Using Stirling Engine to Increase the Efficiency of an IC Engine

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***Abstract*- The Stirling engine is used to remove the electrical load from the internal combustion engine and thereby increasing the fuel efficiency of the engine. The Stirling engine is powered by the temperature difference at the radiator ends. Alternator is used to supply power to all the electrical and electronic appliances in the automobile. At present, the alternator's rotor is rotated by engine's shaft through belt. Now the Stirling engine is used to rotate the rotor of alternator. This paper is to show the increase in efficiency of an engine using Stirling engine.**

***Index Terms* -Stirling engine, radiator, temperature difference, load.**

I. INTRODUCTION

Stirling engine is the oldest engine and it converts the heat energy to mechanical energy with high efficiency. It has many positive properties, e.g. it only needs a temperature difference to work, irrespective of whether the difference is achieved by solar heating or conventional fuel. This makes it very flexible and beneficial to the environment. There were various methods employed to produce electrical energy from mechanical input. And now, finally we adopted in using engine to power an alternator. In automotive engines internal engines are used to power the alternator, which in turn charges the battery. The engine consumes more fuel due to the additional electrical load. Stirling engine is used to reduce that consumption.

A. Stirling Engine

A Stirling engine is a heat engine operating by cyclic compression and expansion of air or other gas, the 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 engines) usage of a working fluid in both its liquid and gaseous phases, the Stirling engine encloses a fixed quantity of permanently gaseous fluid such as air. Typical of 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 difference between the hot and cold reservoir. There are various types of Stirling engine. I used beta type Stirling engine.

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B. Beta Type

A beta Stirling has a single power piston arranged within the same cylinder on the same shaft as a displacer piston. The displacer piston is a loose fit and does not extract any power from the expanding gas but only serves to shuttle the working gas from the hot heat exchanger to the cold heat exchanger. When the working gas is pushed to the hot end of the cylinder it expands and pushes the power piston. When it is pushed to the cold end of the cylinder it contracts and the momentum of the machine, usually enhanced by a flywheel, pushes the power piston the other way to compress the gas. Unlike the alpha type, the beta type avoids the technical problems of hot moving seals.

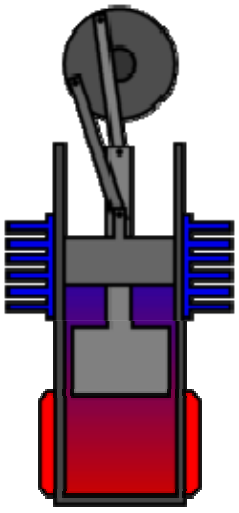

Fig 1: Beta type Stirling engine.

C. Alternator

An alternator is an electromechanical device that converts mechanical energy to electrical energy in the form of alternating current. In principle, any AC electrical generator can be called an alternator, but usually the word refers to small rotating machines driven by automotive and other internal combustion engines. Very large automotive alternators used on buses, heavy equipment or emergency vehicles may produce 300 amperes. Very old automobiles with minimal lighting and electronic devices may have only

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a 30 amperes alternator. Typical passenger car and light truck alternators are rated around 50-70 A, though higher ratings are becoming more common, especially as there is more load on the vehicle's electrical system with, for example, the introduction of air conditioning and electric power steering systems.

Fig 2: Automotive alternator fixed at the lateral side of an engine.

I. POWER CONSUMPTION OF ALTERNATOR

Alternator has to charge a 50A and 12 V batteries, so the power is consumption is 600 Watts. We need minimum of 12 hours to charge 12 Volt Lead Acid batteries. Therefore the total power consumption is 7200 Watts. This amount of power is consumed from engine and it decreases the mileage of the vehicle. The alternator's rotor should be rotated at 2000 RPM to get 60 A of current.

TABLE1
SHOWING THE BRAKE THERMAL EFFICIENCY AT DIFFERENT LOAD

LOAD (Kg)	Eddy current dynamometer (Brake thermal efficiency)	Brake drum dynamometer (Brake thermal efficiency)
0	0	0
2	8	12
4	16	22
6	20	27

II. ALTERNATIVE SOLUTION FOR CHARGING THE BATTERY

In this case, Stirling engine is used to rotate the rotor of the alternator. By doing this, the electrical load on the engine can be nil. The material for cylinder and piston of the Stirling are selected in such way that the specific weight of the Stirling engine is low. Copper is chosen for the construction of cylinder since it has the high thermal conductivity and low density compared to the other materials.

TABLE2
SHOWING THE THERMAL CONDUCTIVITIES AND DENSITIES OF ALUMINIUM

Metal or Alloy	Density (kg/cu.m)	Thermal conductivity (W/m.K)
Aluminium	2560 - 2640	250
Aluminium bronze (3-10% Al)	7700 - 8700	346.1
Copper	8960	401

A. Implementation

The basic requirement to run the Stirling engine is the temperature difference. The temperature difference can be obtained from RADIATOR. The radiator has two ends through which the coolant passes removing the heat from the engine. The heat is transferred to the air present inside the cylinder by conduction and convection. The hot end of the Radiator is in contact with the one end of the Stirling engine and the cold end of the radiator is connected to the other end of the striling engine. It is found that the temperature difference obtained between the radiator ends is approximately equal to 70 degree Celsius.

- $W = R (Th - Tc) \ln (Vb/Va)$
- Thermal Conversion Efficiency = $1 - (Tc / Th)$

T_H - hot side temperature;
T_C - cold side temperature;
R - Universal gas constant;
Vb/Va - volumetric ratio.

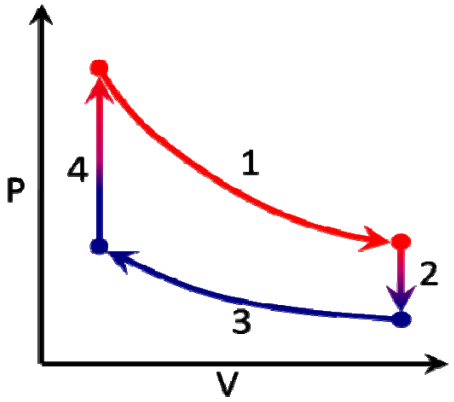

Fig 3: Working cycle of Stirling engine.

With 70 degree temperature difference the power output from the Stirling engine is 950 Watts (assuming the volume ratio to be 5). The alternator consumes 600 Watts power to charge the 12 volt battery, so Stirling engine can be certainly used to run the alternator's rotor and produce current. This type is more advantageous than the conventional method because, Stirling runs at constant speed not like Internal

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Combustion engine. Since the Stirling has low torque, initially it has to be rotated by clutching mechanism. If it is started the Stirling engine can run at constant speed till the temperature difference exists.

Fig 4: Radiator showing the both ends of it.

The ends of a radiator shown in the above picture are used to run the Stirling engine. As the radiator removes the heat from the engine; the hot end has high temperature and since heat carried by the coolant is radiated out the other side of radiator has low temperature. This temperature difference is used to run the Stirling engine at the required of the alternator. The Stirling engine's shaft is coupled with the rotor of the alternator. The alternator produces power since the rotor cuts the magnetic field present inside the alternator.

B. Advantage

- As mentioned before the fuel consumption for an electrically loaded is higher than the engine which is mechanically loaded. So, the electrical load is replaced by mechanical loading.
- Very compact to fit into the engine's cabin.
- Increases the mileage.

III. CONCLUSION

As all the automobile industries working for increase in mileage, this idea will be helpful to do that. Thus by using the Stirling engine to run the alternator, the fuel consumption of an IC engine can be decreased and thereby more kilometres can be travelled per litre than the existing numbers.

REFERENCES

[1] "Thermodynamics and heat powered cycles: A cognitive engineering approach", Chin Wu, Nova science publications, inc.,

[2] "Thermodynamics- An engineering approach"- Yunus A. Cengel, Michael A. Boles, 5th edition.

[3] "A review of Stirling engine mathematical models"- N.C.J C hen, F. P. Griffin

[4] "Advanced 35 W Free-Piston Stirling Engine for Space Power Applications"- J. Gary Wood and Neill Lane

[5] Balmar 95-series Alternator Data sheet

[6] Thorsen, J.E.; Bovin, J.; Carlsen, H, "3 kW Stirling engine for power and heat production"Energy Conversion Engineering Conference, 1996. IECEC 96. Proceedings of the 31st Intersociety, vol.2, pp. 1289 – 1294.

[7] Carlsen, H.; Ammundsen, N.; Traerup, J, "40 kW Stirling engine for solid fuel" Energy Conversion Engineering onference, 1996. IECEC 96.

[8] Gaynor, P.T.; Webb, R.Y.; Lloyd, C.C, "Low temperature differential stirling engine based power generation" Sustainable Energy Technologies, 2008. ICSET 2008. IEEE International C onference.

[9] Shanmuganathan, U. Govarthanan, R. Muthumailvaganan, A. Imayakumar, A,"Modeling and Dynamic Simulation of IC Engine Driven Permanent Magnet Generator Using Matlab/Simulink for Hybrid Tracked Vehicle"Electric and Hybrid Vehicles, 2006. ICEHV '06. IEEE Conference

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