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DEVELOPMENT OF MODEL FOR ELECTRICITY GENERATION FROM WAST HEAT BY USING TEG.

[1*]Dr. V. N. Kalbande [2]A. O. Bargat [3]P. K. Rawkale [4]V. R. Warwade, [5]S. V. Nandeshwar
[1*] Associate Professor [2,3,4 & 5] Research scholar
Department of Mechanical Engineering
Nagpur Institute of Technology, Nagpur, Maharashtra, INDIA

Abstract: This paper presents the investigation of power generation using the combination of heat and thermo-electric generators. Most of the time heat from thermal energy dissipated as waste heat to the environment. The related problems of global warming and dwindling fossil fuel supplies has led to improving the efficiency of any industrial process being a priority. This waste heat can be utilized further for power generation. Two promising technologies that were found to be useful for this purpose were thermoelectric generators and heat pipes. Therefore, this project involved making a concept model of electricity generation by thermoelectric generators using heat pipes and simulated hot air.

***Index Terms* – Waste heat, thermoelectric generator, Heat pipes, Electricity generation**

I. 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 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.

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.

- 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.

In this project the conversion of the heat energy in to electrical energy take place. 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 220 Volt A.C. This 220 Volt A.C voltage is used to activate the loads. We are using 8051 microcontroller AT 89S52 with 16*2 LCD display the voltage from the values of battery is measured with this unit. While TEP Transducer is used to detect the temperature inside the silencer through heat dissipated.

II. BACKGROUND OF INVENTION

In recent years, global warming and the limitations in use of energy resources increase environmental issues of emissions. The possibilities of thermoelectric systems' contribution to "green" technologies, specifically for waste heat recovery from silencer 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.

III. PROBLEM DEFINATION

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.

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

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 the temperature of the waste heat gases and mass flow rate of exhaust gas. Waste heat losses arise both from equipment inefficiencies and from thermodynamic limitations on equipment and processes. For example, consider internal combustion engine 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. It means approximately 60 to 70% energy losses as a waste heat through exhaust (30% as engine cooling system and 30 to 40% as environment through exhaust gas). Exhaust gases immediately leaving the engine can have temperatures as high as 842-1112°F [450-600°C]. Consequently, these gases have high heat content, carrying away as exhaust emission. Efforts can be made to design more energy efficient Engine with better heat transfer and lower exhaust temperatures; however, the laws of thermodynamics place a lower limit on the temperature of exhaust gases. Fig. 1.1 show total energy distributions from internal combustion engine.

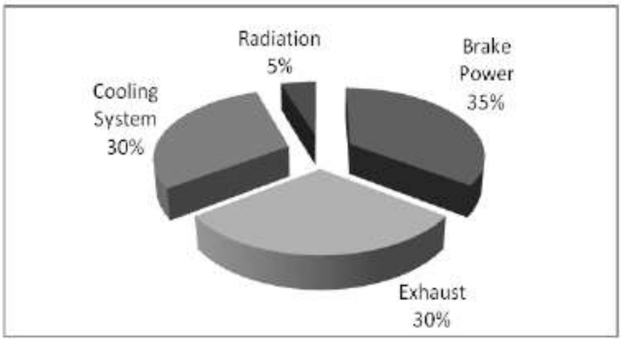


Figure 1: Total Fuel Energy Content in I. C. Engine

Table I. Various Engine and There Output

Sr. No.	Engine type	Power output kW	Waste heat
1	Small air cooled diesel engine	35	30-40% of Energy Waste loss From I.C. Engine
2	Small agriculture tractors and construction machines	150	
3	Water air cooled engine	35-150	
4	Earth moving machineries	520-720	
5	Marine applications	150-220	
6	Trucks and road engines	220	

The table I. shows that various engine and there power ranges. In general, diesel engines have an efficiency of about 35% and thus the rest of the input energy is wasted. Despite recent improvements of diesel engine efficiency, a considerable amount of energy is still expelled to the ambient with the exhaust gas.

Table II. Temperature Range from Diesel Engine

Sr. No.	Engine	Temperature in °C
1	Single Cylinder Four Stroke Diesel Engine	456
2	Four Cylinder Four Stroke Diesel Engine (Tata Indica)	448
3	Six Cylinder Four Stroke Diesel Engine (TATA Truck)	336
4	Four Cylinder Four Stroke Diesel Engine (Mahindra arjun 605 DI)	310
5	Genset (Kirloskar) at power 198hp	383
6	Genset (Cummims) at power 200hp	396

(Ref. - This temperature was taken from survey of various internal combustion engines.) Exhaustive survey was made for measurement of exhaust temperature from internal combustion engine of automotive vehicles and stationary engine it is shown in Table II.

IV. OBJECTIVE OF RESEARCH WORK

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 automobile 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 the internal combustion engine automobiles, including gasoline vehicles and hybrid electric vehicles. 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.

V. LITERATURE SURVEY

Jihad G. Haidar, Jamil I. Ghojel [1] Waste heat recovery from the exhaust of low- power Diesel engine using thermoelectric generators, 20th international conference on thermoelectric(2001), The author studied how to recover waste heat and how to utilize waste heat from different industries.
Mariem SAIDA, Ghada ZAIBI, Mounir SAMET, Abdennaceur KACHOURI [2], A new design of thermoelectric generator for health monitoring, 2017 International Conference on Smart, Monitored and Controlled Cities (SM2C), Kerkennah, Tunisia, February, the author analyzed thermoelectric generator and its specification.
Ahaad Hussein Alladeen, Shanshui Yang, Yazhu Liu, Feng Cao [3], 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 the author studied different types of cooling system and different types of coolant.
Arash Edvin Risseh [4], 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

VI. 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,

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

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.

$$\mathbf{Eemf = -S\ \Delta T}$$

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. 2.

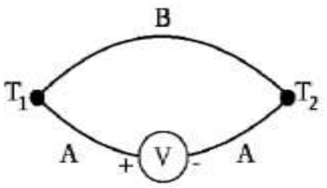


Figure 2: Seebeck Principle

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; a number of thermocouples connected in series are called a thermopile.

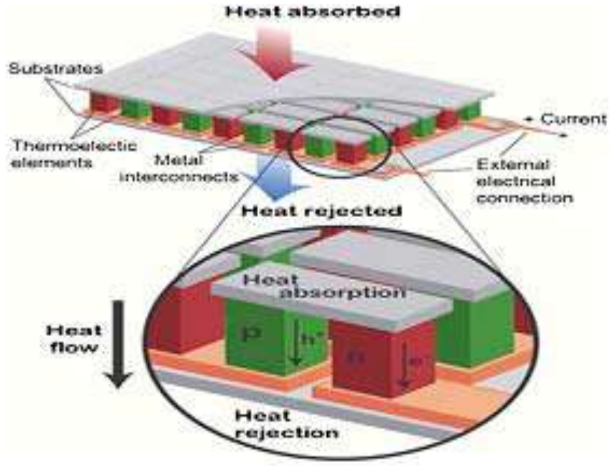


Figure 3: Thermoionic Principle of Operation

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.

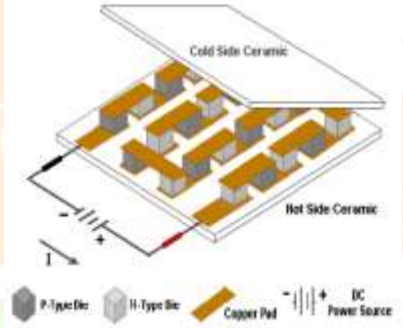


Figure 4 : Internal construction of thermo- electric module

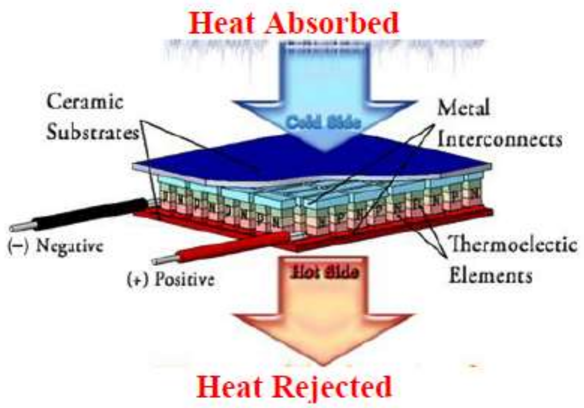


Figure 5 : Operating principle of thermo-electric module.

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.

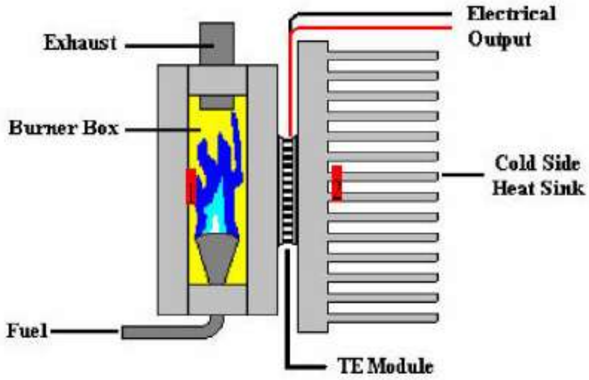


Figure 6 :Working diagram of TEG

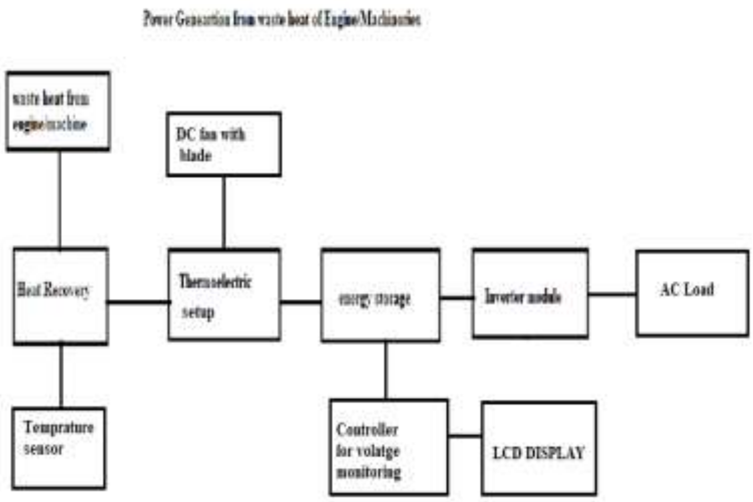


Figure 7 : Block Diagram

VII. 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 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 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.

VIII. DESIGN CALCULATIONS

Specification of Petrol Engine :

Type	Two stroke
Cooling System	Air cooled
Bore/Stroke	50 X 50 mm
Compression Ratio	98.2 cc
Piston Displacement	6.6 : 1
Maximum Torque	0.98 kg-m at 5500RPM

Calculation for Voltage generated :

From the equation of Seebeck effect,

$$V=\alpha\ (Th - Tc)$$

Where, V – Voltage Generated in Volts

α – Seebeck coefficient in µV/K

Th-temperature of hot surface (silencer) in Kelvin

Tc-temperature of cold surface (atmosphere) in Kelvin

α of Bismuth Telluride - 287µV/K

Tc = 303 k

A few temperatures of the hot silencer is taken into consideration and the corresponding voltages that are expected to be generated according to the Seebeck equation is calculated as follows,

$$V = \alpha\ (Th - Tc)$$

Case 1: Th= 403 k V= (287 *10-6)* (403-303) = (287 *10-6)*(100) = 0.0287 V

Case 2: Th= 453 k V = (287 *10-6)* (453-303) = (287 *10-6)*(150) = 0.04305 V These voltages are meager in value . This can be boosted up using the booster circuit.

The experimental results obtained are tabulated as follows:

Table 1: Voltage generated and boosted for different temperatures

Temperature difference δt (k)	Voltage without boosting (volt)	Voltage after boosting (volt)
80	0.02296	1.44
100	0.02870	2.53
120	0.03444	3.21
140	0.04018	3.85
150	0.04305	4.43
160	0.04592	4.94
180	0.05166	5.37
200	0.05740	6.10

Total Power

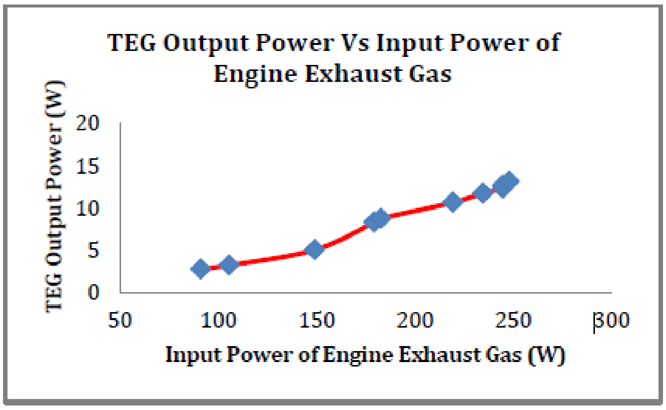
T1= Hot side inlet temperature , T2= Hot side outlet temperature

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

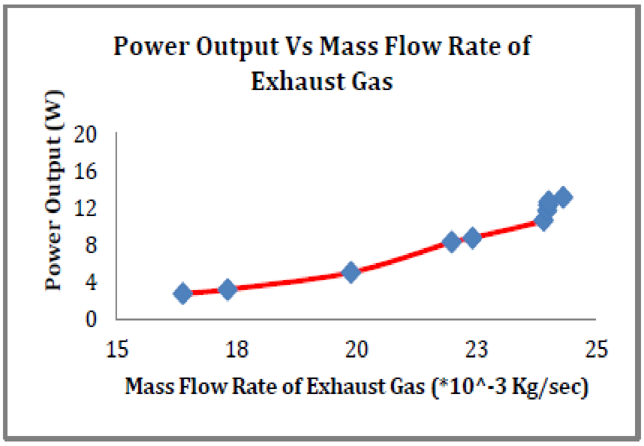
TEG Output Power Vs Input Power of Exhaust heat Gas



Graph 1: 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 10 W, hence the overall efficiency obtained is 5.28%.

Power Output Vs Mass Flow Rate of Exhaust Heat Gas



Graph 2. 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.

IX. 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

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X. 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.

XI. CONCLUSION

Waste heat recovery entails capturing and reusing the waste heat from machineries in industries for generating electricity. It would also help to improve the 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 emission of few amount of wastage heat somehow helps to protect the environmental pollution.

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