

INCREASING THE EFFICIENCY OF TEGs USED TO GENERATE ELECTRICITY FROM EXHAUST GASES USING Si-Ge ALLOYED TEG

Submitted in partial fulfilment of the requirements for the award of Bachelor of
Engineering in Mechanical Engineering

by

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DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

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March – 2021



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of KARAN A V (37150087) and INFANT EDEN MIRANDA (37150077) who carried out the project entitled **"INCREASING THE EFFICIENCY OF TEGs USED TO GENERATE ELECTRICITY FROM EXHAUST GASES USING Si-Ge ALLOYED TEG"** under my supervision from November 2020 to March 2021

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I Karan. A. V (37150087), Infant Eden Miranda (37150077) hereby declare that the project entitled “Increasing the efficiency of TEGs used to generate electricity from exhaust gases using Si-Ge Alloyed TEG” done by me under the guidance of Ass. Prof. P. Karthikeyan and is submitted in partial fulfilment of the requirements for the award of bachelor of Engineering/Technology degree in Mechanical Engineering.

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ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board Of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. S. Prakash, M.E., Ph.D.**, Dean, School of Mechanical Engineering and **Dr. G. Arun Kumar, M.E., Ph. D.**, Head of Department, Dept. of Mechanical Engineering for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Mr. P. KARTHIKEYAN, M.E.**, for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department Of Mechanical Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

Majority of the vehicles commercially available today and on the roads today use internal combustion engines (ICE) for the power source. Such engines use only small share of the fuel primary energy converted to K.E, however most of the fuel primary energy is wasted while dissipated in the ambient air as waste heat or as hot exhaust gas. This exhaust gas can be used to generate a certain amount of electricity. A remarkable potential for improving the efficiency of the Internal Combustion Engine systems lies in the recovery of the energy wasted today. This paper presents an insight of the state of the art of current research of exhaust waste heat recovery systems utilizing thermoelectric generators (TEGs). Such systems provide the direct heat-to-electric energy conversion and allow building the exhaust energy recovery systems without adding moving parts to the vehicles. The review will present the overview related particularly to vehicle engines exhaust energy recovery systems, introducing the key parameters, components and factors that determine the performance of such systems. Since the efficiency of these TEGs is not a lot, we use Si-Ge alloyed TEGs to increase the efficiency and load of the respective TEGs. This allows us to extract more electricity and in turn more power from the waste exhaust gases that is emitted from the vehicles. The efficiency of a TEG (Thermoelectric generator) is only 4-5% which is quite low but it is not a big issue because this process uses free heat and heat energy of no cost as an input and due to the benefits of TEGs, it has become a promising alternative green technology as opposed to the polluting technologies present. The installation position and thermoelectric materials plays a vital role in improving the efficiency.

KEYWORDS : Energy Generation, Waste recovery, TEGs, IC Engines.

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS	ABBREVIATION
E_o	Open circuit voltage of TE module, V
e_a, e_b, e_c, e_s	Distances, m
$h_{contact}$	Contact heat transfer coefficient, $W.m^{-2}.K^{-1}$
I	Current through TE module, A
I_{bat}	Current through battery, A
I_{out}	Output current of electronic convertor, A
I_L	Current in the load, A
K_{pn}	Thermal conductance of one thermocouple, $W.K^{-1}$
n	Number of thermocouple in a module
P	Electrical power for end users, W
P_r	Pressure on the TE module, kPa
q_c	Heat released from the cold side, W
q_h	Heat absorbed on the hot side, W
q_{sc}, q_{sh}	Heat flux through ceramic wafers, W
R	Thermal resistance, $K.W^{-1}$
R_B	Current sense resistance, Ω
R_{ce1}, R_{ce2}	Thermal resistances of the ceramic wafers, $K.W^{-1}$
R_E	Resistance seen by the TE module, Ω
R_{int}	Internal resistance of TE generator, Ω
R_L	Load resistance, Ω
R_{pn}	Electrical resistance of one thermocouple, Ω
T_a	Average temperature, $^{\circ}C$
T_c	Cold-side temperature of TE module, $^{\circ}C$
T_h	Hot-side temperature of TE module, $^{\circ}C$
V_{out}	Output voltage of electronic convertor, V
V_{bat}	Battery voltage, V
V_{TE}	Output voltage of TE module, V
Δ_{pn}	Seebeck coefficient of one thermocouple, $V.K^{-1}$
Δ_n, Δ_p	Thermal conductivities, $W.m^{-1}.K^{-1}$

ρ_n, ρ_p
 $\Omega.m$

Resistivities of the n-type and p-type semiconductors,

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

Due to rapid increase in the carbon dioxide levels and other harmful gases specially ones which contribute towards increase in pollution and global warming, the automotive industry is the primary target therefore many researches have been undertaken in this field. Globally, it is calculated that about one-third of the total energy is used while the remaining is considered as waste heat. The maximum efficiency to which an engine can function is around 25%, so 75 % of the energy left is wasted in the form of heat from parasitic losses and friction resulting in the wastage of 30% in the engine coolant and 40% gaseous waste in exhaust. Thermoelectric Generator is a solid stated device which works on the principle of 'Seebeck effect'. The figure depicts energy distribution in an Internal Combustion Engine.

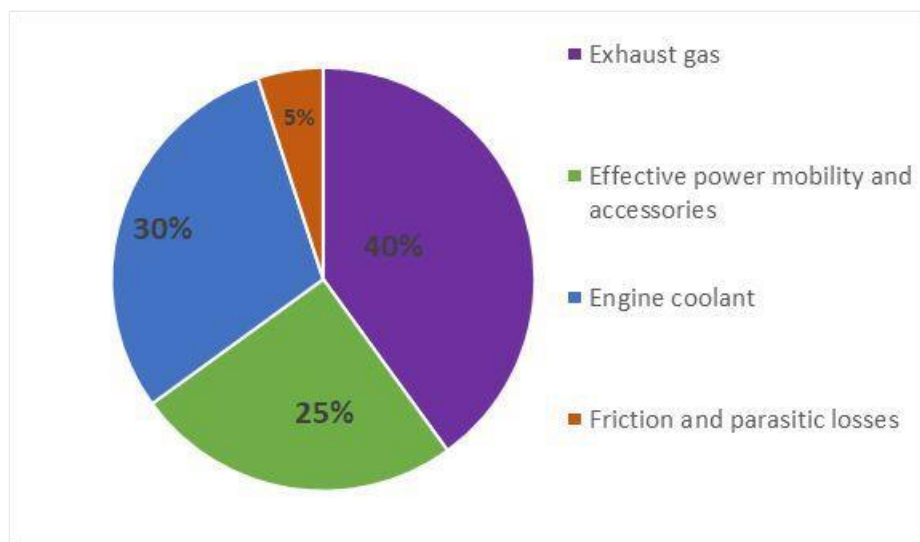


Fig 1.1 Energy distribution in an ICE

ICEs can be seen in solar panels, solar hot water system, biomass power applications, energy power plants and solar pond systems. The installation procedure of a TEG can be fairly easy and has an additional advantage of being

small in size, minimal to no noise during operation and minimal to low maintenance. The highlight is that the input for ICE is freely available thermal energy and the output is usable electrical energy.

A thermoelectric module is made up of a number of thermo elements connected in different electrical channels for different results. They are connected in series to increase the operating voltage and in parallel in order to increase the thermal conductivity. This conversion of waste heat into electricity results in an increase of fuel efficiency by about 20%, research has shown. A Thermoelectric Generator i.e., Two metallic strips, made of different metals and joined at the ends to form a loop, runs on the principle of Seebeck effect. When the junctions are kept at different temperatures, an electric current is formed in the loop and the emf so generated is called the SEEBECK emf or thermo emf and this current can be used to power a load.

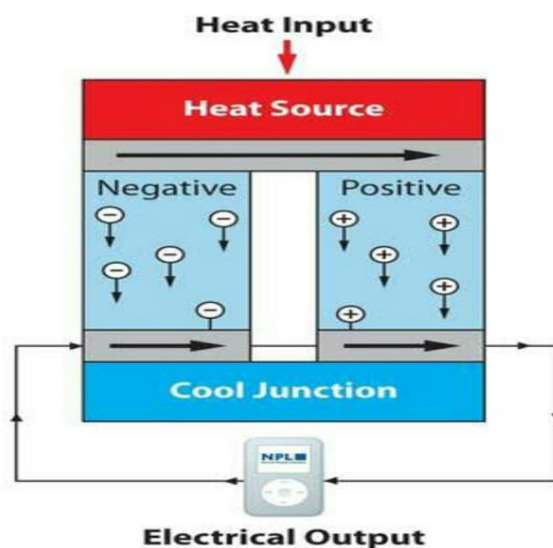


Fig 1.2. Layout of a TEG

The TEG structure is placed between the thermoelectric material which is then sandwiched by the heat exchanger plates on each end. The two heat exchangers are at different temperatures, one at high temperature and the other at lower temperature and they are called the hot side and the cold side. The metal heat exchanger and material of a TEG has a thermally insulated layer present between them. Electrically, the metal is connected to the p type and n type materials. A TEG has two sides, a cold one and a hot one. The hotter side pushes the electrons in n

type leg to the cold side which pass through the metallic connection and then into the p type leg, hence developing current. The more difference in the temperature between cold side and hot side, the more amount of EMF is produced.

1.1. EXPERIMENTAL SETUP

For maximum power to be produced, the speed of the vehicle is the most important criteria. speed of vehicle should be more for better performance of TEG. Since the exhaust temperature is more, the amount of energy available is more for the conversion into electrical energy. There is a rise in optimal length and dip in optimal width based on dynamic optimization simulations when the temperature of the exhaust rises. Temperature is directly proportional to the efficiency and power of a TEG. The figure below shows the temperature of inlet and outlet when the engine is used between 2500 rpm-3400 rpm. Due to the increase in engine speed, the temperature difference between the surfaces of TEM increases rapidly, hence there is a increase in power output also. Another study found that it was possible to produce electricity of 5.9 MW from a 500 MW gas turbine power plant, with the help of a waste heat energy recovery system. An experiment has been performed to check the power output of TEG by varying the speed of the vehicle. The speed of the vehicle was changed between 48.3, 80.6 and 112.7 km/hr and the result was that the output power was directly proportional to the speed of vehicle, likewise the mass flow rate of exhaust and inlet temperature increased according to the speed. At 80 km/hr, the power output with 72 mm * 4 mm TEM was 75 W.

1.2. THERMOELECTRIC EFFECT

A thermoelectric voltage is produced when two metals are connected, due to the different binding energies of the electrons to the metal ions. This voltage depends on the metals themselves and in addition to the temperature. For this thermal voltage to generate a flow of current, the two metals must also be connected at the other end, so as to form a closed circuit. Through this, a thermal voltage is produced at the second junction. In case the temperatures at the two junctions are same, there wouldn't be a flow of current since the partial voltages produced at the two points

cancel each other. Different temperatures at the junctions generates different voltages, ultimately causing current to flow.

This measurement point is the junction which is exposed to the measured temperature. The junction where the temperature is known is the reference junction. The known temperature is usually lower than the measured temperature and hence, the reference junction is called as the cold side or cold junction.

1.3. TEG POWER GENERATION CALCULATION

The equation involved in calculation of the performance of a TEG is

$$Z = \alpha^2 / k \cdot R ,$$

Z = Figure of merit of thermoelectric material

R = Electric Resistivity

K = Thermal Conductivity

α = Seebeck Coefficient which is,

$$\alpha = \Delta V / \Delta T$$

$\bar{T}$ is the average temperature of cold and hot plate of a TEM and when multiplied by Z it makes it dimensionless.

$$ZT \approx \alpha^2 \bar{T} / KR \quad (3)$$

$$\text{and } \bar{T} = (T_H + T_C) / 2$$

As per the second law of thermodynamics,

$$\eta = T_H - T_C / 2$$

The maximum efficiency of conversion of a TEG can be found using,

$$\eta = \{ (1 + ZT)^{1/2} - 1 / ((1 + ZT)^{1/2} + (T_C / T_H)) \}$$

The output efficiency of a TEG mainly depends on two variables, the temperature and MFR of exhaust. Maximum power output and corresponding heat transfer can

be obtained by maximizing the MFR ratio. As the size of a TEG increases, the output power also increases.

1.4. THERMOELECTRIC GENERATOR SYSTEM

1.4.1. TE modules

Thermoelectric materials have a wide range of utility and are utilised in automobiles, power plants, space satellites, etc. Thermoelectric materials can be characterised according to the structure and composition. They can be classified as chalcogenide, clathrates, skutterudites, half-heusler, oxides and silicides.

The alloys of chalcogenide are the most common thermoelectric materials used. The calcogenide materials are popular for their use with (Bi₂Te₃) and (PbTe). The economic use is maximum in the Thermoelectric materials made with Bi₂Te₃, Se and Sb. Thermo electric properties at temperature range 500-600 °C and has been used by NASA as a radioactive thermo electric generator (RTG's) in the PbTe alloys. The stability of a TE material is vital because it shouldn't oxidize within the operating temperature out in the open. But these days, for costructionof TEGs, automobile industries are focusing on bismuth telluride.

Compounds of half heuslers are intermetallic compounds which are thermally stable, they have high thermal conductivity and seebeck coefficient corresponding to K. Due to phonon scattering, the lattice thermal conductivity of these compounds reduces having nano structures. Having very low degradation upto 1000 °C, SiGe alloys are used for high temperature applications. When compared to their bulk alloys, nanostructured SiGe alloys have greater zT value. Bulk Si_{0.8}Ge_{0.2} have zT value of 1 and 0.6 for n type and p type respectively. When nanocomposite thermoelectric materials are used, there is an improvement in zT value.

1.4.2. Heat Exchanger

The heat exchanger is an essential element in AETEG which determines its overall performance. The main function of an heat exchanger is to extract heat from flowing exhaust gas and in order to deliver maximum power output, an optimum design and sizing are both crucial. The efficiency of the TEG which is given by $\eta_{TEG} = \eta_{HE} \times \eta_{TE} \times \epsilon$ where,

η_{HE} = Heat Exchanger Efficiency

η_{TE} = Conversion Efficiency of the cluster TE modules

ε = Ratio of Heat Transfer from modules hot side to cold side

An ideal heat exchanger has low weight and high η_{HE} without causing extreme backpressure to the flow of exhaust gas because the back pressure increases the parasitic losses in the vehicle.

Thermal efficiency of a heat exchanger is dependent on three factors:

- a) Type
- b) Internal Geometrical Shape
- c) Materials of construction

Heat exchangers are classified into different types based on the heat transfer mechanisms and the number of fluids. They can be further classified on the basis of construction type and flow arrangements. These are contact type with direct heat transfer between different mediums, such as gas and solid on the hot side of the system and solid and liquid in the cold side. As per the classification on the basis of construction type and geometrical shape, the heat exchangers used are often box type or tubular with extended surfaces for e.g. fins or heat pipes, depending on the space available for integration into the vehicle.

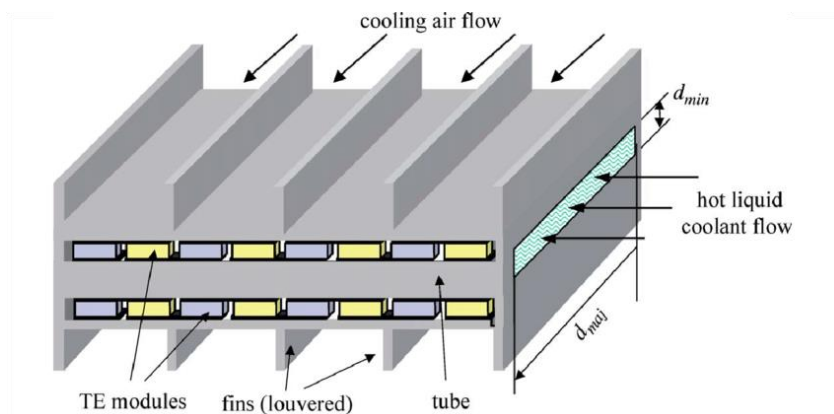


Fig 1.5. Heat Exchanger

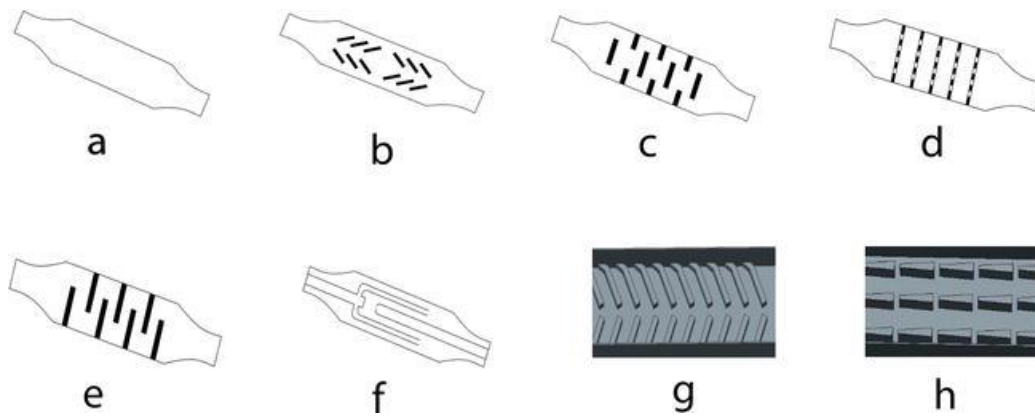


Fig 1.5. Different shapes of arrangement for heat exchangers used in automotive TEG. a) Empty cavity b) Inclined plate c) Parallel plate structure d) Separate plate with holes e) Serial plate structure f) Pipe structure g) Fish bone structure h) Accordion shape

1.4.3. Heat Sink or Cold Side Heat Exchanger

Exchanger

The AETEGs can either be operated at maximum efficiency or maximum power (P_{max}). In the case of automotive exhaust application, it is preferred to maximize the power output as it results in lower engine load and improves the overall fuel efficiency. The P_{max} of a AETEG not only depends on hot side temp (T_H) but the temperature difference (ΔT) between the hot and cold side of the module. Hence for maximizing the power output, the cold side temperature (T_c) of the TE modules should be lowered as much as possible. In case of most of the AETEGs designed and tested in laboratory testing conditions, the cold side temperature was regulated with the help of a water-cooled heat sink. Though in case of actual vehicles, it can be connected to the engine coolant circuit.

In an actual vehicle, the cold side heat exchanger in TEG system can either be a separate TEG coolant circulation system or integrated to the existing engine coolant circuit (integrated cooling system). Connecting the existing engine coolant circuit avoids these complexities while the separate system requires additional space and also increases the overall weight of the vehicle. To prevent the overheating of the coolant, the cooling pump capacity and radiator size may have to be increased to accommodate the additional heat coming from the cold side of the TEG. Temperature of the integrated cooling system increases and exceeds the boiling point of the coolant during a combined simulation and the experimental studies carried out in a 2.0 L 4 cylinder engine, Deng.

1.4.4. Assembly Components

The transfer of heat from the hot side to the cold side i.e., heat exchanger to the heat sink, through the thermoelectric modules is reliant on the assembly of the all different AETEG components in a manner such that thermal contact resistance is minimal between various interfaces. Some of the important factors on which thermal contact is dependent are: the applied contact pressure, surface roughness, the interface materials and their hardness. The assembly components ensure proper enforcing of sufficient force over the modules pressed between the heat exchanger and the heat sink. The difference in temperature of the hot and cold side of the TE module increases with contact pressure since it creates more area of physical contact at the molecular level which results in more heat conductance through the surfaces.

1.5. INSTALLATION POSITION OF TEG

Installing a TEG at an appropriate position is an important task as it determines the output power generated by exhaust heat. In an experiment, TEG was assigned three different positions and then examined the net performances.

- TEG is positioned at the end of the exhaust system.
- TEG is positioned between catalytic converter and muffler.
- TEG is positioned upside of catalytic converter and muffler.

Among these three cases, case 2 was found to be better than case 1 and 3 because in case 2, the heat exchanger obtained a high temperature at the surface and the pressure drop of the catalytic converter, muffler and heat exchanger was relatively low, which met with the requirement of exhaust gas system.

LITERATURE SURVEY

- [1] D.Zabek & F.Morini, 2019. This article covers solid state thermal to electrical energy converters capable of transforming low grade heat directly into electricity for waste heat recovery and thermal energy harvesting. Direct solid state heat engines such, as thermoelectric modules and thermionic devices for spatial temperature gradients, are compared with pyroelectric energy harvesters and thermomagnetic principles for transient changes in temperature. Temperature and size limitations along with the maturity of the technologies are discussed based on energy density and temperature range for the different generator technologies. Despite the low energy conversion efficiency with solid state generators, electric power density ranges from 4 nW/mm² to 324 mW/mm². The most promising sector to implement changes while reducing the primary energy consumption and saving resources, is the processing industry along with stationary and mobile electronics
- [2] M.G. Jadhav & J.S. Sindhu, 2017. In this article, converts the waste heat from the exhaust manifold into electrical energy using a TEG. The output is then boosted by a Joule Thief converter to run the required load or to charge a battery. The experimental results demonstrate that the proposed system recovers considerable amount of waste heat which can be used to power some auxiliary automobile devices.
- [3] V. Venkatesh, 2018 In this article, the amount of heat produced by various exhaust gases was studied and the mathematical concept of power generation due to heat produced was inferred. The heat depends part on the temperature of the waste heat gases and mass flow rate of exhaust gas. Large quantity of hot flue gases is generated from boilers, kilns, ovens and furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered.

- [4] G Rohit & D Manaswini & Vinod Kotebavi & Nagaraja S R, 2017. In this article, the performance study of the thermoelectric generator was done and the experimental setup of the generator was also looked upon. TEG is a semiconductor device that produces electric potential difference when a thermal gradient develops on it. This paper deals with the study of performance of a TEG module for different hot surface temperatures. Performance characteristics used here are voltage, current and power developed by the TEG. One side of the TEG was kept on a hot plate where uniform heat flux was supplied to that. And the other side was cooled by supplying cold water. The results show that the output power increases significantly with increase in the temperature of the hot surface.
- [5] Ismail and Ahmed, 2009. In this article, the various sizes of TEGs and the various applications of micro and macro TEGs were explored. TEGs in various other applications were also studied. Thermoelectric power generators have emerged as a promising alternative green technology due to their distinct advantages. Thermoelectric power generation offer a potential application in the direct conversion of waste-heat energy into electrical power where it is unnecessary to consider the cost of the thermal energy input. The application of this alternative green technology in converting waste-heat energy directly into electrical power can also improve the overall efficiencies of energy conversion systems. In this paper, a background on the basic concepts of thermoelectric power generation is presented and recent patents of thermoelectric power generation with their important and relevant applications to waste-heat energy are reviewed and discussed.

- [6] Adhithya k, Rajeshwar Anand, Balaji G.,Harinarayana J, 2011.In this article, the various temperatures with which TEGs can be operated were studied. In order to maximize the output of concentrator Photovoltaic cells and maintain their operating temperature of concentrator photovoltaic cells must be reduced. A way that could reduce such photovoltaic temperature is by thermally attaching them on top of a thermoelectric generator. A thermoelectric generator in such coupling will act as a low-cost passive-cooling subsystem, as well as a power generator for producing additional energy from the rejected photovoltaic heat. Increasing the area of the proposed photovoltaic cells relative to the thermoelectric generator's hot-side area will result in an increase in the thermoelectric generator's electrical output, but may also result in overheating the photovoltaic cells, hence reducing their performance. Optimization has to be performed for the photovoltaic covering percentage relative to the hot-side area in order to maximize the output of the whole coupled system. This work investigates the electrical and thermal performance of thermoelectric generators in the case of partial illumination of their hot side.
- [7] Gregory P. Meisner, 2010. In this article, the various materials with which TEGs can be made was studied and explored. The power output for the various materials was also analysed. Prototype TEGs are being assembled and installed on the test vehicle. Vehicle modifications and system integration are being completed as the TEGs are installed on the vehicle. Improvements in the performance of TE materials have been achieved, particularly for Skutterudites. Skutterudite modules are being developed for the final prototype TEGs.
- [8] Elistia Liza Namigo,2016. In this article, the various components and constituents of the SiGe alloyed TEG was studied and understood. The various properties of the respective alloys were known and applied. Seebeck coefficient, electrical resistivity, thermal conductivity and specific contact resistance- were measured to determine the figure-of-merit (ZT) as a performance measurement of the materials. Measured Seebeck coefficients

are $34 \mu\text{V/K}$ for p-type and $185 \mu\text{V/K}$ for n-type. Thermal conductivity is around 3 W/mK . Contact resistance is still considerably high and there is no significant reduce on the value as annealing temperature increased from 375°C to 475°C for annealing time of 30 and 60 minutes. The value of ZTs for p-type and n-type material are 0,0086 and 0,063 respectively. From ZT value alone, it can be seen that ZT of p-SiGe should be improved. Since the value of total electrical resistance is determined by the material itself, further work on Ge and doping level variations is required as well as optimization of annealing temperature and time to reduce contact resistance.

CHAPTER 3

AIM AND SCOPE

3.1 AIM OF THE PROJECT

The aim of this project is to increase the voltage output and in turn, the efficiency of the TEG while connected to the Gas Exhaust. The usual Bismuth alloys used can give voltages of only upto 5V but by using the SiGe alloyed TEG, the amount of power output can be increased upto 12V. Not only the power, but the Temperature resistance of the TEG also increases as SiGe alloyed TEG conducts more heat compared to the Bismuth alloyed TEG.

3.2 SCOPE OF THE PROJECT

The scope of this project is :

1. We will generate the facility for the max level by connecting the exploitation thermoelectrical generator in series/parallel.
2. Even the most common heat that is produced (i.e. Heat produced from overheating of laptops) can be utilized by exploitation to get the assembly to produce some electricity to charge instruments like mobile, bulbs etc.
3. By inserting it into the vehicle itself higher than the radiator shows that the battery of the vehicle can charge itself.
4. By using a SiGe alloyed TEG, an increase in the power output of the assembly can be seen. Therefore, due to the increase in the amount of electricity produced, multiple appliances can be powered or run at the same time.

CHAPTER 4

MATERIALS AND EXPERIMENTAL METHOD

4.1 METHODOLOGY

The direct conversion of temperature differences into electric voltage and otherwise can simply be explained as the thermoelectric effect. Voltage is created by a thermoelectric device, when there is a temperature difference between each side. Alternatively, temperature difference is created upon the application of voltage. On the atomic level, charge carriers present in the material diffuse from the hot side to the cold side upon the application of temperature gradient.

4.2 MATERIALS USED

4.2.1 Selection of TEG modules

Thermoelectric properties of p-type and n-type poly-Si70%Ge30%. have been measured (Seebeck coefficient, electrical resistance, thermal conductivity and specific contact resistance fabricated using LPCVD method with dopants density and annealing temperature and time. Figure of merit (and all constituting parameters) of the material has strong dependence on both temperature and the concentration of free carriers which means that each material has its own optimum range of operation. Further work needs to be done in order to further reduce thermal conductivity and specific contact resistance especially in microscopic level via nanostructuring of the material. Improvements in measurement techniques and design needs to be performed especially for measuring both parameters and to determine optimum annealing temperature, time and specific material used for contacts.

Number of SiGe Thermoelectric Generators used : 1

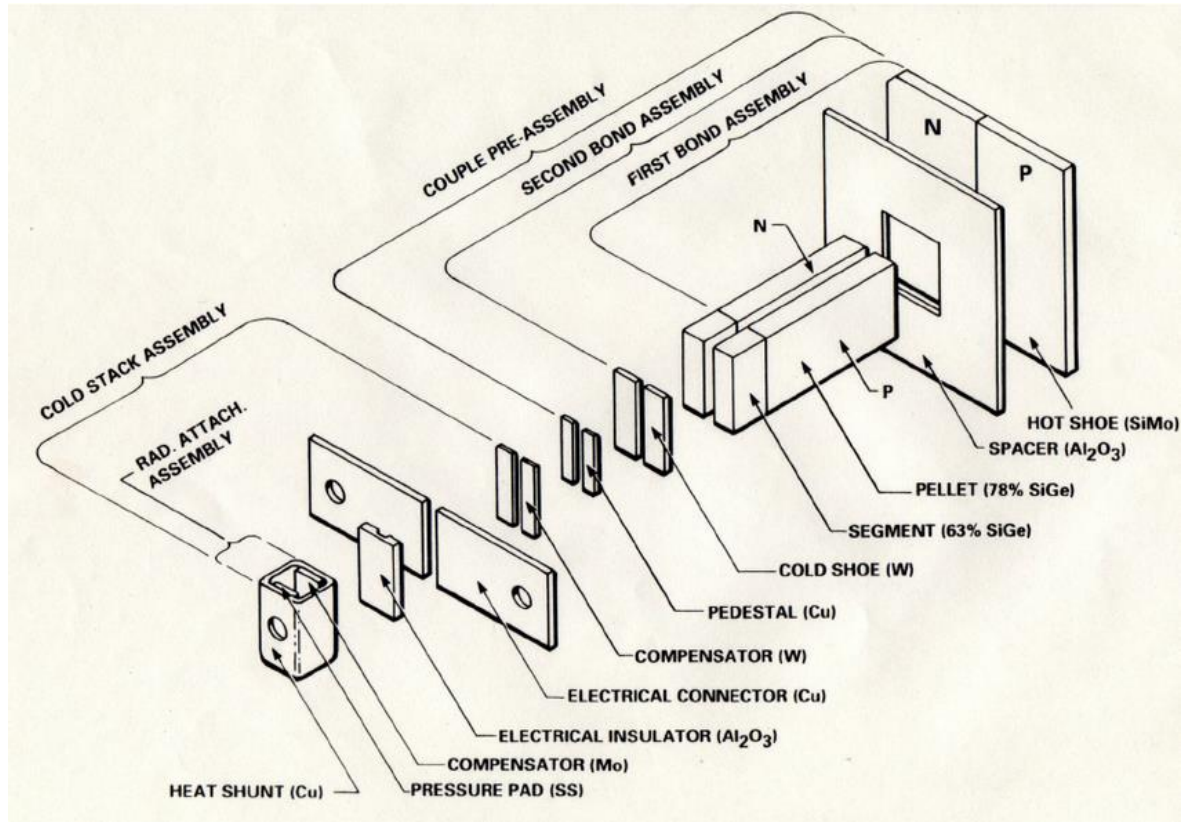


Fig 4.1. Exploded view of SiGe Thermoelectric Generator

4.2.1.1 Thermoelectric Transport and Properties of P-type and N-type SiGe Alloy

The electricity properties of n-type and p-type Si₈₀Ge₂₀ alloys employed by NASA are used because the comparison reference. 1995th edition of the Thermoelectrics reference work mentioned the electricity transport and other physical properties of each n-type and p-type Si₈₀Ge₂₀. [10] SiGe adopts a diamond lattice (space cluster Fd3m) consisting of 2 reposes penetrating face-centered cubic lattices. The lattice constant is composition dependent. In 1921 Vegard projected that a linear relation exists between the Bravais lattice parameter of an alloy and also the concentration of its compounds. Dismuke developed the slight variation from Vegard's law for SiGe alloys in 1964 .

$\text{Si}_{1-y}\text{Ge}_y \text{ (}\mu\text{A)} = (5.431 + 0.20y + 0.027y^2) \text{ (}\mu\text{A)}$ at temperature. For Si₈₀Ge₂₀ the theoretical density is three.00 g/cc. [11] 31

$\text{Si}_{1-y}\text{Ge}_y \text{ (g/cc)} = (2.329 + 3.493y - 0.499y^2)$

The specific heat for SiGe alloys is much an equivalent for the n-type and p-type material. The precise heat at constant pressure, CP, was utilized in the calculations rather than heat energy at constant volume, CV.

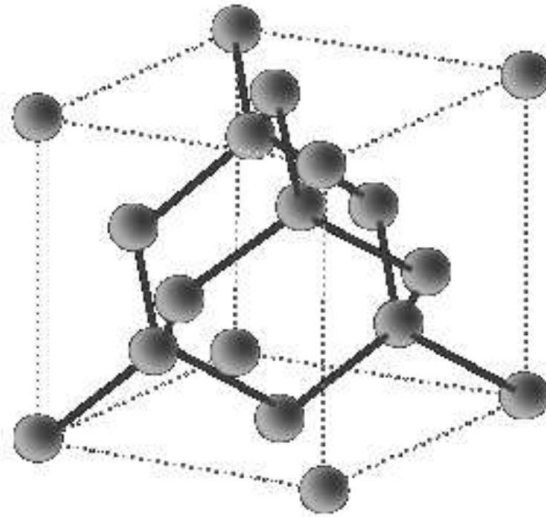


Fig 4.2. SiGe Crystal Strucutre

4.2.2 Aluminum metal plate and fins

Aluminium (Al) is an element of the boron group with atomic number 13. It can be characterised as a soft, silverish white, ductile metal nonmagnetic in nature and is the third most abundant metal. Aluminium has a density around one third that of steel or copper makes it one of the lightest commercially available metal. The high stress to weight ratio created as a result, makes it an essential and crucial structural material which allows high pay loads and resistance to corrosion. Compared to steel, aluminium is three times greater than steel in terms of Thermal conductivity, making it an important material in both heating and cooling applications, for eg. heat exchangers. Combined with it being non-toxic this property means aluminium is extensively used in construction of corrosion resistance devices.



Fig 4.3. Model of aluminium plate

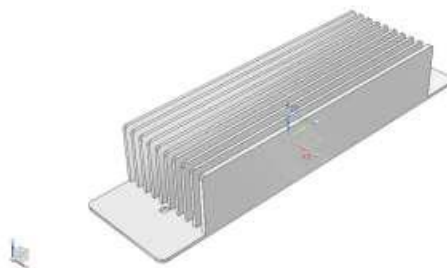


Fig 4.4. Model of Aluminium Fin

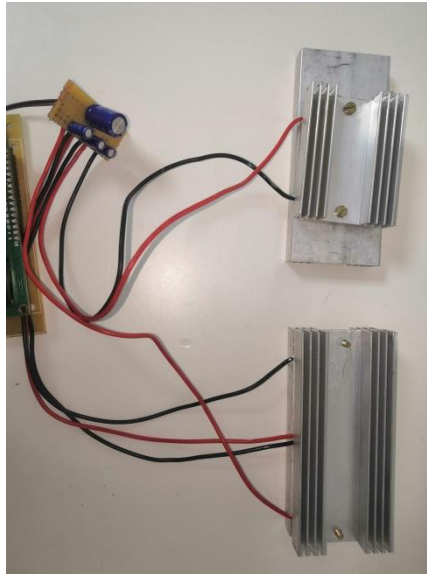


Fig 4.5. Assembled aluminium Fin and plate

4.2.3 Selection of Mounting Spot

The elbow region of mounting spot and the base of the silencer have more concentrated thermal stress because the hot exhaust gas directly hits the elbow region is diverted such that the velocity of gas is reduced in these areas, causing accumulation of more exhaust gas in these spots. Thus, a higher amount of heat is produced in those regions. Our manner of cooling proves to ineffective due to the heat radiation from the adjacent engine block. Also, the high temperature in this area makes it almost impossible to attain the required temperature difference with the help of our cooling method. Taking into consideration how easy it is to fabricate the metal block, ideally it can be mounted on the silencer itself, since the silencer doesn't heat up as much. Hence, by placing the TEG at this part of the silencer, we could allow maximum heat transfer, resulting in a steady production of electric power.

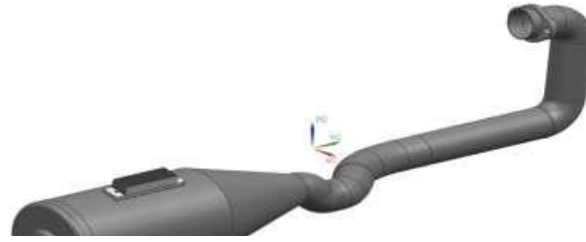


Fig 4.6. Model of Exhaust Pipe with mounted assembly

4.2.4 Arduino

Arduino is a single-board microcontroller to make using electronics in multidisciplinary projects more accessible. The hardware consists of a simple open source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM.

The software consists of a standard programming language compiler and a boot loader that executes on the microcontroller.

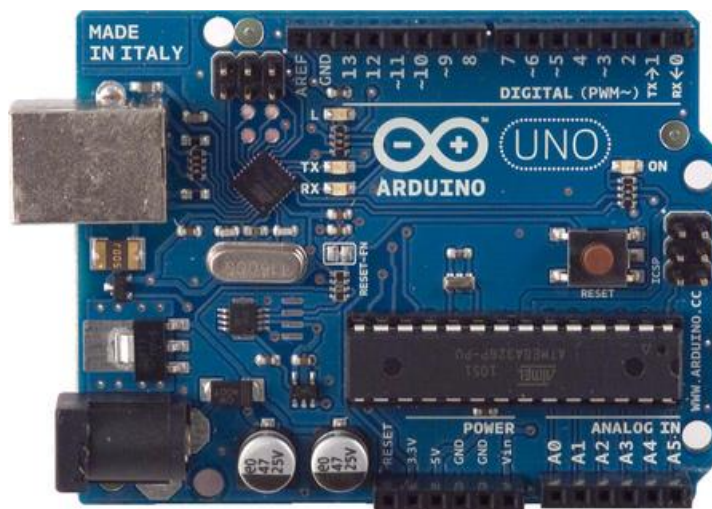


Fig 4.7. Internal Structure of Arudino

Arduino UNO

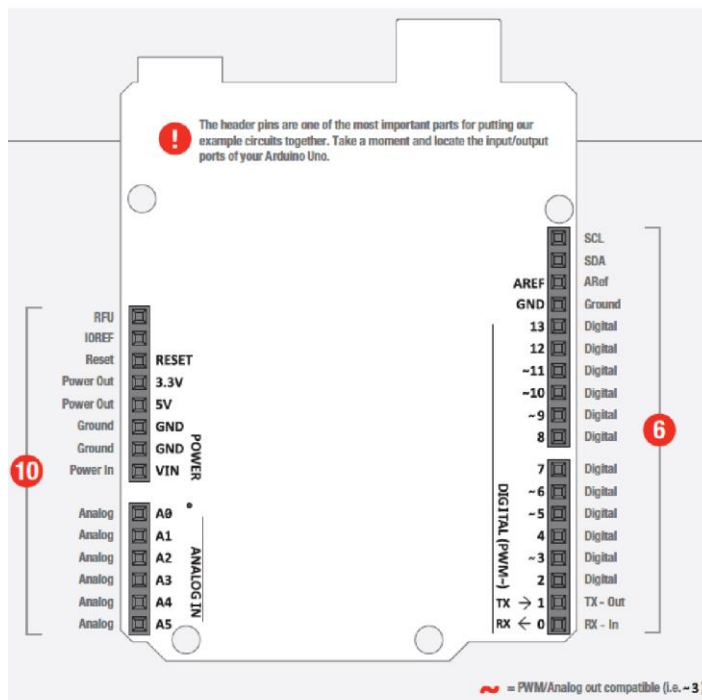


Fig 4.8. Arudino Specifications

4.2.5 DC Motor

A DC motor is any of a category of electrical machines that converts electrical energy power into mechanical power. the foremost common sorts suppose the forces created by magnetic fields. Almost all DC motors have some internal mechanism, mechanical or electronic, to modify the current flow direction of the motor. Most sorts manufacture rotary motion; a linear motor directly produces force and motion in a very line. Little DC motors square measure utilized in tools, toys, and appliances. The universal motor will treat electrical energy however could be a light-weight motor used for moveable power tools and appliances. Larger DC motors square measure utilized in propulsion of electrical vehicles, elevator and hoists, or in drives for steel rolling mills. the arrival of power physical science has created replacement of DC motors with AC motors potential in several Electromagnetic motors A coil of wire with a current running through it generates Associate in Nursing magnetic force field aligned with the middle of the coil. The direction and magnitude

of the flux created by the coil are often modified with the direction and magnitude of the present flowing through it. A simple DC motor features a stationary set of magnets within the stator coil. Associate in Nursingd an coil with one or additional windings of insulated wire wrapped around a soft iron core that concentrates the flux. The windings sometimes have multiple turns round the core, and in massive motors there are often many parallel current methods. The ends of the wire winding square measure connected to a electric switch. The electric switch permits every coil coil to be energized successively and connects the rotating coils with the external power offer through brushes. (Brushless DC motors have physical science that switch the DC current to every coil on and off and don't have any brushes.) The total quantity of current sent to the coil, the coil's size and what it's wrapped around dictate the strength of the magnetic force field created. The sequence of turning a selected coil on or off dictates what direction the effective magnetic force fields square measure pointed. By turning on and off coils in sequence a rotating flux are often created. These rotating magnetic fields move with the magnetic fields of the magnets (permanent or electromagnets) within the stationary a part of the motor (stator) to form a force on the coil that causes it to rotate. In some DC motor styles the stator coil fields use electromagnets to form their magnetic fields which permit larger management over the motor.

At high power levels, DC motors square measure nearly always cooled exploitation forced air.

The speed of a DC motor are often controlled by dynamic the voltage applied to the coil. The introduction of variable resistance within the coil circuit or field circuit allowed speed management. fashionable DC motors square measure usually controlled by power physical science systems that modify the voltage by "chopping" the DC current into on and off cycles that have a good lower voltage. For many years, the traction drives for electric and diesel locomotives (electrical) has been the DC motor. The introduction of DC motors Associate in Nursingd an electrical grid system to run machinery beginning within the decade started a replacement second historic period. DC motors will operate directly from reversible batteries, providing the locomotion for the primary electrical vehicles and today's hybrid cars and electrical cars further as driving a bunch of conductor tools. these days DC motors square measure still found in applications as little as toys and disk drives, or in

massive sizes to control steel rolling mills and paper machines. massive DC motors with severally excited fields were typically used with winder drives for mine hoists, for top force further as swish speed management exploitation thyristor drives. These square measure currently replaced with massive AC motors with variable frequency drives.

In a DC motor, when power is applied externally, the behavior is as such of a DC Generator, in other words, a Dynamo. This feature is employed to curtail and recharge batteries on hybrid automotive and electrical automotives or to come back electricity back to the electrical grid used on a street car or electric power-driven train line once they curtail. This method is termed regenerative braking on hybrid and electrical cars. In diesel electrical locomotives they additionally use their DC motors as generators to curtail however dissipate the energy in electrical device stacks. Newer styles square measure adding massive battery packs to recapture a number of this energy.

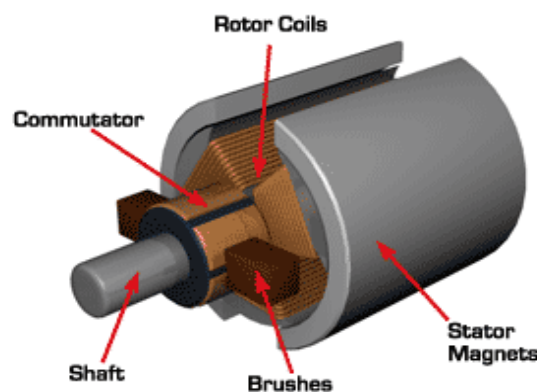


Fig 4.9. DC Motor



Fig 4.10. Picture of DC Motor used

4.2.6 LCD Display

LCDs (Liquid Crystal Displays) square measure used for displaying standing or parameters in embedded systems. LCD sixteenx2 is 16 pin device that has eight information pins (D0-D7) and three management pins (RS, RW, EN). The remaining five pins square measure for offer and backlight for the digital display. The management pins facilitate United States of America put together the digital display in command mode or information mode. They conjointly facilitate put together browse mode or write mode and conjointly once to browse or write. LCD 16x2 will be employed in 4-bit mode or 8-bit mode looking on the necessity of the applying. so as to use it, want|we'd like|we want} to send bound commands to the digital display in command mode and once the digital display is organized consistent with our need, we are able to send the specified information in information mode.

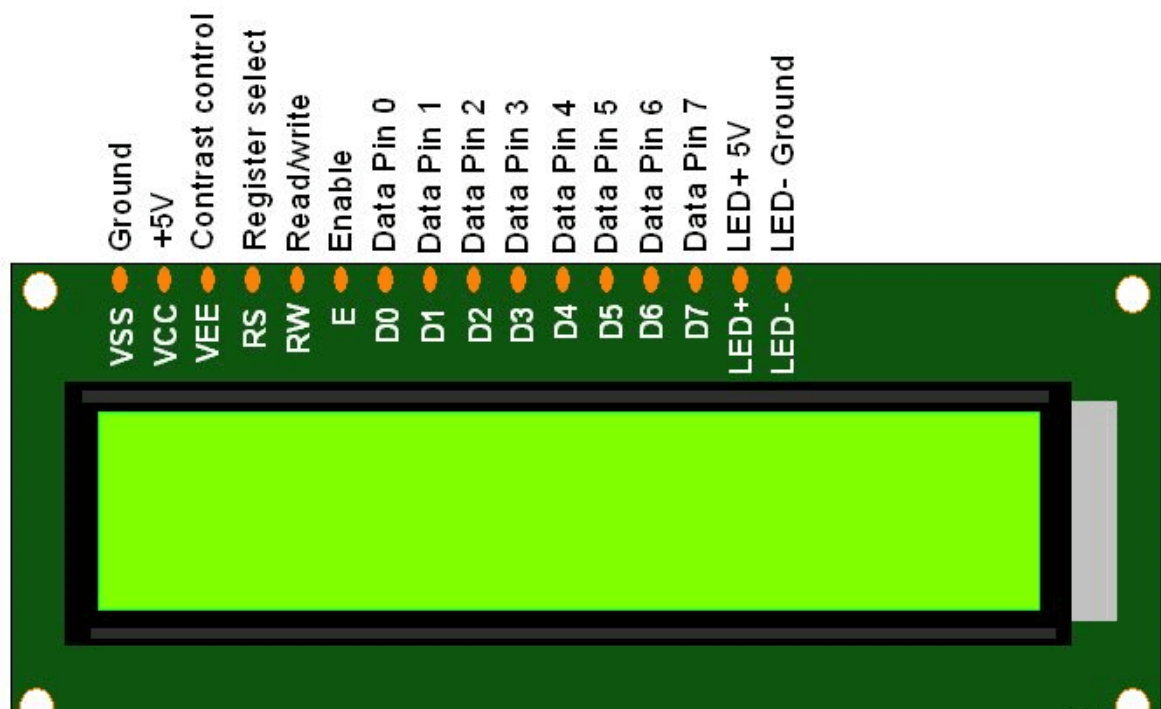


Fig 4.11. LCD Display Specifications



Figure 4.12. LCD Display

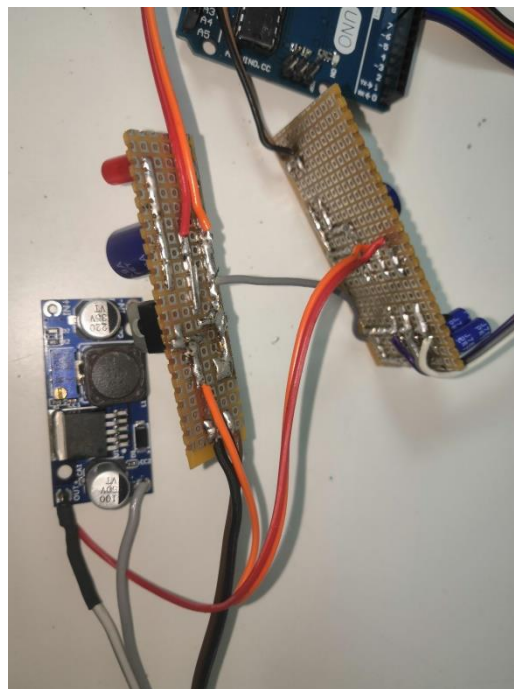
4.3. ASSEMBLY

All the parts were mounted on the silencer after machining in the following manner:

1. The Thermal paste is applied on the curved bottom surface of the Aluminum Block.
2. The Aluminum Block is mounted on the silencer with the two projected bolts properly aligned with the two counter bored holes machined on the metal Block.
3. On the surfaces of four TEGs on the side exposed to hot temperatures, a thin thermal paste layer is applied.
4. They were then carefully placed on the Aluminum Block ensuring that there was no air bubbles trapped between the TEG modules and the Block surface.
5. The surface of the metal block which isn't covered by the TEG modules is then covered with asbestos threads for the purpose of insulation.
6. The "Cold" surface of the TEG modules was applied with thermal paste repeatedly.
7. The aluminum heat sink was mounted on top of these TEG modules with the application of pressure to attain a near perfect contact.
8. This entire setup is then firmly secured to the silencer with the help of two screws on both ends.



Fig 4.13. Assembled Parts



***Fig 4.24. Assembled parts
Internal Strucutre***

4.4 WORKING

Working of TEG mounted on the silencer of the bike:

On to the atmosphere, the electrons and holes of the thermoelectric semiconductors will try to move towards the junction and make the flow of electric current to be possible. To increase the amount of heat leaving the exhaust, the vehicle should be started and the amount of acceleration produced should be increased. As a result, the surface of the exhaust pipe and the silencer becomes heated to extremely high temperatures. The heat dissipated from these hot surfaces into the atmosphere creates a Heat Sink. Here, the atmospheric temperature is lesser than the temperature of the silencer surface creating a temperature difference. This causes the surface to try to attain a state of equilibrium through the heat transformation process. Since this takes a longer amount of time, Thermal Grease is utilised in order to increase the rate of heat transfer. The hot surface of the silencers and the inner surface of the fins present in the upper part, are coated in Thermal Grease. The fins also help in increasing the heat transfer rate. While the vehicle is in motion, there is flow of air in between the fins, acting as the sink. The more the temperature of the surface of the silencer increase, the heat transfer rate increases, as a result of increase in temperature difference. The Peltier module is put in the middle of the hot Silencer Surface, which acts as Heat Source and the atmosphere, which acts as the Heat Sink and the fins are attached on top of the module. The module is made of semiconducting materials. Ultimately, as per the principle of Seebeck Effect, the difference in temperature can directly be converted into voltage with the use of thermoelectric materials. Based on this effect, when the surface heat of the silencer is passed.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 INTRODUCTION

After running the bike for 10 minutes the desired high temperature of 190-200 degree Celsius was obtained on the surface of the silencer. The output voltage of the TEG modules were tested while throttling on neutral gear. Since the bike was stationary air cooling was not a possibility. Instead, water was continuously being poured on the fins to take away the heat. In actual testing the complete assembly was used i.e. all the four TEG modules were connected in series and each module supplied its own share of voltage. Since the TEG modules were connected in series the voltage across the whole circuit was the summation of the individual voltages.

5.2 OUTPUT

TIME (Minutes)	VOLTAGE (Volts)	TEMPERATURE (°C)	BOOSTED VOLTAGE (V)
1	5	30	10.1
2	7	35	13.8
3	6	40	12.2
4	9	60	17.7
5	12	90	23.6
6	10	100	20.1
7	12	120	24.2
8	12.5	140	25.1
9	12.7	160	25.7
10	12.9	200	26.1

Upon conducting the above experiment, it was concluded that by using a SiGe Alloyed TEG, the amount of voltage produced drastically increases. Apart from the voltage, the thermal conductivity of the SiGe TEG has proved to be more because of the temperature resistance while conducting the experiment. At 115 degree Celsius, the amount of voltage produced was 13V. This proves that SiGe alloyed

TEG produces more power compared to the usual Bismuth alloy used everywhere. Given below are the graphs obtained by using a Wi-Fi module to generate the graphs in the assembly.

A Wifi Module was fixed into the assembly to directly get the graph from the assembly. Not only is it more accurate, it also reduces the time consumed to plot graphs.

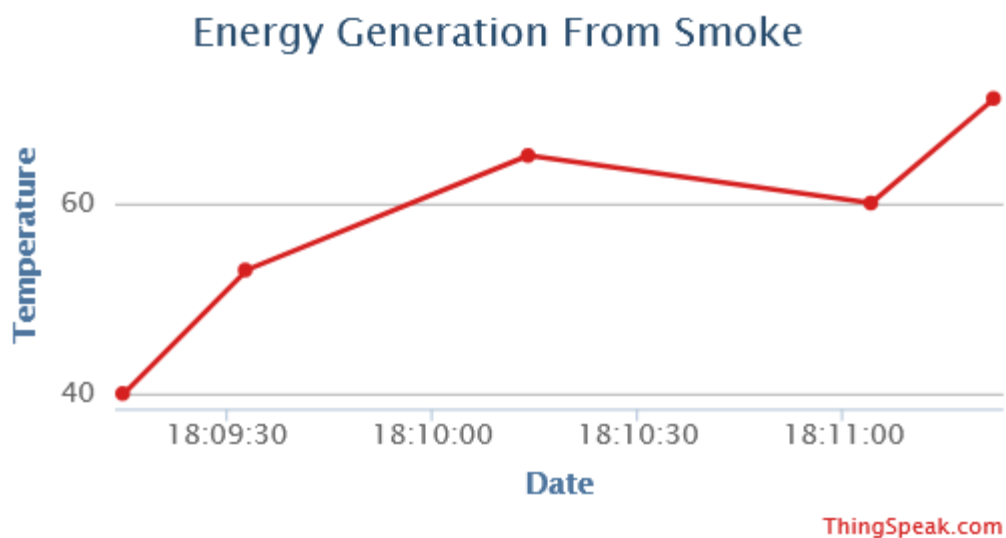


Fig 5.1. Temperature Vs Time Graph

The above graph is a graph between the temperature change with respect to time. We can notice that since the alloy is a SiGe alloyed TEG, the temperature resistance of the TEG is much more compared to the normal Bismuth Alloy TEG.

For every 30 seconds, a constant increase in the temperature can be noticed. SiGe alloys can resist temperatures of upto 200 degree Celsius therefore enabling the assembly to last longer and also generate more power.

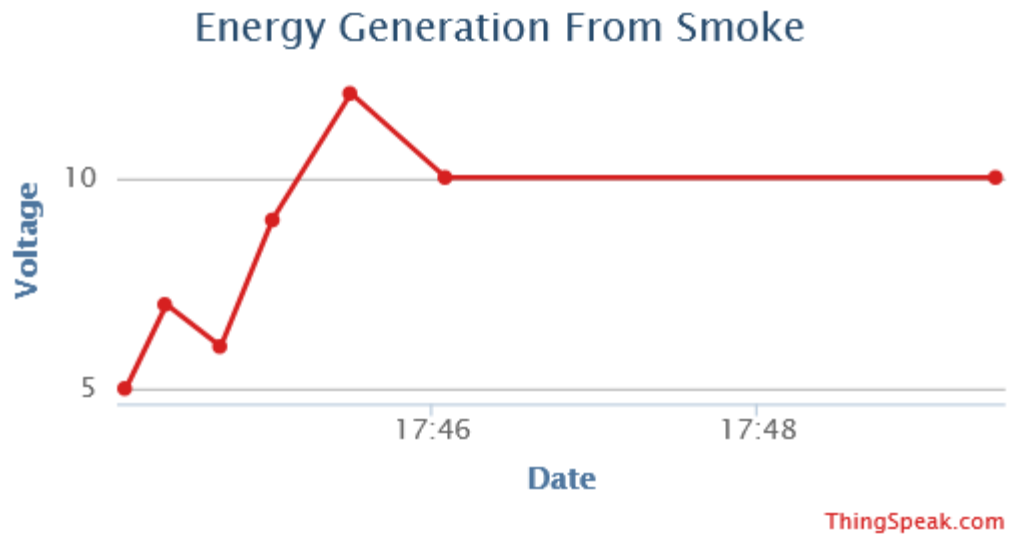


Fig 5.2. Voltage Vs Time Graph

The above graph is a voltage graph with respect to time. From the above graph, we can notice that the voltage increase is gradual for the first two minutes and then constant throughout. This is due to the temperature limit upto which the TE Generator can function. A maximum voltage of upto 12.9V was extracted at 200 degree Celsius. This proves that the amount of electricity increases and so does the efficiency of the TEG. By doubling this voltage, we can generate more power than usual and therefore can be applied to various other applications.

CHAPTER 6

SUMMARY AND CONCLUSION

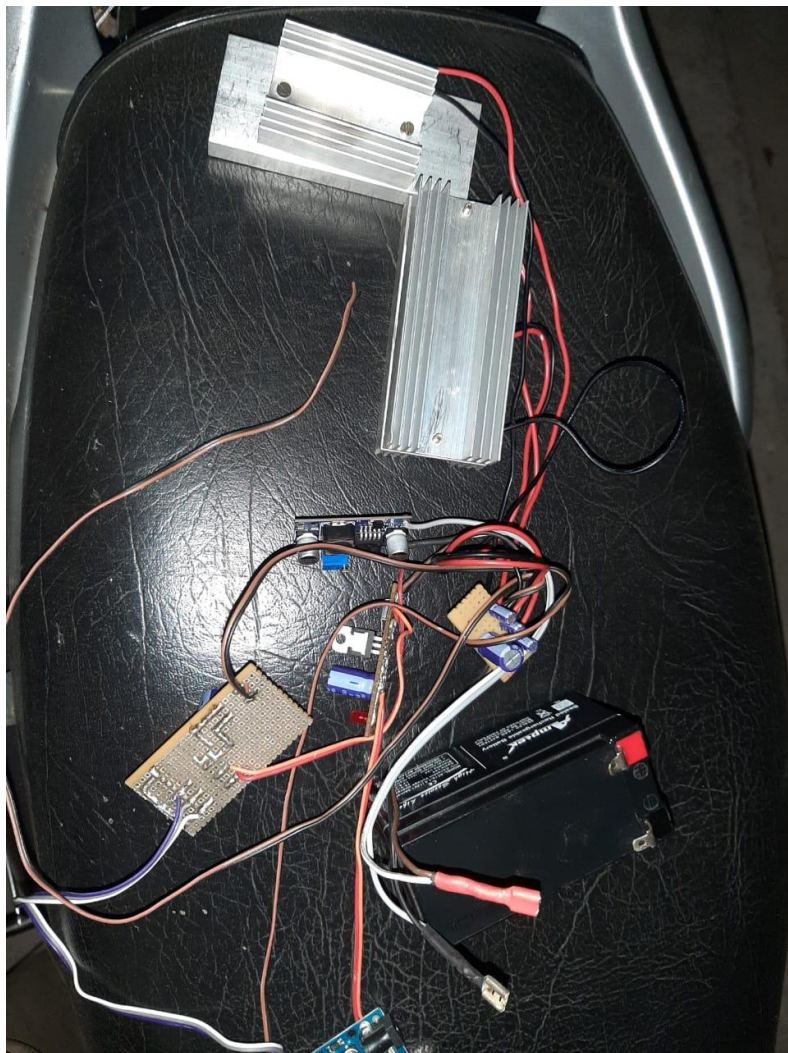
1. This project aims to search out a attainable thanks to recover the waste heat from the exhaust of I.C. engine and increase the potency of the lamb by exploitation otherwise alloyed lamb to supply additional power moreover on style and fabricate one such system to serve the aim.
2. by experimentation it's found that the thermoelectrical generator is connected to the silencer. This generated power either directly accustomed run some auxiliary devices of associate degree automobile or is also keep within the battery and used later.
3. These auxiliary masses may be supplemented from battery to the current system thereby reducing load on generator.
4. The study additionally investigates the impact of engine speed on temperature distinction and voltage generated.
5. The engine performance is unaffected by the designed system as a result of heat extracted from the surface of the bend-pipe of the manifold that doesn't affected the operating of engine.
6. If higher temperature vary is needed then lamb module should be modified to higher temperature vary (200°C). Thus, the on top of expressed system is also with success enforced in numerous automobile engines, with slight changes.

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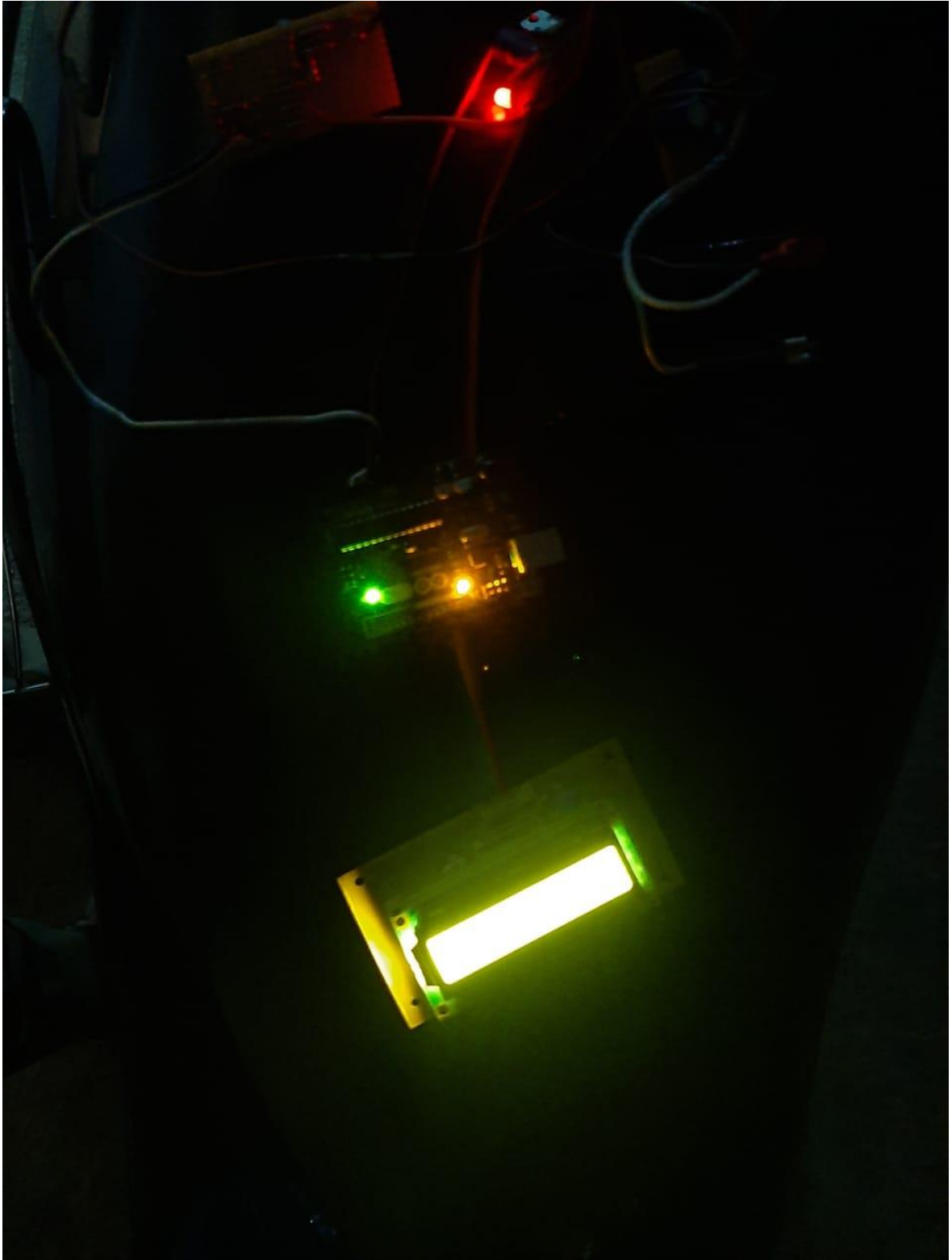
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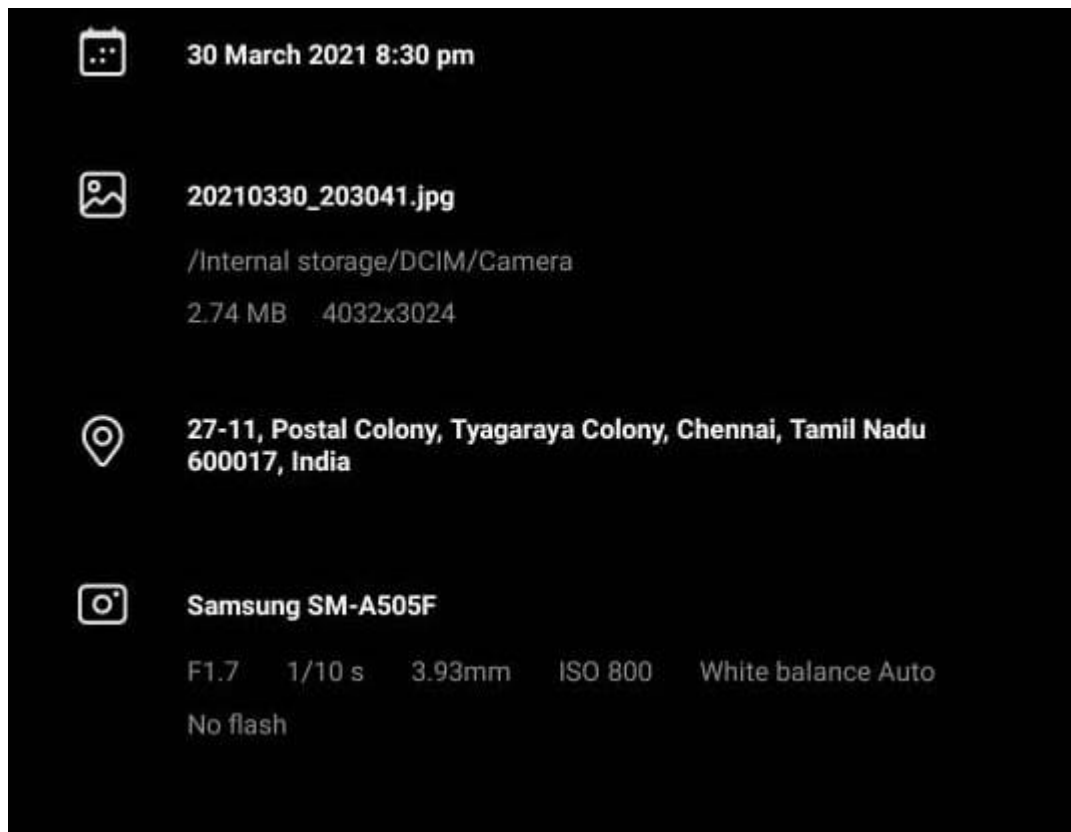
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APPENDIX









Location at which the following pictures were taken.