Stirling Engine Powered Fan

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Abstract—This project was set out to explore the probability of designing a cooling device using Stirling engine. This would include research, design and fabrication. Stirling engines would run on different sources of sufficient external heat to generate the desired motion.Our target beneficiaries would be rural areas of people living in the marginalized areas with little hope of getting access to electricity. The success of this project would afford these people a chance to have a reliable cooling device their homes.

Keywords— Stirling engine; renewable energy; basic cycle

I. INTRODUCTION

What's a Stirling engine?

A Stirling engine is a heat engine operating by cyclic compression and expansion of air at different temperature levels such that there is a net conversion of heat energy to mechanical work. Like the steam engine, the Stirling engine is traditionally classified as an external combustion engine, as all heat transfers to and from the working fluid take place through the engine wall. This contrasts with an internal combustion engine where heat input is by combustion of a fuel within the body of the working fluid. Unlike a steam engine's (or more generally a Rankine cycle engine's) usage of a working fluid in both of its liquid and gaseous phases, the Stirling engine encloses a fixed quantity of air.

As is the case with other heat engines, the general cycle consists of compressing cool gas, heating the gas, expanding the hot gas, and finally cooling the gas before repeating the cycle. The efficiency of the process is narrowly restricted by the efficiency of the Carnot cycle, which depends on the temperature between the hot and cold reservoir.

The Stirling engine is exceptional for its high efficiency compared to steam engines, quiet in operation and the ease with which it can use almost any heat source. This is especially significant as the prices of conventional fuel prices rise in a more "green cautious" world.

Why design a Stirling Engine Fan?

Though India has entered the 21st century and the country is experiencing an information technology revolution, parts of the country still have no electricity and some parts have frequent power cuts.With the average temperature during Indian summers ranging from 32^{o} to 40^{o} and with most Indian families unequipped with cooling solutions to maintain the temperature in their dwelling. The conditions in their dwellings can get quite uncomfortable and inhospitable.

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The frequent power cuts and no electricity in certain regions can aggravate the situation. With these aspects in mind we set out find a solution that can satisfy these requirements and in a very economical way.

- **Scope of design**

The Stirling engine fan we designed and fabricated was in two pieces: a normal Stirling engine that could be heated externally using an open flame and a detachable rotor blade that could be fixed to the Stirling engine there by transferring the power to the rotor. An alpha configuration of the engine was chosen, whose working shall be explained further in this report.The rotor unit consisted of a two blade rotor, similar to the ones being used in aircraft propellers. Its design was simple and with the right diameter and pitch, developing the most optimum thrust as possible.

The aim of choosing this design was to make the manufacturing cost of this engine low and keep it simple. The design and fabrication of the engine are also documented in this report.

II. LITERATURE REVIEW

Introduction

The Stirling engine has over the years evolved. The most common configurations include the Alpha, Beta and Gamma. These vary in the arrangement of the different parts including the displacer, piston and flywheel.

The Stirling engine operates on the Stirling cycle that has a theoretical efficiency close to the Carnot efficiency. In the theory developed later, it is noted that addition of a regenerator in the configuration improves the overall performance and increases the output power of the system.

Basic Components

A Stirling engine consists of a number of basic components, which may vary in design depending on the type and configuration. The most basic are outlined as follows:

- **Power Piston and Cylinder**

This consists of a piston head and connecting rod that slides in an air tight cylinder. The power piston is responsible for transmission of power from the working gas to the flywheel. In addition, the power piston compresses the working fluid on its return stroke, before the heating cycle. Due to the perfect air tight requirement, it is the most critical part in design and fabrication.

- **Displacer Piston and Cylinder**

The displacer is a special purpose piston, used to move the working gas back and forth between the hot and cold heat exchangers. Depending on the type of engine design, the displacer may or may not be sealed to the cylinder, i.e. it is a loose fit within the cylinder and allows the working gas to pass around it as it moves to occupy the part of the cylinder beyond.

- **Source of Heat**

The source of heat may be provided by the combustion of fuel, and since combustion products do not mix with the working fluid, the Stirling engine can run on an assortment of fuels. In addition, other sources such as solar dishes, geothermal energy, and waste heat may be used. Solar powered Stirling engines are becoming increasingly popular as they are a very environmentally friendly option for power production.

- **Flywheel**

The flywheel is connected to the output power of the power piston, and is used to store energy, and provide momentum for smooth running of the engine. It is made of heavy material such as steel, for optimum energy storage.

- **Regenerator**

It is an internal heat exchanger and temporary heat store placed between the hot and cold spaces such that the working fluid passes through it first in one direction then in the other. Its function within the system is to retain heat which would otherwise be exchanged with the environment. It thus enables the thermal efficiency of the cycle to approach the limiting Carnot efficiency.On the flip side, the presence of regenerator (usually a matrix of fine steel wool), increases the "dead space" (unswept volume). This leads to power loss and reduces efficiency gains from the regeneration.

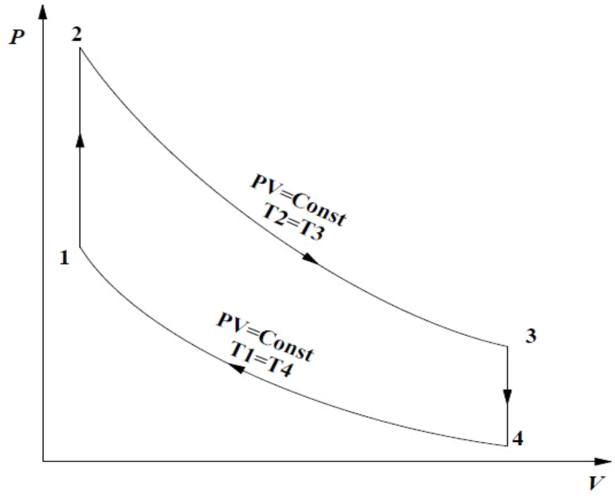
- **Heat Sink**

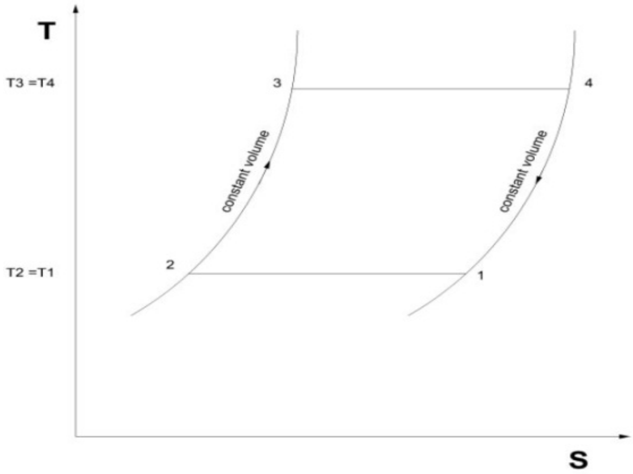
The heat sink is typically the environment at ambient temperature. For small heat engines, finned heat exchangers in the ambient air suffice as a heat sink. In the case of medium to high power engines, a radiator may be required to transfer heat from the engine

III. BASIC STIRLING CYCLE

The Stirling cycle comes closest to the Carnot cycle efficiency while having a higher work ratio. Despite the fact that the efficiency may not be practical in real fabrication and testing, the Stirling engine gives the best output.The idealized Stirling cycle consists of four thermodynamic processes acting on the network of the fluid;

- **2-3: Isothermal expansion**: the expansion space and associated heat exchanger are maintained at a constant high temperature and the gas undergoes isothermal expansion absorbing heat from the heat source.
- **3-4: Constant volume heat removal**: the gas is passed through a regenerator where it cools transferring heat to the regenerator for use in the next cycle.
- **4-1: Isothermal compression**: the compression space and associated heat exchanger are maintained at a constant low temperature so that the gas undergoes isothermal compression, rejecting heat to the cold sink.
- **1-2: Constant volume heat addition**: the gas passes back through the regenerator where it recovers much of the heat transferred in (2) above, heating up on its way to the expansion space.





The Stirling cycle on a P-V & T-S diagram

Theoretically, heat is supplied to the working fluid in the process 2-3 where the gas expands isothermally ($T_2 = T_3$). Further, heat is rejected toan external heat sink in theprocess 4-1 where the gas is compressed isothermally (T_1=T_4). The two isothermals are connected by the constant volume processes 1-2 and 3-4, during which the temperature changes are equal to ($T_2 - T_1$).
Heat supplied from the hot source:(2.2)
Similarly, heat rejected to the cold sink:
Therefore;And as the cycle efficiency, thereforeFor the constant volume process 1-2,
Therefore; This shows that the Stirling cycle has the same efficiency as the Carnot cycle.

IV. DISCUSSION

The project was carried out with an objective to explore the possibility of making a low cost and reliable Stirling engine fan that would run on easily available sources of fuel. This was done with the view of the rural population in their needs of cooling during summers when there was limited supply of electricity. To achieve this, a Stirling engine powered fan was envisaged as a possible route to explore alternative methods. The concept was chosen to take advantage locally available source of energy as well as the hot and sunny weather experienced in some of the marginalized parts of India.

With this vision, sketches were made that led to computer aided designs that gave a graphical representation of what was anticipated during and after fabrication. After designs approval and acquisition for funds and materials, fabrication was carried out in a span of about 8 weeks and a prototype came to being. Tests were carried out with a view of estimating actual efficiency and calculating power output from the engine. The engine was put through a series of tests that were not conclusive due to air loss. The intension to measure the power output was therefore not feasible. Some of the losses of power, were attributed to friction in the engine. In spite of the thorough lubrication that was done, friction was inevitable. From the assessment carried out, the greatest source of friction was in the flywheel assembly. This was because the flywheel assembly constituted several mating pieces, which rubbed on each other during operation. In addition, there was a lot of friction in contact between the piston and power cylinder arrangement. Further, the engine experienced power loss due to out-of-balance masses in the assembly. It is noted that the attachment of the crank shaft to the flywheel introduced an out of balance mass that contributed to the power loss. To rectify this, a re-examination of the parts in the assembly was recommend, in addition to a kinematic assessment of the engine to ensure all parts were balanced.

V. DESIGN & FABRICATION IMPROVEMENTS

Having fabricated the Alpha configuration Stirling Engine, we noted a few areas that needed improvement:

- There was a lot of "out of balance" movement from the fly wheel which might have caused a lot of vibrations if the engine were running. It is therefore necessary to carry out a kinematic assessment to be able to do a mass balance on the flywheel.

VI. CONCLUSION

The project was undertaken to explore the practicality of power production from a Stirling engine powered fan. This included research, design and fabrication. The fabricated model was then tested and it was noted that some air leaks existed in the displacement cylinder. On the overall, the project was successful on several accounts. First, a successful research led to a design that was simulated on Autodesk AutoCAD. In addition, the prototype was fabricated and pointed the project exploration in the right direction. The setbacks encountered were used to give recommendations and pointed out some ways of project improvement. A theoretical energy assessment showed that with an open flame of sufficient temperature, (about 600^{o}C) the designed Stirling engine would generate 45watts of power. In conclusion therefore, the project successfully explored the practicality of generating power from a Hybrid Stirling engine.

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