EXPRIMENTAL INVESTIGATION OF EFFICIENCY OF THERMOELECTRIC GENERATOR FOR WASTE HEAT RECOVERY

Raghav Kumar Raghu[1], Ranpise Aniket[2], Zinjurke Prashant[3], Badade Uttareshwar[4], Kolekar Kailas[5]
UG Students[1,2,3,4], Assistant Professor[5],
Department of Mechanical Engineering, DYPIET, Ambi, Pune, (India).

ABSTRACT: -

Waste heat recovery is the collection of heat created as an undesired by product of the operation of a piece of equipment or machinery to fill a desired purpose elsewhere waste heat recoupling methods range from simple to the complex. In this method, the heat going down a sink or shower drain is recovered by a copper pipe coiling around the drain pipe. On the more complex side, heat recover from liquid cooling systems in data centre can be used for part of facilities where warmer temperature are desired. Burning of fuel causes environmental problem like radio activity, global warming etc. so that these (coal, oil, gases) are the limiting resources hence resulting new technology for electricity generation, by using thermo electric generator to generate power as a most promising technology and environmental free. It is estimated that somewhere between 20 to 50% of industrial energy input is lost as waste heat in the form of hot exhaust gases, cooling water, and heat lost from hot equipment surfaces and heated products. As the industrial sectors continues efforts to improve its energy efficiency, recovering waste heat losses provides an attractive opportunity for an emission-free and less-costly energy resources. Numerous technology and combination of technologies are commercially available for waste heat recovery.

KEYWORDS: - *Waste heat recovery, Peltier plate, Seebeck effect, TEG and I C Engine etc.*

1. INTRODUCTION: -

Thermoelectric power generation offers a potential application in the direct conversion of waste heat energy into electrical energy. During this era of shortage of electricity, it is very essential to convert low grade heat energy into electricity. Waste heat recovery is the most concerned, due to the widespread existence and high accessibility of suitable resources. Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then dumped into the environment even though it could still be reused for some useful and economic purpose. This heat depends in part on temperature of waste heat gases and mass flow rate of exhaust gas. Recently we are depending upon fossil fuels for maximum electricity generation. Recent years cost of unit electricity has increasing to unpredictable levels due the less supply of (oil gas coal). Thus the, green energies are more attractive artificial to electricity generation, as it will also provide a pollution free and cost less. In this innovative project, we are using one device which is used to be created and introduced by human as a renewable energy that is thermo electric generator equipment to generate electricity As we know Renewable energies are, solar energy, wind energy, hydro energy, tidal energy, etc. above energies can produce electricity in different forms and way of generating method. However, if there is no sun light there will no production of electricity alternative sources are necessary for generating electricity or a method of storing energy for future use. Wind and hydro electric energy have their own drawback making them less power production and insufficient for wider usage. The device converting heat energy into electrical energy. This thermoelectric generator is suitable power for space research, Satellites. Satellites are settled at the planets that so far from the earth. For example, thermoelectric devices can be used in vehicles to producing electricity using the waste heat of the engine also. When "electrons" are in motion, we have an Electrical current (i.e., charge per unit time per unit area). Electrical voltage ("pressure") usually is the driving force but, other forces like temperature difference and hence flow of thermal energy/heat can drive the electrons [8,14].

1.1 SCHEMATIC DIAGRAM OF A THERMOELECTRIC GENERATOR (TEG) MODULE: -

In this diagram semiconductor materials such as p-type & n-type are used. There is insulator used above the thermal coating between hot side and cold side heat source is used. Due to heat excitation holes are generated in p-type semiconductor and electrons are generated in n-type semiconductor in this way the flow of electrons take place and electric current is generated.

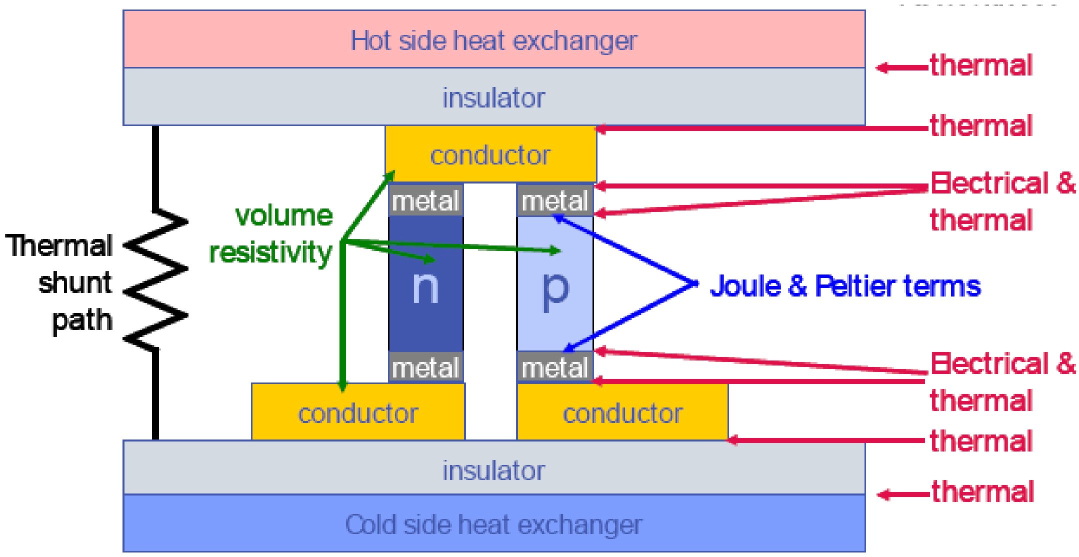


Fig -1: Schematic diagram of TE module [11]

1.2 LITERATURE REVIEW: -

- Kaphungkui N K, , Abhishaek Anku, Phukan Gogoi, Mosoom Subhani,
  In this paper they discuss about the Peltier module and the amplification of the output power with a darlington pair transistors. This proposed model is robust and innovatively designed to generate electricity by using temperature difference. The different readings of temperature and output voltage is given. They amplify their output voltage also. In order to maintain a constant output the water packet which is placed above the heat sink is replaced after 40 minute [2].
- Aggarwal kanika, Vigin M Unnithan , Gaurav Nishant, In this research paper we found that waste heat which is rejected from a process at a temperature enough high above the ambient temperature permit the recovery of energy. Waste heat is heat , which is generated in combustion process and chemical reaction and then flow into the environment even though I could still be reused for some useful and economical purpose the temperature variation in the generator and the maximum voltage obtained from the single module as per increases in number of module the power obtained will be also high [1].
- Daniel Champer ; In this review of thermoelectric application, new thermoelectric module with improved, larger operating range allowing their uses with higher temperature difference for years the development of TEG, has been limited to space and hard access areas where reliability is critical these extreme environment applications have very high added value but their application is very limited in market. In developing and developed countries alike, the various studies and examples presented in the review , show that TEG are good solution to provide some electricity when grid connection is not possible this ability to produce is not possible . this ability to produce some electricity also improves the efficiency of heat generating devices slightly or consistently. The potential of the numerous application described in this paper clearly demonstrate that almost anywhere in industry or in domestic uses it is intersecting to check whether a TEG can be added whenever heat is moving from a hot source to a cold source [3].
- Z.B. Tang, Y.D. Deng, C. Qsv; In this review we found that many automobile manufcture, such as GM in USA, BMW in the Germany, successful developed TEG's to recover the exhaust waste heat. Considering the challenges of complex automotive environment and being made commercially, the based thermoelectric material was selected by most of the automobile manufacturing for application. This work describes the electrical performances of TEM & TEG system under condition, such as the limited working temperature and the inconsistent temperature distributions among the modules in series connection. An individual module test system and a test bench have been design and adopted to test and analyse the impact of thermal imbalance on output electrical power at module and system level [6].

2. DESIGN OF EXPERIMENTAL SET-UP :-

2.1 EXPERIMENTAL SET-UP: -

The set up consists of the Peltier plates which is connected in series (number of Peltier plates 6). The set is mounted in Cu material which is act as a heat source and the other side is connected to Al plate which acts as heat sink. The whole set up is mounted on the bike silencer, the heat which is waste heat from the IC ENGINE during the exhaust stroke is utilized for the production of electricity production [5].

Fig-2: Setup of TEG Based on Silencer

2.2 SPECIFICATIONS OF TEG MODULE USED FOR THE EXPERIMENTATION: -

- Model number : - TEC1-12706
- Voltage : - 12V
- V_{max} (v) : - 15.4V
- I_{max} (A) : - 6A
- Q_{max} (W) : - 92W
- Internal Resistance : - 1.98 Ohm +/- 10%
- Dimensions : - 40mm * 40mm * 3.6mm
- Type : - cooling cells
- Usage : - Refrigerator/Warmer/Generator

2.3 OBJECTIVE OF THE EXPERIMENT: -

- To design the experimental set-up of application of TEG for waste heat recovery.
- To select the waste heat source for the experiment of TEG.
- To investigate the efficiency of thermoelectric generator based on waste heat recovery.

2.4 TAGUCHI METHOD FOR TEG: -

The technique of laying out the conditions of experiments involving multiple factors was first proposed by the Englishman, Sir R. A. Fisher. The method is popularly known as the factorial design of experiments. A full factorial design will identify all possible combinations for a given set of factors. Since most industrial experiments usually involve a significant number of factors, a full factorial design results in a large number of experiments. To reduce the number of experiments to a practical level, only a small set from all the possibilities is selected. The method of selecting a limited number of experiments which produces the most information is known as a partial fraction experiment. Although this method is well known, there are no general guidelines for its application or the analysis of the results obtained by performing the experiments. Taguchi constructed a special set of general design guidelines for factorial experiments that cover many applications. Taguchi has envisaged a new method of conducting the design of experiments which are based on well-defined guidelines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter. The crux of the orthogonal array method lies in choosing the level combinations of the input design variables for each experiment [13].

$$N=1+NV*(L-1)$$

Where,

N=number of experiments conducted, NV=number of parameters, L=number of levels

In our case, NV=2 And L=3

So, N=1+2*(3-1)

N=5

So, number of experiments conducted is 5 [13].

2.5 OBSERVATION AND CALCULATIONS OF EFFICIENCY: -

$$\eta = ((T_h - T_c) / T_c) * ((M-1) / (M+(T_C / T_H))$$

where, $M = (1+1059.5 * (T_h + T_c))^{0.5}$ [12]

Experiment No.1 **Table-1:** Observation Table no. 1

No of plate	Hot side	Cold side	Temp diff	Voltage	current	Efficiency (%)
1	25	24	1	0.1	4.8	0.33
2	40.8	39.2	1.6	0.45	43.5	0.51
3	61	56.7	4.3	1.8	124	1.301
4	64	63.5	0.5	1.75	90.1	0.148
5	70	67.8	2.2	1.67	111.2	0.644
6	68	66	2	1.71	115	0.588

Experiment No.2 **Table-2:** Observation Table no. 2

No of plate	Hot side	Cold side	Temp diff	Voltage	current	Efficiency (%)
1	28	26	2	0.11	5.40	0.667
2	44	41.2	2.8	0.55	40.9	0.792
3	56.7	55.2	1.5	1.5	80.1	0.455
4	69	68.3	0.6	1.62	95.2	0.204
5	73	71.3	1.7	1.88	118.2	0.492
6	77	75	2	1.96	128	0.573

Experiment No.3 **Table-3:** Observation Table no. 3

No of plate	Hot side	Cold side	Temp diff	voltage	current	Efficiency (%)
1	37	34.8	2.2	0.19	5.9	0.712
2	56	55.1	0.9	0.58	45.5	0.7365
3	60	58	2	1.41	89.8	0.602
4	70.81	60	10.81	1.92	119	3.54
5	74	73.6	0.4	0.91	94	0.115
6	68	66.2	1.8	1.5	122.3	0.529

Experiment No.4

Table-4: Observation Table no. 4

No of plate	Hot side	Cold side	Temp diff	voltage	Current	Efficiency (%)
1	42.3	39.8	2.5	0.2	6.2	0.797
2	58	56.2	1.8	0.59	47.9	0.545
3	65	62	3	1.53	92.5	0.894
4	74.50	65	9.5	1.96	125	2.804
5	80.30	78	2.3	0.94	97	0.653
6	69	67.1	1.9	1.7	129.7	0.557

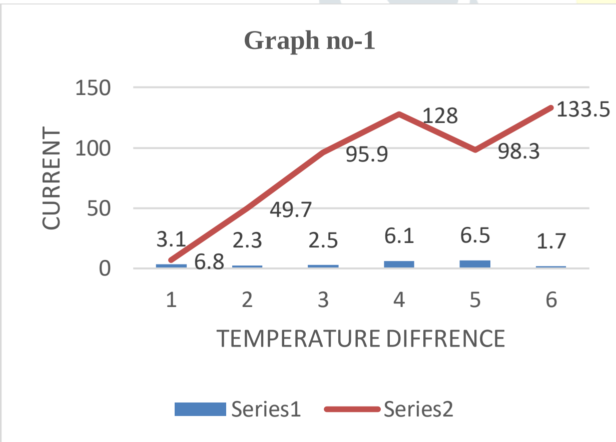
Experiment No.5

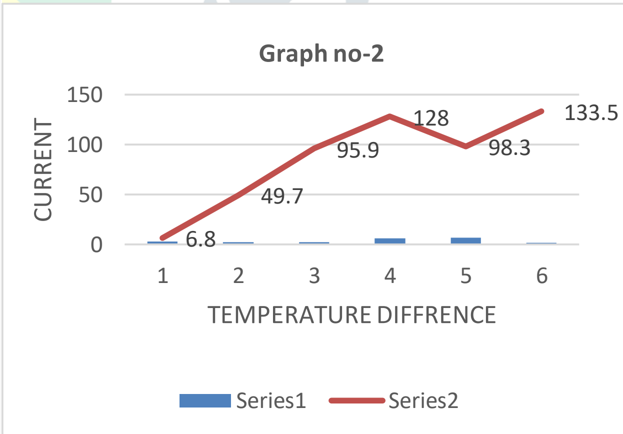
Table-5: Observation Table no. 5

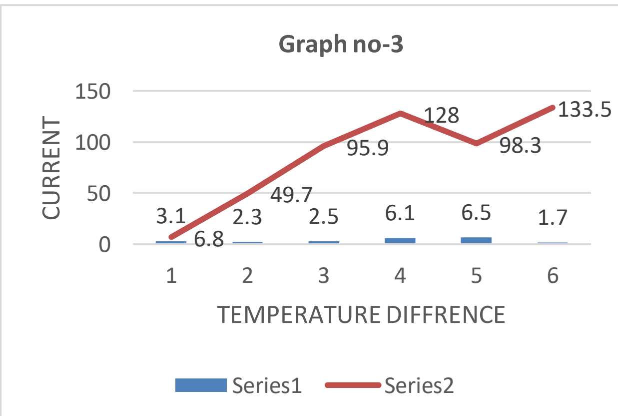
No of plate	Hot side	Cold side	Temp diff	voltage	current	Efficiency (%)
1	44.1	2.5	3.1	0.3	6.8	0.984
2	60.3	1.8	2.3	0.72	49.7	0.693
3	67.5	3	2.5	1.65	95.9	0.737
4	76.2	9.5	6.1	1.98	128	1.77
5	83.7	2.3	6.5	0.97	98.3	1.85
6	70	1.9	1.7	1.9	133.5	0.496

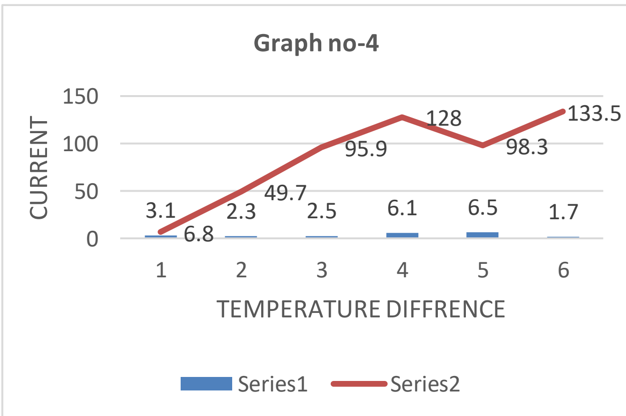
3. RESULT AND DISCUSSION: -

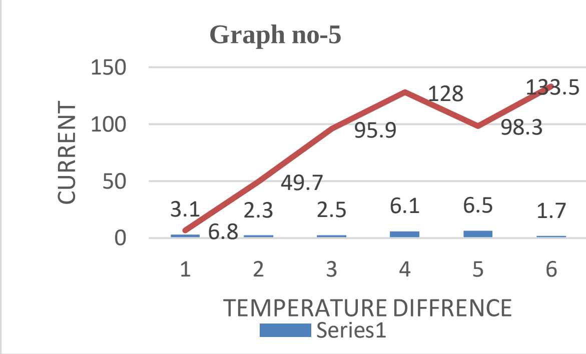
From the observations taken during experiments, the graphs of current against temperature difference are plotted.











From the graphs, it is observed that as the temperature difference in the two sides of Peltier plates increases, the current is also increasing proportionally. Hence, current is directly proportional to temperature difference.

Table-6: Result Table

Experiment no	Average efficiency %
1	0.586%
2	0.5305%
3	1.039%
4	1.0417%
5	1.088%

The TEG module discussed in this work allows for relatively simple performance study using flood heat transfer. Heat provides insights in to current density allocations and heat fluxes with in smaller device. This study has identified a strong need for coordinated search in advanced TEG materials, heat transfer material, heat exchanger technologies. We can increase the efficiency of the TEG by increasing the temperature gradient. The ideal efficiency of the TEG is about 6%.

CONCLUSION: -

Generation of electric energy from waste heat source (I. C. Engine) for the purpose of generation of electricity has been analysed. The average efficiency of the TEG module is 0.85704. If we increase the temperature gradient, then efficiency will increase. Using TEG is one of the suitable methods for recovery of waste exhaust heat. Though the efficiency observed during these experimentations is very less, there is lot of scope to improve it.

FUTURE SCOPE: -

TEG is being used for recovery of the waste heat on a small-scale basis. There is lot of scope for research in developing the applications of TEG for waste heat recovery on large scale also.

The efficiency of TEG can be improved by using the better materials for the Peltier plates of TEG, which can create desired large temperature difference.

TEG can be used with the other waste heat source for waste heat recovery.

4. REFERENCES: -

1. Aggarwal Kanika, Vigin M Unnithan, Gaurav Nishant, (2017), Experimental design analysis of electric power generation refrigeration by using waste heat, International Journal of Advances in Science Engineering & Technology, pp-28-31.
2. Kaphungkui N K, Anku Phukan, Sharma Manash, Gogoi Abhishaek, Masoom Subhani, (2016) Highly efficient electricity generation with Peltier module, International Journal of Engineering Trends & Technology, volume-35 pp-500-503.
3. Daniel Champier, (2017), Thermoelectric generators a review of applications, Energy Conversion & Management 140, pp-167-181.
4. Remeli M. F, L. kiatbodin, B. Singh, K. Yerojporn, A. Date, A. Akbarzadeh, (2015), Power generation from waste heat using heat pipe and thermo electric generator, Energy Procedia 75, pp-645-650.
5. O.M.Al-habahbeh, A-Mohammad, A. khalidi, M.Khafner, (2018), Design optimization of large -scale, Journal of King Saud University-Engineering Sciences 30, pp-177-182.
6. Z.B.Tang, Y.D.Deng, C.Q.SU, W.W.Shuai,C.J.Xie, (2015) A research on thermoelectric generators electrical performance under temperature mis-match condition for automotive waste heat recovery system, Case Study in Thermal Engineering 5, pp-143-150.
7. Solanki P.M., Dr. D.S. Deshmukh, Dr. V.R . Diware, (2016) Design and development of experimental setup for thermo electric generator system performance analysis, International Journal of Science, Spirituality, Business & Technology vol-4, pp-47-51.
8. Prashanta.K, Sonam Wango, (2016), Smart power generation from waste heat by thermo electric generator, International Journal of Mechanical & Production Engineering, pp-45-49.
9. Saniya Leblanc, (2014), thermo electric generator : linking material properties and system in engineering for waste heat recovery application, Sustainable Materials and Technology, pp-26-35.
10. A lessendro Simeone, Yang luo, Elliot Woolley, Shahin Rahimifard, Claudio Boer, (2016), Decision support system or waste heat recovery in manufacturing, International Journal of Science and Research, pp-21-24.
11. B.orr, Akbarzadeh, M. Mochizuki, Singh.R, (2016), A review of car waste heat recover system utilizing thermoelectric generator and heat pipes, Applied Thermal Engineering 101, pp-490-495.
12. Shareef Habeeb Mohammed, Sajid Abdul, Abdul Majeed, Adnan Abdul Mohammed, (2015), Efficiency calculation of thermoelectric generator, International Journal of Science & Research, pp-1520-1522.
13. Shyam Kumar Karna, Dr. Rajeshwar Sahai, (2012), An overview on Taguchi method, International Journal of Engineering and Mathematical Sciences, volume 1, pp-11-18.
14. BCS, Incorporated, (2008), Waste Heat Recovery, Technology and Opportunities in U.S. Industries, pp-1-71.