Producing Electricity From Diesel Engine Exhaust Gas By Using Seebeck Effect

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Abstract- *As a measure against global warming, recovering waste heat and converting it into electrical energy is very effective. While there are various methods of recovering waste heat, much expectation is being entertained of the thermoelectric module that has no moving parts and that is capable of converting waste heat directly into electrical energy. Since discovery of the seebeck effect thermoelectric modules have been studied for more than 180 years. Nevertheless the thermo electric module has not become widespread yet. The major reason for this is the low efficiencies of conventional thermoelectric modules. In recent years, however the characteristics of thermoelectric modules have improved so much that the prospect of thermoelectric power generation has rapidly become very bright.*

The principle involved in Thermoelectric power generation is seebeck effect. It was discovered by the scientist seebeck in 1821, states that when the junctions of two different materials are maintained at two different temperatures, the emf is produced in that circuit. The emf can be stored in a battery and used when ever required.

Our aim is to construct a Thermoelectric power generator for Producing Electricity from Diesel Engine Exhaust Gas ***by*** *Using Seebeck Effect. The power generator is made up of a hot sink, cold sink and a thermo electric module. Here the hot sink is located in the flue side to collect heat, a thermoelectric module to generate electricity and a cold sink with a cooling fan to reject heat to the environment. Here, we should investigate that the correlation between the temperature difference across the module and power output. The voltage developed can be store in a battery and used to power a bulb or fan based on the capacity of power generated*

Keywords- Thermoelectric generator, Seebeck effect, Diesel engine, Exhaust gas heat recovery, Power generation.

I. INTRODUCTION

We know, the universe consists of big natural energy sources like Water, Land , Air, fire & space. The sixth important developed by human is called “electricity” (power genration) . In this modern world, for our daily life the electricity plays a vital role. So first off all we should know about power can be genrated.

POWER GENRATION

The fundamental principles of electricity generation were discovered in the years 1820 -1830 by the British scientist Michael Faraday. Electricity is one type of energy. All matter whether solid, liquid or, gaseous consists of minute particles known as Atoms. According to modern research electric current means a flow of electron. So, we need to know about the atom and the principles involved in it.

1.1.2 ATOM

It has a hard central core known as nucleus. It contains two types of particles one is known as proton and carries positive charge. The other is electrons carry the negative charge. The number of electron and number of protons in atom are equal. So, the atom is electrically neutral. The number of protons in the nucleus of atom gives the atomic number. The total numbers of neutron and proton are known as atomic weight.

1.1.3 TYPES OF POWER GENRATION

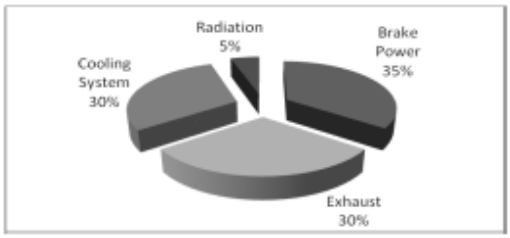
The electricity is produced by the extraction of electrons from an atom. The energies which are used to produce electricity are friction, light, heat, pressure, chemical action, magnetism; in our Experiment we can produce electricity from waste heat.

1.2 POWER GENRTION DUE TO HEAT

Two metal plates are joined together and heating, for purpose of producing electricity. This is called “thermo coupling method”. On heat we can use only waste heat to recover and produce electricity.

1.2.1 Waste heat recovery system

Waste recovery units such as recuperators and regenerators are one of the most widely used heat recovery units but for low temperature working fluids these heat exchangers become ineffective. Thus there is a need of a heat recovery unit which can work at relatively lower temperatures.



Total Fuel Energy Content in Diesel Engine

Many different methods such as Organic Rankine cycle which converts low grade heat source to electricity and piezoelectric generators which directly converts deformations produced in piezoelectric materials into electricity are proposed for secondary heat recovery but limitation being their high investment cost or high equipment weight and increased complexity. TE devices on the other hand are light weight and do not require any moving parts. Performance of TE devices is represented by a dimensionless quantity known as "figure-of-merit" and denoted by "ZT". It's defined as: $\alpha ZT = 2\ \lambda T/\sigma$ Where, ‟σ is electrical conductivity of material „ ‟α is seebeck coefficient of the material„ ‟λ is thermal conductivity of the material.

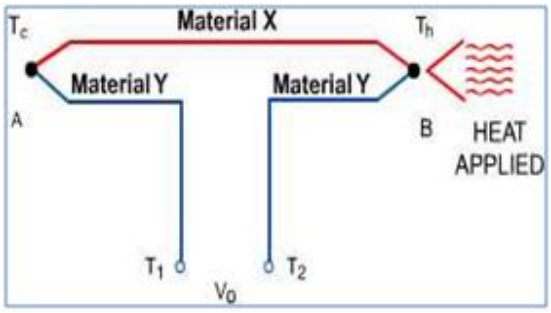
II. DESCRIPTION ABOUT THERMOELECTRIC POWER GENERATION

2.1 SEEBECK EFFECT

To illustrate the Seebeck Effect let us look at a simple thermocouple circuit as shown in the Figure.

The thermocouple conductors are two dissimilar metals denoted as Material x and Material y.

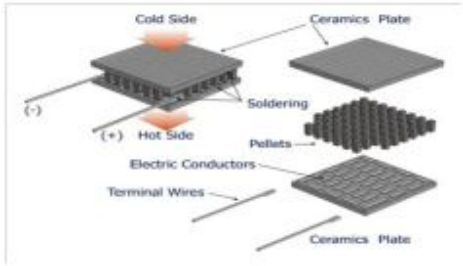
In a typical temperature measurement application, thermocouple A is used as a "reference" and is maintained at a relatively cool temperature of T_c. Thermocouple B is used to measure the temperature of interest (T_h) which, in this example, is higher than temperature T_c. With heat applied to thermocouple B, a voltage will appear across terminals T_1 and T_2



Seebeck effect thermoelectric circuit

2.2 THERMOELECTRIC MODULE

A thermo electric module (TEM) is a solid state of energy it normally consists of an array of pellets from dissimilar semiconductor material (p and n type) joined together thermally parallel and electrically in series The TEM can be used for power generation, cooling and heating.



Single stage Thermoelectric Module

III. EXPERIMENTAL SETUP

The Major components that involve in thermo electric power generation are

- Aluminium block
- Thermoelectric module
- Heat sink

ALUMINIUM BLOCK

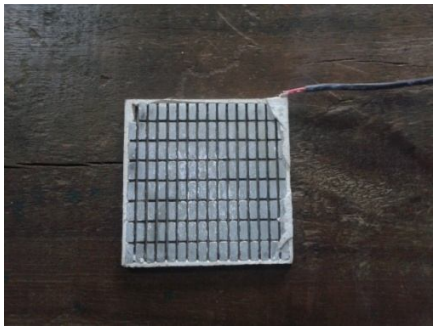
Aluminium block is used as a heat receiver from the exhaust pipe of engine. Here the aluminium block is prepared in the concave shape based on the diameter of the pipe. Now the heat is transferred from engine exhaust to aluminium block and then to the thermoelectric module.

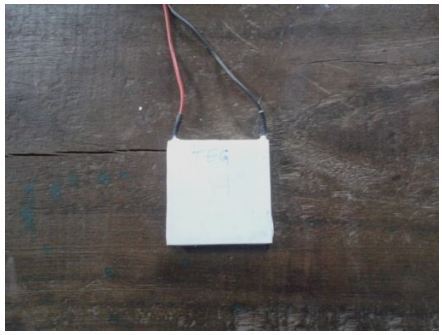
The working of the aluminium block is to absorb heat from the source and to transfer it to the thermo electric modules as it transfers heat it creates hot junction and cold junction there by forming the temperature difference.

Preparation of the aluminium block.

THERMOELECTRIC MODULE

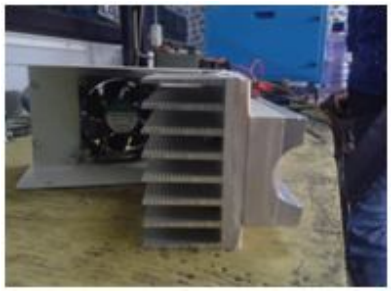
If an environment has a thermal gradient, thermoelectric devices can be applied, since they require little maintenance, and provide electricity for many years

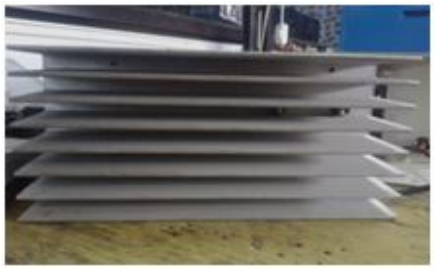




When heat is applied to one surface of the thermoelectric module, the electrons in the n-type semiconductor and the holes in the p-type semiconductor will move away from the heat source. This movement of electrons and holes gives rise to an electrical current. The direction of the current is opposite to the movement of the electrons, and in the same direction as the movement of the holes. By creating the appropriate electrical connections, the current of the thermoelectric generator flows in a closed loop through the p-type and n-type semiconductors and an external load. This pair of n-type and p-type semiconductors forms a thermocouple. A thermoelectric generator can consist of multiple thermocouples connected in series, which increases the voltage output, and in parallel to increase the current output.

HEAT SINK





The heat sink is used to dissipate the heat which is come from the diesel engine exhaust to the thermo electric module. Aluminium fins are using as the heat sink for this process. Here we are using a 2v D.C fan as forced convection process for better cooling of the module. .

There are a few methods that might be used to alleviate the performance limitations arising from the inconveniently thin element size imposed by current growth techniques, but each have associated challenges. An increase in the heat transfer coefficient of the heat sink may be possible with advanced methods such as micro channels or jet impingement, but only at the cost of greatly increased packaging complexity and the energy and space cost of the heat exchanger. One could also stack the elements vertically or use them as part of a segmented device to increase their thickness in the direction of thermal transport

IV. EXPERIMENTAL RESULTS

4.1 DESIGN PROCEDURE:

1. Calculating the voltage that can be produced due to temperature difference.
2. Power generating capacity of each module
3. Total Power output.
4. Number of modules required.

4.1.1 CALCULATING THE VOLTAGE THAT CAN BE PRODUCED DUE TO TEMPERATURE DIFFERENCE AT EXHAUST PIPE:

To calculate the power that can be produced due to temperature difference, let assume that the temperature at the exhaust pipe is about **160^0 C** and the temperature at the cold junction is at **45^0 C**. Then the power produced is can be calculated as follows.

First the voltage produced can be calculated as follows.

$$\mathbf{V = \alpha_m (T_2-T_1)}$$

Where

V= Voltage produced in the circuit.
T_1=Initial temperature of atmosphere
T_2=Final temperature of air.
α_m= seebeck coefficient of module.

CALCULATION OF α_m VALUE:

Figure of merit Z= □□**α^2 / TE**
=0.82 (TGM127-1.0-1.3 module)

Where

T= thermal conductivity for thermo electric module= 1.1W/mk.
E= electrical resistivity of module = 0.5 Ohm-mt.

0.82= **α^2 / (1.1 x 0.5)**
α = 0.0666

The voltage produced can be calculated by using the following formulae.

V=0.0666(160-45)
=7.66Volts.

4.1.2 POWER GENERATION CAPACITY OF EACH MODULE:

Calculation of **E** value for single thermoelectric module:

R= 2EL/A_p
4.2=2xEx3.6/ (30x30)
E= 0.5 Ohm-meter

Where

R=electrical resistance of module=**4.2 Ohm (constant for TGM 127-1.0-1.3 module)**
E=electrical resistivity of module.
L= thermo electric module length=**3.6mm**
A_p = cross sectional area of module=**30x30 mm^2**
α= Seebeck coefficient = **0.066 v/^{0} C**
The current developed in the circuit can be calculated by using the following formulae.

I= α (T_2-T_1)/ (R_L+R)
=0.066(160-45)/ (4.2+4.2)
=0.90357 amps

Where

R_L=External Load resistance. In Ohms
R= Resistance of the thermo electric module Ohms
Here for getting maximum output **R_L=R =4.2** which is constant for specific module.
P_m= (α (T_2-T_1))^2 R_L/ (R_L+R)^2
= (0.066(160-45))^2 4.2/ (4.2+4.2) =3.8 watts
P_m= the power generation capacity of each module

4.1.3 POWER OUTPUT:

The total power which is generated from the engine exhaust can be calculated by using the following formulae.

P=V X I
=7.66 X 0.90357
=**6.92Watts**

4.1.4 NUMBER OF MODULES REQUIRED:

The number of modules which can be used can be calculating by using following formulae.

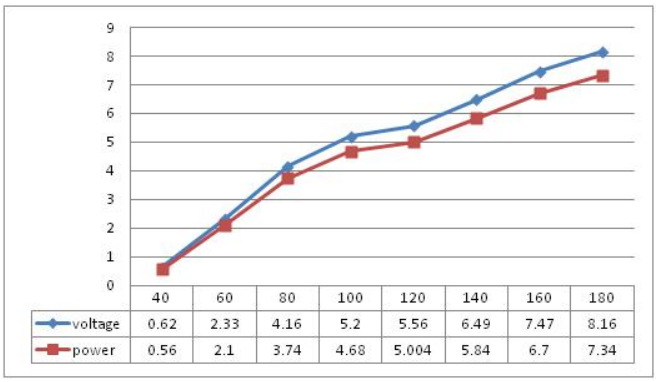
N= Total power output / power produced from each module

= 6.92 watts / 3.8 watts

= **1.82** = **2** (approximately).

4.2 RESULTS AND DISCUSSIONS:

We have fabricated the thermoelectric power generator as per design and tested it. We have tested the thermoelectric power generator, from the heat of Diesel Engine exhaust gas and plotted the graphs by taking the readings of Temperature Vs voltage & Power developed. Those are explained as follows.



	40	60	80	100	120	140	160	180
voltage	0.62	2.33	4.16	5.2	5.56	6.49	7.47	8.16
power	0.56	2.1	3.74	4.68	5.004	5.84	6.7	7.34

V. CONCLUSION

The present research work is oriented for the generation of thermo emf by utilizing the waste heat contents. This work also implies for the utilization of electric field, magnetic field and stress which can exist already in the operating conditions or can be applied externally for better results. The orientation of the thermoelectric modules (parallel or perpendicular) can also be considered related to the strength of external parameters.

The units of energy production can be developed in the various regions by using thermoelectric modules. In these days the society face the energy crisis but also the harmful effects of pollution. The thermoelectricity is a “Green Technology” to generate electricity without any harmful effect. The educational institutions, furnace regions, metro cities, industrial areas, universities and other locations can be selected for the establishment of such energy centres where the waste heat can be easily available and can be recycled after conversion to the same system.

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