Thermoelectric Heat Recovery from Four Stroke Engine

Rohini S. Mohite
B.E. Student of Mechanical Engineering
Shivajirao S. Jondhale College of Engineering
Mumbai, India

Khan Owais Ayyub
B.E. Student of Mechanical Engineering
Shivajirao S. Jondhale College of Engineering
Mumbai, India

Ansari nadir ajaz ahmed
B.E. Student of Mechanical Engineering
Shivajirao S. Jondhale College of Engineering
Mumbai, India

***Abstract*—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 2000C to 4000C 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. 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.

I. INTRODUCTION

Practically there is no system which converts total input energy into output energy, there are some losses. There is no system in the universe which is 100% efficient, due to losses efficiency of the system decreases in practical practices. Automobiles are an example of high energy usage with low efficiency. It has 30% efficiency and roughly 75% of the energy produced during combustion and roughly 75% of the energy produced during combustion is lost in the exhaust or engine coolant in the form of heat. If this energy is tapped and converted into usable energy, the overall efficiency of an engine can be increased. Thermoelectric technology can be used to generate electrical power from heat. Thermoelectric modules are used for that purpose.

Thermoelectricity utilizes the Seebeck effect and Peltier effect which were first observed between 1821 and 1851.Practical thermoelectric devices came into existence in 1960 which were developed significantly and since then number of manufacturers are now marketing thermoelectric modules for power generation, heating and cooling applications. Ongoing research and advances in thermoelectric materials and manufacturing techniques, enables the technology to make an increasing contribution to address the growing low power energy sources typically used in energy harvesting and scavenging systems. Commercial thermoelectric modules can be used to generate a small amount of electrical power, typically in the mW or µW range, if a temperature difference is maintained between two terminals of a thermoelectric module. Alternatively, a thermoelectric module can operate as a heat pump, providing heating or cooling of an object connected to one side of a thermoelectric module if a DC current is applied to the module's input.

The temperature of exhaust gas pipe of an engine is very high when exhaust gases are flowing through it and that is around 200ºC to 300ºC. Thermoelectric modules are ideal for such applications as they are small, with no moving parts and relatively efficient at this temperature. Thermoelectric modules are basically solid state devices that are used to convert thermal energy from temperature gradient to electrical energy. By utilizing a portion of the lost thermal energy through IC engines exhaust to charge the battery instead of using an alternator the overall fuel economy can be increased by 10%.

II. LITERATURE REVIEW

Here is the information about the literatures which we reviewed. Some of the ideas of our project we got from this literature. Some of the highlights of each literature we are mentioning here. Ajay Chandravanshi et al. [1] did their project by using only 4 thermoelectric modules by maintaining the surface temperatures of these modules at different temperatures. Baskar et al. [2] did an experiment to study and analyze the feasibility of retrofitting the waste heat recovery system to two stroke petrol engine. The experimental performance testing has also shown that the overall efficiency of two stroke petrol engines installed with and without the waste heat recovery system is29.67% and 29.2% respectively when the power extraction was 90W. Prathmesh Ramade et al. [3] designed and developed an Automobile Exhaust Thermoelectric System (AETEG) for the waste heat recovery of an automobile engine. The system was retrofitted to the exhaust line of a 4 stroke, cylinder Maruti 800cc SI engine and measurements were taken to study the performance of this system. It was found that to get improved efficiency of this system, thermal management is very important. Double stacked type cold side heat sink gives better temperature gradient across the TEG. Counter flow type arrangement enhances the effective heat transfer. Om Prakash et al. [4] in his paper had studied the importance of thermoelectric generator (TEG) using thermoelectric modules. They concluded that by using Thermoelectric generator, energy can be recovered from a cheaper source but the relative fuel saving may not be in proportion. So there is need of maximizing power generation efficiency of TEG. This can be done by providing large temperature difference between hot and cold side. Three different models of heat exchanger were modeled using CAD and their CFD analysis was done using FLUENT software. The rectangular shaped TEG gave better results as compare to other two models. Therefore Rectangular model was Fabricated and tested on an engine dynamometer. P. Mohamed Shameer et al. [5] in his paper had successfully fabricated an exhaust gas heat recovery power generator. He had directly placed the Peltier module on silencer of the test bike and had also used Booster circuit to increase the output voltage. C. Ramesh Kumar et al.[6] in his paper demonstrated the potential of thermoelectric generation. A detailed experimental work was carried to study the performance of thermoelectric generators under various engine operating conditions. The study revealed that energy can be tapped efficiently from the engine exhaust and in near future thermoelectric generators can reduce the size of the alternator or eliminate them in automobiles.

III. Design Concept Of Project

As mentioned earlier our design concept for project is based on the simple concept from physics which is Seebeck effect in thermoelectricity. This concept is about conversion of temperature difference into voltage output. We have used thermoelectric modules which are also known as thermoelectric modules as they consist of semiconductor materials inside it. Temperature difference is created between hot surface of exhaust pipe of bike and atmosphere. The voltage generated due to this temperature difference can be used to operate bike electronics like headlights, horns etc.

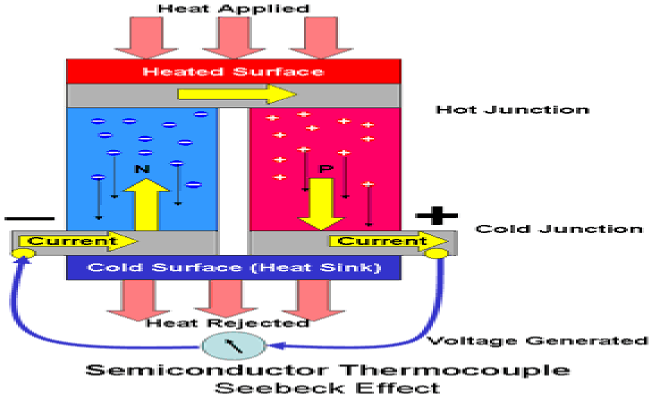

Fig. 1. Seebeck effect of thermoelectricity.

IV. Working Principle Of Thermoelectric Module

The driving principle behind thermoelectric generation is the known as the Seebeck effect. Whenever a temperature gradient is applied to a thermoelectric material, specifically metals or semiconductors, the heat passing through is conducted by the same particles that carry charge. The movement of charge produces a voltage. The junctions of the different conductors are kept at different temperatures which cause an open circuit electromotive force (e.m.f) to develop as follows.

$$V = \alpha (T_h - T_c)$$

Where α is the difference in Seebeck coefficient of two leg materials and has the units of V/K, and T_h and T_c are the hot and cold side absolute temperatures both measured in Kelvin. A German Physicist, Thomas Johann Seebeck, discovered this effect in the early 1800s.

V. Components Of Prototype Of (TEG)

The important components in our project are as follows.

A. *Thermoelectric module*

Considering availability of space, ease of availability, low cost and high life period we have selected the thermoelectric module from TEC1-12076 series which is shown in fig.5.2. This particular series have Bismuth Telluride as semiconductor material.

Fig. 2. Thermoelectric Module Tec1-12706.

B. *Heat sink*

A heat sink is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device into coolant fluid in motion. As per the importance of the heat sink are concerned, it protects the component (here it is thermoelectric module) from damage by emitting excess heat into the surrounding and helps in maintaining temperature difference across the thermoelectric module. The heat sink which we have used in our project is rectangular in shape. It is made up of aluminum due to high conductivity and light weight.

©2015 IJIRCT | ISSN: 2454-5988

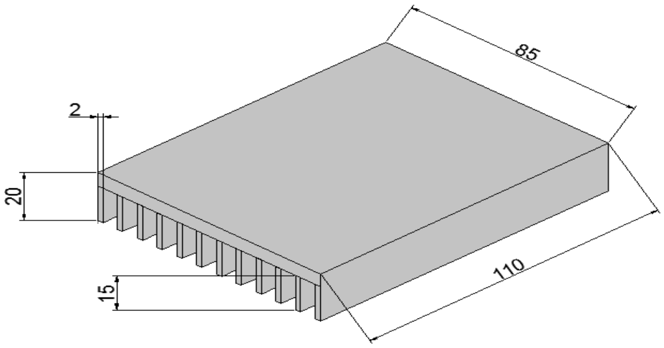

Fig. 3. Rectangular heat sink. *(all dimensions are in mm)*

C. *Separator plate*

Thermal separator is nothing but a metal plate of any suitable material which removes any excess heat from the system and prevents the damage of Peltier module. We have used aluminum plate as a thermal separator in our project, because of its less cost and less weight. Following fig. shows the dimensions of an aluminum plate.

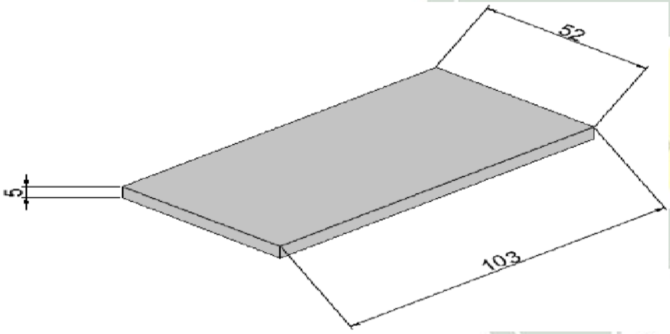

Fig. 4. Aluminum plate as a thermal separator.

D. *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.

Fig. 5. Thermal grease.

E. *Clamp and bolts*

Clamps and bolts are used to mount heat sink and Peltier plate assembly on exhaust pipe of bike.

Fig. 6. Clamp and bolts.

VI. FABRICATION AND ASSEMBLY OF THE PROTOTYPE

Fabrication of the prototype consists of following steps.

- Formation of heat sink from an aluminum slab by milling.
- Formation of thermal separator plate by milling.
- Formation of holes in separator plate and heat sink by tapping.
- Connecting two Peltier modules in series to increase voltage output.
- Mounting of Peltier modules on heat sink using thermal grease.
- Fixing separator plate on Peltier modules with the help of bolts.
- Mounting of TEG model on exhaust pipe of bike with the help of clamp and bolts.

Fig.7 shows the final assembly of the prototype.

Fig. 7. Assembly of prototype.

VII. EXPERIMENTAL TESTING OF THE PROTOTYPE

A. *Apparatus*

1) *Prototype of TEG*

2) *Test bike:* Bajaj Pulsar 200 ns.

3) *Multimeter:* To measure voltage and current at the output wires of Peltier module.

4) *Infrared thermometer:* To measure temperature of the exhaust pipe of bike and surrounding.

Fig. 8. Prototype mounted on test bike.

B. Working Procedure

Prototype is mounted on the vehicle with the help of clamp and bolts. The vehicle is started and the acceleration is given, to increase amount of flue gases flowing through the exhaust pipe. As the surface of exhaust pipe increases the temperature difference between the surface of exhaust pipe and surrounding also increases. This temperature difference is converted into voltage output with the help of thermoelectric module.

The voltage generated can be improved by using more number of thermoelectric modules or by using high output modules.

VIII. Observations and Calculations

TABLE I. OBSERVATION TABLE

Speed of engine (N) (RPM)	Temperature of exhaust pipe (ºC) (T_h)	Voltage (Volt) (V)	Current (Amp.) (I)	Power (Watt) (P_w)
3800	239.8	2.19	0.75	1.64
5000	250	2.52	0.9	2.268
6000	258.6	2.66	1.13	3.005
6500	263	2.77	1.45	4.016
7000	268.5	2.85	1.6	4.56
8000	299.8	3.36	1.95	6.552
8500	313	3.94	2.21	8.707
9000	398	4.45	2.66	11.837

A. Calculations for voltage

Voltage generated by seebeck effect is given by:

$$V = \alpha(T_h - T_c)$$

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

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

T_h= Temperature of hot surface (Kelvin)

T_c= Temperature of cold surface (Kelvin) = 308 K (Atmospheric temperature)

Case 1:

$T_h = 250\ ^0C = 250+273 = 523K$

$T_c = 35\ ^0C = 35+273 = 308K$

$\alpha = 0.0117$ V/K (For selected material)

Putting above values in equation of voltage we get,

$V = 0.0117 \times (523 - 308)$

$V = 2.57$ Volt ………… (Calculated)

For the same case,

$V = 2.52$ Volt ……….. (Experimental)

Case 2:

$T_h = 313\ ^0C = 313+273 = 586K$

$T_c = 35\ ^0C = 35+273 = 308K$

$\alpha = 0.0117$ V/K

Putting above values in equation we get,

$V = 0.0117 \times (586 - 308)$

$V = 3.25$ Volt ………… (Calculated)

For the same case,

$V = 3.94$ Volt ……….. (Experimental)

For both the cases the calculated and experimental values are nearly same and hence we can say that our assumptions are right.

B. Calculations for Power

Case 1:

V= 2.19 Volt

I = 0.75 Ampere

$P_w = V \times I = 1.64$ watts

Case 2:

V= 1.4 Volt

I = 0.54 Ampere

$P_w = V \times I = 0.756$ watts

IX. 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.

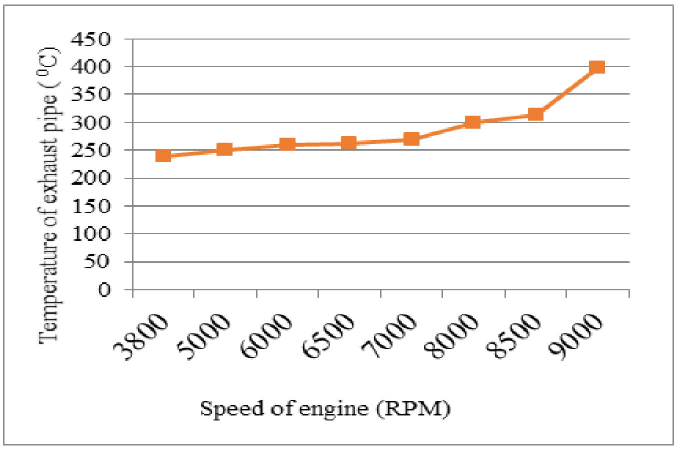

Fig. 9. Speed of engine V/S Temperature of exhaust pipe.

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

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

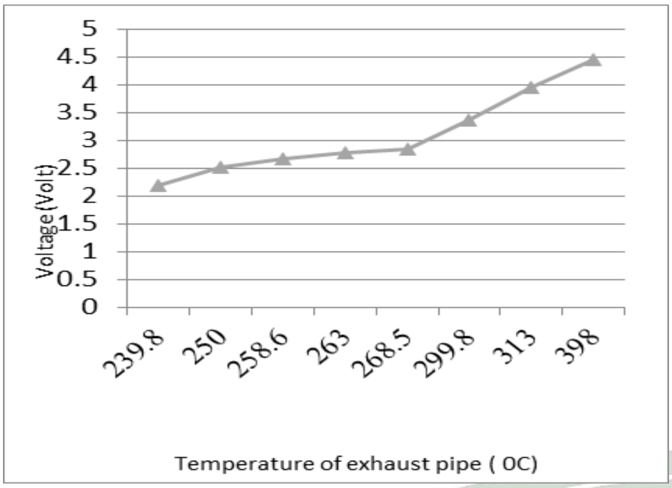

Fig. 10. Temperature of exhaust pipe V/S Voltage.

C. *Relation between voltage and current*

As voltage increases, the current also increases but it is not in exact proportions.

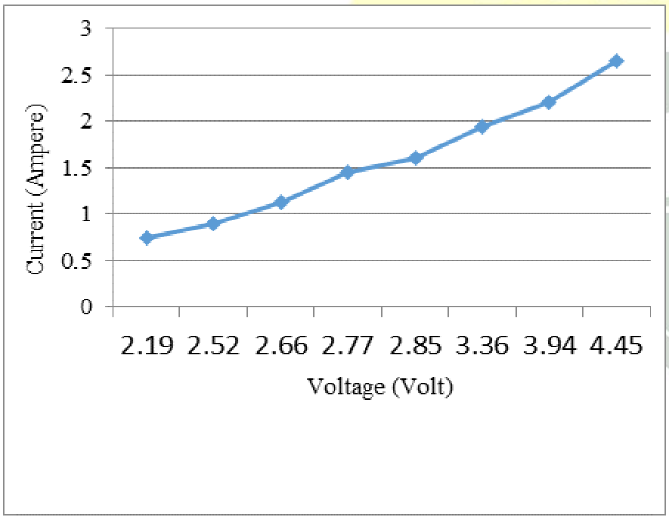

Fig. 11. Voltage V/S current.

D. *Effect of temperature of exhaust pipe on power*

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

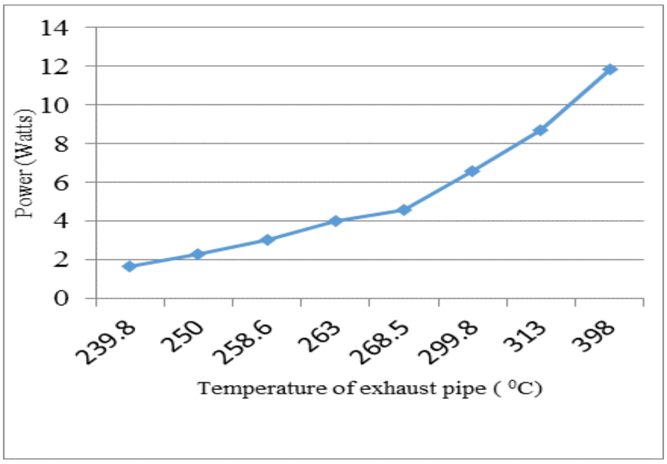

Fig. 12. Temperature of exhaust pipe V/S Power.

CONCLUSION

We have successfully made a Prototype of thermoelectric generator by studying all the required components for it along with their working. After doing experiments we can conclude here that such type of systems of waste heat recovery are feasible and can be applied on large scale. Temperature of exhaust pipe increases with increase in engine speed. Output Seebeck voltage increases with increase in temperature difference across the Peltier plate. Output voltage and current are in linear relation means with increase in voltage; current also increases but not in exact proportion. Output power increases with increase in temperature difference across the Peltier plate. In this way by increasing power output we can increase the overall efficiency of the engine.

REFERENCES

[1] Ajay Chandravanshi, Dr. J. G. Suryavanshi, "Waste Heat Recovery from Exhaust Gases through I C Engine Using Thermoelectric Generator" (Research paper, volume: 3 | Issue: 7 | July 2013 | ISSN - 2249-555X), Visvesvaraya National Institute of Technology, Nagpur (440010) Maharashtra, INDIA.

[2] Baskar P, Seralathan S, Dipin D, Thangavel S, Norman Clifford Francis I, and Arnold C, "Experimental Analysis of Thermoelectric Waste Heat Recovery System Retrofitted to Two Stroke Petrol Engine",, International Journal of Advanced Mechanical Engineering. ISSN 2250-3234 Volume 4, Number 1 (2014), pp. 9-14.

[3] Prathamesh Ramade, Prathamesh Patil, Manoj Shelar, Sameer Chaudhary, Prof. Shivaji Yadav, Prof. Santosh Trimbake-Automobile Exhaust Thermo-Electric Generator Design &Performance Analysis, International Journal of Emerging Technology and Advanced Engineering, (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 5, May 20140).

[4] Om Prakash, Mukesh Pandey, Savita Vyas, "Use of thermoelectric generator for heat recovery from an internal combustion engine", International Journal of Advance Research In Science And Engineering IJARSE, Vol. No.4, Issue 03,ISSN-2319-8354(E), March 2015.

[5] P. Mohamed Shameer1, D. Christopher,"Design of Exhaust Heat Recovery Power Generation System Using Thermo-Electric Generator"-International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438, Volume 4, Issue 1, January 2015.

[6] Kumar, C. R., et al.: " Experimental study on waste heat recovery from an internal combustion engine using thermoelectric technology" Vol. 15, No. 4, pp. 1011-1022 1011, Year 2011.