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SOLAR STIRLING ENGINE

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ABSTRACT
The following report presents the design selection process of Solar Stirling engine. A Stirling engine is the approximate the theoretical Carnot cycle engine and consists of rapid heating and cooling of a gas within piston/cylinder device. There is no exhaust or intake, therefore the Stirling engine consider as an external combustion engine, means the heat applied externally. We intended to utilize power of the sun to provide necessary energy to the system instead of burning conventional fuels. The main purpose of the project is to promote the use of Stirling engines in 'green energy' applications. Due to the high theoretical efficiencies of Stirling engines they are a prime candidate for future solar energy generation research.

KEYWORDS: Solar, Stirling Engine, Heat Engine, Design.

INTRODUCTION
A. Background information

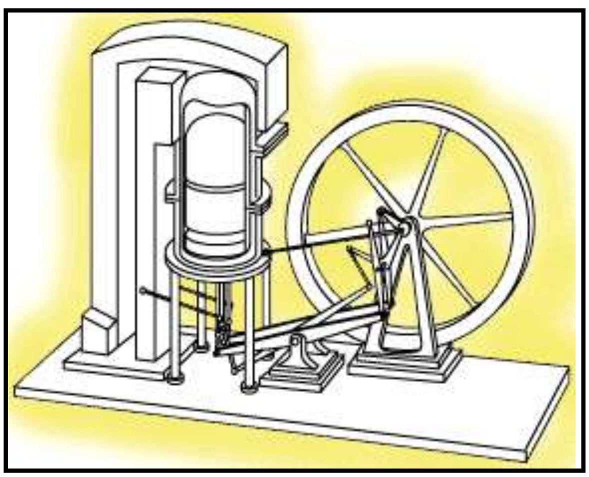

Figure 1: Earliest Stirling Engine

The Stirling Engine is one of the hot air engines. It was invented by Robert Stirling (1790-1878) and his brother James. On September 27, 1816, Robert Stirling applied for a patent for his economizer at the Chancery in Edinburgh, Scotland. Robert Stirling gets a patent for the economizer with an air engine incorporating it in 1817. In 1938, the company "Philips" invested in the hot air engine (economizer), now known as "Stirling engine". Applications were developed in the automobile field. A compact engine with more than 200 horsepower, with efficiency above 30%, was born.

B. What is a Stirling Engine and how it works?

Stirling engines are unique heat engines because their theoretical efficiency is nearly equal to their theoretical maximum efficiency, known as the Carnot Cycle efficiency. There are mainly three types of Stirling engine: (a.) Alpha Stirling engine (b.) Beta Stirling engine (c.) Gamma Stirling Engine.

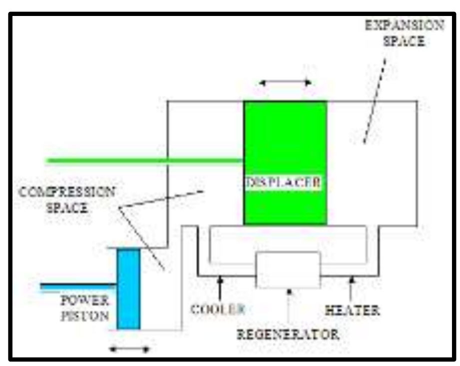

Figure 2: Stirling Engine

The Stirling engine is based on a closed cycle, where the working gas is kept inside the cylinders and heat is added and removed from the working spaces through the cylinder wall. The engine has a working piston, which converts the gas pressure into mechanical power, and a displacer piston, which can move the working gas between the hot and the cold working spaces.

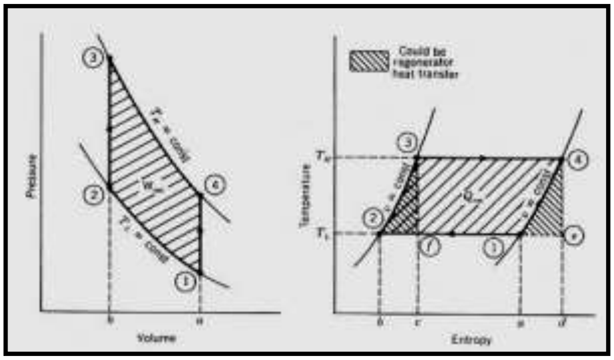

Figure 3: Ideal P-V and T-S Diagram

Stirling engines are powered by the expansion of a gas when heated, followed by the compression of the gas when cooled. The Stirling engine contains a fixed amount of gas which is transferred back and forth between a "cold" end (often room temperature) and a "hot" end (often heated by a kerosene or alcohol burner). The "displacer piston" moves the gas between the two ends and the "power piston" changes the internal volume as the gas expands and contracts.

DESIGN

A. Displacer Cylinder, Power Cylinder, Displacer and Power Piston

For a typical power producing Stirling engine, the ratio of swept volume of displacer cylinder to power cylinder is 1.5 to 2 and for a LTD type Stirling engine, this ratio is 10 to 20. So that we have to first assume the dimensions of power cylinder then we can find displacer side dimensions.

It is desirable to keep the clearance between the displacer and inside diameter of the displacer cylinder as small as possible but the two must not touch because the friction will slow or stop the engine. The reason for the small clearance are:

1. To minimize dead volume in the engine.
2. The increased gas velocity provides better heat transfer from increased turbulence when the gas impinges on the hot or cold plates.

∴ I.D. of displacer cylinder = (O.D. of displacer piston) + (Clearance)

Length of the cylinder = $\frac{3}{2}$(length of displacer)

Length of power cylinder = stroke + power piston length

The selected material for displacer cylinder should have low thermal conductivity and the material for displacer should thermally insulator, light in weight. But for power cylinder material should have high thermal conductivity. Therefore selected materials should be follows:

Displacer cylinder	:	Mild Steel
Displacer	:	UHM-W
Power cylinder	:	Mild Steel or Brass
Power piston	:	Aluminium

Figure 4 : Displacer Cylinder

Figure 5 : Power Cylinder

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Figure 6 : Displacer Piston

The displacer piston is made of UHM-W because it can tolerate higher temperatures than many other plastics such as acrylic or ABS. Plastics such as UHM-W have low thermal conductivity which is also a benefit here.

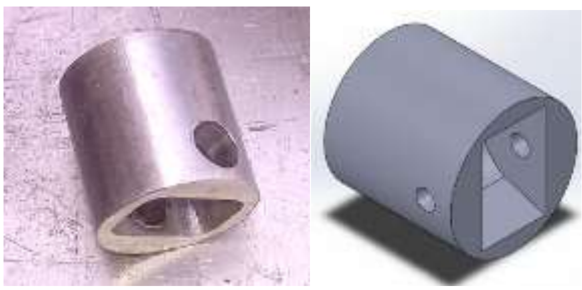

Figure 7 : Power Piston

The power piston is machined from an aluminum block (6061-T6) on CNC machine to slide easily inside the power cylinder but with very little excess clearance. The long piston is used to further reduce leakage. The piston must be able to fall freely through the brass tube when the ends are open and drop very slowly under its own weight when one end is sealed.

B. Displacer Rod

It is used to connect displacer with displacer connecting rod. The design of displacer rod is based on Rankin's formula and Euler's crippling load. For displacer rod, one end is fixed to displacer and other end is hinged. The factor of safety is taken as 9.

Figure 8 : Displacer Rod

C. Connecting Rod

The design of both the connecting rod is also based on Rankin's formula and Euler's crippling load. In both the cases, both the ends are hinged. The factor of safety is taken as 9.

Figure 9 : Power Piston Connecting Rod

Figure 10 : Displacer Connecting Rod

D. Crankshaft

In our case, we use overhung type crankshaft. The radius of the crank is the half of the stroke length.

Figure 11 : Crankshaft

E. Solar collector

The design of solar collector is based on the incidence angle of the sun rays at current location. A transparent cover of some type over the heat collector is absolutely necessary on this type of engine to minimize convection losses.

There are three reasons for losing solar energy before it arrives at the heat collector: 1. Transmission losses through the acrylic cover. 2. Reduced energy on the heat collector as a function of the sun's incidence angle. 3. Transmission losses as a function of the solar path through the atmosphere.

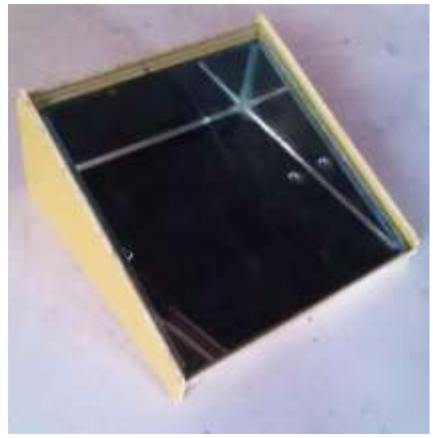

Figure 12 : Solar Collector

The solar collector made from mirror, glass, Aluminium and fiberglass. The mirrors of triangle and rectangular shape fitted on Aluminium plate. The fiberglass used as an insulator which covered on mirror and Aluminium plate to reduce heat losses.

FINAL ASSEMBLY

Figure 13 : Final Assembly

CONCLUSION

The Stirling engines are very flexible. There are lot of different types of engines. They can be very small and run with only a small temperature difference, they are very quiet.
The good point is that they can be constructed in a way they produce no emissions. That means, in combination with solar or geothermal heat, they can be used as a renewable energy source to produce electricity.
The design and development of gamma type solar Stirling engine is covered in this report. The objective of this project was to design and to manufacture a gamma type solar Stirling engine which can run on less solar energy.
In our project we require 20 degree temperature difference between two cylinders.

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