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"Fabrication of Stirling Engine"

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ABSTRACT

The performance of Stirling engines meets the demands of the efficient use of energy and environmental security and therefore they are the subject of much current interest. Hence, the development and investigation of Stirling engine have come to the attention of many scientific institutes and commercial companies. The Stirling engine is both practically and theoretically a significant device, its practical virtue is simple, reliable and safe which was recognized for a full century following its invention by Robert Stirling in 1816. The engine operates on a closed thermodynamic cycle, which is reversible.

The objective of this project paper is to provide fundamental information and present a detailed review of the efforts taken by us for the development of the Stirling cycle engine and techniques used for engine analysis. A number of attempts have been made by us to build and improve the performance of Stirling engines. It is seen that for successful operation of engine system with good efficiency a careful design, proper selection of drive mechanism and engine configuration is essential. This project paper indicates that a Stirling cycle engine working with relatively low temperature with air or helium as working fluid is potentially attractive engines of the future, especially solar-powered low-temperature differential Stirling engines.

Keywords: *Stirling engines, Stirling cycle, thermodynamic cycle*

1. INTRODUCTION:

THERMODYNAMIC CYCLES

A **thermodynamic cycle** consists of a series of thermodynamic processes transferring heat and work, while varying pressure, temperature, and other state variables, eventually returning a system to its initial state. In the process of going through this cycle, the system may perform work on its surroundings, thereby acting as a heat engine. The first law of thermodynamics dictates that the net heat input is equal to the net work output over any cycle. The repeating nature of the process path allows for continuous operation, making the cycle an important concept in thermodynamics. Thermodynamic cycles often use quasistatic processes to model the workings of actual devices.

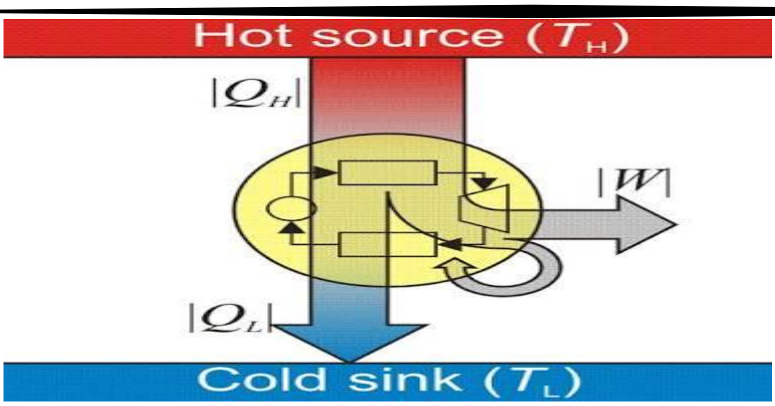

Figure-1

The above diagram shows a basic thermodynamic process where a body is kept in between a hot body and a cold body and there is net work produced.

HEAT AND WORK

Two primary classes of thermodynamic cycles are **power cycles** and **heat pump cycles**. Power cycles are cycles which convert some heat input into a mechanical work output, while heat pump cycles transfer heat from low to high temperatures using mechanical work input. Cycles composed entirely of quasistatic processes can operate as power or heat pump cycles by controlling the process direction. Temperature entropy diagram, the clockwise and counterclockwise directions indicate power and heat pump cycles, respectively. The heat and work of a thermodynamic cycle can defined by 2^{nd} law of thermodynamics.

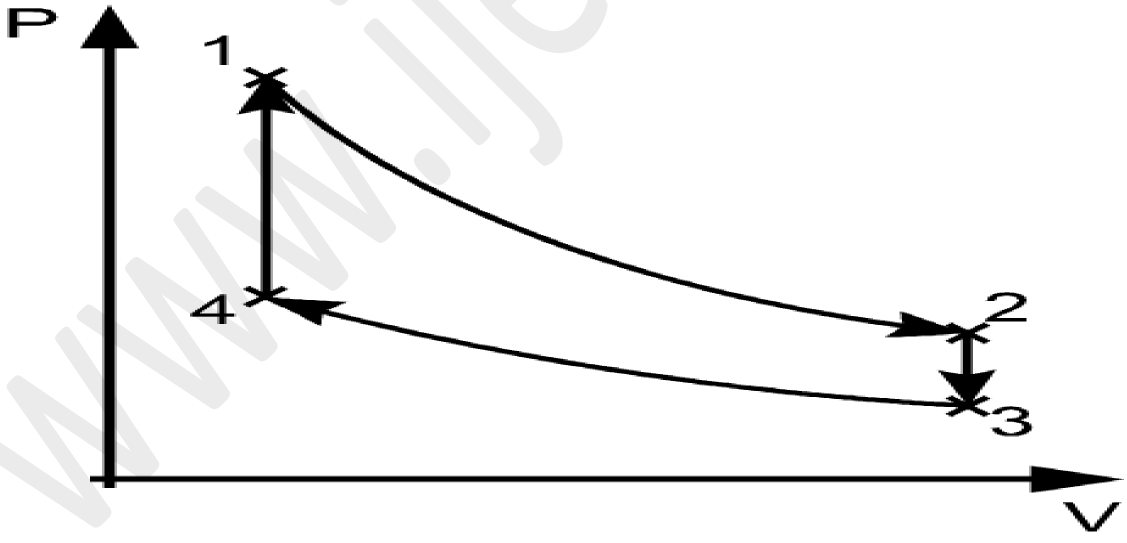

Figure-2

Because the net variation in state properties during a thermodynamic cycle is zero, it forms a closed loop on a PV diagram. A PV diagram's *Y* axis shows pressure (*P*) and *X* axis shows volume (*V*). The area enclosed by the loop is the work (*W*) done by the process:

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$$(1) \qquad W = \oint P\, dV$$

This work is equal to the balance of heat (Q) transferred into the system:

$$(2) \qquad W = Q = Q_{in} - Q_{out}$$

Equation (2) makes a cyclic process similar to an isothermal process: even though the internal energy changes during the course of the cyclic process, when the cyclic process finishes the system's energy is the same as the energy it had when the process began.

2.0 STIRLING CYCLE:-

The idealized Stirling cycle consists of four *thermodynamic processes* acting on the working fluid:

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

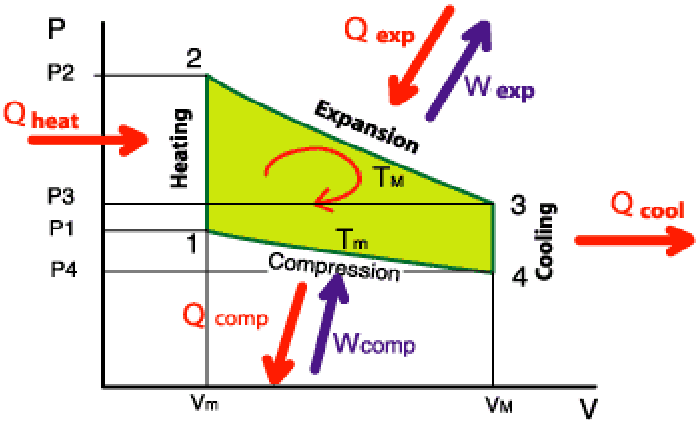

Figure-3

Theoretical thermal efficiency equals that of the hypothetical Carnot cycle – i.e. the highest efficiency attainable by any heat engine. However, though it is useful for illustrating general principles, the ideal cycle deviates substantially from practical Stirling engines. It has been argued that its indiscriminate use in many standard books on engineering thermodynamics has done a disservice to the study of Stirling engines in general.

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3. 0 MODEL DESCRIPTION

3.1 DESIGN AND DRAWING:-

		MATERIAL	LENGTH(Mm)	DIAMETER(Mm)	THICKNESS(Mm)
FLYWHEEL		TIN		85	6
PISTON	1-HOT PISTON	HARD SPONGE	10	85	SOLID
	2-COLD PISTON	HARD PLASTIC	30	16	1
CYLINDER-1		FIBER	20	95	3
CYLINDER-2		HARD PLASTIC	28	18	1
CONNECTING ROD-1		ALUMINUM	38	SOLID	1
CONNECTING ROD-2		ALUMINUM	45	SOLID	1
CRANK SHAFT		ALUMINUM	50	3	SOLID
CASING		TIN	175	100	1

Table-1

The efficiency of stirling engine can be calculated by the formula and if it is properly designed the efficiency will be equal to carnot efficiency and the formula is given by

$$\eta = 1 - T_{cold}/T_{hot}$$

we have determind the value of $T_{hot} = 120+273 = 393k$

$T_{cold} = 40+273 = 313k$

Now $\eta = 1-313/393 = 20.35\%$

3.2 PRO-ENGINEEER DESIGN & SPECIFICATION:-

3.2.1 STAND & CYLINDER:-

Criteria: Good thermal Conductivity, Easily machinable.
Material preferred: Wood, Tin.
Processing: Mig welding
For sealing, M-Seal
Internal grinding through Sand paper

Figure 4 & 5

3.2.2 PISTON:-

Criteria: Light weighted
Material preferred:
Hard sponge (hot piston), hard plastic (cold piston)
Processing: Sealing on
both side Turning on surface Finishing by machine. Casting.

Figure-6

3.2.3 FLYWHEEL:-

Criteria: Light weighted .
Material preferred: Tin .
Processing: Bending to the required crank radius .process by casting.

Figure-7

3.2.4 CONNECTING ROD: -

Criteria: Light weighted
Fatigue resistance
Material preferred:
Aluminum
Processing:-Forging.

3.2.5 CRANKSHAFT:-

Material: Aluminum.
Processing: CNC machine

3.3 FUNCTIONAL DESCRIPTION:-

The engine is designed so that the working gas is generally compressed in the colder portion of the engine and expanded in the hotter portion resulting in a net conversion of heat into work. An internal regenerative heat exchanger increases the Stirling engine's thermal efficiency compared to simpler hot air engines lacking this feature.

3.4 CONFIGURATIONS:-

The **gamma** configuration has two cylinders: one containing a displacer, with a hot and a cold end, and one for the power piston; they are joined to form a single space with the same pressure in both cylinders; the pistons are typically in parallel and joined 90 degrees out of phase on a crankshaft.

3.5 METHODOLOGY:-

3.5.1 ASSEMBLY AND PROCEDURE:-

i. Firstly we have designed our Stirling engine model on the software **CATIA SOFTWARE;** We have calculated our Dimensions requirement on the software. All the analysis taken on the software for the fabrication of our project.

ii. As per the requirement we have gathered our parts from various places from the market. Both the cylinders are connected perpendicularly via a small diameter pipe through welding & M-seal.

iii. For the assembly of our project our workshop was the better place for the fabrication as we get all the facilities at the same place.

iv. For the piston cylinder arrangement. We have used Tin Cylinders for vertical position and PVC Pipe for Horizontal cylinder. For the fabrication of piston for vertical we bayed solid hard fiber of cylindrical shape. Than by using **LATHE machine** available in workshop. By the operations turning on that fiber with a small clearance of 2mm.

v. As per cylinder diameter is considered. Reciprocation of piston in the cylinder is quiet freely. On piston a aluminum link has been attached**(LENGTH AND DIAMETER SPECIFICATION IN TABLE).** By cutting the upper portion of cylinder for placing the horizontal cylinder of varying dia. And upper portion for the air movement. All this parts were arranged than fixed by M-Seal making the arrangement air tight.

vi. Our FLYWHEEL which is acting as crank for both the arrangement is fixed on the crank shaft which is fixed by us.

vii. Crank and links are connected. Now this whole model is placed on rigid structure and clamped by strips to make It rigid while working. Hinged support for the vertical cylinder piston.

viii. Our model is ready to work by providing Heat BY candle. Than by providing sufficient heat so that expansion of air takes place by which the reciprocation of piston takes place easily which will help to rotate our crank easily. Every arrangement in the engine is so light weighted so that reciprocating motion can be achieved easily in both the cylinders.

ix. Working: Through the expansion of air inside the cylinders piston moves vertically upwards and which helps in moving the cold air above the piston to the horizontal cylinder by reciprocating the piston backwards, the link and the connecting rod arrangement is done in such a way that the reciprocation of piston in respective cylinders helps in the rotation of flywheel by the hinged support.

Figure-8

4.0 ADVANTAGES:-

There are several reasons to use a Stirling Engine:

- Inside the pistons can be used air, helium, nitrogen or hydrogen and you don't have to refill it because it uses always the same body of gas.
- To produce heat you can use whatever you want: fuel, oil, gas, nuclear power and of course renewable energies like solar, biomass or geothermal heat.
- The external combustion process can be designed as a continuous process, so the most types of emissions can be reduced.
- If heat comes from a renewable energy source they produce no emissions
- They run very silent and they don't need any air supply. That's why they are used a lot in submarines. E.g. in the Royal Swedish Navy.
- They can run for a very long time because the bearings and seals can be placed at the cool side of the engine → they need less lubricant and they don't have to be checked very often (longer period between the overhauls).

DISADVANTAGES:-

- Initially we have made crankshaft using separate flywheel for both cylinders, in which link-crankshaft assembly functioning is not proper. Hence it is replaced by crankshaft made by bending the rod.
- Firstly we have used large links, this increases weight and vibration. Therefore we have reduced their length.
- Due to the large clearance between piston and cylinder, it is not able to displace by hot air. Hence for decreasing clearance small diameter cylinder is used and reassembling of the model has done.
- Required precision between the crankshaft and link arrangement is not achieved. High precision equipments are costly.
- Proper clearance between piston and cylinder is not provided.
- Weight of the link is more.
- Improper welding, machining and surface finishing.

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