AN EXPERIMENTAL EVALUATION OF AUTOMOBILE WASTE HEAT RECOVERY SYSTEM USING THERMOELECTRIC GENERATOR

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ABSTRACT

This project presents the investigation of power generation using the combination of heat and thermo- electric generators. A majority of thermal energy in two wheeler silencer is dissipated as waste heat to the environment. This waste heat can be utilized further for power generation. The related problems of global warming and dwindling fossil fuel supplies has led to improving the efficiency of any industrial process being a priority. One method to improve the efficiency is to develop methods to utilize waste heat that is usually wasted. Two promising technologies that were found to be useful for this purpose were thermoelectric generators and heat pipes. Therefore, this project involved making a bench type, proof of concept model of power production by thermoelectric generators using heat pipes and simulated hot air. In recent years, global warming and the limitations in use of energy resources increase environmental issues of emissions. Also In industry, most of the expenses are due to energy (both electrical and thermal), labour and materials. Yet, out of them vitality would identify with the sensibility of the expense or potential cost investment funds and therefore vitality the board will help in cost decrease. The possibilities of thermoelectric systems' contribution to "green" technologies, specifically for waste heat recovery from two wheeler silencer exhausting flue gases. It results into extensive research on green technologies producing electricity. As waste heat recovering techniques, such as thermoelectric generator (TEG) is developed. Its implementation in automobile vehicles is carried out in many ways.

Keywords: *Waste heat from silencer, waste heat Recovery, Thermoelectric generator, Controller, Electricity.*

1. Introduction

Recent trend about the best ways of using the deployable sources of energy in to useful work in order to reduce the rate of consumption of fossil fuel as well as pollution. Out of all the available sources, the internal combustion engines are the major consumer of fossil fuel around the globe. Out of the total heat supplied to the engine in the form of fuel, approximately, 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems, resulting in to entropy rise and serious environmental pollution, so it is required to utilized waste heat into useful work.

The Internal Combustion Engine has been a primary power source for automobiles and automotive over the past century. Presently, high fuel costs and concerns about foreign oil dependence have resulted in increasingly complex engine designs to decrease fuel consumption.

Thermoelectric generator direct converts waste-heat energy into electrical power where it is unnecessary to consider the cost of the thermal energy input. The application of this technology can also improve the overall efficiency the of energy conversion systems.

A thermoelectric power generator is a solid state device that provides direct energy conversion from thermal energy (heat) due to a temperature gradient into electrical energy based on "Seebeck effect".

The thermoelectric power cycle, with charge carriers (electrons) serving as the working fluid, follows the fundamental laws of thermodynamics and intimately resembles the power cycle of a conventional heat engine. Thermoelectric power generators offer several distinct advantages over other technologies.

1.2 Problem Definition

Energy Intensive industries require high temperatures to process their product. There is often still heat 'energy' left as a by-product of processing that is frequently simply wasted, vented through smokestacks, and into the air. In same manner lots of heat

is extracted engine from automobiles vehicles silencer which will be crated pollution. In such platform these type technique is useful to control the pollution, also wastage heat to be utilised in the form of power.

The possibilities of thermoelectric systems' contribution to "green" technologies, specifically for waste heat recovery from industry exhausting flue gases. Vast quantities of waste heat are discharged into the earth's environment much of it at temperatures which are too low to recover using conventional electrical power generators. The proposed structure is a distributed multi-section and multi-stage network. The target is to tackle problems facing the traditional single-stage system and to advance TEG application in automotive settings.

- Industrial Manufacturing
- Automobiles System
- Steel, Chemicals, Paper, Cement, Glass, Food Processing
- Oil and Gas Processing
- Gas Compressor Stations
- Refineries etc.

2. Objectives

- To study the available literature and research on TEG application and its performance
- To determine the appropriate suitable working of warmth Heat to electricity through TEG Module and collect the literature on the studies
- To develop the experimental setup for the investigation
- To conduct testing and sample run
- To conduct final experimentation and compile
- To analyse the Result

3. Literature Survey

1. Jihad G. Haidar, Jamil I. Ghojel, "waste heat recovery from the exhaust of low- power Diesel engine using thermoelectric generators, 20TH international conference on thermoelectric(2001), p413-417 From literature survey 1 we studied how to recover waste heat and how to utilize waste heat from different industries.

2. Literature survey 2:-Mariem SAIDA, Ghada ZAIBI, Mounir SAMET, Abdennaceur KACHOURI, A new design of thermoelectric generator for health monitoring, 2017 International Conference on Smart, Monitored and Controlled Cities (SM2C), Kerkennah, Tunisia, February, 17-19, 2017, p 59-63 , From literature survey 2 we analysed about thermoelectric generator and its specification.

3. Literature survey 3:-Ahaad Hussein Alladeen, Shanshui Yang, Yazhu Liu, Feng Cao, Thermoelectric waste heat recovery with cooling system for low gradient temperature using power conditioning to supply 28V to a DC bus, 2017 IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC Asia-Pacific), 2017 , From literature survey 3 we studied different types of cooling system and different types of coolant.

4. Literature survey 4:-ArashEdvinRisseh, Electrical Power Conditioning System for Thermoelectric Waste Heat Recovery in Commercial Vehicles, IEEE Transactions on transportation electrification, 2018, p 2- 16 , From literature survey 4 we got an idea about how to recover the waste heat from automobile application.

4. Project Principle

Seebeck Effect

The Seebeck Effect is the conversion of temperature differences directly into electricity. It is a classic example of an electromotive force (emf) and leads to measurable currents or voltages in the same way as any other emf. Electromotive forces modify Ohm's law by generating currents even in the absence of voltage differences (or vice versa); the local current density is given by,

$$J=\sigma (-\Delta V + Eemf)$$

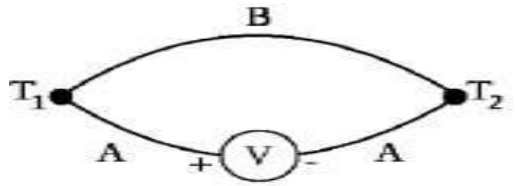
Where, V the local voltage and σ is is the local conductivity. In general the Seebeck effect is described locally by the creation of an electromotive field.

$$Eemf = -S \Delta T$$

Where S is the Seebeck coefficient (also known as thermo-power), a property of the local material, and ΔT is the gradient in temperature T.

Seebeck found that if you placed a temperature gradient across the junctions of

two dissimilar conductors, electrical current would flow. The effect is shown below in the Fig.



Thermoelectricity means the direct conversion of heat into electric energy, or vice versa. According to Joule's law, a conductor carrying a current generates heat at a rate proportional to the product of the resistance (R) of the conductor and the square of the current (I). A circuit of this type is called a thermocouple.

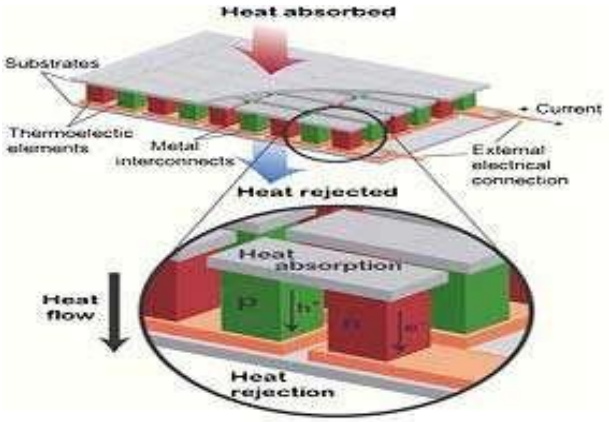


Fig.2-: Thermionic Principle of Operation

Jean C. A. Peltier discovered an effect inverse to the Seebeck effect: If a current passes through a thermocouple, the temperature of one junction increases and the temperature of the other decreases, so that heat is transferred from one junction to the other. The rate of heat transfer is proportional to the current and the direction of transfer is reversed if the current is reversed.

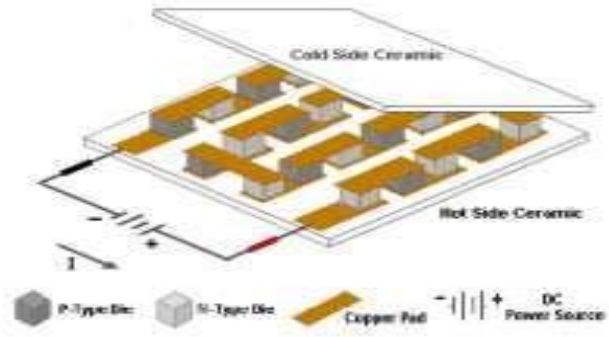


Fig.3-Internal construction of thermo- electric module

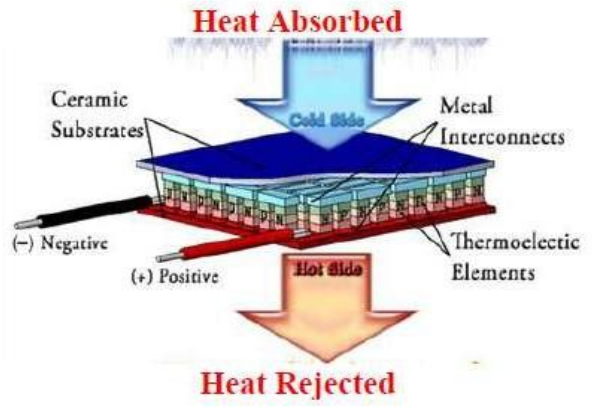


Fig.4-Operating principle of thermo-electric module.

- **In Automobile**

The main focus of energy conversion is on three conversion locations mainly exhaust gas pipe (EGP), exhaust gas recirculation (EGR) cooler, and retarder. The most significant factors for the waste heat quality are power density and temperature range.

The EGP is the target of the most automobile waste heat recovery related research. The exhaust system contains a large portion of the total waste heat in vehicle. The gas flow in exhaust gas pipe is relatively, stable. Fig. shows that TEG utilizing the exhaust gas heat for operation. With exhaust temperatures of 973 K or more, the temperature difference between exhaust gas on the hot side and coolant on the cold side is close to 373 K. This temperature difference is capable of generating 10W of electricity.

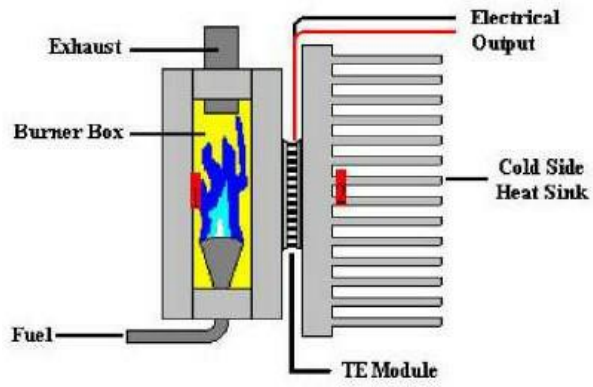


Fig.5-Thermo-electric generator

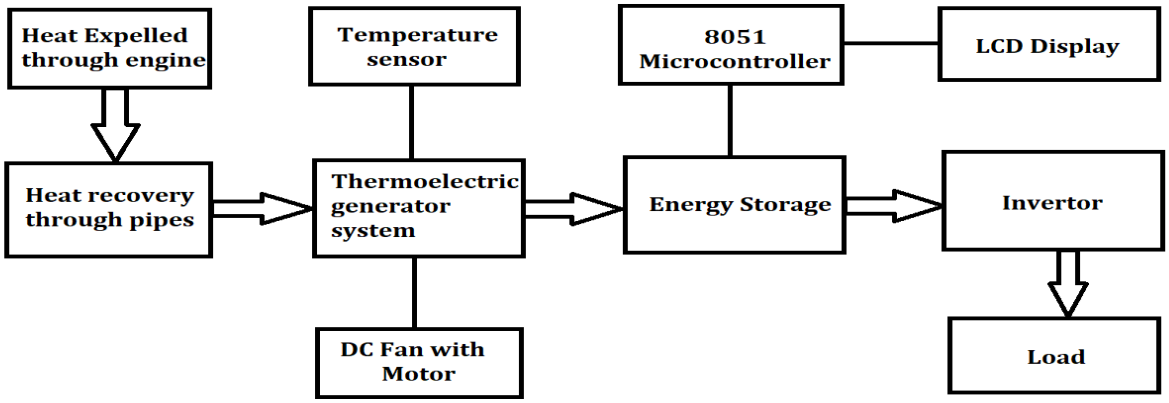


Fig.6-Block Diagram

5. Project Working

Non-conventional energy using is converting mechanical energy into the electrical energy. Here in this project a power generation arrangement is made. Use of thermoelectric principle makes this system efficient and reliable.

In vehicles engine continuously run for their operation. It release large amount of heat. This is wastage heat. We utilized this wastage heat to produce electricity. In this way we can minimize some amount air pollution also.

When we apply TEG with Heat sink module to wastage heat through heat pipe executed from silencer. Then at the same time TEG starts converting Heat energy into Electrical energy. We can measure this heat with the help of temperature sensor attached to the system.

One DC fan is attached to system to indicate the flow and conversion of heat energy into Electrical energy. As the amount of temperature is increases, the flow of fan is also increases.

Generated electrical energy is stored in battery. This stored energy is supply to inverter to convert DC to AC.

At the output AC load is obtain. This AC load is utilized to run various loads in same industry like, fan, AC , light etc.

We also attached 8051microcontroller (AT89S52) with LCD display to measure the amount of voltage stored and remaining in battery.

In this way, whole system work. Start from wastage of heat dissipated through silencer in vehicles. Then conversion of heat into electricity.Indication of conversion electricity through DC fan and motor.Storage of electricity in battery.Conversion of DC voltage to AC voltage with help of inverter. Microcontroller attached to show the voltage present at battery. And last AC load attached to inverter.

If such system utilized in all type of automobiles, the amount of wastage heat can be reduced and we can utilized into electricity. And also minimized air pollution problem cussing by vehicles.

6. Design Calculations

Performance analysis of selected thermoelectric material

Bismuth Telluride (Bi2Te3)

The maximum value of figure of merit,

$Z_{max} = 3 \times 10^{-3} K^{-1}$

The optimum value of the resistance ratio,

$$M = \left[1 + \frac{Z}{2}(T_H + T_L)\right]^{1/2}$$

Where,

= temperature of the source (K)

= temperature of the sink (K)

= 400 K = 315 K

By putting above values in equation,

$$M = \left[1 + \frac{3\times10^{-3}}{2}(400 + 315)\right]^{1/2}$$

We get, M= 1.4396

We know that, the maximum or ideal thermal efficiency of a thermoelectric convertor is given by,

$$n_{th\,max} = \left(1 - \frac{T_L}{T_H}\right)\left[\frac{M-1}{M+\frac{T_L}{T_H}}\right]$$

By putting above values in given equation,

$$n_{th\,max} = \left(1 - \frac{315}{400}\right)\left[\frac{1.4396-1}{1.4396+\frac{315}{400}}\right]$$

We get, maximum thermal efficiency is,

$n_{th\,max}$= 0.083130= 8.313%

All the TEGs designed to be mounted in this position are based on bismuth telluride alloys. It minimizes the amount of heat transfer surface required. This decreases the pressure drop across the generator and results in a lower back pressure. Hence we have selected Bismuth Telluride as TEG material.

Design of Rectangular Straight Fins

Number of fins (Nf) =8

Number of channels (Nch) =Nf -1 =7

Thickness of an individual fin (Tf) =2mm

The length of an individual fin (Lf) =26mm

Thickness of the base (Tb) =7mm

1) Pitch of Fin (Pf)

The pitch of a fin is needed to be known to help determine the spacing between fins. The pitch helps to keep the fins constrained to the size of the heat exchanger.

$$P_f = \frac{W_z - T_f}{N_{ch}} = \frac{60-2}{7} = 8.28\ mm$$

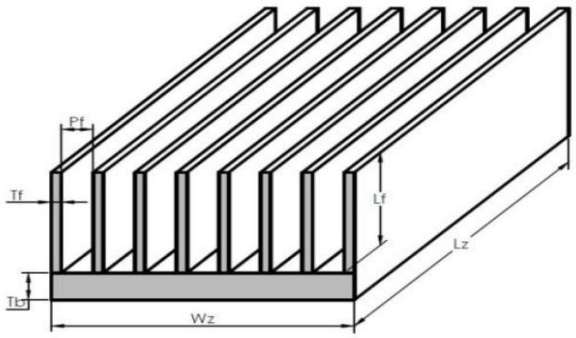


Fig.7- Rectangular Heat Exchanger Geometry

The cross sectional area of the fin, (Ac)

$A_c = T_f \times L_z = 2 \times 120 = 240\ mm^2$

This value is also used in calculating the efficiency of the designed fin.

Total effective surface area, Atot,surf :

Total effective surface area, Atot,surf is the area which fluid flow occurs and convective heat transfer is present.

$A_{tot,surf} = A_{f,surf} + A_{b,surf}$

$A_{tot,surf} = 45360 + 4480 = 49840 mm^2$

Now that the fins have been designed, their performance needs to be evaluated.

T1= Hot side inlet temperature

T2= Hot side outlet temperature

T3= Cold side inlet temperature

T4= Cold side outlet temperature

Tin= Exhaust gas temperature at TEG system inlet

Tex= Exhaust gas temperature at TEG system exit

Project Output

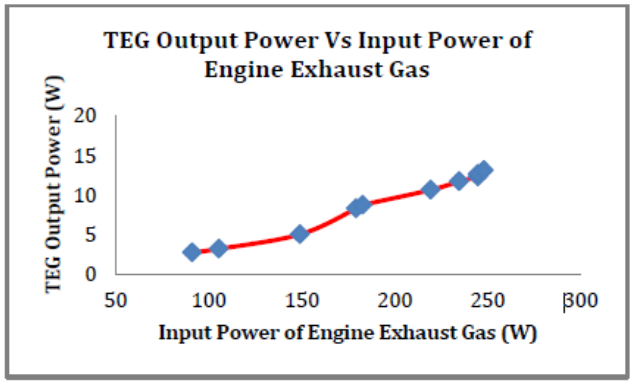


Fig.8-TEG Output Power Vs Input Power

The graph shows that at the engine speed of 3736 rpm, input power of engine exhaust gas is 248.03 W & the TEG output power is 13.106 W, hence the overall efficiency obtained is 5.28%.

Power Output Vs Mass Flow Rate of Exhaust Heat Gas

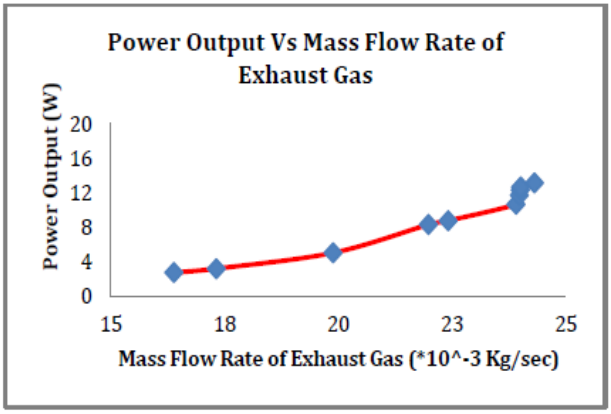


Fig.9- Power Output Vs Mass Flow Rate of Exhaust heat Gas

The graph shows that the power output is function of mass flow rate of exhaust gas. At the mass flow rate of exhaust gas of 24.317 Kg/sec. the power developed by TEG system is average 10 W.

7. Advantages

- Clean, Noise less, Cost is less.
- This is a Non-conventional system ,No fuel is require
- Easy maintenance, portable, Charging time is less.
- Promising technology for solving power crisis to an affordable extent.
- Simple in construction, Pollution free, Reduces transmission losses.
- Wide areas of application# Required less space
- It can be use at any time when it necessary.
- Less number of parts required.

8. Disadvantages

- Improper variation of temperature gradient difference may damage the TEG, Complex design.
- Need proper maintenance every time.

9. Applications

- Thermoelectric Generators are basically used in where the power production is less.
- In many industries amount of heat is executed and been wastage. We can used this hear for electricity using TEG.
- In automobile vehicle produce heat that can be used for generating electricity by using TEG.
- Recharge the battery where ever waste heat is obtained.
- Self charging battery by fixing the TEG at radiator or two wheeler silencers pipe.

10. Conclusion

Waste heat recovery entails capturing and reusing the waste heat from machineries in industries and using it for generating electrical work. It would also help to recognize the improvement in performance and emissions of the machineries if these technologies were adopted by the production industries.

If this concept of thermoelectric system is taken to the practical level then there will be large amount of electricity can be generated, which will be used to run industrial load itself. Also large amount of wastage heat for pollution is also uses in this system in continue manner. And such industries also somehow help to protect the environmental pollution.

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