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Design and Analysis of Power Generation from Waste Heat

Dr. Prashant Kadu[1] , Abhinav Thul[2]

[1]Professor, Department of Mechanical Engineering , Abha Gaikwad-Patil College of Engineering, Nagpur.

[2]Student, Department of Mechanical Engineering , Abha Gaikwad-Patil College of Engineering, Nagpur.

Abstract -
The increasingly worldwide problem regarding rapid economy development and a relative shortage of energy, the internal combustion engine exhaust waste heat and environmental pollution has been more emphasized heavily recently. 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. As waste heat recovering techniques, such as thermoelectric generator (TEG) is developed, Due to distinct benefits of thermoelectric generators, they have become a promising alternative green technology.
Keywords: Waste heat from I. C. Engine, TEGs, Electricity, Voltage and temperature measurement etc.

1. INTRODUCTION

The Internal Combustion Engine has been a primary power source for automobiles and automotives 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.

In this project we are generating electrical power as non-conventional method by heat energy Non-conventional energy systems very essential at this time to our nation. Non-conventional energy using is converting mechanical energy into the electrical energy. Here in this project a mechanical arrangement is made. Use of embedded technology makes this system efficient and reliable. Micro controller allows dynamic and faster control. Liquid crystal display (LCD) makes the system user-friendly. Arduino controller is the heart of the circuit as it controls all the functions.

In this project the conversion of the Heat energy in to electrical energy. By using this energy fan will operates and the energy is stored in a battery. The control mechanism carries the A.C ripples neutralizer, unidirectional current controller and 12V, from this battery supply will pass to the inverter and it is used to drive AC/DC loads. The battery is connected to the inverter. This inverter is used to convert the 12 Volt D.C to the 230 Volt A.C. This 230 Volt A.C voltage is used to activate the loads. We are using conventional battery charging unit also for giving supply to the circuitry.

In this project we are using TEP Transducer .Transducer is a device which converts one form of energy in to another form of energy. This includes electrical, mechanical, light and heat energy also. While the term transducer commonly implies the use of sensors/detector any device which converts energy considered as Transducer.

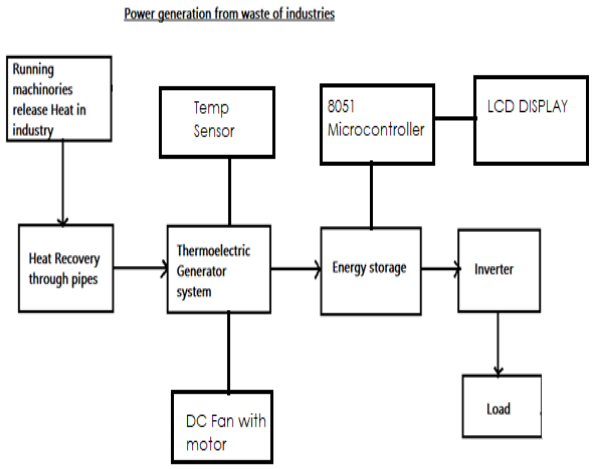
2. OBJECTIVE

- The current research is focusing on a technology, which is able to convert the thermal energy contained in the exhaust gas directly into electric power. In this project concept it invented exhaust gas-based thermoelectric power generator for an industry application.
- In this invention, the exhaust gas gases in the pipe provide the heat source to the thermoelectric power generator. So, this project proposes and implements a thermoelectric waste heat energy recovery system from the exhaust heat from running machineries.
- The key is to directly convert the heat energy from automotive waste heat to electrical energy using a thermoelectric generator. While the electric power generation by such a system is able to generate is still relatively small at a maximum of 10 W from a single TEG module, rapid progress in materials research can make the ambitious objective of generating higher watts by all means of feasible proposition.

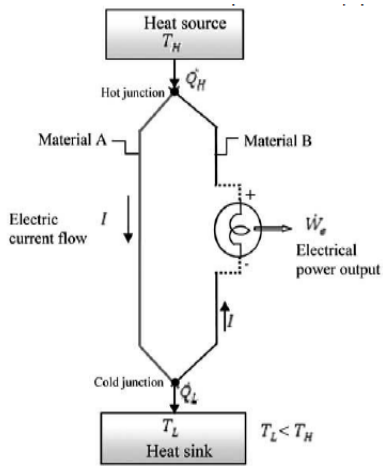
3. FEATURES OF TEG

- They are extremely reliable (typically exceed 100,000 hours of steady-state operation) and silent in operation Since they have no mechanical moving parts and require considerably less maintenance;
- They are simple, compact and safe;
- They have very small size and virtually weightless;
- They are capable of operating at elevated temperatures;
- They are suited for small-scale and remote applications
- Typical of rural power supply, where there is limited or no electricity;
- They are environmentally friendly;
- They are not position-dependent; and
- They are flexible power sources.

4. EXPERIMENTAL BLOCK DIAGRAM



5. WORKING PRINCIPLE



TEG consists of one hot side and one cold side. The hot side with higher temperature, will drive electrons in the n-type leg toward the cold side with lower temperature, which cross the metallic interconnect, and pass into the p-type leg, thus developing a current through the circuit.
If temperature difference is kept constant, then the diffusion of charge carriers will form a constant heat current, hence a constant electrical current.

6. WORKING

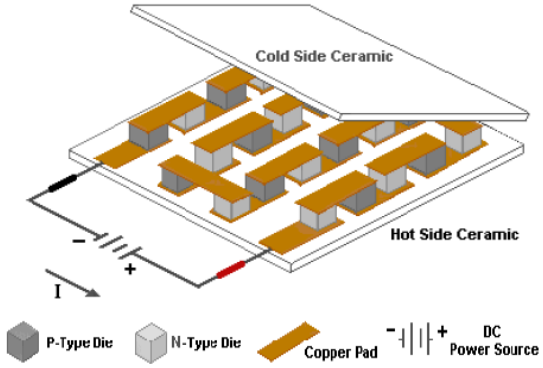
- Non-conventional energy using is converting mechanical energy into the electrical energy. Here in this project a power generation arrangement is made. Use of thermoelectric principle makes this system efficient and reliable.
- In any industry machineries continuously run for their production. It release 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 machine. 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 indicates 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 8051 microcontroller (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 in industry through production process. 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 automobiles industry, the amount of wastage heat we can utilized it. And also minimized air pollution problem cussing by vehicles.

7. COMPONENTS SPECIFICATION

- Thermoelectric plate
- Exhaust fan with Aluminum heat sink
- Silencer
- Heat source (Engine considered device)
- DC motor with fan
- Battery
- Inverter module
- Temperature sensor
- Controller board (8051 controller)
- LCD display (16*2)
- wiring
- switches
- LED bulb
- Metallic Frame
- connector circuit board
- Adapter

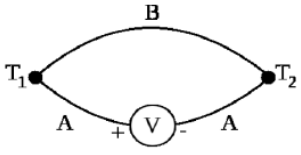
8. NECESSITY OF TEG (THERMO ELECTRICAL GENERATOR)

- TEGs are solid-state device, which means that they have no moving parts during their operations. Together with features that they produce no noise and involve no harmful agents, they are the most widely adopted devices for waste heat recovery.
- Useful electricity generation is possible due to the great amount of waste heat emitted from I.C. engine operation.



Internal construction of thermo- electric module

- **Power Generation in Peltier Plate by Seebeck Effect:** 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.



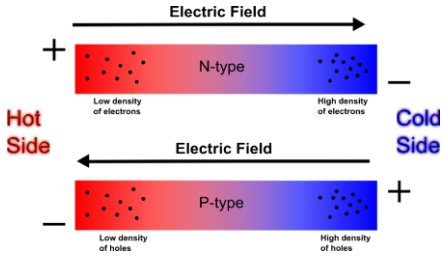
Seeback effect

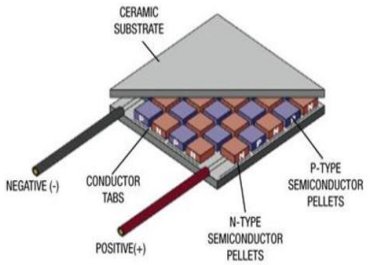
The main focus of energy conversion is on three conversion locations mainly exhaust gas pipe (EGP), exhaust gas recirculation (EGR) cooler, and retarder. The most significant factors for the waste heat quality are power density and temperature range.

- The EGP is the target of the most industries waste heat recovery related research. The exhaust system contains a large portion of the total waste heat in industries. 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.

9. CAD MODEL

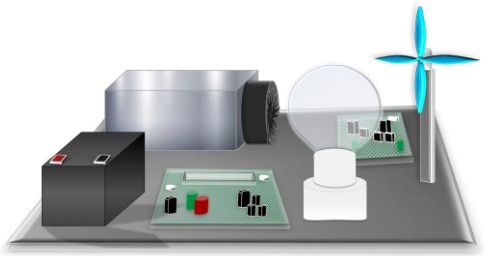
- **Inside Peltier Plate**





- **Thermoelectric Generator System**

- **Overall System**



10. CALCULATION

- **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,

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

By putting above values in given equation,

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

We get, maximum thermal efficiency is

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

- 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.

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

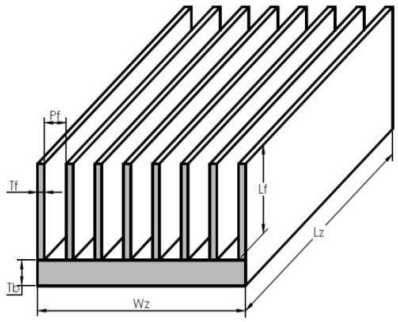


Fig. Rectangular Heat Exchanger Geometry

- 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

11. BENEFITS

- TEGs are solid-state device, which means that they have no moving parts during their operations. No moving parts so maintenance required is less frequently, no chlorofluorocarbons. Temperature control to within fractions of a degree can be maintained, flexible shape, very small size.
- TEGs can be used in environments that are smaller or more severe than conventional refrigeration. TEG has long life, and also it can be controllable by changing the input voltage/current.

12. SCOPE OF THE STUDY

- By using thermoelectric generator connecting in series /parallel we can generate the power for maximum level
- Even body heat also generate the heat that can be utilizing by using TEG to generate the power to charge the portable equipment like laptop mobile etc
- By installed in the vehicle above the radiator means the vehicle battery will charge self.

13. ADVANTAGES

- Clean, Noise less , Cost is less .
- This is a Non-conventional system ,No fuel is require
- Easy maintenance, portable, Charging time is less (maximum temp)
- 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.
- we can charge any electronic devices
- Electricity can used for many purposes
- Efficient and eliminate the grid searching.

14. DISADVANTAGES

Improper variation of temperature gradient difference may damage the TEG, Complex design.

15. 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.

16. 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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