Design and Fabrication of Solar Tracking System for Stirling Engine

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Abstract-Concentrated solar power (CSP) has attracted increasing attention as a renewable energy source with zero carbon emission. For efficient conversion of the externally concentrated heat, a suitable electric generator is crucial. In contrast to the currently widely used steam turbine, the free-piston Stirling electric generator (FPSG) features a flexible power range, high reliability, and zero water consumption. To date, most Stirling electric generators have been integrated with a parabolic dish concentrator in a dish-Stirling system. However, this configuration faces great difficulties in incorporating thermal energy storage or an auxiliary heating facility. To address this, a trough-Stirling concentrated solar power system, in which the parabolic dish concentrator is replaced with a parabolic trough collector (PTC), might be a good collecting device. This project presents different components and various configurations alongside with the feasibility of using solar energy as a source of heat for a Stirling engine. In addition to this, calculation of different components of Stirling engine and parabolic dish like sun heat calculations, Stirling torque calculations, generator calculations, and calculations for following and tracking the light intensity to get maximum solar power. This paper addresses issues which we saw during design and development of solar Stirling engine with generator to be sufficient acceptable for experimental and small wattage applications. This makes the energy usable in homes as a supplemental source of power or as an independent power source. Model is showing that is consisting of the parabolic collector, receiver, Stirling engine, and generator. The design is implemented to include location and depends on properties that affect the performance based on the sun elevation angle, ambient temperature, the wind speed, and density of air (altitude). Here experimental study is conducted on small-scale solar parabolic Stirling engine with generator. Low power is consumed to find the maximum power and highest light intensity. The applications of solar Stirling have green and clean energy generation from sun energy. Overall efficiency of solar Stirling power of system is expected to be around (24-36) percentage.

Index Term-Components, Tracking system, Sterling Engine, Material Selection.

1 INTRODUCTION:

Today we are moving toward the use of natural resource for the energy generation. Stirling engine is one of the effective and efficient devices to convert solar energy into mechanical work. It is the best device as compare to other solar device in power generation.A Stirling cycle machine operates on a closed regenerative thermodynamic cycle using a Working gas, and subjects the gas to expansion and compression processes at different temperatures.

In solar modules, Stirling-Dish, the solar radiation is converted to electricity in three stages. In the first stage, radiation is converted to heat by focusing the solar radiation onto a light absorbing heat pipe by means of a parabolic reflector. In the second stage, the heat is converted to mechanical power by a Stirling engine. In the final stage, the mechanical power is converted to electricity by an alternator. The dish modules 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.

Stirling engine is an external combustion engine, offers potential advantages over conventional engines in fuel choices, noise and emissions. Multi-fuels such as agricultural by-product, biomass, bio-diesel, solar energy and etc., can be employed as a heat source for a stirling engine. This report describes production of electricity using solar powered stirling engine which utilizes solar energy as a heat source. The solar dishes are mounted as parabolic solar collectors with mirrors. As the parabolic dish collects the heat from the source, start up the engine, which is coupled to the dc generator delivers the electricity flow to the load.

1.1 PROBLEM STATEMENT:

1. Population of world is increasing day by day, therefore demand for energy increasing.
2. Temperature of earth is increasing, due to greenhouse effect, so utilization of solar radiation helps in reducing cost of producing electricity.
3. To design & develop solar operated Stirling engine, & also fabricating it.
4. To produce heat required for Stirling engine by using solar collector.

1.2 AIMS AND OBJECTIVES:

1. Design & development of solar operated Stirling engine using solar collector.

2. Using natural renewable energy in place of non-renewable energy source because of depletion of that energy

2 METHODOLOGY:

2.1 Review Stage

1. Operating Stirling Engine
2. Overview of the Components
3. Stirling Engine Thermodynamic Study
4. Setup Construction
5. Material discussion
6. The result and conclusion is drawn

3 MATERIAL SELECTION:

• Stirling Engine

Aluminium type of material used for stirling engine. stirling engine used instead of solar plate because it has high efficiency. ody of the stirling engine is made of aluminium and inner gas used for return stroke in stirling is helium gas because it expand rate is more than any other gas.

• Solar Collector

Aluminium foil used for solar collection because it has high reflectivity than any other foil material used for stirling engine.

• Shaft

Cast iron is used for shaft to sustain power of generation.

• Bearing

6004-2Z SKF Shielded Deep Groove Ball Bearing 20x42x12mm

4 DESIGN OF SETUP:

In construction setup of tracking system, a rectangular frame is used to support whole structure. Two axis mechanism is used to rotate the setup by using two dc motors, bearing and shaft. Dish is made of parabolic shape to collect maximum solar radiation because parabolic shape gives maximum efficiency. Sterling engine is placed at focal point of parabolic dish, where it receives the maximum solar radiation. LDR sensors are mounted on small plate on sterling engine to know the position of sun.

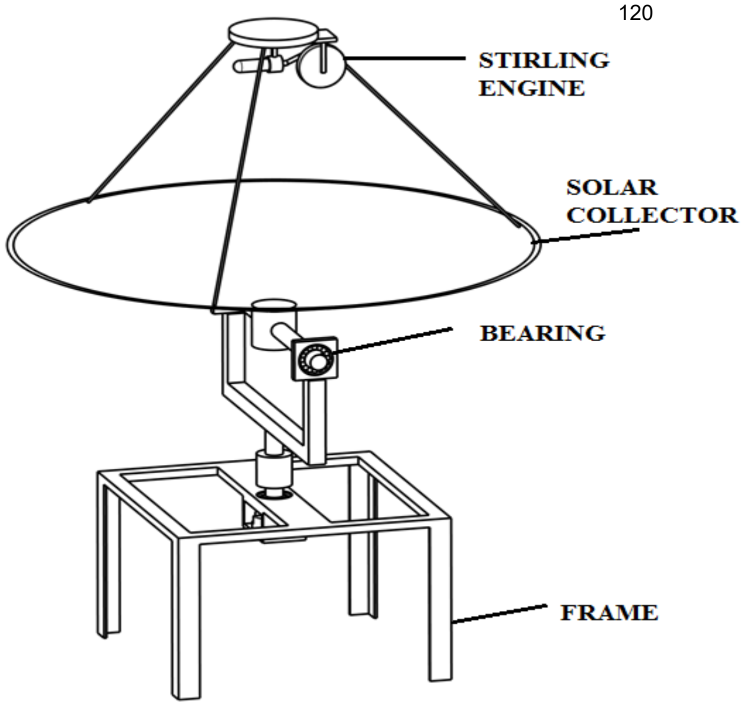
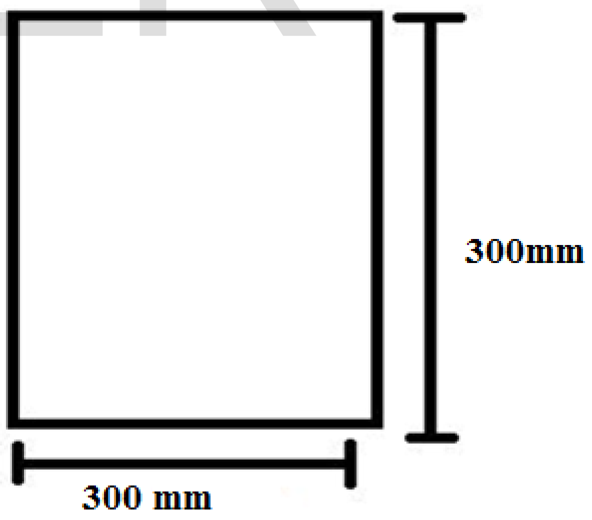


Fig 4.1: Construction of Setup for sterling engine.

5 DESIGN ANDCALCULATION:

5.1 DESIGNOFFRAME



Frame design for safety FOR 25*25*3 L angle mild steel channel

b = 25 mm, d= 25 mm, t = 3 mm.

Consider the maximum load on the frame to be 20 kg.

Max. Bending moment = force*perpendicular distance

= 7*9.81*150

M = 10300.5 Nmm

We know,

M / I = σb / y

M = Bending moment

I = Moment of Inertia about axis of bending that is; *Ixx*

y = Distance of the layer at which the bending stress

(We take always the maximum value of *y*, that is, distance of extreme fiber from N.A.)

E = Modulus of elasticity of beam material.

I = bd3 /12

= 25*25^3 / 12

I = 32552.08 mm4

σb = My / I

= 10300.5 *12.5 / 32552.08

σb = 3.955 N /mm2

The allowable shear stress for material is σallow = Syt / fos

Where Syt = yield stress = 210 MPa = 210 N/mm2

And fos is factor of safety = 2

So σallow= 210/2 = 105 MPa = 105 N/mm2

Comparing above we get,

σb<σallowi.e

3.95539 < 105 N/mm 2

So, design is safe.

5.2DESIGN OF SHAFT

Shafts:

Input Power by AC motor = ¼ HP=188.625W

Following notations will be used for shaft.

d = diameter of shaft,

Mt = torque transmitted by the shaft, =25 Kgcm= 2.4516625 Nm.

W = power transmitted by the shaft (W)

N = rpm of the motor shaft = 1275 rpm

τs = permissible shearing stress,

σb = permissible bending stress, and

Mb = bending moment.

Considering only transmission of torque by a solid shaft. The power transmitted by shaft and the torque in the shaft are related as

W= Mt* ω

If *W* is in Watts and *Mt* in Nm. ω is angular velocity in rad/s and equals 2πN/60

W=2πNMt/60

Mt= 30W/ πN……………………………………eq^n 1

The shearing stress and the torque are related as

$\tau = 16\ Mt*10^3 / \pi*d^3$

If Mt is in Nm and d in mm.

Mt= π/16 ($10^3 \tau\ d^{3)}$ ………………………………… eq^n 2

$d^3 = Mt*16 / \pi 10^3 \tau$

In Eq. (3) W is in Watt, τ in N/mm2, N in rpm and d in mm.

For calculating shaft diameter, d, we substitute the permissible value of shearing stress in place of τ. Table below describes permissible values for steel shaft under various service conditions, when the bending is much smaller than torsional loads.

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Service Condition	**τ s (MPa)**
Heavily loaded short shafts carrying no axial load	48-106
Multiple bearing long shafts carrying no axial load	13-22
Axially loaded shafts (bevel gear drive or helical gear drive couplings etc.)	8-10
Shafts working under heavy overloads (stone crushers, etc.)	4.5-5.3

Table no.5.1.1 Allowable shear stress for shaft

So, equation 3 becomes

$d^3 = Mt*16 / \pi 10^3 \ \tau$

Taking allowable shear stress for shafts under small loads in coupling as τ= 8 MPa = $8*10^6$ Pa

$d^3 = Mt*16 / \pi \ \tau \ 10^6$

$d^3 = 2.45166*16 / \pi*48*10^6$

$d^3 = 2.6012 *10^{-7\ m}$

d= 0.00638m = 6.38mm

Considering factor of safety as 1.5, the shaft size will be

D= 3*d

D= 3*6.38

D= 19.15 mm.

Diameter Size in mm		Diameter Size in inches	
5	22	1/4	7/8
6	24	5/16	1
8	25	3/8	11/4
10	28	7/16	13/8
12	30	5/8	17/16
15	32	1/2	15/8
18	35	3/4	13/4
20	40	11/16	21/4

Table no.5.2.2 En8 Rounds Bright Drawn / Turned bars available sizes

So selected shaft diameter closest to D= 19.38 mm is = D=20 mm.

This is taken as 20 mm to add better safety and availability in market.

So, we take diameter of second shaft will also be 20 mm.

5.3DESIGN OF BEARING:

Sr No.	Application of bearing	Life of bearing in hours
1	Aircraft/Rarely used apparatus	1000-2000
2	Machine used for short period	4000-8000
3	Machine working intermittently & whose breakdown not have serious consequence	8000-12000
4	Machine Work for 8 hour per day	12000-20000
5	Machine work for 24 hour	20000-30000

Table No.5.2.3 Life of Bearing

We know that life of the bearing corresponding to 99% reliability,

L99 = 60 N. LH = 60 × 1275× 20 000 = 1530× 106 revLet

L90 = Life of the bearing corresponding to 90% reliability.

Considering life adjustment factors for operating condition and material as 0.9 and 0.85respectively, we have

$\frac{L_{95}}{L_{90}} = \left(\frac{\log\left(\frac{1}{95}\right)}{\log\left(\frac{1}{90}\right)}\right)^{\frac{1}{b}}$ For ball bearing b=3

$$\frac{L_{95}}{L_{90}} = \left(\frac{0.0519}{0.1054}\right)^{\frac{1}{3}}$$

$$L_{90} = \frac{L_{95}}{\left(\frac{0.0519}{0.1054}\right)^{\frac{1}{3}}}$$

$$L_{90} = 25.42 \times 10^6 \text{ KN}$$

Dynamic Load

$$C = W\left(\frac{L_{90}}{10^6}\right)^{\frac{1}{K}}$$

$C = 1\left(\frac{L_{90}}{10^6}\right)^{\frac{1}{3}}$K=3 for ball bearing

W=Radial Load   W=1

$$C = 2.94\ \text{KN}$$

$$L = \left(\frac{C}{W}\right)^{K} \times 10^6$$

$$L = 25.41 \times 10^6$$

6 RESULT

1. By using two axis mechanism sterling engine receive maximum solar radiation.
2. Due to maximum solar radiation, efficiency of engine is increased mainly in cloudy days.
3. Result from testing suggest that increase in the temperature difference in input increases the speed, efficiency and power of sterling engine.

7 DISCUSSION

Solar operated Stirling engine consists of four LDR sensors attached to the solar collector in uniaxial direction. Working, LDR sensors detects the focal axis of sun radiation and send's signal to microcontroller. In other word microcontroller switches the motor on & adjusts solar reflector to the required direction as per the focal radiation. The rays directed to the solar collector is extracted to the Stirling engine. Hence, thermal energy is converted into mechanical work or electrical energy.

8 CONCLUSION

1. Use of renewable energy source instead of using conventional energy source.

2. Most renewable energy methods have harmful effects on the environment which cause risk for all beings.

3. To protect our world from a like situations and to get high quality energy with less effort, less risk and higher productivity we made our step into our project under clear energy roof.

4. The parabolic type dish gives higher energy output than the other type.

5. The two axis mechanism works efficiently in cloudy days.

9 FUTURE SCOPE

1. On a medium large scale electricity generation: Highest efficiency can be obtained on commercial, practical solar electricity technologies with reasonable area and investment
2. For Industries: Industries could produce green and clean power. Each unit can generate from 10KW to 1MW.
3. On a small scale for home and buildings: These systems are better than PV systems. When set up along with original power lines they could be taken as back up lines.
4. In Agriculture: The latest break-through is Solar Stirling Water pumps that could lift the water in farm fields and stops farmers wait for electricity.

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