Journal of Engineering Sciences
Vol 11, Issue 7,July/2020
ISSN NO:0377-9254

# Experimental Analysis of Thermoelectric Generator for Waste Heat Recovery

Ashutosh Upadhyay 1, Shweta Mishra 2, Anurag Singh 3

*M.Tech Student 1, Assistant Professor 2, Assistant Professor 3*

*Mechanical Department, Institute of Engineering & Technology, Dr. Ram Manohar Lohia Avadh University, Ayodhya, U.P. India*

***Abstract*— We are focusing on the employment of waste heat recovery system in automotives as large portion of heat generated in internal combustion engine is released to the environment by the exhaust, because of the waste heat, the η (efficiency) of automobile devices are drastically reduced. ATEGs are semiconductor devices that produce electric potential difference when a thermal gradient develops on it. This paper deals with the study of TEGs performance at different temperature scale & A Specific study is shown in this paper to understand the requirement of power generation against power need.**

***Keywords*— ATEG ( Automotive Thermo-electric Generator),TEM (Thermoelectric Module)**

## 1. INTRODUCTION

In the recent time (21 century) most concerned topic is the excess pollution due to advancement & excess of automobiles, global warming and pollution is increasing. As most of the automobile's combustion engine operates at approximately 25-35% of total heat produced in the chamber whereas 30-50% of the heat is lost through the exhaust. In this paper we are discussing the way that how we can generate the electricity directly from the waste heat and vice-versa.

TEGs are the semiconductors works on the principle of thermoelectric effect.

Thinking about difficulties of complex cars condition and being made commercially the Be2Ti3 based mass thermoelectric material was chosen by a large portion of car makers for application. However, restricted by the thermoelectric materials, the proficiency of TEGs framework was constrained and absolutely under 5%, [1]. In light of bidirectional attribute of the thermoelectric modules (TEMs), the equivalent TEM can just work in control age mode (Seebeck effect), yet in addition in heating, cooling mode (Peltier effect). Hypothetically, a TEG can't exclusively be utilized as a power generator yet in addition can be utilized as a heating or cooling gadget. When contrasted and existing content for thermoelectric cooling application, there are moderately not many investigations concentrating on thermoelectric heating, investigated the feasibility of cooling or heating air through thermoelectric module. The test outcomes demonstrated that the heating coefficient of performance was higher than that of cooling Cop. Numerous analyst are centered around improving the physical properties of thermoelectric material and assembly strategy of thermoelectric module. The enhancement of the thermal system configuration is similarly significant for improving the power generation of TEGs.

## 2. Available Technologies for waste heat use

There are basically three technologies available including turbo-charging, the Rankine cycle model and the thermoelectric generator (TEG). These three methods have some of their strengths and weakness like turbo-charging is suitable for diesel engines but it's weakness is increased back pressure demand for complex diesel after treatment system& in case of Rankine cycle the advantage is, it utilizes both low and medium temperature regardless of ICE load or drive cycle but it's response to transient efficiency tends to be low [2]

But when we compare advantage and dis-advantage of the TEG with other two, TEG is the most suitable technology, application to light-duty passenger vehicle. This has advantage of having no any mechanically rotating parts, compact package, no noise, no vibration and high reliability. The only Weakness is the low conversion efficiency relatively high cost of thermoelectric materials. In this study, individual thermoelectric module (TEM) test framework has been embraced for the estimating, testing and examining of the information obtained from the TEM utilized. The effect of clamp power/force pressed on the module is decreased and a database about the maximum power output is obtained under various temperature difference. The manufacturing of thermoelectric module is done by coupling two conjugate P-type & N-type doped semiconductor material in an optimized manner. The thermoelectric effect has been known since 1821 when it was founded by Thomas Johann Seebeck. The maximum η of the thermoelectric material for both thermoelectric power generation and cooling is determined by the dimensionless fig of merit ZT, given by

ZT=(S^2*σ/K)T

Where S is seebeck coefficient

σ is the electrical conductivity, S^2*σ is the power factor & K is the thermal conductivity [3]

### 3. Principle of Thermoelectric Generation

The thermoelectric generator works on the principle of seebeck effect and the seebeck effect states that when two junctions formed by joining two dissimilar materials maintained at different temperature, a voltage of order µv/k is generated. The materials utilized here are called thermoelectric materials.

The determination of these materials are based on their properties like thermal conductivity, electrical conductivity, seebeck coefficient etc [4]

The measure of intensity created by the TEG relies upon the temperature difference between the opposite faces of TEG, at the point when one surface is kept up at a higher temperature, heat gets conducted to the other surface which reduce the temperature difference. Hence a heat exchanger should be intended to maintain low temp on the other surface. The target of this study is to fabricate and study the performance of TEG for different temp.

### 4. Geometry of Thermoelectric Generator

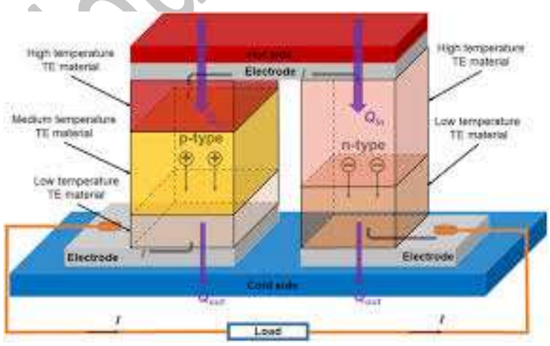



Fig- 1 [5]

Above figure shows geometrical view of thermoelectric generator. It contains a module and ceramic plate on both side and it works between a hot source and a cold sink. Zhongliang [6] explains that two different semiconductors P-type & N-type are kept between hot side and cold sink. An electrode is kept at the upper and lower side of both the semiconductors whereas the upper side of both the semiconductors are connected by the electrode. P-type semiconductor leg is made up of three different thermoelectric materials, high temperature thermoelectric material, medium temperature thermoelectric material & low temperature thermoelectric material whereas N-type leg consist of just two types high temperature thermoelectric material and low temperature thermoelectric material. When heat is applied on the top side of the arrangement flow of electron starts in the circuit and current generation happens.

### 5. Methodology & Construction of Assembly

Bi2Te3 thermoelectric generator module is used in this study. Aluminum heat exchanger for cooling system, Multi Meter & heating surface was prepared, Digital thermometer was used in this study.

Following is the specifications related to the test.

Max operating temperature is 180ᵒc, open circuit voltage is 11.9 volts, thermal conductivity of material is 2w/m-k , density is 7790 kg/m^3 and specific heat is equal to 250 J/kg-k

Two different type of arrangements were made for the test. In first arrangement TEG was sandwiched between the hot plate and aluminum heat exchanger and readings were taken with multi meter. In second case two different chambers of aluminum was made, one for hot side and second for cold side and readings were taken as the temperature increased from 30 degree Celsius, keeping the cold side same throughout test for around 35ᵒc.

### 6.Working of the TEM

Working of the TEM is quite simple, in this test, hot side temperature ranging from 0 degree Celsius to 160 degree Celsius is supplied to the hot side of the module keeping the cold side temperature identical, according to seebeck effect when heat is applied to one if the conductors or semiconductors, heated electron flow towards the cooler side and if the pair is connected by an electrical circuit, direct current flows through that [6]. During this test the

Vol 11, Issue 7,July/2020

ISSN NO:0377-9254

cold side temperature was around 40 degree Celsius to 50 degree Celsius

| S.No. | Temp in $^{o}$c | Voltage in mV | Current in mA | Power (mW) |
|---|---|---|---|---|
| 1 | 32 | 17.4 | 0.89 | 0.0154 |
| 2 | 37 | 228.2 | 1.27 | 0.2943 |
| 3 | 44 | 419 | 1.80 | 0.7542 |
| 4 | 60 | 493 | 11 | 5.4021 |
| 5 | 75 | 570 | 24.7 | 14.079 |
| 6 | 90 | 698 | 49 | 34.202 |
| 7 | 103 | 833 | 74.2 | 61.8082 |
| 8 | 120 | 1288 | 111 | 142.968 |
| 9 | 137 | 1694 | 172 | 292.056 |
| 10 | 145 | 2087 | 203 | 423.661 |
| 11 | 158 | 2578 | 272 | 701.21 |


Fig-2 Aluminum Chamber Model to observe the effect of pressure

Fig-3 Hot Plate Model [7]

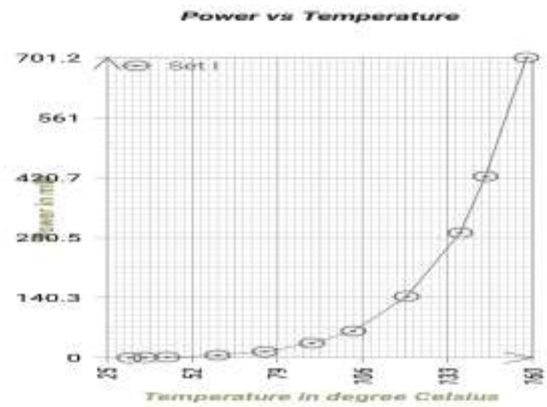
**7. Performance & Result of TEG under varying temperature**

Following reading was taken with the help of simple multi meter when max temperature was around 160$^{o}$c.

From the above chart we can examine that electron movement in the circuit boosts after 60 degree Celsius so the current production increases and further the power generation also increases. After 60 degree Celsius power generation improver so much & goes upto 701.21 mW when the max temperature for the test was around 160 degree Celsius.

From the chart it is clear that when there is 21$^{o}$c change from 137$^{o}$c to 158$^{o}$c, there is increment in power of 409.154mW.

Analysis of temperature range, around 30$^{o}$c no power generation, from 30$^{o}$c to 105$^{o}$c moderate power generation & over 120 degree Celsius great rate of power production.




8. Need of General Electrical Energy for lights used in vehicles

JES Journal of Engineering Sciences

Vol 11, Issue 7,July/2020

ISSN NO:0377-9254

There are two types of light system available for vehicles one is traditional system that is halogen bulbs and the second one is LED system, power consumption in both the systems are completely changed. Brandon Schoettle [3] explained the power consumption by both the different systems as per following chart.

Energy Consumption chart [8]

Baseline wattages for each function in the two systems.

| Function | Power per lamp (W) | |
|---|---|---|
| | Traditional system | LED system |
| DRL, dedicated | 22.9 | 11.4 |
| Low beam | 56.2 | 54.0 |
| High beam | 63.9 | 34.4 |
| Parking/position | 7.4 | 1.7 |
| Turn signal, front | 26.8 | 6.9 |
| Side marker, front | 4.8 | 1.7 |
| Stop | 26.5 | 5.6 |
| Tail | 7.2 | 1.4 |
| CHMSL | 17.7 | 3.0 |
| Turn signal, rear | 26.8 | 6.9 |
| Side marker, rear | 4.8 | 1.7 |
| Backup/reverse | 17.7 | 5.2 |
| License plate | 4.8 | 0.5 |

In the above chart it is shown that how two different system consumes electricity. If all essential lights are of halogen type then it will consume around 287w, whereas if all the lights are changed with the advanced LED system then it will consume about 135w, but all lights are not used simultaneously and then average electricity need falls in the range of 45W-55W.

**CONCLUSION**

Power generation is directly proportional to the temperature of hot side if cold side is kept almost fixed, Electrical Power is directly proportional to temperature gradient.

Thermoelectric generators requires some threshold temperature to start working as about 30$^{o}$c the output was almost zero, but when the temperature increased after 30 degree Celsius it started working.

As per the power readings from the single thermoelectric generator it can produce around 0.8 W of power.

Around 60 thermoelectric generators are needed and assembled with the exhaust system in a way so that whole power generation can be achieved to 45W.

Excess pressure on the module plays important role while generating electricity.

Quite silent operation and power generation is independent of time and light.

**REFERENCES**

1:- Z.B. Tang, A research on thermoelectric generator’s electrical performance, 2015

2:- Yuying Yan, Design of Thermoelectric generator for automotive waste heat recovery, 2017

3:- Kuo Huang, A Novel design of thermoelectric generator for automotive waste heat recovery, CrossMark, 2017

4:- G.Rohit, Performance study of Thermo-Electric Generator, AIP, 2017

5:- Zhongliang Ouyang, Modeling of segmented high performance thermoelectric generator, (2016)

6:- Zhongliang Ouyang, Modeling of segmented high performance thermoelectric generator, (2016)

7:- Z.B. Tang, A research on thermoelectric generator’s electrical performance, 2015

8:- Brandon Schoettle, LEDs and Power consumption of exterior Automotive Lighting, 2008