Implementing Various Designs and Calculations to Increase the Working Efficiency of Stirling Engine at Different Degrees of Temperature

1R. Karthikeyan, 2T. Ramakrishnan and 3S. Nagu
1,2,3Assistant Professor, Department of Mechanical Engineering,
1,2PSNA College of Engineering &Technology, Dindigul-624 622, Tamil Nadu, India
3Chennai Institute of Technology, Kundrathur, Chennai-600069, Tamil Nadu, India

Abstract: An ability to integrate and manage design creates more discerning clients, products, services, sources and higher value relationships that contribute to improved profitability and return on investment. Designing a perfect engine in a collaborative manner will always provide memorable design solutions. An ideal Stirling working cycle has the maximum obtainable efficiency defined by Carnot efficiency and highly efficient Stirling engines can be built, if designed properly. My challenge is to find the optional balance resulting in the best engine design.

Keywords: Profitability; Design; Efficiency; Carnot Efficiency; Stirling Engine;

I. INTRODUCTION

Stirling engine was contributed by Robert Stirling in 1816. A small Stirling engine driven from natural gas could supply a single family house with heat and power with a high level of energy utilization. Now a day the usage of Stirling engine increasing rapidly and it is becoming familiar among inventors and scientists. The Norwegian navy has installed Stirling engines on three submarines due to their particularly, quite operation. NASA Space agency applied Stirling engines in recent United States space missions and particularly, some American companies have applied Stirling engine prototypes to solar concentration, energy production plants. Stirling engine uses the potential energy, difference between its hot and cold end to establish a cycle of fixed amount of gas expanding and contracting with in the engine, thus converting the temperature difference across the machine into mechanical power. They can run directly on any available heat source, so they can be employed to run on heat from solar, geo thermal, nuclear, biological sources. They operate at relatively low pressure and thus are much safer than any typical steam engines. Even a small demonstration engines have been built will run on temperature difference between room temperature and melting water ice.

II. FACTORS INFLUENCING DESIGN OF STIRLING ENGINE

When I decided to design a high Stirling engine working cycle, I am in need to consider some factors.

A. Dead Volume

Keep the dead volume to a minimum. It is a volume that is “unswept” by the motions of the pistons. If the dead volume increases, then it decreases the engine power. It is constant at all times.

B. Pumping losses

We should keep the pumping losses minimum. It is the friction losses carried by the working gas as it pushes through the passage way of heater, cooler and regenerator.

[a] and [b] could not be achieved easily. If I need to satisfy [b], I have to design the engine using more narrow tubes for the gas to flow through that is for maximizing heating/cooling, then the volume of the engine increases. This results in greater volume and [a] will not be satisfied.

C. Material/ Machine part

Each and every material/machine part such as gas or fuel, displacer material, piston material, regenerator, flywheel has its own influence when calculating the efficiency of Stirling engine. The solution is to compromise these things to achieve the best possible design.

III. STIRLING CONFIGURATION

As we all knows, Stirling engine working cycle depends upon three main configurations.

Fig 3.1: Stirling Configuration

A. Beta Engine Features

Here I decided to try the design of beta type Stirling engine working cycle. The Beta configuration is the classic Stirling engine configuration and has enjoyed popularity from its inception until today. Stirling’s original engine from his patent drawing of 1816 shows a beta arrangement.

Figure 3.2: Beta Engine
Unlike Alpha machine, Beta engine has a single power piston and displacer whose ideal purpose is to displace the working gas at constant volume and shuttle it between the expansion and compression spaces through the series arrangement cooler, regenerator and heater.

IV. DISPLACER

A displacer mechanically moves the gas between a heated location and a cooled position. It is also a light weight piston that does not have any contact with the interior part of Stirling engine. When the displacer is on the cool side the gas is pushed to the hot side and it is expanded. When it is on the hot side the gas is compressed and cooled.

A. Displacer Material

A stainless steel metal was selected as the displacer material, because it can tolerate higher temperature. It has low thermal conductivity which is also a benefit here. It has quite low heat transmission coefficient. A good displacer material should reduce the heat transfer between heater and the cold place.

It was often selected for its corrosion resistant. Mechanical properties such as strength, ductility and toughness are therefore also important considerations for the designer of coefficient engine. Stainless steels are most commonly used for their corrosion resistance. The second most common reason stainless steels are used for their high temperature properties. Stainless steels can be found in applications where high temperature oxidation resistance is necessary and in other applications where high temperature strength is requirement.

V. POWER PISTON

The displacer pushes the air in the engine to the hot end, where it heat up and expands. This expansion pushes the power piston outwards setting the air expands inside. The power piston thus turns the rotating parts around which moves the displacer and so moves the air inside the engine to the cold end. The air cooled down and make the piston to move inwards. It needs to be able to move in the cylinder freely, but also to move in the cylinder in a change of air pressure.

A. Power Piston Material

Many materials are ruled out as unsuitable due to the elevated temperature conditions that the cylinder / piston may subjected to plastics are self-lubricating but could not stand the heat. They have stable mechanical properties but are not rigid. Some are self-lubricating, heat tolerant, thermally and mechanically stable but the cost is extremely high.

VI. MECHANICAL ANALYSIS

VII. CALCULATION

Working cycle efficiency

Provided heat

\[ Q_{\text{exp}} = \int P \, dv \]

\[ Q_{\text{exp}} = nRT_{\text{max}} \ln(V_{\text{max}}/V_{\text{min}}) \]

\[ Q_{\text{heat}} = nCV(T_{\text{max}}-T_{\text{min}}) \]
Q_{total}= nC\Delta T + nRT_{max} \ln \left(\frac{V_{max}}{V_{min}}\right)

Mechanical Energy recovered

W_{net} = W_{exp} + W_{comp}

\[ W_{net} = \int \text{exp P} dv + \int \text{comp P} dv \]

\[ W_{net} = nRT_{max-T_{min}} \ln \left(\frac{V_{max}}{V_{min}}\right) \]

Cycle Efficiency

Efficiency = \frac{R(T_{max-T_{min}})}{\ln \left(\frac{V_{max}}{V_{min}}\right)} \left( \frac{CV(T_{max-T_{min}})}{R_{max}} + \frac{nRT_{max}V_{max}}{V_{min}} \right)

CONCLUSION

My experience with this experiment made me to learn several new things. It is not an easy task to attain the greater efficiency. I calculated various output values by providing various heat temperatures as input values. After all these calculation I only achieved efficiency about 20 to 22% efficiency. It is not my expected efficiency and also it is not a worst try.

Observations

Temperature is constant during both compression and expansion phases.

Comparisons with different tests and data monitored the efficiency of a beta type of the Stirling engine very closely. The temperature difference (\Delta T=T_{max-T_{min}}) between hot side and cool side has a significant effect on the output power and efficiency, in a few observations it seemed that efficiency was proportional to \Delta T, the highest temperature difference \Delta T causing the highest efficiency.

if it were possible to change the TC fast enough technically, the speed could be controlled desirably by a combination of changes in the input power and the TC, since control problem is the highest disadvantage of a Stirling engine. Noise or incompatibility between software and hardware can cause numerous problems and errors in the results. I will surely overcome all my faults and will attain much greater cycle efficiency in my future project.

References


