Volume-3, Issue-10, Oct-2014 • ISSN No 2277 - 8160

Research Paper | Engineering

Solar Powered Stirling Engine- A New Hope

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ABSTRACT *The planet is progressively marching towards a serious energy crisis owing to an escalating desire of energy becoming greater than its supply. We have always accepted that the energy we make use of each day is not unrestricted, still we take it for granted. In the energy deficient world it is strongly felt that the use of solar energy as possible source is not being fully utilised. So in an attempt to deploy its use a novel concept of "Solar Powered Stirling Engine"is introduced in this paper. The Stirling-Engine used here runs using solar heat radiation concentrate by 'Solar Concentrator'. A Stirling engine is basically a heat engine that operates by cyclic compression and expansion of air or other gas, the working fluid, at different temperature levels such that there is net conversion of heat energy to mechanical work. In general Stirling engines have comparatively high thermodynamic efficiencies. Because they need only heat, Stirling engines also permits high fuel flexibility and allow for better control for emission. The purpose of this study is to provide an alternate energy source to operate Stirling engine.*

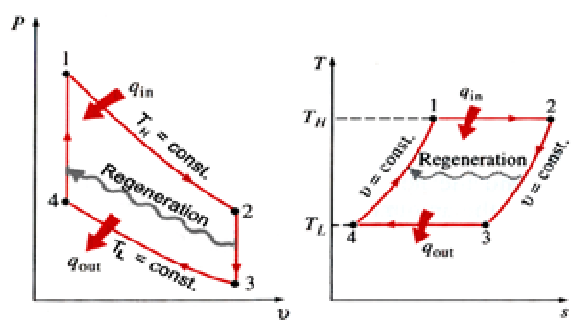
KEYWORDS : Stirling Engine, Solar Energy, Solar Powered Stirling Engine.

INTRODUCTION

Coal and other relic fuels which have taken three million years to form are likely to deplete soon. In the last two hundred years, we have consumed 60% of all resources. For sustainable development, we need to adopt energy efficiency measures. Today, 85% of primary energy comes from non-renewable, and relic sources (coal, oil, etc.). These reserves are continually diminishing with increasing consumption and will not exist for future generation.Of the existing sources of renewable energy, the most promising is the sun. It is the most abundant source of energy on the planet and it is a phenomenal source of light and heat. Scientific Australianmagazine states, "The energy in sunlight arresting the Earth for 40 minutes is the equivalent to global energy consumption for one year." (Systems, Technology, 2009). Therefore, it motivates engineers to design way of capturing this incredible natural resource for use in power generation as an alternative to other methods such as relic fuels. The era of the engines started from the year of 1770, when the father of the IC engines, Nicholas Cugnot first designed the Internal-combustion engine and from that year the era of the engines started. Then in 1813, Stirling engine first came into scene which was designed by Robert Stirling and which was more powerful and conventional than the IC engine and overcome most of the drawbacks of the IC engine. The Stirling engine (or Stirling's air engine as it was known at the time) was invented and patented by Robert Stirling in 1816.In its simplest form a Stirling engine consists of a cylinder containing a gas, a piston and a displacer. The regenerator and a flywheel are other complimentary parts of the engine. When heat part of cylinder is heated up by an external heat source, the temperature rises and gas expands proportional in to the temperature of the heat side. Total volume is constant and limited by a piston thus expanded gas pushes the piston down, so the volume of the pressured gas is increased and the gas loses its pressure and temperature, then the piston backs to the heat side and compresses the gas by momentum force of the flywheel, when it reaches near its up limit the displacer also pushes the cooled gas to the heat side of the cylinder so that the gas is compressed and it can be prepared to do another cycle. The expanding gas pushes the piston down again to produce mechanical energy for doing work, this cycling will continue till an external heat source is available. There are three types of Stirling engines:-Alpha-Stirling engine, Beta-Stirling engine & Gamma-Stirling engine.

Stirling Engine cycle

The Stirling cycle is a heat addition and heat dissipation method just like the well-known Carnot cycle. Heat addition comes from the high temperature reservoir, TH, and then further in the cycle, heat is rejected to the low temperature reservoir. In our Stirling engine, the high temperature reservoir is provided by the sun solar energy. During the heat addition and rejection phases, the basic Stirling cycle is a constant temperature process. During the next two stages of the cycle, a regenerator yields an increment in temperature while volume remains stagnant within the system.



The four steps are summarized as follows:

1-2 T = constant → expansion (heat addition from external source)

2-3 v = constant → regeneration (internal heat transfer from the working fluid to the regenerator)

3-4 T = constant → compression (heat rejection to external sink)

4-1 v = constant → regeneration (internal heat transfer from regenerator back to the working fluid)

Solar Concentrator

Solar concentrator is a device that allows the collection of sunlight from a large area and focusing it on a smaller receiver or exit. The material used to fabricate the concentrator varies depending on the usage. For solar thermal, most of the concentrators are made from mirrors while for the BIPV system, the concentrator is either made of glass or transparent plastic.For the past four decades, there have been a lot of developments involving the designs of the solar concentrators. The different types of solar concentrators are listed below.

- Parabolic Concentrator
- Hyperboloid Concentrator

- Fresnel Lens Concentrator
- Compound Parabolic Concentrator (CPC)
- Dielectric Totally Internally Reflecting Concentrator (DTIRC)
- Flat High Concentration Devices
- Quantum Dot Concentrator (QDC)

Materials and Methods

Design

Many model Stirling engines are sold as educational aids. Generally this type of model has a little DC motor and a drive belt. There are usually a few other sensors and connections to help students learn and understand how a Stirling engine generator works. However the Stirling engine here has been designed. Stirling engine has different important partslike cylinder, piston, crankshaft, flywheel etc. The material used for the cylinder is glass whereas aluminium alloy has been used to make piston. The other parts are made with steel. The parts have been manufactured on CNC machines. The different parts of the engine has been shown in the Fig.(2). This very primary attempt to make a Stirling engine. The figure(3) shows the Stirling Engine.

Fig. 2 Parts of engine.

Fig. 3 Stirling Engine

Parabolic Solar Concentrator The two dimensional design of a parabolic concentrator is equals to a parabola. It is widely used as a reflecting solar concentrator. A distinct property that it has is that it can focus all the parallel rays from the sun to a single focus point, F as shown in Figure (4). The solar concentrator which has been used is shown in fig(5).

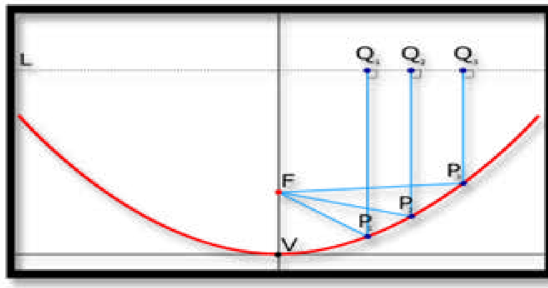


Fig 4 Parabolic geometry.

Fig 5 Solar concentrator

RESULTS AND DISCUSSION

CalculationsThe following calculations were made to estimate the efficiency of the engine. Calculations were based on ideal Stirling cycle the ideal gas low. The temperature of the hot sink has been measured with the help of thermo couple. In order to measure the RPM of the engine 'Tachometer' has been used. The efficiency of the Stirling engine has been measured based on Carnot formula.

Cold Sink Temperature T_L=70°C=343k

Hot Sink Temperature T_H=230°C=503k

$\eta = (1-T_L/T_H) \times 100\%$

$= (1-343/503) \times 100\%$

$= 31.80\%$

The results obtain after the test haveshown that Stirling engine can be ran by creating temperature difference between the hot and cold sink with help of solar radiation which can be concentrated by using solar concentrators. In which the hot sink temperature is 230°C and cold sink temperature is 70°C has been achieved. The efficiency achieved is 31.80%. The RPM achieved is 148. The efficiency can be increased by altering many parameters. The working fluid used is Air, instead of Air if the Hydrogen is used than the torque and the RPM will be triple than air. The size of the solar concentrator is also small, if area and size of the concentrator increased the efficiency will increased. The automatic system can be attached to the concentrator in order to maintain the accurate position of the concentrator with hour angle. The torque and power of the engine can be calculated by using proper techniques and tools. Ongoing research and development efforts on solar-powered Stirling engines in world shows considerable promise for future applications. The Stirling engine efficiency may be low, but reliability is high and costs are low. Simplicity and reliability are keys to a cost effective Stirling solar generator.Southern California Edison (SCE) and Stirling Energy Systems(SES) are building a huge 1,800ha (4,500ac) solar power generating station in Southern California. When complete, the power station will be the world's largest solar facility, producing more electricity than all other US solar projects combined. The figure(6) shows the solar powered Stirling engine power plant. Also Jason Tsao of Torrance, California created an apparatus that combines a solar Stirling cycle with wind energy to power system that can provide air conditioning, refrigeration, space-heating, hot water, and electricity to a modern home.

Fig 6 Solar Powered Stirling Engine Power Plant

CONCLUSIONAs said earlier that it is an attempt to operate Stirling engine with help of solar power. The Engine has run smoothly and without any noise pollution. The aim of this study is to find a feasible solution which may lead to a preliminary conceptual design of a workable solar-powered Stirling engine, which has been achieved.

ACKNOWLEDGEMENTSThe authors would like to thank HemilVarkhade, Jainam Shah and Rajan Patel for their help during the project.

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