ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Fabrication of a Vertical Gamma Type Stirling Engine

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ABSTRACT:
Generation of electricity from fossil fuels such as coal has been one of the major problems in the society due to raising energy demands and environmental pollution. The energy generation is very low comparable to the energy consumption (electrical energy at most). Usage of renewable energy as a heat source can overcome the above problem of electricity generation, one of the important ways of harvesting Solar energy is by developing Stirling engine working on the solar power. This project focuses on the design and fabrication of a Vertical Gamma type Starling engine that drives on both simple heat energy and solar power. In order to extract more efficient work, concentrating collectors are used for future work.

Keywords:
Stirling Engine, Concentrating Collector, Work, Efficiency.

1.INTRODUCTION:
Due to the shortage of fossil fuels in present days the generation of electrical energy is becoming a very huge problem in the society. To overcome this, the renewable sources like solar, wind, tidal etc., are been used, of which solar power is the most available source and has been used a lot. Generally the solar energy is harvested using solar panels which are costly .For domestic purpose it is difficult to buy the solar panels for generating electricity. So, there is need for another equipment which should be at moderate cost and available to the society. In this situation Stirling engine plays a very important role.

In this study we stated the construction and working of Stirling engine using solar energy as the input power. Solar energy collectors are been used to harvest the solar energy for the functioning of our Stirling engine. Stirling engine was first proposed by Robert Stirling in 1816 (UK, Patent no.4081). It is a simple type of external combustion engine. Stirling engine converts heat energy to mechanical energy .The essential features of the Stirling engine however are that it is a closed cycle, external combustion engine. This means that it uses a fixed amount of working fluid ,usually air but other gases may be used, enclosed in a sealed container and the heat consumed by the engine is applied externally .This allows the engine to run on just about any heat source including fossil fuels , hot air , solar, chemical and nuclear energy. It can also work with very low temperature differentials as low as $7^{o}C$ between the heat source and the heat sink so that it can be powered by body heat and even the steam from a cup of coffee. Since it can use heat from a constant flame and does not depend on explosions as in a internal combustion engine, the engine run silently. The operation of stirling engine on different sources is shown in Figure 1.

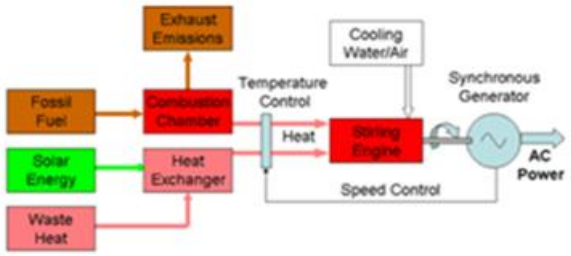

Figure 1 Stirling Engine Operated on Different Sources

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2. WORKING PRINCIPLE:

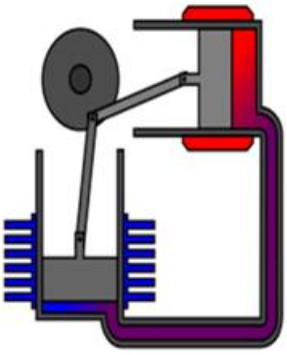
The Stirling engine relies on the property of gases that they expand when heated and contract when cooled. If the gas is contained within a fixed volume, it'spressure will increase on heating and decrease on cooling (Charles Law). The pressure increases and decreases will cause the piston to move out and in. Repeated heating and cooling will cause a reciprocating movement of the piston which can be converted to rotary motion using a conventional connecting rod and a crank shaft with a flywheel. Theoretical Efficiency (η**)** of the Stirling engine is given by Carnot's law thus:

η

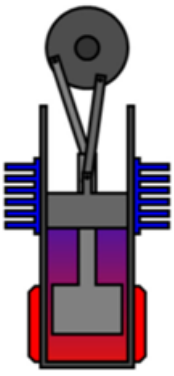
Where,

T_C = Temperature of the gas when it is cold, T_h= Temperature of gas when it is hot.

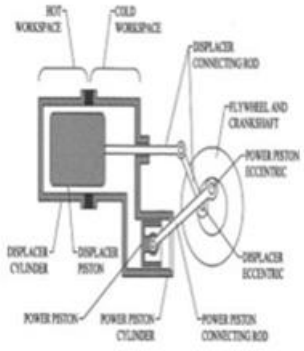
Figure 2 shows different types of stirling engines such as Alpha, Beta and Gamma type.



(a)



(b)



(c)

Figure 2 (a) Alpha; (b) Beta; (c) Gamma type Stirling engine

3. GAMMA STIRLING ENGINE:

The Gamma type Stirling Engine shown in Fig 3 has the simpler construction compared to other Stirling Engines. Due to which the Designers choose this more than the others .The only disadvantage is it has low compression ratio.

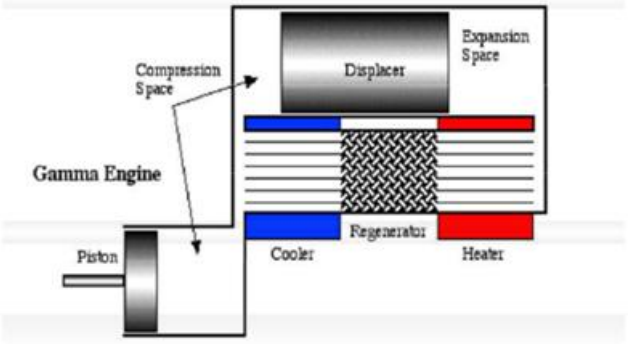


Figure 3 Gamma Type Stirling Engine

4. SOURCES:

The Stirling Engine can work on many sources like Solar, Thermal, Nuclear etc, As Solar Energy is the renewable energy and abundant in nature with free of cost we have preferred Solar source rather than the other sources. The main problem in using solar energy is to harvest it .So we are using the solar concentrating collectors to overcome this problem. The best concentrating collector that can increase the efficiency and performance of Stirling Engine is the Sun Flower Solar Collector. Fig.4 shows the working of Stirling engine using Solar Power.

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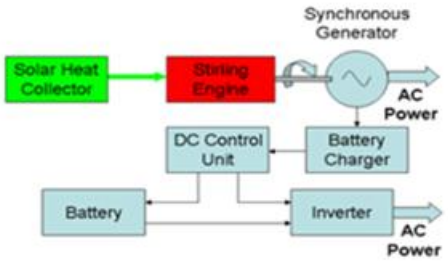

Figure 4 Solar powered Stirling Engine

This type of Stirling Engine setup is used for only domestic purpose as it's efficiency is very low about 20% .So these are used to pump water and to generate electricity for small house hold appliances. So this may help to generate some part the total energy that is used in present day world. Shung-Wen Kanget .al [1] has investigated in his paper about the shaft power, engine torque, brake thermal efficiency with engine speed and engine performance at various heat inputs. The engine is tested with the heat input of 156.3W, 187.6W, 223.2W. In the paper they tested the single and twin power cylinder using an electric source as heat input and temperature is about 612^{O}C and 574^{O}C.

The maximum torque obtained is 0.13Nm at 405rpm and 0.15Nm at 412rpm; and a maximum shaft power of 5.73W at 456rpm and 6.47 W at 412 rpm and a maximum brake thermal efficiency of 2.57% at 456rpm and 2.9% at 412rpm. Can Cinar et al [2] suggested in his paper that a gamma type Stirling Engine with 276cc swept volume was designed. The working fluid in the Engine is taken as air and helium. Working characteristics of the engine are obtained in a range of temperature 700-1000^{O}C and range of pressure is 1-4.5 bar. Maximum power obtained is 128.3 W at 4bar and at 1000^{O}C. Paul T.et .al [3] stated in his paper the usage of Solar Stirling Engine and the power generation using it.In his paper a 500W prototype Stirling Engine system has been designed to determine the potential visibility of using low enthalpy heat sources, where temperature differentials may be as low as 30^{O}C.

Ding Guozhong et.al [4] designed and simulated a 3KW Stiring Engine based on testing V-type machine. The enine was driven by solar energy .the consideration of radiant energy density solar energy was non – constant and electrical heating as employed to serve as the auxiliary heat source. There was about 1.83 KW output work of the manufactured engine during the simulation and the efficiency achieved was about 25.4%.

M. Tarawnehet .al [5] developed a thermodynamic based model in his paper. The influence of thermo-physical parameters on the Stirling Engine performance was investigated. Some governing equations were developed and employed to investigate the pressure, temperature, volume, mass flow, and convective heat transfer during the compression and expansion processes. Leakage of the working fluid due to the leakages and energy losses are investigated under the working conditions .additionally the use of other related correlations ensures the model accuracy while the resulted small difference are within the expected ranges. In comparison with similar studies, the calculation procedure can be used to investigate the engine performance under different operating conditions.

AsawariBhagat et al [6] designed and thermodynamically analysed a solar stirling model of alpha configuration. In order to provide heat to the engine, a parabolic solar concentrator is used. They also determined the work extracted from a 49cc stirling engine and also calculated the effect of regenerator effectiveness on Stirling cycle efficiency, Variation of expansion volume, Compression volume and total volume with respect to crank angle variation. Koichi [7] developed a compact and low cost gamma type Stirling with simple moving-tube-type heat exchangers along with the development of rhombic mechanism. Helium is used as working gas for an engine with speed of 4000 rpm and mean pressure of 0.8 MPa in order to achieve shaft power of 50 W.

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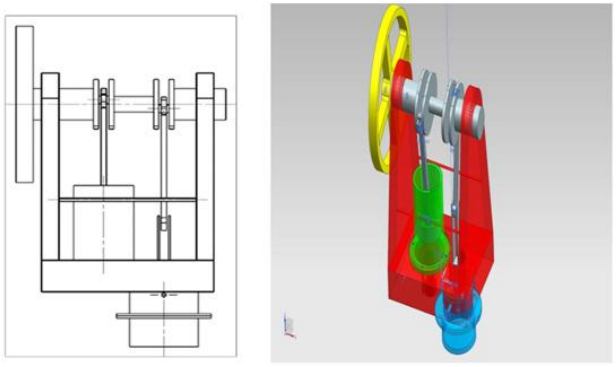
The resultsindicated that a higher performance heat exchanger and decreasing of mechanical loss are needed for the attainment of the target performance. A literature review on solar-powered Stirling engines and low temperature differential Stirling engines technology has been provided by Bancha Kongtragool et al [8]. A feasible solution which may lead to a preliminary conceptual design of a workable solar-powered low temperature differential Stirling engine has been found. The results from the study also indicated that vertical, double-acting, gamma-configuration Stirling engines working with relatively low temperature air are potentially attractive engines of the future.

Anish Saini et al [9] dealt with the powering of water pump using parabolic mirror to concentrate the solar beams for the working of stirling engine. They also extended their work in order to generate electric power from the water drawn from underground. Rakesh K. Bumataria et al [10] reviewed many research works for the development of Solar Stirling engine which will help in development of the engine which can be used for pumping water at rural areas using solar energy as a source. The work has been expanded in order to generate electricity by attaching a generator of required capacity to the shaft of stirling engine. Mohsin J Dadi et al [11] stated in his paper that gamma Stirling Engine is the best way to recover the waste heat. He reviewed about the Gamma Stirling Engine and He stated that to fabricate it easily with available material and it should run at low temperature difference with high efficiency. The inferences drew from the above literatures shows that stirling engine is one of the engine which can produce huge work impact with low temperature source. These results also reveal that the solar energy can be one of the abundant energy source to operate the stirling engine for power generation.
The objective of this paper focuses on the development of a prototype for a solar powered stirling engine using concentrating collectors.

5. DESIGN AND FABRICATION:

The design that we have opted is a simple gamma type Stirling Engine. The 2D Model and the 3D model of the Stirling Engine has been shown in Figure 5



(a) (b)

Figure 5 (a) 2D Drafting (b) 3D Assembly

5.1. SPECIFICATIONS OF THE COMPONENTS:

The following parts shown in Table 1 are designed and fabricated which are assembled into a Stirling Engine.

Table 1 Components Specification

S. No	Part Name	Specifications
1.	Bore	2.86 cm
2.	Power piston Stroke	3.18 cm
3.	Swept volume	20.3cm^3
4.	Bore	3.56 cm
5.	Displacer piston Stroke	3.18cm
6.	Swept volume	31.53 cm^3
7.	Swept volume ratio	1.55
8.	Compression ratio	1.4
9.	Phase angle	90

5.2. FABRICATED MODEL

The model of the Gamma type Stirling Engine fabricated by additive manufacturing (3D printing) is shown in Figure 8.

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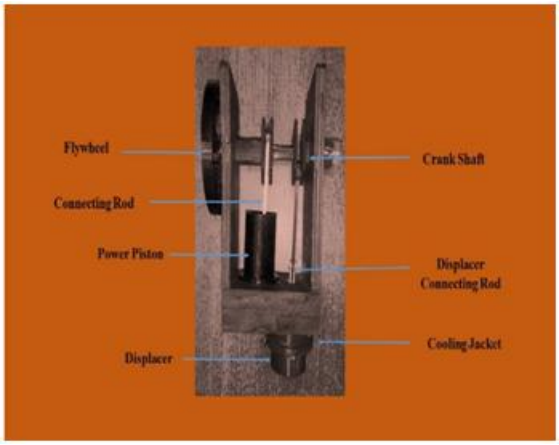

Figure 8 3D Printed Stirling Engine

5.3. MATERIALS USED FOR THE FABRICATION:

For an efficient operation of the fabricated stirling engine shown above in Fig. 8, the materials indicated for each component is shown in Table 2.

Table 2 Materials used for fabrication:

S. No	COMPONENTS	MATERIAL USED
1.	Cooling Jacket	Copper
2.	Crank Shaft	Aluminium
3.	Displacer Connecting Rod	Aluminium
4.	Displacer Cylinder	Copper
5.	Displacer Pin	Aluminium
6.	Displacer	Aluminium
7.	Frame	Steel
8.	Flywheel	Aluminium
9.	Piston Pin	Aluminium
10.	Power Cylinder	Aluminium
11.	Power Piston Rod Cap	Aluminium
12.	Power Piston Rod	Aluminium
13.	Power Piston	Aluminium

5.4. WORKING OF FABRICATED MODEL:

In this, the fabricated Stirling engine model will be working on the Solar Concentrating Collector as solar energy as the input source. The solar collector will be concentrating the solar energy as a beam and focuses on the Stirling Engine .This will create a Temperature difference between the two sides of the Regenerator. This makes the Displacer to reciprocate in the regenerator. Because of this reciprocating motion one stroke of the cycle will be completed and the other stroke is done by Diaphragm. The reciprocating motion is converted to the rotating motion by connecting the piston rod to the flywheel.

Heat Input on the Stirling engine is

m= mass flow rate (kg/sec)

cp= specific heat constant of the gas or air(KJ/kg.K)

T_h= Temperature of the hot end

T_c= Temperature of the cold end

The work done by the Stirling Engine is:

$W=2\pi NT/60$

Where,

N= Speed obtained in the flywheel (rpm) T= Torque (N.m)

6. CONCLUSION & FUTURE SCOPE:

In future, the usage of renewable sources such as solar, tidal, wind, geothermal etc. would be high due to increasing energy consumption and depletion of fossil fuels. As India is rich in most of the renewable sources especially in solar power, the power generation can be achieved from the engines operated on low temperature source. Stirling engines are such type of engines which produce maximum work on low temperature source. A prototype of a solar operated stirling engine has been designed and fabricated. The future scope of this prototype fabrication can be extended for a real stirling engine operated on solar energy from which the extracted work can be used for power generation.

REFERENCES:

[1] Shung-Wen Kang, Meng-Yuan Kuo, Jian-You Chen, Wen- An Lu. Fabrication and Test of Gamma-Type Stirling Engine. PEA-AIT International Conference on Energy and Sustainable Development: Issues and Strategies (ESD 2010).

[2] Can Cinar, Halit Karabulut. Manufacturing and testing of a gamma type Stirling engine. Renewable Energy 2005; 30:57-66.

[3] Paul T. Gaynor, Russell Y. Webb and Caleb C.Lloyd. Power Generation Using Low Temperature Differential Stirling Engine Technology". World Geothermal Congress 2010. Indonesia.

[4] Ding Guozhong, Yan Jiwei, Shu Shuiming, Duan Chen, A Typical Simulation of a 3KW Stirling Engine, TELKOMNIKA. Indonesian Journal of Electrical Engineering Vol.10, No.6, October 2012, pp. 1273~1279.

[5] Tarawneh, F. Al-Ghathian, M. A. Nawafleh, N.Al-Kloub, Numerical Simulation and Performance Evaluation of Stirling Engine Cycle. Jordan Journal of Mechanical and Industrial Engineering, Volume 4, Number 5, November 2010 ISSN 1995-6665,Pages 615– 628.

[6] Asawari Bhagat , Akshay Modi, Prathamesh Hinganikar, Prasad Tambekar, N.U.Kakade, B.N.Kale, Design of Alpha Stirling Engine in Conjunction with Solar Concentrator .International Research Journal of Engineering and Technology, Volume :03 ,Issue :04, April-2016, e-ISSN: 2395-0056, p-ISSN: 2395-0072.

[7] Koichi HIRATA Development of a small 50W Class Stirling Engine .International Society of Mechanical Engineers.

[8] B. Kongtragool, S. Wongwises, A review of solar powered Stirling engines and low temperature differential Stirling engine, Science Direct renewable and sustainable energy, 7 ,2003, 131 – 154.

[9] Anish Saini, Shivam Kohli, AjeshJ.Pillai, Solar Powered Stirling Engine Driven Water Pump. International Journal of Research in Engineering and Technology. eISSN :2319- 1163,pISSN:2321-73.

[10] Rakesh K. Bumataria, Nikul K. Patel, Review of Stirling Engines for Pumping Water using Solar Energy as a source of Power. International Journal of Engineering Research and Applications. Vol.3, Issue 1, January -February 2013,pp. 864-868. ISSN: 2248-9622.

[11] Mohsin J Dadi, Imran M Molvi, Alpesh V Mehta, A Review Article on The Most Efficient Waste Heat Recovery Device: A Gamma Type Stirling Engine. International Journal of Advanced Engineering Technology. E-ISSN 0976-3945.

[12] Mathew Alphonse, R. Ramesh Kumar, M. Senthil Kumar and K Karthik, Design and Thermal Analysis of Stirling Engine using Industrial Applications of Ceramic Material, International Journal of Mechanical Engineering and Technology (IJMET) Volume 8, Issue 6, June 2017, pp. 273-282.