistons by using cotton it acts as insulated chamber, test tube as gas chamber in engine, truck alignment,15v dc motor, concave lens, sterling engine, engine alignment, steam engine.

Fig. 6: Piston tube

Fig. 7: Gas tube heat

Fig. 8: Stirling engine with

1) Why this methodology:

We choose aluminum sheet as outer cover of the body because it has less weight among all available materials of us. Here we choose reflecting mirrors for transferring focal point which is easily available in market. For reducing the cost of equipment we made cylinders, piston and fly wheel with available materials. There are several types of engines, among them we pick Stirling engine because the input of the Stirling engine is natural source. We made concave mirror for producing heat at one point with low cost.

Steps of assembling the components: In this process we assembled the entire components what we made in the proper way:

Initially make a truck with proper dimensions - On the container of the truck place a concave mirror on facing sun - Arrange the concave lens in perfect manner in order to focus on the body - Concave lens should maintain 45deg angle - Reflecting mirrors also maintain some angles - Through confronting mirrors, the focus point will generate and send our required instructions. - Position the Stirling engine such that the focused point acts on the chamber - When the focal point acts on the gas chamber of the Stirling engine, heat is generated. - When the heat produced in the gas chamber due to some pressure differences piston will move which is present in the chamber - Basically the chamber is filled with gaseous, fluid or air etc - When the piston moves, shaft will rotate - From the shaft we connect it to motor which will produce electrical energy - Alignment of the all components should follow limitations of design considerations - Dimensions of every component in perfect manner - The main thing of the project is that every component is of low weight - Alignment of the engine is in perfect order. - Piston in the engine should rotate freely. - Cylinders should be leaked proof - All the components should be tested before assembling. - Assemble all the components in required set up.

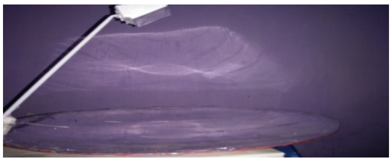

Fig. 9: Reflecting focal mirror

2) Working Principle:

The main principle of the project is using the sun as input source and producing mechanical energy as output. Here we choose reflecting mirrors for transferring focal point which is easily available in market. In this, mechanical energy is produced by solar heat by assembling components which is described below. We designed a equipment which produces both mechanical and electrical energy at low input. In the equipment we made a refrigeration truck in optimum size by placing a concave mirror on the top of truck on focusing the sun rays should fall on the mirror. As it is a concave mirror it reflects the sun rays into one focal point .that focal is sent to our required direction by placing mirrors. Place a Stirling engine where the focal point is formed .arrange the Stirling engine in order to gas chamber of Stirling engine should be focused by Stirling engine. As heat is produced in the gas chamber of Stirling engine, piston gets moment. When the piston moves, mechanical energy is produced, with the help of this mechanical energy, when it was made to connect with dc motor this mechanical energy gets converted to electrical energy. From the exhaust of steam engine some flue gases will be exhausted and these flue gases were utilized for further process.

Alignment of all components will also be constrained by design constraints, e.g., once the engine is started, the heat of compression and ignition maintains the required temperature of the hot bulb, and the blow-lamp or other heat source may be removed. Thereafter, the engine needs just air, oil, and lubricating oil to operate, as well as no external heat. However, with low power, the bulb may cool excessively, and a throttle might reduce the delivery of cold, fresh air. In addition, as the engine's load increases, so does the bulb's temperature, forcing the ignition period to advance; water is dripped into the air intake to prevent pre-ignition. Likewise, if the engine's load is insufficient, the combustion temperatures may not be adequate to keep the hot bulb at the desired temperature.

Application of this prototype design is to generate the power that may be nearly 30-100 LCD bulbswhich may be lightened.

III. Results and Calculations

Dimensions, Specifications, and focus point for a concave mirror:

Focal point: The focal point is the place in space where light travelling parallel to the primary axis and incident on the mirror will converge after reflection, as seen in figure 12 below. In reality, if a concave mirror were used to gather light from the sun, it would converge at the focal point.

Thickness = 3mm, Diameter = 350mm, Focal point = ----? , Depth = 30mm

Focal Point $$f = \frac{D \times D}{16 \times C} = \frac{350 \times 350}{16 \times 30} = \frac{1{,}22{,}500}{480} = 255.$$

Where D = Diameter of the concave mirror in mm = 350 mm
C = Depth of the mirror in mm
= 30 mm

Case Study report of Power input and output:

Power $= V$

Table 1. Case study report corresponding to Power along with Speed and Focal Point temperature taken for 4 consecutive days

Serial No.	Day Number	Atmospheric Temperature in °C	Focal Point Temperature in °C	Speed in rpm	Voltage in Volts	Current in Amperes	Power in Kilowatts
1	1	37	160	783	6.01	0.256	0.00154
2	2	34	154	606	5.21	0.210	0.00109
3	3	40	177	800	6.2	0.262	0.00162
4	4	36.5	159	757	5.8	0.240	0.0014

We get the power values at various conditions, so we get the average power output of 1.4105W/hr or 0.0014105 KW.Through these various power and RPM values we can calculate the torque.

Calculation of Torque from the website http://wentec.com/unipower/calculators/power_torque.asp using the below given formula

Torque, $$T = \frac{9.5488 \times P}{Speed}$$

Table 2. Table captions should be placed above the tables

Serial Number	Power in KW	Speed in rpm	Torque in N-m
1	0.00154	783	0.0000187805
2	0.00109	606	0.0000171752
3	0.00162	800	0.0000193363
4	0.0014	757	0.0000176596

We get the torque values at various conditions, so we get the average torque output of 0.0000182379N – m or 0.0182379 N - mm.

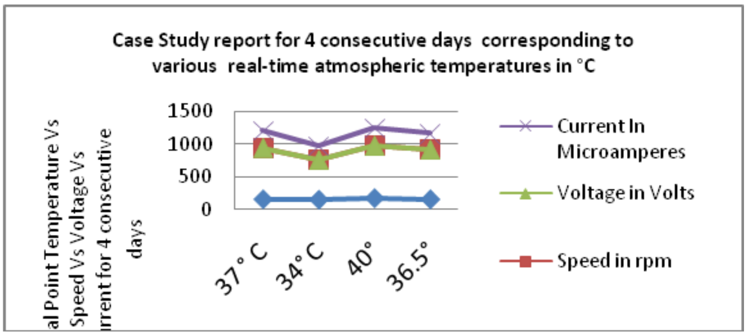

Fig. 10: Case Study report for 4 consecutive days concerning the various real-time atmospheric temperatures in °C

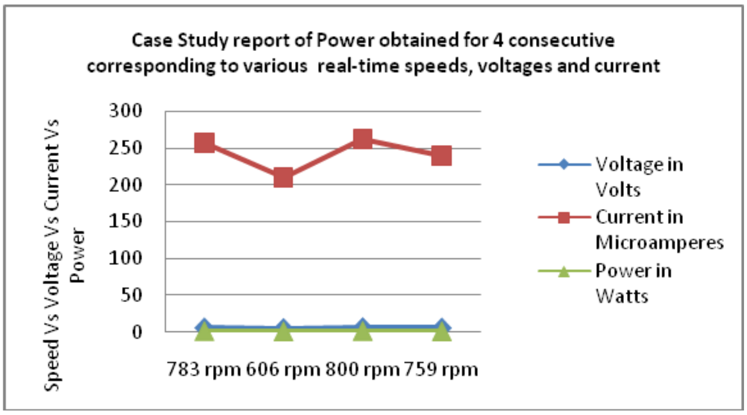

Fig. 11: Case Study report of Power obtained for 4 consecutive days concerning the various real-time speeds in rpm at corresponding voltages in volts and current in Microamperes

IV. Conclusion and Future Scope

We haven't encountered many new insights, problems, or solutions to the engine's various components throughout the development, fabrication, and testing processes of our Stirling engine. For the engine design, we used thermodynamic principles and established formulas to predict its power output at different temperatures. Through perseverance and creative problem solving, we were able to build the engine and integrate the data collection devices inside. Our engine's maximum power output is merely 1.62 watts, according to the calculations. Despite this, the engine was still unable to start. Pressurizing the system is necessary to increase the engine's work output since system pressure is directly proportional to output. Incompressible gas flow between the hot and cold sides of the engine would be enhanced if the pressure within the system were increased. In order to avoid an explosive decompression, it is necessary to utilise a pressure gauge to keep an eye on the machine. An other technique for increasing the engine's efficiency is to reduce the engine's dead volume. The dead volume of the system may be lowered by altering the size and shapes of the pipes, the heater, and the chiller. The current heater layout is functional, but not ideal for the transfer of gases from the hot piston to the pipe that connects to the cold side of the engine.

The proper development of the compressor was partially disregarded due to financial restrictions and the prioritisation of the design and production of the necessary cooler and heater sections. Changing or rebuilding engine components to make them more Stirling engine-compatible might improve the compressor's performance. For optimal cooling and heating, piston phase angles would have to be changed. Reduced friction may be achieved by bearings and bushings placed along the rotor of the compressor crankshaft. To maintain an internal temperature differential, we built an engine, even though our design couldn't support a work conversion from heat of the burner to mechanical spinning of the crankshaft.

Opportunities for Future Improvement:

A lot of bugs still need to be worked out in the engine. Engine inability to do meaningful work first and foremost. By using a foil-type generator instead of a mesh-type generator, a large risk of engine damage was reduced. This is likely due to friction between the crankshaft and piston linkages and/or weaker bearings. There is general agreement, however, that our current technique would be more successful and have less dead volume if we used a mesh regenerator without steel wool. The diameter of the tubing that connects the caps may also be reduced to reduce dead volume. A large amount of extra pipe space is likely to have a significant impact on the rate of mass transfer between hot and cold working fluids. The absence of pressurisation in the engine might provide a development opportunity. Stirling engines were under some kind of pressure in the majority of our experiments. Pressurization is being hampered by leakage problems on the hot side, which may become apparent if the pressure is elevated. In addition, the increasing pressure might pose a danger to the public. It will be required to have acceptable fit tolerances for pressurisation. Precautions should be made to avoid exposure to severe temperatures in addition to establishing a technique for measuring pressure.

REFERENCES

[1] Gallup, D., and Mancini, T.: The Utility-Scale Joint-Venture ProgramIn: Proceedings of 29th IECEC, Monterey, CA, ~ISBN 1-56347-91-8!pp. 1703–1708.

[2] Bean, J. R., and Diver, R. B.: Technical Status of the Dish/Stirling Joint Venture Program In: Proceedings of 30th IECEC, Orlando, FL, pp. 2.497–2.504. (1995).

[3] Jaffe, L. D: A Review of Test Results on Solar Thermal Power Modules with Dish-Mounted Stirling and Brayton Cycle Engines In: ASME Journal of.Solar Energy Eng., 110~4! pp. 268–274, NY USA(1988).

[4] Lopez, C., and Stone, K.:Design and Performance of the Southern California Edison Stirling Dish Solar Engineering In : Proceedings. of ASME in: International Solar Energy Conference. ~ISBN 0-7918-762-2!, pp. 945–952, Maui, HI.(1992).

[5] Koshaim B: Report from book Concentrating Solar Power Technology: Principles, Developments and Applications related Fifty KW Solar Membrane Concentrator In: The SOLERAS Program, Saudi Arabian National Center for Science and Technologyhttps://books.google.co.in/books In: pp 322 – 325 (1986).

[6] Stine, W: An International Survey of Parabolic Dish/Stirling Engine Electrical Power Generation Technology In: Solar Engineering Proceedings of ASME/ ASES Joint Solar Energy Conference., Washington, D.C.(1993).

[7] The International Energy Agency, Solar Power And Chemical Energy Systems,http://www.solarpaces.org last accessed 2019/03/24

[8] U.S. Department of Energy, June 2003, Parabolic Trough Solar Thermal Electric Power Plants, Available from: http://www.nrel.gov/docs/fy03osti/34186.pdf last accessed 2019/03/24

[9] Ausra, Inc., 2007: An Introduction to Solar Thermal Electric Power In http://ausra.com/pdfs/SolarThermal101_final last accessed 2019/03/24.