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# Design and Fabrication of Stirling Engine using Slider Crank mechanism

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## Abstract

Stirling Engine is a closed cycle heat engine that works on the principle of cyclic compression and expansion of air or other gas (air) at different temperatures, that results in net conversion of heat energy to mechanical work. [1] [2] .To be specific, The Stirling engine is closed-cycle regenerative heat engine that works with permanent gaseous working fluid. Closed-cycle, means a system in which the working fluid is permanently contained inside the system. Strictly speaking, including a regenerator differentiates a Stirling engine from other closed-cycle hot air engines. [3] The Stirling engine has higher efficiency compared to steam engines, and it can use almost any heat source. In Stirling engine heat source is generated externally unlike internal combustion like in Otto cycle or diesel cycle engines.

**Keywords:** Closed cycle; Efficiency; External combustion; Heat Engine; Internal combustion; Regenerator; Stirling Engine.

## 1. Introduction

A Stirling engine is a heat engine which operates by the cyclic compression and expansion of air at different temperatures that results in conversion of heat energy into mechanical energy. A Stirling Engine is a closed-cycle regenerative heat engine (which means the gas contains within the system in the entire process). Regenerative means including a specific type of heat exchanger and a thermal store known as regenerator. The name Stirling engine was named after the scientist Robert Stirling who is known as one of the fathers of hot air engines. Robert Stirling introduced the first air engine in 1816. [4] And received the patent of his second hot air engine with his brother James Stirling in 1827.[5] Later in 1829, Parkinson and Crossly [6] introduced the principle that air has greater density than atmosphere. Following the same idea James Stirling built Dundee engine. [7] In 1818 the first practical use of Stirling engine was used in quarry for pumping water. Later on, by 21st century, Stirling Engines were used in dish type. A mirror dish that resembles a satellite dish that focuses the sunlight onto thermal receiver that absorbs the heat and collects it using a fluid which transfers it into Stirling Engine that can be later used to produce electricity.[8]

## 2. Layout analysis

**A. Raw materials used:**

i. Ball bearings-2 (1 inch and 10 mm diameter)
ii. Connecting rod (1 mm diameter steel wire, 13 cm for hot cylinder and 12 cm for cold cylinder)
iii. Hexagonal nut and screw-2 (13 cm height and 10 mm diameter)
iv. L-Shaped clamps-2 (made of mild steel)
v. Pistons-2 (Injection syringe piston)
vi. Piston Cylinder-2 (Glass Test Tube, 16cm long for hot cylinder and 12 cm for cold cylinder)
vii. Rotary wheels-2 (made of hardened steel 4 inch size with slots to hold 1mm screws)
viii. U-Shaped clamp-2 (made of mild steel)
ix. Water level pipe (diameter 10 mm)
x. Wooden base (50 x 30 mm)

**B. Assembly and working**

1) Initially, A base is set up which is made up of wood with plastic bushes underneath. Two Hexagonal nuts welded with C-Shaped clamps are fixed to the wooden base.

2) Two hexagonal nuts are welded with 5 cm iron plates at the top and are bolted two U-shaped clamps on the top, which are used to hold two glass test tubes.

3) The two glass tubes are used as piston cylinder which has openings on two sides.

4) The two test tubes are connected with a pipe fitted with rubber cork to facilitate the heat flow.

5) The first tube is set on a candle or a lighter for generation of heat, which works as hot cylinder.

6) The glass tube is connected with the first one by means of a water level pipe serves as cold cylinder.

7) Both the hot and cold cylinders consists of piston rods made of plastic are attached to a connecting rod which are bolted to rotary wheel.

8) The two rotary wheels are connected by means of a shaft along with a bearing wheel to facilitate the rotation of wheel as shown in fig 1

9) Finally, when the candle is set fire, after heating it for some time the rotary wheel starts rotating slowly.

10) And the crank shaft connected to rotary wheel also rotates. As, a result, heat generated flows through the pipe and rotates continuously.

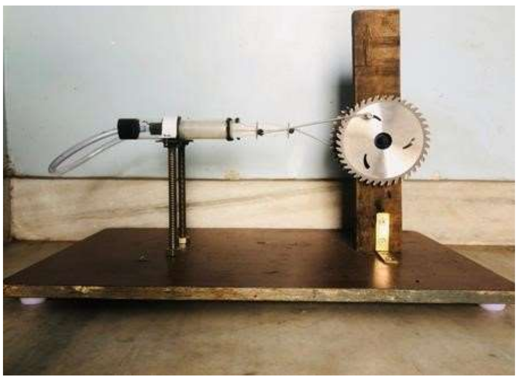

Fig.1 Side View

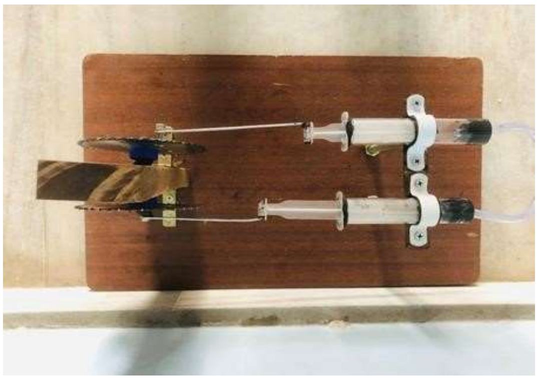

Fig.2 Top View

## 3. Results

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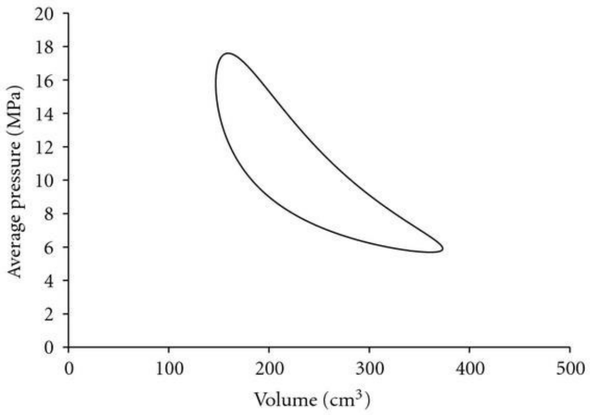
### *A. Basic Performance*

In Figure, the *P-V* diagram of the basic engine is presented. Because the integration of area inside the *P-V* curve indicates the network, this diagram is called as the work diagram.




**P-V diagram**

Stirling cycle was devised by Stirling, which consists of two isothermal processes and two constant volume processes. The last two processes are performed with the help of a refrigerator to make this cycle reversible. The p-v and t-s diagram of this cycle are shown in the figure.

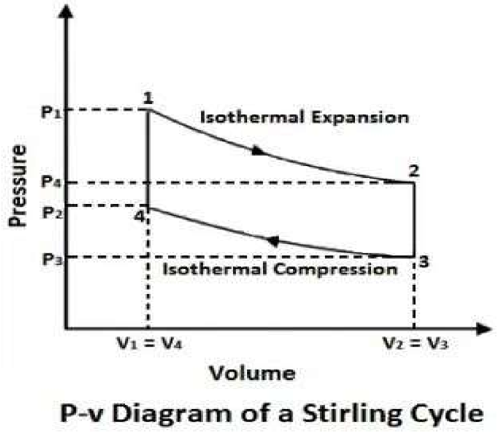



**Fig (a)**

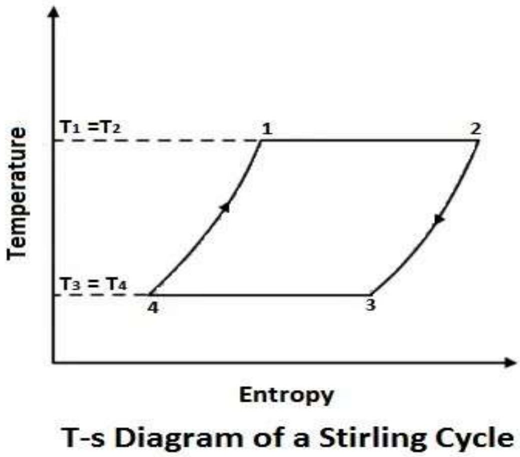



**Fig (b)**

**Stages of an ideal Stirling cycle:**

The below mentioned are the four cycles of an ideal Stirling engine

i. Isothermal expansion (1-2)
ii. Constant volume cooling (2-3)
iii. Isothermal compression (3-4)
iv. Constant volume heating (4-1)

**i. Isothermal expansion (1-2)**

The air expands at a constant temperature, T1 or T2 from V1 to V2. Which implies that temperature T1 is equals to T2. This Isothermal expansion is represented by the graph 1-2 in fig (a) and fig (b).

Heat given = Work done during Isothermal expansion

**ii. Constant volume heating (2-3)**
Air then passes through the regenerator and is cooled at constant volume to a temperature T3. This process is represented by a graph 2-3 in Fig (a) and Fig (b). In this process heat is rejected.

**iii. Isothermal expansion (3-4)**
Air then expands isothermally, at a constant temperature T3 in the engine from V3 to V4. This process is represented by the graph 3-4 on Fig (a) and Fig (b). Again heat is rejected during this process.

**iv. Constant volume heating (4-1)**
Finally, Air is heated at constant volume to the temperature T1, By sending the air in opposite direction of process 2-3. At the end of the process it can be observed that the air is restored to the initial state. During this process heat is absorbed by air.

### *B. Calculations*

Efficiency of Stirling engine can be calculated using the following formulae

*Efficiency = (output)/(input)*

The input to the system can be estimated by taking the difference in temperature between the heated part and heat sink.

*Input energy per second = Mass of air* x $C_p$ *of air* x $\Delta T$

Mass of air is determined as;

*Mass = Density* (ρ) x *volume* (ν)

$\rho = 1.2\ kg/m^3$
$\nu = 1200\ x10^{-6}\ m^3$
$C_p = 1005.0\ J/kg\text{-}K$
$\Delta T = (393\text{-}300) = 93\ K$

*Input energy per second* = $1.2 \times 1000 \times 10^{-6} \times 1005.0 \times 93$

**= 112.158 J/s**

The output of Stirling engine can be theoretically determined using Baele equation.

*Power (W) = Mean effective pressure in MPa* x *Swept volume* ($cm^3$) x *rotation (Hz)* x $N_b$

$N_b = 0.1112.0$

Swept volume is 12 cm long and 2.5 cm in diameter

Swept Volume = $\pi \times (2.5^2/4) \times 12 = 58.875\ cm^3$

Power (W) = (1-(rt) (rv)) (ln (rv)/ (rt (γ-1))

(rt) = *temperature ratio* = ((27+273)/ (120+273)) = 0.76

(rv) = *compression ratio* = ($\nu_1/\nu_2$) = (251.2/188.4) = 1.33 *W* = (1-0.76) x (1.33) x (ln (1.33)/0.76x0.4) = 2.99

*Actual Efficiency* = (2.99/112.15) x 100 = 2.66

The Efficiency Engine is 2.66%. (Actual)

This actual efficiency can be compared to theoretical Stirling Engine Efficiency.

*Ideal Theoretical Efficiency* $=1 - (T_{min}/T_{max})$

$=1 - ((27+273)/(120+273)) \times 100$

**= 23.66%**

## 4. Conclusions

In this paper, As a result, the working conditions and characteristics of the engine can be encapsulated as follows

i. If the heater temperature increases, the thermal efficiency and total input heat also increases.
ii. If cooler temperatures are reduced thermal efficiency and total input heat will be increased eventually. Apart from changes in heater temperature, total input heat has been increased exponentially.

iii. Engines that have higher regenerator effectiveness have high thermal efficiency due to the lower total input heat.
iv. By considering all the gases we can conclude that helium has good characteristics during working. As helium has high specific heat coefficient it needs lower input energy, Which eventually increases the thermal efficiency of the engine.

## References

[1] Stirling Engines", G. Walker (1980), Clarendon Press, Oxford, page 1: "A Stirling engine is a mechanical device which operates on a *closed* regenerative thermodynamic cycle, with cyclic compression and expansion of the working fluid at different temperature levels.

[2] W.R. Martini (1983). "Stirling Engine Design Manual (2nd edition)". NASA. p. 6. Retrieved 19 January 2009.

[3] "The Hot Air Engine of the 19th Century". *hotairengines.org*

[4] "The Stirling 1816 hot air engine". *hotairengines.org*.

[5] "The Stirling 1827 air engine". *hotairengines.org*.

[6] "Parkinson & Crossley hot air engine". *hotairengines.org*.

[7] "The Dundee Stirling Engine". *hotairengines.org*.

[8] "Learning about renewable energy". NREL – National Renewable Energy Laboratory. Archived from the original on 2 May 2016. Retrieved 25 April 2016.