Stirling Engine

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Abstract— Stirling engine is a mechanical device working theoretically on Stirling cycle. It is external combustion engine. There are mainly three types of Stirling engine is available. Alpha, Beta and Gamma. It uses Air, Hydrogen, Helium, Nitrogen or Steam as working fluid. But this is a new designed metal body Stirling engine which is different from these three types. It is contain conical shape cold cylinder, power piston, regenerator, hot cylinder etc. It can be used as waste heat recovery engine. This is metal body Stirling engine so it is also used for practical application and also for power generation. Internal combustion engine is developed in 19th century. But it efficiency is only 35- 40%. And it is also used fossil fuels which is high in cost and limited in nature. And exhaust emission of Internal Combustion engine is also high. But the Stirling engine offer possibility for having high efficiency engine with less emission in comparison with internal combustion engine. The ideal Stirling engine cycle has the same theoretical efficiency as Carnot heat engine (for the same input and output temperatures). And it is uses renewable resources. So the cost of power production is also low. Our ultimate aim is to develop metal body Stirling engine which can be used for practical application.

Key words: Stirling Engine, Metal Body, Waste Heat Recovery, Renewable Resources

I. INTRODUCTION

A. *What's a Stirling Engine?*

A Stirling engine is a heat engine operating by cyclic compression and expansion of working fluid 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 Rankin cycle engine's) usage of a working fluid in both of its liquid and gaseous phases, the Stirling engine encloses a fixed quantity of working fluid. 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 of 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. Competition from Internal combustion The invention of the internal combustion engine in the 1900's put the nail on the coffin for the Stirling type of engine because it generated more power and proved to be more practical in the automobile industry.

Due to the rigorous solar energy exploration taking place in the developed economies, this old technology is be given a newer and fresher approach.

In the Kenyan scenario, the Stirling engine hopes to offer energy to rural and marginalized areas where the most common sources of energy include:

- Biomass fuel –from burning of charcoal, firewood, rice husks, coal, maize cobs among others
- Biogas- which has become of great use in the rural areas for both cooking and lighting
- Solar heating- which has made its debut in the rural areas as an alternative means of cooking energy through use of solar concentrators.

II. A BRIEF HISTORY OF THE STIRLING ENGINE

A. *Reverend Robert Stirling*

On September 27, 1816, Church of Scotland minister Robert Stirling applied for a patent for his economizer in Edinburgh, Scotland. The device was in the form of an inverted heat engine, and incorporated the characteristic phase shift between the displacer and piston that we see in all Stirling Engines today.

The engine also featured the cyclic heating and cooling of the internal gas by means of an external heat source, but the device was not yet known as a Stirling Engine. That name was coined nearly one hundred years later by Dutch engineer Rolf Meijer to describe all types of closed cycle regenerative gas engines.

Stirling originally regarded his engine as a perpetual motion machine of the second kind (i.e. all heat supplied would be converted into work even though his original hot air engine did not include a cooling system.

Due to the invention of the more powerful internal combustion engine at the middle of the 19th century, the Stirling technology was abandoned. But even so, the Stirling engine had an extra advantage over the steam engine due to its low operating cost. Also, the steam engine was prone to major failures like explosions. The only major problem with the Stirling engine was its tendency to fail when the cylinder being heated became too hot.

Although improvements were made to curb up the problem, stiff competition from the internal combustion engine forced the hot air engine out of the commercial scene.

Over the years, researchers have continued on Stirling engines, working out many of the design solutions that are used today in low temperature differential Stirling engines.

III. DESIGN OF A PROTOTYPE ENGINE

In order to develop a compact and low cost Stirling engine, a new design type Stirling engine that had to be designed given below.

Generally In design of Stirling Engine there are two cylinder (hot and cold cylinder), two pistons, connecting rod, crank and any heat source are used.

But in this new design is different than this.

A. Displacer Cylinder:-

Fig. 1: displacer cylinder Actual and in designing Software

This is displacer cylinder. In which steam, helium, Neon, Nitrogen etc. gases can used. In this design is based on working fluid steam. So the heat is provided at bottom of this cylinder. And water inside cylinder is converted into steam. So for fast this process there are a copper cylinder is used. Due to its high thermal conductivity the heat transfer become fast. There is conical shape provided because of concentration of steam on piston.

The dimensions of this cylinder are calculated based on volumetric expansion Ratio.

1) Volumetric Expansion:

a) Why Steam is used as a working fluid:-

The volumetric expansion co efficient of air is 0.003671 cm^3/ c. that means the as a change in temperature of a 1 c the 0.003671 cm^3 volume of air is changed. Helium, Nitrogen, hydrogen, air and steam has a higher volumetric expansion co-efficient. So these gases are also used as a working fluid. The volumetric expansion of argon and hydrogen is higher than air. But the hydrogen is explosive so it can't be used as a working fluid. The air is available easily and easily used. And the volumetric co-efficient of expansion is good. So the air is used as a working fluid.

The equation of a volumetric expansion is.

$V_2 = V_1 [1 + \beta (T_1 - T_2)]$

Assume if Air is used than $\beta = 0.003671$ cm^3/c

If the initial volume is $V_1 = 250$ cm^3

And $T_1 - T_2 = 20$

Then $V_2 = 250 [1 + 0.003671 * 20]$

$= 268.355$ cm^3

So, this equation gives the change in volume according to temperature change. So by this volumetric expansion co efficient displacer is designed.

But this is a metal body Stirling engine so air is not developed a high force. So instand of air steam is used as working fluid. The displacer cylinder contains water into it. When heat is provided from bottom of cylinder water is converted into steam. And this steam is act as working fluid of Stirling Engine.

Top of this cylinder there are head is provided with internal thread. And external thread is provided on cylinder. And it is tightly fitted with the help of Teflon tap.

B. Displacer (Regenerator):

Fig. 2: Displacer (regenerator)

The regenerator represents class of heat exchangers in which heat is alternately stored and removed from a surface this heat transfer surface is usually referred to as the matrix of the regenerator. For continuous operation, the matrix must be moved into and out of the fixed hot and cold fluid streams. In this case, the regenerator is called a rotary regenerator. If, on the other hand, the hot and cold fluid streams are switched into and out of the matrix, the regenerator is referred to as a fixed matrix regenerator.

This regenerator is transfer the heat between bottom air to top air and top air to bottom air. Regenerator is a wire mesh.

C. Connecting Pipe:

Fig 3: Connecting Pipe Actual and in Designing Software

This is used for transferring air from displacer cylinder to power cylinder. This pipe is made from copper because of its high thermal conductivity. These copper pipes are generally used in air conditioner.

Copper tubes used in refrigerator are used to make connecting pipe. Pipe bender and cutter used to get desire shape and brazing is used to eliminate leakage of working fluid from it.

D. Power Cylinder:

Fig. 4: Power Cylinder

This is power cylinder. It is contain power piston. The power cylinder is mainly responsible for generation of power because actual pressure acts on this and by this crank shaft is rotate. This cylinder contains high temperature and pressure steam. So for cooling purpose there are fins is provided. And also provided small hole at bottom for steam. Basically aluminum alloy is used.

E. Power Piston:

Fig. 5: Power Piston

Power Piston is made from Aluminum with high accuracy. It is placed in the power cylinder and the engine efficiency is mainly depending on this piston working. This piston is containing three rings. One oil ring and two compression ring. This piston contain a small key which is used for connect the piston with connecting rod. The bottom surface of the piston is generally flat. And its length and diameter are selected as per the requirement.

F. Crank Shaft and Crank:

Fig. 6: Crank shaft and crank actual and in designing software

This the most important part of engine. This is converting the reciprocating motion of piston into rotary motion. It is required that the shaft of crank is withstanding this high pressure with proper balancing. If shaft is unbalanced than it produced vibration on the engine.

It is must require that the shaft is withstand this high pressure. There are two crank connected 90 degree with each other. The power piston is 90 degree ahead than displacer.

Light weight material Aluminum is used as having less inertia and gravitational force on engine which limits the power output.

G. Nylon Ring:

Fig. 7: Nylon ring

Heat is provided at bottom of this cylinder. And water inside cylinder is converted into steam. So for increase steam generation process there is a copper cylinder is used. Due to its high thermal conductivity the heat transfer become fast. There is conical shape provided because of concentration of steam on piston. There is cylinder head is provided with internal thread. And from this head steam is transfer to the power cylinder. In this cylinder displacer (regenerator) is provided. This is connected to the crank shaft by connecting rod. So there is required that displacer connecting rod move reciprocating motion and also cylinder is leak proof. So for that purpose cylinder head is provided. Which contain internal threads and the head can easily remove whenever required. And also for leak proof motion the nylon ring is provided. This nylon ring prevent the leakage of steam when connecting rod is move in reciprocating motion.

IV. Assembly of Stirling Engine

Fig. 4: Stirling engine actual and in designing software

In fig shows the complete assembly of this engine. Working of this engine is done by four strokes.

A. Stroke 1:

At a time of starting of the engine the power piston is at a bottom position and the displacer is at a middle position shown in figure.

So, the cylinder has contain steam of volume V_1=……

The cylinder is heated by a burner at a bottom position .so the temperature of steam is increased. So, as a temperature of steam increased the steam is expanded proportional to the temperature. So it forces the piston in upward direction and piston start moving in upward direction. At this stroke heat is supplied. And power piston reached a middle position and the displacer at a bottom position.

B. Stroke 2:

In a Stirling engine the power piston is at middle and the displacer is at a bottom. The hot steam is passed from the hot cylinder to a cold cylinder by passing from the regenerator. And the energy from a hot steam is taken by the regenerator and the temperature of a steam is decreased and this cold steam is forced the power piston.

C. Stroke 3:

In a starting of a third stroke the hot piston is at a top position and the displacer is at a middle position. The steam is completely expanded in this stroke. And its volume is increase from V_1 to V_2. When the hot piston is reach a top position. This stroke is called a third stroke and the temperature of a steam is become a minimum.

D. Stroke 4:

The hot piston is at a middle position and a displacer is a bottom position. This stroke is a same as a second stroke. This stroke the hot piston move bottom.

V. IMPORTANT NOTES ABOUT STIRLING ENGINE

The Stirling engine is not a self-starting engine. In starting of starling engine some initial pre rotation is required.

The pre rotation is given by manually by a hand or by a motor.

For starting of engine first the heat is given at the bottom. And after some time the pre rotation is given to the crank. When the hot steam starts to force on piston and the steam expand and contrast continuously. Then the engine starts working. The Stirling engines use any source of energy.

VI. CONCLUSION

There are many designed Stirling engines are developed but no one can use for practical application. This is new designed Stirling engine it can be use for practical purpose. If we continuously give heat from bottom of cylinder than continuously rotation of shaft is produced. And heat is supplied at bottom of cylinder so any heat source can be used. This Stirling engine is also run by solar energy. In so many industries heat is wasted in exhaust gases. If we used flue gases to run the Stirling engine we definitely increases plant efficiency.

Stirling engine give a constant rotation of shaft so use of generator we also produced electricity in rural area by waste. The construction of this engine is also simple compared to IC engine and it can be easily manufactured.

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