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# Evaluation of Waste Heat Recovery in the Form of Electric Current from Exhaust of an Automobile through Seebeck Effect

*Narayan Gurjar, Punam Kumar Agade*

Madhyanchal Professional University, Department of Mechanical Engineering, Bhopal, MP

ABSTRACT

The current worldwide trend of increasing transportation is responsible for increasing the use of internal combustion engines. I.C engines, the devices with a high energy usage and low efficiency because roughly 75 % of the energy produced during combustion is lost in the exhaust and in the coolant of the engine in the form of heat. Energy crisis and thermal energy management are the critical topics of present scenario. As we know that a major part of the heat supplied in an internal combustion engine is not converted into useful energy, but dumped into the atmosphere as waste heat so it becomes necessary to recover this waste heat. Thermoelectric modules are solid state devices that are used to convert thermal energy from a temperature gradient to electrical energy. This temperature difference can be obtained from exhaust gas pipe, as outer surface of the exhaust pipe of engines can reach the temperature up to $200^0$C to $400^0$C when exhaust gases are flowing through it. Prototype of thermoelectric generator is made to produce power on small scale from waste heat of exhaust flue gases of two wheeler using two peltier modules connecting in series and experiments were carried out on that prototype. As a huge amount of energy is lost, there is urgent need to design a advice to trap this loss. This thesis proposes and implements a waste heat recovery system using a thermoelectric generator (TEG) designed for four stroke I.C. engine. The experimental results demonstrate that this concept of waste heat recovery is feasible as we are getting considerable voltage output by the prototype which we have made. In this way we can say that thermoelectric generators may play an important role in enhancing the overall efficiency of an internal combustion engine as they help in tapping and converting waste heat energy from exhaust into usable energy. This same concept can be implemented on big scale for waste heat recovery so that to achieve development through green technology.

Keywords— Thermoelectric module, Seebeck effect, Heat of exhaust gases, Temperature difference, waste heat recovery.

## INTRODUCTION

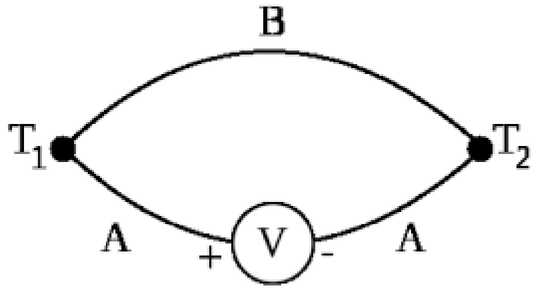
The automotive industry is one of the most important economic sectors in the world. Cars use IC engines, which have a significant loss of power up to 70% in the form of heat. In more recent times, scientists have tried and experimented with automotive technology with ease, but have been unable to control the loss of an IC engine in the form of waste heaters. This paper focuses primarily on regulating the heat of the IC engine waste, instead focusing on capturing waste heat to generate electricity using a suitable thermoelectric generator (TEG).
Thermoelectric generator (TEG) is a device that converts thermal energy directly into electrical energy, using background effects. The use of TEG in the car's IC engine is a revolutionary concept, which reduces the load on the alternating battery alternator, thus contributing to a reduction in fuel consumption.

The temperature of the 'bend pipe' outlet where the gas flows, between 200 ° C and 300 ° C, by placing a copper plate in the folding pipe of the thermoelectric modular thermal mixing is made, connecting the other cold area with an aluminum heat sink, discussed in detail in the paper. As this potential difference is made, electrical energy is generated using a visual back effect. The power output generated is further enhanced using a booster circuit and tested for each load.

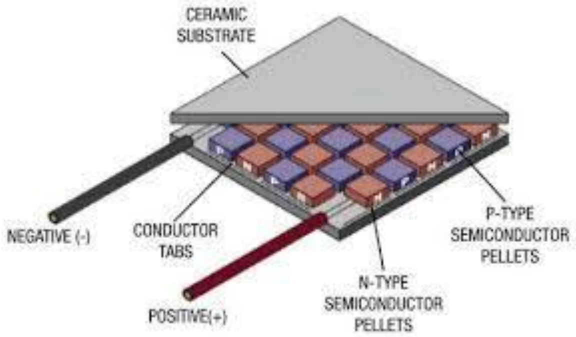
The temperature of the exhaust gas pipe is very high when the exhaust gases flow and that can be $200^o$C to $300^o$C. Thermoelectric modules are suitable for such use as they are small, have no moving parts and are efficient at this temperature. Thermoelectric modules are solid state devices that are primarily used to convert thermal energy from gradient heat to electrical energy. By using part of the lost heat energy with IC engines to charge the battery instead of using something else, the fuel economy could increase by 10%.
The conversion of temperature difference to electric current and vice versa is called the thermoelectric effect. In 1981, Thomas Johann Seebeck discovered that a region with two different metals with different temperatures could divert a compass magnet. He saw that there was an electric current being drawn, which by the law of Ampere distorted the magnet. Also the electric current or electric current due to temperature differences can drive the electric current in a closed circuit.

### *1.1 Working of TEG:*

The EMF cause by temperature gradient across the junctions of two dissimilar conductors, which form a close loop is seebeck effect shown in figure 1.1.




Seebeck effect




1.1 Concept of Thermoelectric generator

One pair of thermoelectric is made from two 'pellets' of semiconductor material commonly made with Bismuth Telluride (Bi2Te3). One of these pellets is impregnated with impurities to form a P-type pellet; another is drawn from donor impurities to produce an N-type pellet. Two pellets are physically connected on one side, usually with a piece of brass, and are fitted between two exterior ceramic plates providing electrical separation and structural integrity. The thermoelectric semiconductor power supplies A and B combined together show the figure. 1.1, if the temperature difference is maintained between both sides of the thermoelectric pair (T1 and T2), the thermal energy that will travel through this device with this heat and electrical energy, called Seebeck voltage, will be generated. If the resistive load is connected to all thermoelectric pair discharge terminals, electrical energy will flow to that load and a voltage (V) will be generated from that load. Functional thermoelectric modules are made up of a number of these thermoelectric pairs that are electrically connected in series and thermally alike.

### *1.2. TEG Types:*

Thermoelectric production materials and there are temperatures as follows. There are a number of consumer goods to date but few are identified as consumer goods.

| Sr no | TEG Materials | Temperature range |
|---|---|---|
| 1 | Material based on Si-Ge alloys | Higher temperature upto1300K |
| 2 | Materials based on alloys of Lead (Pb) | Intermediate temperature up to 850K |
| 3 | Alloys based on Bismuth (Bi) in combinations with Antimony(An), Tellurium (Te) or Selenium (Se) | Low temperature up to 450K |

### *1.1 Types of TEG*

Performance of Thermoelectric Materials at various temperatures
The figure of merit Z describes material performance. It depends on the thermoelectric material properties.
$Z = \alpha^2\sigma / K$
where, α =Seeback coefficient, σ = electrical conductivity, k = thermal conductivity
Single pair of thermoelectric couple contains one p and n type of semiconductor legs and a module has number of couples electrically connected in series and thermally in parallel. The enclosed parallel plates are made up from ceramic substrate which is electrical insulators.
The Seebeck effect is the best example of an electromotive force. Through the Seebeck effect, we can also calculate the measurable electric currents or voltages in the same way as electromotive forces.

The local current density can be calculated using the formula,

$$J = \sigma(-\Delta V + E_{emf})$$

Where,

$\Delta V$ - The potential difference developed

$E_{emf}$ - Electromotive force

σ - The local conductivity

The electromotive force created will explain the Seebeck effect and the equation of electromotive force in terms of the Seebeck coefficient is given by,

$$\Rightarrow E_{emf} = -S\Delta T$$

Where,

S - The Seebeck coefficient

$\Delta T$ - The temperature gradient

The Seebeck coefficient is a measure of the amount of potential induced per difference in temperature. S is one of the transport properties of the material used.

The Seebeck coefficients generally vary with the temperature and the Seebeck coefficient depends on the composition of the conductor. Generally, the Seebeck coefficient at room temperature ranges from -100V/K to 1000V/K.

## LITERATURE SURVEY

Akash Pandey et al. [2021] The purpose of this current paper is to present a summary of the various studies designed to achieve thermal uniformity, heat transfer rate, and AXEG pressure reduction indicators for AETEG. Future ideas of good heat exchange designs are also proposed that could improve the rate of heat recovery from engine exhaustion.

Hanlin Cheng et al. [2020] This paper shows significant advances in thermal harvesting by the development of hybrid ionic / electronic thermoelectric converter (HTEC). The device consists of an electronic unit and an ionic unit. The electronic unit is made of thermoelectric polymer, poly (3,4-ethylenedioxythiophene): poly (styrene sulfonate) (PEDOT: PSS), and ionic unit is made of ionogel. In addition to the conversion of heat to electricity by the electronic unit from the heating core due to the Seebeck effect, the ionic unit can generate electricity from temperature fluctuations due to thermal ionic diffusion (Soret effect). Energy production can be several times higher than a thermoelectric generator using PEDOT: PSS. Because waste heat temperatures are often variable, HTECs can increase the conversion of very high heat to electric energy than conventional thermoelectric generators with only electronic conductors.
UB Jiang et al. [2020] Here, we show that we can significantly reduce the lattice transmission of n-type PbS-based material to 0.4 W m-1 K-1 by introducing zigzag nano bars with a similar diameter around 1 nm. Electron flow was also successfully enhanced by reducing the active size using Se alloying. Finally, an odd statistical value of 1.7 to 900 K was obtained from the sample of n-type $Pb_{0.93}Sb_{0.05}S_{0.5}Se_{0.5}$. The thermoelectric power

generation module is built with this n-type PbS and our p-type PbTe made with high performance. It showed a high efficiency of 8.0% with a temperature difference of 565 K. In addition, a separate module containing in- / p-Bi2Te3 and n-PbS / p-PbTe was made, showing a high efficiency of 11.2% with a temperature difference of 585 K. This same functionality is similar to the reported PbTe modules, and was recognized at a much lower cost. As a result, low-performance n-type PbS-based products as a promising PbTe alternative will promote the wide commercial application of thermoelectric power generation.

Mohamed Amine Zoui et al. [2020] In this review, generators of state-of-the-art thermoelectric technologies, applications and recent advances are reported. Basic information on thermoelectric effect, basic rules, and parameters affecting the effectiveness of common and new thermoelectric materials is discussed. Thermoelectricity applications are organized into three main domains. The first group deals with the use of heat emitted from radioisotope to supply electricity to various devices. In this group, space exploration was the only application in which thermoelectricity was successful. In the second group, a natural heat source may appear to be useful in generating electricity, but since thermoelectricity is still in the first stage due to the conversion efficiency, applications are at a laboratory level. The third group is moving ahead at an alarming rate, largely because the investigation is funded by governments and / or car manufacturers, with the ultimate goal of reducing fuel consumption and ultimately reducing the impact of greenhouse gas emissions.

Ragupathi et al. [2020] The current research work focuses on generating electricity from thermal energy that is distributed by hot gas (BEG) internal combustion engine (IC). A horizontal pass straight duct (HTSPD) temperature (HE) with thermoelectric generator (TEG) was used to obtain power. The HTSPD HE model was developed, developed and investigated by testing the potential for power generation in relation to TEG.

U Nesrine Jaziri et al. [2019] This paper introduces an in-depth analysis of TEGs, starting with a detailed description of their operating principles, types (planetary, vertical and mixed), materials used, value qualifications, development strategies that include the arrangement of different thermoelectric properties (standard, isolated and cascaded ), and the technology used and the types of substrates (silicon, ceramics and polymers). This document also describes the exploitation of TEGs in a variety of fields from low-power applications (medical and wearable devices, IoT: internet of things, and WSN: wireless network) to high-power applications (industrial electronics, automotive engines, and aerospace)

L.S. Hewawasam et al. [2019] This paper study was designed to understand the possibility of combining TEG with engine muffler, without disrupting the performance of the muffler to reverse the waste heat of the engine exhaust system. The findings of the study show that thermo-electric modules (TEMs) can be easily integrated into a muffler and that electricity can be easily utilized using the output power available from the exhaust hot power.

Murat EmreDemir et al. [2017] The waste recycling system (WHR) is designed to be available after a recycling vehicle recycling and recycling process, and consists of a shell and a thermal shell to heat its pipes covered with electrical wiring. Three different Perovskite-type oxide composites of thermoelectric materials ($CaMn_{0.98}Nb_{0.02}O_3$, $La_{1.98}Sr_{0.02}CuO_4$ and $GdCo_{0.95}Ni0_{.05}O_3$) were selected, selected and mathematically selected. Variations in physical properties, efficiency and energy output in relation to temperature and condition are set.

Hassan Fagehi et al. [2016], In this work, analytical models have been developed to calculate the performance of a thermoelectric generator system and test validation. The first part of this concept is about the analytical model, using positive statistics in which communication resistance is included. The model was used to validate the module testing conducted by GM, which showed good agreement. Therefore, the effect of leg length and materials on ceramic plates was investigated. Based on the concept of leg length and ceramic plate materials and the improvement of hot and cold side temperature, the new design is introduced with a significant improvement in density compared to the textbooks.

Tzer-Ming Jeng et al. [2016] This study combined techniques for high-performance heat transfer and thermoelectric modification to form a thermoelectric generator system installed in a single-cylinder exhaust pipe and a single stroke of 35.8 c.c. migration. The system is made up of a heat absorber, thermoelectric generator modules and an external heat sink. A pin-fin array was inserted into the rotating shaft to form a heat absorber, which could increase the heat exchange and heat exchange time to reach the heat absorber and increase thermoelectric conversion effectively

Aravind Karuppaiah et al. [2014] The project describes the construction and analysis of TEG materials used. A study of factors affecting TEG performance is studied. Item features, TEG efficiency and heat transfer to TEG are also studied using BOOKS

Ajay Chandravanshi et al. [2013] developed their project using only four thermoelectric modules by keeping temperatures higher than these modules at different temperatures.

T Stephen John [2013] studied High Efficiency Seebeck Thermoelectric Device for Power System Design and Efficiency Calculation. The House of Commons Review has a Mission. Here Bismuth telluride material is used and it is found that the thermoelectric power produced is more than 2.5 watt DC per TEG, which is economically attractive.

P. Mohamed Shameer et al. [2013] in his paper he had successfully produced a gas-fired emission gas. He had installed the Peltier module directly on the test bike silencer and had also used the Booster circuit to increase the output power.

R. Saidur et. al. [2013] studied in Technologies to rediscover the heat emitted by internal combustion engines. The study also revealed the power of technology when combined with other devices to increase the efficiency of vehicles. It should be noted that TEG technology can be combined with other technologies such as PV, turbocharger or Rankine bottle cycle process to increase energy efficiency, reduce fuel consumption and greenhouse gas (GHG) emissions.

## III. RESEARCH OBJECTIVE

The project proposes and implements a system for the detection of electrical energy from heat from internal fire vehicles, including petrol vehicles and hybrid electric vehicles. The key is to directly convert heat energy from car waste heat to electric power using a thermoelectric generator.

Therefore, the energy stored in the battery can be increased. The test results show that the proposed system can work well under a variety of operating conditions, and is promising for the automotive industry.

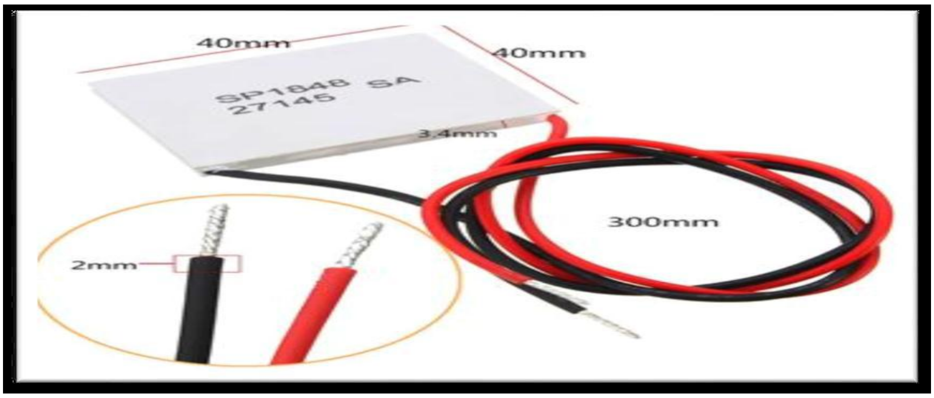
## IV METHODOLOGY

### 4.1 DESIGN CONCEPT OF PROJECT

As mentioned earlier our project design concept is based on a simple concept from physics that is a Seebeck effect on thermoelectricity. This concept is about changing the temperature difference of an electrical output. We have used thermoelectric modules also known as thermoelectric modules as they contain semiconductor materials within them. The temperature difference is made between the hot spot of the exhaust pipe and the air. Electric power generated due to this temperature difference can be used to use bike electronics like front lights, horns etc.

### 4.2 MATERIALS AND EQUIPMENTS USED IN THE EXPERIMENT

**(i) Thermoelectric generator:**




4.1 Thermoelectric generator

A thermoelectric generator is a semiconductor based electronic component that converts heat into electricity using a substance called Seebeck effect. Two thermoelectric generators connected to the series are used in the test setup.

The thermoelectric module of bismuth telluride with operating temperatures reaches 150° C. The power output of the TEG module is 3.2 watts at 100° C. raises electricity.

1. Model : SP1848-27145
2. Operating Temperature : -40 to 150°C
3. Cable Length: 20cm (approx).
4. Principle: Seebeck effect.

5. Raw material: bismuth telluride.

6. Size : 40mmx40mmx3.4mm

7. Merit (Z): 2.5 ~ 3.0 × 10-3W / ℃

Bismuth telluride based module is easily available at a low cost with different power and size so this module is used in present work.

**(ii) Heat source and heat sink:**

A heat source is an object that produces or radiates heat.

**1) Copper heat source**

Copper has a high thermal conductivity and a melting point that is easy to heat in the silencer bend pipe that transmits heat to the thermoelectric generator. So in this test set, a copper plate is used as the heat source on the hot side. The TEG hot compounds are connected to the required copper plate in the I.C. an engine carrying hot exhaust gases. This copper plate has a smooth surface and a size of 185mm x75mm x6mm serves as a heat source. A heat sink is a substance that absorbs and distributes heat from another object using a thermal connection.

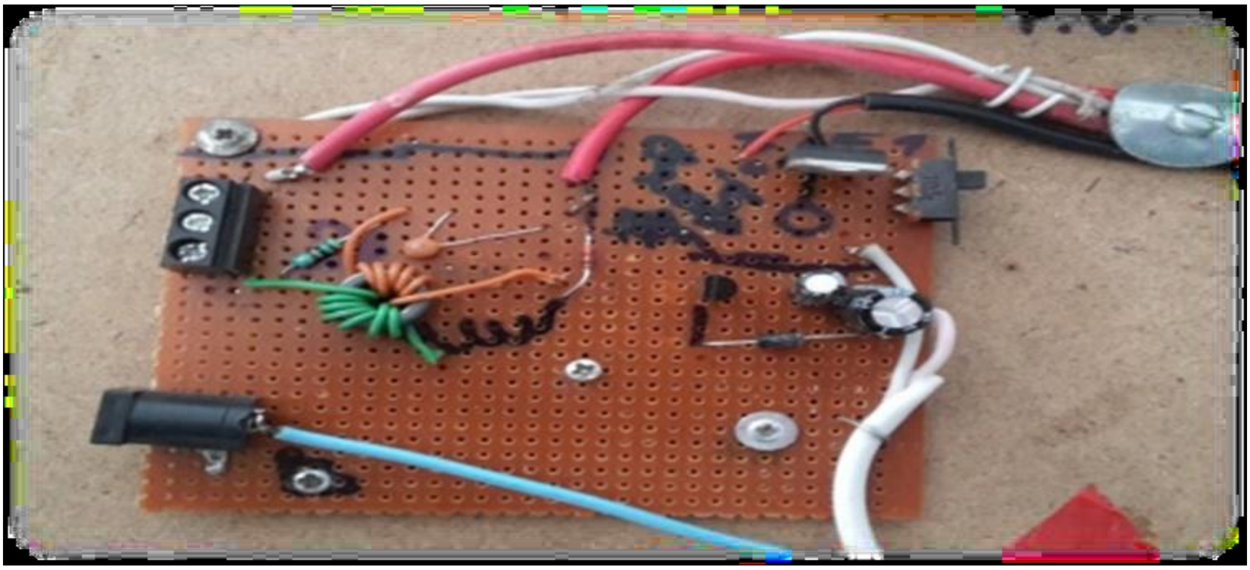
**2) Aluminum heat sink**

4.2 Aluminum heat sink fabricated for the present study

A low-grade aluminum heat sink is used in the current investigation. Contains a number of cool wings with an air-conditioning system. The temperature of the aluminum heat sink (on the cold side) is the room temperature (approximately 26 to 30 ° C). Aluminum heat sinks are 25 points in size and are spread over an area of 70mm x80mm with a diameter of 0.5mm shown in the picture. Two heat sinks are used in the test set. Aluminum heat sink is used because it has high thermal conductivity and is readily available, low cost, low weight and flat back side is well attached with TEG.

**(iii) Booster circuit:**

The reinforcement converter is used to increase the input power obtained from TEG. EMF produced from TEG may not be sufficient to carry the load. There are several types of voltage booster circuits. For this task a simple Joule Thief circuit with round ferrite toroid, resistance (1K) and NPN transistor is used. This circuit is used for DC to DC voltage booster but its efficiency is 70% to 80% .The voltage booster circuit is used to increase the low power output of TEG [6]. In this scale the function developed by the booster circuit is displayed using a digital multimeter, as shown in the figure.



4.3 Joule Thief Converter (Booster circuit)

The reinforcement converter is used to increase the input power obtained from TEG. EMF produced from TEG may not be sufficient to carry the load. There are several types of voltage booster circuits. For this task a simple Joule Thief circuit with round ferrite toroid, resistance (1K) and NPN transistor is used. This circuit is used for DC to DC voltage booster but its efficiency is 70% to 80% .The voltage booster circuit is used to increase the low power output of TEG [6]. In this scale the function developed by the booster circuit is displayed using a digital multimeter, as shown in the figure.

**(iv) Multimeters:**

Continuous monitoring of system performance is a necessary part of the test, in which case three multimeters are connected throughout the circuit in three different locations. One is connected to the back of the TEG module to monitor its output power. The second is connected to the back of the booster power support circuit and the third is connected beyond the current flow load monitor. DT830D digital type with DC voltage range 200 V with accuracy ± 0.5% and dc range current 200 MA- 10 A, with accuracy ± 1.2% and ± 2.0% respectively used in testing.

**(v) Digital thermometer:**

This test set consists of two digital thermometers, which measure the temperature (of the hot spot) of the copper plate and the (cold street) aluminum heat sink. The diameter of the digital thermometer on the hot side is 50˚c to 200˚c and the cold side of the digital thermometer range is 50˚c to 99˚c both thermometers have a type probe.

**(vi) Heat attachment:**

Hot adhesive is a viscous liquid that has grease-like properties. Increases the thermal conductivity of the hot display by filling the small air gaps that exist due to incomplete or smooth surfaces. Heat insulation is applied to both TEG compounds to transfer smooth heat. It is very hot but usually electric. In this set made of white with white color is used that can withstand temperatures up to 150˚C.

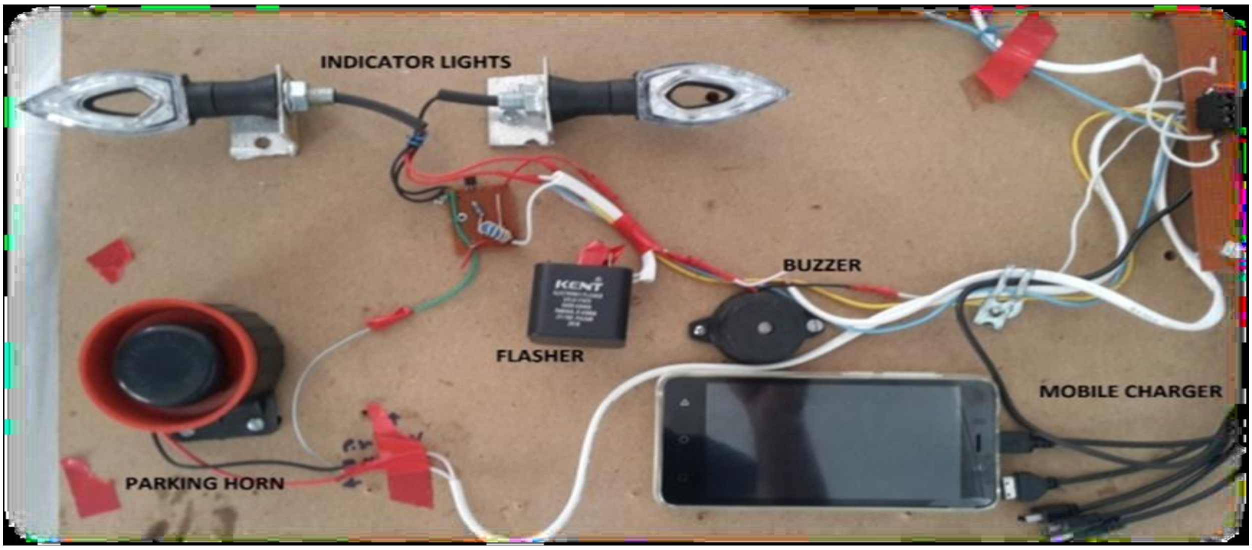
**(vii) I.C. Engine:**

The I C engine used in the system has the following specifications: shown in figure.

| | | |
|---|---|---|
| 1 | Engine Displacement | 92.20 cc |
| 2 | Engine type | 4-stroke, Single Cylinder, Air-Cooled engine |
| 3 | Engine starting | Kick Start |
| 4 | Maximum power | 7.00 bhp@8000 rpm |
| 5 | Maximum torque | 0.73 @ 5000 rpm |

4.1 I C engine specifications

**4.4 Load:**




4.4 Load attached across TEG

The load attached across the circuit have-

(a) LED Indicator

(b) Electronic Flasher

(c) Piezoelectric Buzzer

(d)Mobile charger

(e) Parking Horn

**(a) LED Indicator:**

The LED light signal of the universal lamp lasts up to 100 times longer than an incandescent lamp. Open much faster than standard bulbs, Save energy, longevity, eco-friendly, design flexibility, low weight. The lamps have 20 LEDs each, a short stem and an old dark look

Details: -

Color: -a blue

LED at 20 light each

Operating voltage 9 to 12 V

**(b) Electronic Flasher:**

The turning mirror flasher is a tool installed in the car's lighting system with the main function of making the turn signal lights illuminate when the opening signal button is activated left or right. The electronic flasher is used for LED indicator with very low power consumption. The electronic flasher stays on top of the electro-mechanical flasher and hot flasher. Low power consumption, low weight, low size, long life, no noise and sensitive.

Details: -

KENT electric flasher (two pins)

Voltage 9 V to 12 V

It works from 0.05 A to 7 A

Temperature range from -40 ˚C to 85˚C

**c) Piezoelectric Buzzer:**

It is an electrical device commonly used to produce sound. Low weight, easy construction and low price. Illustrated with a picture.

Details:

Operating Voltage- 6 to 12 V

Current- 20mA @ 12 V

Decible-70

Tone – continuous

**d) Mobile charger:**

Specifications:

It is L7805 voltage regulator (Output 5 V)

It contains 5 charging point.

Power consumptions 1 to 2 W

**e) Thermal grease**

Thermal grease is a viscous fluid substance, originally with properties alike to grease, which increases the thermal conductivity of a thermal interface by filling microscopic air-gaps present due to the imperfectly flat and smooth surfaces of the components.

**f) Clamp and bolts**

Clamps and bolts are used to mount heat sink and Peltier plate assembly on fins of engine cylinder.

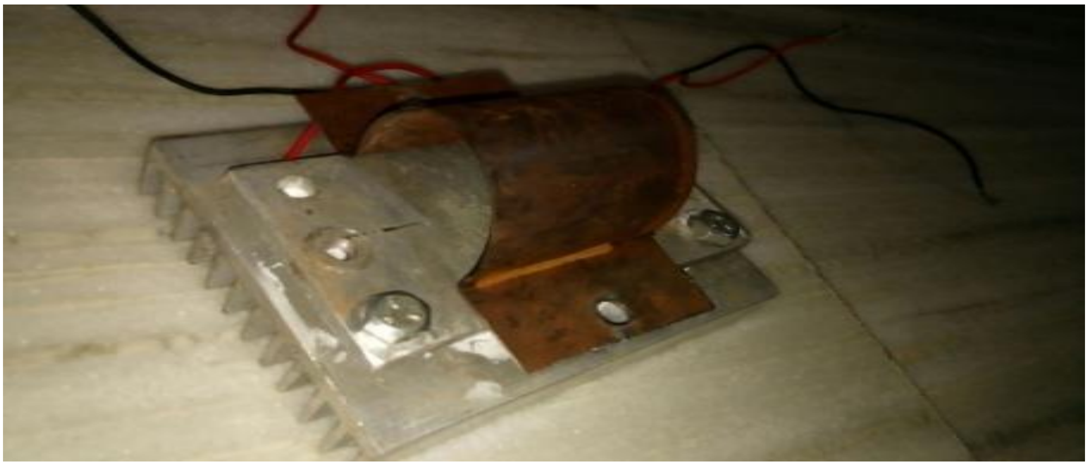
### *4.5 FABRICATION AND ASSEMBLY OF THE PROTOTYPE*

Modeling consists of the following steps.

- Construction of heat sink in aluminum vessel for grinding.
- The formation of a hot separator plate by grinding.
- The formation of holes in the separator plate and heat sink by tapping.
- Connecting two Peltier modules to a series to increase power outages.
- Installation of Peltier modules in a heat sink using hot grease.
- Adjusting the separation plate on the Peltier modules with the help of bolts.
- Mounting the TEG model to the exhaust pipe with the help of ties and bolts.

### *4.6. EXPERIMENTATION*

**4.6.1 Experimental setup:**



**TEG Setup fabricated**

The exhaust pipe exhaust pipe of the IC engine mentioned above, a 6 mm thick copper plate is welded to make the connection of the thermo electric generator. Two thermoelectric generators connected to the series, are placed on a hot plate that forms a junction, on one side of the TEG, a cold aluminum sink is connected as shown on the figs. 10. Between the hot and cold joints the TEG's fitted with nuts and bolts shown in Figure 9. The hot and cold temperature of the TEG side are continuously monitored using digital thermometers. Thermal adhesive is used in the assembly to ensure proper contact between the surfaces and the thermal conductivity.

**4.6.2 Operating Procedure**

Prototype riding a car with the help of telephones and bolts. The car is started and accelerated, increasing the amount of flue gases flowing through the exhaust pipe. As the top of the exhaust pipe increases the temperature difference between the surface of the exhaust pipe and its surroundings also increases. This temperature difference is converted into a power output with the help of a thermoelectric module. The power output generated can be improved by using a large number of thermoelectric modules or by using high output modules.

**4.6.3 Release of Temptation:**

As the engine starts, the hot road warms up and the heat transfer rate rises throughout the thermoelectric generator, now with the effect of Seebeck it begins to generate electricity. The power output generated will be very large which is why the Joule Thief voltage booster shown in figure is used to increase power. Two digital multimeters attached to continuously monitor the power output generated and amplified. This increased voltage is connected to the entire load and tests are performed. One important thing to note is that, if the system is attached to the car, when the car conveys air flowing over the wings of the Aluminum sink it will quickly create more cooling of the sink, which is why it maintains a significant temperature difference throughout TEG and mass production. Readings were taken using the engine at different RPMs, recorded in a table.

**4.6.4 EXPERIMENTAL RESULTS**

The designed system is made to run at three different Speeds and the results are as follows

4.2 Voltage generated at various rpm

| Speed Rpm | Time (Sec) | Sink temp (ambient) ($t_1$) ˚c | Source temp ($t_2$) ˚c | Temp ($t_2$-$t_1$) ˚c | Generated voltage (V) | Boosted Voltage |
|---|---|---|---|---|---|---|
| 2000 | 558 | 31 | 118.2 | 87.2 | 1.02 | 9.23 |
| | 634 | 31 | 143.1 | 112.1 | 1.31 | 12.14 |
| | 927 | 31 | 164.7 | 133.7 | 1.56 | 16.05 |
| 4000 | 378 | 31 | 127.5 | 96.5 | 1.13 | 10.15 |
| | 589 | 31 | 151.2 | 120.2 | 1.42 | 13.04 |
| | 782 | 31 | 171.9 | 140.9 | 1.65 | 17.08 |
| 6000 | 403 | 31 | 138.3 | 107.3 | 1.26 | 11.02 |
| | 611 | 31 | 150.5 | 119.5 | 1.40 | 13.12 |
| | 812 | 31 | 181.6 | 150.6 | 1.77 | 18.22 |

*Calculations for voltage*

Voltage generated by seeback effect is given by:

$V = \alpha (T_2 - T_1)$

Where, V= voltage generated due to temperature difference (Volts)

α = Seeback coefficient (V/K) = 0.0117 V/K for selected module

$T_2$ = Temperature of hot surface

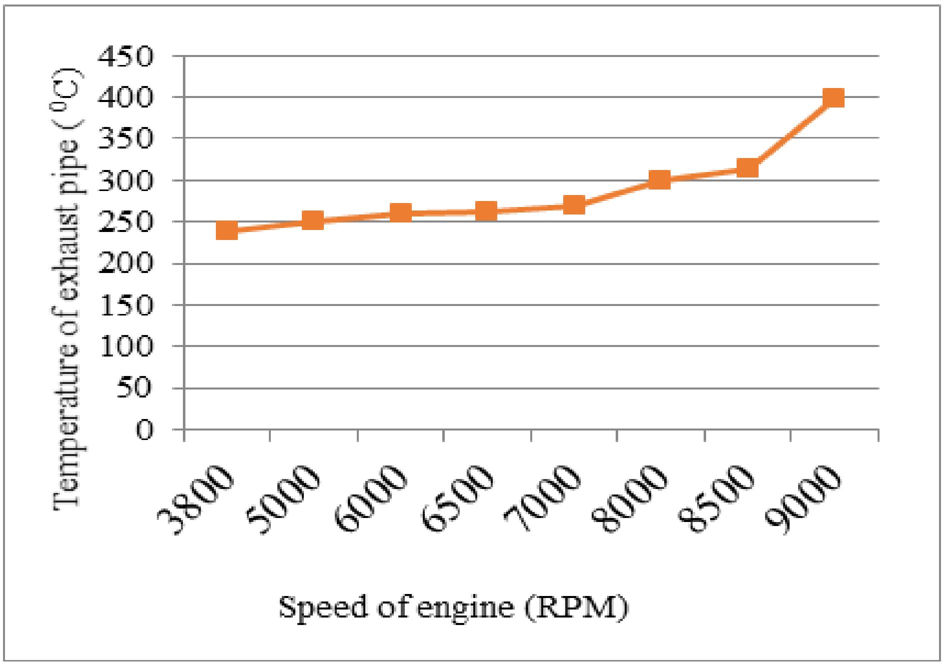
$T_1$ = Temperature of cold surface = (Atmospheric temperature)

| **Case 1:** | **Case 2:** | **Case 3:** |
|---|---|---|
| $T_2$ =118.2°C<br>$T_1$ = 31°C<br>α = 0.0117 V/K (For selected material)<br>Putting above values in equation of voltage we get,<br>V = 0.0117 (118.2-31)<br>V = 1.02 volt | $T_2$ =143.1°C<br>$T_1$ = 31°C<br>α = 0.0117 V/K (For selected material)<br>Putting above values in equation of voltage we get,<br>V = 0.0117 (143.1-31)<br>V = 1.13 volt | $T_2$ =164.7°C<br>$T_1$ = 31°C<br>α = 0.0117 V/K (For selected material)<br>Putting above values in equation of voltage we get,<br>V = 0.0117 (164.7-31)<br>V = 1.56 volt |
| **Case 4:** | **Case 5:** | **Case 6:** |
| $T_2$ =127.5°C<br>$T_1$ = 31°C<br>α = 0.0117 V/K (For selected material)<br>Putting above values in equation of voltage we get,<br>V = 0.0117 (127.5-31)<br>V = 1.13 volt | $T_2$ =151.2°C<br>$T_1$ = 31°C<br>α = 0.0117 V/K (For selected material)<br>Putting above values in equation of voltage we get,<br>V = 0.0117 (151.2-31)<br>V = 1.42 volt | $T_2$ =171.9°C<br>$T_1$ = 31°C<br>α = 0.0117 V/K (For selected material)<br>Putting above values in equation of voltage we get,<br>V = 0.0117 (171.9-31)<br>V = 1.65 volt |
| **Case 7:** | **Case 8:** | **Case 9:** |
| $T_2$ =138.3°C<br>$T_1$ = 31°C<br>α = 0.0117 V/K (For selected material)<br>Putting above values in equation of voltage we get,<br>V = 0.0117 (138.3-31)<br>V = 1.26 volt | $T_2$ =150.5°C<br>$T_1$ = 31°C<br>α = 0.0117 V/K (For selected material)<br>Putting above values in equation of voltage we get,<br>V = 0.0117 (150.5-31)<br>V = 1.40 volt | $T_2$ =181.6°C<br>$T_1$ = 31°C<br>α = 0.0117 V/K (For selected material)<br>Putting above values in equation of voltage we get,<br>V = 0.0117 (181.6-31)<br>V = 1.77 volt |

## IV RESULTS AND DISCUSSIONS

*A. Effect of increase in speed of engine on temperature of exhaust pipe*

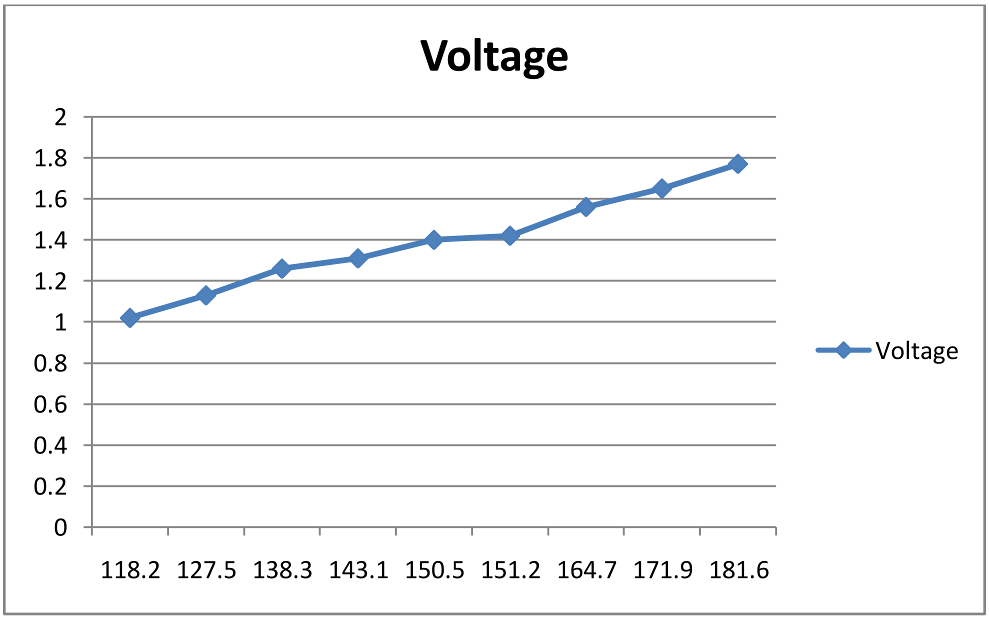
As speed of the engine increases, temperature of exhaust pipe also increases.




5.1 Speed of engine V/S Temperature of exhaust pipe.

*B. Effect of temperature of exhaust pipe on the output voltage*

As temperature of exhaust pipe increases, the output voltage also increases.



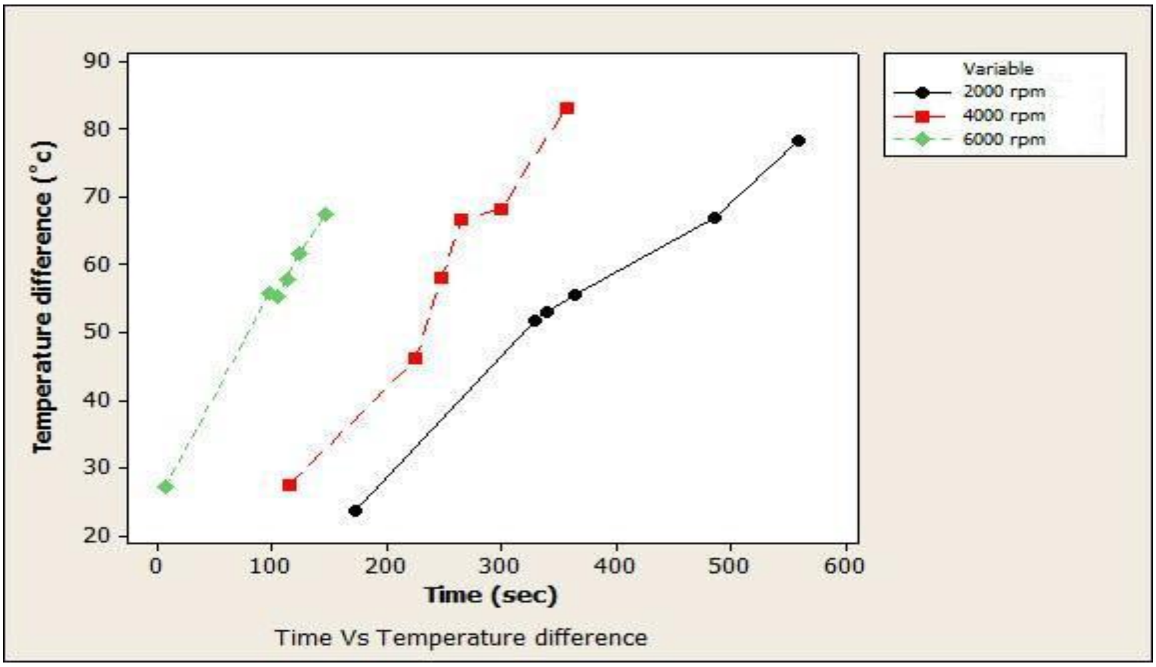

5.2 Temperature of exhaust pipe V/S Voltage.

## V DISCUSSION

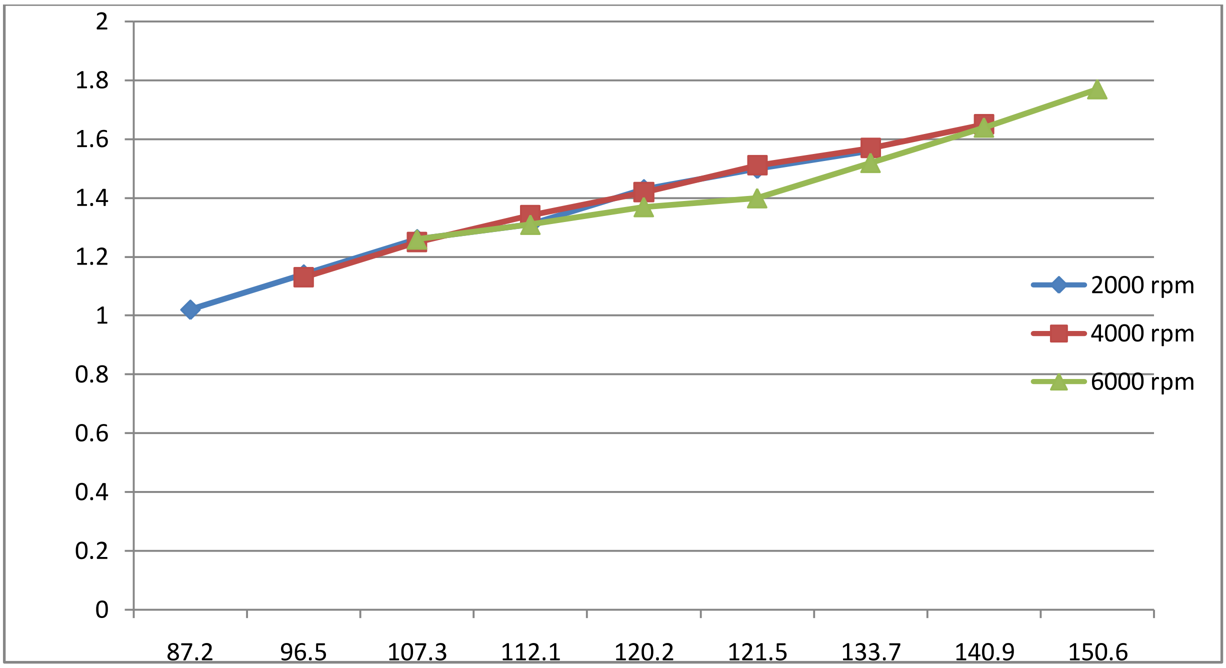
The TEG used in the current test operates between a temperature range of 40˚C to 180˚C as the engine is running, the silencer temperature reaches 180˚C. When the engine is operating at 2000rpm then the heat source attached to the surface is heated to 118.2˚C in 9.3 minutes and the power output is 1.02 volts. Similarly when the engine is operating at 4000rpm the heat source receives heat up to 127˚C in 5.95 minutes of power output is 1.13 volts. When the engine is operating at 6000 rpm the heat source heats up to 107˚C in 2.43 minutes and produces volumes of 1.26. The test set uses only two TEGs that operate at a maximum temperature difference of 150˚C. And it works at high temperatures up to 180˚C. Thermocouples are attached to the surface of the silencer pipe, the recorded temperature of the silencer pipe is approximately 140˚C when the vehicle is operating (on the road). If the silencers bend the pipe temperature property above 180˚C it will require a high temperature TEG (200˚C). The main purpose of the Joule CKT thief is to increase the power output generated by TEG as TEG generates less electricity and that power is not enough to use the load. The load connected throughout the system is controlled by indicators, an electric flasher, and an electronic horn. The temperature difference by displaying the voltage graph at a speed of 6000 rpm of the engine at 146 seconds gives a temperature difference of 107.3˚C and at that time we obtained 1.26 volts. And at a speed of 6000 rpm the engine offers a much higher temperature difference than 2000 rpm and 4000 rpm.

## VI CONCLUSION

We have successfully developed the Prototype of thermoelectric generator by studying all its necessary components and their functionality. After conducting research we can conclude here that such types of waste recovery systems are possible and can be used on a large scale. The temperature of the exhaust pipe increases with the increase in engine speed. Seebeck's output power increases with the temperature difference across the Peltier plate. The output power and current strength are at the expense of relationships and methods with the increase in power; At the moment it is also rising but not in direct proportion. Exhaust capacity increases with increasing temperature variations throughout the Peltier plate. In this way by increasing the power output we can increase the efficiency of the engine.




6.2 Time is directly proportional to temperature difference.




6.3 Temperature difference is directly proportional to voltage

1. This project aims to find a possible way to rediscover waste heat in the I.C. engine and design and design such a system to achieve the purpose.
2. By testing it is found that when two thermoelectric generators are connected to a series. This generated energy is used directly to make certain car auxiliary devices or can be stored on a battery and used later.
3. These future loads can be assisted by the battery in this system and thus reduce the load on the alternator.
4. The study also investigates the effect of engine speed on temperature and power variations.
5. Engine performance is not affected by the built-in system because the heat emitted from the surface of the overhead reciprocating pipe does not affect engine performance.
6. If a high temperature is required the TEG module should be switched to a high temperature (200˚C). Therefore, the above-mentioned system can be used successfully in various car engines, with minimal changes.

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