Analysis of Power Generation from Exhaust Gas on 4 Stroke 4 Cylinder Petrol Engine using Thermoelectric Generator

Sharad Chandra Rajpoot
Assistant Professor
Department of Mechanical Engineering
G.E.C. Jagdalpur ,Chhattisgarh,India

Govind Mishra
Department of Mechanical Engineering
Disha Institute of Management and Technology Raipur
Chhattisgarh , India

Ravi Singh Manser
Department of Mechanical Engineering
Disha Institute of Management and Technology Raipur
Chhattisgarh , India

Uday Sahu
Department of Mechanical Engineering
Disha Institute of Management and Technology Raipur
Chhattisgarh , India

Sumit Singh Rajput
Department of Mechanical Engineering
Disha Institute of Management and Technology Raipur
Chhattisgarh , India

Abstract

Currently, a great deal of the automotive industry's R&D effort is focused on improving overall vehicle efficiency. Almost every type of internal combustion engine work on the principle of heat engine. It converts the chemical energy into thermal energy and in the form of pressure of air carrying the heat, piston movement is done. Traditionally, only 25 to 30% of energy is begin utilized to run the vehicle and accessories mounted on the engine and left amount of energy is wasted in various ways likes in the form of exhaust and cooling of engine component. The useful engine is used to run the engine as well as generator. So the efficiency of those engine were very low. But one method to improve the efficiency is to develop methods to utilize waste heat that is usually wasted. One of the promising technology that was found to be useful for this purpose were thermoelectric generator. Therefore, this project involved making a bench type, proof of concept model of power production by thermoelectric generator and heat from exhaust emission of engine. In this study we investigated the use of thermoelectric generator for power production. The output energy checked by increasing of cylinder one by the help of morsh test. Power develop on the engine is checked by the morsh test. Thermoelectric generator so to impart stream of exhaust gas on surface of it and to generate small electric D.C. type of current developing upon temperature difference across intercooler or heat exchanger is installed in path of exhaust gas on seebeck effect. An output Voltage of 200mV was generated using a single Bi2Te3 thermoelectric module for a temperature difference of about 40o C. So can be able to change battery, tail lamp, head lamp, parking light, door light, indicator lump, G.P.S. system, night vision camera etc. So as to reduce frictional power against alternator can save fuel and also in automotive industry to increase the efficiency of engine.

Keywords- I.C. Engine, Thermoelectric Generator, Exhaust Gas, Intercooler, Seebeck Effect, Thermal Energy, Power Production, Morsh Test

I. INTRODUCTION

The automotive world is on the verge of a major shift in paradigm, essaying a revival of the end of the 19th century, where electric vehicles were the ruler anther than the exception. You can see much study in recent year has focused on better fuel efficiency in automotive industry. About 40% of the heat energy supplied to an IC engine is rejected in the exhaust as waste heat. If approximately 6% heat can be recovered from the engine exhaust, it can meet the electrical requirement of an automobile and it would be possible to reduce the fuel consumption around 10%. Heat is rejected thought exhaust gases at high temperature when compared to heat rejected thought coolant and lubricating oil. This shows the possibility of energy conversion using a thermoelectric generator (TEG) to top the exhaust heat energy. TEG is like a heat engine which converts that heat energy into electric energy and it works on the principle on seebeck effect. In this project we are demonstrating for better efficiency analysis of power generation using thermoelectric plate for exhaust gas on 4 stroke petrol engine. Show that the variation of power by using the no of cylinder done by the morsh test. In this process we want to show that this is a profitable technology in now days scenario because the fuel resource are getting low so such type of technology will helped to save fuel.

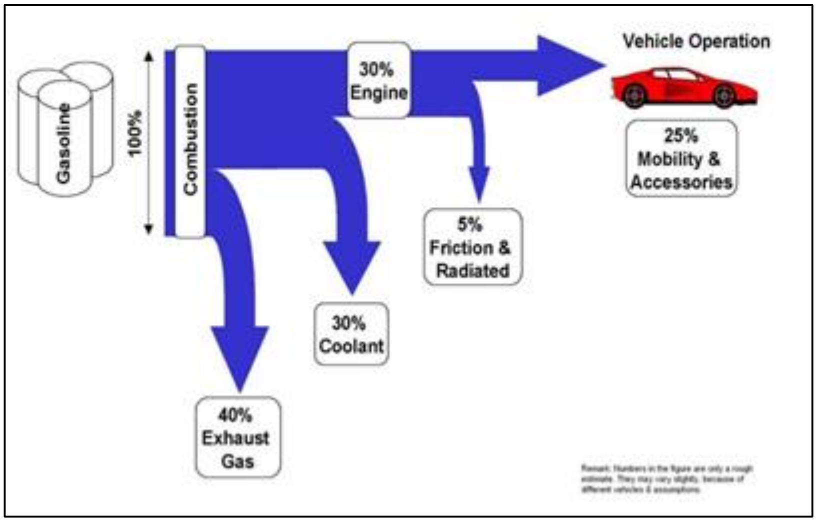


Fig. 1: Typical energy path in gasoline fueled internal combustion engine vehicle

A. Means for Improving Fuel Economy

Engine that burn petrol or diesel fuel propel almost all passenger car and light duty trucks. A schematic of the energy budget for a gasoline fueled internal combustion engine vehicle is shown in figure (1.1) about 70% of the available energy in the fuel is rejected as heat in the exhaust and coolant. The remainder is transformed into mechanical energy or work. Some of the work is used to overcome frictional losses in the transmission and other parts of the drive train and to operate the vehicle accessories (alternator, coolant pump, fuel pump etc.).

As a result only about 20 to 25% of the original energy contained in the fuel is actually used to propel the vehicle. This propulsion energy overcomes (1) the intercooler when accelerating or climbing hills, (2) the aerodynamic drag, and (3) the rolling resistance of the tires on the road. Consequently there are two general ways to reduce vehicle fuel consumption; (1) increase the overallefficiencyofthepowertrain(engine,transmission,finaldrive)inordertodelivermore work from the fuel consumed and (2) reduce the require work (weight, aerodynamics, rolling resistance and accessory load) to propel the vehicle.

B. Waste Energy Recovery

Waste heat from the exhaust gas from the vehicle accounts for account for a considerable portion of the fuel energy that is not utilized, about 40% from figure (1.1). Therefore a mean to improve to the fuel economy is to increase the overall efficiency of the power train by recovering waste heat from the exhaust gas of the vehicle. According to “1999 bosch automotive electric and electronics hand book” the average electrical power consumption of an automobile is about 600 watts. This load is carried by an in efficient engine/alternator system.Theobjectiveistoreducetheloadonthealternatorandconsequentlyontheengineby converting the waste heat from the exhaust gas of the vehicle into electrical. Clarkson University has formed a team to design, build, test and simulate a proto type automotive exhaust thermoelectric generator (AETEG) that offsets the engine shaft power by converting the west heat into electrical energy.

The AETEG work on the principle of thermoelectricity: when the junctions formed by joining two dissimilar current carrying conductors is known as thermoelectric couple. In a typical generator heat exchanger are used to transfer heat from the heat source and the sink to junction of the thermocouple. The heat exchanger are the thermoelectric couple unit is known as a thermoelectric generator(TEG).The AETEG has the vehicle exhaust gas as it sheet source and the engine coolant as heat sink. Thermoelectric conversion is a solid-state technology with no moving parts, which is simple and reliable.

C. Working Principle

In ATEGs, thermoelectric materials are packed between the hot-side and the cold-side heat exchangers. The thermoelectric materials are made up of p-type and n-type semiconductors, while the heat exchangers are metal plates with high thermal conductivity.

The temperature difference between the two surfaces of the thermoelectric module(s) generates electricity using the Seebeck Effect. When hot exhaust from the engine passes through an exhaust ATEG, the charge carriers of the semiconductors within the generator diffuse from the hot-side heat exchanger to the cold-side exchanger as sown in Fig.4. The build-up of charge carrier’s results in a net charge, producing an electrostatic potential while the heat transfer drives a current. With exhaust temperatures of 700°C (~1300°F) or more, the temperature difference between exhaust gas on the hot side and coolant on the cold side is several hundred degrees. This temperature difference is capable of generating 500-750 W of electricity.

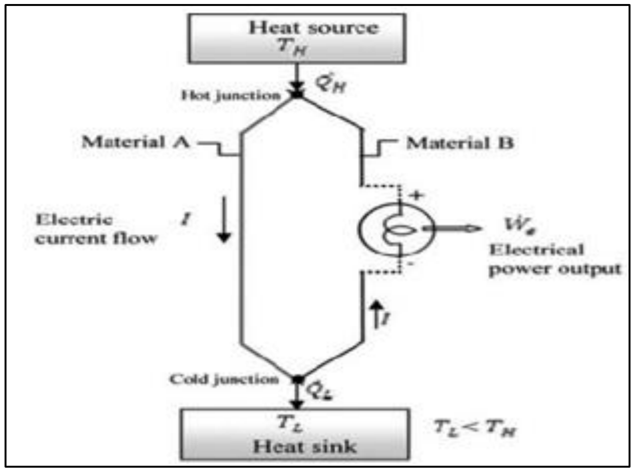


Fig. 2: Principle of thermoelectric generator

1) See-Beck 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,

$$J = \sigma\,(\Delta V + E_{emf})$$

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

$$E_{emf} = -S\,\Delta T$$

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.

2) Thermoelectric Principle of Operation

Thermoelectric Power Generator (TEG) is a solid state device which converts Heat Energy into Electrical Energy. All the exciting conventional power generators convert Thermal Energy into Mechanical Energy then to Electrical Energy. So here no mechanical work (no moving parts). So it produce less noise and no pollution when compare to conventional power generators.

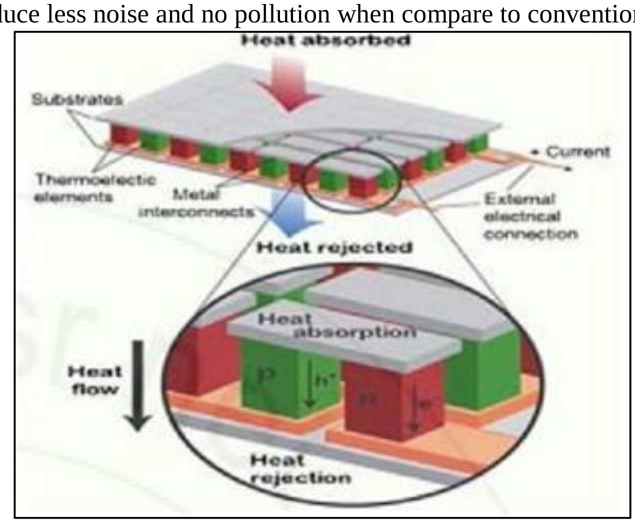


Fig. 3: Thermionic Principle of Operation Jean C. A. Peltier discovered an effect inverse

TEG is working by Thermo Electric Effect (seebeck) effect. When TEG held between temperature gradients (Hot end, Cold end) it produce some voltage this voltage is called seebeck voltage. TEG has Modules which is semiconductors (p,n). Here electrons acting as a thermoelectric power fluid (working medium). Pair of p-type semiconductor and n-type semiconductor is called as a Module. These semiconductors highly doped by pollutants in order to increase the Electric conductivity. TEG has shield it avoid modules damaging due to high temperature. The efficiency of TEG and voltage generated by TEG is directly proportional to semiconductor material and temperature gradients. So selections of semiconductor based on electric conductivity of the material and try to increase the temperature difference value. This semiconductor is coupled by copper electrode. Increasing no of modules and no of stages and coupling no of TEG increase overall efficiency and voltage output. Exciting efficiency of TEG is 4.2% to 6%. When using stages it increases the efficiency to7%.

D. Objective

- The objective of this paper is to know the how many modules are used in future for better efficiency. Which are play a key role for better utilization of TEG.
- Understand the working of actual multi cylinder petrol engine and it various auxiliary system.
- Discuss the techniques to find indicated power and friction power of multi cylinder engine by Morse test.
- Improve the US06 fuel economy for light-duty vehicles by 5% using advanced low cost TE technology
- (1) Low cost, (2) Innovative TEG System Design, (3) Leverage innovative electrical & thermal management strategies, (4) Durable TE modules (4) TEG Manufacturability (5) Production Scale-up Plans

II. PROBLEM IDENTIFICATION

One of the most important phases of conducting a research is the choice of a suitable problem. Beginners are likely to select a problem that is much too broad in scope. This possibly could be the result of the researcher's lack of understanding of the nature of research and the process of problem- solving activity. This may also be brought about by the researcher's enthusiasm and desire to solve a problem immediate.

On the part of the professional researchers, they are aware that research is quite a tedious task, painfully slow, but greatly spectacular towards the end. They realize that the process of problem solving in research is one that requires a lot of patience, being aware that research is such a very difficult task. It has been claimed by Leedy (1988) that the problem is the axial center around which the whole research effort turns, hence, it is but important that the statement of the problem must be expressed with utmost verbal precision. Then, the problem is fractionated into more manageable sub problems.

After finding the problem following point we have analysis as problem of our project to picare as follows:-

1) Firstly we close a suitable place to fit the module no loss where we get accurate reading, high efficiency and no loss of exhaust.
2) After finding the suitable place we place the heat sink on it in the opposite direction so that heat carrying is would occur in huge amount.
3) In the cold side if we are the atmospheric air to keep cold we can't get temperature deferent in high amount for getting high temperature different are use water block to get high output gain.(heat carrying capacity of water is more than atmospheric air)
4) For the flow of water into water block we are water pump which is use to flow water continuously.
5) The water block is getting hot as the flow of exhaust increases reduce the temperature of water block we are use the heat sink with a fan which is mount on the top of heat sink.
6) For the working of fan we need some input source of energy so we use energy which comes out from TEG. We connect the booster circuit to TEG to increase or step up the voltage to 12V after this we change the battery to run the fan.
7) While we were using digital multi meter for measuring of current we can't get accurate value so fix this problem we connect an ampere meter. This is connected in series to the circuit and gets accurate value.
8) For getting higher temperature from exhaust for getting high voltage we use the accelerator into high range

III. EXPERIMENTAL SETUP AND PROCEDURE

A. Apparatus used

4 stroke 4 cylinder petrol engine, Thermoelectric module, Thermal paste at the heat sink with fan, Flexible joint and millimeter, Temperature Gun, booster circuit, water block, submersible D.C. pump.

B. Description of the Equipment

1) 4 Stroke 4 Cylinder Petrol Engine

The engine is 4cylinder 4stroke Maruti Zipsy,s petrol engine is used to perform the experiment. The fuel used is HS petrol and the rated power of the engine is 10HP at 1500 rpm. The arrangement of the cylinder is inline. The cylinder bore diameter is 68mm and the stroke length is 75 mm. The compression ratio is 7.8:1. The diameter of the orifice is 26mm. The specific gravity of the fuel used is 0.69 gm/cc and the calorific value is 10650 Kcal/Kg. The coefficient of discharge is 0.62.

Fig. 4: 4 stork 4 cylinder petrol engine

The performance of the engine depends on the interrelationship between power developed, speed and specific fuel consumption at each operating condition within the useful range of speed and load.

1) Fuel Consumption Measurements: The fuel is supply to the engine through a graduated fuel gauge with a three way cock between main tank and carburettor.
2) Air Consumption Measurement: the suction side of the cylinder is connected to an anti- pulsating air chamber. A manometer is provided to measure the pressure drop across an orifice of 20 mm diameter provided in air inlet pipe of air tank. This pressure drop is used to calculate the actual mass flow rate of into the cylinder.
3) Loading of Engine: the engine test rig is directly coupled to a hydraulic dynamometer, which is loaded by water flow into the dynamometer at constant head pressure. Operating gate valve provided on the inlet inline of dynamometer can vary the load.
4) Exhaust Gas Calorimeter: the exhaust gas from the engine is passed an exhaust gas calorimeter. The calorimeter is shell and tube type heat exchanger, which is used to find the quantity of heat taken away by exhaust gases by simple energy balance.
5) Temperature Measurement: the temperature of exhaust gas entering and leaving the calorimeter engine cooling water inlet, outlet and ambient temperature are sensed by thermocouple and directly indicated on a digital temperature indicator.
6) Water Flow Measurement:- two rota meter are provided at the of the engine jacket and exhaust gas calorimeter to measure the quantity of water allowed into the engine jacket as well as calorimeter.

C. Thermoelectric Module

The thermoelectric – TEP-1264.1.5 power module is designed and manufactured for converting heat source directly into electricity. The module is Bi-Te based thermoelectric module that can work at the temperature of as high as 330^0C (626K) heat source continuously, and a up to 400^0C (752K) intermittently. The thermoelectric module will generate DC electricity as long as there is a temperature difference across the module. The more power will be generated when the temperate difference across the module become larger, and the efficiency of converting heat energy into electricity will increase therefore. The module is stuck with the high thermal conductivity graphite sheet on its both side of the ceramic plate to provide low contact thermal resistance, hence you do not need to apply thermal grease or other heat transfer compound when you install the module. The graphite sheet can work well in extremely high temperature.

The material used is Bismuth telluride and the type is thermoelectric generator. Dimension of the module is 40mmx40mmx3.5mm and the recommended operating temperature range is - 40^0C to 150^0C. The module comprises of 127 couples and the cable length is approximately 20cm.

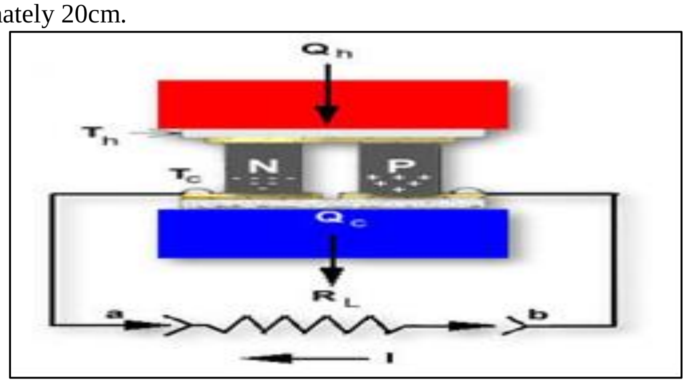
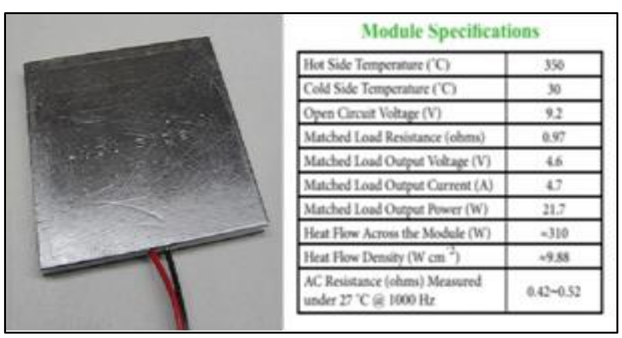


Fig. 5: Thermoelectric power module

1) Operating Parameters: Seebeck Effect thermoelectric power modules are design with high temperature bonding materials that allow them to withstand temperatures of up to 360°C (680°F). As long as the module is placed into a system, whereby the hot side is at a higher temperature than the cold side, DC power will be produced. A unique new class of module is now available. Incorporating 2 optimized semi-conductors of N-type A material & P-type A material to form a hybrid module of superior performance & temperature stability. The TEG1- PB class of module is able to operate continuously in higher temperatures than traditional BiTe material only. The ceramic surfaces are equipped with graphite sheets, which displace the need for thermal grease. These novel modules work best in the 220 to 360C Temperature range and offer superior performance over 260C hot side, compared to standard BiTe modules.



Module Specifications

Hot Side Temperature (˚C)	350
Cold Side Temperature (˚C)	30
Open Circuit Voltage (V)	9.2
Matched Load Resistance (ohms)	0.97
Matched Load Output Voltage (V)	4.6
Matched Load Output Current (A)	4.7
Matched Load Output Power (W)	21.7
Heat Flow Across the Module (W)	≈310
Heat Flow Density (W cm⁻²)	≈9.88
AC Resistance (ohms) Measured under 27 ˚C @ 1000 Hz	0.42~0.52

Fig. 6: Specification of the module

2) Material selection: The thermoelectric generator setup consist of ceramic substrate, electrical insulators, electrical conductors, thermo electric modules and lead wires. The selection of the material for each purpose is based on the cost effectiveness and corresponding thermal conductivities. For high see-back effect the TEM module must have high electrical conductivity and low thermal conductivity, a Bi2Te3 module satisfies both the requirement. The base plate must have a decent thermal conductivity not high enough to burn the module such as steel whose thermal conductivity is 50.2 w/mK. For the fin material and fin base plate aluminum is chosen as it is has a thermal conductivity of 206 w/mK and melting temperature of 6600C. The material that is chosen like aluminum and steel are also cost effective. The temperature has to be monitored continuously using thermocouple so temperature gun because operating the module above the operating temperature might burn it and will render it useless. Thermoelectric module is fixed between the base plates using the screw provided at both the ends and the experiment is performed.

Table 1: N-type material groups by best temperature range

Group	Material	BTR
Hot Side Material (700 K-1000 K)	CoSb3, PbTe, SiGe	650-1100, 600-850>1000
Cold Side Material (300 K-400 K)	B2Te3	<350

Table 2: P-type material groups by best temperature range

Group	Material	BTR
Hot Side Material (700 K-1000K)	Zn4Sb3, CeFe4Sb12, SiGe, TAGS	>600 >850 900-1300, 650-800
Cold Side Material (300 K-400 K)	Bi2Te3	<450

Table 3: Material used in TEG with range of temperature

S.no.	TEG Material	Temperature Range
1.	Alloys based on Bismuth (Bi) in combinations with Antimony(An), Tellurium (Te) or Selenium (Se)	Low temperature up to 450K
2.	Materials based on alloys of Lead (Pb)	Intermediate temperature up to 850K
3.	Material based on Si-Ge alloys	Higher temperature upto1300K

Table 4: Property of different material

Properties		Hastelloy	Steel	Stainless steel	Copper	Duralumin
Type		–	AISI 1010	AISI 302	99.9 Cu + Ag	–
Melt point [K]		1533	1670	1670	1293	923
Density [kgm^{-3}]		8300	7830	8055	8950	2770
k [$Wm^{-1}K^{-1}$]	$T = 294$ K	9.1	–	–	–	–
	$T = 300$ K	-	64	15	386	174
	$T = 473$ K	14.1	–	–	–	–
	$T = 500$ K	–	54	19	–	188
k_p [$Jkg^{-1}K^{-1}$]	$T = 294$ K	486	–	–	–	–
	$T = 300$ K	–	434	480	385	875

3) Thermoelectric Shield: It is the material which protects the module damage due to high temperature. Mostly ceramic material or steel can also be used depending upon the required temperature gradient. It should be thick.

1) Thermal Paste at the Heat Sink with Fan

Thermal grease (also called CPU grease, heat paste, heat sink compound, heat sink paste, thermal compound, thermal gel, thermal interface material, or thermal paste) is a viscous fluid substance, originally with properties similar to grease, which increases the thermal conductivity of a thermal interface between heat sinks and heat sources by filling microscopic air-gaps present due to the imperfectly flat and smooth surfaces of the components. The main role of thermal grease is to eliminate air gaps or spaces from the interface area so as to maximize heat transfer. The compound has far greater thermal conductivity than air (but far less than metal). In electronics, it is often used to aid a component's thermal dissipation via a heat sink.

A heat sink is designed to maximize its surface area in contact with the cooling medium surrounding it, such as the air. Air velocity, choice of material, protrusion design and surface treatment are factors that affect the performance of a heat sink. Heat sink attachment methods andthermalinterfacematerialsalsoaffectthedietemperatureoftheintegratedcircuit.Thermal grease improve the heat sink's performance by filling air gaps between the heat sink and the heat spreader on the device. A heat sink is usually made out of copper and/or aluminum. Copper is used because it has many desirable properties for thermally efficient and durable heat exchangers. First and foremost, copper is an excellent conductor of heat. This means that copper's high thermal conductivity allows heat to pass through it quickly. Aluminum is used in applications where weight is a big concern.

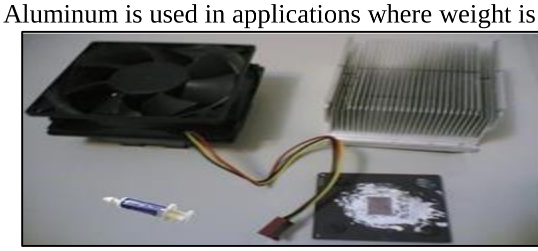


Fig. 7: Heat sink with fan

2) Flexible Joint and Multimeter

A multimeter is an electronic measuring instrument that combines several measurement functions in one unit. Atypical multimeter can measure voltage, current, and resistance. Digital multimeters display a numeric value. Digital multimeters are now far more common due to their cost and precision. We are using for measure the voltage and current.

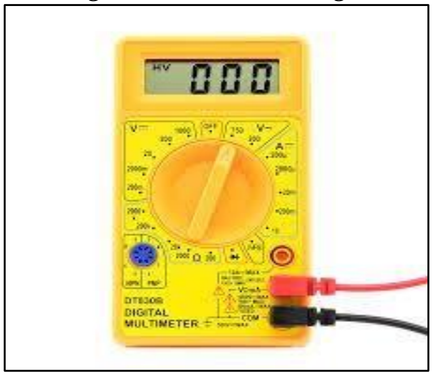


Fig. 8: Multimeter

3) Thermometer

A thermometer is a device that measures temperature. A thermometer has two important elements: (1) a temperature sensor in which some physical change occurs with temperature, and (2) some means of converting this physical change into a numerical value. In this project we are using fixed thermometer, which are permanently joint with exhaust pipe. It shows the exhaust temperature of the engine. In which we can see the exhaust temperature of the engine.

4) Boost Circuit

A booster circuit is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). This is based on the theory that inductor holds current and passes in opposite direction. It has a poor efficiency of 60-80%. So we can’t use it for a large project. We can use it for low power consuming models like 12 V and 3 V models which requires 250 mA current. We have to spend 650 mA with 80% efficiency. In this circuit we are going to put DC pulse of around 2V through TEG and amplifying to 12 V as output. We need to fallow the below for expected voltage range. 6 V to 12 V @1 A: 80 turns of 24swg wire in a 0.5 mm ferrite core. 6 V to 12 V @500 mA: 60 turns of 36swg wire in a 0.5 mm ferrite core.

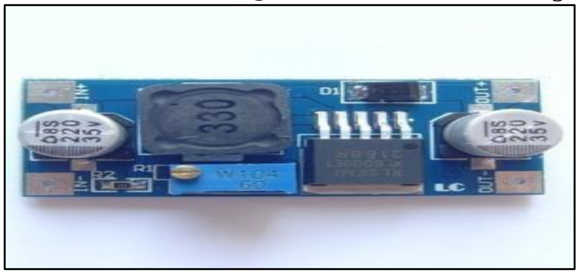


Fig. 9: Booster Circuit

5) Water Block

A water block is the water cooling equivalent of a heat sink. It consists of at least two main parts; the "base", which is the area that makes contact with the device being cooled and is usually manufactured from metals with high thermal conductivity such as aluminum or copper. The second part, the "top" ensures the water is contained safely inside the water block and has connections that allow hosing to connect it with the water cooling loop. The top can be made of the same metal as the base, transparent Perspex, Delr in, Nylon, or HDPE.A water block is better at dissipating heat than an air-cooled heat sink due to water's Higher specific heat capacity and thermal conductivity. The water is usually pumped through to a radiator which allows a fan pushing air through it to take the heat created from the device and expel it into the air. A radiator is more efficient than a heat sink/air cooler at removing heat because it has a much larger surface area. Installation of a water block is also similar to that of a heat sink, with a thermal pad or thermal grease placed between it and the device being cooled to aid in heat conduction.

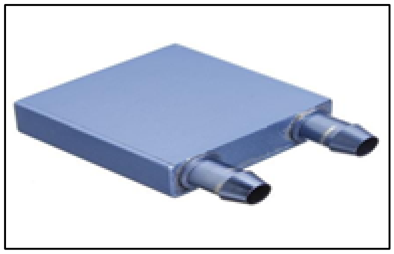


Fig. 10: Water block

6) Working Procedure

The vehicle is started and the acceleration is to be given, so that the amount of heat leaving the exhaust will be increased. Due to this heat, the surface of the exhaust pipe and the silencer will be heated to very high temperatures. These hot surfaces will try to liberate the heat to the atmosphere, which acts as a Heat Sink. Since the atmospheric temperature is less than that of the silencer surface, a temperature difference is created and hence the surface tries to attain the equilibrium state through the heat transformation process. But this will take much longer time. Hence in order to increase the rate of heat transfer the Thermal Grease is used. The Thermal Grease is coated on the hot surface of the silencers and also in the inner surface of the fins which are present in the upper part. The fins are also used to increase the heat transfer rate. As the vehicle moves, the air flow will take place between the fins and it acts as the sink.

IV. METHODOLOGY

A. Setup to Harness Energy from Engine Heat

Parts required: An engine with an exhaust system, a generator; a rechargeable DC battery; mild steel for constructing frames; connecting wires, A thermocouple unit; metal clamps(stainless steel screw)

1) Procedure

– The hottest part of the exhaust system is identified. This would likely be on the exhaust pipe.
– The thermocouple is clamped onto the spot, such that one side is exposed to heat, while the other side is exposed to atmosphere. This provides the temperature difference required for the thermocouple to generate electricity.
– Leads from the thermocouple are connected to the battery via inverter, which would be stored in a DC rechargeable battery of matching capacity (12V, 5A).

The entire setup is to be housed on the exhaust pipe. For this purpose, the exhaust pipe is dismembered; the casing is mounted, and fixed back.

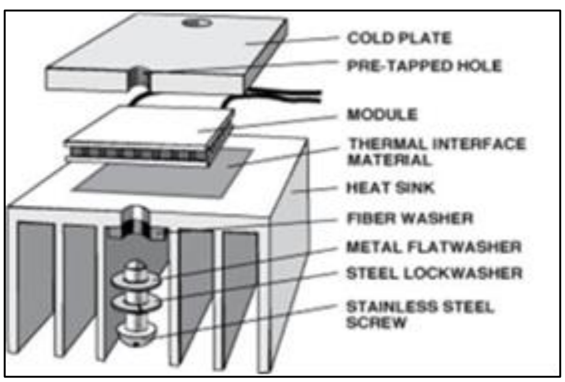


Fig. 11: Schematic diagram setup to harness energy from engine

B. Specification of Engine

1) Make: Maruti Zipsy's
2) No. of Cylinders: 4
3) Bore: 68 Mm
4) Stroke: 75 Mm
5) Rated Speed: 1500 Rpm
6) B.P. 10 H.P.
7) Orifice Diameter: 35mm
8) Fuel: Petrol
9) Cooling System: Water cooled
10) Type: Four stroke

11) Compression Ratio:7.8:1
12) Types of cylinder arrangement: inline
13) Type of ignition: battery ignition
14) Type of lubrication: modified splash lubrication
15) Type of starting: self-starting
16) Type of governing: Quantit/governing

C. Standard Data for Calculations

1) D0: Diameter of orifice = 26 mm
2) A0: Cross section area of orifice = 5.30066×10-^{2}m^{2}
3) Cd: Coefficient of discharge = 0.62
4) Pa: Density of air at 0 oC = 1.293 Kg/m^{3}
5) Pw: Density of manometer fluid (water) = 1000 Kg/m^{3}
6) g: Acceleration due to gravity = 9.81 m/s^{2}
7) 1 Hp: 746 Watts
8) Cp: Specific heat of water = 4.18 KJ/kg^{0}C
9) Cv: Calorific Value of petrol = 44517 KJ/kg
10) Specific gravity of petrol = 0.716
11) Difference of Water Manometer Reading, hw = 0.065.m
12) Calorimeter Cooling Water Flow Rate, mwc = 0.0556 Kg/min
13) Engine Cooling Water Flow Rate, mwe = 0.0556 Kg/min
14) Room temperature, T = 35 ^{0}C

Table 5: Gear 1

Cut off	Voltage (V)	Current (A)	Tw3	Tw4	Tg5	Tg6
All firing	245	1.3	38	45	300	250
Cut off - 1	215	1.0	33	35	268	180
Cut off - 2	210	1.5	33	37	245	150
Cut off - 3	205	1.7	33	37	240	135
Cut off - 4	172	1.6	34	38	250	155

1) Engine Cooling water inlet temperature, T1 = 38 ^{0}C
2) Engine cooling water Outlet temperature, T2 = 55 ^{0}C

Table 6: Gear 2

Cut off	Voltage (V)	Current (A)	Tw3	Tw4	Tg5	Tg6
All firing	295	1.6	38	45	380	300
Cut off - 1	270	1.4	40	45	335	290
Cut off - 2	171	1.2	37	41	342	272
Cut off - 3	221	1.2	38	40	336	260
Cut off - 4	283	1.5	48	46	349	275

1) Engine Cooling water inlet temperature, T1 = 38 ^{0}C
2) Engine cooling water Outlet temperature, T2 = 54 ^{0}C

Table 7: Gear 3

Cut off	Voltage (V)	Current (A)	Tw3	Tw4	Tg5	Tg6
All firing	292	1.5	38	79	440	397
Cut off - 1	227	1.2	38	110	430	367
Cut off - 2	244	1.3	38	90	405	359
Cut off - 3	212	1.2	37	100	400	347
Cut off - 4	220	1.4	36	105	420	360

1) Engine Cooling water inlet temperature, T1 = 38 ^{0}C
2) Engine cooling water Outlet temperature, T2 = 54 ^{0}C

D. Calculations

1) Engine Performance Parameter

1) Brake Power (BP) =0.472KW
2) Indicated Power

Time for 10cc of fuel consumption, t = 6.78 Sec,

Total Fuel consumption, TFC = m_f × 60….kg / hr.TFC = 0.0635 × 60….kg / hr. TFC = 3.813 kg / hr.

Indicated Power, I.P = B.P + F.P

I.P = 0.472 + 0.1431

I.P = 0.6151 KW

Mass of air intake, m_a = … *a* ×V_a……kg/min m_a = 1.293×0.6585……kg/min m_a = 0.851 kg/min

Density of air … a = 1.293 Kg/m^3
Theoretical Air intake:
Diameter of piston, D = 0.068 m Stroke length, L = 0.075 m Engine speed, N = 1500 rpm
Swept volume at STP, Vs = Va ×*Ts/Ta*…….m^3/min
Vs = 0.61993 × *303/298*…….m^3/min Vs = 0.7902 m^3/min
Where Ta = Ambient Temperature, 298^0 K
Heat Balance Sheet on Minute Basis:
Heat input, HI = T.F.C ×CV…… KJ/min
HI = 0.0635× 44517…… KJ/min HI = 2826.8295
HI = T.F.C ×CV…… KJ/min
KJ/minHI = 0.0635× 44517…… KJ/min HI = 2826.8295 KJ/min
Heat Equivalent of B.P, $H_{B.P}$ = B.P × 60..KJ/min
$H_{B.P}$ = 0.472× 60 ………..KJ/min $H_{B.P}$ = 28.32 KJ/min
Heat gained by calorimeter cooling water, $H_{wc} = m_{wc} \times C_{pw} \times (T_4 - T_3)$
Hwc = 0.0556 ×4.187 × (79 - 38) mg ×Cpg ×(T5 - T6) = mwc ×Cpw ×(T4- T3)
0.9145 × Cpg× (440 - 397) = 0.0556 ×4.187 × (79 - 38)
Specific heat of gas, C_{pg} = 14.563 kJ/kg.k
H_{eg}= mg ×Cpg× (T_5 - T_6) …..KJ/min
H_{eg}= 0.9145 × 14.563 × (440-397) …..KJ/min
H_{eg}= 572.66 KJ/min
Heat unaccounted loss, H_u = HI – (H_{eg} + H_{we} + $H_{F.P}$ + H_{BP})…..KJ/min
H_u = 2826.8295 – (572.668+ 223.2 + 8.58 + 28.32)…..KJ/min H_u = 1994.124 KJ/min

V. RESULT

A. Engine Performance

- Based upon above reading the calculations were done on 2nd gear. The Brake power of the engine was found to be 0.472 KW.
- The volumetric efficiency found to be 96.70%.
- Brake thermal efficiency and indicated thermal efficiency was found to be 1.00% and 1.30%. Mechanical efficiency was found to be 76.73%.
- The B.M.E.P. was 34.67KPa and I.M.E.P. was 45.17KPa.
- Specific fuel consumption 8.096 Kg/KW-hr

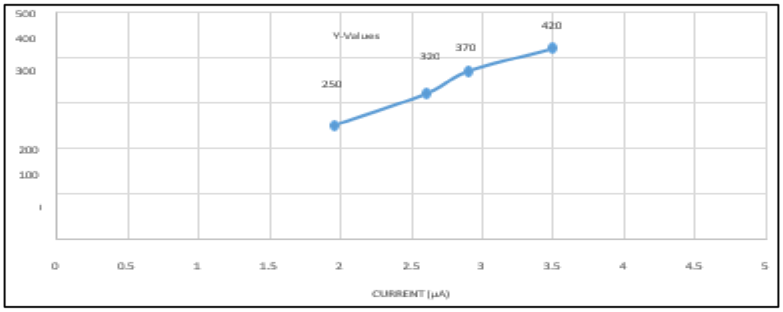
B. TEG Performance

As the number of gear increase temperature increases, so when temperature increases then heat transmission to TEG also increases. So current generation by the TEG will increases, on other side of the TEG it should be cooled for batter and efficiency. The table shown below is obtained based on TEG performance and on the bases of these values graph between temperature and voltage, temperature and current, temperature and power.

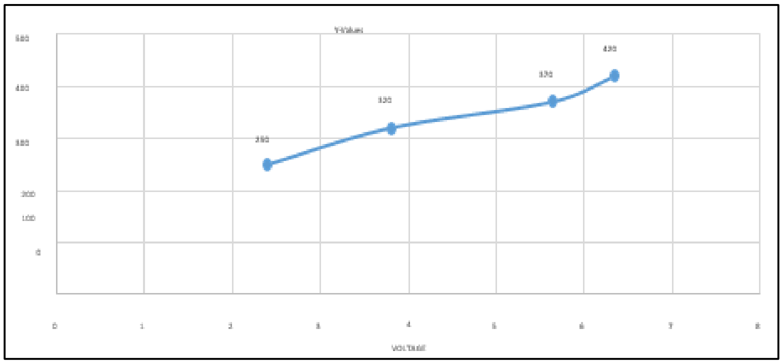
Table 8: Variation of Voltage and Current with Temperature

Gear	*Temperature Difference(^{0}C)*	*Voltage (V)*	*Current (mA)*	*Power (W)*
Gear-1	*250*	*2.4*	*1.95*	*4.68*
Gear-2	*320*	*3.80*	*2.6*	*9.88*
Gear-3	*360*	*5.63*	*2.9*	*16.32*
Gear-4	*420*	*6.35*	*3.4*	*21.59*

Graph between temp. Diff. and current



Graph 1:



Graph 2:

VI. CONCLUSION

In this project we have successfully experimented with petrol engine using thermoelectric generator by morsh test. Thus the suitable power generated by the TEG. Can be implemented for domestic and commercial use at an afford dabble cost. The efficiency of the engine will not be affected because only the surface heat of the silencer is drawn out. The main objective of this project is to recover the surface exhaust heat to avoid the accidents (Burn-outs) caused by the overheated silencers, and to convert the recovered heat to useful electric energy. This objective has been successfully accomplished in this project. The output could be increased by connecting a number of TEGs in series, so that the voltage gets added up leading to increased power.

Reusing the waste heat from internal combustion engine and using it for electrical work. By using this thermoelectric system one can generate electricity from the high temperature difference and it is available at low cost. If this concept of thermoelectric system is taken to the nano level or micro level then there will be ample amount of electricity can be generated which are just wasted into the atmosphere. The energy produced from this system could be used to power any auxiliary devices in an automobile directly or it could be stored in a battery and then used later.

VII. FUTURE PROSPECTS

– Finding ways to enhance output.
– Designing a system for four-wheelers
– Making the project design enclosure more compact.
– Experimenting with Piezoelectric materials as an added source for Power Generation.
– Experimenting with magnets attached to a vehicle's fuel line have been claimed to improve fuel economy by aligning fuel molecules

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