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Abstract

The study is based on the experimental setup with a specific possibility of recuperating waste heat from an exhaust of an automobile and furthermore to design, fabrication of one such system that can be accomplished the point of producing power by utilizing the thermoelectric power generator. The Experimental work is carried out on an I.C engine having displacement of 127cc. To design a system which has two important components, firstly heat absorber and heat sink. The heat absorber can be used for the hot side of the thermoelectric generator and heat sink can be used for the cold side of the thermoelectric generator. The staggered arrangement is done on both heat sink and heat absorber to enhance the heat transfer rate so that thermoelectric generator could increase its efficiency. Use of copper as a heat sink could beneficial for the cold side of the thermoelectric module because copper has a high thermal conductivity. The material of heat absorber is aluminium alloys 6061 have been anodized to protect it from corrosion. The TEG module we used to be SP1848-27145. The material of this thermoelectric generator is bismuth telluride. The bismuth telluride based TEG could be easily available and the cost of this TEG is cheap. The power generation from the TEG continuously monitor with respect to the variable temperature condition across the TEG device at different rpm of an engine with time and the generated power with two TEG based on the designed module is around 10.02 watts.

1. INTRODUCTION

A thermoelectric generator a device which creates power by heat, it works on squander heat likewise, in a thermoelectric generator, a change occurred straightforwardly heat into power. A thermoelectric generator offers a few discernible points of interest over other power plants.

The working conditions behind the thermoelectric generator are a “See beck effect” which stated as “whenever there is a temperature difference between the two junctions in a loop, made up of two dissimilar conductors, thermal electromotive force is produced in the loop. Such a loop is known as a thermoelectric generator.” The emf originated is proportional to the temperature difference between the two junctions. A thermoelectric generator offers several distinct advantages over other power plants. It has saliently features namely compactness, lightweight, noiseless operation, highly reliable, safe power source, and no moving parts. The remarkable advantage of thermoelectric generator is that it can operated by low grade waste heat (< 200°C) of automobiles. Lowest maintenance cost of any other power generation sources is also good advantages and perfectly for automobile exhausts heat recovery. Finally, the waste heat from automobile vehicle has a potential of power generation by use of thermoelectric generator.

Jadhav et al. [1] has conducted experiment using exhaust manifold of and four-stroke I.C engine 92.20cc with two TEGs and shows that the experimental setup absorbs an optimised amount oh heat energy which can be utilized for electricity generation. Ankik et al. [2] observing the accompanying outcomes for a Bismuth Telluride thermoelectric generator (TEC1-12706) and achieved a power of 4.057 watts at temperature of a 68°C. Jeng et al. [3] concluded an actual four-stroke single cylinder of 35.8 cc for the experimental setup on a test of generation of electricity by the exhaust of the engine and design a pin-fin arrangement type with including inside a thermoelectric generator and concluded that power 2.5W has been generated at a speed of an engine is 5400 rpm. Wango et al. [4] generating power presently there is a lack of non-renewable energy source, oil, gas, and so on consuming of these falls causes a natural issue like radioactivity contamination, an unnatural weather change. The best alternative for electricity generation is TEG. By utilizing this vitality is utilized to charge the portable hardware. X. Liu et al. [5] a standout amongst the most promising green innovation is a thermoelectric power...
generator. The investigation of TEG system described, which are embraced to survey the attainability of automobile application. A system is designed with an implement of a four thermoelectric power generator and assembled into a vehicle and concluded that the power generation could be easily further increases with the hot side temperature rise and subsequently the voltage gets altered and this temperature difference easily enhances the electricity generation. Chien-Chou Weng et al. [6] carries computational study based on number and the normal rate on the heat-exchanger of the thermoelectric generator using ANSYS and discovered that actualizing more thermoelectric couple does not really create more power altogether and above all else, the normal power per TE couple diminishes quickly. Karri et al. [7] canvassed the differentiation between the two types of a thermoelectric module based on the efficiency of the thermoelectric generator by using of waste heat of a sports utility vehicle (SUV) and natural gas power generator engine. First one is bismuth telluride (Bi2Te3), and second is quantum-well (QW) device. The advanced QW based TEG produced around 5.3-5.8 kW resulting with a fuel saving of around 3%. K.T. Wojciechowski et al. [8] carried his work on a prototype thermoelectric generator (TEG) and the test were performed by using the dynamometer to compare the parameter of heat recovering from both spark ignition engine and a self-ignition engine and conclude that CI engine has a better efficiency than the Spark ignition type engine. Therefore, the waste heat from the exhaust of CI engine is much higher than that of the SI engine and the power generated by using TEG heat-exchanger from the self-ignition engine was a 44 W at 1600 rpm. JIHUI YANG et al. [9] studies an automobile application for the thermoelectric power generator that is from the waste heat of an engine exhaust. It can be used for both HVAC and the power generation, environmental issues will be somewhat solved by selecting the thermoelectric power generator and comes up with a scope of integrating requirement for the materials of the thermoelectric power generator which ultimately enable us the output of HVAC system with unique features such as silent in operation, very light in weight, durability increases due to no movable parts and faster in operation. Champier et al. [10] carried an experimental setup for electricity generation using Biomass with utilization of Thermoelectric Module and proves that 6 watts of power can be generated by using a thermoelectric generator. Jadhao et al. [11] summarise the overall issue with respect to quick monetary improvement and a relative lack of energy, the IC engine exhaust waste, and natural contamination has been more underlined vigorously as of late and recognized that there are substantial possibilities of vitality investment funds using waste warmth recuperation advancements. For waste, heat recuperation thermoelectric generator is utilized low heat, which has low productivity. It is useful for a similar measure of increments in heat productivity and a decrease in discharge. Vazquez et al. [12] studied and summarized that most extreme electric power created in TEGs for automobile oscillate between 43 W and 193 W, with the exception of in the TEGs composed by HI-Z to be mounted in trucks. This electrical power has been just accomplished regularly in an auto-running at 65 km/h (climb slope). Hendricks et al. [13] exhibited a coordinated system examination approach that enables one to at the same time evaluate impacts of vital system outline parameters on system execution and increases system power ability. Incorporated system investigations are giving basic data on how much power is accessible at different areas in deplete surges of LDP and HD vehicles. Dirksen et al. [14] carried out an investigation surveys on diesel cycle based on the capability of waste heat thermoelectric power generation and gas turbine co-generation as an assembled unit. The capability of waste heat TEG was examined utilizing a yearly cost, framework life expectancies, bank loan fees, system cost, maintenance cost and concluded that it is less economic to use TEG but the rate of improvement in TEG materials to make an excellent semiconductor material with higher Seebeck coefficients materials. Rowe et al. [15] based on extensive study on the TEG utilities and applications, Rowe concluded that a TEG has unique features such as silent in operation, it has no moving parts and very reliable. For past 10 years, TEG materials have a lot improve and attracted towards the green sources of power generation, any kind of heat source could totally change into the direct generation of electricity. The conversion efficiency as the major consideration and capital cost and high reliability. A thermoelectric generator has a wide application in automobile industries.

2. EXPERIMENTAL SETUP

In this section of Experimental setup, Figure 1 represents the mounted view of TEG module over a two-wheeler exhaust. The thermoelectric conversion device is situated in the exhaust of an engine. In above figure, it is represented the use of heat sink is made up of copper. The engine displacement is of 127c.c. and above the engine a fuel tank is situated for a flow of a fuel into an engine. A silencer is attached after the TEG device and by doing this a thermoelectric conversion device acts as a silencer also and very effective for reducing the sound from an engine. A thermoelectric power generator are placed in between the pin-fin absorber and copper heat sink but
before placing the thermoelectric power generator in between them firstly apply thermal heat sink paste for better
heat conduction between two surfaces.

![Figure 1 Experimental setup](image1)

3. COMPONENTS

All the components are discussed and their function and how they manufacture are all discuss in below.

3.1.1 **Engine:** The engine used in this experimental setup has following Specifications

![Figure 2 Engine](image2)

The engine which use in this experimental setup has displacement of 127 c.c. and the type of an
engine is 550 series. The maximum rpm of an engine is 3600 and the start type is recoil. The
governor system of the engine is mechanical and the ignition system of an engine is electronic. The
cooling system of an engine is air cooled.
3.1.2 Thermoelectric conversion device:

CAD modelling of this thermoelectric transformation system has been carried out CREO 4.0 tool. Fig 2 comprise a two TEG which are placed in-between heat source and sink. Heat exchange rate has been enhanced and optimized with the utilization of array of fins. Fins are arranged in staggered, both on a heat sink and heat source. The material of this system is aluminium alloys with an anode so that it cannot affect by corrosions. The material of the heat source is also the aluminium alloys 6061 anodized and the material of heat sink is the cooper.

Figure 3 TEG device with Thermoelectric Generator
Figure 4 Shows a cross sectional and Exploded view of TEG conversion device

Figure 5 A TEG conversion device with dimension in mm

Figure 6 Staggered arrangement of pin-fin absorber including dimensions in mm
4. EQUIPMENT USED IN EXPERIMENTATIONS

For experimentation we used three equipment which is voltage booster circuits, thermal heat sink paste and the battery. The following are the brief discussion of this three-equipment used in the experimentation.

4.1 Voltage booster:
Voltage booster is a diode rectifier circuit which creates an amplified voltage in comparison to the applied voltage. One elective approach is to utilize a diode voltage booster circuit which increments or step-up the voltage without the utilization of a transformer.

The above figure shows the voltage booster circuit. Voltage booster are comparative from multiple points of view to rectifiers in that they change over AC-to-DC voltages for use in numerous electrical and electronic circuit applications, for example, in microwave stoves, solid electric field curls for cathode-beam tubes, electrostatic and high voltage test hardware, and so forth, where it is important to have a high DC voltage created from a generally low AC supply. The benefit of "Voltage booster Circuits" is that it enables higher voltages to be made from a low voltage control source without a requirement for a costly high voltage transformer as the voltage booster circuit makes it conceivable to utilize a transformer with a lower step-up ratio than would be required if a standard full wave supply were utilized. However, while voltage booster can help the voltage, they can just supply less current to a high-resistance load due to the produced voltage rapidly drops-off as load current increments. We use DSN6009 4A voltage booster circuit is a high-performance step-up voltage and current boost module. The input operated voltage is 3V~32V and the output voltage 5V~35V and maximum input current is 4A.

4.2 Thermal Heat Sink Paste:

Heat paste additionally called thermal heat sink paste is a substance used to capture the better heat conduction between two surfaces and is usually utilized between a chip and a heatsink. The figure below shows the thermal heat sink paste Some have minuscule sections and others may even have a slight bend, which produces air holes between the microchip and the heatsink and decreases the cooling execution of the heatsink The air holes are filled by applying a thin layer of a thermal heat sink paste to the highest point of the microchip and the base of the heatsink.
It is electrically insulating but thermally conductive and it is just a silicon-based white colour paste which can be used to resist the higher temperatures, we apply only hot side of the thermoelectric generator.

4.3 Battery:

A battery of 12V and 7Ah can be charged by the voltage which is generated by the thermoelectric generator but the voltage booster connection is must because the voltage which is generated by the TEG is somewhat a tiny with the help of voltage booster circuit connection that voltage can be increased and utilized for charging the battery.

By doing so we can easily replace the alternator from the bike which helps the generation of power, as the electricity generated from the thermoelectric generator by use of engine exhaust waste heat so by replacing an alternator from bike, the engine might be running smoothly because of less load is connected

5. RESULTS AND DISCUSSION

The result of this experimentation is performed on a bike which have engine whose displacement is 127 cc. The voltage, current, power, resistance, temperature difference, voltage of booster circuit and time are tabulated, and all readings are unloading conditions and plots graphs. Experiments were conducted at different engine rpm based on the cases mentioned below to determine the performance of TEG:

- CASE-1 Comparison between the Temperature difference and Time
- CASE-2 Comparison between Voltage and Temperature difference
- CASE-3 Comparison between the Temperature difference and Current
- CASE-4 Comparison of Current and Voltage
- CASE-5 Comparison of Temperature difference and Power
- CASE-6 Comparison between the Time and Voltage
- CASE-7 Comparison between the Time and Current of the system
- CASE-8 Comparison between the Power and Time of an TEG system

5.1 CASE-1 Comparison between the Temperature difference and Time
In this investigation a comparative study between the temperature difference and time at different rpm has been carried out. The temperatures of both sides pin-fin absorber which is heat source for the TEG and the temperature of heat sink which is cold source for the TEG, temperature is recorded by the RTD-100 and time by the timer and both readings are continuously monitor.

![Graph showing temperature difference vs time](image1)

Figure 13 Variation of Time with respect to Temperature Difference at different engine RPM

The above shows the temperature difference increases with time at different rpm and the shortest time period is of 3300 rpm in 117 seconds and temperature difference is 107.5°C but in 1850 rpm the temperature difference is 96.7°C in 306 seconds.

5.2 CASE-2 (Comparison between Voltage and Temperature difference)

The temperature of both side heat source and the sink is measured using RTD-100 and voltage is measured. The engine rpm is measured by the tachometer and the reading are taken at different rpm of an engine.

![Graph showing temperature difference vs voltage](image2)

Figure 14 Variation of Voltage w.r.t Temperature Difference at different engine rpm

The above figure shows the variational aspect between voltage and temperature difference at different rpm. From above graph one can easily say that voltage is directly proportional to temperature difference. The maximum temperature difference is 112.1°C at 2800 rpm and voltage 9.20 volts generated. The minimum temperature difference is 24.2°C at 3300 rpm and the voltage 2.00 volts generated. The voltage is steadily increasing with increasing the temperature differences.

5.3 CASE-3 (Comparison between the Temperature difference and Current)

In this investigation a comparison between the current and temperature difference at different rpm of an engine. The engine rpm is measured by the tachometer and the reading are taken at different rpm of an engine.
The above figure reflects the variation of current and temperature difference at different rpm of an engine. From above graph one can easily say that current is directly proportional to temperature difference. The maximum temperature difference is 112.1°C at 2800 rpm and current 1.09 amps generated. The minimum temperature difference is 24.2°C at 3300 rpm and the current 0.17 amps generated. The current is steadily increasing with increasing the temperature differences across the thermoelectric generator.

5.4 CASE-4 (Comparison of Current and Voltage)

In this case an investigation between the current and the voltage at different rpm of an engine. The two thermoelectric generators are connected in series and taken the readings.

The above figure shows variation in current and the voltage. It is clearly seen from graph that the current is in direct proportion to that of the generated voltage. The maximum voltage generated is 9.20 volts at 2800 rpm of an engine and the current generated is 1.09 amps. The minimum voltage generated is 2.00 volts at 3300 rpm of an engine and the current generated is 0.17 amps. The voltage steadily increases and the current is also increasing.

5.5 CASE-5 (Comparison of Temperature difference and Power)

In this case an investigation between the temperature difference and the power across the thermoelectric generator. The temperature of both side heat source and sink are measured with RTD-100. The engine rpm is measured by the tachometer and the reading are taken at different rpm of an engine. The power is calculated by ohms law.
The above figure shows the variation of power with temperature difference at variable RPM. The temperature difference is directly proportional to the power as a result power increases with increment of temperature across the thermoelectric generator. The maximum power is 10.02 watts at 2800 rpm of an engine and temperature difference is 112.1°C. The minimum temperature difference is 24.2°C at 3300 rpm of an engine and the power generated is 0.34 watts.

5.6 CASE-6 (Comparison between the Time and Voltage)

In this investigation a comparison between the voltage and time at different rpm of an engine. All the reading is continuously monitor.

The above shows the time and voltage. The maximum time is 306 seconds 1850 rpm of an engine and the voltage generated is 8.90 volts. The minimum time is 29 seconds in 3300 rpm of an engine and the voltage generated is 2.00 volts. The maximum voltage generated is 9.20 volts and the time is 145 seconds at 2800 rpm of an engine. The above graph shows that a particular rpm voltage increases with the time. In particular rpm of an engine the temperature differences increase with the time, the voltage is also increasing and the current increases also. By above graph shows the voltage increases with time, as time increases the voltage is also start increasing.

5.7 CASE-7 (Comparison between the Time and Current generation)

In this investigation a comparison between the current and time at different rpm of an engine has been studied.
The above figure shows the current and time of a thermoelectric conversion system. The maximum time is 306 seconds at 1850 rpm and the current generated is 0.91amps. The minimum time is 29 seconds in 3300 rpm and the current generated is 0.17 amps. The maximum current generated is 1.09 amps in 2800 rpm and the time is 145 seconds.

5.8 CASE-8 (Comparison between the Power and Time of an TEG system)

In this investigation a comparison between the power and time at different rpm of an engine. All the reading is continuously monitor.

CONCLUSION

This experiment aim is to investigate the power generation from a TEG by using waste heat recovery of an engine as well as to build one such system which serves the aim and it has been found that the two TEG used in the system having configuration of 127cc Engine which can easily be used to charge the battery or to run the electrical devices of an automobile. The study also shows that the engine performance is unaffected by designed and used this TEG conversion device and last but not least if a higher temperature is needed then the thermoelectric
generator must be changed to a greater temperature range so that power generation also be increased. This present thermoelectric conversion system with two thermoelectric generator modules is generated 10.02 watts of power and for more Power Output for the same RPM, the thermoelectric generator module design and be further improved.

REFERENCES


