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Waste Heat Energy Recovery from Muffler of I.C. Engine Using Thermoelectric Power Generator

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Abstract
In an internal combustion engine, the most important part of the heat delivered is not recycled as work output, but discarded into the atmosphere by means of unused waste heat. The energy discarded to the atmosphere through exhaust gas is around 30 to 40% of the energy delivered by the fuel.If this waste heat energy is selected and altered into serviceable energy, the overall efficiency of an engine can be enhanced.Thermo Electric Generators (TEGs)work on basic principle of Seebeck effect andare compact devices that alter thermal energy from a temperature difference to electrical energy. In this project, TEGs are placed over the hot muffler to obtain a temperature difference between hot and cold surfaces. The performance of TEG in electrical power output is measured over various RPMs of the Engine and the time for maximum electrical power output is evaluated.

Keywords:waste heat recovery; direct energy conversion; thermoelectric generator; I.C. engine; power generation

1. Introduction

The thermoelectric generator (TEG) is a device for directly converting thermal energy into electrical energy based on the Seebeck effect. The TEGs have many advantages such as no moving mechanical parts, long-lived, quiet, environmentally friendly and requiring little maintenance [Z.B. Tang, et al,2014]. As a significant cause for the fuel crisis and environmental pollution, the internal combustion engine (ICE) drives vehicles with only 30% of the total heat generated by the gasoline used. During this process, the other 40% of the heat is lost through waste gas exhaust and 30% by the coolant. The TEG using automobile waste exhaust as heat source is believed a new way to reduce ICE loads as well as the alternator and then decrease fuel consumption and environmental pollution.

According to the Otto cycle [Y. Y. Hasio, et al, 2010], during the operating process, it is necessary for internal combustion engine to release heat to the atmosphere for finalizing the thermodynamic process. Subsequently, only about 30% energy released from used up fuel is converted as driving force, the other 70% is either released by exhaust gas, or ejected by the cooling system. Energy lost from distributed heat can be recovered by several ways, thermoelectric generator (TEG) is considered beneficial by several auto manufacturers. Through the effect of temperature difference, waste heat can be converted into electricity from the muffler of an engine.

2. *Working principle of thermoelectric generator*

A thermoelectric (TE) material holds the capacity to convert thermal energy into electrical energy through a process known as the Seebeck effect, which is based on electron kinetics within differing metallic semiconductors. Two semiconductors are present in a thermoelectric module, a p-type and an n-type, which are attached thermally in parallel and electrically in series.

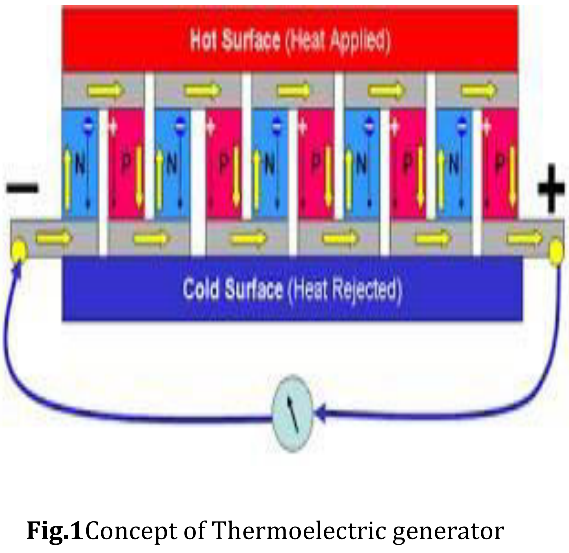

Fig.1 Concept of Thermoelectric generator

The electrons mobility is affected when a temperature difference is applied to a thermoelectric module. The electrons on the hot side of the module have more kinetic energy than the electrons on the cold side, due to the presence of thermal energy.

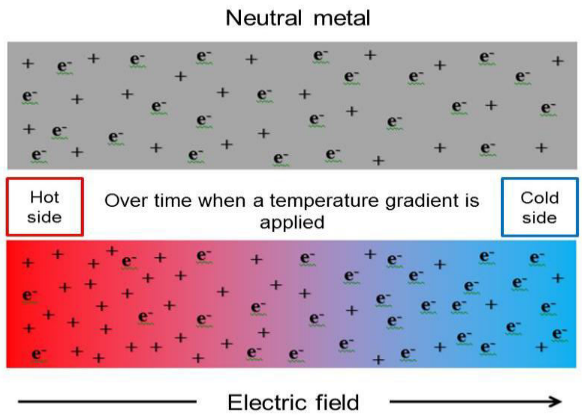

Fig.2 Electron kinetics within a metal before and after a temperature gradient is applied

3. Experimental Procedure and setup

The entire system consists of engine mounted on foundation support. The TEG is bounded with epoxy on the hot surface placed over muffler. The cold surface of TEG is opened to ambient temperature.

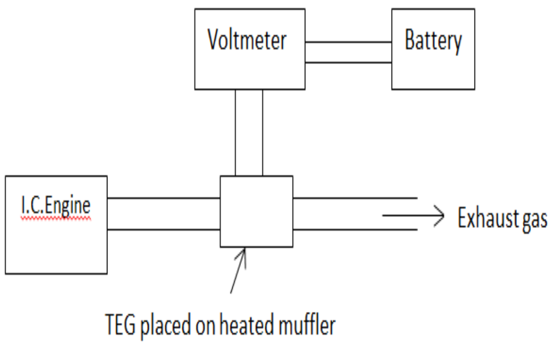

Fig.3 Schematic diagram of Set up

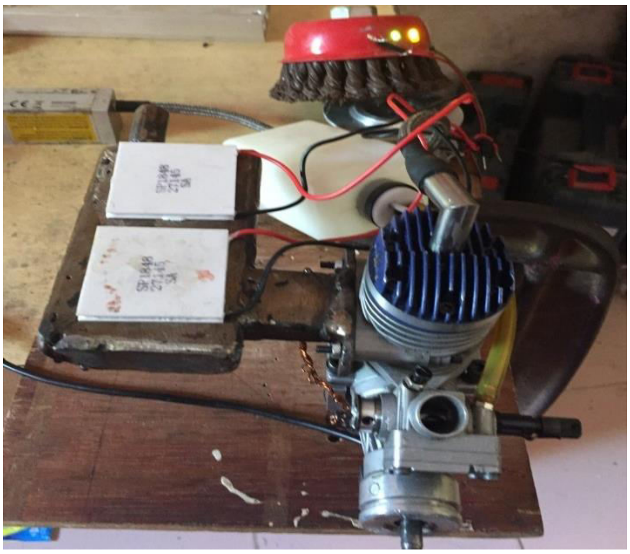

Fig.4 Experimental set up

The 10cc engine works on normal load, which is varied by different throttle conditions as input parameter. The output of TEG is measured by using multimeter for voltage and current, for different operating speeds of engine with respect to time.

Table 1 Specification of engine

Specification of Petrol engine	
Displacement	9.73 cc
Bore	24 mm
No. of cylinder	1
No. of strokes	2
Rated power	1.8 HP
RPM range	3000 to 18000 rpm
Exhaust gas temperature	150^{0}C

Fig.5 Actual model of thermoelectric generator

Table 2 Specification of TEG module

Type	Thermoelectric generator
Model	SP1848-27145
Module weight	27 g
Cable length	20 cm(Approx)
Material	Bismuth telluride(Bi_2Te_3)
Size	40mm*40mm*3.4mm
Operating temperature	-40^{0}C to 150^{0}C
Rated voltage	0.97 to 4.8 V
No. of thermocouples	127

4. Results and Discussion

The Engine is operated at normal working conditions for various speeds. The temperature difference between the hot and cold side of the TEG is observed for these RPMs and the following readings for voltage and current are noted.

The voltage produced due to temperature difference is observed for 4000, 10000 and 16000 RPM.

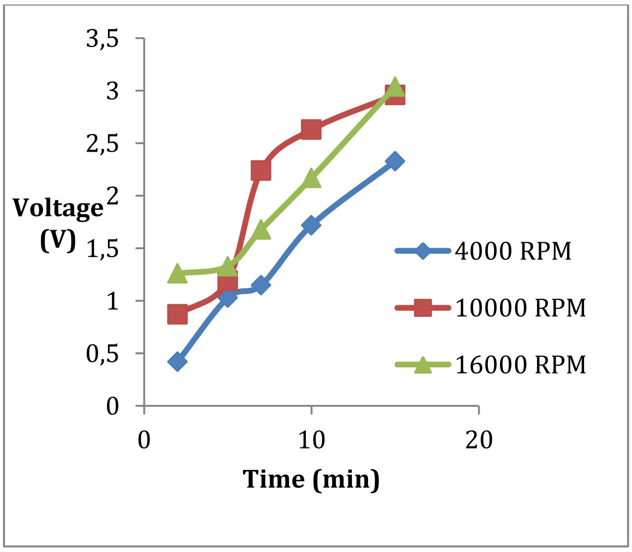

Fig.6 Time versus Voltage graph for various RPMs

The maximum voltage obtained after a time period of 15 minutes shows similar voltages for 16000 and 10000RPM.

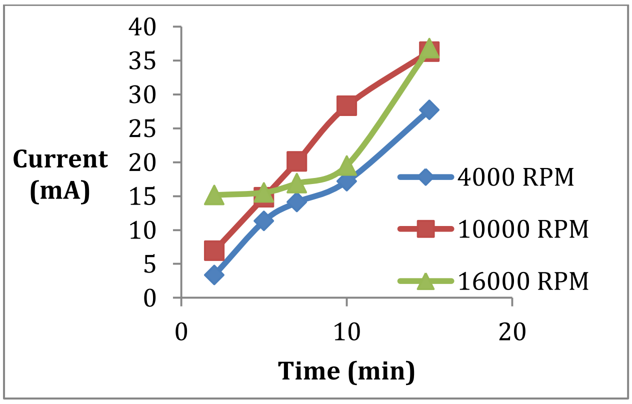

Fig.7 Time Versus current graph for various RPMs

The current which is considerable for minimum working is obtained above 30 mA. The 4000 RPM speed is not sufficient for the application of producing required current.

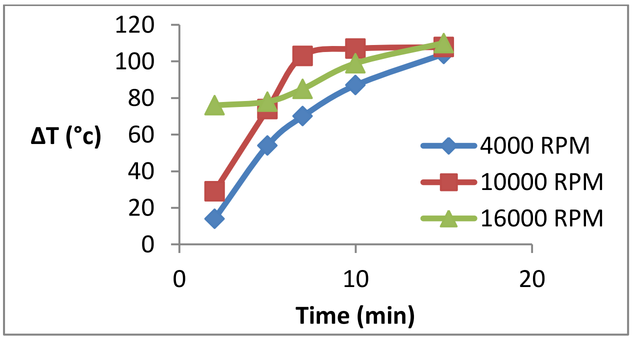

Fig.8 Time versus ΔT for various RPMs

The temperature difference is the main concern for the working of TEG for producing required electric power. The observations are made for above RPMs. It is observed that after 15 minutes, the values remain constant.

The following observations are made for temperature difference observed between the Hot and Cold side of TEG for various RPMs.

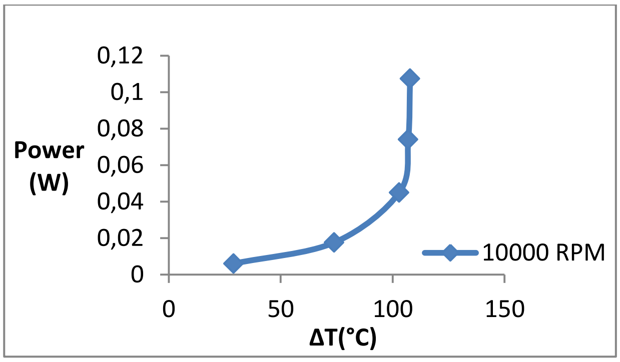

Fig.9 ΔT versus Power for 10000 RPM

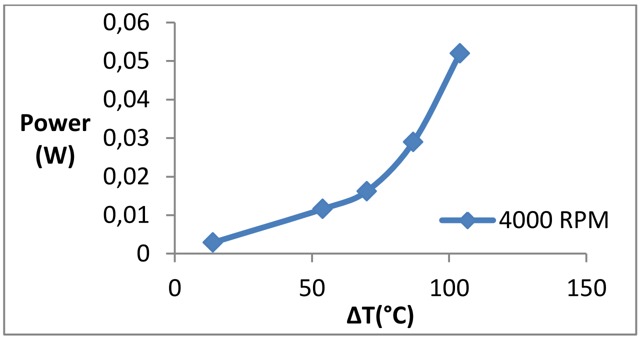

Fig.10ΔTversus Power for 4000 RPM

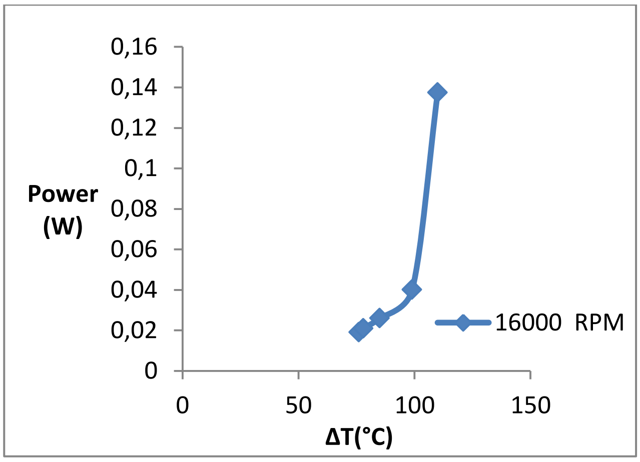

Fig.11 Time versus ΔT for 16000 RPM

The maximum power produced from TEG is observed for 16000 RPM. The Engine works at normal working load conditions for 20 minutes.

Conclusion

Waste heat from I.C. engine is captured and reused for producing electrical work. As the temperature difference increases, the voltage generated increases respectively.The maximum voltage produced for single TEG is 3.04 V at 16000 RPM after 15 minutes of normal load condition of engine. Here, the temperature difference is 110^{0}C. The current produced is 36.8 mA. This power produced is sufficient to glow LEDs or transmit signals for control operations.

In the future, the model can be developed for maximum power output by using TEGs in series. The temperature can be distributed evenly by using internal fins inside muffler without much effect on back pressure. The cold side of the TEG can be provided with cooling jackets or fins so as to increase temperature difference.

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